Democratic Socialist Republic of Sri Lanka
Survey Department of Sri Lanka (SDSL)

THE DIGITAL TOPOGRAPHIC MAPPING PROJECT
FOR
RECONSTRUCTION OF NORTHERN REGION

FINAL REPORT

January 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

KOKUSAI KOGYO CO.,LTD

AERO ASAHI CORPORATION

1 USD = 77.95 Yen   1 LKD = 0.685 Yen

PREFACE

In response to a request from the Government of Sri Lanka, the Government of Japan decided to conduct “The Digital Topographic Mapping Project for Reconstruction of Northern Region” and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team, headed by Mr. Akira NISHIMURA of KOKUSAI KOGYO CO., LTD., and consisting of KOKUSAI KOGYO CO., LTD. and AERO ASAHI CORPORATION, between February 2010 and November 2011.

The team held discussions with the officials concerned of the Government of Sri Lanka and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of digital topographic mapping in Sri Lanka and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Sri Lanka for their close cooperation extended to the study.

January 2011

Kiyofumi KONISHI
Director General
Economic Infrastructure Department
Japan International Cooperation Agency

Letter of Transmittal

Mr. Kiyofumi KONISHI
Director General
Economic Infrastructure Department
Japan International Cooperation Agency

It is a great honor to submit herewith the final report of Digital Topographic Mapping Project for Reconstruction of Northern Region in the Democratic Socialist Republic of Sri Lanka. This report incorporates the suggestions received from the Japan International Cooperation Agency (JICA) and concerned authorities, as well as the agencies concerned of the Government of Sri Lanka including the Survey Department of Sri Lanka (SDSL).

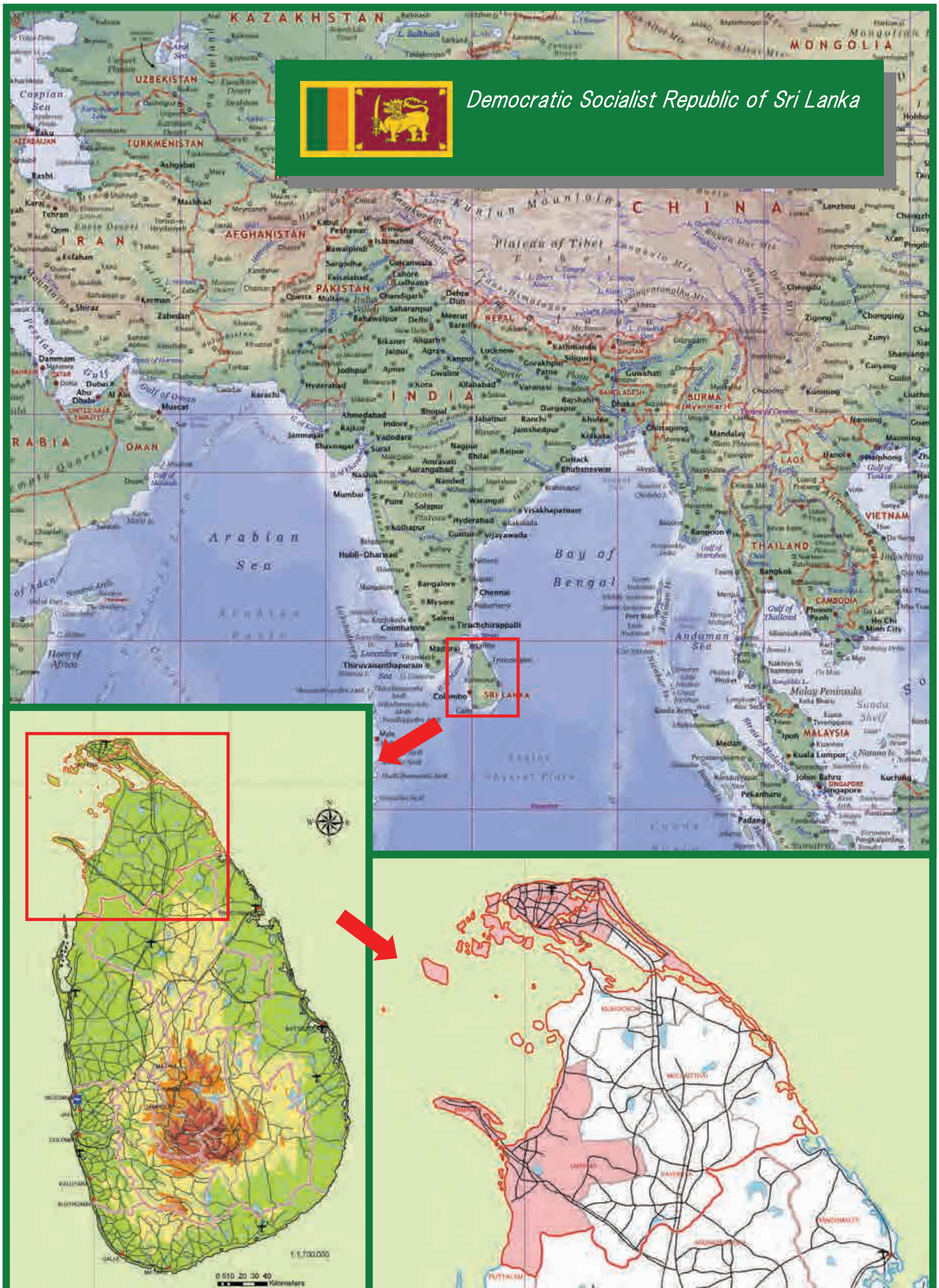
During the Study, a digital topographic map at the scale level of 1:10,000 for part of the Northern Region was developed, and the techniques (GPS survey, leveling, digital aerial triangulation, digital plotting/editing, GIS structualization and map symbolization) concerned with this work were transferred to the SDSL. Furthermore, activities (seminar/workshop) concerning the dissemination of geographic information were implemented.

In the final part of this report, specific issues and recommendations are made based on the results of the study, and the work manual (Guideline), which covers developing, maintaining and managing the geospatial data and GIS database, is attached in the report. From the viewpoint of maintaining and developing the results of the study, I hope that these issues, recommendations and the work manual (Guideline) are promptly accepted for implementation and the manual used by the agencies concerned of the Government of Sri Lanka.

On behalf of the study team, I would like to express my sincere gratitude to JICA, the Ministry of Foreign Affairs, the Ministry of Land, Infrastructure, Transport and Tourism, and the agencies concerned for the valuable advice and cooperation they provided us during the implementation of this study. I would also like to extend my deep appreciation to the agencies concerned of the Government of Sri Lanka, including SDSL, for their generous assistance and cooperation during our stay in Sri Lanka.

January 2011

Akira NISHIMURA
Team Leader
Digital Topographic Mapping Project for
Reconstruction of Northern Region in the
Democratic Socialist Republic of Sri Lanka



Location map of Digital Topographic Mapping Project for
Reconstruction of Northern Region in Sri Lanka

Photo Album

Office of SDSL

Entrance of SDSL

Triangulation point

Bench mark

Aerial Photography

Aerial Photography

Photo Album

Photo Signalization

Photo Signalization

Photo Control Point Survey（GPS Survey）

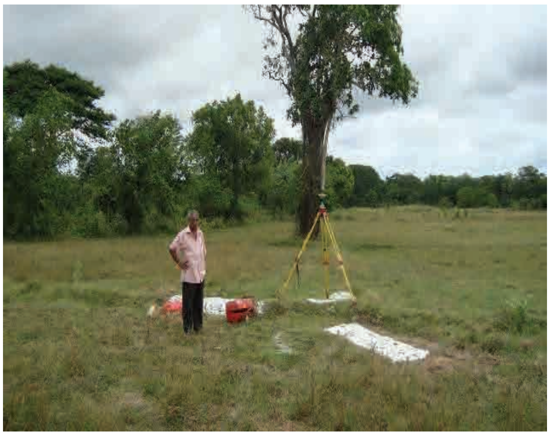


Photo Control Point Survey (GPS Survey）

Photo Control Point Survey(Leveling）

Photo Control Point Survey(Leveling）

Photo Album

Field identification

Field identification

Supplementary Field Identification

Supplementary Field Identification

Technology Transfer（Field Identification）

Technology Transfer（Field Identification）

Photo Album

Technology Transfer（Digital A・T）

Technology Transfer（Digital A・T）

Technology Transfer（Digital Plotting）

Technology Transfer（Digital Plotting）

Technology Transfer（Digital Editing）

Technology Transfer（Digital Editing）

Photo Album

Technology Transfer（GIS）

Technology Transfer（GIS）

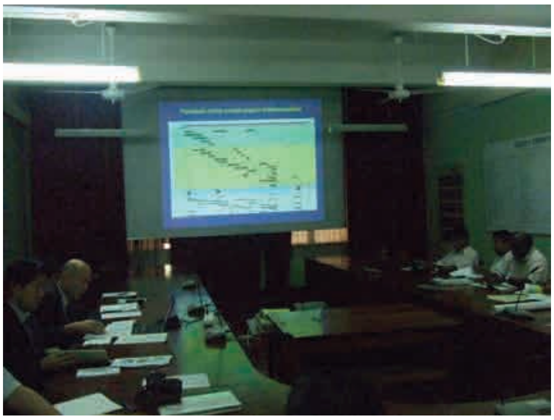
Technology Transfer（Map symbolization）

Technology Transfer（Map symbolization）

Technology Transfer（Sup Field Identification）

Technology Transfer（Sup Field Identification）

Photo Album



Inception Report (Explanation and Discussion)

Inception Report (Explanation and Discussion)

Interim Report (Explanation and Discussion)

Interim Report (Explanation and Discussion)

DF Report (Explanation and Discussion)

DF Report (Explanation and Discussion)

Photo Album

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Photo Album

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Seminar / Workshop

Executive Summary

1. Outline of the Study

1.1 Objective of the Study

Nearly 30 years of armed conflict in Sri Lanka came to an end in May 2009. This long armed conflict inflicted severe damage on people’s lives and on the social infrastructure required for their livelihoods, especially in the Northern Region.

The reconstruction of the region and the livelihoods of its people has always been an important issue since the end of the armed conflict. The formulation of reconstruction plans and their implementation requires the latest geographic information.

Against this background, this Study was implemented for the following objectives:

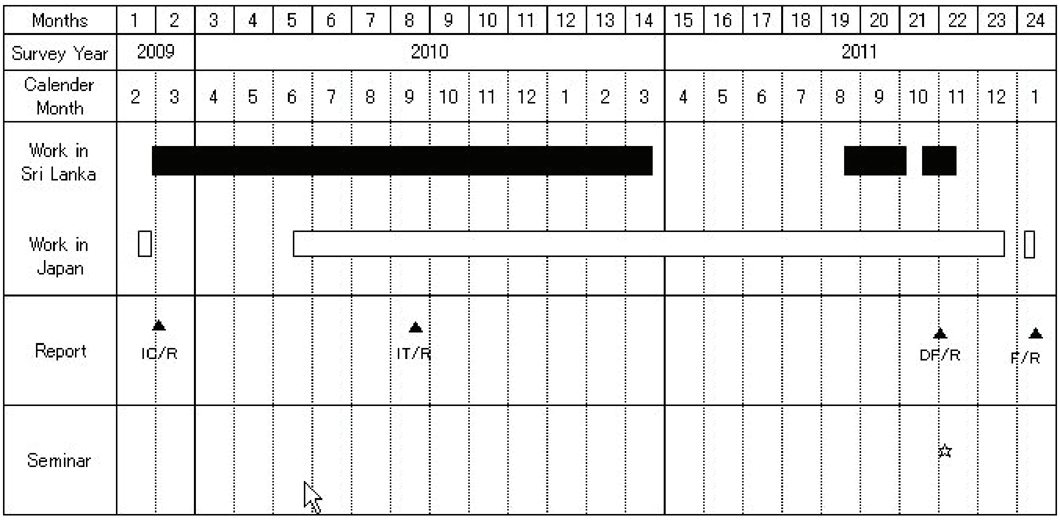
a. Aerial photographs of the entire Northern Province of Sri Lanka

b. Production of 1/10,000-scale digital topographic maps of Mannar and Jaffna Districts in Sri Lanka

c. Technology transfer for the production of digital topographic maps through implementation of a and b.

1.2 Study Implementation Schedule

The chart below gives an outline of the schedule for implementation of the Study.



The Study commenced in February 2011 and was completed in January 2011. It consisted of “Work in Japan” and “Work in Sri Lanka.”

(1) Work in Japan

The work in Japan consisted of such tasks as aerial triangulation and digital plotting/compilation. It was implemented in six phases. (Phase 1 began on 10th February 2010 and Phase 6 was completed on 15th January 2012).

(2) Work in Sri Lanka

The work in Sri Lanka consisted of such tasks as control point survey and the transfer of various technologies. It was implemented in six phases. (Phase 1 began on 28th February 2010 and Phase 6 was completed on 9th November 2011).

1.3 Implementation of the Survey

1.3.1 Implementation of the Digital Topographic Mapping

Digital photogrammetry was used to carry out the following work in order to achieve objectives ‘a’ and ‘b’ of the Study.

(1)Discussion of Specifications

Discussions were held between the Survey Department of Sri Lanka (SDSL) and the Study Team on the geodetic reference system (ellipsoid of reference and coordinate system) and the digital map specifications required for the production of digital topographic maps. Discussions were also held on the areas to be mapped in Mannar and Jaffna Districts.

(2) Aerial Photography

The aerial photography was subcontracted to a local company, Finnmap FM International, which was awarded the contract in a competitive tender.

The subcontractor took aerial photographs of the entire Northern Region over two periods, the first in June 2010 and the second in March 2011, after permits had been obtained from the various relevant authorities, including the Ministry of Defence and the Civil Aviation Authority. The main specifications for the aerial photography were as follows:

* Scale of photography:	1/20,000
* Type of photography:	Colour photography
* Method of photography:	GPS/IMU method
* Percentage of duplicate coverage:	Overlap: 60 % (standard)
	Sidelap 30 % (standard)

(3) Photo Control Point Survey

Photo control point survey (GPS survey and levelling) to establish photo control points required for the subsequent aerial triangulation was implemented with technical assistance from SDSL. Before the implementation of the photo control point survey, air photo signals had been placed at all photo control points (horizontal control points).

1) GPS Survey

The GPS receivers of SDSL were used for 8-hour continuous observation of the existed control points and 1-hour simultaneous observation of newly-established photo control points.

After the analysis of the observed data, the coordinates of each photo control point were calculated in the geodetic reference system stipulated in the specifications. The elevation of each of the photo control points was measured, wherever possible, in the levelling work described below.

2) Levelling

Levelling was carried out on the routes deduced from the data on aerial photographs and satellite imagery, with technical assistance from SDSL and its equipment.

Sketches of the vertical control points established in the levelling work were made and used as reference materials for pricking on aerial photographs.

As mentioned above, the elevations of the horizontal control points surveyed in the GPS surveying were measured, wherever possible, in the levelling.

(4) Field Identification

Field identification was implemented in Jaffna District and elsewhere using the aerial photographs, with technical assistance from SDSL.

1) Photo Interpretation for Field Identification

Before the field surveys, aerial photographs were interpreted in the office.

In the photo interpretation, interpretable features were identified on aerial photographs in accordance with the established map symbol specifications.

2) Field Identification

Field surveys were carried out with the aerial photographs used in the photo interpretation. Feature data which could not be obtained from photo interpretation (such as data on features which could not be identified in the photographs, names of roads and structures, etc.) were collected in the surveys.

(5)Aerial Triangulation

Aerial triangulation was implemented separately for the area for which digital topographic maps were to be produced and for the entire Northern Region including the area for which digital topographic maps were to be produced, because of the delay in carrying out the aerial photography.

1) Aerial Triangulation for Digital Topographic Mapping

Aerial triangulation for digital topographic mapping was implemented in four blocks, namely, the southern part of Jaffna District, the islands, the northern part of Jaffna District and Mannar District, over two periods.

Before the implementation of the aerial triangulation, the number and locations of photo control points in each block were evaluated for the purpose of accuracy control. It was concluded from this evaluation that aerial triangulation with the established photo control points would satisfy the degree of accuracy required for the 1/10,000-scale digital topographic maps if it was used together with the results of the GPS/IMU analysis.

After the evaluation, aerial triangulation using the bundle method was implemented for the image data obtained from the aerial photography and the results of the photo control point survey.

2) Aerial Triangulation of the entire Northern Province

Digital and analog aerial triangulation of the entire Northern Region was carried out. Part of the island area was excluded from the calculation of the aerial triangulation of the entire region. Instead, the orientation elements required for plotting were calculated separately.

a. Digital aerial triangulation of the entire Northern Region

Digital aerial triangulation of the entire Northern Region was carried out using the same method as the aerial triangulation of the area for digital topographic mapping.

b. Analog aerial triangulation of the entire Northern Region

Analog aerial triangulation of the entire Northern Region was carried out by means of the following procedures:

Selection of points: Tie points were established in overlapped aerial photograph.

Pricking: Tie points selected as described above and other points was pricked on diapositive film.

Observation: Machine coordinates of the pricked tie points and photo control points were observed.

Inner orientation: The machine coordinates of the tie points and photo control points were transformed into photographic coordinates in the inner orientation.

Relative orientation: The photographic coordinates of the tie points and photo control points were transformed into model coordinates in the relative orientation.

Adjustment calculation by the bundle method:

Adjustment calculation by the bundle method was carried out using the photographic coordinates of the tie points and photo control points and the results of the photo control point survey.

(6)Digital Plotting/Compilation

Digital plotting and compilation was carried out using the results of the aerial triangulation and the field identification in accordance with the map symbol specifications.

1) Digital Plotting

Digital data of topographic features were obtained in accordance with the map symbol specifications, using various types of digital plotters. The digital data of topographic features that were obtained are either point, line or polygon in form, in accordance with the map symbol specifications.

2) Digital Compilation

Digital compilation was carried out using the digitally-plotted data and CAD software for data compilation, MicroStationV8.

In practice, in the digital compilation each symbol was moved to the appropriate location, annotations and administrative boundaries were added and consistency between topographic features data was established. In the final stage, items for supplementary field verification were identified.

7) Supplementary Field Verification

Uncertainties identified in the digital plotting/compilation were eliminated and administrative boundaries and names were confirmed definitively in the supplementary field verification. The supplementary field verification was implemented with technical assistance from SDSL.

1) Implementation Period and Organizations Involved

The supplementary field verification was implemented over two periods, with technical assistance from SDSL. Eleven teams of SDSL staff members carried out the supplementary field verification in the period of October 2010 and 12 teams in the period of September 2009.

2) Details of the Work

Data on administrative boundaries and names, road classifications and the results of the control point were obtained in the indoor work. Meanwhile, uncertainties identified in the digital plotting/compilation were eliminated and data on additional features to be represented on the maps were obtained in the field work. Data on road kilometer posts, high-voltage transmission lines and a disused railroad, the names of major road intersections and major facilities and annotations were also obtained.

(8) Supplementary Digital Compilation

The results of the supplementary field verification (the results of the elimination of uncertainties, acquisition of data on road kilometer posts, high-voltage transmission lines, etc.) were added to the topographic map data in such a way as to maintain data consistency with nearby features.

(9)Digital Data Structuralization

The data processed in the digital compilation after field completion were structuralized.

1) Structuralizing Compilation

The data processed in the supplementary digital completion were inspected and corrected for logical errors and were structuralized topologically.

2) Data Format Conversion

The data processed in the structuralizing compilation were converted into data in DXF and SHPE formats per each map sheet.

(10) Map Symbolization

AI data for printing 1/10,000-scale maps were produced from the structuralized digital topographic map data.

1) Map Symbolization of Topographic Map Data

Map symbols were created in accordance with the map symbol specifications and correspondence was established between the symbols created and each topographic feature data. The order of feature layers was rearranged for better representation on the output topographic maps. Where two or more feature symbols overlap, the location of symbols on the map was transferred so as to make all the symbols distinguishable.

2) Map Symbolization of Marginal Information

Topographic features in legends included in marginal information were symbolized in accordance with the map symbol specifications. The other marginal information was also symbolized.

3) Integration of Symbolized Topographic Map Data and Symbolized Marginal Information Data

AI data for output maps were produced by integrating symbolized topographic map data and marginal information data and adding data such as the map sheet number and title to each sheet.

(11)Production of Digital Data File

Vector data in DXF and SHPE formats produced in the digital data structuralization and symbolized AI data converted into raster format (PDF format) were stored on DVDs and other recording media.

1.3.2Implementation of Technology Transfer

Technologies in the technical fields relevant to digital photogrammetry were transferred to the counterparts in order to achieve objective ‘c’ of this Study.

(1) Photo Control Point Survey

Since SDSL already had sufficient experience in photo control point survey (GPS survey and levelling), the focus of the technology transfer in photo control point survey was on the technologies required for the implementation of aerial triangulation.

1) GSP Survey

Methods of calculating the number of photo control points and distributing photo control points required for the implementation of aerial triangulation were transferred to the counterparts.

2) Levelling

Methods of calculating the number of vertical control points and distributing vertical control points required for implementing aerial triangulation and for determining levelling routes were transferred to the counterparts.

3) Installation of Air Photo Signal and Pricking

Since the focus of the technology transfer was on the implementation of aerial triangulation, technologies for installing air photo signals and pricking, including the preparation of detailed drawing of air photo signals and pricking points, were also transferred to the counterparts.

(2) Field Identification

Since SDSL had no experience of field identification using aerial photographs, technologies required for this, including indoor photo interpretation and practical work in field identification, were transferred to the counterparts.

(3) Aerial Triangulation

SDSL had abundant experience in analog aerial triangulation and knew the general technologies for aerial triangulation. Therefore, technology transfer in aerial triangulation was implemented with the focus on how to use the software for digital aerial triangulation introduced in this project.

(4) Digital Plotting/Compilation

SDSL had abundant experience in digital plotting/compilation. SDSL owns digital plotters, though none of them are of the same model as the plotter used in this Study, and is routinely implementing digital plotting work. Similarly, SDSL is implementing digital compilation using an older version of the digital compilation software which was introduced in the project.

Under these circumstances, the technology transfer in digital plotting/compilation was implemented with the focus on how to use the digital plotting system to be introduced in the project, and how to use the latest digital compilation software.

(5) Supplementary Field Verification

SDSL had abundant experience in supplementary field verification using output maps of digitally edited data. Based on this, technology transfer in supplementary field verification included the following:

a. How to eliminate uncertainties identified in the digital plotting/compilation;
b. How to make a final confirmation on certain features
c. How to create and use annotation data files
d. Schedule management and accuracy control technologies

(6) Digital Data Structuralization

SDSL had experience in various kinds of works in which Arc GIS software was used. Therefore, the focus of the technology transfer in digital data structuralization was on the development and use of technologies to facilitate and automate data processing (including structuralization), in which the staff of SDSL were involved routinely in their work, instead of the basic operation of the latest ArcGIS software introduced in the project.

(7)Map Symbolization

Technologies for the use of the software introduced in the project (Adobe Illustrator) for transforming the data processed in the supplementary digital completion into AI data for maps to be printed out were transferred to the counterparts in the technology transfer in map symbolization. The actual technologies transferred are listed below.

a. Establishment of printing environments
b. Basic operation of Adobe Illustrator CS5
c. Production of topographic map symbols in accordance with the map symbol specifications
d. Special map symbolization technologies (change of scale, rearrangement of the layer order, trimming, etc.);
e. Production of data files for printout topographic maps

1.3.3 Other Work

(1)Holding of Seminar/Workshop

A seminar/workshop was held on 4th November 2011 with the participation of the Secretary of the Ministry of Land and Land Development, the ministry in charge of SDSL.

At the seminar/workshop, the process by which the project was implemented and the results of its implementation were presented, and the results of the technology transfer (including demonstrations) was revealed to a wide public audience. Samples of the digital topographic maps that had been produced were also shown at the seminar/workshop. SDSL announced its plan to produce digital topographic maps of the unmapped areas of the Northern Region. In addition, the guidelines for the future production of geospatial data by SDSL were presented.

(2)Reports

1) Preparation of the Reports

The following reports were prepared in the project:

a. Inception Report: Describing the outline of the project and methods of implementation.

b. Interim Report: Describing the achievements of project implementation by the end of September 2010 and the work scheduled for implementation thereafter.

c. Draft Final Report: Describing the progress and results of the implementation of the project in its entirety.

d. Final Report: Describing the progress and results of the implementation of the project in its entirety, tasks remaining and recommendations for future activities.

2) Explanation and Discussion of the Reports

After the completion of the Inception Report, Interim Report and Draft Final Report respectively, an explanation of the report was given to SDSL and discussions were held with them on the report.

At each explanation/discussion meeting, the SDSL side approved the report after raising some technical questions and making a few requests.

1.4 Results of the Implementation of the Survey

1.4.1 Results of the Production of Digital Topographic Mapping

(1) Discussion of the Specifications

In discussions between the SDSL and the Study Team, it was decided to use the following geodetic reference system in the project:

Reference ellipsoid:	Everest 1830
Coordinate system:	Sri Lanka Datum 1999 (SLD-99-2)
Projection method:	Transverse Mercator projection

The map symbol specifications for 1/10,000-scale digital topographic maps were established. The areas in Mannar and Jaffna Districts for topographic mapping (100 map sheets covering an area of 2,008.2 km^2) were also determined.

(2) Aerial Photography

Aerial photography of the entire target area of approximately 9,000 km^2 (2,494 photographs from 61 flight courses) was eventually completed after many difficulties.

(3) Photo Control Point Survey

One hundred and five control points were established in GPS survey, and levelling was carried out over a length of approximately 550 km over several phases.

(4) Field Identification

Field identification was carried out in a 36 km^2 area in Jaffna District.

(5)Aerial Triangulation

While aerial triangulation was implemented initially for the area for topographic mapping, in the end digital aerial triangulation (2,127 photographs from 61 flight courses) and analog aerial triangulation (2,031 photographs from 61 flight courses) of the entire region were carried out.

(6) Digital Plotting/Compilation

Data for the area of 2,008.2 km^2 on the 100 map sheets were digitally plotted and compiled.

(7)Supplementary field verification

Supplementary field verification of the area of 2,008.2 km^2 on the 100 map sheets was implemented over two phases.

(8) Supplementary Digital Compilation, Digital Data Structuralization and Map Symbolization

Supplementary digital compilation, digital data structuralization and map symbolization of topographic map data on the area of 2,008.2 km^2 on the 100 map sheets were implemented.

(9)Production of Digital Data File

Files in the various formats of topographic map data corresponding to the area of 2,008.2 km^2 on the 100 map sheets were produced.

1.4.2 Results of the Implementation of Technology Transfer

(1)Photo Control Point Survey

1) GPS Survey

The counterparts have fully mastered how to calculate the number of photo control points for GPS survey. At the same time, they are not considered to have sufficiently mastered the method of distributing photo control points, because of a lack of practice.

2) Levelling

The counterparts have completely mastered how to select levelling routes and how to make reasonable observations.

(2)Field Identification

Because only a limited amount of field identification has been carried out, it is not considered that the counterparts have sufficiently mastered the technologies for field identification. They will need more experience to gain complete mastery of the technologies.

(3)Aerial Triangulation

The counterparts have become able to make full use of the software for digital aerial triangulation that was introduced. This proves that they have completely mastered the technologies used in the aerial triangulation.

(4) Digital Plotting/Compilation

The counterparts have completely mastered the use of the latest digital plotting/compilation system introduced in the project, partly due to their prior practical experience in digital plotting/compilation.

(5) Supplementary Field Verification

The counterparts have completely mastered the technology in supplementary field verification partly due to their prior practical experience in supplementary field verification. However, they have yet to master the technology for the preparation of a supplementary field verification manual.

(6) Digital Data Structuralization

The transferred technologies were at higher levels than originally planned and the counterparts have fully mastered the technologies that enable them to use the software to facilitate and automate data structuralization.

(7) Map Symbolization

Although the counterparts had not had experience in map symbolization using the map symbolization software that was introduced, they have completely mastered the basics of it and have become able to carry out map symbolization.

1.5 Production of Project

The implementation of the Study has produced the following outputs:

(1) Study Reports

a. Inception Report		in English, 25 copies
b. Interim Report		in English, 25 copies
c. Draft Final Report		
	Main	in English, 25 copies
	Summary	in English, 25 copies
d. Final Report		
	Main	in English, 25 copies
	Summary	in English, 25 copies

(2) Products

a. Aerial photographs		
	Exposed films	1 set
	Digital data files	1 set
	Contact prints	2 sets
	Aerial photography index maps	1 set
b. Field survey results		1 set
c. Aerial triangulation results		1 set

d. Digital data files (scale 1/10,000 topographic maps) 1 set

2. Efforts toward the Development of Digital Topographic Maps

2.1 Effective Use of the Project Outputs

2.1.1 Effective Use of the Digital Topographic Maps

Digital topographic maps covering approximately a quarter of the entire Northern Region were produced in this project in accordance with the specifications.

The following are required for the use of the digital topographic maps that were produced:

*Publication and dissemination of the specifications for the digital topographic maps

*Public availability of the digital topographic maps and the implementation of publicity activities to promote their use

*Establishment of a mechanism for the supply of digital topographic maps (including a pricing policy and supply method)

2.1.2 Effective Use of the Results of the Technology Transfer

The Study Team has evaluated the results of the technology transfer carried out during the implementation period of this project. Apart from the evaluation by the study Team, SDSL should implement an independent evaluation of the results of the technology transfer using the reports of the recipients of the technology transfer. This evaluation will mark the first step for SDSL toward the effective use of the results of the technology transfer.

2.2 Tasks based on the Results of the Technology Transfer

Since the technology transfer was carried out over a number of different technical fields, some difference has been noted in the level of the results of the technology transfer depending on the technical field.

The level of mastery is high in the fields where SDSL had prior experience in the use of similar technologies (observation and analytical calculation in the photo control point survey, digital plotting/compilation, supplementary field verification and digital data structuralization). The level of mastery of the transferred technologies is also high in those fields where the transferred technologies have been used repeatedly (installation of air photo signals and production of sketches of pricked points).

At the same time, the level of mastery of the transferred technologies is low in technical fields in which the counterparts had little prior experience or where the transferred technologies have not been used repeatedly (distribution of photo control points and map symbolization).

These findings reveal the need for improvement in the level of mastery of the transferred technologies in those technical fields where the level of mastery is low, by means of repeated practice, dissemination of the mastered technologies and improvement in productivity of the mastered technologies.

2.3 Production of Digital Topographic Maps for the Remaining Unmapped Areas in the Northern Region

At the end of the completion of the Project there have been high expectations for the production of digital topographic maps of the unmapped area of the Northern Region.

2.3.1 The Map Production Project for the Unmapped Areas in the Northern Region by SDSL

SDSL announced its plan for the production of digital topographic maps of the unmapped areas based on the relevant government office. The announced plan assumes completion of digital plotting/compilation of the entire area, which is to be carried out according to the order of priority of each map sheet by June 2014. In an alternative plan, which assumes doubling of the work force, the date for the completion is set in March 2013.

2.3.2 Issues Requiring Attention in the Production of Digital Topographic Maps of the Unmapped Areas of the Northern Region

There are several issues requiring attention (in the processes following digital plotting, in particular) before SDSL's plan for the production of the digital topographic maps can be implemented.

(1) Improvement of the Technical Capacity to Produce Digital Topographic Maps

The results of the Project include the results of the digital and analog aerial triangulation. While it is expected that these outputs will be used in the production of digital topographic maps, the following issues require attention:

*Effective use of the results of the digital and analog aerial triangulation

*Dissemination of technical capacity and improvement of productivity in digital plotting/compilation

*Establishment of an implementation mechanism and improvement of productivity in supplementary field verification

*Improvement of productivity in map symbolization.

(2) Production Plan of Digital Topographic Maps of the Unmapped Areas of the Northern Region

SDSL has already formulated a plan for the production of digital topographic maps of the remaining areas. However, the following issues require attention while details of the plan are being finalized.

*Human and material resources available to SDSL as inputs to the map production plan

*Production per unit time in each technical process following digital plotting (digital compilation, supplementary field verification and map symbolization).

(3)Production of Digital Topographic Maps of the Unmapped Areas of the Northern Region

After the production of digital topographic maps commences, measures must be taken to ensure the quality of the maps, *i.e.* accuracy control in each process and evaluation of the quality of final products.

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Chapter1 Outline of the Project

1.1 Backgrounds of the Project

In the Democratic Socialist Republic of Sri Lanka (hereinafter Sri Lanka) the civil war that lasted nearly 30 years ended in May 2009 when government forces defeated the Liberation Tigers of Tamil Eelam (LTTE), and took control of the whole country. However, fierce fighting in the north since January 2009 displaced approximately 280,000 persons and the Northern Region is faced with urgent issues such as mine clearance, rebuilding infrastructure, and repatriating the internally displaced persons (IDP).

The people of northern Sri Lanka suffered enormously during the long civil war; therefore, rapidly aiding their recovery is of utmost precedence from the perspectives of security, stability and development of Sri Lanka. Further, the Government of Japan has made '*assistance for consolidation of peace and reconstruction*' a main pillar of its country specific assistance plan for Sri Lanka; based on this JICA has made '*improving resident's livelihoods and social environment in war affected areas*' one of its development issues.

On the other hand, JICA undertook a series of information gathering and confirmation surveys in Northern Region from September 2009 to get a hold on the situation in the north including the repatriation of IDP, because, there was little progress made on this for some time after the war. These surveys confirmed the needs and high expectations of assistance in fields closely related to the livelihoods of residents such as rebuilding livelihoods (skills training, creating jobs and recovery of agriculture and fishery industries, and renovating/constructing fisheries facilities and small irrigation facilities to this purpose) and waste management in communities and local governments in Jaffna and Mannar districts where IDPs will actually be rehabilitated.

Against this backdrop, IDP repatriation has moved into full-swing since October 2009, with reports that as of November 2010 approximately 10,000 IDP had been repatriated to Mannar District and approx. 70,000 to Jaffna District. As mentioned above, however, the environment awaiting the returning IDP is insufficient; therefore the development of core infrastructure to support livelihoods is a particularly urgent issue.

This project is to undertake aerial photography to grasp the situation in the Northern Region to contribute to its recovery, and to make 1:10,000 scale topographic maps needed to establish a recovery plan for an area covering approx. 2,000 km^2 of Mannar and Jaffna districts.

Moreover, in the process, the project's purpose is to transfer digital topographic mapping techniques. The technical transfer for digital topographic mapping aims to develop the necessary capacity so that the Sri Lankan government can independently make 1:10,000 digital topographic maps of the remaining area after the project is over.

Further, the counterpart (hereinafter C/P) organisation is the Survey Department of Sri Lanka (hereinafter SDSL).

1.2 Objectives of the Project

The objectives of this Project were as follows:

(1) Aerial photography of the entire Northern Region of Sri Lanka.

(2) Production of 1:10,000-scale topographic maps of Mannar and Jaffna Districts of Sri Lanka.

(3) Technology transfers for production of digital topographic maps through implementation of (1) and (2) mentioned above.

1.3 Outline of the Project

1.3.1 Outline of the Digital topographic map production

The target areas by project objective were as follows:

(1) Aerial photography: Approximately 9,000 km^2 area of Northern Region

(2) Area for production of 1:10,000-scale digital topographic maps: Approximately 2,000 km^2 area of Mannar and Jaffna Districts

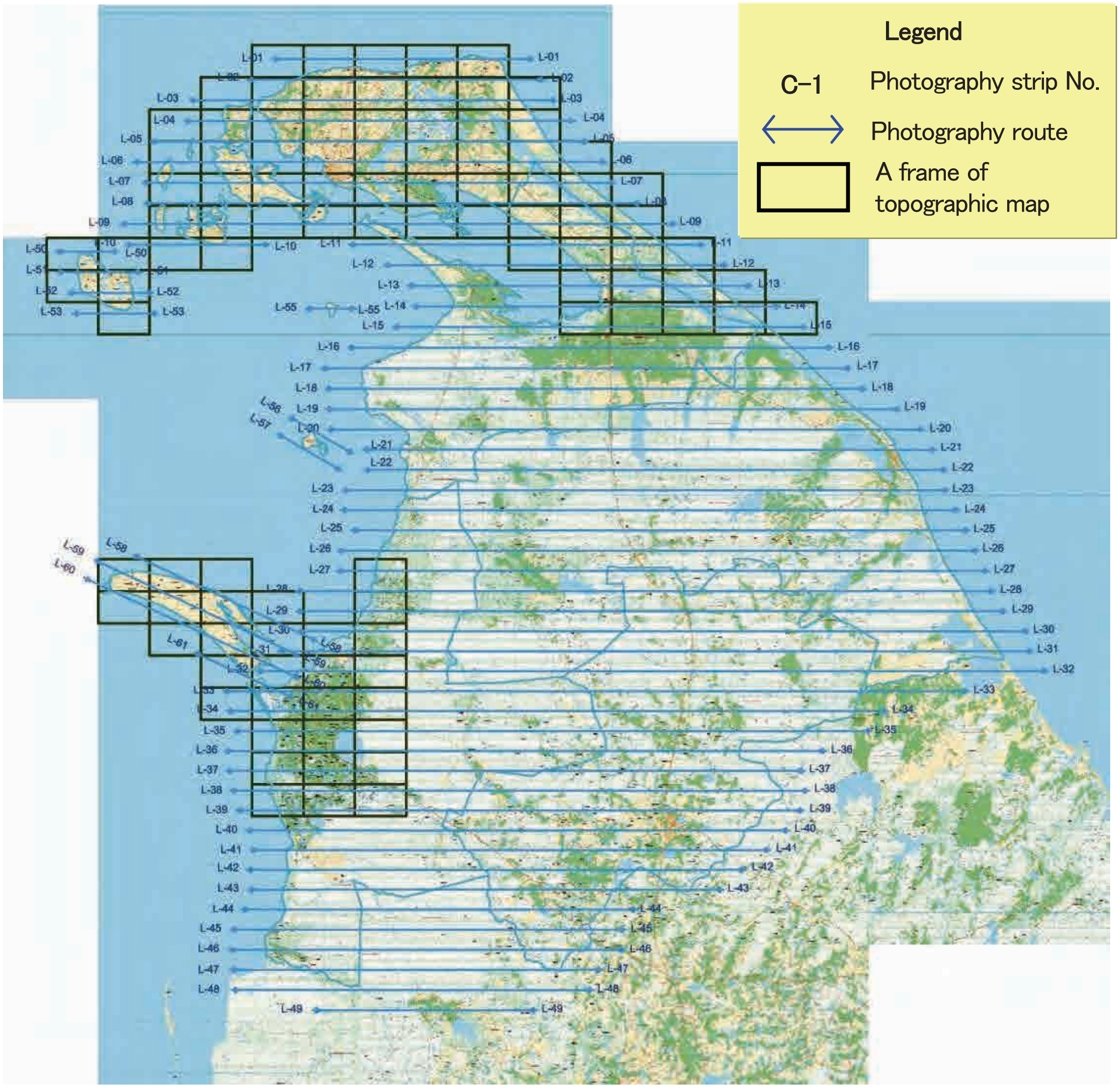


Fig 1-1 Implemented Aerial photography and Plotting targeted areas

1.3.2 Outline of the Technology transfers

Technology transfer of the following techniques was implemented for the employees of SDSL, the counterpart agency:

GPS Photo control point survey, Levelling, Field identification, Supplementary field verification

Digital photogrammetry (Digital aerial triangulation, Digital plotting/compilation)

GIS Structualization

Map symbolization

1.3.3 Outline of the other works

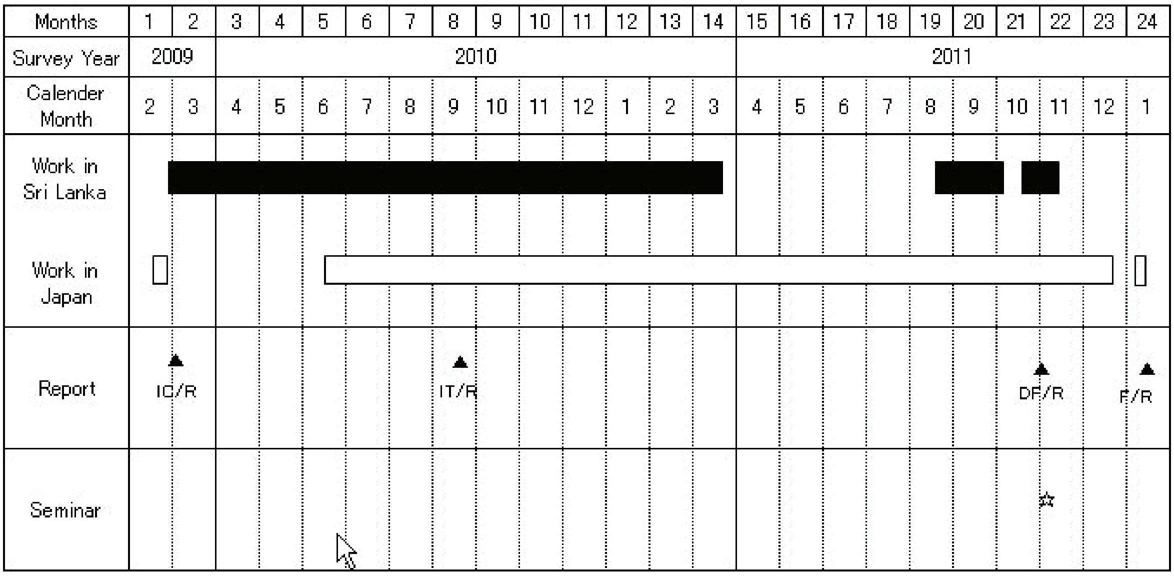
The following works were implemented as other works

Holding of seminar/workshop

Preparation, Explanation of and discussion on various reports

1.4 Work schedule

1.4.1 Outline of work schedule



The outline of work schedule for the project was as follow.

As above outline of work schedule, the project was scheduled to commence in February 2009 and finish in January 2012.

1.5 Products of the project

（1） Project reports

The following reports were made and submitted:

a.	Inception report	English	25sets
b.	Interim report	English	25sets
c.	Draft final report		
	Main report	English	25sets
	Summary	English	25sets
d.	Final report		
	Main report	English	25sets
	Summary	English	25sets

（2） Products

The following products were made and submitted during this project

a. Aerial photography（scale 1/20,000 : color）

Exposed film	1 set
Diapositives	1 set
Digital data file	1 set
Contact prints	2 sets
Aerial photograph index map	1 set
b. Field survey result	1 set
c. Aerial triangulation result	1 set
d. Digital data file (scale 1/10,000topographic map)	1 set

Chapter2 Project implementation

2.1 Basic policies of the project

2.1.1 Basic policies for project implementation

On the basis of the objectives of the Project, the following basic implementation policies had been established:

（1） Basic Polices

Basic Policy 1: Aerial photography will be carried out at appropriate times and the results of the aerial photography will be promptly used in the subsequent works.

Basic Policy 2: Topographic maps will be produced in accordance with specifications to be determined in a discussion based on the conventional specifications of SDSL and JICA's specifications for their use in drafting a future reconstruction plan

Basic Policy 3: Technology transfer to SDSL will be implemented in such a way that SDSL will be able to produce digital topographic maps of the remaining area independently after the completion of the Project

（2） Approaches to the basic policies

The following approaches were taken toward realization of each of the basic policies:

1) Approaches to Basic Policy 1

a. Approach 1-1: Procedures for subcontracting the aerial photography will be taken promptly.

b. Approach 1-2: Various permits required for the aerial photography will be obtained from the authorities concerned so as not to miss the appropriate time for the aerial photography.

2) Approaches to Basic Policy 2

a. Approach 2-1: Geographic information items required for drafting a reconstruction plan will be confirmed and finalized.

b. Approach 2-2: Consistency will be established between the specifications used by SDSL and JICA's specifications and the specifications agreed upon by both parties will be used for the production of digital topographic maps.

3) Approaches to Basic Policy 3

a. Approach 3-1: A plan for technology transfer appropriate for the current technological level in production of digital topographic maps at SDSL will be produced.

b. Approach 3-2: Technology transfer will be carried out with focus on the technologies which enable production of digital topographic maps of the remaining area in a short period.

c. Approach 3-3: Advice will be provided on drafting and implementing a project for production of digital topographic maps of the remaining area.

d. Approach 3-4: The technology transfer will be intensively implemented during the on-site On the Job Training (OJT) as the focus of the training is on planning, management and sorting methods

2.2 Contents of project work implemented

2.2.1 Content and quantity project work implemented

To achieve the objectives, the project work was divided into four parts.

Part 1 : Production of digital topographic maps

Part 2 : Technology transfer

Part 3 : Seminar/Workshop

Part 4 : Production of, Explanation of and Discussion on various reports

（1） Production of digital topographic maps

The composition, description and quantity of this work are outline in Table 2-1.

Table 2-1 Description and quantity of digital topographic mapping

Work Item	Outline of Work	Quantity
Collection, sorting and analysis of relevant materials and information	Relevant materials and information were collected, sorted and analyzed for the implementation of the project.	1 set
Map specification	The specification related to the digital topographic mapping was discussed and determined with the counterpart agency.	1set
Aerial photography	The aerial photography necessary for digital topographic mapping was carried out.	Approx 9,000km^2
Photo control survey	The photo control point survey was made by using the GPS survey system and the leveling system, and the photo signalization and the pricking were carried out.	Photo control points : 105 points Levelling : approx 550km

Work Item	Outline of Work	Quantity
Aerial triangulation	The orientation elements necessary for digital mapping were obtained through calculation process using the results of the photo control point survey. In addition, the digital and analogue aerial triangulation was implemented from the view point of subsequent works.	Digital method : 61 Strips 2127 sheets Analogue method : 61 Strips 2031 sheets
Field identification	The various types of information (including geographic names and annotations) which are not available by photo interpretation were collected in field identification using the aerial photograph.	758km^2
Digital plotting	Digital plotting at 10,000 levels was conducted by using the results of aerial triangulation, photo interpretation and field identification.	2008.2km^2
Digital compilation	Digital compilation using digital plotting data was conducted in accordance with the map symbol specification.	2008.2km^2
Supplementary field verification	The doubtful points arising from digital plotting/compilation and the administrative boundaries and annotations were clarified in the field.	2008.2km^2
Supplementary digital compilation	Digital data based on the results of Supplementary field verification were compiled.	2008.2km^2
Digital data structuralization	Supplemental digital compilation data were structuralized on GIS software.	2008.2km^2
Map symbolization	Supplementary digital compilation data were symbolized in accordance with the map symbol specification.	2008.2km^2
Production of digital data file	The digital data files were created by storing the structualization data, map symbolization data and output mapping data on a media.	1 set (2008.2km^2)

（2） Technology transfer

The technologies and their outline that were targeted for transferred were shown in Table 2-2.

Table 2-2 Technology to be transferred

Technical field	Transferred Technology	Outline
Photo control point survey	GPS survey (Photo control point survey for Aerial triangulation ）	Planning method (Method for determining the number of photo control points and distributing the photo control points) Method for installing air-photo signals (size, shape, etc.)
	Levelling (levelling for Aerial	Planning method (Method for

	triangulation)	setting levelling routes) Observation method (Rational observation)
Field identification(including supplementary field verification)	Field identification using aerial photography Supplementary field verification	Method of preparation and planning, Method of execution (incl. method of photo interpretation) Method of results compilation
Digital photogrammetry	Digital Aerial triangulation	Implementation plan Method of implementation Method of results evaluation
	Digital plotting	Digital plotter operating procedure Setup of digital plotting environment Digital plotting Handling of plotted data
	Digital compilation	Setup of map symbols Digital compilation Handling of compiled data
Digital data structualization (GIS structualizaton)	Structualization of topographic mapping data into GIS database	Method of application of latest GIS software Structualization of topographic mapping data into GIS database
Map symbolization	Production and distribution of map symbol etc	Production of marginal information and legends Production of printing data

（3） Seminar/Workshop

The name and description of this works are outlined in table 2-3.

Table 2-3 Outline of the seminar/workshop

Work Item	Outline of Work
Seminar/Workshop	The Seminar/Workshop was held on November 4th, 2011 at Water Edge. Approximately 150 people, including the Deputy Minister and the Vice Minister of the Ministry of Land and Land Development, the competent ministry of SDSL, and staff of the Embassy of Japan, attended the Seminar/Workshop. The actual activities implemented in the Project and the outputs of the Project were explained and a plan for the production of digital topographic maps in future was presented at the Seminar/Workshop.

（4） Production of, Explanation of and Discussion on various reports

The name and description of this works are outlined in table 2-4.

Table 2-4 Outline of the various reports

Work Item	Outline of Work
Production of, explanation of and discussion on Inception report	The Inception Report giving the outline, schedule and implementation method of the Project was prepared and the explanation of and discussion on the Report took place.
Production of, explanation of and discussion on Interim report	Progress made in the Project up to the end of September 2009 was reported per work field, and the subsequent schedule of the Project was also drawn up.
Production of, explanation of and discussion on draft Final report	The outline, progress and results of the Project were compiled in the Draft Final Report. The guidelines for data development, maintenance and operation, GIS database and system configuration (Work Manual) were drafted as recommendations. The explanation of and discussion on the Report took place.
Production of the final report	The outcomes of the explanation and discussion on the Draft Final Report and the Seminar/Workshop were summarized and the Final Report on which reflected the results of summarization was prepared.

（５） Flow chart

The following is a flowchart of project works.

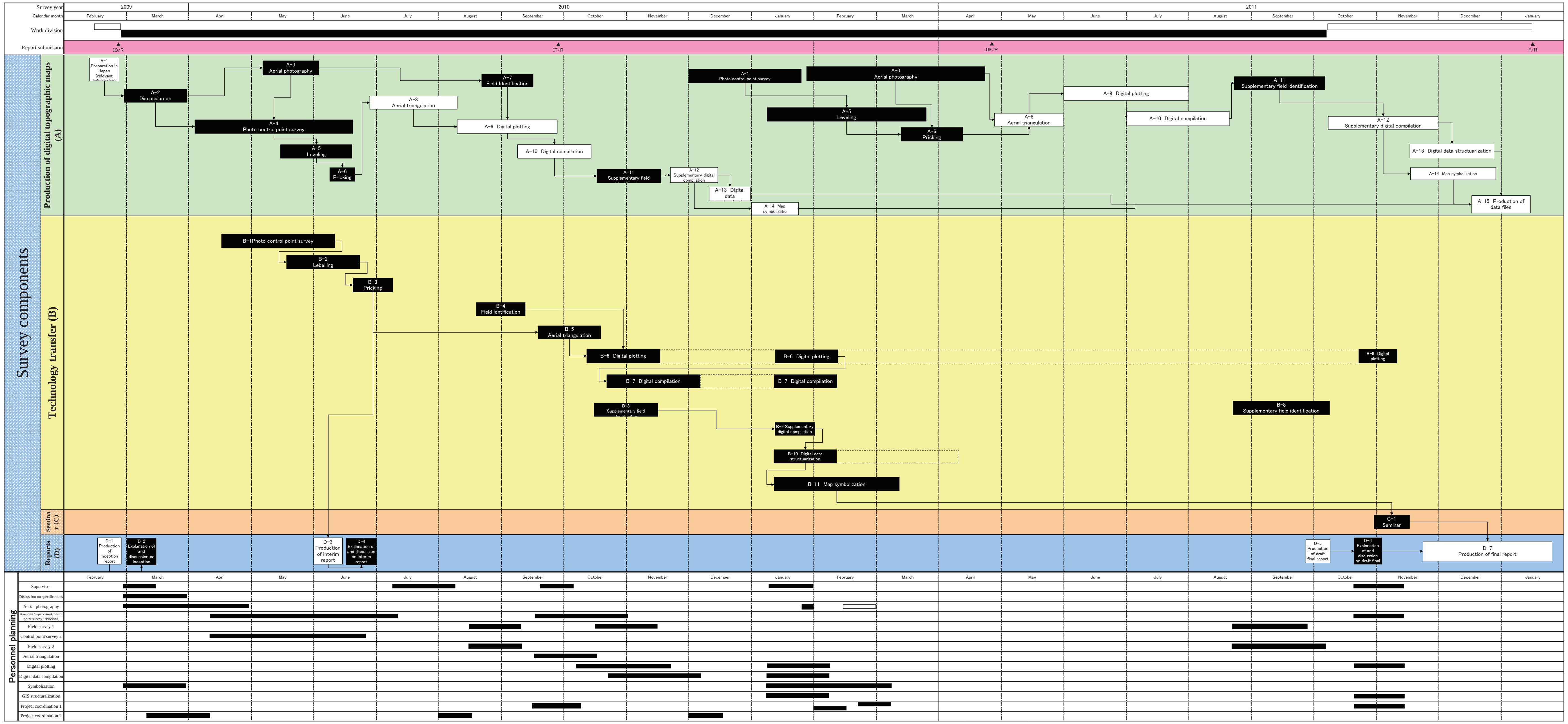


Fig 2-1 Flow Chart

2.3 Composition of Study team

The Study Team that was made up as follows implemented the project.

Study Work in charge	Name of Member	Main Work Items
Team leader	Nishimura Akira	• General operation and management of all the study weeks
Map specification	Chiba Zenichi	• Discussion of the specifications for digital topographic mapping
Aerial photography	Usuda Kentarou	• Selection of local subcontractor for aerial photography • Drawing up of the specifications for aerial photography • Supervision of aerial photography
Sub-leader/Photo control point survey/ 1/Pricking	Harada Takashi	• Support of operations in all the works covered by the Study • Operation and supervision of photo control point survey for digital topographic mapping as well as technology transfer of the same • Operation and supervision of pricking for digital topographic mapping as well as technology transfer of the same
Photo control point survey 2	Ishizuka kazuhiro	• Operation and supervision of photo control point survey for digital topographic mapping as well as technology transfer of the same
Field identification1	Ishizuka kazuhiro Nishio Satoru	• Operation and supervision of photo control point survey for digital topographic mapping as well as technology transfer of the same
Field identification2	Usuda kentarou	• Operation and supervision of field survey (supplementary field verification) for digital topographic mapping as well as technology transfer of the same
Aerial triangulation	Nakamura Mitsutomo	• Technology transfer of digital aerial triangulation
Digital plotting	Ikeda Yoshiaki	• Technology transfer of digital plotting
Digital compilation	Hoshino Jyun	• Technology transfer of digital compilation
GIS structualization	CHE Wentao	• Technology transfer of conversion (structualization) of topographic mapping data into GIS database
Map symbolization	Fukumoto Yoshimitsu	• Technology transfer of map symbolization of topographic mapping data
Coordinator 1	Kato Takayuki Usuda kentarou Takahashi	• Assistance in technology transfer of aerial triangulation • Coordination of the supervision assistance

Study Work in charge	Name of Member	Main Work Items
	Masahiko Ishijima Norio	work for aerial photography • Coordination of the Study works
Coordinator 2	Oouchi Yuuji Hirahara Naomi	• Coordination of the Study works

Chapter3 Results of the Project

3.1 Project works and their timing

3.1.1 Project work items

（1） Production of digital topographic maps

The following project works as production of digital topographic maps was implemented:

- A-1：Preparation in Japan (collection, sorting and analysis of materials and information
- A-2：Map specification
- A-3：Aerial photography
- A-4：Photo control point survey
- A-5：Levelling
- A-6：Pricking
- A-7：Field identification
- A-8：Aerial triangulation
- A-9：Digital plotting
- A-10：Digital compilation
- A-11：Supplementary field verification
- A-12：Supplementary digital compilation
- A-13：Digital data structualization
- A-14：Map symbolization
- A-15：Production of digital data files

（2） Technology transfer

The following works as technology transfer was implemented:

- B-1：Photo control point survey
- B-2：Levelling
- B-3：Pricking
- B-4：Field identification
- B-5：Aerial triangulation
- B-6：Digital plotting
- B-7：Digital compilation
- B-8：Supplementary field verification
- B-9：Supplementary digital compilation

B-10：Digital data structualization

B-11：Map symbolization

（3） **Seminar/Workshop**

The following project work as seminar/workshop was implemented:

C-1：Holding seminar/Workshop

（4） **Production of, Explanation of and Discussion on various reports**

The following project works as a production of, Explanation of and discussion on various reports:

D-1：Production of inception report

D-2：Explanation of and discussion on Inception report

D-3：Production of Interim report

D-4：Explanation of and Discussion on Interim report

D-5：Production of Draft final report

D-6：Explanation of and Discussion on Draft final report

D-7：Production of Final report

3.1.2 Timing of each project works

The detail work schedule that contains the project work items and its timing is shown in Table 3-1.

（1） **First work in Japan**

Timing：10 February 2010～27 February 2010

Works： A-1：Preparation in Japan (collection, sorting and analysis of materials and information

D-1：Production of Inception report

（2） **First work in Sri Lanka**

Timing：28 February 2010～5 August 2010

Works： A-2：Map specification

A-3：Aerial photography

A-4：Photo control point survey

A-5：Levelling

A-6：Pricking

B-1：Photo control point survey

B-2：Levelling

B-3：Pricking

D-2：Explanation of and Discussion on Inception report

（3） Second works in Japan

Timing：6 August 2010～14 October 2010

Works： A-8：Aerial triangulation

A-9：Digital plotting

A-10：Digital compilation

（4） Second works in Sri Lanka

Timing：15 August 2010～8 September 2010

Works： A-7：Field identification

B-4：Field identification

（5） Third works in Japan

Timing：17 September 2010～4 December 2010

Works： A-11：Supplementary field verification

B-5：Aerial triangulation

B-6：Digital plotting

B-7：Digital compilation

B-8：Supplementary field verification

（6） Third works in Japan

Timing：14 November 2010～31 January 2011

Works： A-12：Supplementary digital compilation

A-13：Digital data structualization

A-14：Map symbolization

（7） Forth works in Sri Lanka

Timing：11 December 2010～13 May 2011

Works： A-3：Aerial photography

A-4：Photo control point survey

A-5：Levelling

A-6：Pricking

B-6：Digital plotting

B-9：Supplementary digital compilation

B-10：Digital data structualization

B-11：Map symbolization

（８） Forth works in Japan

Timing：23 April 2011～27 August 2011

Works：

A-8：Aerial triangulation

A-9：Digital plotting

A-10：Digital compilation

（９） Fifth works in Sri Lanka

Timing： 28 August 2011～11 October 2011

Works：

A-11：Supplementary field verification

B-8：Supplementary field verification

（１０） Fifth works in Japan

Timing：12 October 2011～15 January 2012

Works：

A-12：Supplementary digital compilation

A-13：Digital data structualization

A-14：Map symbolization

A-15：Production of digital data files

D-5：Production of Draft final report

（１１） Sixth works in Sri Lanka

Timing：21 October 2011～9 November 2011

Works：

B-6：Digital plotting

B-10：Digital data structualization

C-1：Holding Seminar /Workshop

D-6：Explanation of and Discussion on Draft final report

（１２） Sixth works in Japan

Timing：10 November 2011～15 January 2012

Works： D-7：Production of Final report

Table 3-1 Detailed Schedule

Survey year: 2009 (February–March); 2010 (April–March); 2011 (April–January)

Calendar month: February, March, April, May, June, July, August, September, October, November, December, January, February, March, April, May, June, July, August, September, October, November, December, January

Report submission: ▲ IC/R (March 2009), ▲ IT/R (September–October 2010), ▲ DF/R (October 2011), ▲ F/R (January 2011)

Production of digital topographic maps	A-1	Preparation in Japan (collection, sorting and analysis of relevant materials and information)
	A-2	Map specification
	A-3	Aerial photography
	A-4	Control point survey
	A-5	Leveling
	A-6	Pricking
	A-7	Field identification
	A-8	Aerial triangulation
	A-9	Digital plotting
	A-10	Digital compilation
	A-11	Supplementary field identification
	A-12	Digital editing of supplementary survey data
	A-13	Digital data structuralization
	A-14	Symbolization
	A-15	Production of digital data files
Technology transfer	B-1	Control point survey
	B-2	Leveling
	B-3	Pricking
	B-4	Field survey
	B-5	Aerial triangulation
	B-6	Digital plotting
	B-7	Digital data compilation
	B-8	Supplementary field survey
	B-9	Digital editing of supplementary survey data
	B-10	Digital data structuralization
	B-11	Symbolization
Seminar/Workshop	C-1	Seminar
Reports	D-1	Production of Inception Report
	D-2	Explanation of and discussion on Inception Report
	D-3	Production of Interim Report
	D-4	Explanation of and discussion on Interim Report
	D-5	Production of draft Final Report
	D-6	Discussion on draft Final Report
	D-7	Production of Final Report

Personnel Planning (months: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1)

Personnel Planning
Team Leader
Map specification
Aerial photography
Sub-leader/Control point survey 1/Pricking
Field identification 1
Control point survey 2
Field identification 2
Aerial triangulation
Digital plotting
Digital compilation
Map symbolization
GIS data structuralization
Coordination 1
Coordination 2

Legend: ■ Field survey; □ Work in Japan; Production of digital topographic maps; Technology transfer; Seminar; Reports

3.2 Results of the Project

3.2.1 Production of digital topographic maps

（1） Specification of digital topographic mapping

Discussions were held and consensus formed on the basic specifications (including survey standards, map symbol specifications) for the production of 1:10,000 scale topographic maps. In principle, the basic specifications were based on the conventional specifications used by SDSL, while making reference to JICA's specifications.

However, the map symbol specifications were discussed and determined with SDSL in July and October 2010. Further, the plotting area was also discussed and decided upon.

１） Discussion on Survey standards

The survey standards to be used in the photo control point survey and digital plotting were discussed with SDSL and decided upon as follows. However, some of the standards (including geodesic datum point) were changed, with priority given to the results of the discussions.

Coordnate System: Sri Lanka Datum 1999 (SLD-99-2)

Reference Ellipsoid: Everest (1830)

A (long radius) = 6,377,276.345m

b (short radius) = 6,356,075.413m

Projection: Transverse Mercator projection

Origin point of coordinate: Pidurutalagala Easting 80° 46 ' 18.16710"

Northing 7° 00' 1.69750"

False origin: E = 200,000ｍ, N = 200,000ｍ

Scale factor: 0.9999238418

Standards elevation: In accordance with the existing Bench mark

２） Discussion on Map symbol specification

SDSL has produced map symbol specifications for the following scales:

- 1:50,000 analogue topographic map symbol specifications
- 1:10,000 analogue topographic map symbol specifications
- 1:50,000 digital topographic map symbol specifications
- 1:10,000 digital topographic map symbol specifications

The discussions were held based on these map specifications, *Basic Cartographic Principles* edited by SDSL, and *Data Capture Model -10K Geo-database-* specifications made by SDSL. Map symbol specifications from previous JICA topographic mapping projects of other countries were also taken as reference.

Picture 3-1 Discussion on map symbol specification

In the actual discussions, the focus shifted from the analogue map symbol specifications and map symbol specifications of previous JICA projects to a stronger emphasis on those of the *Data Capture Model -10K Geo-database-* from the perspective of effectively utilizing the produced digital data on a GIS. In accordance with this change in focus, these specifications were investigated in detail and the items that should be adopted for the digital topographic mapping were selected. The procedures of the selection were as follows.

- make the organizational system for acquisition of topographic feature data conform to the *Data Capture Model -10K Geo-database-*,
- adopt the main item of topographic features,
- make the possible values, under these main item of topographic features, specific topographic features that should be acquired, and
- specify the details of each topographic feature to be acquired such as the code number, data type, definition, acquisition standard, acquisition method, shape and color of symbol.

New map symbol specifications were made by making major revisions to those prepared and made so far by the study team according to these procedures.

At July 2010, the majority of the map symbol specifications have been decided, however, specific map symbols (shape, color, size) were decided upon provisionally. A sample map sheet would be made with these provisional symbols represented; and how they look would be reconsidered before making a final decision on symbol representation.

The marginal information-which makes up part of the map specifications are prepared based on the existing 1:10,000 analogue topographic maps-for the topographic map print-outs, and the part of the marginal information was slightly changed and was discussed. There was no disagreement with this proposed change, although, it was decided to re-examine it on a sample map print-out. Further, SDSL was requested to decide and provide the magnetic deviation constant for each map.

It was agreed that the digital topographic maps would have the following annotation:

"This digital map was prepared jointly by Japan International Cooperation Agency (JICA) under the Japanese Government Technical Cooperation Program and the Government of Sri Lanka"

A sample map printout (including marginal information) was prepared based on the results of discussions up until October 2010.

Discussions were held using this map to finalise the map symbol specifications (mainly on the shape, size and colour of the symbols). A final version was settled on after making some revisions. Marginal information was also finalised after some revisions were made as a result of discussions in April 2011.

The magnetic deviation constant of each 1:10,000 scale topographic maps was provided by SDSL.

3） Discussion on plotting area

Prior to deciding on the plotting area, the size of the 1:10,000 topographic map print-outs was discussed. It was decided that the size would be the same as the existing SDSL maps, 5 km high × 8 km wide. Accordingly, the plotting area was discussed based on this map size. The discussions decided upon an area of *ca.* 2,008.2 km^2 based on the S/W consensus. The decided upon plotting areas and sheet numbers for each district is as follows:

- Jaffna District *ca.* 1,273.6 km^2 (69 sheets)
- Manna District *ca.* 734.6 km^2 (31 sheets)

Further, maps of the plotting area and sheet divisions in each district are as follows.

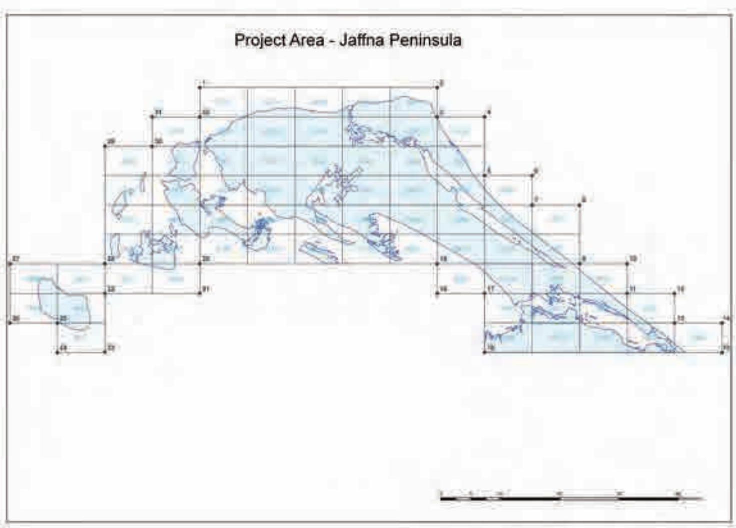


Fig 3-1 Jaffna District plotting area and 1/10,000sheet division

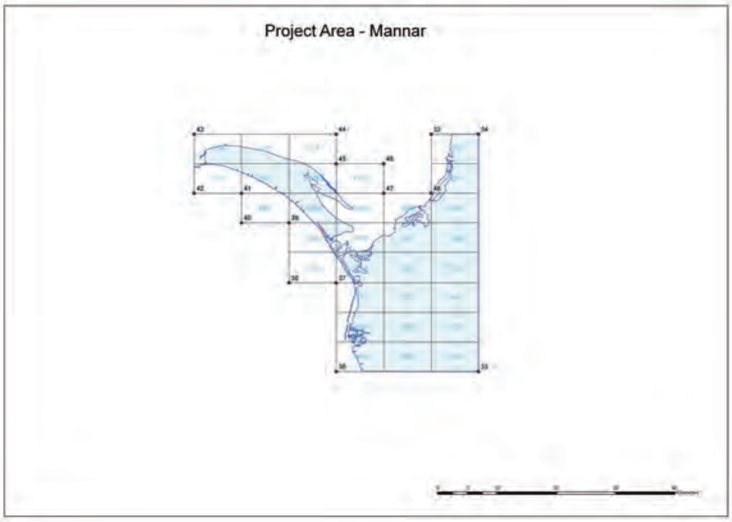


Fig 3-2 Mannar District plotting area and 1/10,000sheets division

（２） Aerial photography

The aerial photography was implemented by a locally subcontracted company.

１） Selection of aerial photography subcontractor

For the selection of a subcontractor, the urgency of the project, the most appropriate timing for aerial photography, and the civil service stagnation entailed with the Sri Lankan general election on 8 April 2010 were all taken into consideration.

a. Local subcontractor tender

Due to the aforementioned situation, it was decided to hold an invited tender rather than a public tender. The selection standards for tender invitation were: that the company has the experience and track record to implement the aerial photography work smoothly, has a local office or branch office in Sri Lanka or a neighboring country, contract negotiations, aerial photography equipment, and can rapidly assign personnel.

As a result, the following three companies were invited to tender:

・National Remote Sensing Agency

Balanager, Hyderabad – 500037, India.

・Fugro Spatial Solutions PTY LTD

18 Prowse Street, West Perth 6005 Western Australia.

・Finnmap FM International

Malminkaari 5, F 1-00700 Helsinki, Finland.

Tender documents were sent to the above three companies by email on 22 February 2010 to request their tender. The deadline for submission of tender documents reaching the SDSL office was 3 March

2010.

b. Selection of local subcontractor

Fugro and Finnmap submitted the necessary tender documents by the submission deadline of noon, 3 March 2010. However, the National Remote Sensing Agency did not submit a tender by this deadline. As a result, it was disqualified from the tender.

The proposals for the aerial photography work of the two companies that adhered to the tender deadline, Fugro and Finnmap, were evaluated from a technical perspective. As a result, both companies' proposals were evaluated as having sufficient technical capacity to appropriately implement the aerial photography work.

The technical evaluation of the two proposals revealed both companies were of equal capacity, therefore, the tender prices were evaluated to select one company. The criteria for the tender price evaluation was that the company that submitted the lowest tendered price—which also cleared the estimated minimum amount necessary to implement the work—would be selected.

As a result, Finnmap, as the company that submitted the lowest tender price clearing the minimum price, was selected as the first nominated subcontractor.

Contract negotiations were entered with Finnmap in accordance with this outcome, and the contract was concluded, upon confirming its content, on 8 March 2010. The contracted work commencement date at this stage was 19 May 2010.

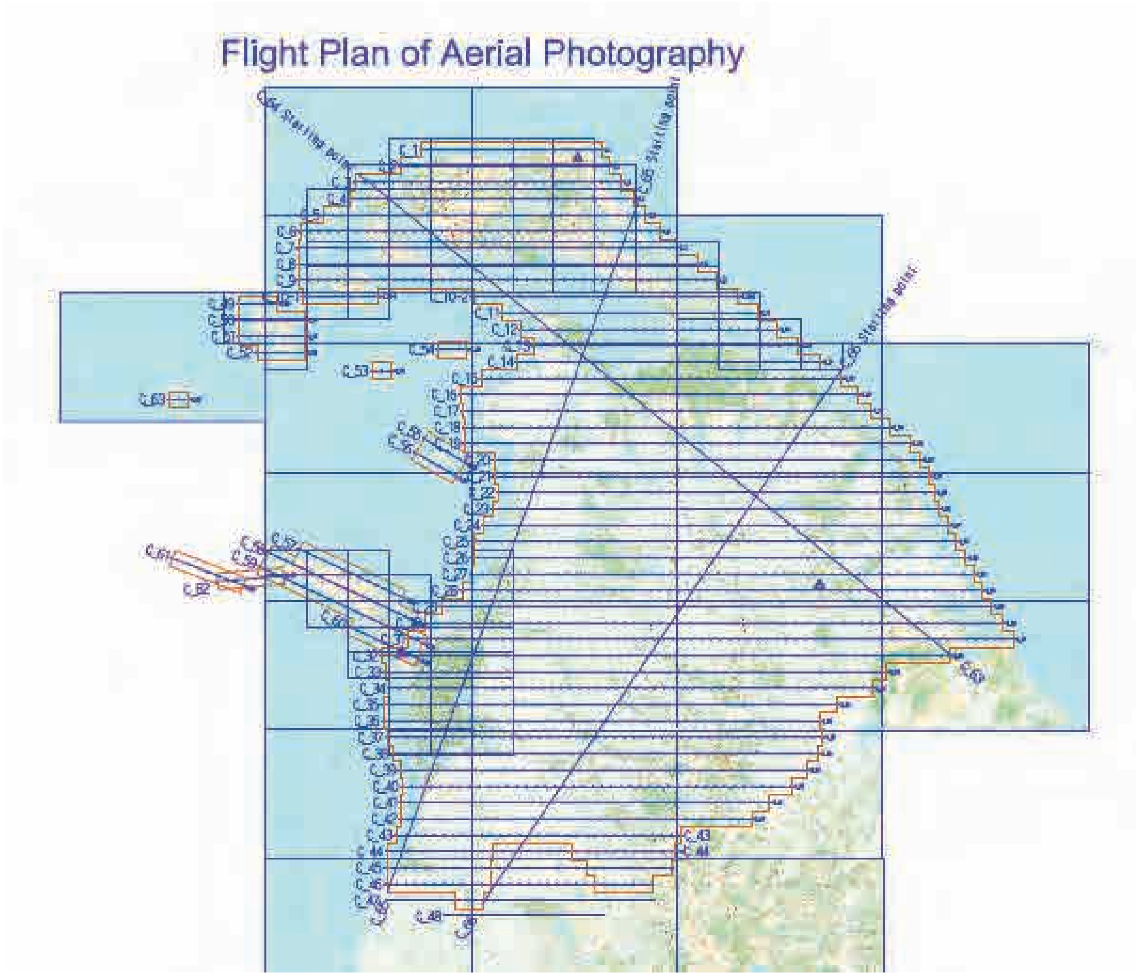
２） Consultation prior to aerial photography

Discussions were held with the field representative of the selected subcontractor, Finnmap, on technical specifications of the aerial photography. These discussions confirmed the following aerial photography specifications outlined in the contract.

Area:	*ca.* 9,000 km^2 of Northern Region
Scale:	1:20,000
Type:	Color photographs
Overlap:	Overlap of 60%±5% and a side lap of 30%±5% side lap, in principle
Method	GPS/IMU method

The actual aerial photography strips were changed, according to SDSL's request during the Inception Report explanation/discussions, from non-continuous to continuous strips; and at the same time it was agreed to add three cross line aerial photography for aerial triangulation adjustment calculations, if possible.

The decided upon map for aerial photography is shown below.



Picture 3-2 Consultation of aerial photography

3） Obtaining permits for aerial photography

Basic permission to photograph the target area (Northern Region) was obtained from the Sri Lankan Ministry of Defense at the time the project was decided to be implemented.

Therefore, the permits obtained after the selection of the aerial photography company were for the entry of the aerial photography aircraft into Sri Lanka, landing, apron space and takeoff, and visas for the aerial photography crew to enter Sri Lanka.

Finnmap initially planned to transfer its aircraft and crew from Thailand. Visas were obtained for the mainly Thai crew by SDSL submitting their applications via the Ministry of Defense to the immigration department. Immediately after obtaining the visas however, there was a sudden change of a crew member, meaning a visa had to be reapplied for.

To obtain permission for the aerial photography aircraft flight plan (including entry and landing) the necessary information (such as the aircraft owner, type, registration number, nationality, call sign, fuel type, pilot name, planned aerial photography period, aerial photography base, entry route) was acquired, the Civil Aviation Authority of Sri Lanka and the Air Force were applied, and permission was obtained to land in Colombo on 19 March 2010.

Moreover, the flight plan was as follows:

Bangkok (Thailand) - Chittagong (Bangladesh) - Calcutta (India) - Bhubaneswar (India) - Rajahmundry (India) - Chennai (India)

4） Aircraft ferry flight plan

The aerial photography aircraft was scheduled to arrive in Sri Lanka according to the abovementioned plan, however, it took longer than expected to obtain landing and takeoff permission in the countries of transit. Therefore, permission was obtained again from the Sri Lankan Civil Aviation Agency for arrival in Colombo on 31 March 2010. Nevertheless, notice was received from Indian authorities that a refueling stop would have to be changed, therefore, once more, an application was made to change to permit with the Sri Lankan authority and with the special dispensation from SDSL, and permission was obtained.

Picture 3-3 Discussion on aerial photography

Accordingly, the aircraft departed Bangkok; however, while flying through Indian airspace, it had engine trouble and had to make an emergency landing. This meant that 8 April 2010 Colombo arrival flight plan also became impossible.

As such, Finnmap decided to dispatch a replacement aircraft from the Netherlands. Landing and takeoff permission was obtained in the transit countries for this flight plan. Then, the various permits in Sri Lanka, from the director of the survey department, Civil Aviation Authority, Air Force, and immigration department, were applied for and obtained.

The aircraft (Piper PA-31T Cheyenna Ⅱ) departed the Netherlands on 8 May 2010, based on these permits, transiting in Greece, Saudi Arabia and India, and arrived in Katunayaka International Airport in Colombo on 11 May 2010. The aircraft then immediately flew to Ratmalana Airport, an air force base in Southern Colombo to be fitted with an aerial camera.

５） Aerial photography implementation

The aerial camera (Zeiss LMK-15CM) was fitted at Ratmalana Airport on 12 May 2010; and the GPS/IMU devices were adjusted ready for aerial photography. Also, SDSL's ground survey team was put in charge of the standards points' GPS survey during the aerial photography.

Picture 3-4 Aircraft for aerial photo

Picture 3-5 Setting up the aerial camera

The aerial photography was implemented—after the aircraft was prepared for flight at this airport—according to weather reports from the Jaffna Airport meteorological observatory in the aerial photography area.

The most suitable season for aerial photography had passed by the time the aircraft finally arrived, and when it did, aerial photography was not possible due to an out of season cyclone and poor weather which followed this.

As a result of this situation—aircraft arrival delay, poor weather—negotiations were held with Finnmap regarding the contract period. An agreement was reached to extend the aircraft's stay until 18 June 2010.

In accordance with this agreement the airport was changed from Ratmalana to Trincomalee, which is closer to the aerial photography area, so as to be able to respond rapidly when the weather improved.

The poor weather continued until 31 May 2010, finally improving the next day, 1 June, when 14 strips of approximately 370 photos were taken in Jaffna District. Further, the following day, 2 June, 15 photos in three strips of the outlying island section of Mannar District were taken.

However, the remaining aerial photography, unfortunately, could not be completed by 18 June 2010, the deadline for the aircraft's stay in the aforementioned extended contract period.

For these reasons, the aerial photography in this period came to an end with 17 strips and 380 photos.

6） Outputs of the aerial photography

The 380 aerial photographs of the completed 14 strips were developed and inspected for adoption or rejection.

The inspection found all of the photography met the specifications, and so were adopted. After which the aerial photos were digitized to the prescribed precision, and at the same time, the prescribed number of contact prints and diapositive film were made.

7） Discussion of implementation plan of remaining aerial photography

Discussions were held with Finnmap on how to respond to the remaining photography work. under the condition of extending the aircraft's stay until 18 June 2010 because of climatic conditions and it looked difficult to complete the aerial photography of the entire area within this period

The following matters were agreed upon through these discussions.

- The remaining aerial photography will be implemented during the next dry season, in January and February 2011
- The aircraft is to be flown to Sri Lanka by January 2011 to implement this aerial photography
- The contract period is to be further extended until 31 May 2011 to implement this work

8） Remaining aerial photography

Preparations got underway in December 2010 so that the aerial photography of the remaining area can be implemented smoothly according to the abovementioned agreement with Finnmap.

A request was made to Finnmap—based on the procedures of the aerial photography in 2010—for the selection of a project manager, aerial photography crew, and aircraft to implement the aerial photography. Copies of their team members' passports for Sri Lankan entry visa applications were also requested. Further, they were asked to prepare and provide a Sri Lankan landing permit application (aviation authority) for their aircraft.

9） Obtaining permission for aerial photography

The landing permit application and passport copies received from Finnmap were submitted to the appropriate authorities via SDSL, and the necessary visas and landing permit were obtained by mid-January 2011.

１０） Preparing for photography and aircraft re-entry

After obtaining the various permits, the aircraft arrived in Colombo—flying from Vientiane, Laos via Chennai, India—on January 20, 2011. The aerial photography crew had also assembled in Colombo by that stage.

１１） Implementation of aerial re-photography

a. Installation of aerial camera etc, test flight and standby for aerial photography

On January 26, 2011, the aerial camera (Leica RC30) and the navigation system (including GPS/IMU) were installed at Ratmalana Airport.

Picture 3-6 Aerial Camera Leica RC30

Picture 3-7 Aerial camera Installed on airplane

After that, on January 31, 2011 a test flight was made over the city of Colombo to link with the GPS control points station. After the test flight, the test aircraft was on standby at Ratmalana Airport from February 1, 2011 until it was relocated to the Trincomalee/China Bay Air Force Base near the area to be photographed on February 10, 2011 and remained on standby there.

Picture 3-8 Photographic coverage and Trincomalee/China Bay Air Force Base

Picture 3-9 Trincomalee/China Bay Air Force Base

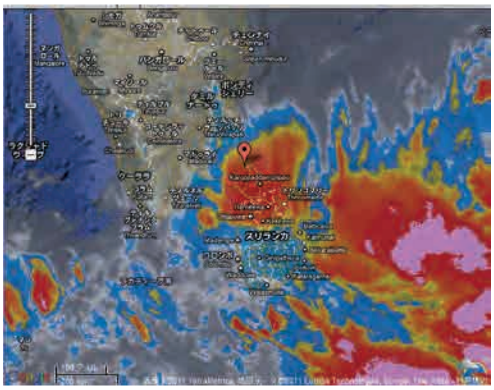


Fig 3-3 Meteorological image of Sri Lanka on January 31, 2011

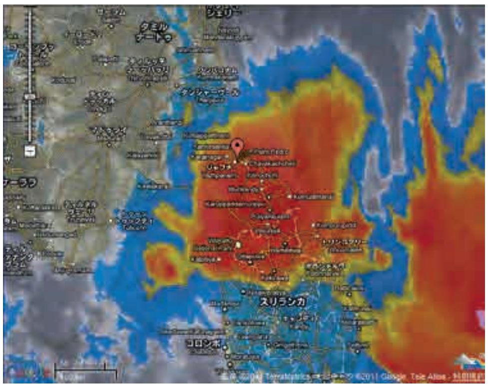


Fig 3-4 Meteorological image of Northern Region on January 31, 2011

b. Weather conditions

Weather conditions in the target area were monitored as follows in order to ensure the aerial photography could be carried out without fail:

* The aerial photography crews contacted the control towers or weather observatories at Jaffna, Mannar and Vauniya airports between 6:30am and 6:45am every morning and obtained accurate weather information.
* The aerial photography crews contacted the crews on regular flight duty from Ratmalana Airport to Jaffna or Trincomalee Airport to collect weather information.
* They collected meteorological satellite images from the Internet

However, heavy rains and major flooding occurred due to unseasonal monsoons in February 2011. The aerial photography crews were not blessed with good weather for aerial photography.

c. Aerial re-photography

While weather conditions did not improve, 4 courses in the south of Mannar District were photographed on February 13, 2011 for the first time this season. However, when the photos were developed it was clear that, regrettably, the photographic area was covered with mist. As a result, re-photography was planned.

The bad weather mentioned above continued until the end of February 2011, but the weather recovered early in March 2011 and the aerial photography was carried out under favorable conditions as described below.

* March 6: 4 courses in Mannar District (approx. 67 photos)
* March 7: 8 courses in the southern area of Mannar District (approx. 290 photos)
* March 8: 12 courses around Jaffna (approx. 410 photos)
* March 9: 10 courses in the southern district (approx. 523 photos)
* March 10: 14 courses from the central district to the southern district (approx. 787 photos)

＊ March 11: One course in the southern district (approx. 37 photos)

The results of aerial photography confirmed that there were no omissions in the planned area of photography. The photographic work was successfully completed on March 19, 2011.

１２） Cancellation of the cross line aerial photography

The Study Team had reached an extra-contractual agreement with the sub-contractor for the implementation of cross line aerial photography by the sub-contractor upon confirmation of the specifications. However, this aerial photography was not implemented because of the poor weather conditions and the priority given to aerial photography of the entire target area. Instead, both GPS/IMU and control points whose number was comparable to the number of control points used in aerial photography without GPS/IMU were used in the aerial photography. Therefore, the Study Team concluded that such aerial photography guaranteed the accuracy of the aerial triangulation with or without cross line aerial photography. This was another reason for the cancellation of the cross line aerial photography.

１３） Outputs of aerial re-photography

a. Inspection of photographs

After the completion of the aerial photography, a total of 8 rolls of films (2,114 photos on 48 courses) were developed and inspected for adoption or rejection. As a result, all the photographs satisfied the specifications and were adopted. The details of the inspection were as follows:

＊ Photographic overlap area: Overlap 60%±5%; Side-lap 30%±5%

＊ Camera rotation elements: κ (10°), φ (3°) and ω (3°) or less

＊ Halation, clouds or mist on photo image

＊ Route deviation from planned course in actual course of photography

＊ Course overlaps on discontinuously taken photos

b. Scanning of aerial photographic films

The aerial photographic films were scanned at a resolution of 20μm using an appropriate scanner. The following items were inspected and all were adopted as the results of the inspection satisfied the specifications:

＊ Image clarity of fiducial mark and meters and gauges of camera

＊ Image quality related to image clarity and defects such as stains, flaws, blurs, light fog (color cast) and finger prints

＊ Color density

＊ Resolution

c. Contact prints

Contact prints (color) were produced from the negative films using a color contact photo printer. The following items were inspected and all were adopted as the results of the inspection satisfied the specifications:

＊ Clarity of fiducial mark and meters and gauges of camera on contact prints

＊ Image quality of contact prints related to image clarity and defects such as stains, flaws, blurs, light fog (color cast) and finger prints

＊Color density

d. Diapositive films

Diapositive films (color) were produced from the negative films using a color positive film printer. The following items were inspected and all were adopted as the results of the inspection satisfied the specifications:

＊ Film shrinkage (30µm max. with a standard deviation of 20µm or less) based on the calibration data of the camera in use

＊ Clarity of fiducial mark and meters and gauges of camera on contact prints

＊ Diapositive film image quality related to image clarity and defects such as stains, flaws, blurs, light fog (color cast) and finger prints

＊ Color density

（３） Photo control point survey

The photo control point survey (GPS survey) was to be implemented for the entire photography area. This was not only enable the aerial triangulation of the topographic mapping area (*ca.* 2008.2 km^2), but was also implemented with the future aerial triangulation of the entire area of aerial photography (*ca.* 9,000km^2) in mind, to enable its topographic mapping.

The photo control point survey was implemented using SDSL equipment by technical cooperation.

１） Establishing a photo control point survey implementation plan

Before the discussions with SDSL on implementation of the photo control point survey, a distribution plan was established based on publicly available information on the situation of national control point distribution and the aerial photography plan. The number of photo control points was decided upon based on JICA's overseas survey work specifications so that a desired accuracy is achieved in the 1:10,000 topographic mapping. That number was 101 points. The photo control points were then distributed appropriately for this number.

2） Implementation plan of photo control point survey

Discussions were held with SDSL based on the established photo control point implementation plan. In these discussions it was found that, beside the publicly available national control point information, there existed fundamental and secondary GPS control points installed by another project and GPS points installed by an Institute of Surveying and Mapping (ISM) project.

The photo control point survey plan was reviewed and renewed by adding this additional information to the publicly available photo control point information, and an agreement on it was reached with SDSL.

The distribution of newly installed photo control points in the agreed to plan is not much different to the original draft, and is characterized by the already surveyed control points to be adopted including many of the control points newly installed by another project. As a result, the total number of photo control points was 110.

The specification discussions had already decided the applicable surveying standards, however, the following parameter values were adopted for the conversion from WGS84 to Everest (1830).

Shift volume:	$\triangle X=0.2933$ $\triangle Y=-766.9499$ $\triangle Z=-87.7131$
Rotation factor (seconds):	$\kappa=0.192704$ $\varphi=1.6950677$ $\omega=3.4730161$
Scale factor:	$Co=1.000000393$

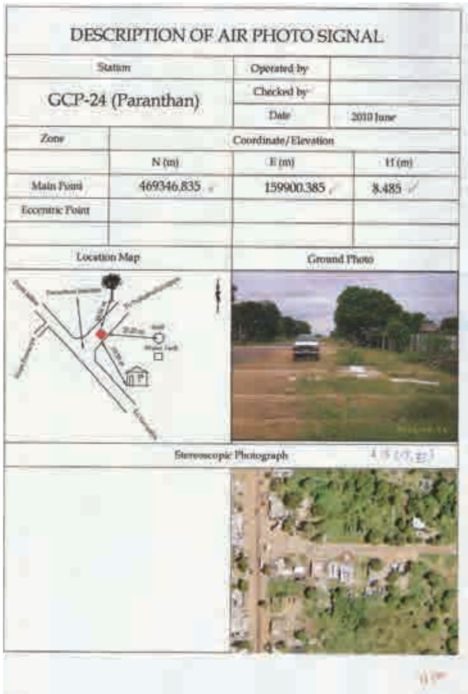
3） Installation of air-photo signals

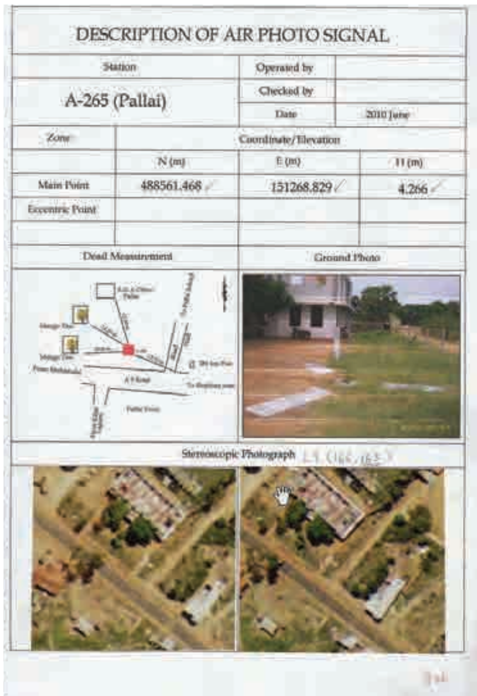
The installation of air-photo signals was undertaken as follows based on the new photo control point distribution plan decided upon in discussions with SDSL.

Picture 3-10 Air photo signalization

Picture 3-11 Installed air photo signal

Initially it was envisaged that there would not be much time between the implementation of the photo control point survey and the implementation of the aerial photography, therefore, the location of all photo control points were to be decided by pricking. However, as there was more time than expected before the start of aerial photography and a request from SDSL with personnel support (personnel from three offices including Jaffna), all of the photo control points could be installed with air-photo signals basically.





Further, the air-photo signals were installed timely again due to the major delays to aerial photography, weather interruptions (rain, cyclone) and so on.

As the aerial photography of the entire area was not completed by June 2010, the air photo signals were installed on the photo control points in the unphotographed areas as necessary in time for the restart of aerial photography (late January 2011). However, air photo signals were not installed on some of the photo control points due to the overhead flooding by the heavy rain in January 2011, so those photo control points were dealt with by means of pricking.

４） Implementation of photo control point survey (GPS survey)

a. Control points already surveyed

The aforementioned fundamental and secondary control points (newly installed or re-measured by GPS geodetic survey as part of the geodetic system conversion in 1999) were used in the photo control point survey (GPS survey). The fundamental and secondary control points used were as follows:

Fundamental control points (6 points): AA04, A208, A251, A255, A256, A257

Secondary control points (18 points): A258, A259, A260, A261, A262, A263, A264, A265, A266, A267, A268, A269, A270, A271, A272, A273, A274, A275, A276, A277, A278, A279, A280

b. Observation equipment

The following GPS receivers possessed by ISM were used in the photo control point (GPS) survey.

LEICA SR530 (2 frequencys)

LEICA SR1200 (2 frequencys)

c. Photo control point (GPS) survey observation

Before the GPS survey observation, observation conditions using analysis software were inputted and an observation plan was established, which was then implemented.

The GPS observation survey was implemented by installing receivers at known points for approximately 8 hours of continuous observation, and for new photo control points, on the other hand, for 1 hour of simultaneous observation with the known points to obtain data at 15 second intervals.

Moreover, due to the situation with the aerial photography, priority was given to the implementation of the photo control point (GPS) survey of Jaffna and Mannar districts. The photo control point (GPS) survey of priority areas was completed on 19 July 2010.

The GPS survey of photo control points in districts other than the priority districts had been completed by the time of the commencement of aerial photography in March 2011.

Picture 3-12 GPS Observation

d. Analytical calculation

＊Analytical calculation of horizontal position

The analytical calculation of horizontal positions involved baseline analysis using GPS observation data, inspection of closure difference of an arbitrary polygon obtained from the baseline analysis, three dimensional adjustment calculation, and coordinate conversion.

85 baselines were analyzed using the observation data. These all returned good analysis results. The inspection of closure difference of an arbitrary polygon using baseline vectors of these analysis results also returned good results. It was then found that there was no problem with the shape of the network or the observation amount, and that the standard deviation of the residual error at each ground control point from the results of the three dimensional network adjustment results, based on the least squares method carried out in WGS84, was within the limit values. After which, the

horizontal position coordinates of the newly installed photo control points were determined by fixing all of the known points and by calculating the three dimensional network adjustment in the coordinate system adopted in the survey standards (Everest ellipsoid).

The accuracy of the photo control point horizontal coordinates after adjustment calculation were within a standard deviation of ±4 cm (limit value is generally 10 cm), therefore, a sufficiently acceptable accuracy was obtained.

＊Analytical calculation of height

The area including Sri Lanka's Northern Region is known to be unique in that the geoidal undulation between the WGS84 ellipsoid surface and the geoid surface is approximately -96 ｍ to -100 m. The orthometric height of each of the newly installed photo control points were calculated based on a geoid height model made for the surrounding area using the elevation values (orthometric height) of four known points that were used in the 3-D network adjustment.

The known points in the table below were used to make the geoid height model, and the new points were the inspection points used to check the accuracy of the geoid height model. The inspection of the new points found an error of approximately ±5 cm and a maximum error of 12 cm.

GCP/BM	Ortho Height (m)	GCP/BM	Ortho Height (m)
A264 (known point)	12.1730	GCP-11 (new point)	3.1210
A265 (known point)	4.2660	GCP-15 (new point)	1.3010
A267 (known point)	4.2030	GCP-16 (new point)	3.8610
A269 (known point)	6.7884	GCP- 2 (new point)	3.4260
BM PONNALEI	1.3204	GCP-24 (new point)	8.4850
BM_A9_155MP	31.3313	GCP- 6 (new point)	1.8480

(The two BM points above are Sri Lankan vertical reference levelling points, and the orthometric heights of the remaining 10 points were calculated by direct levelling)

（4） Levelling

The levelling is to be implemented for the entire aerial photography area for the same reasons as with the photo control point (GPS) survey.

１） Establishment of a levelling implementation plan

Levelling was planned for *ca.* 550 km (ca. 2 km intervals, install height control points by pricking) mostly along main roads according to the aerial photography plan and publicly available information, as in the case of the photo control point (GPS) survey.

2） Levelling implementation plan

Discussions were held with SDSL on the details of the aforementioned levelling implementation plan. As a result, it was decided to implement the levelling for the following points:

- in principle, fixed points will be installed approx. every 2 km along the levelling route,
- duplicate observation will be implemented for the entire levelling route (in order to prevent errors such as misreading), and

the closure difference limit value of the duplicate observation is 50mm√S (km).

3） Implementation of levelling

a. Existing benchmarks

A precise network of fundamental and secondary benchmarks has been established since the 1920s, when Sri Lanka was a British colony, with fundamental benchmarks installed in part of the target area, Jaffna and Vavuniaya in the Northern Region.

The field reconnaissance was implemented based on the record of benchmarks before the implementation of the levelling. This found that many of the benchmarks had been destroyed during the long lasting civil war, particularly along the eastern coast.

b. Observation equipment

The levelling was implemented as SDSL technical cooperation using ISM's Kern tilting level.

c. Levelling observation

Levelling observation was implemented, based on the field reconnaissance of the existing benchmark, with efficient observation of *ca.* 8 km per day for the initial levelling plan of *ca.* 500 km, except the routes that could be omitted by pricking of existing benchmarks.

Picture 3-13　Observation of Leveling

Picture 3-14　Observation of Leveling

Moreover, due to the situation with the aerial photography, as in the case of the photo control point (GPS) survey, priority was given to the implementation of the levelling in Jaffna and Mannar districts.

The levelling of priority areas was completed on 28 July 2010.

The levelling in areas other than the priority areas had been completed by the time of the commencement of aerial photography in March 2011.

Furthermore, the closure difference of the duplicate observation ascertained immediately after the observation for all completed routes were within the limit values.

The elevation of as many of the photo control points as possible in the horizontal position was determined in the levelling survey.

d. Computation

The computations of the levelling observations were all processed as single route calculations. Thus, the computation of priority areas were implemented by single route calculation to decide the elevation of pricking points and added on horizontal photo control points.

（５） Pricking

As mentioned above, the initial plan was to use pricking rather than air-photo signals to identify photo control points (horizontal photo control points) on aerial photos. However, pricking was implemented for the height control points in levelling, while, in principle, air-photo signals are to be installed at every photo control point.

１） Pricking of horizontal photo control points

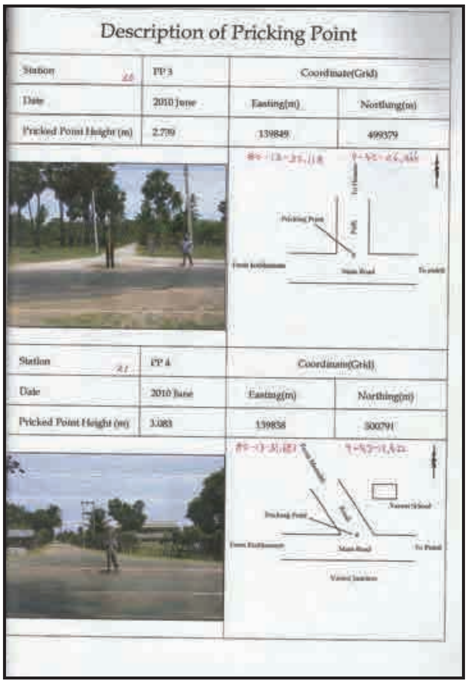
Horizontal photo control points were, in principle, all to have air-photo signals installed, however, the air-photo signal at 4 photo control points (GCP25, 84, 87, 102) could not be confirmed on the aerial photo after photography. Therefore, pricking was undertaken for that 4 points and its location was measured in the field to find its coordinates.

２） Pricking of height control points

The aerial photography had not been completed at the time the height control points were installed by levelling. Therefore, pricking of height control points every *ca.*2 km was undertaken by measuring the general coordinates with handy GPS of intersections on roads that can be identified on the aerial photos, at the same time descriptions were made for the detailed blueprint. Their locations were also identified on Google Earth. Then, after the aerial photos were obtained, pricking was implemented based on the position data such as that identified on Google Earth, the general coordinate values and the description.

The pricking for the non-priority areas was carried out by March 2011.

Picture 3-15　Selection of the pricking point



Description of Pricking Point

Station	PP 3	Coordinate(Grid)	
Date	2010 June	Easting(m)	Northing(m)
Pricked Point Height (m)	2.739	139849	499379

Station	PP 4	Coordinate(Grid)	
Date	2010 June	Easting(m)	Northing(m)
Pricked Point Height (m)	3.083	139836	500791

（6） Field identification

Discussions of the implementation methods were held with SDSL before implementing the field identification.

1） Field identification procedure

In the discussions with SDSL on the field identification procedures, it was found that SDSL:

a. implements field identifications using topographic maps after plotting and compilation to clarify areas of uncertainty, and has never implemented field identifications using aerial photos before the plotting and compilation,

b. plots using photo interpretation on a 3D stereo model and then for the compilation the operator compiles the uncertain features with instructions for the field identification (supplementary field identification); therefore, only one field identification is needed, and

c. SDSL has not made a photo interpretation key even for similar work in the past; therefore, the plotting and compilation was entrusted to an experienced photo interpretation expert because the climate and vegetation in the north of Sri Lanka are different to that in the south.

The field identification is to be implemented according to the following procedures taking into consideration the above facts and how plotting and compilation work is implemented in Japan.

＊The field identification is to be implemented using aerial photos that meet overseas surveying standards with reference to scale 1:10,000 color and black and white mosaic aerial photographs, the photo interpretation key to be made, and existing topographic map prints and their digital data files (scale 1:50,000). (However, there is no fixed amount to be implemented).

＊The photo interpretation key is to be made jointly during the field survey and is to be limited to part of the map symbol specifications, namely vegetation, land use and hydrology, for plotting and compilation work in Japan

２） Field identification preparations

Color mosaic photos (one set) and black and white photos (two sets) of the same scale as the plotting, 1:10,000, were printed in Japan in preparation.

Also, SDSL was requested to provide geographic information in its possession. It prepared the following:

a. 1; 50,000 topographic map data file

b. 1; 100,000 district maps

c. 1; 10,000 map of Jaffna City

d. National road map

The location information of main road kilo posts administered by the Road Development Authority (RDA) is either to be directly surveyed or SDSL is to request it of RDA during the supplementary field verification.

３） Implementation structure of field identification

The implementation structure was made up by two surveyors from the photogrammetry division in SDSL headquarters for the aerial photo interpretation before the field identification.

On the other hand, the area of field identification outdoors, Jaffna and Kilinochchi districts that were photographed, have many mine zones and off-limit areas as a result of the civil war. Therefore, the utmost priority was given to safety outdoors during the field identification. The implementation structure was two groups, each made up of one SDSL worker and one study team member.

Further, to be prepared for the unexpected, close contact was maintained with SDSL headquarters and the JICA office by cellular phone, particularly, regular contact (SMS) was made without fail every morning and evening with the JICA office.

４） Timing of field identification

The field identification, including preliminary discussions, information gathering, photo interpretation, arrangement, was implemented over 25 days from 13 August to 8 September 2010. The outdoor part of the field identification took three days covering Jaffna City and its surrounds and the area along state road A9.

５） Field identification implementation

Two surveyors from the photogrammetry division undertook the preliminary photo interpretation using color and black and white mosaic photos in SDSL headquarters in accordance with the overseas surveying specifications. This photo interpretation was mainly carried out for the areas around Jaffna City and Chavakachcheri. The photo interpretation work was an opportunity for both the study team and SDSL to gain an understanding/awareness of and to solve the various queries they each had such as effective utilization of the photo interpretation key and how to deal with feature definitions and image characteristics of difficult to interpret features including vegetation (coconut, palm yard, grassland, barren land, marsh), land type (homesteads/garden) and hydrology (pond, tank, water hole, villu).

Picture 3-16 Photo interpretation

Picture 3-17 Discussion of outdoor field identification area

During the outdoor part of the field identification two 4WDs were used, and with the color and black and white mosaic photos, emphasis was placed on solving the queries and uncertain points that came up in the preliminary photo interpretation and it was visually verified the features in the field against those on the photos. The features confirmed and the solved queries were marked on the mosaic photos with the map symbol codes. Also, where necessary, the target feature was surveyed and the location identified using a handy GPS to get its coordinates and field photos were taken

６） Field identification outputs

The following outputs were gained through the field identification:

a. Photo interpretation key (13 topographic features)

b. Mosaic photos with the field identification information written on them

c. Photos of features taken in the field

（７） Aerial triangulation

The aerial triangulation work was implemented, taking into account the progress of aerial photography and the subsequent work processes (such as digital plotting/compilation and supplementary field verification).

As a result, the aerial triangulations targeted for topographic mapping (Jaffna District and Mannar District) was given priority and implemented. After that, the digital and analog aerial triangulations of the entire target area for aerial photography were implemented.

1） Digital aerial triangulation of target area for topographic mapping

The digital aerial triangulation was implemented in 2 periods, dividing the topographic mapping area into 4 blocks, taking into account the progress of aerial photography and the geographical positions of the areas for topographic mapping.

a. Implementation periods

The implementation periods and the targeted areas were as follows:

July 2010 period: In the south of Jaffna District and islands

May 2011 period: In the north of Jaffna District, and Mannar District

b. Implemented work quantities of each period and block

The implemented work quantities of each period and block were as follows:

＊ July 2010 period in the south of Jaffna District:

Strips: 20 strips

Photo sheets: 303 sheets

＊ July 2010 period in islands:

Strips: 4 strips

Photo sheets: 23 sheets

＊ May 2011 period in the north of Jaffna District:

Strips: 5 strips

Photo sheets: 148 sheets

＊ May 2011 period in Mannar District:

Strips: 17 strips

Photo sheets: 203 sheets

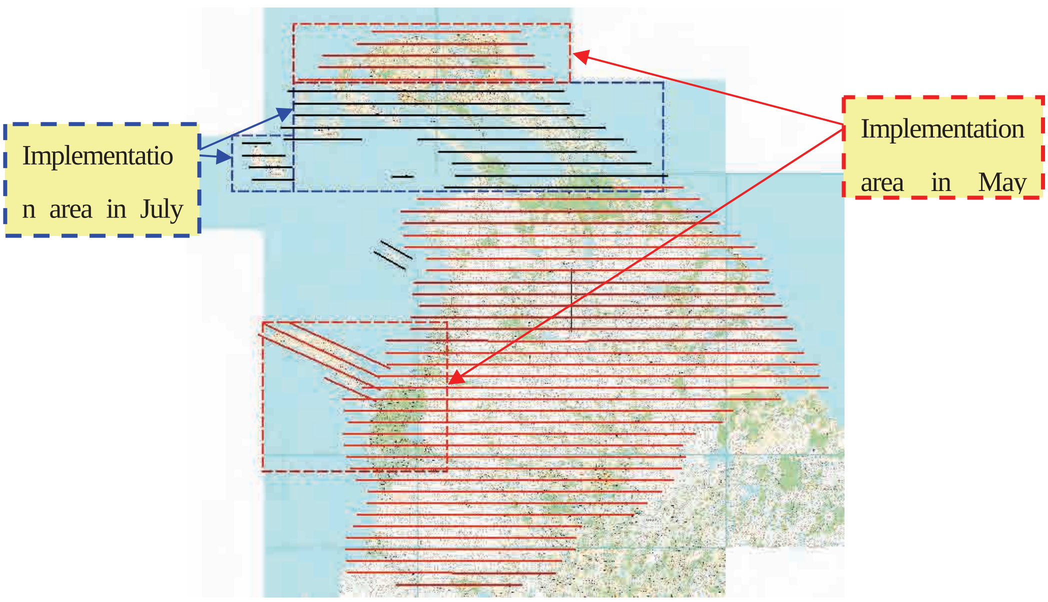


Fig 3-5 Implementation area of aerial triangulation in the target area for topographic mapping

c. Evaluation of number and distribution of photo control points in each block

The photo control point surveys (GPS survey and leveling) were planned (for distribution of photo control points) and implemented on the condition that the aerial triangulation would be implemented over the entire target area for aerial photography. In implementing the partial aerial triangulation work, therefore, the number and distribution of available photo control points were evaluated based on the results of photo control point survey and leveling.

＊ South of Jaffna District and islands

The number and distribution of photo control points available for the work quantity of aerial triangulation were not sufficient to meet the Work Specification, but by also using GPS/IMU results, it was judged that the insufficiency was not at a level at which there was any problem with accuracy in the digital plotting of 1/10,000 topographic maps.

＊ North of Jaffna District, and Mannar District

The number and distribution of photo control points for the implementation area of aerial triangulation were not sufficient in both districts, but by also using GPS/IMU results, it was judged that the positional accuracy would be obtained in digital plotting of 1/10,000 topographic maps.

d. Preparatory work

The aerial photos were scanned at a resolution of 1,270 dpi (20μm). After that, the quality inspection was carried out for the scanned data to confirm that the data would present no problem in the subsequent works of digital aerial triangulation and digital plotting. In addition, the results of photo control point survey and leveling, GPS/IMU results and the camera calibration data were collected. Then, the aerial triangulation work plan map was prepared by depicting the photo principal points, photo control points and leveling routes on the topographic map.

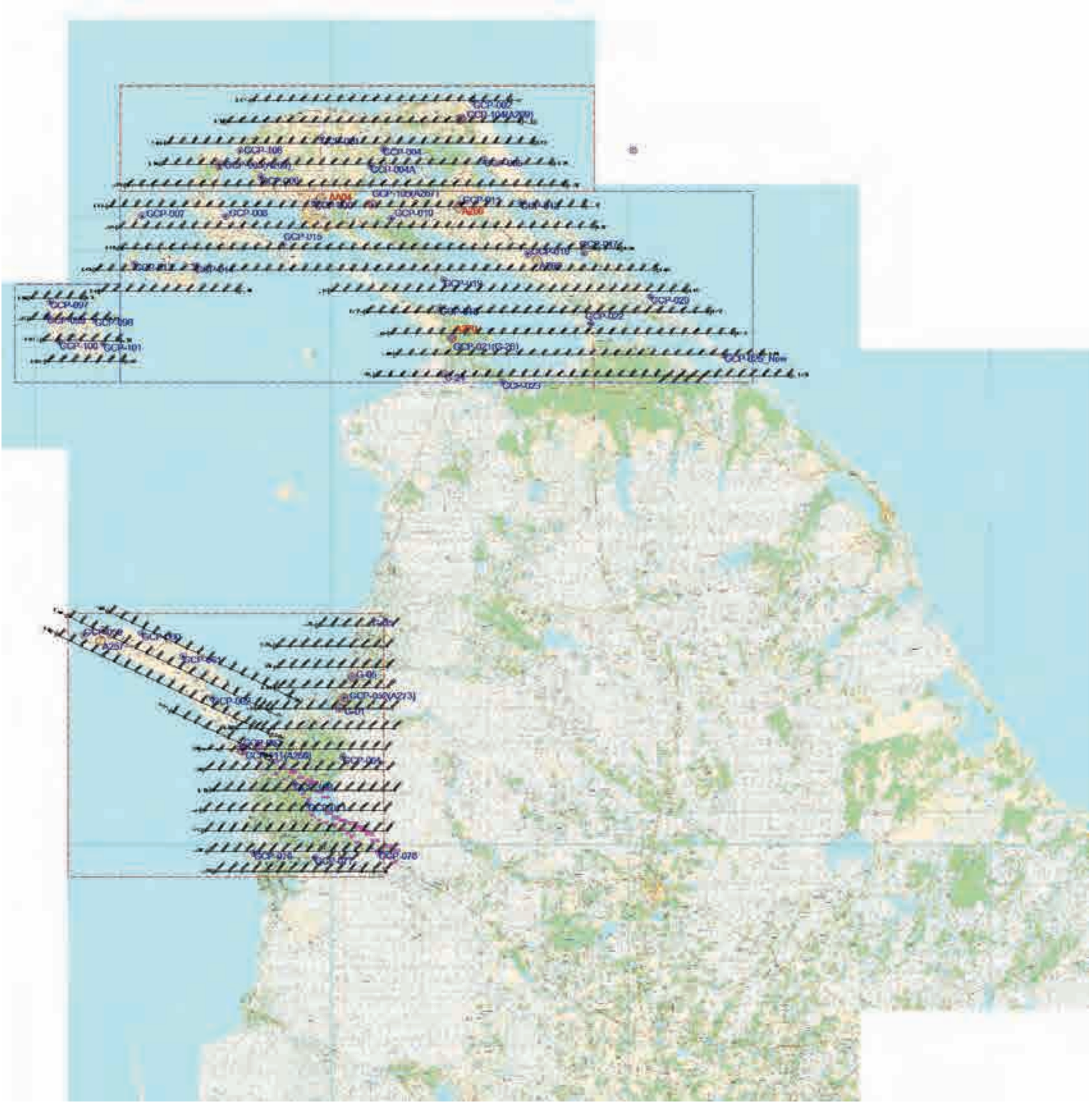


Fig 3-6 Aerial triangulation plan map

e. Verification of accuracy of POS data (GPS/IMU data)

＊ Verification of Position and Orientation System (POS) data as of July 2010 period

The photo control points were observed using only the results (exterior orientation elements) from the POS data (GPS/IMU data) in the digital photogrammetry system. As a result, the differences from the coordinate values obtained in the field survey were within several meters. As the differences occurred in the same direction, it was estimated that there was an error in the inclination of the POS data. Thus, the weights **ω, φ, κ** were set to low weights in the adjustment calculation.

＊ Verification of POS data as of May 2011 period

As the same tendency as that seen in July 2010 period appeared in the verification results, the weights **ω, φ, κ** were set to low weights in order to standardize the adjustment calculation process.

f. Tie-point observations

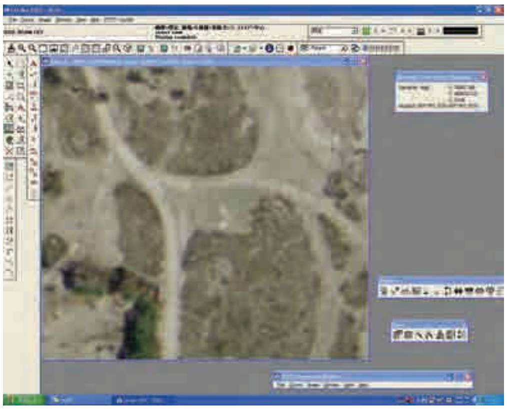
Tie-points were automatically extracted in the duplicate parts of aerial photos to observe their coordinates using the digital photogrammetry system. For the incomplete models such as islands and coastal areas, tie-points were extracted manually to observe their coordinates. The automatically extracted tie-points reached several dozen points per model.

The relative orientation was implemented to calculate the model coordinates of tie points using the coordinates of the observed tie-points. For the intersection residuals in the calculated model coordinates between models, a standard deviation of 15μ or less and 30μ or less at maximum was specified. If any observed values did not meet the specifications, the observations were repeated.

g. Photo control point surveys

The photo control points (horizontal and vertical) obtained from the photo control point surveys and leveling were defined on aerial photos using the sketch maps which were one of the survey outcomes and their coordinates were observed in the digital photogrammetry system.

The resulting values of these photo control points (XY coordinates and elevation values) were also input into this system.



Picture 3-18 Photo control point observation in digital photogrammetry system

h. Adjustment calculation by the bundle method and its results

The adjustment calculation in aerial triangulation was made by the bundle method using the results of photo control point surveys, leveling and POS analysis (GPS/IMU analysis).

The control point residuals which were the indexes for evaluation of the results of adjustment calculation were as follows:

＊ July 2010 period: South of Jaffna District

・ Control point vector residuals

【Horizontal】

Maximum value: 0.569m (limit value 1.22m)

Standard deviation: 0.229m (limit value 0.61m)

【Elevation】

Maximum value: 0.639m (limit value 1.22m)

Standard deviation: 0.163m (limit value 0.61m)

・ Pass point/tie-point residuals

【Horizontal】

Maximum value: 0.026mm (limit value 0.030mm)

Standard deviation: 0.0139mm (limit value 0.015mm)

＊ July 2010 period: Islands

・ Control point vector residuals

【Horizontal】

Maximum value: 0.258m (limit value 1.22m)

Standard deviation: 0.173m (limit value 0.61m)

【Elevation】

Maximum value: 0.159m (limit value 1.22m)

Standard deviation: 0.112m (limit value 0.61m)

・ Pass point/tie-point residuals

【Horizontal】

Maximum value: 0.026mm (limit value 0.030mm)

Standard deviation: 0.0139mm (limit value 0.015mm)

＊ July 2011 period: North of Jaffna District

・ Control point vector residuals

【Horizontal】

Maximum value: 0.459m (limit value 1.22m)

Standard deviation: 0.211m (limit value 0.61m)

【Elevation】

Maximum value: 0.158m (limit value 1.22m)

Standard deviation: 0.339m (limit value 0.61m)

・ Pass point/tie-point residuals

【Horizontal】

Maximum value: 0.027mm (limit value 0.030mm)

Standard deviation: 0.004mm (limit value 0.015mm)

＊ July 2011 period: Mannar District

・ Control point vector residuals

【Horizontal】

Maximum value: 0.833m (limit value 1.22m)

Standard deviation: 0.370m (limit value 0.61m)

【Elevation】

Maximum value: 1.054m (limit value 1.22m)

Standard deviation: 0.398m (limit value 0.61m)

・ Pass point/tie-point residuals

【Horizontal】

Maximum value: 0.0287mm (limit value 0.030mm)

Standard deviation: 0.0055mm (limit value 0.015mm)

The flight height above ground for photography that is necessary for calculation of the limit values of residuals is 3,050m, and the limit values of the standard deviation and maximum value based on that value were as follows:

Limit value of standard deviation: 0.02% 0.61m

Limit value of maximum value: 0.04% 1.22m

The standard deviations and maximum values of the residuals in each block and each period were lower than these limit values. Therefore, there was no problem with the results of digital aerial triangulations.

The exterior orientation elements and etc. of the results of adjustment calculation were output in the Exterior Orientation (EO) format and in the ori format for use in the subsequent digital plotting.

２） Digital aerial triangulation of entire area

Digital aerial triangulation of the entire area was carried out with a method similar to the one used in the digital aerial triangulation of the topographic map production area. The part of the island area was excluded from adjustment calculation for the digital aerial triangulation of the entire area. Instead, the results of the digital aerial triangulation of the topographic map production area and results of independent calculation of orientation elements required for mapping were used for the mapping of part of the island area.

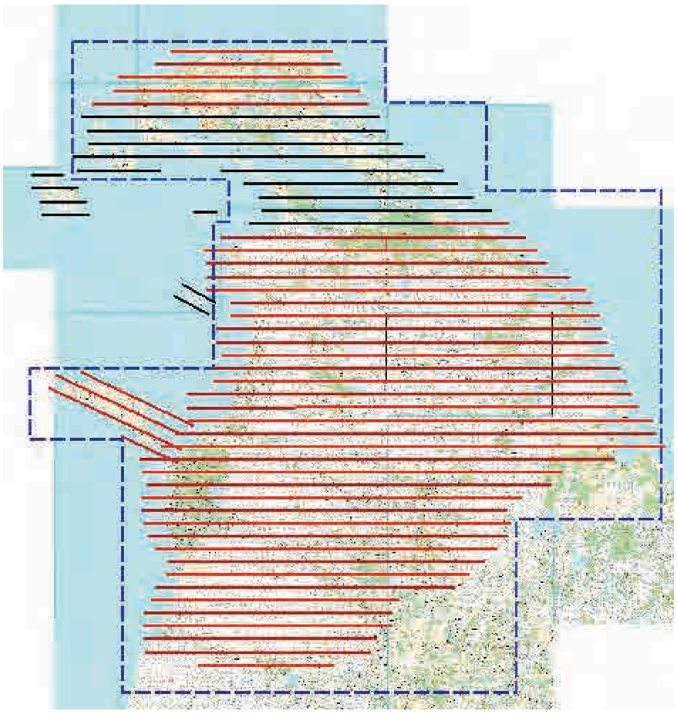
a. Quantity of work

The quantity of work in the digital aerial triangulation of the entire area was as follows:

Strips: 61 strips

Photo sheets: 2127 sheets

The area in which the digital aerial triangulation of the entire area was implemented is shown below.



b. Results of adjustment calculation with bundle method

Adjustment calculation with bundle method for the aerial triangulation of the entire area was done with data obtained from the photo control point survey and results of the POS analysis (GPS/IMU analysis).

Before the implementation of the aerial triangulation of the entire area, aerial triangulation work plan maps were produced by representing principal points, photo control points, and levelling routes on topographic maps.

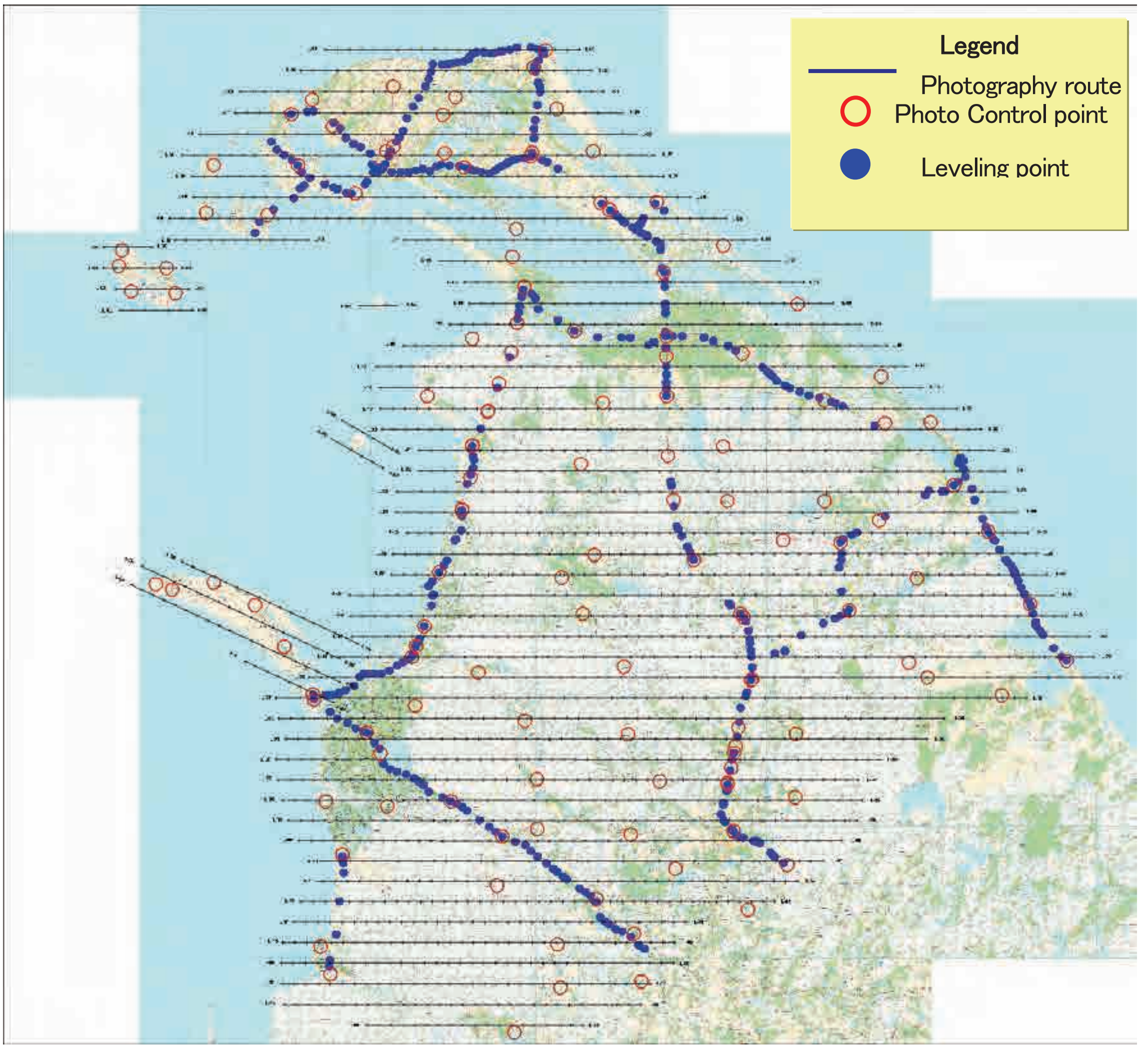


Fig 3-7 Aerial triangulation plan map

The photo control point residuals which were the indexes for evaluation of the results of adjustment calculation were as follows:

＊Digital aerial triangulation of entire area

・ Photo control point vector residuals

【Horizontal】

Maximum value: 1.120m (limit value 1.22m)

Standard deviation: 0.539m (limit value 0.61m)

【Elevation】

Maximum value: 0.814m (limit value 1.22m)

Standard deviation: 0.212m (limit value 0.61m)

・ Pass point/tie-point residuals

【Horizontal】

Maximum value: 0.0288mm (limit value 0.030mm)

Standard deviation: 0.0044mm (limit value 0.015mm)

The standard deviation and maximum of the photo control point residuals and pass point/tie point residuals were below the tolerance limits and the results of the digital aerial triangulation of the entire area were accurate.

The exterior orientation elements and etc. of the results of adjustment calculation were output in the Exterior Orientation (EO) format and the ori format.

3） Analog aerial triangulation of entire area

Analogue aerial triangulation of the entire area was implemented in order to enable the counterparts to perform plotting of the entire Northern Region also with an analogue plotter equipped with encoder, and the entire area of analogue aerial triangulation was divided 11 blocks in order to carry out the adjustment calculation. Calculation of part of the island area was excluded from adjustment calculation for the divided analogue aerial triangulation of the entire area. Instead, the results of the digital aerial triangulation and results of independent calculation of orientation elements required for plotting were used for the plotting of the part of the island area.

a. Quantity of Work

The quantity of work implemented in the analogue aerial triangulation of 11 blocks was as follows:

Number of flight courses: 61 strips

Number of photographs: 2031 sheets

The difference in the quantities of works between the digital and analogue aerial triangulation derives from the fact that duplicate photographs taken from a same flight course on different days were used in the aerial triangulation.

b. Preparation for each block

Contact prints (or output prints) of aerial photographs and diapositive films required for analogue aerial triangulation were collected. The results of photo control point survey (GPS survey and levelling), those of the analysis of GPS/IMU data and the calibration data of the aerial cameras were also collected.

The collected data were used for creation of aerial triangulation work plan maps, on which locations of principal points, photo control points and levelling routes were represented, and the area of the aerial triangulation was established.

c. Selection of Tie points for each block

The horizontal and height photo control points were confirmed on the aerial photographs of the area subject to analogue aerial triangulation based on the work plan maps. Tie points between models and flight courses were selected on the aerial photographs.

d. Pricking for each block

The tie points and other points selected on the aerial photographs were pricked on diapositive films using a point transfer instrument.

e. Observation for each block

Machine coordinates of the tie points pricked and photo control points on the diapositive films were obtained by observing the points on the diapositive with a stereocomparator.

f. Inner Orientation for each block

The machine coordinates of tie points, etc. obtained in “e. Observation for each block” were transformed into photographic coordinates through the process of inner orientation, which is a process of coordinate transformation to photographic coordinates using fiducial mark on aerial photographs. The maximum residuals of fiducial marks were within the tolerance range for all aerial photographs.

g. Relative Orientation for each block

Relative orientation was performed to create models from the photographic coordinates of tie points, etc. obtained in “f. Inner Orientation for each block.” The residual y-parallax after the relative orientation was within the tolerance range in all created models.

h. Adjustment Calculation with Bundle Method and the Results of the Calculation for each block

Adjustment calculation with bundle method was performed using the photographic coordinates of tie points and other points obtained through the inner orientation and the results of the photo control point survey.

The photo control point residuals and the pass point / tie point residuals which were the indexes for evaluation of the results of adjustment calculation of each block were as follows:

＊Analogue aerial triangulation of each block for entire area

・ Photo control point vector residuals for each block

【Horizontal】

Maximum value: 0.355～0.930m (limit value 1.22m)

Standard deviation: 0.141～0.407m (limit value 0.61m)

【Elevation】

Maximum value: 0.414～0.989m (limit value 1.22m)

Standard deviation: 0.209～0.428m (limit value 0.61m)

・Pass point/tie-point residuals for each block

【Horizontal】

Maximum value: 0.018～0.029mm (limit value 0.030mm)

Standard deviation: 0.004～0.009mm (limit value 0.015mm)

The standard deviation and maximum of the photo control point residuals and pass point / tie point residuals for each block were below the tolerance limits and the results of the analogue aerial triangulation of the each block were accurate.

The results of the adjustment calculation were used for the calculation of orientation elements of each model. The orientation elements and the coordinates of tie points and other points were output by each model separately.

（8） Digital plotting

1） Outline

Based on the results of aerial triangulation and field identifications, the data for the topographic features as specified by the map symbols specifications were acquired by means of digital stereo plotters.

2） Specifications

Photo scale	1/20,000	
Plotting scale	1/10,000	
Plotting areas	2,008.2k ㎡	
Plotted map sheets	100 sheets	
Contour	Intermediate	5m
	Index	25m
	Supplementary	2.5m
Projection	Transverse Mercator projection	
Sheet size	East-West	8km
	North-South	5km

3） Equipment used

Digital stereo plotter
SoftPlotter（BOEING）
Summit（DAT/EM）
LPS（Leica）、
ImageStation（INTERGRAPH）

4） Preparation for plotting

In the plotting work using the digital stereo plotters, the data of the cameras were imported as data.

Table 3-2 Main data of cameras

	First period	Second period

Manufacturer	ZEISS	Leica
Camera type	LMK-15CM	RC30
Lens No.	272 304/C	13215
Focal distance	152.139mm	152.90mm

５） Production of stereo model

The stereo images (stereo models) to be used in digital plotting with the digital stereo plotter were produced from the digitalized photo image data, the results of aerial triangulation and the camera data.

６） Digital plotting

The digital plotting work was implemented with reference to the field identification photos. Also the stereo images that could not be plotted from the field identification photos only were interpreted with reference to the photo interpretation keys to implement the digital plotting.

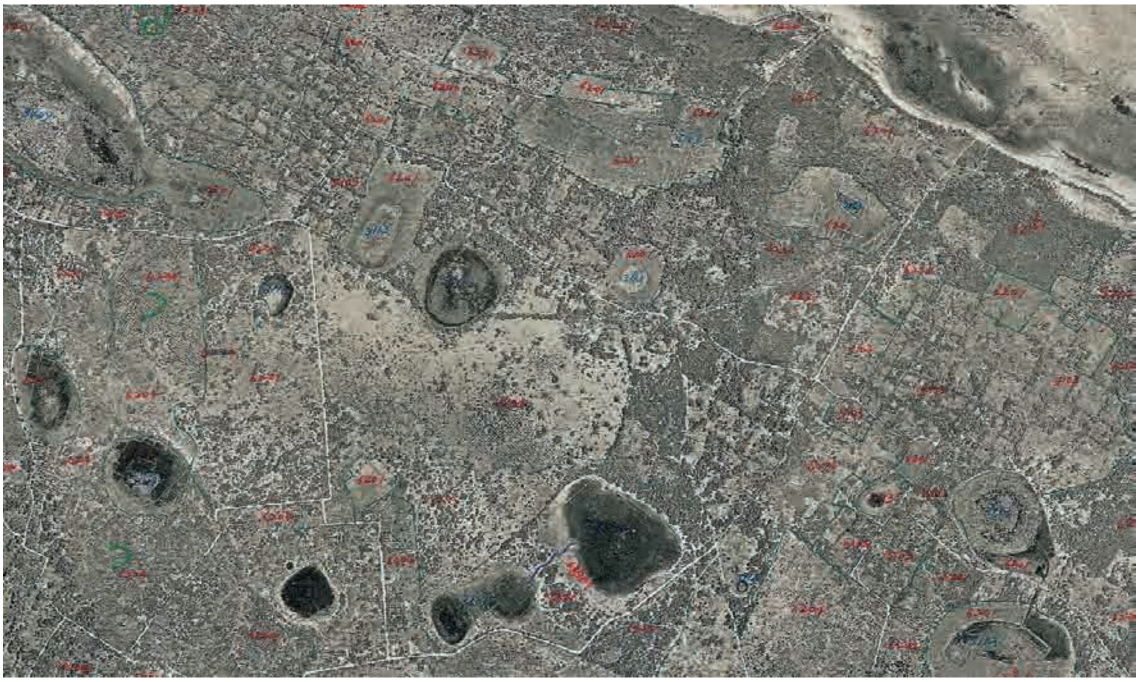


Fig 3-8 Field identification photograph

Fig 3-9　Photo interpretation keys

7） Results of digital plotting

The data for digital plotting was produced in Bentley MicroStationV8DGN format.

Fig 3-10　Results of digital plotting

（9） Digital compilation

1） Specification

Compilation scale 1/10,000

Compilation area 2,008.2k㎡

Compiled map sheets 100 sheets

Sheet size East-West 8km North- South 5km

2） Equipment used

Compilation CAD MicroStationV8（Bentley）

3） Digital compilation

Based on the results of the digital plotting, annotations and administrative boundaries were input with reference to the field identification photos, existing maps (1/50,000) and existing data (SHP file) to carry out the digital compilation work.

4） Details

a. Use of existing data (SHAPE file)

Symbols, annotations and administrative boundaries were compiled with reference to existing data.

b. Checking things in supplementary field verification

The items which showed a doubtful connection between the results of digital plotting and the various materials were marked with checking mark for checking in the supplementary field verification.

Table 3-3 Checking descriptions

Mark	Code	Description	Remarks
—	9901	Area line, leader line, etc.	
A	9902	Indefinite symbol	Symbol
B	9903	Indefinite vegetation	Land use
C	9904	Indefinite area	Area
D	9905	Indefinite shape	Shape
E	9906	Indefinite position	Position
F	9907	Indefinite annotation	Name/Annotation
G	9908	Indefinite planimetric feature	Feature

5） Results of digital compilation

The data for digital compilation was created in the Bentley MicroStationV8DGN format.

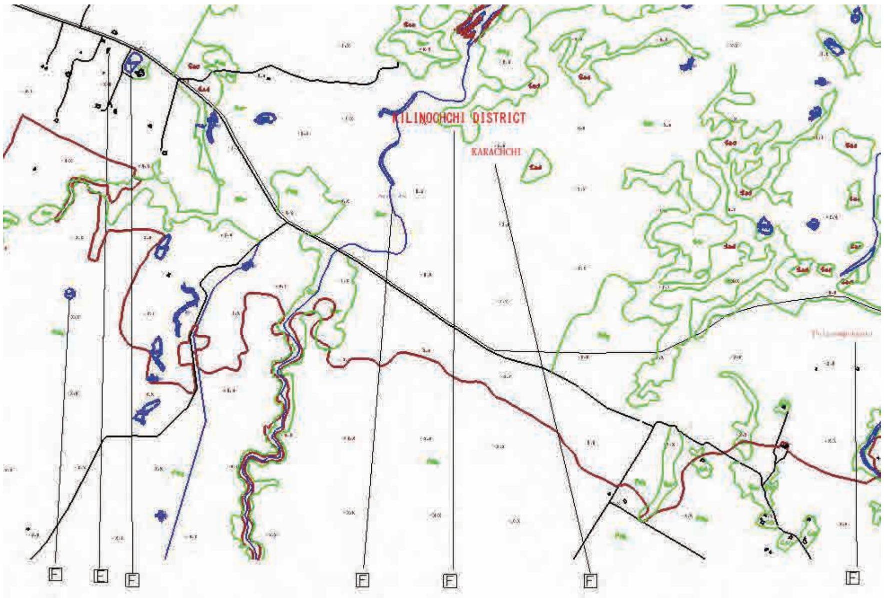


Fig 3-11 Results of digital compilation

（１０） Supplementary field verification

The supplementary field verification was implemented for the elimination of uncertainties identified in the digital plotting/compilation regarding representations of the topographic features on the maps and for the final confirmation of administrative boundaries and names. As SDSL was to implement these activities in principle, the Study Team provided appropriate technical guidance and supervision on the methods to be used in the supplementary field verification and the composition of the survey teams.

The supplementary field verification consisted of two major components: collection of data and reference materials in Colombo and field work in the Jaffna and Mannar Areas. Details of the work in the supplementary field verification are as follows:

１） Implementation Periods and Locations

The work was implemented in two periods as mentioned below.

[First period]

October 15th – 19th 2010:	Discussion of the work and collection of various types of data and reference materials in Colombo
October 20th – 30th 2010:	Implementation of the supplementary field verification work in southern Jaffna Area
October 31st – November 13th 2010:	Receipt of various types of data and reference materials in Colombo

[Second period]

28th August – 4th September 2011:	Discussion of the work and collection of various types of data and reference materials in Colombo
September 5th – 21st 2011:	Implementation of the supplementary field verification work in northern Jaffna Area and Mannar Area
September 22nd – October 11th 2011:	Receipt of various types of data and reference materials in Colombo

２） Input

The actual inputs of the Japanese and Sri Lankan sides to the supplementary field verification were as follows:

	Japanese side	Sri Lankan side
First period	Two people	28 people (in 11 survey teams)
Second period	Two people	31 people (in 12 survey teams)
Total	Four people	59 people

３） Description of the work

The data and reference materials collected in Colombo and the work implemented in the supplementary field verification are as follows:

・Details of the data and reference materials studied in Colombo

a. Administrative boundaries and names

The Study Team obtained the digital data (Code Nos. 8101 – 8104) from SDSL. The Study Team held discussions and agreed with SDSL not to include Grama / Niladhari Division Boundary (8105) and the administrative boundaries below it.

b. Road classification (Code Nos. 2101 – 2104)

The Study Team obtained the digital data (Code Nos. 2101 – 2104) or maps containing detailed instructions on editing from SDSL.

c. Control points

The Study Team obtained a document listing the names and code numbers of the control points (one benchmark and eight triangulation points) as a list of control points. Meanwhile, as the photo control points established in this Project were meant to be temporary, the Study Team and SDSL agreed not to represent them on the maps.

d. Magnetic declination

The Study Team obtained the data on magnetic declination from SDSL.

Picture 3-19 Sorting the data collected in the field completion

Picture 3-20 Supplementary field verification work

・Detail of the supplementary field verification

A field survey was conducted in the field for the elimination of uncertainties identified in the digital plotting/compilation. The findings of the field survey were summarized on the completion sheets, which were used as reference materials in the supplementary digital compilation. In addition to the field survey on the intended subjects, the supplementary field verification was conducted on additional features whose representation on maps was considered necessary in the field. Among the features included in the map symbol specifications which are believed to be in areas inaccessible for the supplementary field verification, including suspected mine fields and military bases, those whose exact locations had been specified by photo interpretations were incorporated in the data obtained from the supplementary field verification.

Kilometre posts along the Class A and AB roads and power transmission lines of 33 kV or above were surveyed in the supplementary field verification. Since there is a plan to restore the abandoned railway line (2306) and the abandoned stations (2307), their locations identified on the existing 1:50,000-scale topo-maps and interpreted in the photographs were incorporated in the data obtained from the supplementary field verification.

Regarding the annotations, it was decided to apply the annotations of the 1/10,000-scale city maps of Jaffna City. For the rest of the target area, the names of major intersections or major facilities were identified in the supplementary field verification.

４） Quantities of the Work

The table below shows the actual quantities in the supplementary field verification work. The total number of maps studied in the supplementary field verification was 100, of which 69 were of the Jaffna Area and 31 were of the Mannar Area.

	Quantity of supplementary field verification work (number of locations)	Number of annotations
First period	1,039	112
Second period	768	292
Total	1,807	404

（１１） Supplementary digital compilation

１） Specification

Compilation scale　1/10,000

Compilation area　2,008.2k ㎡

Compiled map sheets　100 sheets

Sheet size　East-West　8km　South-North　5km

２） Equipment used

Compilation CAD　MicroStationV8（Bentley）

３） Supplementary digital compilation

Supplementary digital compilation was carried out based on the results of supplementary field verification.

Fig 3-12　Results of supplementary field identification (kilometer posts, power transmission line)

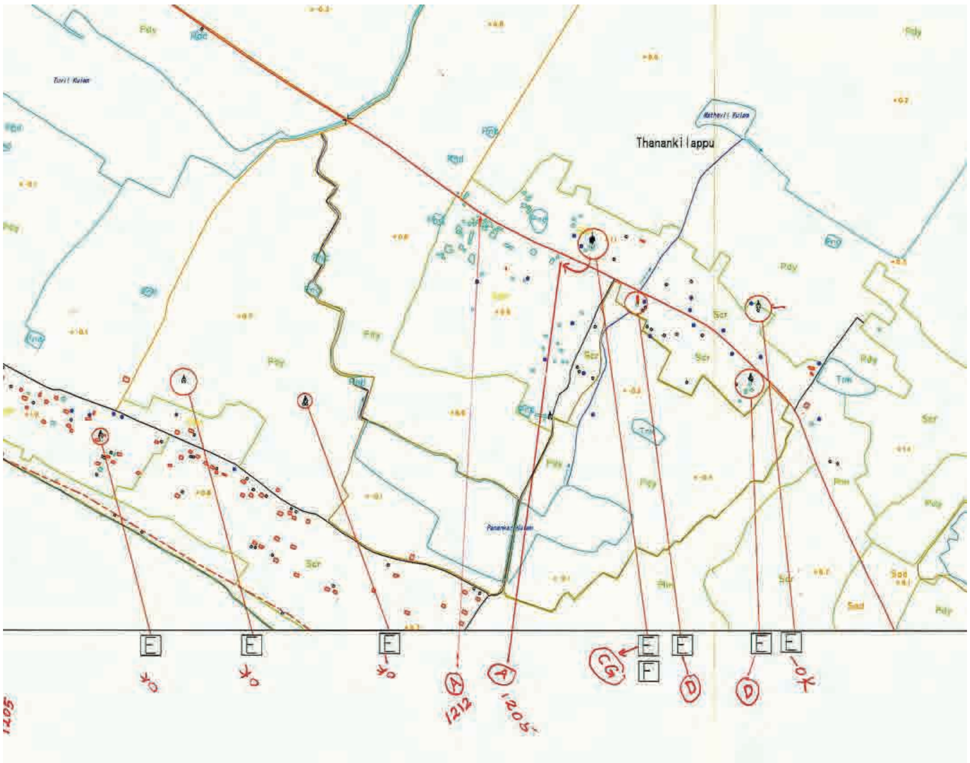


Fig 3-13　Results of supplementary field identification (items confirmed in digital compilation)

４） Details

a. Input kilometer posts

Symbols were affixed to kilometer post positions as identified in the field and the kilometer figures were indicated.

b. Input of power transmission line

Symbols were affixed to transmission line positions as identified in the field and the transmitted power voltages were indicated.

c. Other results of supplementary field verification

Topographic features were corrected based on the identified results for the things to be identified in digital compilation.

（１２） Digital data structualization

Digital data files with data that had been compiled digitally after supplementary completion were structured.　This data structuring involved structural compilation and conversion of data format.

１） Structural compilation

In the structural compilation, data was inspected and corrected for logical errors and was topologically structured. MicroStation V8 was used in this process.

a. Inspection and correction of logical errors

A logic inspection of the following geometric figures was conducted on topographic features which are defined as correlated figures.

Item	Explanation
Edge matching	There should be no unmatched edge.
Undershoot	There should be no undershooting.
Overshoot	There should be no dangle.
Areal overlap	There should be no unallowable overlap.
Consistency of area classification	There should not be more than one code for an area. Consistency of area classification should be maintained between neat lines.

b. Topological structuring of data

Data of linear structures such as roads and water edges were used for production of polygon data for vegetation, land use, etc. enclosed by those linear structures.

All topographic features were classified into line, polygon or point data in accordance with the map symbol specification established in the discussion between the Study Team and SDSL.

２） Conversion of data format

Structurally compiled data was converted into DXF format and SHAPE format by sheet.

（１３） Map symbolization

Structured digital topographic map data was used for production of 1:10,000-scale AI data.

１） Details of the symbolization work

AI data consisting of vector data files arranged into layers by map symbol code and by map sheet were produced by processing the structured digital topographic map data for map symbolization as mentioned below.

a. Map symbolization of topographic map sheet

Line widths, colours, symbols, patterns, annotations, etc. were produced and processed in accordance with the map symbol specifications for the data in the files arranged in layers by map symbol code. To improve representation of the map, the order of layers was rearranged, supplementary layers were added, objects were relocated and slight adjustments were made on objects.

b. Adjustment for printing of topographic maps

Minimum adjustment mentioned below was made to objects which were difficult to visually recognize on the map.

- * Minor adjustment of the location of a mark hidden behind a road symbol represented with a certain width to make it visible on the map
- * Minor adjustment of the locations of letters hidden behind a road symbol represented with a certain width to make them visible on the map
- * Line feed of an array of letters
- * Relocation of a symbol of an administrative boundary where a shoreline or a road line is the boundary
- * Minor adjustment by slightly moving a symbol of road hidden by a symbol of an adjacent road represented with a certain width to make it visible on the map

c. Map symbolization of marginal information

Marginal information of topographic maps was symbolized in accordance with the outcome of the discussion between the Study Team and SDSL. In this symbolization, a legend was produced in accordance with the map symbols stipulated in the map symbol specifications for representations on topographic maps. Other pieces of marginal information were added to map data.

d. Integration of symbolized topographic data and symbolized marginal information data

Data for printout was produced by integrating symbolized topographic map data and symbolized marginal information data and entering data such as sheet number and sheet title for each map sheet.

２） Quantity and outputs of the work

a. Quantity of the work

- * AI data (topographic map + marginal information): 100 sheets

b. Details of the output data

- * File format: PostScript file (Adobe Illustrator CS5 format)
- * Colour mode: CMYK (four-color printout mode)
- * Colours used: CMYK + Brown (special order colour)
- * Finished map size (including marginal information):

  657 mm (north-south) x 883 mm (east-west)

（１４） Production of digital data files

１） Production of Vector Data Files

As part of the structuralization of the digital data, the data generated in the supplementary digital compilation were converted into Shape-format data and DXF-format data to produce vector data.

Vector data files were produced with these converted data.

a. Data to be included in data files

In order to enable revision of the digital topographic maps due to secular changes, it was decided to use digital data which had been structuralized but not symbolized on the maps, for the production of the data files.

b. Unit of data file production and data file production

A data file was produced for each map. Vector data files of Shape-format data and DXF-format data were produced for each map.

c.Data storage

The produced vector data were stored on media such as DVDs and CDs.

２） Production of Raster Data Files

The data generated in the supplementary digital compilation were processed, as required, in the map symbolizing and the processed data were used for the production of raster data files.

a. Integration of topographic map data and marginal information data

Marginal information data of a certain map, which differed from those of any other map depending on map units such as map numbers, were integrated with the corresponding topographic map data.

b. Production of raster data

The integrated data of a map were converted into PDF-format data to create a raster file.

c. Data storage

The produced raster data were stored on media such as DVDs and CDs.

3.2.2 Technology transfer

（１） Photo control point survey

The whole range of techniques relevant to photo control point survey, namely GPS survey, was the target of the technical transfer. However, it was found that SDSL has plenty of experience in this field. Therefore, the technical transfer was implemented with this in mind.

１） SDSL's capacity to implement photo control point (GPS) surveys

All of the SDSL regional offices already have much experience using GPS receivers in control point surveying, cadastral surveying and topographic surveying. They have sufficient capacity in the various techniques required to establish plans for various types of work such as observation planning, GPS surveying, and analysis of observation data.

On the other hand, they have relatively limited experience in photo control point survey for aerial triangulation in photogrammetry, and they have insufficient level and skill base to make a photo control point description to calculate the necessary number of photo control points and distribution conditions for aerial triangulation.

２） Implementation of technical transfer for photo control point survey

As mentioned above, because of SDSL's technical capacity in photo control point (GPS) survey, it was decided not to place emphasis on the technical transfer in making plans for observation and for GPS surveying itself, observation, and analysis calculation; rather emphasis was placed on transferring photo control point survey techniques for aerial photogrammetry.

Picture 3-21 Distribution of photo control points plan

As a result, the technical transfer was implemented focusing on how to calculate the necessary number of photo control points and method of photo control point distribution for aerial triangulation taking into consideration the aerial photography plan.

Also, techniques were transferred on how to install air-photo signals (including place, shape and size) at photo control points for aerial triangulation and on making a description of these.

３） Results of photo control point survey technology transfer

The following are the results of the transfer of the various techniques that the photo control point technology transfer focused on.

a. Techniques for how to calculate the number of photo control points and distribution

SDSL obtained the ability to calculate independently, and sufficiently understood how to calculate the number of photo control points necessary for aerial triangulation. However, it cannot be said that they have reached a sufficient level or understanding of how to distribute the necessary photo control points calculated with regards to the aerial photography plan as to be applied to similar work, because they only have experience doing this once. Further training and experience is necessary.

b. Installation of air-photo signals and making a description

This time a lot of experience was gained in these two techniques and they gained a sufficient understanding as a result of this repetition.

（2） Levelling

The whole ranges of techniques for implementing levelling were the target of the technology transfer. However, SDSL, which has a great deal of experience, had a low necessity for technology transfer of general levelling including theory.

１） SDSL's levelling implementation capacity

Those in charge of levelling at SDSL have a great deal of practical experience implementing, and have sufficient understanding of general theory of levelling as a method of measuring height, selection of leveling route, observation, computation, and output evaluation (method of deciding whether to re-survey).

However, they have limited experience in levelling for height control points for aerial triangulation; and although they have minimum capacity in its implementation, this is not high.

２） Implementation of levelling technical transfer

From the aforementioned situation, the technical transfer was implemented with emphasis on planning levelling for aerial triangulation. More specifically, techniques were transferred for how to distribute height control points for aerial triangulation and how to decide on a levelling route based on the distribution. Also, rational methods of observation were explained with the aim of improving their understanding and observation efficiency.

３） Result of levelling technical transfer

The outputs of technology transfer in this field were as follows.

a. Distribution of height control points for aerial triangulation

Regarding technical capacity in planning levelling routes based on the distribution of height control points, SDSL obtained these techniques and a sufficient understanding; grasping them as an extension to the selection of general levelling routes.

b. Using and understanding rational observation methods

They understood the redundant observation methods. The amount of levelling they can implement in one day can be expected to increase as a result of their changing to rational observation.

（3） Pricking

１） SDSL's pricking implementation capacity

Pricking is mainly implemented on each photo control point (horizontal and height) for use in aerial triangulation. In the past, SDSL didn’t have experience of pricking.

２） Implementation of pricking technology transfer

Air-photo signals were, in principle, installed at all horizontal photo control points; therefore, there was almost no need to implement pricking technology transfer. Moreover, the aerial photographs needed for pricking were not ready due to the delayed aerial photography, therefore, techniques were transferred for making descriptions of pricking points (obtaining general coordinates of pricking points and sketches of pricking point surrounds) to be ready for when the aerial photos arrived.

３） Outputs of pricking technical transfer

Many descriptions were made for height control points. Through this experience, description making techniques gained a footing in SDSL.

（４） Field identification

The procedure of field work employed by SDSL for topographic mapping is to use map sheets from after the plotting and compilation stages. On the other hand, the procedure used in the field identification technology transfer is to use aerial photos.

１） SDSL's capacity for implementation of field identification using aerial photos

Employees of the photogrammetry division at SDSL headquarters are used to using aerial photos on a daily basis in their plotting and compilation work. Therefore, they have sufficient skills in (preliminary) photo interpretation using stereo images. On the other hand, the main role of employees in SDSL regional offices is outdoor surveying work such as cadastral surveys. Therefore, they are adept at handling surveying equipment used outdoors and for cadastral mapping. However, they had almost no track record in using aerial photos for field surveys, and almost no experience using them for photo interpretation or surveying.

２） Implementation of technology transfer for field identifications using aerial photos

a. Targets of the technology transfer

Four SDSL workers were the target of the technology transfer, two for (preliminary) photo interpretation and two for field identifications using aerial photos outdoors.

b. Technology transfer for (preliminary) photo interpretation

As mentioned earlier, workers from SDSL headquarters have basic photo interpretation skills, therefore, they were taught, based on the prepared map symbol specifications, how to identify the reason for queries and uncertainties that turned up in photo interpretation through characteristic of the photographic images and definitions of topographic features in map symbol specifications. In this way, the transfer of field identification preliminary photo interpretation techniques using photo interpretation was implemented. Techniques for representing the preliminary photo interpretation results on photos, and identifying problems and how to represent them were also transferred.

Picture 3-22 Preparation for field identification

Picture 3-23 Field identification in the field

The technology transfer using aerial photos in the field, due to their lack of experience, aimed at proficiency in identifying and confirming topographic features on the photos based on the map symbol specifications, and how to solve problems in the field. Further, techniques for representing the results of feature identification and problem solving with the photos were transferred.

３） Output of technology transfer for field identification using aerial photos

The following are the outputs of the technology transfer:

a. Can undertake (preliminary) photo interpretation of vegetation, land classification, hydrology and so on using a photo interpretation key,

b. Can understand how difficult each feature in the map symbol specifications is to survey, which features to pay special attention to, and how to distinguish each feature in the field,

c. Can succinctly represent the results confirmed in the field (including resolved queries) on aerial photos, and

d. Can undertake efficient field identifications using aerial photos by taking the survey route into consideration.

Field identification is a task requiring skill and experience to swiftly confirm and succinctly represent topographic features on aerial photos basically according to the map symbol specifications. They are evaluated to gain an understanding of this work relatively quickly. They grasped how to distinguish the characteristics on the aerial photo images with actual features and once they get used to this, they should be highly capable at its implementation.

（５） Aerial triangulation

Technology transfer of the skills necessary of aerial triangulation for SDSL was implemented according to basic policy 3. The technology transfer was implemented using the data from Jaffna District, where part of the aerial photography has been completed. Emphasis was placed on the transfer of practical aerial triangulation methods and technical information needed to obtain usable results with the provided software.

1） Software used for technical transfer

The trainees from SDSL were transferred techniques using digital aerial triangulation modules in the software—LPS and ORIMA—provided by this Project.

2） Technology transfer flowchart

The technology transfer was implemented according to the following flowchart.

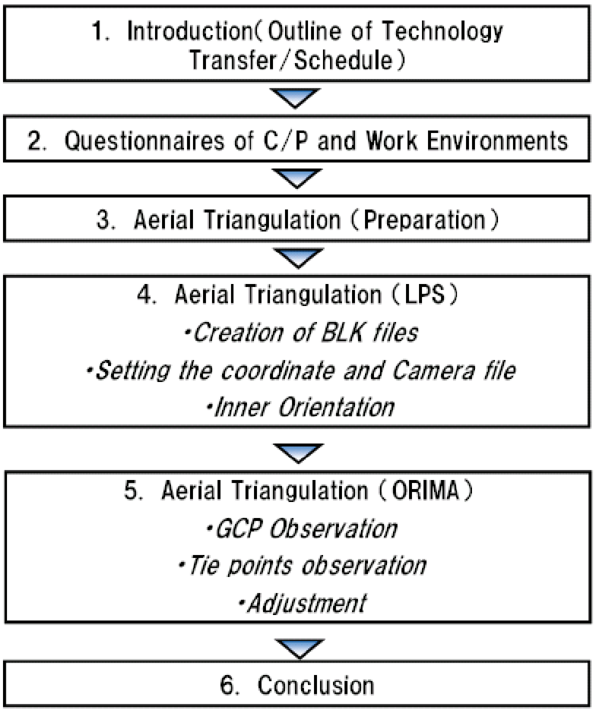


Fig 3-14 Flowchart of the aerial triangulation technical transfer

3） Technology transfer implementation

The questionnaire undertaken in advance found that the trainees have many years of work experience in photogrammetry, and have a high general technical level in analogue methods and practical experience of aerial triangulation. The technology transfer was implemented with these findings in mind.

Demographic statistics at Photogrammetry team

Average	24
Longest	31
Shortest	20
Mode	20

Less than 20	0
20 - 24	7
25 - 29	5
Over 30	2
Total	*14*

Number of years in profession

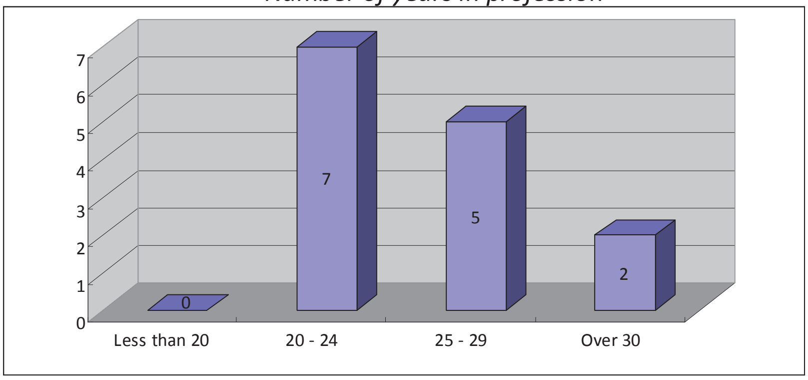


Fig 3-15 Photogrammetry experience of the trainees

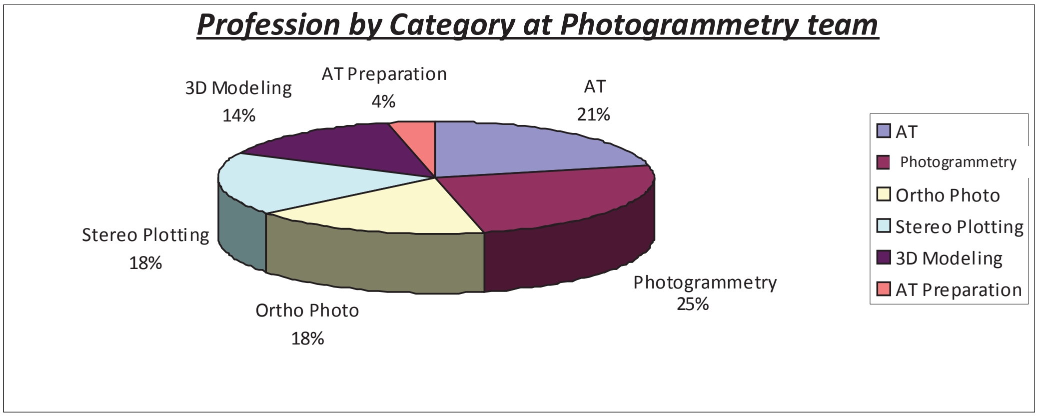


Fig 3-16 Profession of the trainees

The technology transfer was implemented in the aforementioned manner for 3 trainees and 4 observers. Each task was first carried out by the Study Team based on the manual, and were then undertaken by the trainees in a similar manner. When further explanation was deemed necessary, presentations were given using additional information. Further, a review was held to confirm the transfer items and content at the midway stage by the trainees and Study Team.

Picture 3-24 Technical explanation for trainees

Picture 3-25 Training of LPS

Picture 3-26　Training of ORIMA

Picture 3-27　Trainee practicing independently

4） Results of the technology transfer

The results of the technology transfer are as follows.

a. Tasks using LPS

The transfer involved making block files (*.blk file) in LPS, and preparatory work to register data such as the camera used for aerial photography, ground control points, GPS/IMU and the coordinate system employed for the work. Inner orientation work to transfer from observed coordinates to photo coordinates was also transferred involving registering and converting aerial image data in LPS, positional information between camera fiducial marks. Also completed was the transfer of techniques using LPS for aerial triangulation was completed.

b. Tasks using ORIMA

Techniques were transferred—based on the outcome of the aforementioned LPS transfer—to preset ORIMA such as uploading ground control point (GCP) data and *.blk files.

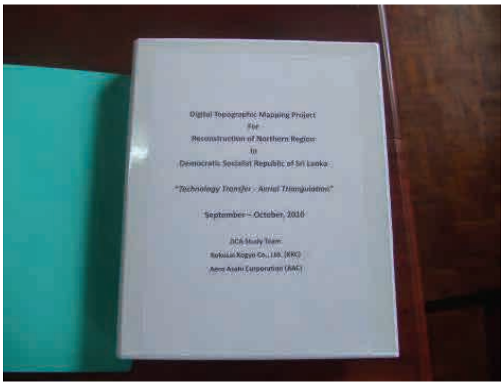
Techniques for ground control point stereography and to represent these outputs in the *.blk files, and for joining images (both sidelap and overlap) using automatic point measurement (APM) were transferred. Also, techniques such as how to implement adjustment calculations using the bundle method and evaluate these results (residual error), and how to delete data based on this evaluation and various methods for reobserving and additional observations, and how to finalise the calculation results (outputs) was also transferred.

c. Overall understanding of technical transfer content and supplementary information

The technology transfer of digital aerial triangulation procedures can be mostly considered complete, despite time limitations, as a result of the trainees' flexibility and high level of experience and understanding of basic theory of photogrammetry. Time constraints meant that sufficient time could not be allocated to repeated training during the technical transfer. Therefore, it is vital that the trainees maintain their proficiency and increase their efficiency by revising what they have learnt using the data from the technology transfer.

At the end of the technology transfer there was an opportunity to discuss with the trainees on utilization of data and trends of related technologies. These discussions provided a chance to exchange opinions and information on technical trends of digital aerial sensors for data acquisition (photography), a process that precedes aerial triangulation, and on how to utilize the data after aerial triangulation. It was clear from these discussions that they are spatial information experts in Sri Lanka and have a high interest in related technologies and their utilization. It is also clear that they will contribute to raising the overall level of SDSL in future. Moreover, the manuals and explanatory materials on the technology transfer (aerial triangulation) were printed and bound and provided to the trainees with the digital data.

Picture 3-28 Group photo of trainees



Picture 3-29 Bound manual and explanatory materials

5） Conclusion

This technical transfer is considered a first step towards full-scale digital photogrammetry technical transfer in SDSL. The trainees' level of understanding and interest in digital methods is high; and it is hoped that with the continued use of LPS/ORIMA in future the trainees will build up experience and deepen their knowledge of the software and that progress with its technical application will continue. The Study Team also wishes to support this learning process to the extent possible.

（6） Digital plotting

The preliminary study had made clear that SDSL possessed a number of digital plotters (Analog plotter with encoder: A8 and B8; Analytic plotter: SD3000; Digital plotter: VirtuoZo) and had experience and the capacity to carry out digital plotting in the large and medium scale. Therefore, the technology transfer to SDSL was carried out with the stress on adaptation to the newly introduced hardware and software, keeping in mind the need to provide efficient work schemes (including how to inspect the plotted data logically and how to produce contours from plotted data).

1） Period and target trainees

Technology transfer of digital plotting was basically conducted in the same way as the same items of technology were transferred to different groups of trainees at the request of SDSL. The table below indicates the period of training and number of trainees. All the trainees were technicians in the Photogrammetry Department of SDSL and most of them had 20 years or more practical experience in photogrammetry.

Table 3-4　Period of training and number of trainees

No	Period of Technology Transfer	Number of Trainees
1	October 8, 2010 to November 19, 2010	7
2	January 11, 2011 to February 10, 2011	4

2） Equipment used

The technology transfer was carried out using the digital plotting system “LPS” and the digital plotting module “PRO600” for LPS introduced to SDSL in this Project. The “TopoMouse” was used as the input device.

Picture 3-30　Digital Plotting System LPS

Picture 3-31　Input device TopoMouse

3） Items of technology transfer

The technology transfer was carried out with emphasis on operation, the explanations and exercises for the following items being repeated in order to ensure the trainees gained the relevant technology:

a. Preparation before start of digital plotting

One of the major differences between analog and digital systems lies in the process in which the stereo models can be produced readily from the results of aerial triangulation in the digital system in contrast with the analog system which requires a deal of experience in relative and absolute orientations.

In view of the above difference, it was considered important for the trainees to gain a deepener understanding of LPS operation and digital processing. Therefore the technology transfer began with an explanation of the general work flow starting with the production of the project file.

For the digital plotting module "PRO600", the environmental setup necessary to do the plotting work was outlined.

b. Digital plotting work

The LPS digital plotting module "PRO600" is an add-on tool to the compilation CAD "MicroStation". As SDSL had been using MicroStation as the CAD connected to the analog/analytic plotter and the digital plotter, the SDSL technicians were familiar with the standard functions and operating procedure of MicroStation. On the other hand, they were not familiar with plotting using the input device "TopoMouse". Therefore, the technology transfer was carried out with emphasis on their gaining familiarity with the operation of PRO600 and TopoMouse as they carried out the plotting work for the target areas, with explanations given from time to time of the operating procedure for the PRO600 and how to acquire data efficiently.

c. Data check

The data checking method and compilation method necessary to configure the GIS database using PRO600 functions were explained.

d. Automatic contour production using DEM

As SDSL strongly desired that the technicians become familiar with the automatic production of contours, how to produce automatic contours using PRODTM, which is one of the functions of PRO600, was explained. As the terrains in the target areas were flat, the technology transfer was carried out using images of other districts. This explanation was given in the second and subsequent courses of technology transfer, and manuals were distributed to the trainees from the first course.

Picture 3-32 Training of trainees in technology transfer

4） **Results of technology transfer**

The results of the technology transfer were as follows:

a. Preparation before start of digital plotting

【LPS】

A series of technologies, covering everything from production of the project file to production of stereo models using the LPS, were transferred to the counterparts as listed below.

- Setup of geodetic system and projection method
- Registration of camera information
- Importing of external orientation elements and photographic images
- Inner orientation
- Change of status of external orientation elements

In changing the external orientation elements into a given format for the LPS, it became clear that the trainees had little experience in the compilation of text files using Text Editor and Excel etc. Therefore, some examples of techniques were explained and compilation using the software was demonstrated. As a result, the trainees became familiar with the technology for importing the external orientation elements into the LPS not depend on a certain system and producing the stereo models.

【PRO600】

After the preparatory work with LPS, the technologies covering the start of the plotting module PRO600 to digital plotting were transferred, including the following technologies for setting various parameters and operating methods:

- Creation of PRO600 project file
- Registration of library catalog/CELL file/SEED file
- Setting of various parameters (snap radius, setting value of stream mode, etc.)
- Creation and registration of plotting file
- Stereo model selection method
- How to change the attributes (color, shape, size) of measuring marks
- Operational setup of TopoMouse and how to do button mapping (functional registration)

For the library catalog/CELL file/SEED file, SDSL was provided with the files created in Japan in accordance with the Map Symbol Specifications as determined in the meeting on specifications. The details of the library catalog including how to register and compile were explained to the trainees.

b. Digital plotting work

The technology transfer for the digital plotting work was carried out using the stereo models for the target districts to transfer the following technologies:

- Understanding of the differences between the PRO600 tool and the standard tool for MicroStation and the operating procedures for those tools

- How to acquire and represent planimetric features in accordance with the acquisition standards
- How to overlay field survey photos and ortho-images
- TopoMouse operation

For TopoMouse, the SDSL technicians were at the level where they were capable of operating the functions which are used repeatedly, but to operate other functions they needed to look at the button map. Since the method of operation is different from handle operation, they appeared to feel some stress when doing the plotting work. In particular, it seemed that they felt particularly stressed by contour plotting. For stress-free operation, it is important for them to use the functions repeatedly, and the trainees are expected to make continued efforts in operation in future.

c. Data check

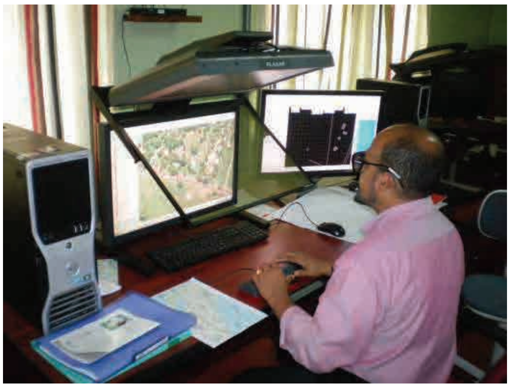
How to check line connections of data using the functions of PRO600 was explained and the technologies for checking the preset values for data check, carrying out the data check and setting up for indication and correction of data check results were transferred to the counterparts. As the Bentley Map used in digital compilation has similar tools, the trainees were given advice in selecting the optimum tool for efficient working.

d. Automatic contour production using DEM

The technology transfer for the production of contours as break lines from the plotted data and by the addition of break lines was carried out as follows:

- Creation of empty topographic data file using the LPS tool
- Selection of codes to be handled as break lines and import of the codes into the topographic data file
- Setting of parameters for contour creation

The use of this technology allows contours to be drawn easily with TopoMouse and it is expected that contours will be drawn efficiently.



Picture 3-33 Independent work by trainees

5） Evaluation of technology transfer

Whether the trainees were at the level at which they were capable of plotting using the LPS independently or not was evaluated using the map prepared in their independent work.

The map shown below is part of the data that the trainees produced through digital plotting, and shows that they were at the level at which they were capable of acquiring planimetric features (photo interpretation) and map representation (drawing) with no problem.

In addition, through repeated exercises they became familiar with the operation for stereo model creation using LPS. As a result, it can be judged that in future SDSL will be capable of independent digital plotting at the scale of 1/10,000 using the LPS.

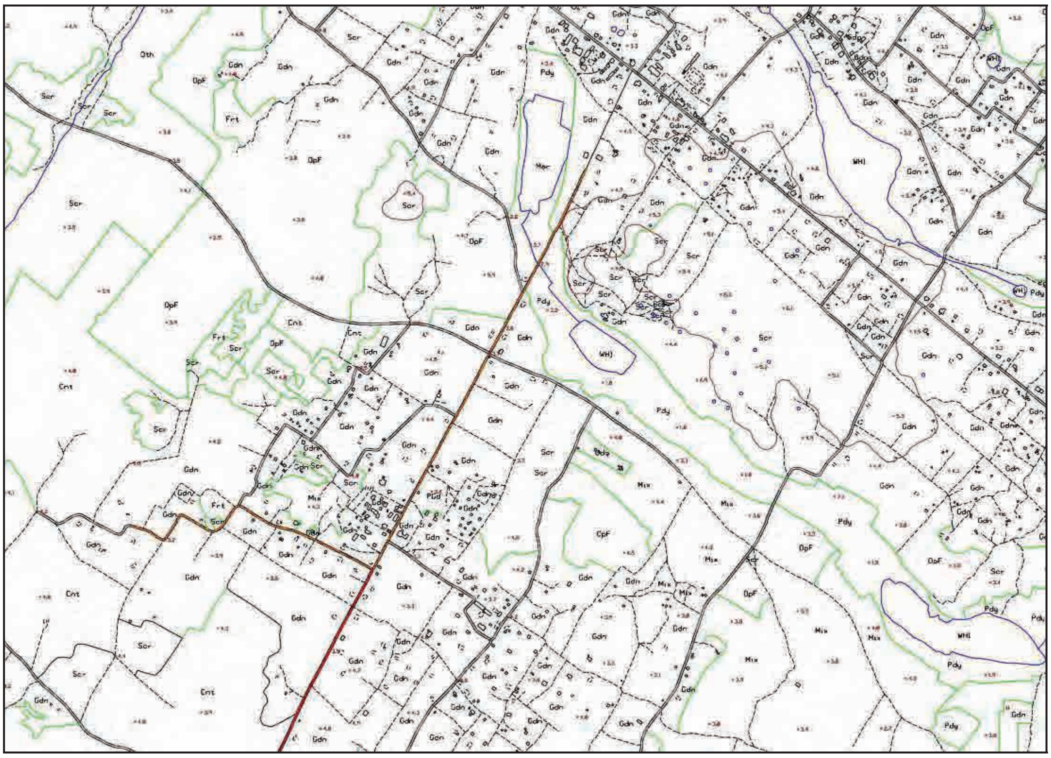


Fig 3-17 Part of data plotted by trainees

6） Conclusion

The digital plotting technology of SDSL was already somewhat established, as judged from the years of experience of the trainees and the plotting systems possessed by SDSL. On the basis of this judgment, it is considered that the technology transfer for digital plotting technology using LPS/PRO600 was implemented successfully, taking into account the provision of new knowledge which will be used effectively in future works and the information that will lead to higher work efficiency. The trainees not only had sufficient understanding of photogrammetry and secure plotting technology, but were also willing to absorb new technologies. From this viewpoint, it is hoped that SDSL will continue to use the LPS/PRO600 in future.

（７） Digital compilation (including supplementary digital compilation)

SDSL is already performing digital compilation operation using CAD software.

This project performed technology transfer not using the above-mentioned existing CAD software but the software of a digital compilation system introduced in this project (an upgrade version of the existing CAD software and totally different software). At first, the basic operations of each software was covered in technology transfer. Next, the applied operations were covered in the technology transfer, allowing the trainees to learn the operations required to perform digital compilation based on the 1/10,000 map symbol specification scheduled after the end of this Project.

１） Period and targeted trainees

The technology transfer of digital compilation was performed in two sessions. The following table shows the implementation periods and numbers of trainees.

All the trainees were the technicians of the photogrammetry division of SDSL, most of whom had work experience of photogrammetry over 20 years. However, none of the trainees was specialized in digital compilation and supplementary digital compilation.

Table 3-5 Periods and number of trainees

No	Implemented period	No. of trainees
Period 1	October 22, 2010 to December 4, 2010	6
Period 2	January 11, 2011 to February 10, 2011	6

２） Equipment used (software)

Technology transfer was carried out using CAD software "Microstation V8 XM Edition" and "Bentley MAP" introduced in this project.

３） Description of technology transfer

The technology transfer was carried out with emphasis on operation, the explanations and exercises for the following 5 items being repeated in order to ensure the trainees gained the relevant technology.

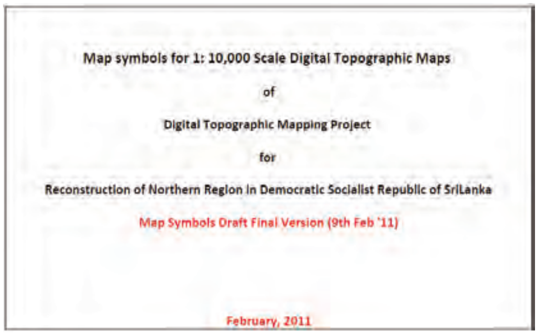
a. Understanding of 1/10,000 map symbol specification

In the digital plotting and compilation by SDSL, features in a model are interpreted and acquired and handled as data associated with one of the layers (feature types) already specified in the environmental settings.

During the development of topographic map data, however, a relevant specification (1/10,000 map symbol specification) must be used as the basis for acquisition and handling of data. Therefore, the map symbol specification of 1/10,000 topographic maps being created in the Project were explained in detail to promote understanding of features to be acquired, acquisition standard, and data types. Additionally, emphasis was given on the importance of the following items in acquisition and handling of data according to the map symbol specification:

(1) If any unknown feature is encountered, a decision must be made to classify it into one of the layers (features).

(2) Utmost attention must be paid to data types. Any mistake must be corrected.



Map symbols for 1: 10,000 Scale Digital Topographic Maps

of

Digital Topographic Mapping Project

for

Reconstruction of Northern Region in Democratic Socialist Republic of SriLanka

Map Symbols Draft Final Version (9th Feb '11)

February, 2011

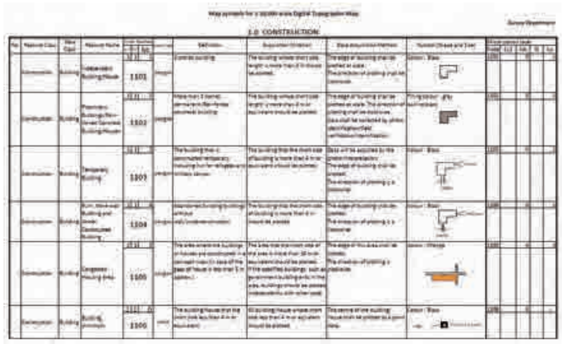


Fig 3-18 1/10000 map symbol specification

b. Basic operation technology of software of an introduced digital compilation system

CAD software usually used by SDSL for digital compilation operations (Microstation v7; hereinafter referred to as v7) and CAD software introduced in this Project (Microstation V8XM; hereinafter referred to as v8) are the same product of different versions. v8 has inherited the basic user interfaces, tools, operation procedures, etc. of v7. Therefore, technology transfer was provided with an emphasis on the operation procedures of functions added to v8 (e.g., scaling and movement of screen). Additionally, the basic operation procedures of "Bentley Map" newly introduced was also covered in technology transfer.

c. Technology for setting a digital compilation environment according to the map symbol specification

The symbols and line types used in output maps of topographic map data, one of the digital compilation environments, were initially those which made and provided by the study team according to the map symbol specification. In consideration of the future operations, however, technology transfer was provided on how to make such symbols, etc. and how to set up the environment using them.

SDSL, having not enough experience of making such symbols and line types before, was given technology transfer on making symbols and line types adopted in the 1/10,000 topographic map symbol specification as well as making original symbols, line types, and various patterns.

The technology transfer involved procedures for setup and call of symbols and line types that have been made and setup of the environment on v8.

Fig 3-19 Before setup of line types

Fig 3-20 After setup of line types

d. Basic operations required for digital compilation

SDSL has performed digital compilation operations using v7, whose basic operation procedures are not very different from v8. Therefore, the technology transfer was focused on the newly added or improved operation procedures and tools in terms of the following four points:

＊Tools in general

＊Shortcut functions

＊Making of command files

＊Making, correction, and check of topologies

e. Quality control and data management

As part of quality control, the procedure for logical check of digital data using v8 and Bentley MAP and the procedure for analog check of output maps of data were covered in the technology transfer. Since the data acquired in digital compilation is used in the subsequent structualization and map symbolization operations, the importance of this quality control was asserted, and some advice was given on the quality control procedures for the data.

４） Results of technology transfer

The results of the implemented technology transfer were as follows:

a. Understanding of 1/10,000 map symbol specification

Whereas operators used to handle any unknown features by making arbitrary changes in the layers, etc., the trainees understood that this practice gives adverse influences on subsequent processes. The trainees have acquired a habit of checking the map symbol specification in such a case as required when proceeding with the work and have understood the importance of the map symbol specification.

b. Basic operation technology of software of an introduced digital compilation system

The trainees, all of whom had the experience with v7, learned the basic operation technologies for v8 without any particular problem. However, the user interfaces of v8 had some new layouts and gave at first a little confusion to the trainees during operation. As a workaround, the customize function of v8 was used to give a v7-like layout to the user interfaces to avoid confusions. The new functions added in v8 (such as scaling and move of the screen) can be operated in the same procedures as v7. However, the trainees learned the operation procedures of v8, which are easier and help them save the operation time.

c. Technology for setting a digital compilation environment according to the map symbol specification

The technology of making symbols was acquired without problem because it is an intuitive procedure.

The technology of making line types, having a wide range of setting values, was expected to require a lot of time to learn. Therefore, the technology transfer progressed from making of simple line types to making of gradually more complex line types, resulting in successful acquisition of this technology.

Additionally, the trainees also acquired the v8 environment setup technology such as setup and call of symbols and line types that have been made.

d. Basic operations required for digital compilation

＊Tools in general

The tools added or upgraded in v8 required to make 1/10,000 digital topographic map were explained and demonstrated one by one. The trainees learned to use the tools through hands-on practice.

＊Shortcut functions

The trainees from SDSL did not have an experience of using the shortcut functions through keyboard operations. Therefore, the procedures using both the mouse and the keyboard were demonstrated. The trainees acquired these procedures through hands-on practice. Although these operations are possible using only the mouse, the operations can be far more efficiently performed if the keyboard shortcut keys are also used.

＊Making of command files

The making of command files for semi-automatically producing data or the making of command files for manipulating and deleting the setting values of layers were covered in the technology transfer. However, it is hoped that the trainees who did not have experience in making such files before will acquire more experience in this regard in the future.

＊Making, correction, and check of topologies

Technology transfer was provided on and the trainees acquired the technologies for checking whether polygon data specified in the map symbol specification is generated correctly using Bentley MAP and correcting and producing the data. In this process, too, the importance of the map symbol specification and the effective usages of them were reaffirmed.

Fig 3-21 Before polygon generation

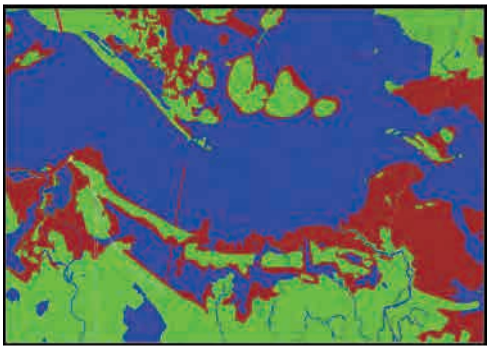


Fig 3-22 After polygon generation

e. Quality control and data management

＊Data check

Microstation v8 has an additional function of performing logical check of data in automatic processing. The check and correction of data using this function was covered in the technology transfer, and the trainees acquired this technology. Errors encountered in this check proved to be the basis for decision-making by considering which planimetric features should be focused on in order to decrease them during digital compilation. This is considered to contribute to efficiency improvement of digital compilation operations.

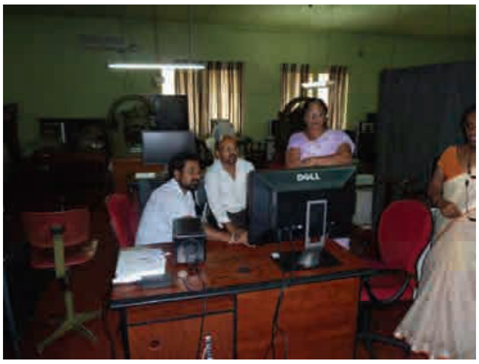
＊Output and visual check

The visual check technique of outputting topographic map data acquired in digital compilation and comparing it with field survey photographs was covered in the technology transfer.

＊Optimization of data file management

The management of data files after completion of processes was not unified and left to the arbitrary handling by individual operators. Therefore, the necessity of unified management of original data and understanding of risk of data deletion were asserted. Advice was given on encouraging unified management of data and avoiding risk of data deletion by producing a dedicated folder for each of the processes, performing unified management of data in these folders, and taking a backup of data in the folders.

Picture 3-34　Scene practice



Picture 3-35　Scene of practice done by trainees

5） Evaluation of technology transfer

The trainees understood the importance of the map symbol specification in producing 1/10,000 digital topographic maps and learned to perform technical operation of digital compilation according to them without problems.　Additionally, they even became capable of performing limited quality control using the function of logical check of data included in the latest software package used in this technology transfer project.

6） Summery

Through the implementation of technology transfer, it became apparent that the counterpart has a very high interest in and capability of understanding and absorbing new technologies.　We hope that the counterpart will reconsider work procedure of digital compilation, make the most of the latest software that has been introduced, and perform more efficient digital compilation operations.

（8） Supplementary field verification

It was known that SDSL had knowledge and experience in the implementation of supplementary field verifications required for the production of topographic maps. On the basis of this fact, the Study Team prepared a (draft) Work manual which described the technologies to be used in the Project on the assumption that SDSL had high technical capacity, and provided lectures explaining the details of the technologies at the beginning of the work.

The Study Team also implemented a preliminary interview survey to measure how aware SDSL personnel were of the concept of “supplementary field verification.”　The survey results revealed that their technical capacity of the supplementary field verification using the output-maps was high. On the basis of this finding, the Study Team decided to recommend adoption of the OJT method for the technology transfer, in which experts advise their counterparts while implementing the actual work. OJT-based technology transfer was implemented for targeting the following technical subjects:

a　How to eliminate uncertainties identified in the digital plotting/compilation

b　How to implement final confirmation of administrative boundaries, road classifications and annotations

c How to prepare and use annotation data files

d Schedule management and accuracy control technologies

e How to prepare a supplementary field verification manual

1） Content and Implementation of the Technology Transfer

Before the implementation of the supplementary field verification work, the Study Team provided the counterparts who were to implement the work with adequate explanation of the Work Manual and transferred the technology required to maintain the integrity of the work. In addition, on the first day of the supplementary field verification work, all the counterparts were engaged in the supplementary field verification work and the Study Team transferred the technology by OJT to confirm that the work could be implemented in the field as described in the Work Manual.

a How to eliminate uncertainties identified in the digital plotting/compilation

The subjects for the supplementary field verification (uncertainties) identified in the digital plotting/compilation were represented on the maps for field work after being classified into the seven categories shown in the table below. The Study Team transferred the technology to simplify the supplementary field verification work in each subject to the counterparts.

Instructions for supplementary field verification	
A	Uncertain symbol
B	Uncertain vegetation
C	Uncertain range or length
D	Uncertain shape
E	Uncertain location
F	Uncertain annotation
G	Uncertain feature

Picture 3-36 Supplementary field verification

Picture 3-37 How to sort the results of the field works

b How to implement final confirmation of administrative boundaries, road classifications and annotations

Various types of digital reference data which the Study Team had obtained before were described on the output maps for the second period of the supplementary field verification. In addition to the set of output maps to be used in the field, another set of output maps was prepared. These maps were used for the technology transfer on how to conduct final confirmation of administrative boundaries, road classifications and annotations either in the field during the supplementary field verification or at SDSL Headquarters.

c How to prepare and use the annotation data files

Spelling patterns specific to Sri Lanka are used in the annotations on the maps. Annotation lists are written by hand during the supplementary field verification. Therefore, there is a possibility of the handwritten annotations being transcribed incorrectly in the supplementary digital compilation. In order to eliminate this possibility, it was decided to prepare digital annotation lists. Accordingly, the Study Team transferred to the counterparts the technology on how to prepare digital annotation lists as a means to eliminate errors in the transcription and to facilitate the supplementary digital compilation work.

d Schedule management and accuracy control technologies

In order to facilitate schedule management and accuracy control, the Study Team transferred to the counterparts the technology on how to use Accuracy Control Charts to control the accuracy of the results of supplementary field verification.

e How to prepare a supplementary field verification manual

The Study Team provided SDSL with the “Work Manual” which was used for the explanation of the supplementary field verification work as a (draft) Supplementary Field Verification Manual for the independent production of 1:10,000-scale topographic maps by SDSL in future. Then, the Study Team transferred the expertise in preparation of the supplementary field verification manual to SDSL.

The Study Team expects SDSL to revise this (draft) manual to make it more resourceful using the outcomes of this technology transfer and experience in the supplementary field verification work implemented in accordance with the Work Manual.

２） Evaluation of the Outcomes of the Technology Transfer

The Study Team evaluated the outcomes of the OJT-based technology transfer in supplementary field verification on the basis of the progress and outputs of the supplementary field verification.

a How to eliminate uncertainties identified in the digital plotting/compilation

Since these uncertainties were clearly described on the output maps for the supplementary field verification, it is possible to confirm whether the technology to eliminate uncertainties has been transferred successfully or not by studying whether the survey was implemented in accordance with the (draft) Work Manual and whether the survey thus implemented has eliminated the uncertainties.

Since the field survey has been implemented in accordance with the (draft) Work Manual, results indicating the elimination of uncertainties have been clearly described on the output maps, and the number of erroneous entries and omissions recorded on the Accuracy Control Charts was small, the Study Team considers that the counterparts have duly mastered the transferred technology.

b How to implement final confirmation of administrative boundaries, road classifications and annotations

It is also possible to evaluate whether the technology has been transferred successfully or not by studying whether the supplementary field verification has been implemented in accordance with the (draft) Work Manual as set forth in (a).

Since the data have been obtained as described in the (draft) Work Manual, the quality of the outputs and the appropriateness of the methods used, it was evaluated that the counterparts have duly mastered the transferred technology.

c How to create and use annotation data files

The Study Team considers that the counterparts became fully aware of the importance of the creation of annotation data files in the technology transfer. Meanwhile, the current situation in the field, in which there is not enough equipment including PCs and, therefore, the number of people who can use them is limited, was revealed to the Study Team.

d Schedule management and accuracy control technologies

Since the counterparts have managed to complete the predetermined quantity of work within the predetermined period with the human and material resources available in this supplementary field verification, the Study Team considers that they have mastered the schedule management technology. Since the counterparts have completed the Accuracy Control Charts in which erroneous description and omission in each map are recorded, the Study Team considers that they have mastered the accuracy control technology.

e How to prepare a field completion manual

The Study Team considered the “(draft) Supplementary Field Verification Work Manual” as the implementation manual of works and transferred the knowledge and technology used in its preparation to the counterparts. However, a revised version of the Manual, on the basis of the knowledge and technologies for creating the manual or of their experience in work implementation of the OJT in this Project was not created. Therefore, it is difficult to decide whether the counterparts have mastered the transferred technology or not.

（９） Digital data structualization

The technology transfer of digital data structualization was going to be carried out using ArcGIS 10.0 software introduced in this project. On the other hand, the SDSL trainees in this field already had three to five years' work experience using this software. Therefore, the technology transfer on digital data structualization using this software was reconsidered by omitting the part on the basic operations of this software in the initial plan and focusing on the latest tools, latest technologies, and applied use of introduced software related to the digital data structualization (structualization of topographic map digital data) in everyday work of the trainees.

１） Period and trainees

Period: January 11, 2011 to February 10, 2011

Target trainees: Six (All of the six persons already had three to five years' work experience of using ArcGIS.)

２） Equipment used (Software)

The software used in the technology transfer was ArcGIS 10.0 by ESRI of the U.S.A. Two licenses were used in total; one introduced in this Project and another owned by SDSL.

３） Details of technology transfer

a. Transformation of dgn files of Microstation to File Geodatabase of ArcGIS

File Geodatabase is a native data structualization of ArcGIS, a major data format used to compile and manage data. In this Project, however, topographic map data is provided in dgn files of Microstation. Therefore, it is necessary to transform dgn files to File Geodatabase in order to use the topographic map data on ArcGIS. For this purpose, two transformation methods using ArtToolbox and ArcCatalog respectively were covered in the technology transfer. The technology transfer on transformation provided detailed explanation on how to transform annotations, points, lines, and polygons and configure the tools to be used. Transformation practice was also provided on the dwg, DXF, and shape files in addition to dgn files. Additionally, the Python program was provided to automate the operations described in the above.

b. Data structualization

Topographic map data transformed to File Geodatabase is stored to a feature class in a feature dataset. According to the layer information of dgn, the content of dgn files is put together into the feature class to build a topology. In this process, errors of the stored data are detected and corrected. This series of procedures was explained and the usable technologies were covered in the technology transfer.

c. Data compilation

It was planned to transfer the technology of correcting errors in data using the compilation function of ArcMAP and the latest batch compilation tools of ArcGIS 10.0. However, the trainees were already familiar with the compilation function of ArcMAP. Therefore, it was planned to focus the technology transfer on the use of the latest batch compilation tools of ArcGIS 10.0.

d. Data projective transformation

It was planned to explain and provide training on how to perform transformation between longitude/latitude coordinates and UTM coordinates using projective transformation tools of ArcToolbox. For such a transformation from a longitude/latitude coordinate to a UTM coordinate and back to a longitude/latitude coordinate, technology transfer was provided on the procedure of setting a number of significant digits to ensure that there is no difference between a coordinate before the transformations and a coordinate after the final transformation.

e. Attribute search and spatial search

It was planned to explain and provide training using the attribute search and spatial search functions of ArcMAP and ArcToolbox. In particular, it was also planned to provide training on how to detect a spatial arrangement error between feature classes using the spatial search function.

f. Export of a large number of maps to PDF files using Data Driven Pages

The Data Driven Pages function, using one layout, repetitiously processes a map range by the unit of this layout and outputs multiple pages in the PDF format of this layout. It was planned to provide the technology transfer of this function.

g. Production of 3D data using TIN and Terrain

It was planned to explain and provide training on how to build TIN and Terrain, create contour lines, produce DEM, produce shaded relief maps, and produce 3D data.

h. Mutual transformation between KML files and ArcGIS data

It was planned to explain and provide training on how to perform mutual transformation between KML files of Google Earth and ArcGIS data using ArtcToolbox. After the technology transfer, SDSL will become capable of displaying ArcGIS data on Google Earth with ease.

i. Building of a road network

It was planned to explain and provide training on how to build a road network using the Network Analyst extension of ArcGIS.

j Update of Personal Geodatabase

SDSL manages GIS data using Personal Geodatabase. Since Personal Geodatabase has a data size limit of 2.1 GB, it was planned to explain and provide training on how to update it to File Geodatabase that can store up to 1TB data. It was planned to provide the Python that can automatically update all the Personal Geodatabase data owned by SDSL to File Geodatabase.

k. Use of Bing Map data as background data

ArcMAP has online data of ArcGIS, such as Bing Maps Aerial and Bing Maps Road. It was planned to explain and provide demonstration and training on how to use it as background data.

l. Utilization of mosaic datasets

The use of a mosaic dataset enables storage/management and high-speed display/search of a large volume of raster data and ortho image data. It was planned to explain and provide demonstration and training on the method and procedure of producing mosaic datasets.

m. Use of attribute domains

Attribute domains are rules that define valid values of field types. It was planned to explain and provide demonstration and training on how to use and set up the attribute domains, types, and subtypes.

n. Use of the batch processing mode of ArcToolbox

The batch processing mode of ArcToolbox is convenient in processing multiple pieces and a large volume of data using the same tool. It was planned to explain and provide demonstration and training on how to use this processing mode.

Picture 3-38 Data structualization of digital data

4） Results of technology transfer

As the results of the technology transfer, SDSL:

＊Acquired the technology of manual and automatic transformation of topographic map dgn data to ArcGIS data.

＊Acquired the technology of putting together topographic map data transformed to file geodatabases into feature classes to build a topology and searching for and correcting errors in order to produce GIS data.

＊Can use the attribute search and spatial search functions of necessary features to detect attribute and spatial arrangement errors. It can also correct detected errors in a batch processing using the compilation tool.

＊Can import ArcGIS Online data such as Bing Maps Aerial and Bing Maps Road to use the latest background data.

＊Acquired the technology of mutual transformation between KML files of Google Earth and ArcGIS data.

＊Learned how to export a large number of maps based on Data Driven Pages to PDF files with ease, thus significantly improving the efficiency of producing output maps from topographic map data.

＊Acquired the technology of processing a large volume of data using the batch processing mode of ArcToolbox.

＊Can perform high-speed display and search of a large volume of raster data and ortho image data, making the most of mosaic datasets. Can use ortho image data as background data more easily than before.

＊Successfully performed automatic update of ArcGIS data already managed in Personal Geodatabase to the latest format, File Geodatabase.

＊Learned how to produce 3D Surface data as well as contour lines, DEMs, and shaded relief maps based on the building of TIN and Terrain.

＊Successfully improved the efficiency of inputting attributes using attribute domains.

５） Evaluation of technology transfer

Whether the trainees have become capable of structualization digital data using ArcGIS on their own was evaluated using a pilot operation of transforming dgn files of topographic map data to produce GIS data.

The technical part of the pilot operation included production of a new File Geodatabase, production of a feature dataset and a feature class, transformation of common data in such formats as dgn, dwg, DXF, and shape to feature classes, compilation of data, building of a topology, detection and correction of errors, production of layers, output of maps, and creation of 3D data. The pilot operation was repetitiously performed to confirm that these technologies have been acquired. Therefore, the evaluation confirmed that SDSL is capable of producing structualization GIS data using ArcGIS on its own.

６） Summery

SDSL had an accumulation of a production degree of experience in work using ArcGIS. Based on this premise, technology transfer was provided, covering the latest technologies of and the concepts, techniques, efficiency improvement tips for efficient utilization tools of ArcGIS and providing the Python program that can perform automatic processing. The training strengthened the understanding of structualization of digital data using ArcGIS and familiarization with technologies, giving an impression of strong enthusiasm to absorb new technologies. From the above fact, it can be expected that SDSL will use ArcGIS in a continuous and progressive way in the future.

（１０） Map symbolization

The technology transfer on map symbolization was performed to allow SDSL to produce data for printed 1/10,000 topographic maps on its own. Data acquired in supplementary digital compilation (DXF format) was used in the technology transfer on map symbolization.

１） Implementation periods and target trainees

The technology transfer of the same content was provided to four different groups in the implementation periods.

Group	Implemented period	No. of trainees
Group1	January 18, 2011 to January 28, 2011 (8 days)	4
Group 2	January 31, 2011 to February 11, 2011 (9 days)	4
Group 3	February 14, 2011 to February 25, 2011 (8 days)	4
Group 4	February 28, 2011 to March 11, 2011 (9 days)	4

None of the trainees had a work experience in map symbolization nor an experience of using Adobe Illustrator to be used in map symbolization.

２） Equipment used (software)

The technology transfer on map symbolization was performed using Adobe Illustrator (2 licenses), graphic software introduced in this Project

３） Description of technology transfer

To ensure efficient technology transfer in a limited period of time, a focus was placed on map symbolization using actual data acquired in supplementary digital compilation (DXF format). The description of the implemented technology transfer was as follows:

a. Setup of print environment

In consideration of printing using data produced in map symbolization, it was planned to explain how to set up the following print environment for the current data.

・Explanation of Desk Top Publishing (DTP)

・Requirements for input data for printed maps

- Overprint
- Film output
- Others

b. Basic operations of Adobe Illustrator CS5

It was planned to provide technology transfer on the following usage methods of software with a focus on the functions of Adobe Illustrator CS5 to be used to produce topographic map data for printed maps.

- Use of the select tool
- Accurate drawing of figures by numerical value input
- Scaling, rotation, and move of figures
- Use of Group, Lock, and Hide commands
- Fill and line representation
- Layer operations
- Creation of patterns and brushes
- Other

c. Preparation for map symbolization operations

It was planned to transfer the following technologies for creating objects required to produce topographic map data for printed maps according to the map symbol specification:

- Explanation of how to register Swatch Colors (Process Colors, Spot Colors)
- Creation and registration of vegetation patterns
- Creation and registration of brush patterns
- Creation of symbol marks

d. Map symbolization operations

It was planned to perform the following map symbolization operations using a data file created in supplementary digital compilation (DXF format) (Drawing No.: 04-20).

- Scale-down transformation of data files (DXF format) to 1/10,000 scale
- Identification of hierarchical relationships of layers
- Transformation of objects according to the map symbol specification
- Correction of inconsistencies
- Trimming of topographic maps

e. Production of topographic map data files for printed maps through composition of topographic map data and marginal information data

f. Data correction (including correction of secular changes)


Picture 3-39 Map symbolization

4) Results of technology transfer

a. Setup of print environment

Since we explained the fact that the print film output was different from the conventional plotter output (RGB), the meaning of overprint for preventing plate misalignment, and the technique of "printing four colors plus one special color", the counterpart understood the overall concept of printing digital data. It was also confirmed that SDSL has the print department, which can therefore print symbolization data on its own if it acquires output films (from the outside).

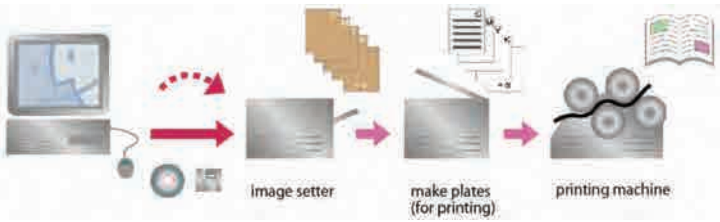


Fig 3-23 Flow of printing digital data

b. Basic operations of Adobe Illustrator CS5

As a result of explanation using an original basic operation manual specialized in map symbolization and technology transfer through training using assignments, the counterpart mostly learned the operations of Adobe Illustrator required for map symbolization. In particular, extensive time was spent on the technology transfer on the layer operations and the creation of patterns and brushes, which are effective in map symbolization.

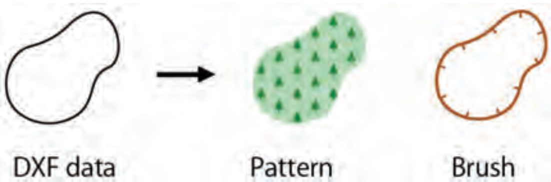


Fig 3-24 Transformation of DXF data using patterns and brushes

c. Preparation for map symbolization operation

According to the map symbol specifications, the registered colors (Swatch Colors) to be used in map symbolization were determined to be 11 process colors (CMYK) and one spot color (special color). The trainees understood that, when color needs to be changed, they can do so by changing the swatch colors to apply color changes all at once to patterns, brushes, and symbol marks created using multiple switch colors.

In addition, the trainees learned to create palette files (work files), create vegetation patterns, symbol brushes (marks), and line brushes (such as depressions, artificial sloops and etc.) required for symbolization according to the map symbol specifications, and place each of them on a layer with the same name as the map symbol code to store them in a file. In this process, they also learned to paste objects stored in a file into another file acquired in supplementary digital compilation (DXF format) and transform all the objects in a layer at once using the Eyedropper tool.

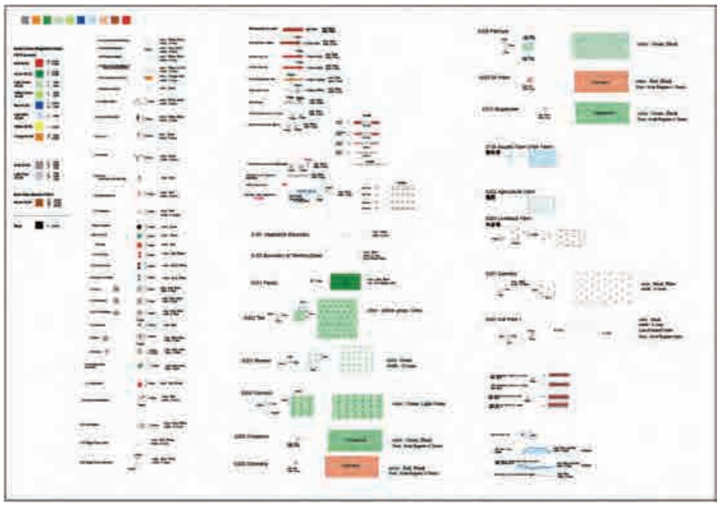


Fig 3-25 Palette file including layer information (one copy)

d. Map symbolization operation

＊Scale-down transformation of DXF data to 1/10,000 scale

The trainees acquired the technology of batch scale-down transformation using a command to reduce the map sheet size to 800 mm right-left and 500 mm up-down. In this process, it was necessary to move the text close to the neat lines into the neat line area (because the text recognized by Adobe Illustrator is larger than that of visually recognized, causing an error in the entire size of a map). The trainees understood this point and learned how to deal with it.

＊Identification of hierarchical relationships of layers

Through the discussion with the digital compilation team, they were assigned to classify layers by map symbol codes. They used layer names that were the same as the map symbol codes. The layers were identified in the following order:

（Ascending order from the bottom）

6.0 Vegetation→5.0 Land Classification→7.1 Topographic Features（Contour Lines）→3.0 Hydrography→7.1 Topographic Features（Depression、Sloops）→2.0 Transportation→1.0 Construction（Buildings）→4.0 Associated Features→1.0 Construction（Symbol Marks）→8.0 Boundaries→9.0 Toponymy →Neat Lines

＊Transformation of objects according to the map symbol specifications

Using the palette files created in the preparatory stage, the trainees acquired the technologies of transforming polygon colors, embedding patterns, transforming line types, line colors, and line gauges, and transforming fonts, sizes, and colors of annotations for each of the layers (format codes). It was planned to express dual-line roads (represented by two lines, up and down) using two layers including one added layer, and the trainees learned how to do this.

Fig 3-26 DXF file that has been output in digital compilation (0420)

＊Correction of inconsistencies

When batch attribute transformation is performed by applying a line brush to the DXF data consisting of one line such as a cliff or a railroad line, an inconsistency may occur in the data. In such a case, the consistency must be maintained by either dividing the line segment and correcting part of it manually or using the command "Simplify" or "Round Corner" that decreases the number of segments (points) without changing the forms of the line segments. This technology was also transferred to SDSL:

＊Trimming of maps

All the objects of data acquired in supplementary digital compilation (DXF format) are divided with neat lines and there are losses of data in the neat line areas. Objects with line widths such as roads with data losses are extended to out of the neat line area to remove the losses, and the "Clipping Mask" in the layer operation is applied to delete the part out of the neat line area. This technology was also transferred.

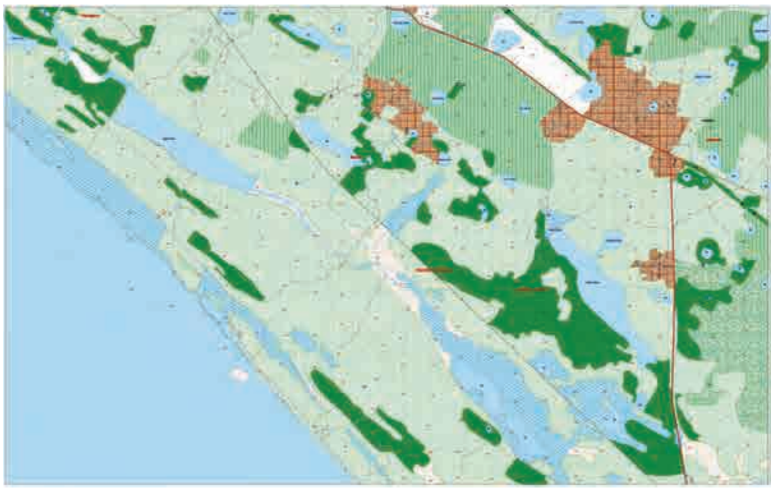


Fig 3-27 3-22 File of completed symbolization (0420)

e. Production of topographic map data files for printed maps through composition of topographic map data and marginal data

The trainees also learned how to compose basic marginal information files containing trim marks and produced topographic map data, and then they learned how to replace the information such as sheet number, attainment, and title to produce topographic map files for printed maps.

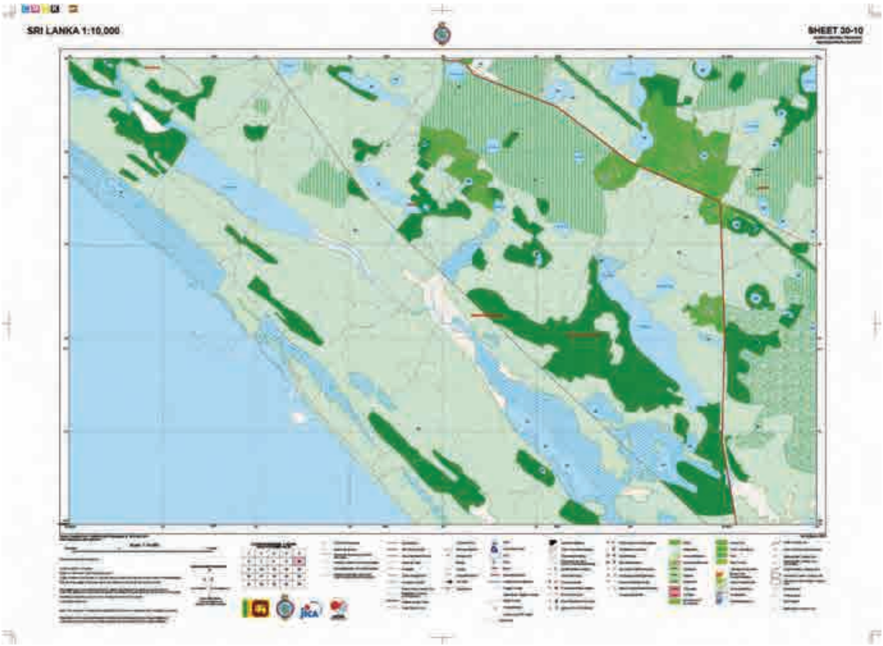


Fig 3-28 Completed map file for printing (0420)

f. Data correction (including correction of secular changes)

When data acquired in supplementary digital compilation needs to be corrected, data of layers to be corrected including the neat line area (DXF format) is replaced on Adobe Illustrator and given with the map symbol of layers to be corrected. The trainees learned this procedure.

5） Evaluation of technology transfer

The counterpart of SDSL, despite having no experience of using the graphic software Adobe Illustrator, learned fairly well the creation of objects to be used in topographic maps and the processes from input of data acquired in supplementary digital compilation (DXF format) to map symbolization. From this fact, we can evaluate that the trainees' understanding and acquisition has reached a level at which they can produce map data for printing.

6） Others

Based on the results of the technology transfer, the counterpart will be capable of developing 1/10,000 map symbolization data and, using this data, producing small-scale maps by scale-down compilation. Furthermore, it will also be capable of producing thematic maps by changing the specifications. It is hoped that SDSL will realize these possibilities by pursuing maintenance, propagation, and development of technologies acquired in the technology transfer and develop various print data on its own.

3.2.3 Seminar/Workshop

（1） Holding Seminar/Workshop

The Seminar/Workshop was held on November 4th 2011 at Water Edge. Approximately 150 people, including the Deputy Minister and the Vice Minister of the Ministry of Land and Land Development, the competent ministry of SDSL, and staff of the Embassy of Japan, attended the Seminar/Workshop.

At the beginning of the Seminar/Workshop, guests of honour from the institutions involved in the Project gave addresses. The addresses were followed by a presentation explaining the outline of the Project (reasons, purposes, progress and outcomes of the implementation of the Project). Then, SDSL gave a presentation depicting their activities, a plan for the dissemination of the project outputs and a future activity plan. SDSL also announced a plan for the production of digital topographic maps of an area covering approximately 7,000 km^2 which could not be achieved in this Project. After the presentation by SDSL, the Study Team and the SDSL trainees respectively gave a presentation on the specifications of the digital topographic maps produced in the Project and the outputs of the implemented technology transfer (mainly digital photogrammetry).

During the afternoon break, the trainees in the technology transfer demonstrated digital mapping using the skills they had mastered in the technology transfer and explained about digital plotter and its use to the participants of the Seminar/Workshop. In addition, some of the participants practiced digital plotting.

In the afternoon session, the Study Team gave a presentation on the progress and outcome of the technology transfer and SDSL gave a presentation on matters related to GIS data construction. At the close of the Seminar/Workshop, The Study Team presented, as a recommendation, a set of guidelines (work manual) summarizing the matters to be noted when producing various types of geospatial data independently by SDSL.

The participants of the Seminar/Workshop were requested to fill in a questionnaire. The questionnaire asked for any requests to SDSL regarding the use and distribution of the digital topographic maps produced in the Project or the production of digital topographic maps of the Northern Region and for any comments or recommendations regarding the Project.

3.2.4 Reports

The reports was produced, explained and discussed.

（1） Production of Inception report (IC/R)

The Inception Report was produced by compiling the basic policies, procedures (including procedures and components of technology transfer), implementation structure, schedule and so on based on the documents collected in Japan and the preliminary investigation.

（2） Explanation of and Discussion on Inception report

The explanation and discussion of the IC/R was held on 4th March 2010 in order to explain the implementation of the project and discuss its content. Present on the Sri Lankan side were nine members of SDSL management including its director, and four members of the study team and one person from the JICA Sri Lanka Office.

The content of the project including its purpose, target, basic policy, procedures, schedule, and outputs, were explained based on the report. The main questions and answers after the explanation were:

Q: Can photography strips 44 to 46 be taken consecutively?

A: The planned contract with the photography company is for an area of 9,000 ㎢. However, we will negotiate with them when we conclude the contract.

Q: The overlap percentage of the aerial photography is standard; however, what will you do if it is insufficient?

A: The photography inspector will check the overlap and request a reshoot if it is insufficient.

Q: I want to reconfirm the number of photo control points.

A: There are approximately 100 horizontal and 200 height control points.

Q: Is the accuracy of the height control points approximately 10 cm?

A: The average of basic leveling and GPS levels is just over 10 cm.

Q: Is a resolution to scan the aerial photo film of 20μ sufficient?

A: 20μ is sufficient. If the resolution is any greater it will make the data file too large and will not be practical for tasks to follow such as digital plotting.

Q: Is it possible to convert scale 1:10,000 data to scale 1:50,000 data?

A: It is possible if the specifications (digital format) of both are fixed, although it is a process that is complicated and takes experience.

Q: Can you provide us (SDSL) with two sets of color contact prints rather than one?

A: We will negotiate with JICA Tokyo whether we can provide you with their set.

Q: Can you provide SDSL with some of the accuracy control sheets?

A: Sure, we will provide them.

With these questions and answers, the Inception Report was approved. The above details were compiled in the Minutes of Meeting and both parties signed it.

（3） Production of Interim report (IT/R)

The Interim Report was produced detailing the progress of the project, evaluation of its implementation as of the end of September 2010, and how and when the rest of the project will proceed.

（4） Explanation of and Discussion on Interim report

The Interim Report discussion to explain the progress of project implementation up to the end of September 2010 was held on September 28, 2010. Participating were six senior staff of SDSL including the director, four members of the Study Team, and one representative from the JICA Sri Lanka office.

In the discussion the implementation status of each component of the project up to the end of September 2010 was explained according to the Interim Report. The mid-term results of the project and their evaluation were also explained. The discussion after the explanation involved the following questions and answers.

Q: Did the aerial triangulation of the photographed area including the results of the GCP survey progress without problem?

A: As mentioned in the Interim Report, there was no problem with the number and distribution of GCP necessary for aerial triangulation of the photographed area and it produced good results. There was also no problem with the GCP survey.

Q: When will the remaining photography be implemented?

A: In the next dry season in January and February 2011. Therefore, the photography contract period has been extended until May 2011. Also, there are various tasks to undertake before the next photography so that it goes smoothly.

Q: What will be the implementation structure of the upcoming field identification?

A: The Study Team has requested SDSL that it be implemented by ten teams. SDSL replied there is no problem on the personnel side, but have been approached to discuss getting hold of the necessary vehicles.

Besides the above questions and answers there was discussion to confirm matters regarding the public release of the digital topographic map outputs. It covered the following.

Even though the digital topographic map outputs are of the Northern Region, SDSL intends to sell these to the public. However, in order to obtain aerial photos it is still necessary to get permission from the Ministry of Defence.

The Interim Report, the above questions and answers, and the discussion results were approved.

The above content was outlined in the minutes of meeting and signed by both parties.

（５） Production of Draft final report (DF/R)

The Draft Final Report covering the results and implementation status of the whole project has been made. Moreover, two guidelines (work manuals) were made, one so that SDSL can independently produce, update and manage various data (geographic spatial data) in future, and another for establishing and designing the system for a GIS database.

（６） Explanation of and Discussion on Draft final report

”Explanation and Discussion of the Draft Final Report” was held on November 1st 2011 at the SDSL Office to explain and discuss the contents of the Draft Final Report including the actual progress and the outcome of the project implementation. Nine senior staff members of SDSL, including the Surveyor General, five members of the Study Team and a staff member of JICA Sri Lanka Office attended the explanation/discussion.

The Study Team explained the outline of the Project, implementation of the Project, outcomes of the Project implementation and production of digital topographic maps in future in accordance with the Draft Final Report. After the explanation, discussion of the Report was held. The main subjects of the discussion were as follows:

* Description of the background to cancellation at the implementation stage of the cross-line aerial photography which was included in the original aerial photography plan should be added to the Report.
* SDSL requested attachment of the calibration data of the aerial cameras used in the aerial photography to the Report for future use. The data on the cameras was to be attached to the Report as requested.
* The results of the questionnaire survey on requests for digital mapping conducted at the seminar should be incorporated in the Report.
* Regarding lessons learned from the project implementation, SDSL remarked that the digital topographic maps produced and technologies mastered in the Project would be very beneficial and the outputs of the field surveying, the map symbol specifications for the digital maps, the technology transfer manual and the guidelines on generation, maintenance and management of various types of data (work manual) would be very useful.

* SDSL publicly announced a plan for the production of digital topographic maps of the unmapped areas in the Northern Region. SDSL aims to complete the mapping by June 2014.
* In the map production plan mentioned above, SDSL intends to use various types of plotters. SDSL intends to implement the office work (digital plotting/compilation) and the field work (supplementary field verification) simultaneously.
* SDSL also has a plan to produce digital ortho-photos, in addition to the plan for digital map production.

（7） Production of Final report (F/R)

The Study Team prepared the Final Report by making revisions and additions to the Draft Final Report as required by the outcome of the explanation and discussion of the Draft Final Report and the progress and outcome of the work implemented after the completion of the Draft Final Report. The following were the major revisions and additions:

* The background to the partial change in the aerial photography plan
* Plans for the production of digital topographic maps of the unmapped areas in the Northern Region, etc.
* The results of the questionnaire survey conducted at the seminar/workshop
* The progress and outcome of the work implemented after the completion of the Draft Final Report.

As supplementary reference materials, the map symbol specifications for digital maps, the calibration data of the aerial cameras and the guidelines (work manual) were attached to the Final Report.

3.3 Lessons Learned During the Implementation of This Project and from the Results of the Implementation

3.3.1 Lessons Learned During the Implementation of This Project

（1） Aerial photography

a. We visited the Civil Aviation Authority, the Ministry of Defense and the Air Force many times in order to obtain the various permits required for the aerial photography. Although we knew that organizational relationships play an important role in obtaining such permits, we also became keenly aware of the importance of personal relationships with relevant personnel in facilitating the acquisition of such permits. From this experience, we recommend that personal connections should be fully utilized in the acquisition of various permits.

b. When the aircraft to be used for the photography suffered engine trouble during the flight, the subcontractor made arrangements for a replacement aircraft. Therefore, although implementation of the photography was delayed, we managed to take aerial photographs of part of the targeted area.

From this experience, we consider that the contract for aerial photography should be awarded to a company with the capacity, at least, to make arrangements for a replacement aircraft and that the contract with such a company should confirm or specify such arrangements for a replacement aircraft as a contractual condition.

（２） Procurement of Equipment to be Used in the Project

a. The equipment used in the technology transfer was procured locally after confirming the required specifications with the counterparts (C/Ps) in Sri Lanka. Although the equipment was delivered a few days after the scheduled delivery date, fortunately, this delay did not affect the content or the duration of the technology transfer. With regard to the procurement of equipment for the project (including that for the technology transfer), the required equipment (with specifications, brand names, quantities, etc.) and the locations at which such equipment can be procured need to be clarified at the start of the project. The equipment (specifications, brand names, quantities and composition), especially equipment such as software and 3D mouse that the operability and sustainability of techniques are different based on the past experience, must be discussed and decided upon with the C/P institution.

3.3.2 Lessons Learned from the Results of the Implementation of This Project

（１） Specifications for the Digital Topographic Maps to be Produced

The map symbol specifications for the digital topographic maps were created using the existing map symbol specifications for analog/digital maps and for the geodatabase as reference.

Since a digital topographic map is viewed as a form of geospatial data, the map symbol specifications will have to be converted to specifications for topographic maps which incorporate the concept of a topographic map database in the GIS. Needless to say, the above-mentioned argument is based on the assumption that the purposes of use of the GIS have been clearly established.

（２） Aerial photography

Taking into account increasingly abnormal weather conditions these days, the aerial photography should be completed immediately after the beginning of the project implementation in this type of project. Otherwise, any delay in the aerial photography will seriously affect the progress of the entire project. Therefore, the project must be start before the dry season, which is the best time for aerial photography and the appropriate responses must be taken for the weather condition.

（３） Procurement of Equipment for the Project

As mentioned above, the delivery of the procured equipment was slightly delayed. However, the project implementation was unaffected by the delay, because the original implementation schedule allowed some extra time to accommodate delays and because the project component implemented with the procured equipment could be implemented independently from the other components by the study team members and the trainees (recipients of the technology transfer) who were not involved in any other component of the project. From this observation, it is recommended that any project component in which procured equipment is to be used should be so designed that it can be implemented independently from the other components and by project members and C/Ps who are not involved in any other component of the project and that the implementation schedule should allow some extra time, even if only a limited time is allowed for the project implementation.

（4） Technology Transfer

It is not easy to quantify the output of technology transfer. This is because the output of technology transfer is not tangible (*i.e.* the output is the acquisition of technical capacity by the C/Ps) and it is difficult to present it in a tangible form.

The output maps of the digital plotting, the digital compilation and the map symbolization produced by the C/Ps using the transferred technologies in the parts of the technology transfer are represented, albeit indirectly, the outputs of the technology transfer. Such presentation of the output of technology transfer, even in an indirect form, is also important as an achievement of the technology transfer purposes.

Chapter4 Efforts toward the Development of Digital Topographic Maps

4.1 Effective Use of the Project Outputs

In this project, color aerial photographs of the entire Northern Region were taken (on a scale of 1:20,000) and digital topographic maps (on a scale of 1:10,000) were produced for part of the region (*ca.* 2,000 km^2). In the technology transfer, certain output has been achieved in the technology transfer mainly in digital photogrammetry.

4.1.1 Effective Use of the Digital Topographic Maps

Although digital topographic maps have only been produced for less than a quarter of the entire Northern Region, effective use of these maps is expected because they have been produced in accordance with the specifications.

（１） Publication of Digital Topographic Maps and Their Specifications

It is a matter of primary importance to make public the produced digital topographic maps and their specifications. Measures shall be taken to make relevant government offices and the general public aware of the publication of the maps and their specifications, including the conditions for their use, and to facilitate the use of the information contained in them when a decision has been made on their publication.

At the same time, interviews shall be conducted with users regarding their demands concerning the data and their demands shall be analyzed to decide whether it is possible to provide the data demanded by the users or whether it is possible to provide such data by implementation of some additional work.

（２） Awareness Creation Activities to Promote Use of the Digital Topographic Maps

Awareness creation activities customized mainly for relevant government offices, local authorities and donor organizations shall be conducted individually in order to create the opportunity for them to use the digital topographic maps first.

（３） Supply System of the Digital Topographic Maps

A system shall be developed in order to respond to actual demand for the use of the digital topographic maps expected to be created by the awareness creation activities. In practice, a decision shall be made on copyrights, supply methods (supply points, supply media, etc.), prices and etc. which are to be established.

4.1.2 Effective Use of the Outputs of the Technology Transfer

The Study Team is evaluating the output of the implemented technology transfer as described in the main report and in the following paragraph. SDSL will also have to evaluate itself as the recipient organization of the implemented technology transfer on the basis of the reports of the recipients of the technology transfer and to propose actions to be taken on the basis of the evaluation results. This evaluation shall be the first step for SDSL toward effective use of the outputs of the technology transfer.

4.2 Tasks Based on the Results of Technology Transfer

4.2.1 Summary of the Results of Technology Transfer (Proficiency)

In the project, the following technologies to be applied to making of 1:10,000 scale digital topographic maps were transferred:

Photo Control point survey: Installation of air-photo signals, GPS survey, levelling, and pricking

Field identification: Field identification (using aerial photos) and supplementary field verification

Digital photogrammetry: Digital aerial triangulation, digital plotting and compilation, digital data structurization, map symbolization

As a result, the proficiency levels and remaining tasks for various transferred technologies have been discovered through the evaluation of technology transfer. The following table shows the evaluation results:

Transferred Technology	Proficiency Level
Photo control point survey: Installation of air-photo signals	Trainees installed numerous air-photo signals and acquired sufficient proficiency from significant effects of repetitive learning.
Photo control point survey: GPS survey	Trainees acquired sufficient proficiency in GPS survey observation and analysis calculation. Trainees acquired sufficient proficiency for quantity calculation for photo control points but do not yet have sufficient experience for allocation of photo control points.
Photo control point survey: Levelling	Trainees acquired sufficient proficiency in observation and calculation of levelling as well as determination of levelling routes for aerial triangulation.
Photo control point survey: Pricking	Trainees acquired sufficient proficiency in making a description of photo control points required for and relevant to implementation of pricking.
Field identification: Field identification (using aerial photos)	Trainees did not have any experience in this field but acquired sufficient proficiency in photo interpretation. They don't acquire sufficient proficiency in field identification outdoors using aerial photos.
Field identification:	While the counterparts have not sufficiently mastered field identification using

Supplementary field verification	aerial photographs, they have satisfactorily mastered the supplementary field verification.
Digital photogrammetry: Digital aerial triangulation	Trainees acquired digital methods using the introduced equipment (hardware and software) and can produce ordinary results. However, they have not sufficiently improved proficiency through repetition.
Digital photogrammetry: Digital plotting and compilation	Trainees already had abundant experience in digital plotting and compilation and therefore achieved high proficiency in them.
Digital photogrammetry: Digital data structurization	Trainees already had abundant experience with a previous version of the introduced software. Therefore they had sufficient proficiency in simple uses of it.
Digital photogrammetry: Map symbolization	Trainees did not have any experience with the concept of map symbolization or the introduced software but acquired all the techniques for map symbolization.

4.2.2 Summary of the Results of Technology Transfer (Tasks)

From the summary of the results of the technology transfer mentioned above and also from practical operation of the transferred technologies, the tasks shown in the table below have come to light.

Transferred Technology	Remaining Task
Photo control point survey: Installation of air-photo signals	Response to changes in size of the signals in accordance with changes in photo scales and adjustment between timings of aerial photographing and installation of signals (to minimize ineffective marking operations) are the tasks to be carried out.
Photo control point survey: GPS survey	Acquisition of experience in simulation and implementation of allocation plans for photo control points for aerial triangulation according to rules and theories are the tasks to be carried out.
Photo control point survey: Levelling	No task remains in particular for the acquired technologies. However, improvement of productivity in levelling is the task to be carried out.
Photo control point survey: Pricking	Actual implementation of pricking on aerial photos not yet implemented due to a delay in aerial photographing and its post-processing is the task to be carried out.
Field identification: Field identification (using aerial photos)	No field identification using aerial photos is conducted in the current method used by SDSL. Based on this current situation, it is necessary to examine whether this survey method is effective for SDSL.
Field identification: Supplementary field verification	There is a need for a study to decide whether to continue to use the output-map-based field completion method currently in use alone in supplementary field verification or to use it in combination with an aerial-photograph-based method.
Digital photogrammetry: Digital aerial triangulation	Improvement of proficiency through repetition and consequent improvement of productivity are the tasks to be carried out.
Digital photogrammetry: Digital plotting and	Improvement of proficiency in specific usages of introduced equipment and new functions as well as improvement of productivity are the tasks to be carried

compilation	out.
Digital photogrammetry: Digital data structurization	Adequate handling of errors that occur in the automation and structurization process of digital data structurization is the task to be carried out.
Digital photogrammetry: Map symbolization	Acquisition of experience in map symbolization based on the technology transfer outputs, and improvement of proficiency through this process are the major tasks to be carried out.

4.3 Production of Digital Topographic Maps for the Remaining Unmapped Areas in the Northern Region

The project performed aerial photography in the entire area of the Northern Region. Digital/analog aerial triangulation on this entire area was also performed. Furthermore, digital topographic maps (scale level of 1:10,000) of the about 20% of the Northern Region were also developed.

On the other hand, the development of digital topographic maps of the entire area of the Northern Region is an urgent task to be carried out from the viewpoint of reconstruction and development.

4.3.1 Improvement of Technical Abilities for Producing Digital Topographic Maps

The core technologies for producing digital topographic maps are digital photogrammetry and field identification that have been covered in the technology transfer.

（1） Field Identification

Applying the field identification method currently adopted by SDSL (supplementary field verification method using output maps of compilation data) is an effective way to achieve development of digital topographic maps. Furthermore, having the staff familiarize themselves with new digital topographic map specifications will promote their proficiency and work efficiency.

（2） Plotting and Compilation

As described earlier, SDSL basically owns the technologies of digital plotting and compilation. Therefore, improvement of proficiency in new digital topographic map specifications is important in promoting development of digital topographic maps of the Northern Region. Furthermore, it is important to effectively use the outputs of digital/analog aerial triangulation, which are the outputs of the project, on the plotting equipment of SDSL. In other words, it is important to improve the proficiency of utilization and productivity of digital plotters, analog plotters with encoders, and digital compilation equipment based on the new digital topographic map specifications through implementation of actual operations.

（3） Digital Data Structurization and Map Symbolization

Trainees have acquired basic technologies for both structurization and map symbolization of data after digital compilation. Therefore, it is important to improve the proficiency in applying the technologies to actual operations (improve the speed of implementing the operations) and propagate the technologies to other staff members.

4.3.2 Formulation of a Project to Produce Digital Topographic Maps of the Remaining Unmapped Areas in the Northern Region

Digital topographic maps have not been produced for areas covering approximately 7,000 km^2 in the Northern Region. Production of topographic maps of these areas will require consideration of issues other than improvement in the technical capacity mentioned in the preceding paragraph. A map production plan shall be formulated with all these issues taken into consideration.

（1） To Establish the Priority Order for Digital Map Production within the Unmapped Areas

High priority for mapping shall be given to areas where implementation of reconstruction and formulation of a plan which would be the basis of the reconstruction are urgently required, such as areas which used to have a high population density and areas which used to be farmland, in the remaining *ca.* 7,000 km^2 of unmapped area.

（2） Human and Material Resources of SDSL which can be Mobilized for Mapping

The human resources (number of technicians and working hours at each mapping stage) and material resources (number of equipment and motor vehicles) which SDSL will be able to use for production of digital topographic maps of the remaining *ca.* 7,000 km^2 of unmapped area shall be identified.

（3） Per-Unit Production at Each Technical Stage

There is another important element, in addition to the above-mentioned human and material resources which can be mobilized, for formulation of a map production plan: per-unit production at each technical process. This is a general statistic value. SDSL will have to obtain accurate figures for the statistics for per-unit production, and to formulate a feasible map production plan using these values.

4.3.3 Project to Produce Digital Topographic Maps of the Remaining Unmapped Areas in the Northern Region

（1） Gathering of Information Required for the Map Production Project

Regarding the formulation of a project to produce digital topographic maps of the remaining areas, Information needs to be gathered on priority areas, human and material resources available for map production and per-unit production

The information items to be gathered are listed below:

It is assumed in this project that, of the required for production of digital topographic maps, the map symbol specifications, aerial photographs and results of aerial triangulation have already been established / obtained.

Area of the priority areas

Number of digital plotters (with operators), per-unit production in digital plotting

Number of digital compilation equipment (with operators), per-unit production in digital compilation

Number of supplementary field verification teams (with vehicles), per-unit production in supplementary field verification

Number of equipment for map symbolization (with operators), per-unit production in map symbolization

（２） Formulation of the Map Production Project

On the basis of the information gathered as mentioned above, a map production project shall be formulated taking into consideration the degree of overlap with each process involved in the project.

１） Numbers of Days Required to Complete Each Process

The number of days required to complete each process shall be estimated taking into consideration the sizes of the target areas and priority areas and available material and human resources.

２） The Overall Implementation Schedule (Map Production Project) with Overlapping Implementation Period for Each Process

The overall implementation schedule (map production project) shall be formulated on the basis of the number of days required to complete each process, allowing for overlapping of the implementation period for each process, by taking into consideration the actual work involved in each process.

（３） The Map Production Project for the unmapping areas in the Northern Region by SDSL

SDSL has formulated a plan for digital plotting/compilation with order of priority (attached hereto) taking into consideration the requests of the interested government offices and contact prints available to SDSL. The plan aims at production of 224 maps covering an area of approximately 7,000 m^2. Map production will begin in December 2011 and be completed by June 2014 using normal work shifts. If a two-shift system is introduced, the digital plotting/compilation will be completed by March 2013. The plan assumes completion of digital plotting/compilation of five maps (200 km^2) per month using normal work shifts. It also assumes that the field survey team can implement supplementary field verification at the rate of the area covered by two maps (80 km^2) per month.

It will obviously require a significant amount of time and budget to complete this plan regardless of which work-shift system is adopted. Therefore, securing necessary budget and human resources, in addition to mapping productivity improvements, will be vital to achieving the plan.

4.3.4 Project to Produce Digital Topographic Maps of the Remaining Unmapped Areas in the Northern Region

The map production project shall be launched once the required human and material resources have been mobilized in accordance with the map production project formulated in the preceding paragraphs.

Once the implementation of the digital topographic map production project has begun, accuracy control measures will have to be carried out at each process to maintain the product quality. At the same time, project implementation will need to be constantly monitored in order to prevent any delays. Against inevitable delay, measures such as revision of the map production project by reviewing the various implementation conditions shall be taken to minimize delays in implementation without compromising the consistency of the entire map production project.