No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MYANMAR SURVEY DEPARTMENT, MINISTRY OF FORESTRY

THE STUDY ON
THE ESTABLISHMENT OF GEOGRAPHIC DATABASE
FOR NATIONAL REHABILITATION AND DEVELOPMENT
PROGRAMME
IN THE UNION OF MYANMAR

Executive Summary

AUGUST,2004

ASIA AIR SURVEY CO., LTD.
AERO ASAHI CORPORATION

SD
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Preface

In response to a request from The Union of Myanmar, the Government of Japan decided to conduct a Study on the Establishment of Geographic Database for National Rehabilitation and Development Programme and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Junichi KOSEKI of Asia Air Survey Co., Ltd. and consists of Aero Asahi Corporation, Ltd. from January 2002 to August 2004.

The team held discussions with the officials concerned of the Government of the Union of Myanmar and conducted field surveys at 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 this project and to the enhancement of friendly relationship between our two countries.

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

August 2004

Kazuhisa Matsuoka,
Vice President
Japan International Cooperation Agency

Letter of Transmittal

August 2004

Mr. Kazuhisa MATSUOKA
Vice President
Japan International Cooperation Agency

Dear Mr. Matsuoka,

It is my great pleasure to submit herewith the Final Report for the Study on the establishment of geographic database for national rehabilitation and development programme in the Union of Myanmar.

The Study Team consists of Asia Air Survey Co., Ltd. (AAS) and Aero Asahi Corporation (AAC) conducted field survey in Myanmar during the period from January 2002 to July 2004, and office work such as digital topographic mapping during the period from July 2002 to April 2004 as per the contract with the Japan International Cooperation Agency.

During the field survey in Myanmar, discussions with the officials of Myanmar Survey Department in the Union of Myanmar (SD) were held. Based on the results of the discussions with SD, digital topographic maps, other final results and final report were prepared.

On behalf of the Study Team, I would like to express by heartfelt appreciation to SD in Myanmar and other authorities concerned for their diligent cooperation and assistance and for the heartfelt hospitality which they extended to the Study Team during our stay in Myanmar.

I am also greatly indebted to the Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Embassy of Japan in Myanmar, JICA office in Myanmar for giving us valuable suggestion and assistance during the preparation of this report.

Yours faithfully,

Junichi Koseki
Team Leader for the Study on the establishment of geographic database for national rehabilitation and development programme in the Union of Myanmar

Summary of the Study

	Item of Work		Volume of Work
1.	Aerial photography		
	Photo scale		1:50,000
	Aerial photography		44,658 km2
	Positive film making		1 set, 1244 photos
	Contact prints		1 set, 1244 photos
	2 times enlarged prints	plotted out	1 set, 1244 photos
	Scanning of aerial photos		1 set, 1244 photos
2.	Ground control point survey		
	GPS observation		Existing: 3 point, New: 47 points
	Leveling		100 km
	Pricking		48 points(GPS),22 points(BM)
3.	Aerial triangulation		
	Block adjustment		1,100 models
4.	Digital topographic mapping		
	Map scale		1:50,000
	Mapping area		33,000 km^2
	Number of sheets		48 sheets
	Contour interval	Main contour interval	10m
	Digital plotting		33,000 km2
	Field identification		33,000 km2
	Digital compilation 1		33,000 km2
	Field completion		33,000 km2
	Digital compilation 2	after field completion	33,000 km2
5.	Data creation		
	Topographic dataset		48 sheets
	Spatial data framework		1 set
	GIS database		1 set
6.	Production of CD-ROM, etc.		
	Topographic dataset		1 set
	Spatial data framework		10 sets
	GIS database		1 set
	Technical Specification		30 sets
	Survey Manual		30 sets
	GIS Guideline		50 sets
7.	Printing of maps		
	1:50,000 scale topographic map	Printed by SD	500 sets
	1:50,000 scale land use map	plotted out(11sheets)	1 set
8	Reports		
	Inception report		20 sets
	Progress report 1		20 sets
	Progress report 2		20sets
	Interim report		20 sets
	Progress report 3		20 sets
	Draft final report		20 sets
	Final report	Main,Summary, Documents	50 sets
	Final report(CD-ROM)		1 set
9	Technical Seminar		
	Seminar 1		
	Seminar 2		

Summary of the Study and Suggestions

1. Background of the Study

The Union of Myanmar, which has a population of 46.4 million and a land area of 68,000 square km, became a member of ASEAN in 1997 and is pushing ahead with an open economic policy that promotes investment by foreign capital. In addition, Myanmar has prepared a plan for national reconstruction and development, and is working towards the improvement of its old and ill-equipped social infrastructure, the development of national resources and the conservation of nature.

Though topographic maps and geographic information database are essential in pushing forward the open policy, existing topographic maps covering the whole country are one-inch-to-one-mile maps that were produced in the 1940s. The base maps of Myanmar have not been revised for more than fifty years.
Therefore it is a matter of great urgency to revise and prepare topographic maps and a geographic information database and to utilize them in applications of all kinds, if the development plans are to be realized efficiently; but the instruments and technology for topographic mapping are far behind the times because of some other reasons.

In view of this situation in November, 2000 the Myanmar government requested the preparation of topographic maps and a geographic information database, and the transfer of technology to enable them to produce topographic maps and a geographic information database , and thus this project was put into effect.

2. Execution of the Study

The Japan International Cooperation Agency (hereby-after called JICA) dispatched the Study Team to Yangon, Union of Myanmar in January 2002. The Study Team carried out surveys in Myanmar and Japan for 27 months until July 2004, with technology transfer and the building of a geographic information database. The total number of Japanese engineers involved in this project was 38 persons.

3. Procurement of equipment for the Study

In order to carry out the Study, the following equipment was procured for technology transfer. This equipment was used in the field survey and the technology transfer.

List of equipment procured

Fiscal year	Name of equipment	Set	Type of equipment
2002	GPS survey System Digital Level	3 3	Trimble TS 5700 Leica NA3003
2003	Digital plotter Digital Compilation System	3 4	Summit Evolution TNTmips

The Study Team procured 5 personal computers and GIS software for the preparation of the geographic information database. This equipment was used in the technology transfer.

4. Counterpart organization: Survey Department

The counterpart organization in this project is the Survey Department (SD), which belongs to the Ministry of Forestry. The Survey Department is composed of six divisions, namely the No.1 Survey Division and Training School, the Geodetic Survey and No.2 Survey Division, the Aerial Survey and Aerial Photography Division, the Map Reproduction Division, the International Boundary Survey and Town Planning Survey Division and the Planning & Administration Division. About 900 technicians belong to this department.

The Survey Department started a project to revise base maps, called the UTM project, in August 2000. This project is aimed at modern topographic mapping by the use of the newest horizontal datum, adoption of the metric system, the renewal of map projection methods and annotation in English.
For this purpose, the Survey Department introduced the latest digital topographic mapping equipment and has received technological assistance from a consortium of FINNMAP Corporation (Finland) and SUNTAC Corporation (Myanmar).

In August 2000, the 1st order of the geodetic network framework was completed and the horizontal data determined, and from 2001 work has been underway on digital topographic mapping. In order to undertake the digital topographic mapping, a satellite navigation system for aerial photography, a GPS survey system and digital level for ground surveying, a digital plotter system and a digital compilation system for mapping were introduced, and the Survey Department trained technicians and carried out digital mapping using this equipment. This project is still in operation.

5. Technology Transfer

The Survey Department is carrying out the UTM project as explained above. Therefore the Survey Department skills in topographic mapping of are improving day by day. It is under these circumstances that the Study was started. Because this JICA project aimed to produce topographic maps and build a geographic information database, the Study Team put particular effort into the transfer of technology in managing digital data. The technology transfer was carried out after the Study Team surveyed and analyzed the methods that the SD is at present actually using to produce topographic maps.

The Study Team surveyed details of the work of the UTM project. The digital technology used in the UTM project is for the preparation of topographic maps, not for the building of a geographic information database. Therefore, a topographic dataset was prepared first to be used both for the production of topographic maps and for the building of the GIS, and then topographic maps were prepared based on this. This is nowadays normal procedure.

The purpose of this Study was to apply digital technology and prepare digital products. Teaching and supervision of the work in the field was carried out through on-the-job training, with Study Team members and counterparts working together. During indoor work such as digital plotting, digital compilation, symbolization, supplementary compilation after field verification and preparation of the topographic dataset were carried out, the technologies for the work was transferred by working an area corresponding to 10 % of the total study area, using the procured equipment.

The results of technology transfer were confirmed every year by both the Study Team and the Survey Department and evaluated in two seminars. In these seminars, the technicians in charge of the work presented the details of their work. They compiled details of the work, prepared slides for presentation and gave their presentations in a limited period of time. From the quality of the presentations, it can be judged that the technology transfer was sufficient.

In this seminar English was used for the presentations. This was the first time that the technicians from SD had given presentations in English. It is significant that there were close discussions between the counterparts and the Japanese technicians in the preparation of materials for the presentations.

In addition two counterparts underwent training in Japan, and they underwent practical training both through the project work and also through the building of the GIS. Through this they gained an understanding of the current state of GIS application in Japan and also gained information on the Japanese survey administration.

6. Technical specifications with map symbols and application rules

The technical specifications with map symbols and application rules of this Study were prepared to standardize specifications and to ensure the necessary quality. Standards for survey elements such as horizontal datum, vertical datum, reference ellipsoid, transform parameter between WGS-84 ellipsoid and Everest 1830 ellipsoid and map projection, are defined in these technical specifications. The general flowchart of topographic mapping was also defined, together with the geographic features to be acquired, definitions, application rules and symbols.

7. Preparation of topographic dataset by photogrammetry

The topographic dataset, topographic data set is source data of Topographic maps was prepared by using photogrammetry method.

The work process followed general procedure for the preparation of topographic maps, as follows.

1) Ground Control Survey (GPS Survey)
2) Aerial photography
3) Ground Control Survey (Leveling)
4) Aerial triangulation
5) Digital plotting
6) Field verification
7) Digital Compilation / Map symbolization
8) Supplementary field verification
9) Compilation after supplementary field verification

8. Preparation of operating manual for topographic mapping

An operating manual was prepared to explain the details of topographic mapping.

The use of this operating manual will standardize mapping procedures and make uniform the quality of the prepared topographic data. This is a useful textbook for training new technicians.

In the Study digital mapping was carried out efficiently and quickly using the digital equipment.

The necessary materials, necessary instruments, detailed work procedure and final products in each work step of the topographic mapping were laid down for each step.

The Study Team prepared the drafts manuscript in the preparation of the topographic map operating manual, and revised and completed it during the technology transfer.

9. Preparation of framework dataset for GIS

GIS framework datasets were prepared which were used to build the geographic database.

As these geographic databases are in the DWG file format, which is the defacto standard, they are easily imported to any GIS software.

GIS datasets prepared by different organizations will be shared according to the same framework data. New spatial analysis will be performed using integrated GIS data.

The topographic data prepared in the Study were structuralized for use in GIS. As the topographic datasets are prepared in order to produce topographic maps, these datasets are sorted and stored per each map sheet. GIS framework data were standardized for each UTM zone.

10. Building of Geographic information database

A Geographic Information system of the delta area was built experimentally based on the GIS framework data, in order to confirm that the GIS framework data can be used to build GIS.

Geographic features were confirmed on the basis of documents and data collected in the Study, and the attribute data of these geographic features were prepared. A Geographic information database composed of shape data and attribute data was prepared.

The geographic information database will be completed by adding other new information in the future, because this geographic information database was prepared from limited information

11. Preparation of GIS Guidelines

In order to encourage the use of GIS among related organizations, it is important to share geographic data. Guidelines were prepared listing items that should be observed in the construction of a GIS to allow the sharing of framework data.

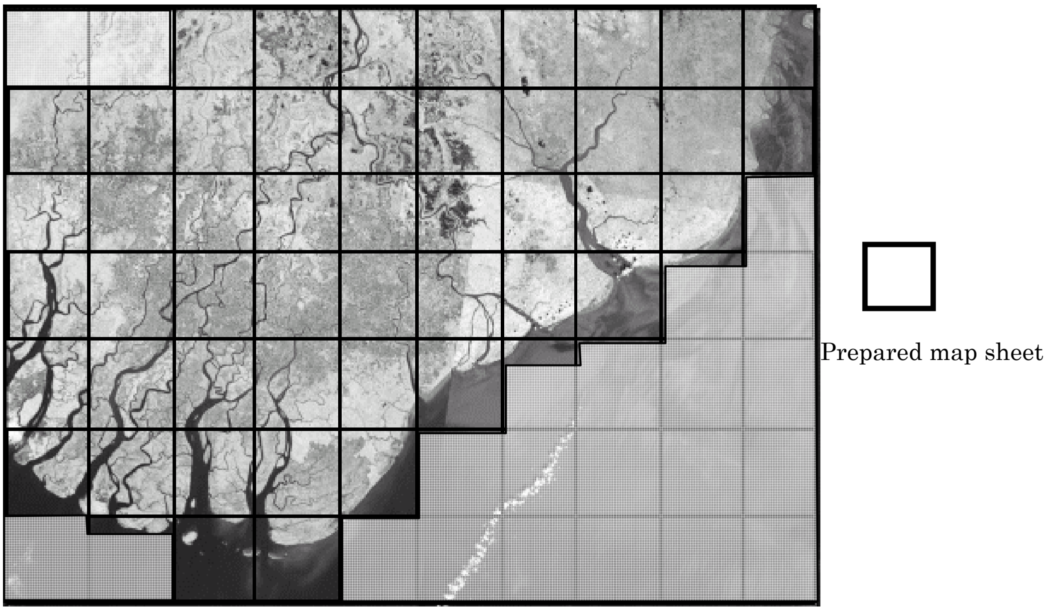
As a GIS is composed of hardware, software and the geographic database, each of these elements should be examined to enable the sharing of the geographic database. The purpose of building the GIS, criteria for the selection of hardware and software and the necessity of the geographic database ware stated in these guidelines. Of these the most expensive item is the preparation of the geographic database.

The initial cost for the production of the geographic database will be reduced by using the GIS framework data as background data, and new information can be plotted on it easily. It is easy for one organization to overlay some information, because other organizations also use the same framework data. Various organizations will be able to share the geographic database built from common framework data.

Intermediate products of the Study were listed in these guidelines. The possibility of acquiring new geographic information was also introduced.

12. Preparation of drawing data for topographic map

Drawing data for topographic map of 48 sheets were prepared by map symbolizing process. The Survey Department printed 48 topographic maps using these drawing data sets.



Study area (Background image was Orthophoto prepared in this Study)

13. Preparation of land-use maps

Land-use maps were produced as an example of thematic map-making using topographic data. The target area was selected in the Yangon metropolitan area, where much reconstruction and development is planned in the near future. 11 sheets of land-use maps on a scale of 1/50,000 covering Yangon city and surrounding areas were produced.

Land use was classified into 23 categories for the development of the Yangon metropolitan area.

Land use classification was carried out based on topographic data and with reference to collected materials, and then drafts of land-use maps were prepared. Final classification was carried out in the field survey based on the drafts. Finally the land-use maps were produced.

14. Disclosure of various geographic datasets

Various kinds of geographic information dataset were prepared in this Study. These geographic information datasets are used by many different users and are a very useful application of GIS.

Geographic information datasets prepared in the Study.

1) Topographic dataset
   Dataset to be used in the construction of GIS and preparation of topographic maps
2) Framework dataset for GIS
   Structuralized topographic dataset to be used in GIS
3) Drafting dataset for topographic map
   Raster image dataset of print map
   A printed map with the same content as the topographic map can be produced using this image dataset
4) Geographic information database
   Database prepared to add additional information based on the framework dataset
5) Aerial photo image dataset
   Image dataset of scanned aerial photos taken in the Study with 20 μ resolution
6) Ground control dataset
   Ground control-point dataset prepared and verified in the Study
7) DTM dataset
   Digital terrain model with 100m interval lattice
8) Orthophoto image dataset
   Orthophoto image dataset covering 48 sheets of 1/50,000 scale topographic map
9) Land-use dataset
   The land-use dataset covers 11 sheets of 1/50,000 scale topographic map
10) Image data of field work photos
   Photos taken of fieldwork of the Study

15. Issues in the Study

The following issues arose during the Study.

These issues should be resolved in the implementation of any further Study.

1) More time for technology transfer
   The time allowed for technology transfer was limited **to only** about one month not including the field survey. The Study Team passed on to the counterparts' basic photogrammetric and mapping technology, but it was extremely difficult for the counterparts to carry out the work for 10% of the Study area in just one month.
   Ideally, the time allowed for technology transfer in each work item should be three months.
2) Preparation of working environment
   The maintenance of infrastructure is not better now in Myanmar, with electric power posing a particular problem. The work was affected only slightly by electric power

failures because the digital plotters and digital compilation system were installed in the same building as the laboratory of the UTM project. However other work such as film making, plate making and printing were affected significantly, and sometimes interrupted. The installation of equipment such as power generators should be considered to prepare a better working environment.

3) Preparation of Gazetteer

Place names are also important elements in the preparation of topographic maps. In this Study, place names are represented in English on the map, therefore place names in the Myanmar language were translated into English.

However, the spelling of place names was different from that collected in the field by the technicians, and therefore place names were revised several times.

For further topographic mapping, place names should be collected firstly, a gazetteer prepared and the correct place names determined.

If a gazetteer is prepared, repeated revision will not be necessary and the correct annotation can be prepared quickly.

16. Suggestions for Survey Department

The Study Team suggested the following items so that the SD can develop further.

1) Construction of a national spatial data framework

National spatial data are the basic materials for understanding the current condition of the land and drawing up development programs. Spatial data are defined as social infrastructure together with roads, railways, dams etc., and should be maintained by the state.

The spatial data infrastructure is considered the foundation for the efficient use of the special data.

In this Study, a spatial data framework of the Ayeyawady delta area was prepared. If the topographic data that the SD has already produced in the UTM project are converted into GIS base data these data sets can be integrated and a national spatial data framework prepared.

Now, many countries are developing a national spatial data framework, but existing maps possessed by each country are old and revising them is a problem.

2) National Spatial Data Infrastructure (NSDI)

It is said that the NSDI is composed of the following items.

Ａ) Policy to use the national spatial data infrastructure

The Government of Myanmar is promoting the construction of a high-grade information and communication society, professing that they will build an e-Government.

Ｂ） Infrastructure for information communication

An organization to promote the use of the NSDI will be established and then a clearinghouse will be set up for the purpose of information retrieval and use.

Ｃ） Standards for distribution of information

Preparation of spatial data based on international standards.

The International Organization for Standards （ISO）is now drawing up standards for geographic information in the technical committee TC211.

Ｄ） Partnerships between industry, universities and government for the efficient operation of the NSDI

A steering committee should be organized to promote the efficient operation of the NSDI.

Ｅ） Spatial data used as a framework and shared by many users

A spatial data framework covering the whole country should be prepared.

3) Construction of a Geographic Information Center

The SD is the only organization in charge of map-making in Myanmar. The SD should collect various kinds of information concerning maps and build a clearinghouse in order to distribute this information to other ministries or government offices. The SD therefore should construct a Geographic Information Center.

The SD should join international scientific societies such as the TC211 in ISO or the United Nations Regional Cartographic Conference for Asia and the Pacific and become an organization that brings together information relating to the world map.

In this way, the SD should create a place where technicians and personnel interested in GIS can exchange information with each other.

4) Disclosure of activities

The production of topographic maps requires high-grade technology and is very difficult work. However, topographic maps are essential for understanding the national land. Therefore the SD makes its daily activities known to the nation. The SD should prepare a homepage on the Internet and give out information regarding the topographic maps and aerial photographs possessed by the SD, and thus put the different resources possessed by the SD to good use.

The SD owns a lot of instruments for the preparation of topographic maps but some of them are out of order. These instruments are very useful in understanding the principals of surveying and photogrammetry. Therefore these instruments should also be put on display to the public. It may be an idea to put on display panels explaining topographic mapping in a museum of mapping.

5) Map-reading and dissemination

A map carries a lot of information on it, but it is very difficult to read the information, and training is necessary.

Therefore education from an early age is necessary, and the Survey Department should prepare atlases and supplementary readers for social studies classes in elementary and secondary school.

Abbreviation

Abbreviation	Contents
SD	Survey Department
JICA	Japan International Cooperation Agency
TIN	Triangulated Irregular Network
NSDI	National Spatial Data Infrastructure
ISO	International Organization for Standardization
GPS	Global Positioning System
UTM	Universal Transverse Mercator
GIS	Geographic Information System
UPS	Uninterruptible Power Supply
DEM	Digital Elevation Model
TC２１１	Technical Committee 211
ASEAN	Association of South East Asian Nations
DWG	Drawing file of Auto-Cad inner format
CD-ROM	Compact Disk Read Only Memory

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1. Outline of the Study

1.1 Objectives of the Study

The objectives of the Study are:

1) To prepare 1:50,000 scale digital-based topographic maps and spatial data framework for GIS covering the Study area, both of which are necessary for the national rehabilitation and development program.

2) To prepare GIS guidelines to enable the use and sharing of the spatial data framework by a wide variety of users, and

3) To transfer related technology to Myanmar counterpart personnel through the Study.

In accordance with the above objectives, the targets to achieve in this Study are:

1) To execute the national development plan efficiently using the topographic maps and other products of the Study,

2) To use the digital topographic maps in building GIS in other organizations and

3) To enhance the abilities of the SD to enable the unaided implementation of the UTM project.

1.2 Study Area and location

The location and scope of the Study Area are shown in Figure1.1.1, and includes Yangon Division, Ayeyawady Division and a part of Bago Division in the southern part of Myanmar.

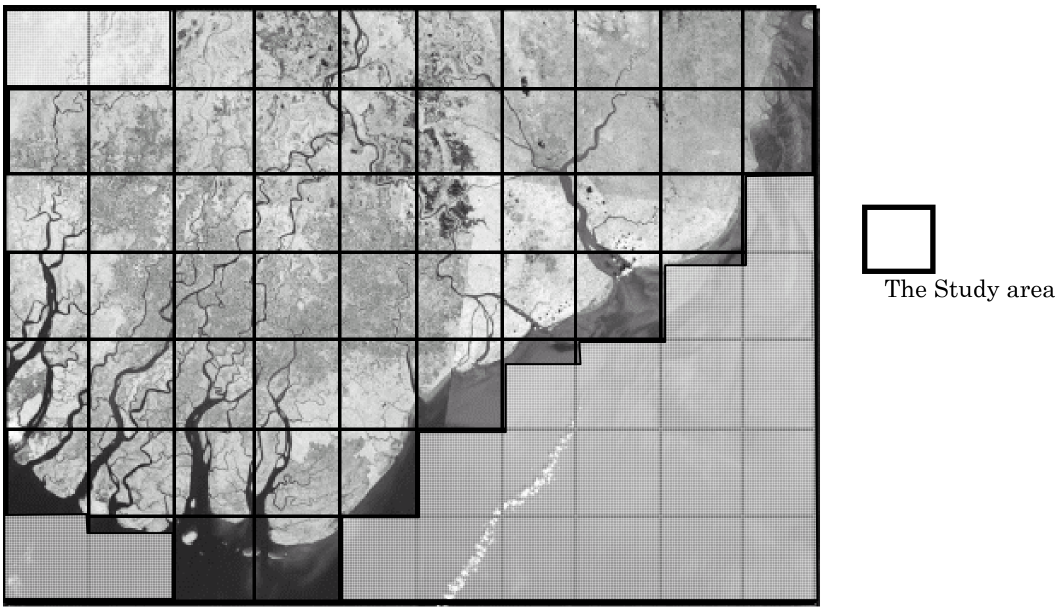


Figure 1.1.1 Study area (Background image is orthophoto prepared by the Study)

1.3 Flowchart of the Study

Flowchart is as follows:

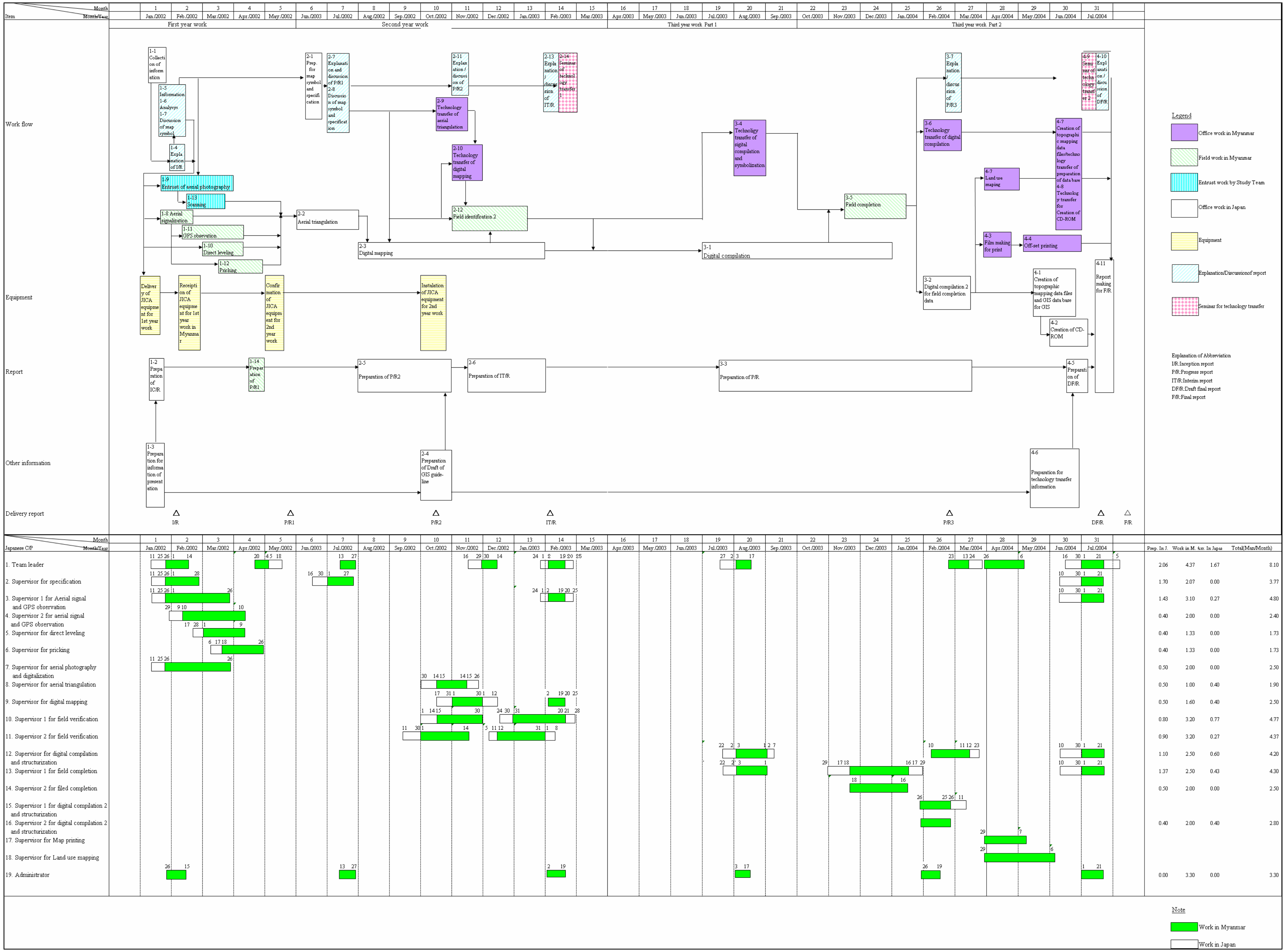


Fig. 1-3-1 Flowchart of the study

1.4 Formation of the Study Team

The Study Team was organized and carried out fieldwork under the leadership of Junichi KOSEKI.

Table 1.1.1 Assignments for the Study

Year	Assignment	Name	Period	Days
The first year	Leader	Junichi KOSEKI	26. 1.2002～14 .2.2002	20 days
			20. 4.2002～ 4. 5.2002	14 days
	Specifications	Toru WATANABE	26.1.2002～28.2.2002	34 days
	GPS survey	Shinichi KONO	26. 1.2002～26. 3.2002	60 days
		Hiromasa TAKAHASHI	10. 2.2002～10. 4.2002	60 days
	Leveling	Koichi KAMIMURA	1. 3.2002～10. 4.2002	40 days
	Pricking	Hiromi OGAWA	18. 3.2002～26. 4.2002	40 days
	Aerial photography	Hideto HOSODA	26. 1.2002～26. 3.2002	60 days
	Coordinator	Ichiro NONAKA	26. 1.2002～15. 2.2002	15 days
The second year	Leader	Junichi KOSEKI	7.13.2002～27. 7.2002	15 days
			30.11.2002～14.12.2002	15 days
			2. 2.2003～19. 2.2003	18 days
	Aerial triangulation	Kiyofumi TAMARI	15.10.2002～13.11.2002	30 days
	Digital plotting	Tsuneo TERADA	1.11.2002～30.11.2002	30 days
	Field identification	Nobuo SHIMIZU	1.11.2002～15.12.2002	45 days
		Yoshitaka GOMI	1.10.2002～14.11.2002	45 days
	Seminar 1	Shinichi KONO	2. 2.2003～19. 2.2003	18 days
		Tsuneo TERADA	2. 2.2003～19. 2.2003	18 days
		Nobuo SHIMIZU	2. 2.2003～19. 2.2003	18 days
	Coordinator	Michi HAYASHI	13. 7.2002～27. 7.2002	15 days

Year	Assignment	Name	Period	Days
The third year Part 1	Leader	Junichi KOSEKI	3. 8.2003～17. 8.2003	15 days
	Digital compilation/ Map symbolization	Minori ONAKA	3. 8.2003～ 1. 9.2003	30 days
		Yoshiteru MATSUSHITA	3. 8.2003～ 1. 9.2003	30 days
	Coordinator	Michi HAYASHI	3. 8.2003～17. 8.2003	15 days
The third year Part 2	Leader	Junichi KOSEKI	24.11.2003～1.12.2003	8 days
			26.1.2004～19. 2.2004	25 days
			1. 7.2004～21. 7.2004	21 days
	Field completion	Yoshitaka GOMI	18.11.2003～16. 1.2004	60 days
		Kentaro USUDA	18.11.2003～16. 1.2004	60 days
	Digital compilation 2/ structurization	Minori ONAKA Yoshiteru MATSUSHITA	26. 1.2004～25. 2.2004 26. 1.2004～25. 2.2004	30 days 30 days
	Printing	Junichi KOSEKI	3.29.2004～ 7. 5.2004	40 days
	Land use mapping	Yoshiteru MATSUSHITA	29. 3.2004～ 6. 6.2004	70 days
	Seminar 2	Shinichi KONO	1. 7.2004～21. 7.2004	21 days
		Nobuo SHIMIZU	1. 7.2004～21. 7.2004	21 days
		Yoshitaka GOMI	1. 7.2004～21. 7.2004	21 days
	Coordinator	Ichiro NONAKA	29. 1.2004～19. 2.2004	25 days
			1. 7.2004～21. 7.2004	21 days

1.5 Overview of the Study

The Study was carried out over a period of three years. Work items to be executed in each year are shown below.

(1) The first year Study

The following works were executed in the first year from January 11 to June 17, 2002.

1） Preparation and discussion of Inception report

2） Preparation and discussion of technical specifications

3) Execution of targeting (Cooperative work, technical guidance)

4） Execution of aerial photography (Re-contract in Myanmar)

5） Execution of GPS survey (Cooperative work, technical guidance)

6） Execution of 4th order leveling (Cooperative work, technical guidance)

7） Execution of pricking (Cooperative work, technical guidance)

8） Preparation of Progress Report 1

（2） The second year Study

The following works were executed in the second year from June 26, 2002 to March 13, 2003.

1） Preparation and discussion of Progress Report

2） Preparation and discussion of map symbols and rules of application

3） Execution of aerial triangulation (Work in Japan and technical guidance)

4） Execution of digital plotting (Work in Japan and technical guidance)

5） Preparation and discussion of GIS guidelines

6） Execution of field verification (Cooperative work, technical guidance)

7） Preparation and discussion of Progress Report 2

8） Preparation of Interim Report

9） Seminar for technology transfer

（3） The third year Part1 Study

The following works were executed in the third year Part 1 from May 30 to September 19, 2003.

1） Preparation and discussion of Interim Report

2） Execution of digital compilation (Work in Japan and technical guidance)

3） Execution of field completion (Cooperative work, technical guidance)

4) Execution of digital compilation of result of field completion (Work in Japan and technical guidance)

5） Preparation and discussion of Progress Report 3

（4） The third year Part 2 Study

The following works were executed in the third year Part 2 from October 10, 2003 until August 30, 2004.

1） Preparation of topographic data files (Work in Japan and technical guidance)

2） Map printing(Work in Myanmar and technical guidance)

3） Land use mapping (Work in Japan, Field work and technical guidance)

4） Preparation of CD-ROM (Work in Japan and technical guidance)

5） Preparation of Draft Final Report

1.6 Scope of the Study

（1） Scope of aerial photography

The area of aerial photography was determined as the area between 15° 45´ N and 17° 15´ N latitude, and between 94° 30´ E and 97° 00´ E longitude. The area covers approximately 33,000km^2.

However, it was not possible to take photographs of the ground over Yangon owing to the flight prohibition.

The Study area corresponded to 47 existing sheets of 1/50,000 scale map.

（2） Area of topographic mapping

The mapping area of the Study was decided formally after division of the land area and sea area using aerial triangulation and orthophoto. This area covered 52 sheets of topographic map at a scale of 1/50,000 in the index map defined by SD. However, 4 sheets of them contained only a small land area, and these sheets were included in the above-mentioned map sheets so that eventually 48 sheets of topographic map were produced in the Study.

（3） Preparation of materials for another project

Some of the final products were reproduced for another project for the Ministry of Forestry was and were used by JICA in the mangrove project

These products were delivered to the JICA Office in Myanmar on April 3, 2003.

1) Contact prints	1 set
2) Double-size enlarged photos	2 sets
3) Positive film	1 set
4) Aerial photo digital data	1 set
5) Index map for aerial photos	1 set

1.7 Points to be kept in mind during the Study

(1) Technical guidance carried out on the basis of results of survey and analysis of the technology of Survey Department ("SD").

At the present time SD is implementing the UTM project, and has the technology to produce topographic maps. When each work process is implemented, the Study Team should first survey the content of the technology in the possession of the SD, and prepare a program to produce efficient, quality results with an understanding of the technical skills available.

（2） Application of digital technology

At one time the production of topographic maps demanded skill and experience, involving the precise operation of advanced instruments. However nowadays it is easy to train engineers with precision using computer-assisted instruments. Therefore digital instruments such as GPS, digital level, Handy GPS, digital plotter and a digital compilation system were introduced, and digital technology such as digital cameras and scanners were used to get high quality results.

（3） Preparation of operating manual

An operating manual was ultimately prepared by recording and compiling details of the work carried out in the cooperative work and technical guidance.

This operation manual will be useful when the work is repeated and in the instruction of younger technicians.

(4) Work processes emphasized quality

Topographic mapping involves a lot of work processes. In order to implement each item efficiently, quality control should be properly implemented in each work process, in order to avoid retrogression in the work.

1.8 Report Organization

The final reports in English consist of 2 volumes and an executive summary as follows:

1. Executive Summary
2. Volume 1: Main Report
3. Volume 2: Documents
    1) Technical Specifications for Digital Topographic Mapping
    2) The Survey Manual For Topographic Mapping
    3) GIS Guideline

2. Discussion of technical specifications for digital mapping

The study team discussed technical specifications for topographic mapping.

Firstly the draft prepared by the study team was revised through the work. Finally technical specifications, map symbols and rules for application were revised several times and arranged in numbered versions.

2.1 Confirmation of geodetic elements

The study team confirmed geodetic elements to define geographic locations correctly.

A mapping project called the UTM project, with duration of 6 years and covering the whole country, started in FY 2001. The first order geodetic network, called Myanmar Datum 2000, has already been completed and coordinated with the world geodetic system in the UTM project.

Therefore, this study adopted the same geodetic elements and will be consistent with the UTM project.

2.1.2 Geodetic elements and data

The following data were adopted in the Study.

(1) Reference ellipsoid

The Everest 1830 ellipsoid was adopted as is usual.

Semi-major axis: a=6,377,276.345m

Flattening: f=1/300.8017

(2) Horizontal position

Coordinates of the first order control point (Yangon) were adopted as the horizontal position.

Name of control point：Yangon（Kaynathpo）

Latitude: N 16° 58´ 20.62762˝

Longitude: E 96° 07´ 36.99653˝

(3) Transformation parameters from WGS-84 ellipsoid to Everest ellipsoid

The transformation parameters used were those adopted for Myanmar Datum 2000.

The values of the parameters are as follows.

⊿X=-246.632m

⊿Y=-784.833m

⊿Z =-276.923m

These values were decided assuming a Geoid height of 0 meters at the Yangon control point.

(4) Altitude

The mean sea level of the Andaman Sea as observed by the tide observatory in Kyaikkami was adopted as the standard altitude. Therefore, elevation is determined on the basis of existing benchmarks.

(5) Map projection

The UTM map projection was adopted instead of the Lambert projection. Both zone 46 and zone 47 are included in the Study. The central meridians are 93 E and 99 E respectively.

(6) Size of map sheet

The size of map sheet was set at 15 minutes x 15 minutes.

（One degree of latitude and longitude is divided into units of 15 minutes each, the points being joined to create four corners. One sheet is defined as the area enclosed by these 4 corners. ）

2.2 Verification of geographic features obtained

The technical specifications were prepared with map symbols and application rules of the geographic features obtained, after both sides had discussed the geographic features obtained. Map symbols and application rules were analyzed with reference to existing maps.

2.2.1 Preparation of technical specifications

Three kinds of existing maps were collected. All maps were produced based on specifications adopted when the Survey Department of India produced 1-inch-to–1-mile maps. The same specifications were adopted in the UTM project. The study team should align fully with the UTM project, and therefore map symbols and application rules were examined carefully. Although new maps produced in the UTM project covered the inland area, this study area covers the coastal delta area. Therefore water geographic features related to sea areas were added.

1) Topographic map at a scale of 1:63,360 produced by the Survey Department of India in the 1940s.
2) Topographic map at a scale of 1:50,000 produced by the Myanmar Survey Department in the 1970s.
3) Topographic map at a scale of 1/50,000 produced by the UTM project

2.2.2 Revision of technical specifications

The details of the technical specifications were discussed during the work in the study several times. The technical specifications contain descriptions of map symbols and application rules.

1) Map symbols and application rules

Geographic features were obtained according to the technical specifications. The technical specifications were reviewed because various questions arose during the study. The SD questioned the description of features when translated from English into Myanmar. The study team indicated problems arising in the digital plotting and digital compilation procedures in Japan. Both sides discussed these questions and resolved them.

Version 1: Draft initially prepared by study team (1/7/2002)
Version 2: Draft compiled after discussions between study team and SD（4/12/2002）
Version 3: Revised draft (14/02/2003)
Version 4: Addition of annotation data (14/02/2003)
Version 5: Final version (14/02/2003)

2.3 Definition of marginal information edition

This was prepared based on the marginal information edition used in the UTM project, with some modifications.

The following items were added to the maps. Details of the marginal information are given in the operating manual.

1) Text stating that this is a joint project of JICA and the SD.
2) Logo mark of JICA
3) Variation of magnetic north

"This map was produced jointly by Japan International Cooperation Agency (JICA) and Survey Department, Ministry of Forestry in the Union of Myanmar, under the Japanese Government Technical Cooperation Program."

3. Present condition of the counterpart agency

The Survey Department (SD) is an organization in charge of map-making which belongs to the Ministry of Forestry. It was separated from the Survey Department of India, and has long been producing topographic maps. As is clear from the production of forestry maps in 1925, the use of photogrammetry in the production of maps goes back a long way.

(Note) 「AERO-PHOTO SURVEY AND MAPPING OF THE FORESTS OF THE IRRAWADDY DELTA」, BURMA FOREST BULLETIN NO.11, 1925.

3.1 Organizational chart

The SD is composed of six Divisions under the Director General, as shown in Figure 3.1.1.

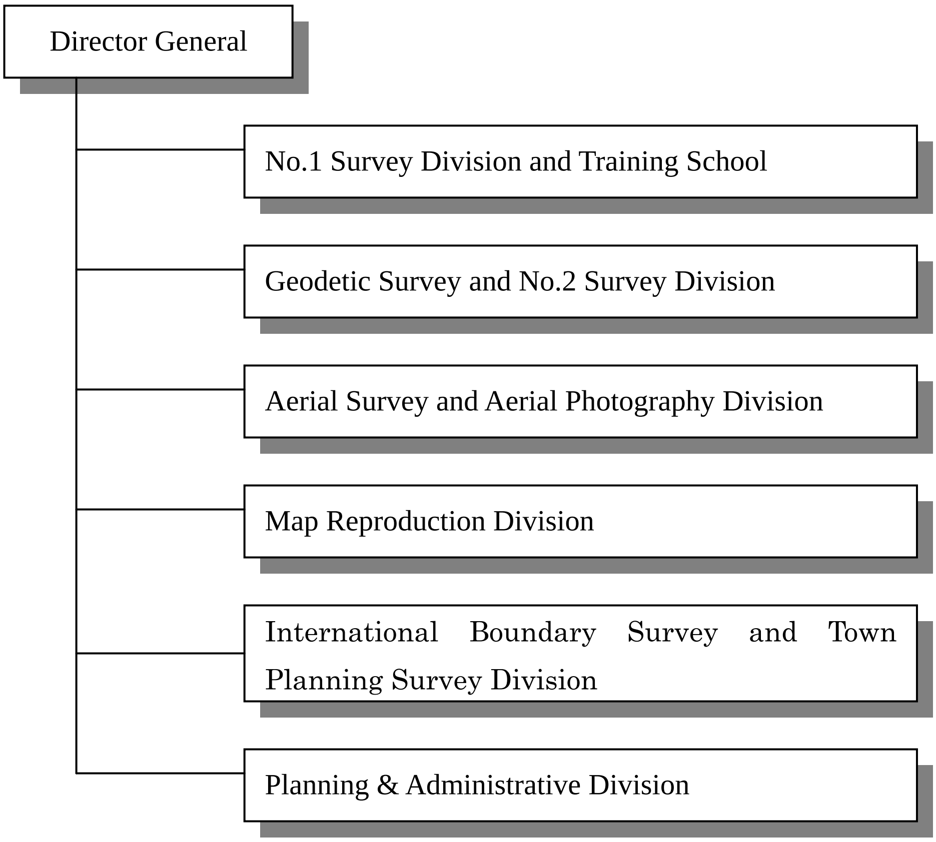


Figure 3.1.1 Organizational chart of the SD

(Source: Survey Department)

The Divisions undertake the following services.

1) No.1 Survey Division and Training School

   Execution of all kinds of survey in the northern part of Myanmar (second- and third-order geodetic survey, second- and third-order leveling and topographic mapping)

   Training for Survey Department staff

2) Geodetic Survey and No.2 Survey Division

   Execution of first-order control survey and first-order leveling.

   Execution of all kinds of survey in the southern part of Myanmar (second- and third-order geodetic survey, second- and third-order leveling and topographic mapping)

3) Aerial Survey and Aerial Photography Division

   Aerial photography and photogrammetry

4) Map Reproduction Division

   Map compilation and map printing

5) International Boundary Survey and Town Planning Survey Division

   Execution of boundary surveys, surveying for official projects and contracting of private sector

6) Planning & Administrative Division

   Administrative section

3.2 Equipment possessed by the SD

The equipment possessed by the SD is shown in Table 3.2.1. While most of the equipment is old, it is clear that there is a sufficient quantity of equipment and that the production capacity is high. From their possession of an operational analog plotter (A8) with encoder, it is clear that they are moving from analog to digital technology. There is no analytical plotter. Modern instruments have been introduced in order to implement the UTM project that is presently under way. The equipment introduced for the UTM project is shown in Table 3.4.2.

Table 3.2.1 Equipment owned by the SD

Instrument	Type of instrument	Set	Remarks
Geodesy/ Surveying	Level N3	11	2 sets are usable
	Level N2	5	
	TheodliteT3	4	
	TheodliteT2	18	
	Total Station	5	Leica:3,Topcon:2
	GPS	5	ASHTEC
	Electro-tachometer	1	
Photo-processing	Airplane for photography	1	Cessna, Citation II, MAF4400
		1	RC-10 (out of order)
	Aerial camera	6	For mono-color, HOPE134
	Developing instrument	1	SPEK3030
	Contact printer	1	For paper, Quimipol
	Developing instrument		
Photogrammetry	Universal plotter	1	A7 (out of order)
	Precise plotter	5	A8,B8
	Orthometric projector	1	PPO8
	Rectifier	1	SEG-VI
Map printing	Printer for PS plate	1	Yoshitani (Japan)
	Offset printer	3	Heidelberg,2-color type
	Process camera	2	1:manual, 1:Automatic(C520F)

Source: Study Team

3.3 Topographic maps held by the SD

SD owns base maps such as 1-inch-to–1-mile, 1-inch-to-2-miles and 1-inch-to-4-miles that were handed on from the Survey Department of India. In addition the SD also produces many other map-related materials, such as general maps of the whole country, calendars, etc. The maps owned by the SD are shown in Table 3.3.1.

Table 3.3.1 Maps owned by SD, with coverage ratios

Name of map	Scale	Contour	No of Sheets	Coverage ratio
1-inch-to-1-mile map	1/63,360	50feet	888	88%
1-inch-to-2-mile map	1/126,720	100feet	296	98%
1-inch-to-4-mile map	1/253,440	250feet	92	100%
State and Division map	1/8,000,000		14	100%

Some maps are on sale at the SD store. The prices are shown in Table 3.3.2.

Table 3.3.2 Maps sold by SD, with prices

No.	Type of map	Price (Kyat)
1	Map of Myanmar (1 inch to 32 miles) in English	375
2	Map of Myanmar (1 inch to 32 miles) in Myanmar	375
3	Map of Myanmar (1 inch to 45 miles) in English	250
4	Map of Myanmar (1 inch to 45 miles) in Myanmar	250
5	Map of Myanmar (1 inch to 20 miles) in English	875
6	Map of Myanmar (1 inch to 20 miles) in Myanmar	875
7	Map of Yangon (3 inches to 1 mile) in Myanmar	1,000
8	World map (1: 30 million) in English(2 sheets combined)	1,000
9	Calendar for 2004	1,500
10	Topographic Map (1 inch to 1 mile, 1 inch to 2 miles and 1 inch to 4 miles) [Note 1]	850

1Kyat=0.135 yen

[Note 1](By permission of Authorities concerned)

3.4 UTM project

The SD initiated this project to prepare topographic maps of the whole country. The Study Team carried out an investigation of the UTM Project...

1) Overview of UTM Project

The topographic maps produced by the Survey Department of India are already obsolete since 50 years have passed since they were produced; there have been many changes and the maps are no longer accurate. Therefore, the Myanmar government decided to make new base maps; this is the UTM project. Global standards were adopted to make the new maps, with updated horizontal data, the adoption of the metric system, and the updating of the projection system to UTM projection instead of Lambert, and the use of English annotation. The work was carried out with the technical cooperation of a consortium of FINNMAP Corporation (Finland) and SUNTAC Corporation (Myanmar). In order to increase the efficiency of technology acquisition, the project was planned to cover 6 years, and was carried out under the budget of the Myanmar government.

2) Progress of UTM project to date and in the future

At the present time, 16 sheets of topographic maps produced in the pilot project and 160 sheets produced in the first stage have been completed, and this project is still in progress.

Table 3.4.1 Number of map sheets produced in each stage

Stage	Year	Prepared maps (sheets)
Pilot stage	2001	16 sheets
The first stage	2002	160 sheets
The second stage	2003	201 sheets
The third stage	2004	245 sheets
The forth stage	2005	245 sheets
The fifth stage	2006	245 sheets

3) Equipment procured in UTM project

The following new equipment was introduced by the SD in order to carry out the UTM project.

Table 3.4.2 Equipment procured in UTM project

Instrument	Type of instrument	Set	Remarks
Geodesy	GPS survey system Digital Level	5 2	Ashtech Leica NA2002
Aerial Photography	Computer controlled navigation system	1	CCNS 4
Photogrammetry	Aerial triangulation software Digital plotter Digital compilation	1 10 6	MATCH-AT DVP(8 sets), Summit Evolution (2 sets) TNTmips
Printing	Image setter	1	

4）Map symbols and marginal information

The map symbols and marginal information are based on the specifications produced by the Survey Department of India, adapted to digital technology. One map sheet produced in the pilot stage of the UTM project was supplied by the SD as a sample.

5) Work flow of topographic mapping in UTM project

The work processes adopted in the UTM project are almost identical to those used in Japan.

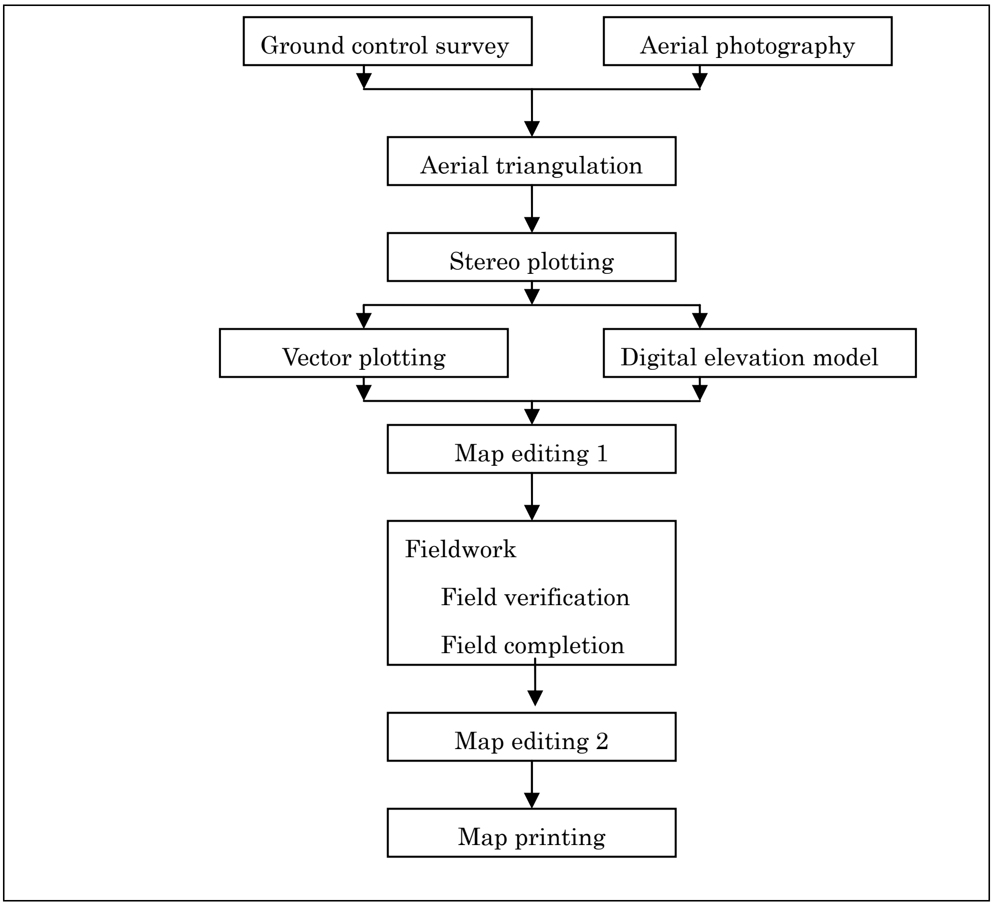


Figure 3.4.1 Work process in UTM project

3.5 Counterpart organization in the Study and their technology

Mr. U Kan Sint, the director of the photogrammetry division, was assigned as the chief counterpart for the JICA mapping project. The SD also created a system by which counterparts were assigned from the relevant division when a work process was started.

In the first stage, the SD took partial charge of fieldwork such as the ground control survey, field verification and supplementary field survey, and inspection. Initially a private company consortium took charge of other work processes such as digital plotting and digital compilation, but at the present time the SD implements almost all work processes.

The technical specifications and operating manuals produced in the Study are used in the project.

4. Procurement of equipment

4.1 Procurement of instruments and documents

In order to implement technology transfer in the Study, equipment needed for the technology transfer and implementation of cooperative work was introduced by JICA (see Figure 4.4.1). Equipment related to geodetic work, photogrammetric work and GIS was procured. In addition, books and documents related to the above-mentioned disciplines were also bought.

4.2 Instruments related to geodetic work

GPS survey instruments and digital levels were introduced in the first year for the ground control survey.

Table 4.2.1 Instruments introduced in the first year

Name of instrument	Sets	Remarks
GPS survey system	3	Trimble TS5700
Personal computer	1	Note Type for GPS
Digital level	3	Leica NA3003
Plane table	2	Tamura Type
Pocket compass	6	Ushikata S27
Handy GPS	6	Garmin 38E

4.3 Instruments related to photogrammetry

Instruments used in digital plotting and compilation were introduced in the second year.

Table 4.3.1 Instruments introduced in the second year

Name of instrument	Sets	Remarks
Digital plotter system	3	Summit Evolution
Aerial triangulation program	1	PAT-M
Digital compilation system	4	TNTmips
Color plotter	1	A0 Type
Printer	1	A3 Type
Uninterruptible Power Supply	1	

4.4 Other instruments related to education

(1) Personal computer 5 sets

Five personal computers were introduced as supplementary tools for the technology transfer, and were used in the preparation of statistical data and material such as slides for seminars.

(2) GIS software 1 set

GIS software was introduced for data exchange and to study the possibility of using various types of GIS, for the purpose of disseminating the spatial data framework prepared in the Study.

Two types of software, Arc/View and GeoMedia, were selected as candidates. Arc/View was selected because of its cheaper price.

Arc/View is one of the most popular GIS software applications. Many GIS reference books on the market explain GIS based on Arc/View software. Furthermore, many GIS software applications support the Shape file format, which is the Arc/View record format, for data exchange. An understanding of Arc/View is extremely useful when considering methods of exchanging the data prepared.

4.5 Purchase of reference books

The disciplines covered by technical transfer in the Study are Geodesy, Photogrammetry, Surveying and GIS. The technical transfer should not merely provide training in the operation of the instruments; a deep understanding of the theoretical background must also be passed on. Therefore a large number of reference books were purchased as supplementary teaching materials.

1) Purchased reference books

About 30 books purchased in the Study are shown in Attached Data 1.

2) Collected materials

Magnetic chart (MAGNETIC VARIATION 2000 AND ANNUAL RATES OF CHANGE Reduced to the Epoch 2000.0 No.5374 British Geological Survey).

Documents about the state of topographic mapping in Asian countries were collected at the United Nations conference on Asia and the Pacific, July 2003.

3) Collected maps

Topographic maps to a scale of 1/50,000 (Kumamoto, Yatsushiro, the northeastern part of Iriomote Island and the west part of Iriomote Island in Japan)

-Topographic maps to a scale of 1/10,000 (Okinawa in Japan)

-Land use maps to a scale of 1/25,000 (Ageo, Totsuka in Japan)

4) Collected educational CDs

CD-ROMs for educational purposes regarding GPS, Photogrammetry, Remote sensing and GIS were collected. (Attached Data 2)

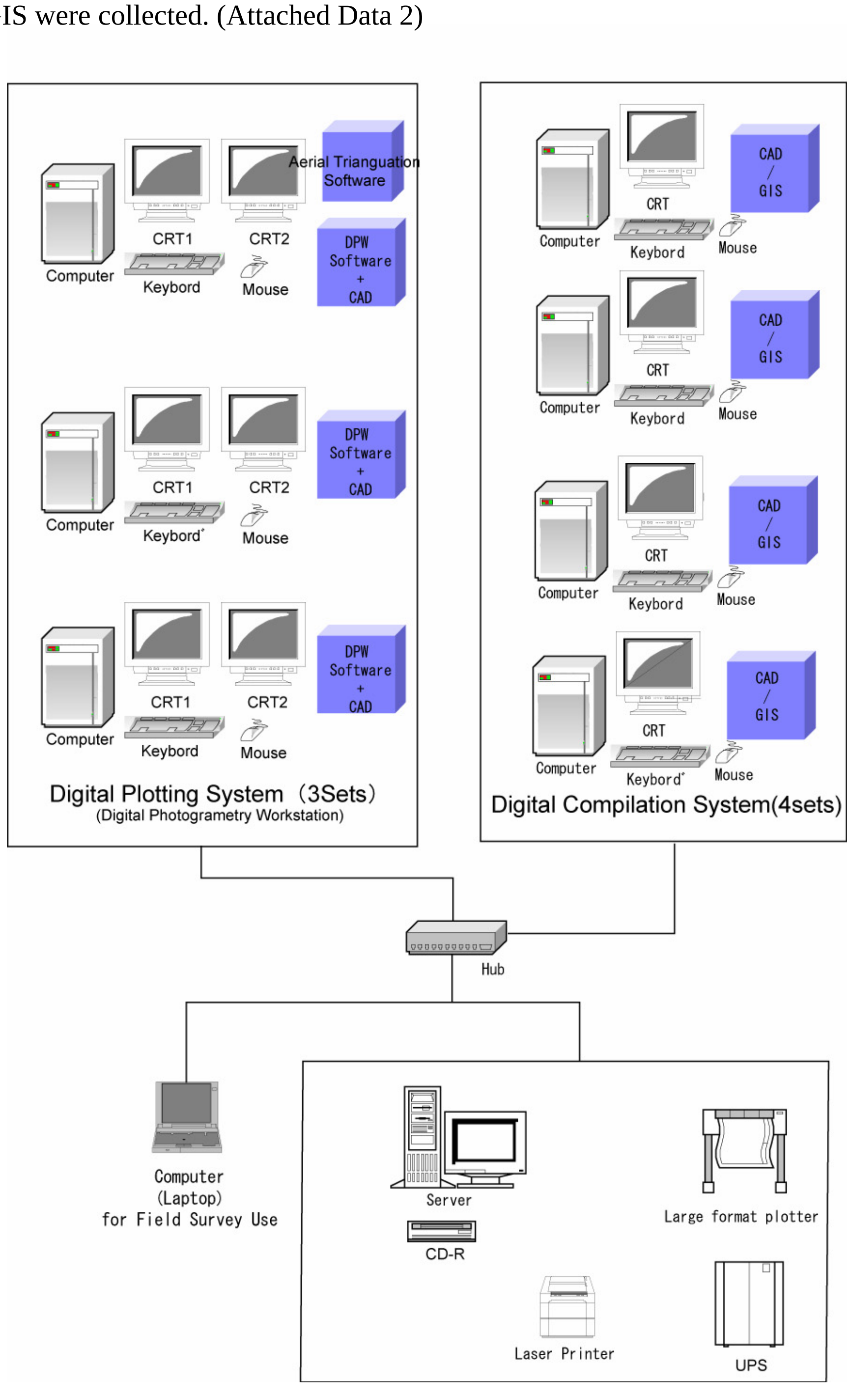


Figure 4.4.1 Architecture of topographic mapping introduced in the Study

5. Aerial photography

Aerial photographs were taken to cover the Study area south of latitude 17 degrees 15 minutes N and west of longitude 97 degrees E. This work was carried out as a commissioned work in Myanmar.

5.1 Specifications for aerial photography

The following specifications were adopted for aerial photography.

1) Photo scale: 1/50,000
2) Area of photography: 33,000km2
3) Number of photos: Approximately 1,244 photos
4) Overlap : 60％
5) Side lap: 30%
6) Type of film: Black and white (Panchromatic)
7) Record of 3 dimensional exposure positions by DGPS

5.2 Work plan

5.2.1 Procedure to start aerial photography

Permission to take aerial photographs in Myanmar was necessary, and application for permission was made.

The Study Team submitted the application for permission to take aerial photographs on 30th January 2002.

It took a long time until permission was issued because Yangon was included in the area to be photographed. Unfortunately, the Study Team could not get flight permission for the central part of Yangon. Eventually permission to take aerial photographs excluding the central part of Yangon was obtained on 28 February 2004.

5.2.2 Selection of contractor for aerial photography

Aerial photography was commissioned to a contractor in Myanmar. The specifications were confirmed between the SD and the Study Team. The drafts of Tender Documents and Technical Specifications prepared in Japan were submitted and approved by JICA. These were distributed among the local contractors tendering for the aerial photography.

1) Tendering and selection of contractor

The explanatory meeting for the contract for aerial photography was held based on approved tender documents. Three companies, SUNTAC Technologies, FINNMAP International and Thai Flying Service, participated in the tender. SUNTAC Technologies was considered superior in terms of technology and experience, and the Study Team selected SUNTAC Technologies as the contractor.

2) Conclusion of aerial photography contract

After approval had been obtained in accordance with the accepted procedure for contracting with a local contractor, the contract with SUNTAC Technologies was concluded.

5.3 Execution of aerial photography

Aerial photography covering the Study area and adjacent areas was carried out during 11days from 1st March to 11th March 2002. Additional cross courses were executed for airborne GPS support aerial triangulation.

The following instruments and equipment were used for the aerial photography.

Aircraft: Cessna, Citation II, MAF4400

Computer Controlled Navigation System: CCNS4

Aerial Camera : Leica　RC-30　No.5126（Focal Length: 153.19mm）

Aerial film : Agfa　Aviopan 80

With regard to the flight prohibition over Yangon, two cross flights north to south were added to reduce the lack of image as far as possible, but a narrow strip of land (approximately 3 x 10km of the central part of Yangon city) was missing. The SD accepted the lack.

Photo scale: 1:50,000

Flight course: 36 courses

Total distance of photography: 5548km

Area photographed : 44,658km2（total distance x effective width）

Number of photographs：1244photos

Actual time spent on photography：29 hours

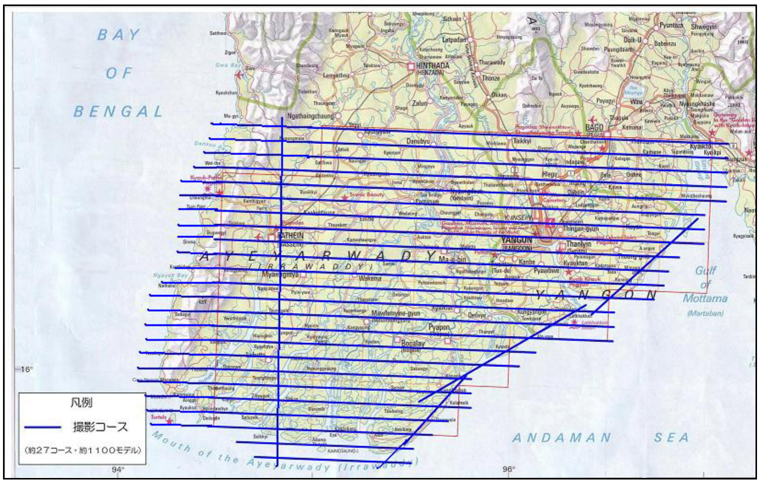


Figure 5.3.1 Area in which aerial photography was carried out

Contact prints were printed using negative film. The aerial photographs delivered by the contractor were inspected for quality and to check that they covered the whole Study area, based on the contact prints. The negative films were annotated and numbered for administrative purposes.

All the photographs were accepted by the Study Team after confirmation of their quality and coverage of the Study area.

5.4 Quality control

The quality of the photographs was inspected with regard to such elements as flight height, flight course, overlap between adjacent photos and between adjacent courses, clearness of fiducial marks, results of photo processing and condition of image.

5.5 Preparation of double-size enlarged prints

The double-size enlarged prints are necessary for identification in the field. However, there was no rectifier such as the SEG-VI for double-size enlargement in the Survey Department.

The SEG-VI owned by the SD was in a state of disrepair, with no expectation of it being repaired.

The double-size enlarged prints were prepared by computer processing using scanned digital image data from the negative film.

5.6 Exposure position recording by GPS observation

The airborne exposure positions of the aerial photographs were observed using the Differential method between GPS antenna position on the aircraft and reference points on the ground. These data were used both to prepare the flight index map and to carry out aerial triangulation. The procedure to get the exposure positions as three-dimensional coordinates with reference to the Myanmar Datum 2000 system was as follows:

1) Continuous GPS observation at the ground reference point.

2) Continuous GPS observation of the GPS antenna position during aerial photography, and recording of event marks.

3) Data processing to calculate latitude, longitude and height above the ellipsoid on the WGS –84 Ellipsoid.

4) Calculation of the exposure position of three-dimensional coordinates above the WGS-84 ellipsoid through interpolation of the time of the event mark

5) Conversion of each position on WGS-84 to the Myanmar Datum 2000 system.

6) Conversion of each position on the Datum 2000 to the plane coordinates by UTM map projection

7) Correction of height using the Geoid undulation map. The position and elevation of each exposure station on the Datum 2000 were determined.

Table 5.6.1 Record of exposure positions

001	2	17.243316539	94.452050135	7708.887	447417.622810	0.130	0.130	0.156
001	2	17.244969107	94.495498038	7709.192	447454.655089	0.086	0.086	0.105
001	3	17.245944728	94.538733860	7709.272	447491.409670	0.089	0.090	0.110
001	4	17.246913137	94.582060754	7710.381	447528.163838	0.095	0.095	0.119
001	5	17.247679748	94.625429303	7710.816	447564.360688	0.091	0.091	0.112
001	6	17.248757037	94.668615513	7711.865	447599.722777	0.092	0.092	0.112
001	7	17.249694974	94.711832042	7712.536	447634.527910	0.096	0.097	0.119
001	8	17.250597760	94.754970827	7711.212	447668.776211	0.093	0.093	0.113
001	9	17.251304590	94.798300616	7708.216	447702.746127	0.116	0.116	0.143
001	10	17.252962690	94.841498208	7709.184	447736.437337	0.107	0.107	0.130
001	11	17.253689530	94.885017492	7707.868	447770.129081	0.093	0.093	0.114
001	12	17.254412986	94.928141777	7706.266	447803.263638	0.099	0.099	0.126
001	13	17.255471485	94.971590261	7705.258	447836.398180	0.089	0.089	0.112
001	14	17.256509827	95.014689675	7707.022	447869.254952	0.076	0.076	0.093
001	15	17.257087819	95.057950676	7704.319	447902.110659	0.097	0.097	0.119
001	16	17.257812035	95.101153596	7707.391	447934.967254	0.103	0.103	0.153
001	17	17.258356501	95.144204092	7705.017	447967.545319	0.098	0.099	0.123
001	18	17.259257814	95.187797077	7704.887	448000.401499	0.073	0.073	0.086
001	19	17.260143107	95.230984624	7707.324	448032.980032	0.094	0.095	0.142
001	20	17.260856929	95.273997575	7705.952	448065.279684	0.072	0.073	0.086
001	21	17.261561295	95.317164700	7705.067	448097.579735	0.072	0.072	0.089

Attn.: Values listed from left to right:
Course No., photo No., latitude, longitude, height, and time, S.D. of X, Y and Z
*SD=Standard deviation

5.7 Production of digital image (scanning)

Digital images of the aerial photos were produced from negative film by direct scanning using a precision photo scanner. This image dataset was saved to CD-ROM, and used aerial triangulation and digital mapping.

Aerial photos were scanned at 1200 dpi (Approx. 20 micrometers equivalent to approximately 1m resolution on the ground).

A total of 1,242 photos were scanned and recorded to CD-ROM (251 discs).

The scanning equipment used and its specifications are as follows:

Table 5.7.1 Scanner specifications

Item	Specifications
Scanner	Ultra Scan 5000
Size of scan	280 x 440mm
Resolution	50dpi-10, 160dpi
Accuracy of scanning	±2 μ
Data correction function	Auto self-calibration, self checking on-the-fly
Scanning type (color)	Color

5.8 Final products of aerial photography

The following products were prepared.

1) Negative film	1 Set
2) Flight index map	1 Set
3) Positive films	1 Set
4) Contact prints	1 Set
5) Double-size enlarged prints	1 Set
6) File of exposure positions	1 Set
7) Digital image data	1 Set

Table 5.8.1 Total number of photos taken in the Study

Run No	Roll No.	Photo No.	No. of Photos
1	14	1 - 61	61
1	18	188 - 193	6
2	14	62 - 123	62
3	14	124 - 185	62
4	15	129 - 190	62
5	15	66 - 128	63
6	14	186 - 221	36
6	14	222 - 252	31
7	18	67 - 107	41
7	18	120 - 136	17
8	18	172 - 187	16
8	17	228 - 269	42
9	15	1 - 65	65
10	17	170 - 227	58
11	17	111 - 169	59
12	17	54 - 110	57
13	16	72 - 127	56
14	16	21 - 71	51
15	15	191 - 238	48
16	16	1 - 20	20
16	15	239 - 264	26

Run No	Roll No.	Photo No.	No. of Photos
17	16	128 - 167	40
18	16	168 - 206	39
19	16	207 - 242	36
20	16	243 - 266	24
20	17	1 - 12	12
21	17	13 - 35	23
22	17	36 - 53	18
23	18	55 - 66	12
24	18	39 - 54	16
25	18	18 - 38	21
26	18	1 - 17	17
N1	18	108 - 113	6
N2	18	114 - 119	6
T1	18	137 - 171	35
Total number of photos			1244

6. Control point survey

Ground control points were established in order to carry out aerial triangulation.

The topographic maps and topographic map data for this Study were plotted using the UTM projected plane. The Study area was divided into 2 zones, Zone 46 and Zone 47. The execution of aerial triangulation was also divided into two areas.

6.1 GPS Survey

Plane coordinates and the height of ground control points were determined by GPS survey.

The following counterparts and engineers worked on the GPS survey.

Table 6.1.1 Surveyors and CP who worked on the GPS survey

Assignment	Name	Position
CP1	U Than Hlaing	Leader/Deputy director of Geodetic department
CP2	U Ko Latt	Surveyor
Group 1	U Khin Mg Aye	Surveyor
Group 2	U Thet Oo	Surveyor
Group 3	U Win Myint Oo	Assistant Surveyor
Group 4	U Than Aye	Assistant Surveyor
Group 5	U Nuein Zay Aung	Assistant Surveyor

6.1.1 Operating plan

Initially, the establishment of 100 ground control points was planned. However, after field reconnaissance this plan was reconsidered for the sake of efficiency, as there are no roads across the rivers, and movement by boat is also hazardous in the Ayeyawady delta area. Airborne GPS support aerial triangulation was adopted to maintain sufficient accuracy with fewer control points. The cross course of aerial photography had already been added.

The number of ground control points was decided on the basis of the number in the UTM Project and the specifications for mapping done in Japan. In the end 48 ground control points and 21 vertical control points were set up in the Study area and their coordinates surveyed.

6.1.2 Establishment of ground control station

The ground control stations were established by one of the following methods.

1) On unpaved ground, drive a wooden post into the ground and knock in a nail on the top of the post

2) Where a concrete rivet can be driven into the ground, drive in a concrete rivet

3) At points where the SD so requests, sink a concrete pile.

The following items were taken into consideration when pricking points were selected.

1) Points more than 15 degrees above ground capable of receiving signals from the satellites.

2) Avoidance of places with powerful electric transmission sources

3) Avoidance of structures with zinc roofs.

4) Points within 50 m of prickable geographic feature (Ex. Intersection of roads).

5) Ability to observe geographic features pricked directly from the control point.

6.1.3 Observation of GPS survey

1) Selection of observed points

Ground control points were selected at suitable locations, close to planned locations and convenient for GPS observation as well as for pricking geographic features.

The following planning map for GPS observation was prepared.

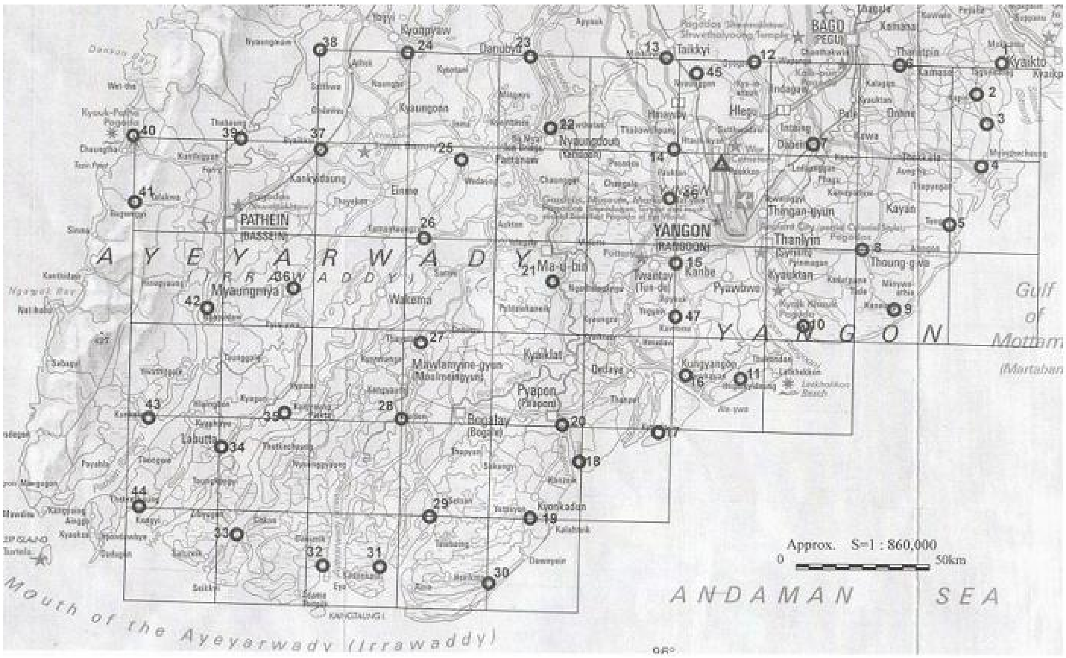


Figure 6.1.1 Planning map for observation

2) Specifications for GPS observation

The GPS survey was carried out according to the following specifications.

Table 6.1.2 Specifications for Observation in GPS Survey

Item	Remarks
Method of Observation	Static Observation
Observation time	3 hours
Interval of data acquisition	Every 30 seconds
Number of satellites	4 or more satellites simultaneously

3) Instruments used

Because of the delay in obtaining GPS instruments at the commencement of the GPS observation, the Study Team carried out the observation using rental GPS instruments. The same set of GPS receiver and antenna were used at all times by each work group for the GPS observation. The instruments used and group organization is shown in Table 6.1.3.

Table 6.1.3 Instruments used in GPS survey

Group	Leader of group	Type of instrument	Serial No	
			Receiver	Antenna
1	U Khin Mg Aye	ASHTECH Z12	SN220005103	SN6180
2	U Thet Oo	ASHTECH Z12	SN220001471	SN6189
3	U Win Myint Oo	ASHTECH Z12	SNLP02433	SN700228C1415
4	U Than Aye	ASHTECH Z12	SNLP00350	SNLP13350
5	U Nuein Zay Aung	ASHTECH Z12	SNLP02211	SN700328A0413

4) Work plan

The lack of radio communication made it difficult to confirm each group's preparations for GPS observation. Therefore, one session per day was planned, to avoid discrepancies in simultaneous observations.

6.1.4 Base line analysis

Base line analysis was carried out using the observed raw data in the following steps.

1) Calculation was done using PRIZM software manufactured by ASHTECH.

2) Base lines should be analyzed on the same day. However analysis was done at the completion of every third session, as it was very difficult to return to the computation

site.

3) The Yangon primary control station was selected as the first known control station to start computation. The first computation was carried out on the WGS-84 ellipsoid. Finally, the results were transformed to the Myanmar Datum 2000.

6.1.5 Quality control

Quality control of the GPS observations was carried out in the following 3 steps. All of the observations were accepted.

1) Study of standard deviation of observations in each component

The tolerance of standard deviation in each component of observed lines by fixed single point network adjustment was less than 30mm.

2) Inspection by residuals of duplicated base lines

As these observed base lines were very long, therefore, the tolerance was defined after examination by the SD.

3) Misclosures of closed polygons were inspected

Misclosures of closed polygons the sides of which were composed of different observed base lines were computed. The tolerance was sought with reference to Japanese Public Survey Regulation standards. After discussion with the SD, the tolerance of misclosure was defined as 1 ppm of total side length, of which the maximum was 80km. In this Study 8 polygons were inspected.

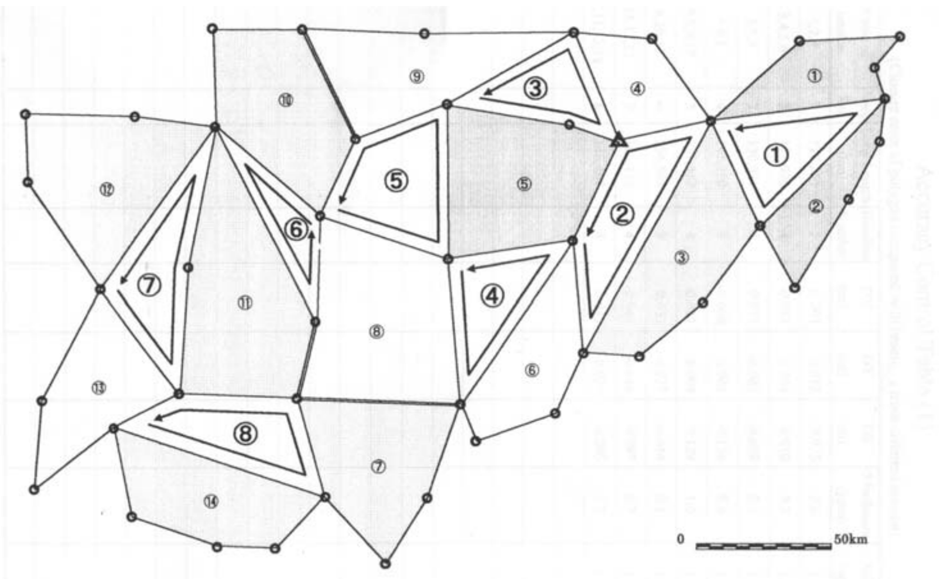


Figure 6.1.2 Closure polygons to check accuracy

Table 6.1.4 Misclosure in closed polygons

Name of session	Loop No.	Loop Length (km)	Baseline Number	DX (m)	DY (m)	DZ (m)	Misclosure (ppm)	Allow. (ppm)
1,2,3	1	133,251	3	0.001	0.012	0.075	0.6	1.0
3,4,5,6	2	171,920	4	-0.044	0.004	0.010	0.3	1.0
4,5,9	3	130,921	4	0.021	-0.003	-0.029	0.3	1.0
5,6,8	4	143,150	3	-0.008	0.002	-0.126	0.9	1.0
5,8,9,10	5	137,317	4	-0.051	0.004	0.129	1.0	1.0
8,10,11	6	134,593	3	0.052	-0.027	-0.044	0.5	1.0
11,12,13	7	166,412	4	-0.043	-0.044	-0.097	0.7	1.0
7,11,13,14	8	148,497	4	0.011	0.029	-0.006	0.2	1.0

(2) Inspection of discrepancies between DX, DY and DZ components of base line

The number of duplicated base lines inspected in this Study was three. Three may seem a small number for 14 observation sessions, but this was unavoidable for the following reasons:

It was very difficult to access the Study area.

Because of the lack of radio communication, it was necessary to allow leeway in the observation process.

Because customs clearance for the instruments furnished had been delayed, instruments were borrowed from a private company, so that it was necessary to reduce expenditure.

Table 6.1.5 Inspection of duplicated sides

Baseline	Session		Baseline	DX		DY		DZ	
from → to	No.	adopted	(km)	(m)	diff.	(m)	diff.	(m)	diff.
GCP24 → GCP25	9	○	35,256	14356.346	3mm	-8380.543	2mm	31397.522	4mm
	10			14356.343	0.1ppm	-8380.541	0.1ppm	31397.518	0.1ppm
GCP27 → GCP28	8	○	23634	2437.788	1mm	6863.009	18mm	-22484.050	24mm
	11			2437.789	0ppm	6862.991	0.8ppm	-22484.074	1.0ppm
GCP20 → GCP28	7	○	46785	46586.102	4mm	4238.672	37mm	780.824	9mm
	8			46586.106	0.1ppm	4238.635	0.8ppm	780.825	0.2ppm

(3) Inspection of standard deviation of each component of the baseline vector after fixed single point network adjustment

The result of this inspection was a deviation of 60 to 70mm. Since the purpose of this control point survey was to prepare topographic maps to a scale of 1:50,000, this level of accuracy was acceptable.

(4) The final results of the GPS observation

The Yangon first-order triangulation point was the only existing point in the Study area. Therefore, the calculation result of the fixed single point adjustment network was confirmed as the final result.

6.1.6 Final results

The following documents were prepared.

1）Distribution map of control points
2）Final result of control points
3）Description of control points

6.2 Direct leveling

In order to improve the height accuracy of aerial triangulation, a height control point survey was carried out by direct leveling. The orthometric height of some GPS control points was surveyed by direct leveling. Heights of other GPS points were determined to correct ellipsoidal heights using the Geoid undulation map. Therefore, approximately 100 km of leveling was carried out additionally for height controls.

Initially it was planned to survey 300km of leveling route, but it was found that many leveling routes already existed within the Study area. Therefore, it was decided to improve work efficiency by using the existing level points for the height control points.
The main assigned surveyors are shown in Table 6.2.1.

Figure 6.2.1 Leveling

Figure 6.2.2 Leveling

Table 6.2.1 Main assigned surveyors for leveling

Role	Member	Position
Counterpart	U Maung Maung Soe	Manager, SD
Surveyor (Group1)	U Than Tun Kyaing	SD
Surveyor (Group2)	U Tin Winn	SD
Surveyor (Group3)	U Than Khine	SD
Assistant surveyor (Group1)	U Banyar	SD
Assistant surveyor (Group1)	U Ko Ko Htwe	SD
Assistant surveyor (Group2)	U Tun Aung	SD
Assistant surveyor (Group2)	U Aung Kyaw Moe	SD
Assistant surveyor (Group3)	U Thein Kyi	SD
Assistant surveyor (Group3)	U Saw L Htoo	SD

6.2.1 Work Plan

A work plan for new direct leveling was drawn up using existing leveling routes based on accumulated documents. Some GPS control points were selected for height control point by direct leveling from the nearest benchmark. The height control points are pricked on enlarged photographs.

6.2.2 Field reconnaissance of existing benchmarks

The actual leveling routes were decided after field reconnaissance had been carried out along the planned leveling routes. After field reconnaissance, the total amount of leveling work was as follows:

Existing leveling routes for pricking	4 routes
New direct leveling routes	21 routes
Total leveling distance	Approx.100 km

6.2.3 Surveying

The direct leveling was carried out along the selected leveling routes. Leveling was carried out according to the following specifications over a period of 23 days, from 11th March 2002 to 2nd April 2002.

Table 6.2.2 Specifications for conventional leveling

Item	Remarks
Type of Level	NA3003
Limit of sight distance	Within 100m
Reading	1 mm unit
Leveling Rods	Aluminum Rod
Closure error	Within 50mm$\sqrt{S}$

The following levels were used for surveying.

Table 6.2.3 Levels used in Conventional leveling

Group	Leader of Group	Type of Level	Serial No.
Group1	U ThanTun Kyaing	Leica NA3003	310349
Group2	U Tin Winn	Leica NA3003	310354
Group3	U Than Khine	Leica NA3003	310290

Figure 6.2.3 NA3003 Level and Rod

Direct leveling routes surveyed are shown in Figure 6.2.4:

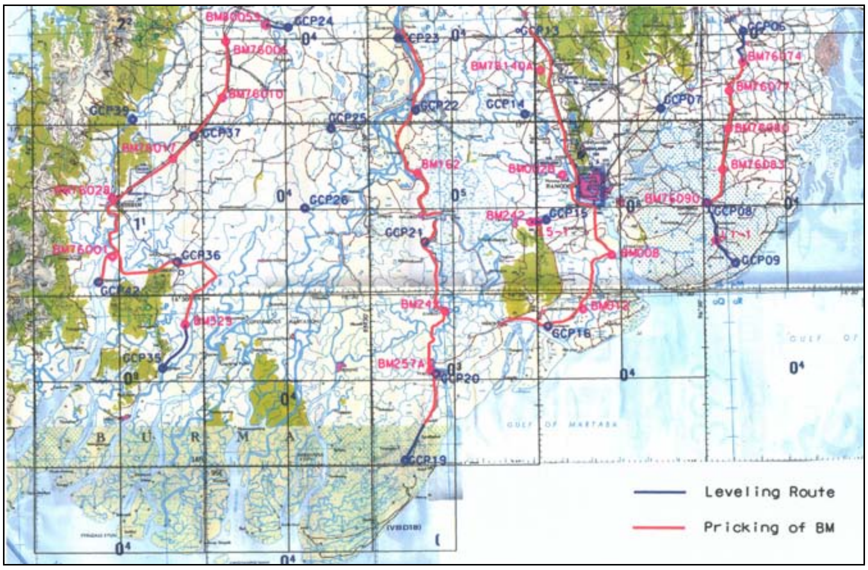


Figure 6.2.4 Newly-surveyed leveling routes (Blue lines)

6.2.4 Quality control

Quality was checked by seeking closure errors in loop observation or by residuals between the observed value and height of existing benchmarks.

Table 6.2.4 Misclosure of leveling loop

Route No.	Survey date	Out	Return	Distance	Misclosure
GCP 6	30.3.02	5.676	5.656	12.14	0.020
GCP 8	12.3.02	3.255	3.255	0.41	0.000
GCP 9	15.3.02	4.097	4.085	23.22	0.012
GCP13	22.3.02	9.252	9.251	0.10	0.001

Route No.	Survey date	Out	Return	Distance	Misclosure
GCP14	23.3.02	3.279	3.280	0.20	-0.001
GCP15	19.3.02	3.142	3.124	6.52	0.018
GCP16	23.3.02	1.574	1.562	2.15	0.012
GCP19	22.3.02	1.514	1.551	12.11	-0.037
GCP20	21.3.02	1.863	1.847	2.46	0.016
GCP21	27.3.02	2.461	2.463	1.47	-0.002
GCP22	27.3.02	7.594	7.590	1.48	0.004
GCP23	27.3.02	8.272	8.274	1.23	-0.002
GCP24	01.4.02	7.697	7.710	4.98	-0.013
GCP25	28.3.02	4.092	4.096	0.61	-0.004
GCP35	03.4.02	1.567	1.576	22.21	-0.009
GCP36	01.4.02	2.693	2.693	0.20	0.000
GCP37	13.3.02	4.132	4.133	1.08	-0.001
GCP39	02.4.02	4.959	4.966	2.96	-0.007
GCP42	02.4.02	13.182	13.181	0.93	0.001

6.2.5 Calculation of Geoid height

The Geoid height was calculated from the difference between the ellipsoidal height from the GPS survey and the orthometric height from the direct leveling.

Table 6.2.5 Calculation of Geoid height

Control point number	Ellipsoidal height	Orthometric height	Geoid height
GCP 6	9.459	5.666	3.793
GCP 7	5.715	3.674	2.041
GCP 8	7.153	3.255	3.898
GCP 9	9.286	4.091	5.195
GCP13	7.232	9.251	-2.019
GCP14	1.923	3.280	-1.357
GCP15	3.297	3.133	0.164
GCP16	2.838	1.568	1.270
GCP19	-0.177	1.533	-1.710
GCP20	0.495	1.855	-1.360
GCP21	-0.522	2.462	-2.984

6.2.6 Preparation of Geoid undulation map

The Geoid undulation map was prepared by plotting these Geoid heights, so that the ellipsoidal height represented on the contour map was corrected to orthometric height.

The three-dimensional coordinates of control points were finally determined by correction of the GPS observed height values, based on this map.

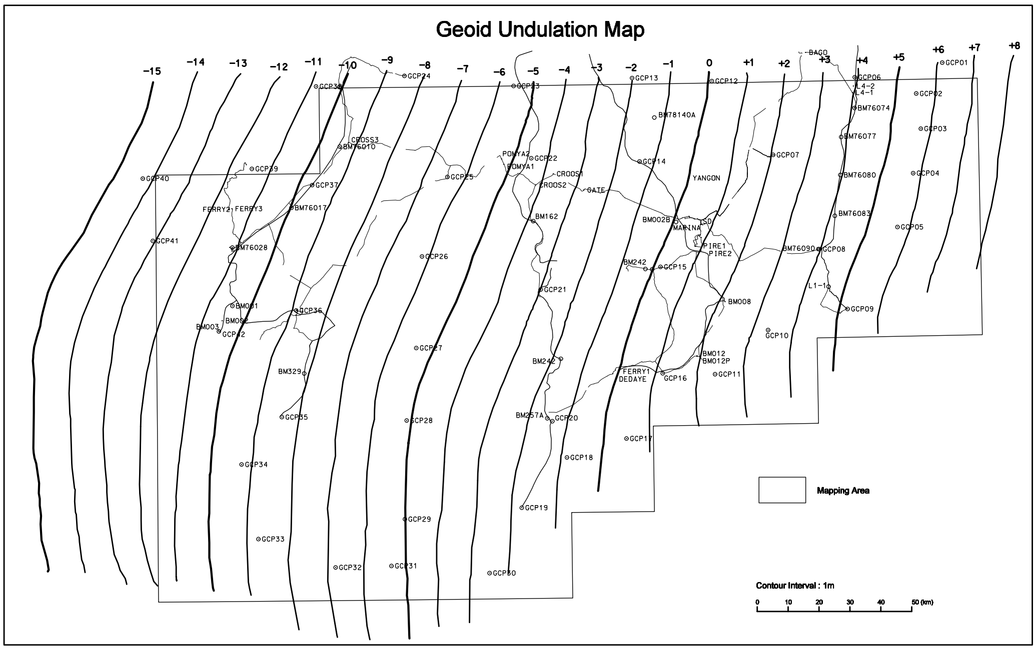


Figure 6.2.5 Geoid undulation map

The undulation tendency of Geoid from this map was for the most part consistent with the “World Geoid Map”. This map is also consistent with another Geoid map built from the results of 1st order geodetic surveying in Myanmar.

6.2.7 Final products

The following documents were prepared as the final products of the direct leveling.

1) The leveling route map
2) Final results of control points
3) Description of pricked vertical controls
4) Observation and calculation sheets
5) Quality control sheets
6) Data file of existing benchmarks

Table 6.2.6 Final results of ground control points

Point	Latitude	Longitude	Elevation
CP1	17 17 47.59278	96 54 04.66392	6.838
CP2	17 12 27.33679	96 49 13.34660	8.039
CP3	17 06 16.33948	96 49 54.83889	6.440
CP4	16 58 30.15540	96 48 22.77351	5.563
CP5	16 49 07.28353	96 45 20.26332	5.818
CP6	17 15 30.93444	96 38 04.77391	5.666
CP7	17 02 09.32125	96 22 56.96203	3.674
CP8	16 45 29.42592	96 31 04.40737	3.255
CP9	16 34 55.01365	96 35 59.93285	4.091
CP10	16 31 27.61514	96 21 29.28448	3.205
CP11	16 23 51.82746	96 11 44.13339	2.841
CP12	17 15 17.06961	96 12 00.75262	17.968
CP13	17 16 02.69170	95 57 27.61311	9.251
CP14	17 01 22.80945	95 58 35.91976	3.280
CP15	16 42 49.78827	96 02 07.66822	3.133
CP16	16 24 09.58878	96 02 13.80987	1.568
CP17	16 12 47.74297	95 55 28.85373	1.986
CP18	16 09 37.34699	95 44 38.35775	1.478
CP19	16 00 53.98163	95 36 20.05449	1.533
CP20	16 16 01.16866	95 42 04.41439	1.855
CP21	16 39 09.12020	95 40 17.65442	2.462
CP22	17 02 13.36812	95 38 52.71095	7.592
CP23	17 14.56.59543	95 35 49.86044	8.273
CP24	17 16 56.81354	95 15 56.41370	7.704
CP25	16 59 07.97699	95 23 33.74227	4.094
CP26	16 45 13.32206	95 18 45.26281	5.767
CP27	16 29 10.11677	95 17 31.81230	1.723
CP28	16 16 27.66521	95 15 48.72276	2.075
CP29	15 59 07.79885	95 15 06.74128	2.461
CP30	15 49 30.17661	95 30 21.44821	6.297
CP31	15 50 56.84648	95 12 35.61978	3.526

CP32	15 50 46.88472	95 02 27.97411	2.634
CP33	15 55 53.08777	94 48 31.94974	4.290
CP34	16 09 00.57196	94 45 35.80424	1.848
CP35	16 17 16.14139	94 52 59.00425	2.023
CP36	16 35 58.48119	94 55 45.33720	2.860
CP37	16 57 57.54212	94 58 54.84423	4.133
CP38	17 15 16.25476	94 59 48.05136	5.207
CP39	17 00 55.31344	94 47 56.99368	4.962
CP40	16 59 22.56513	94 28 02.26891	30.386
CP41	16 48 24.17929	94 29 46.98551	36.538
CP42	16 32 25.24750	94 41 40.21199	13.181
CP43	16 14 00.44075	94 32 45.60766	1.816
CP44	15 59 53.34165	94 31 54.57647	2.135
CPAA	17 13 10.10662	96 02 48.04941	19.572
CPBB	16 52 28.90815	95 59 10.22204	3.376
CPCC	16 33 21.80390	96 00 30.46302	5.015
YANG	16 58 20.62800	96 07 36.99652	54.750

6.3 Pricking

Aerial signals could not be set up on the control points because the aerial photography had precedence.

Control points were identified on the aerial photographs by pricking. These planimetric or height control points will be used for aerial triangulation.

6.3.1 Instruction in pricking

Pricking work is a very important step in the execution of aerial triangulation, and is also difficult work. Therefore surveyors to carry out the pricking work were trained before the pricking work was started.

Figure6.3.1 Surveying of eccentric elements

Figure 6.3.2 Pagoda as pricked point

6.3.2 Work plan

The GPS survey and pricking work were carried out at the same time. When this work started, the aerial photographs were not yet prepared. Therefore existing aerial photographs were reprinted and utilized for some of the pricking. Other control points were pricked on the new photographs.

Pricking for vertical control points was carried out to prick existing benchmarks and additional points during direct leveling.

6.3.3 Execution of pricking

Pricking work was executed according to the following steps.

(1) Confirmation of pricked points in GPS survey and leveling

The points pricked using existing aerial photographs were transferred to their position on the new aerial photographs using the description of pricked points.

1）Pricking of objective features and/or reference points

2）Surveying of eccentric elements

3）Drawing of sketches

4）Calculation of coordinates for pricked points and reference points

5）Preparation of a description of pricking points

(2) Pricking of existing benchmarks

Existing benchmarks essential for aerial triangulation were pricked on the new aerial photographs. Other existing benchmarks were also surveyed to identify them on the map when digital plotting is carried out.

1）Pricking of objective features

2）Surveying of relative heights between pricked features and existing benchmarks

3）Marking of pricked points on contact prints

Table 6.3.1 Surveyors assigned to Pricking

Role	Member	Position
Counterpart	U Nyan Tun	Manager, ST
Counterpart	U Khin Maung Aye	SD
Assistant Surveyor	U Thet Oo	SD
Assistant Surveyor	U Win Myint Oo	ST
Assistant Surveyor	U Than Aye	ST

6.3.4 Quality control

Quality control point of the pricking was carried out with regard to the following items

1) Quality of pricking

The state of the pricking was classified into 4 ranks.

Excellent: Pricked points are easily identifiable, the best pricking points having been selected.

Good: Pricked points are identifiable.

Normal: Pricked points are identifiable using the description of points.

Bad: Pricked points are difficult to identify.

2) Whether elements of eccentricity have been surveyed or not.

3) Whether the coordinates of eccentric points have been computed or not.

As shown in Table 6.3.2, no B-rank items were contained in the results of the quality control and all data were accepted.

Table 6.3.2 Evaluation of pricking

Rank	E	G	N	B	Total
No. of Points	0	26	22	0	48

6.3.5 Final results

Following the pricking, the following final products were prepared:

1) Description of pricked point (Description is included in the GPS observation results.)

2) Quality control

6.4 Signalization

Prior to the aerial photography, setting up ground signals is an effective way of identifying control points on an aerial photograph for aerial triangulation. In this Study, pricking work was adopted instead of signalization, because priority was given to the aerial photography. Signals were set up on the Yangon primary control point only and experimentally in the SD grounds.

6.4.1 Size and shape of signal

Experiments were conducted to examine suitable sizes and shapes of signal, so that similar photogrammetric work may be carried out in the future. Three kinds of shape and two sizes of signal were set up in the SD grounds.

Figure 6.4.1 Triple-bladed signal

Figure 6.4.2 Square signal

Figure 6.4.3 Four-bladed signal

6.4.2 Identification of signal

Each signal was checked for visibility on digital aerial photo images.

1) Setting the signal

The signal is set centered on the ground control point. The center of the ground control point is marked by a wooden stake. There must be a space between the wooden stake and the white signal

On pavements or building roofs, white paint was used for the signal; on grassland, a wooden stake and white plastic sheet were used.

2) Type, shape and size of signal

Different types and shapes of signal were tested for visibility on the aerial photos.

The types and sizes of signal were as follows:

Square signal:	3.0mx3.0m (white paint, with 1m x 1m hole in the center)
Triple-bladed signal:	4.0mx0.9m (white paint)
Four-bladed signal:	5.0mx1.0m (white plastic sheeting)
	4.0mx0.9m (white paint)

3) Conclusion

It was confirmed that signals with three and four blades are easily identifiable...

The size of signal tested was sufficiently visible on a scale of 1:50,000 with 20-micrometer resolution.

7. Aerial triangulation

Aerial triangulation was carried out to analyze the orientation parameters of aerial photographs to gain information on the topographic features from the stereo model.

The Study area is divided into two UTM zones, Zone 46 and 47, and so the aerial triangulation was carried out separately in the two zones.

In this Study, the positions of the exposure stations were observed continuously by airborne GPS.

7.1 Airborne GPS supported aerial triangulation

Airborne GPS supported aerial triangulation was carried out in order to get the normal degree of precision with a smaller number of ground control points.

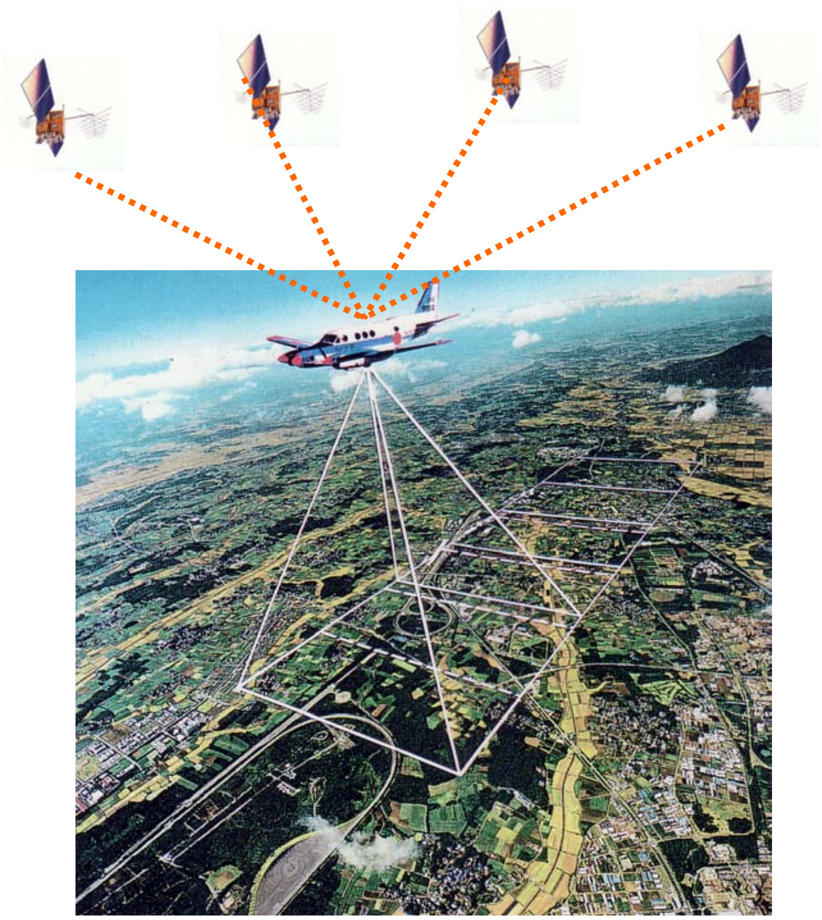


Figure 7.1.1 Airborne GPS supported photogrammetry

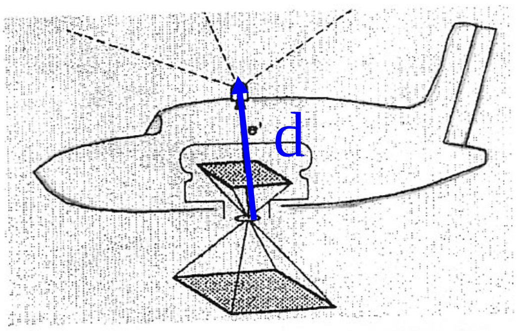
7.2 Materials used in aerial triangulation

The following materials were used for the aerial triangulation.

1) Index map of aerial photos
2) Digital aerial image data
3) Results and descriptions of ground control points
4) 3D-airborne position data file fro the taking of the aerial photos
5) Particulars of aerial camera

Table 7.2.1 Parameters of Aerial Camera

Type and name	Leica RC-30
Focal distance	153.19mm
Fiducial data	Less than 6μ
Distortion	Less than 5μ
Offset of GPS antenna	Adjusted



d is the offset vector from the center of the camera to the GPS antenna.

Figure 7.2.1 Offset of GPS antenna

7.3 Instruments used

The following instruments and software were used for the aerial triangulation.

1) Hardware

Digital Plotter: Socet Set system manufactured by LH Systems of Switzerland.

2）Software

PAT-B block adjustment program manufactured by LH Systems of Switzerland.

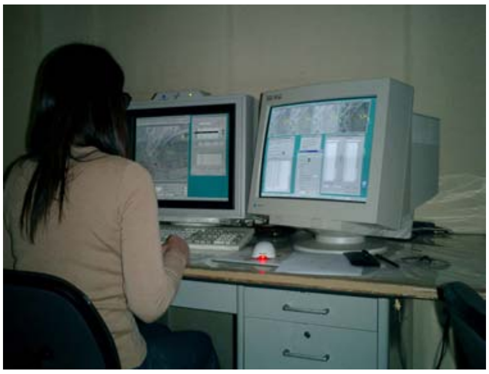


Figure 7.3.1 Undertaking aerial triangulation

7.4 Scope of aerial triangulation

Two blocks of aerial triangulation were implemented using the Block Adjustment program over the whole study area, comprising 1,100 models.

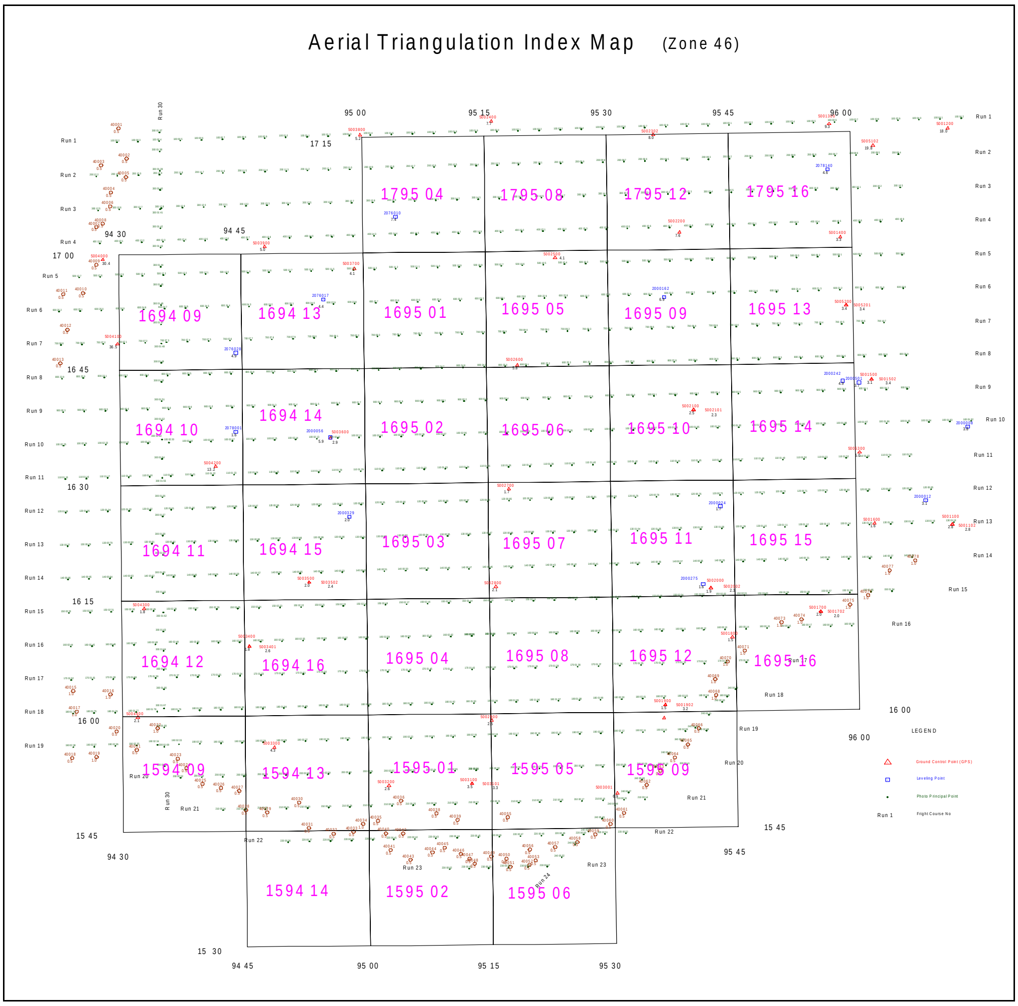


Fig. 7.4.1 Aerial triangulation index map for Zone 46

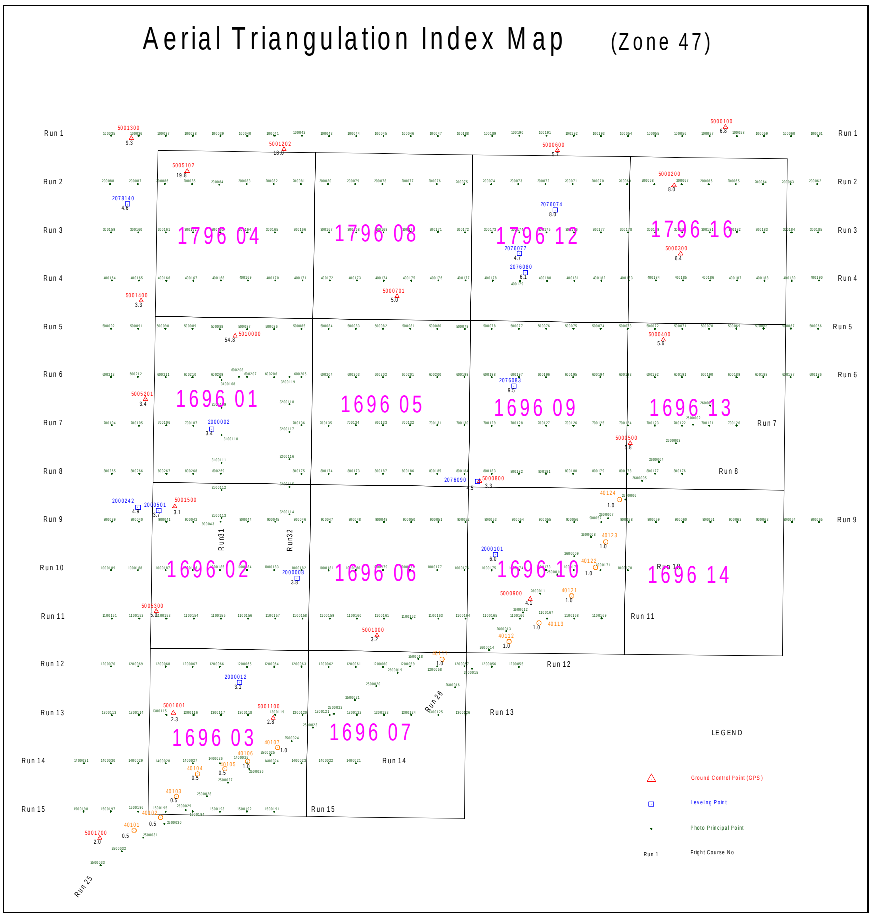


Fig. 7.4.2 Aerial triangulation index map for Zone 47

7.5 Procedure for aerial triangulation

Aerial triangulation was performed according to the following procedure.

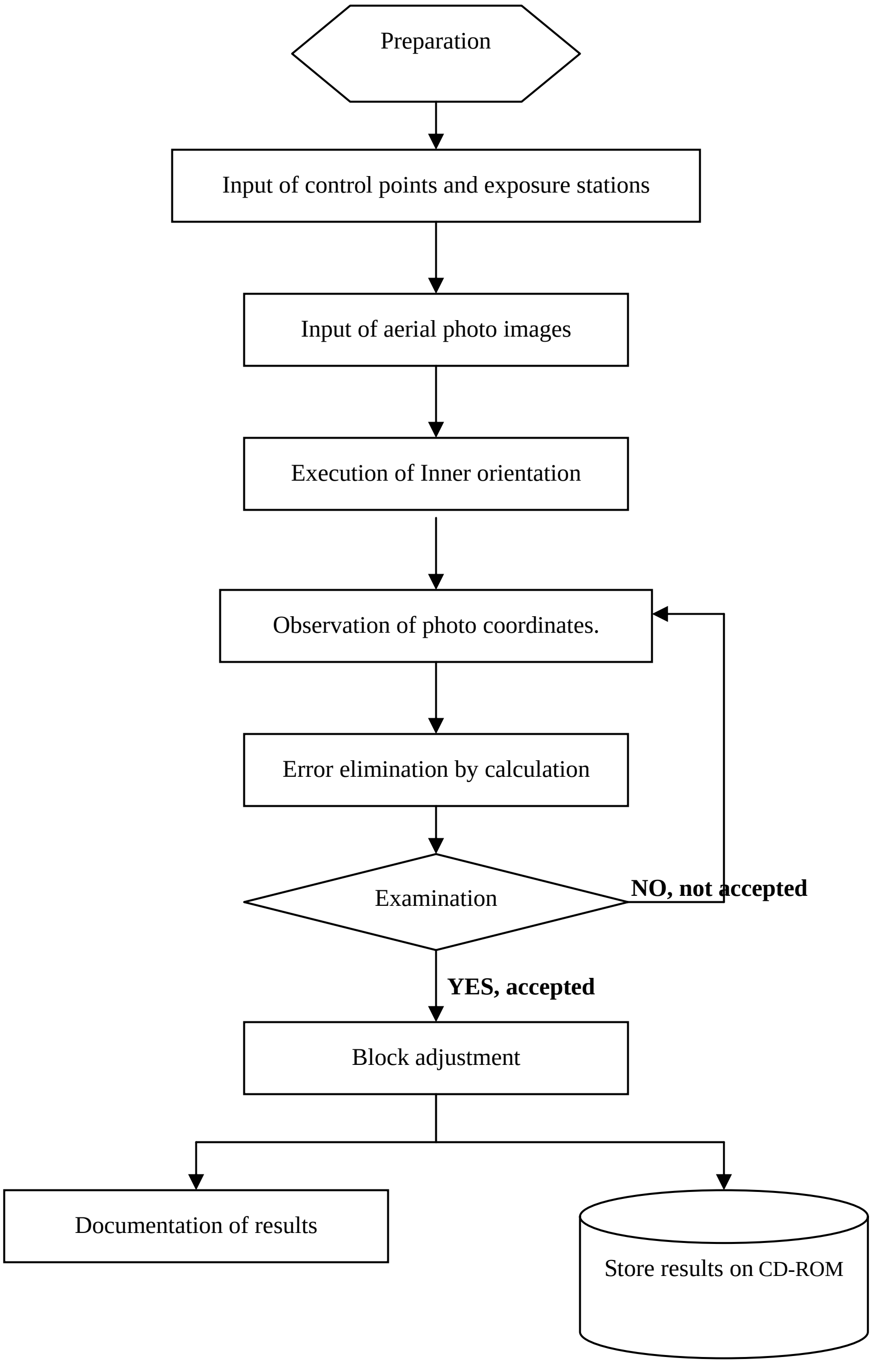


Fig. 7.5.1 Procedure for aerial triangulation

7.6 Quality control

The quality of the aerial triangulation was evaluated according to error tolerance. The following tolerances were set for each step of computation.

1) Residuals on fiducial marks after transformation shall be less than 0.030mm.
2) Residuals on positive film after relative orientation shall be less than 0.020mm.
3) Standard deviation of residuals in plane position and elevation on control points shall be less than 0.02% of flight height, with a maximum of less than 0.04% of flight height within the same block.
4) Standard deviation of intersected residuals of bundles shall be less than 0.015mm, with a maximum of less than 0.030mm within the same block.

Table 7.6.1 Results of adjustment

	Axis	Mean	Maximum
Zone46	X	0.602	1.686
	Y	0.628	1.547
	Z	0.006	0.023
Zone47	X	0.375	0.678
	Y	0.585	1.058
	Z	0.007	0.019

Unit: mm

7.7 Points of concern in performing aerial triangulation

As a result of carrying out the aerial triangulation, some issues were noted. When the same kind of work is done in the future, attention should be given to the following points.

1) Scanning of aerial photos
Some lines of scanned data were omitted due to vibration.
The scanner itself should be placed on a stable surface that is not affected by vibration or shock.
2) Selection of pricking points
Pricking points more suitable as reference points were found near the pricked point at some control stations.
Suitable reference points should be selected and pricked in order to improve the precision of the aerial triangulation.
3) Additional flight courses
Cross flight courses were added, but ground control points were not included in these flight

courses. If those ground control points are included in the cross flight, it can be expected that better accuracy would result.

7.8 Final results

The following products were prepared as a result of the aerial triangulation.

1) Final result table for aerial triangulation

2) Final result data for aerial triangulation

These final results are being used by the Survey Department to connect to the second stage of the UTM project presently under way.