No.

JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO GEOGRÁFICO AGUSTÍN CODAZZI
IN THE REPUBLIC OF COLOMBIA

THE STUDY ON THE FORMULATION OF GEOGRAPHIC DATA BASE OF THE PRINCIPAL CITIES IN THE ATLANTIC COAST IN REPUBLIC OF COLOMBIA

FINAL REPORT

DECEMBER 2007

ASIA AIR SURVEY CO., LTD.

PASCO CORPORATION

SD
JR
07－091

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PREFACE

In response to a request from the Government of Colombia, the Government of Japan decided to conduct a study on The Study on the Formulation of Geographic Data Base of the Principal Cities in the Atlantic Coast in the Republic of Colombia and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Yoshitaka GOMI of ASIA AIR SURVEY Co., LTD. and consists of ASIA AIR SURVEY Co., LTD. and PASCO Corporation between August, 2005 and November, 2007.

The team held discussions with the officials concerned of the Government of Colombia, 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 Colombia for their close cooperation extended to the study.

December 2007

Eiji HASHIMOTO,
Deputy Vice President
Japan International Cooperation Agency

Letter of Transmittal

Mr.Eiji HASHIMOTO
Deputy Vice President
Japan International Cooperation Agency

Dear Mr.Hashimoto

It is my great pleasure to submit herewith the Final report for the Study on the Formulation of Geographic Data Base of the Principal Cities in the Atlantic Coast in Republic of Colombia.

The Study team consists of Asia Air Survey Co., Ltd and Pasco Corporation conducted field survey in Colombia during the period from August 2005 to October 2007, and office work such as digital topographic mapping during the period from August 2005 to December 2007 as per the contract with the Japan International Cooperation Agency.

During the field survey in Colombia, discussions with the officials of Instituo Geográfico Augustín Codazzi (IGAC) were held. Base on the results of the discussions with IGAC, digital topographic maps, other final results and final report was prepared.

On behalf of the Study team, I would like to express may heartfelt appreciation to IGAC in Colombia and other authorities concerned for the their diligent cooperation and assistance for the heartfelt hospitality which they extended to the Study team during our stay in Colombia.

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

Yours faithfully,

Yoshitaka GOMI

Team Leader for the Study on the Formulation of Geographic Data Base
of the Principal Cities in the Atlantic Coast in Republic of Colombia

Metropolitan area of Barranquilla

Santa Marta

Cartagena

Location Map

Abbreviation

Abbreviation	In Spanish	English translation
ACCI	Agencia Colombiana de Cooperacion Internacional	Agency for International Cooperation
CAD	Computer Aided Design	Computer Aided Design
CIAF	Centro de investigación y Desarrollo en Información Geográfica	Center for Interpretation of Aerial Photographs
DANE	Departamento Administrativo Nacional de Estadística	National Statistical Department
DNP	Departamento Nacional de Planeación	National Planning Department
DTM	Digital Terrain Model	Digital Terrain Model
GIS	Geographical Information System	Geographical Information System
GPS	Global Positioning System	Global Positioning System
ICDE	Infrastructura Colombiana de Datos Espaciales	Colombia Spatial Data Infrastructure
IDB	Inter-American Development Bank	Inter-American Development Bank
IGAC	Instituto Geografico Agustin Codazzi	Instituto Geografico Agustin Codazzi
JICA	Agencia de Cooperación Internacional del Japón	Japan International Cooperation Agency
POT	Plan de Ordenamiento Territorial	Land use plan

Summary of the Study

	Item of work	Volume of Work
1	**Aerial photography**	
	Photo scale	1/10,000
	Aerial photography area	400km^2
	Positive film making	Cartagena 328 photos Barranquilla 622 photos Santa Marta 380 photos
	Scanning of positive film	1,330 photos
2	**Ground control point survey**	
	GPS observation	Cartagena 37 points Barranquilla 42 points Santa Marta 26 points
	Pricking	Cartagena 37 points Barranquilla 42 points Santa Marta 26 points
	Field identification	400km^2
3	**Aerial triangulation**	
	Aerial triangulation	Cartagena 198 models Barranquilla 331 models Santa Marta 175 models
4	**Digital topographic mapping**	
	Map scale	1/2,000
	Mapping area	400km2
	Number of sheets	Cartagena 120 sheets Barranquilla 196 sheets Santa Marta 103 sheets
	Contour interval (Main contour interval)	2 m
5	**Basic Data creation**	
	Area	400km2
6	**GIS model system**	
	GIS model system CD-Rom	1 sets
7	**Production of CD-Rom**	
	Digital map data file	5 sets
8	**Polyester base map**	
	1/2,000cale of polyester base map	2 sets
9	**Report**	
	Inception Report	English 20 sets Spanish 10 sets
	Interim Report	English 20 sets Spanish 10 sets
	Draft Final Report (Main, Summary)	English 20 sets Spanish 10 sets
	Final Report (Main, Summary)	Japanese 10 sets (Summary) English 20 sets Spanish 10 sets

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CHAPTER 1 INTRODUCTION AND BACKGROUND OF THE STUDY

1.1 Background of the Study

Colombia is striving to implement social and economic development, following the guide line of the Quadrennial Development Plan which support the part of Plan

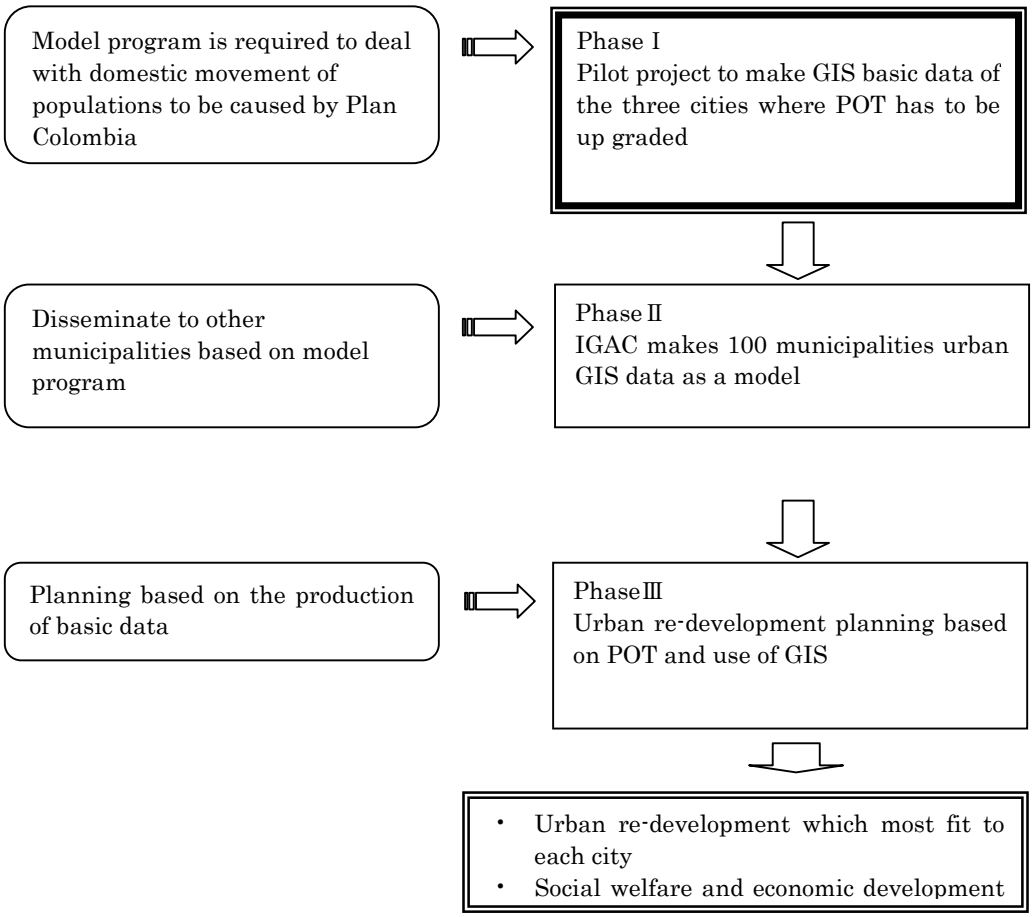
In Colombia, making or updating Plano Ordinaminento Territorial (POT)is a pre-requisite condition before any infrastructure development project is implemented.

However, in many municipalities, making high quality POT is hampered by the lack of reliable and up-to-date geographic information.

As the national survey and mapping institute of Colombia, IGAC (Instituto Geográfico Agustín Codazzi) is responsible for the production of maps and geographic information of Colombia. IGAC has a long history and experience in photogrammetric mapping and its production facilities have been modernized constantly. However, as for the 1/2,000 scale digital map production using modern digital mapping systems, IGAC had not fully established procedures for the full scale production and was seeking for an opportunity to improve efficiency of production.

In responding to the request from the Colombian government for technical assistance, JICA decided to produce 1/2,000 scale digital maps and basic GIS data of three Atlantic cities, namely, Santa Marta, Barranquilla and Cartagena. Total mapping area is 400 km^2. During the course of this map production, it was expected that technologies for mass production of 1/2,000 digital maps and basic GIS data are transferred to IGAC by the JICA Study Team. Also, it was planned that IGAC's mapping procedures and methods are reviewed by IGAC and JICA Study Team to check to see if IGAC is going to be self sustainable in terms of the 1/2,000 map and basic GIS production of 100 municipalities.

Plan Colombia :
A national plan consisting of the basic strategy to realize peace, fairness and strengthened institution which aim at the eradication of persisting political and economic instability. With this plan, it is expected to realize peace, integration of various races and regain confidence of international society and recovery of battered economy in order to make stable society.



: Can be covered within this project in Colombia.

POT(Plan de Ordenamiento Territorial)means the land use plan to be prepared to control urban development and promote healthy growth.

1.2 Scope of the study

1.2.1 Purpose

The purpose of the study is summarized as follows:

(1) To support making POT aimed at the urban planning for the 103 municipalities in Colombia. And as for three Atlantic coastal cities where urban area is spreading and therefore making reliable urban development plan is given high priority, the JICA Study Team made basic GIS data based on the 1/2,000 scale digital topographic maps. Also a sample of GIS model system is made to show the value of reliable and accurate geographic information and the method to use them.

(2) Carrying out self sustainability analysis of IGAC's 1/2,000 scale map and basic GIS data making program for the remaining 100 municipalities.

(3) Transfer technologies required in modern digital mapping to IGAC through the activities described in item (1) and (2) above.

1.2.2 Target area

The target of this study is the three cities located along the Atlantic coast, namely, Cartagena, Santa Marta and Metropolitan area of Barranquilla. Colombia. Total mapping size is 400 km^2 (Figure 1-1).

Figure 1-1 Study Areas (Cartagena, Metropolitan area of Barranquilla and Santa Marta.)

1.2.3 Physical output

The following material or system were made in the Study

- Field classification result
- Aerial triangulation result
- Printed maps in polyester paper
- Basic GIS data made from 1/2,000 scale map
- Sample of GIS model system

1.3 Summary of the study

The contents of work implemented in the study are summarized as follows.

First of all the study was started in July, 2005 when the JICA Study Team started its preparatory work in Japan. The JICA Study Team visited Colombia total five times and the study was completed in December 2007 when the JICA Study Team delivered the final output of the study to JICA Tokyo office.

Aerial photography, film scanning, ground control point survey and field identification survey were planned and implemented by IGAC. The JICA study Team arrived at Colombia after the completion of aerial photography and film scanning. The JICA Study Team provided various advices on ground control point survey and field identification survey.

Aerial triangulation, digital mapping, digital editing and data structurization were carried out in Japan.

Through the process of the study, IGAC staff and the JICA Study Team tried new techniques such as the use of data recorder with GPS in field identification survey.

Since IGAC technical staff already had knowledge in the operation of digital mapping instruments, technology transfer was made mainly as a form of technical discussions rather than giving instructions on the operation of instruments. A series of discussions were made to check problems of current production process or to exchange opinion on production techniques.

Major subjects of discussion and examination were as follows:

- Number and distribution of GCP used in aerial triangulation
- Use of orthophoto in field identification survey

- Use of data recorder with GPS (RECON) in field identification survey
- Format of point description
- Specifications of map symbols
- Geographic feature catalogue
- Contents of the basic GIS data
- Sheet allotment of 1/2,000 scale maps
- Handling of local coordinate systems
- Cooperation and communication among different division or group
- Use of orthophotos as background in the inspection of map quality

Map production methods being employed by IGAC have been formulated based on specific conditions of Colombia including history of the organization. Therefore, some of the methods advised by the JICA Study Team may not directly fit to IGAC's situation. However, observation of the JICA Study Team which was made from different point of view from IGAC contributed to the identification of problems which cannot be noticed by IGAC.

Further, since the JICA Study Team actually made maps and geographic data in the study, the JICA Study Team could review and examine IGAC's technical specifications. Findings of the JICA Study Team on the specifications will be useful for IGAC when it subcontracts out the digital mapping work to local private firms.

As for the results of the self sustainability analysis, it was concluded that IGAC has basic technical skills required in the production of 1/2,000 scale digital maps and basic GIS data. As for the promotion of the use of GIS, it was found that almost all the local municipalities do not have knowledge, experience, staff and instruments for handling paper maps. Therefore, it would be useful to use IGAC regional offices in the promotion of GIS data.

CHAPTER 2 FRAMEWORK OF THE STUDY

The study was conducted in close communication between the JICA Study Team and IGAC. A series of meetings were held to confirm the detailed scope of work of the study and technical specifications. Coordinating Committee was organized to share project information with major stakeholders of the study. This chapter explains how the study was managed.

2.1 Project Management Tools

Smooth communication among stakeholders of the study is a key for the successful implementation of the study. For this purpose, several devices were used in the study. They are Coordinating Committee meetings, discussion on reports and specifications, seminars and workshop.

2.1.1 Coordinating Committee

Coordinating Committee was organized to monitor the progress of the study by major stakeholders. Committee members are:

- IGAC (Instituto Geográfico Agustín Codazzi)
- DANE (Departamento Administrativo Nacional de Estadística)
- DNP (Departamento Nacional de Planeación)
- ACCI (Agencia Colombiana de Cooperacion Internacional)
- Municipalities of Cartagena, Barranquilla and Santa Marta,
- Director of Territorial office of IGAC (Cartagena, Barranquilla and Santa Marta)
- The JICA Study Team

Coordinating Committee meeting was held every year when the JICA Study Team was in Colombia. The JICA Study Team explained the contents and the progress of the study and collected opinion of the participants on the study. The committee meeting was particularly important for the three municipalities who are the direct beneficiaries of the outcome of the study.

(1) The First Coordinating Committee Meeting

The First Coordinating Committee Meeting was held on February 10, 2006 at the IGAC territorial office in Santa Marta. The JICA Study Team explained the purpose and contents of the project and the progress of the work in Colombia and collected the opinions of the participants.

Comments from the participants were as follows:

- Participants have high expectation on the new topographic maps
- As for the problem of cities the following two points were listed.
  - Even if new data are provided, local offices do not have sufficient enough number of machine and staff who have sufficient training.
  - Data updating cannot be done.

(2) The Second Coordinating Committee meeting

The Second Coordinating Committee meeting was held on September 10, 2006 at the IGAC territorial office in Cartagena. The JICA Study Team explained the results of the first year's activities. Discussion was made mainly on the use of the data to be made in the study. During the discussions, territorial director and her staff asked IGAC to strengthen its education and training

(3) The Third Coordinating Committee meeting

The Third Coordinating Committee meeting was held on October 22, 2007 at IGAC. This was the last Coordinating Committee meeting for the study and the results of the study were presented to the participants.

2.1.2 Presentation of reports

The JICA Study Team prepared draft Inception Report and submitted it to IGAC at the beginning of the Study. The Inception Report contains the understanding of the JICA Study Team on the project contents and schedule. A series of meetings were held between IGAC and the JICA Study Team to discuss the project contents and the results of the meetings were compiled as a Minutes of Meeting. Actual project activities were started after the both parties agreed on the project contents.

The JICA Study Team prepared Interim Report in the middle of the project period to report to IGAC the progress of the Study and also to propose any changes to be made in the contents or schedule of the Study. Minutes of Meetings were also made to record the results of the discussion.

Draft Final Report was made by the JICA Study Team in September 2007 and submitted to IGAC to confirm the results about the two and a half years work.

2.1.3 Seminars and Workshop

One workshop and two seminars were held. Participants were invited from inside and outside IGAC. The purpose of the seminars and workshop was to inform the participants of the purpose and outcome of the Study as well as to exchange technical opinions on the method of survey and mapping with the participants. The three small seminars in the three cities were particularly aimed at the introduction of the project outcome and model GIS.

(1) Workshop

After the completion of the first year's activities and at the beginning of the second year's work, a workshop was held at IGAC headquarters in Bogotá to report the progress of the study and also to introduce the output of the study to stakeholders and potential user of the project output. Technical details of the work implemented by January 2006 were explained. At the same time, the participants were asked how they are going to use the project output. Their answers showed that they are expecting to use the 1/2,000 scale maps and basic GIS data for various purposes such as cadastral surveys, urban planning and land use planning.

(2) Seminar #1

The first seminar was held in September 2006 at IGAC headquarters in Bogotá. Progress of the study and findings were presented to IGAC staff and stakeholders.

(3) Seminar #2

The second and last seminar was held at IGAC headquarters in Bogotá to report the progress of the study as well as findings of the JICA Study Team. Also in order to disseminate the information on the outcome of the Study, the JICA Study Team member visited all of the three municipalities and had a small seminar in each city. In this small seminars, particular emphasis was placed on the explanation on the use of GIS for POT making.

2.2 Summary of activities

Contents of the work implemented by IGAC and the JICA Study Team are summarized on the Table 2-1 in a chronological order.

Table 2-1 Contents of the work implemented by IGAC and the JICA Study Team

	Work undertaken by IGAC	Work undertaken by JICA
June 2005	• Aerial photography • Film scanning	
Mid Aug 2005 – End Aug 2005		• Analysis of information collected by the preliminary study team • Preparation of Inception Report
End Aug 2005 – Early Nov 2005	• Determination of work method and specifications • Ground control point survey	• Explanation of work plan • Receipt of aerial photography results • Basic information collection on IGAC • Determination of work method and specifications
Early Nov 2005 – End Mar 2006		• Aerial triangulation • Orthophoto production • Making sample map • Digital mapping • Digital editing • Making GIS model system
Mid Jan 2006 – End Mar 2006		• Determination of map symbols • Field identification survey • Self sustainability analysis • Workshop • Preparation for instrument procurement
Early June 2006 – End Sept 2006		• Digital mapping • Digital editing • Preparation for field completion survey • Preparation of interim report
Early Jul 2006 – Early Dec 2006	• Field completion survey	• Interim report meeting • Coordinating Committee meeting • Technology transfer seminar • Self sustainability analysis • Survey for the promotion of GIS • GIS model system making
Early Oct 2006 – End Mar 2007		• Self sustainability analysis • Structurization • Editing after field completion • Symbolization of maps
Mid Jun 2007 – Mid Jul 2007	• Proof checking • Preliminary discussion of Draft Final Report (DFR)	• Proof checking • Preliminary discussion of DFR • Additional survey for self sustainability analysis
Mid Jul 2007 – Mid Sept 2007	• Proof checking	• Correction based on the results of proof checking
Mid Sept 2007 – Mid Oct 2007	• Discussion of DFR • Certification of maps	• Discussion of DFR • Seminars • Coordinating Committee meeting • Certification of maps
Mid Oct 2007 – Dec 2007		• Making map data files • Map printing on polyester base

2.3 JICA Study Team

Members of the JICA Study Team, their role and duration of participation in the work in Colombia are summarized as follows (Table2-2).

Table 2-2 Members of the JICA Study Team

Name	Participating Period	Responsibility
Gomi, Yoshitaka	Aug 25, 2005 - Sept 23, 2005 Jan 15, 2006 - Feb 20, 2006 Jul 9, 2006 - July 23, 2006 July 24, 2006 - Aug 22, 2006 Aug 27, 2006 - Sept 25, 2006 Oct 10, 2006 - Nov 8, 2006 Sept 26, 2007 - Oct 25, 2007	Leader Leader Leader GIS Model system Leader GIS Model system Leader
Koseki, Junichi	Aug 25, 2005 - Oct 3, 2005	Technical specifications
Nakata, Yutaka	Aug 25, 2005 - Nov 2, 2005	Ground control point survey I
Nakayama, Masakuni	Sept 26, 2005 - Nov 4, 2005	Ground control point survey II
Kono, Shinichi	Aug 25, 2005 - Sept 23, 2005 Jan 22, 2006 - Mar 22, 2006 Aug 13, 2006 - Sept 26, 2006	Field identification survey Field identification survey Field identification survey
Kawaguchi, Manabu	Jan 22, 2006 - Mar 22, 2006	Field identification survey
Matsushita, Yoshiteru	Sept 7, 2005 - Oct 6, 2005 Jan 22, 2006 - Feb 10, 2006 Sept 3, 2006 - Oct 17, 2006 June 17, 2007 - July 16, 2007 Sept 26, 2007 - Oct 25, 2007	Digital editing (procurement of instruments) Digital editing Digital editing/Symbolization Digital editing/Symbolization Digital editing/Symbolization
Sugita, Akihiro	Oct 8, 2006 - Nov 6, 2006	Strucutrization/Printing
Sata, Nobuhiro	Aug 27, 2006 - Sept 25, 2006	Digital mapping
Suwabe, Kazumi	Sept 26, 2005 - Nov 4, 2005	GIS model system
Ono, Shigeru	Jan 22, 2006 - Feb 20, 2006 July 9, 2006 - Aug 7, 2006 Sept 10, 2006 - Nov 8, 2006 Jun 17, 2007 - July 16, 2007	Self sustainability analysis Self sustainability analysis Self sustainability analysis Self sustainability analysis
Takei, Mitsuko	Aug 25, 2005 - Sept 23, 2005 Jan 22, 2006 - Feb 20, 2006 Jun 9, 2006 - July 23, 2006 Sept 10, 2006 - Sept 17, 2006	Interpretor Interpretor Interpretor Interpretor
Furuya, Toru	Aug 21, 2005 - Sept 23, 2005 Jan 15, 2006 - Mar 22, 2006	Coordinator Coordinator
Nonaka, Ichiro	Aug 20, 2006 - Sept 18, 2006	Coordinator
Hayashi, Michi	Sept 26, 2007 - Oct 25, 2007	Coordinator

CHAPTER 3 DISCUSSION ON TECHNICAL SPECIFICATIONS

During the course of the study the JICA Study Team and IGAC had a series of meetings to confirm the contents and specifications of the study. In the meetings on the contents of reports also related to technical specifications. Scope of work and specifications discussed and confirmed in the meetings are summarized below.

3.1 Inception Report Meeting

The JICA Study Team made two and a half years work plan based on JICA specifications for the Study. The plan which includes contents, accuracy and procedures, was compiled as Inception Report (Draft) and presented to IGAC (Figure 3-1).

The discussion on the contents of the Inception Report was held on August 31, 2005. Contents of the discussion were recorded as Minutes of Meeting (Appendix 1).

(1) The JICA Study Team requested IGAC to provide the available data, information related to the Study and assign counterpart personnel and IGAC manifested its agreement and was carried out promptly.

(2) IGAC made a comment that progress of aerial photography for study area was completed with 80% overlap and the negative films were scanned with the size of pixel of 15 microns, and the JICA Study Team accepted the explanation.

(3) The JICA Study Team requested IGAC to take Japan the negative films, digital data file, contact prints and IGAC agreed it.

(4) Both parties agreed that the boundaries of 1/2,000 scale digital topographic mapping area shown on the Scope of Work are tentative. So, both parties agreed that the exact boundaries would be decided through the discussion based on the actual requirement.

(5) The JICA Study Team explained that for determination of the exact boundary of 1/2,000 scale digital topographic mapping area orthophoto would be used and IGAC accepted the criteria.

(6) The JICA Study Team requested IGAC to carry out the necessary actions in order to

establish a Coordinating Committee and Technical Team.

(7) Both parties agreed that IGAC carries out an initial proposal of the distribution of ground control points necessary. This proposal will be analyzed by the JICA Study Team and discussed with IGAC in order to carrying out the necessary adjustments to produce the plan of GPS survey.

(8) IGAC requested to the JICA Study Team to consider the schedule of field survey that was programmed from January to February due to the readiness of the budget of IGAC, and the JICA Study Team agreed to consider the adjustment of the schedule.

(9) The JICA Study Team explained that with the digital image of aerial photographs and the results of aerial triangulation, orthophoto image would be produced sheet by sheet. This orthophoto will be used for the field identification and IGAC agreed it.

(10) IGAC expressed the necessity to carry out part of the technology transfer in Japan. The JICA Study Team manifested to transmit the application from IGAC to the JICA Headquarters.

(11) The JICA Study Team proposed holding of the workshop for the technology transfer to IGAC in January, and IGAC accepted it.

(12) The JICA Study Team requested IGAC to prepare the necessary office for the Study and was prepared with satisfactory.


Figure 3-1 Inception report meeting

3.2 Discussions on map symbols and specifications (1)

During the first visit of the JICA Study Team to Colombia in 2005, the team discussed map symbols and technical specifications with IGAC. The results of the discussion were as summarized below.

(1) Basic parameters for survey

Basic parameters for survey such as the definition of datum, it was determined that the following elements would be used. These parameters are the same with those being used in IGAC's 1/2,000 scale mapping.

- Geodetic datum: MAGNA SIRGAS
- Map Project: Cartesian projection.
- Coordinate system: Local coordinate system for each of the three cities.

(2) Map sheet allotment

To be determined after the mapping area is officially determined.

(3) Mapping items

The JICA Study Team prepared draft plan for the geographic features to be drawn on the map and their map symbols to confirm the definition of geographic features and criteria for feature identification. The JICA Study Team prepared the draft based on CO-U and CS2000. However, IGAC presented Unico de Modelo as the specification for 1/2,000 scale topographic mapping. Therefore, the JICA Study Team checked the contents of Unico de Modelo in discussing the mapping specifications with IGAC

The JICA Study Team also asked IGAC to clarify the definition of geographic features which were not clear according to existing IGAC specifications.

3.3 Discussions on map symbol and specifications (2)

Discussions on map symbols and mapping specifications were also conducted during the second visit of the JICA Study Team to Colombia between January 2006 and February 2006. The results of the discussions were as summarized below.

(1) Map symbol

Discussions of map symbols were held based on the sample map prepared in Japan. The map

symbols which are used in the 1/2,000 scale maps in the Study are as attached to this Minutes of Meeting as Appendix 2.

(2) Mapping area

Size of the mapping area agreed between the Preparatory JICA Study Team and IGAC in March 2005 was about 400km^2. However, after measuring actual size of the area on new orthophotos which were made by the JICA Study Team in Japan from the new aerial photographs taken by IGAC, it was found that the size of the mapping area shown on the map used for the determination of the area was approximately 420km^2 The JICA Study Team presented this result to IGAC and asked IGAC to review the mapping boundary. As the result of IGAC's review, the size of the mapping areas was determined as follows.

Cartagena	:	11,000 ha
Barranquill	:	19,900 ha
Santa Maruta	:	9,100 ha

(3) Marginal Information

The JICA Study Team proposed to print the annotation shown below in the marginal information of the map.

"**This map was prepared jointly by Japan International Cooperation Agency (JICA) under the Japanese Government Technical Cooperation Program and the Government of Republic of Colombia.**"

IGAC requested to put the name of IGAC in the note as follows:

"**Este mapa fue preparado por la Agencia de Cooperación Internacional del Japón conjuntamente con el Instituto Geográfico Agustín Codazzi (IGAC) bajo el Programa de Cooperación Técnica del Gobierno del Japón en la República de Colombia.**"

After consultation with the JICA headquarters, The JICA Study Team agreed to include the name of IGAC. The annotation will be read as follows:

English sentence (reference) :

"**This map was prepared jointly by Japan International Cooperation Agency (JICA) and Instituto Geográfico Agustín Codazzi (IGAC) under the Japanese Government Technical Cooperation Program in the Republic of Colombia.**"

(4) Determination of the coastline

Locations of coastline captured in aerial photographs differs from one flight course to the other because of time gap between fight lines. Therefore, the JICA Study Team judged that the coastline shown on the aerial photos could not be used to draw coastlines. IGAC decided that it would provide the JICA Study Team with coastline location data.

(5) Use of Orthophoto and RECON in field survey

In the Inception Report of the Study the JICA Study Team proposed to use orthophotos printed on paper in the field identification survey. However, IGAC requested the JICA Study Team to use RECON GPS system in order to carry out the field survey efficiently in very limited time. The JICA Study Team agreed to use the RECON system on the condition that if any problem arises in the operation of the system, the conventional method of using paper printed orthophoto would be adopted.

(6) Information to be collected by field identification survey

1) Because all the annotation on the maps should be in Spanish, IGAC shall check spelling of the Spanish annotation and shall provide the JICA Study Team with the correct annotation in a digital format.

2) Before the start of the field identification survey, the content of information to be collected during the field identification survey was discussed and agreed upon between the JICA Study Team and IGAC. However, since inconsistency arose after the start of the field identification survey, the contents were checked again on February 10 and the JICA Study Team and IGAC confirmed that the original contents agreed upon before the start of the survey should not be changed.

(7) Scanning of the orthophoto used in the field identification survey

The JICA Study Team will take orthophotos used in the field identification survey to Japan at the end of the second stage of work in Colombia. IGAC will keep the scanned image of the orthophotos.

(8) Purpose of the Study and scope of technology transfer

The purpose and the contents of the Study were explained in the Inception Report and also during the initial meetings between the JICA Study Team and IGAC in August 2005. However, in order to make the understanding about the purpose and the scope of work very clear, the JICA

Study Team explained them again including the scope of work of the Self Sustainability Analysis. Particularly, it was confirmed that IGAC is responsible for the production of maps and basic GIS data for 100 municipalities.

As for the scope of the technology transfer, it was confirmed that the emphasis would be placed on the quality control and production management which are required in mass production of maps and basic GIS data.

(9) List of 100 municipalities
After reviewing the list of 100 municipalities which was presented to the Preliminary Study team in March 2005, IGAC provided the JICA Study Team with the revised list attached to this Minutes of Meeting.

3.4 Interim Report Meeting

In order to report the activities between August 2005 and June 2006 and also to discuss the work plan between July 2006 and the end of the project, the JICA Study Team made Interim Report and presented to IGAC. Meeting on this report was held on July 14, 2006 (Figure 3-2). The items discussed and confirmed are as follows (Appendix 3).

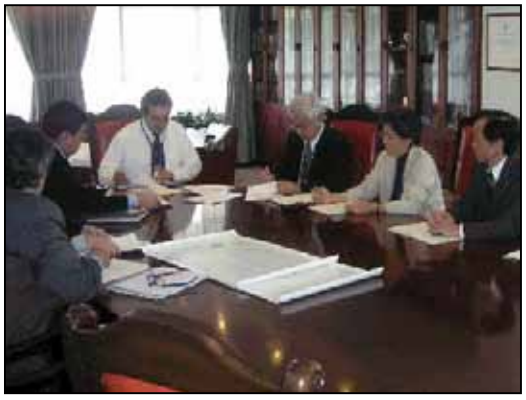



Figure 3-2 Interim report meeting

3.4.1 Interim Report Meeting

(1) The JICA Study Team explained the contents of the Interim Report to IGAC. IGAC suggested minor changes mostly in wording and place names and requested to add description on the instruments and equipment procured by JICA for the Study including the reasons for the selection of the procured brand. After the correction, the JICA Study Team and IGAC agreed on the contents of the Interim Report.

(2) IGAC also requested the JICA Study Team to make a digest version of the report so that IGAC can distribute them to its regional offices and also to relevant organizations. The JICA Study Team agreed to make the digest version in digital format so that IGAC can make necessary number of printed copies from it.

3.4.2 Issues related to the second stage of the study

(1) Determination of the coastlines

Based on the agreement made in the first stage of the Study, the JICA Study Team requested IGAC to provide data on the coastlines which should be drawn on the 1/2,000 maps now being produced. IGAC informed the JICA Study Team as follows:

1) Coastlines which are captured on aerial photos should be drawn as the coastlines on the map. Disconnection of coastlines between adjacent flight courses can be smoothed out manually during the mapping process.

2) In the marginal information area of the map sheet, an explanatory note will be inserted to explain the method of the determination of the coastlines. This note will be made by IGAC in Spanish and provided to the JICA Study Team. Also, this marginal note shall appear only on map sheets which have coastlines in it.

The JICA Study Team agreed with the IGAC's proposal on the coastline.

(2) Inspection of annotation

In the first stage, IGAC and the JICA Study Team agreed that IGAC should take responsibility for the spelling of map annotation. The JICA Study Team asked IGAC to correct annotations which were found incorrect or doubtful during the mapping process in Japan. IGAC agreed to inspect the annotation and make corrections if necessary.

(3) Returning negative film

In the first stage of the Study, the JICA Study Team brought seven rolls of aerial negative film covering the Study area to Japan to carry out the mapping work. Since all the work in which negative film is used were completed, the JICA Study Team informed IGAC that the team would return every negative film by the end of October 2006. IGAC agreed with this plan.

(4) Technical training in Japan

IGAC asked the JICA Study Team to give IGAC counterpart personnel opportunities to receive

training in Japan related to the Study as previously requested in the Minutes of Meeting on the Scope of Work of the Study. IGAC also stated the importance of sending its counterpart personnel to Japan for the inspection and authorization of the maps being produced by the JICA Study Team in Japan. The JICA Study Team agreed to convey the message to JICA.

3.5 Draft Final Report Meeting

Meeting for the explanation and discussion of Draft Final Report was held between IGAC and the JICA Study Team on September 2007. The JICA Study Team explained the outline of the project and result of the product.

After the explanation and discussion between IGAC and the JICA Study Team, IGAC confirmed about some numerical value that was quoted in the report, and IGAC accepted the contents of draft finals report.

JICA Study Team explained to IGAC that the final result will be delivered to the JICA headquarters and will be delivered to IGAC via JICA Colombia office.

A final result of the study is as follows:

A delivery item to IGAC

- Final reports
  - ・ Main report — Twenty (20) copies in English and ten (10) in Spanish (Ten (10) of each version will be giving to IGAC)
  - ・ Summary — Twenty (20) copies in English and ten (10) in Spanish (Ten (10) of each version will be giving to IGAC)
  - ・ Summary in Japanese — Ten (10) copies in Japanese
- Result article
  - ・ Polyester base map — Two (2) sets (3 cities(419sheet)×2 sets)
  - ・ Digital map data file — Five (5) sets (CD)

The item, which was already delivered to IGAC, is as follows:

- Other items
  - Field survey result One (1) set
  - Aerial triangulation result One (1) set
  - GIS model system One (1) set

- Borrowing article which was returned to IGAC

  Aerial photo (1/10,000)

Negative film	One (1) set
Digital data file	One (1) set
Contact print	One (1) set
Aerial photo index map	One (1) set

A set of negative film and the contact print was returned to IGAC after the work was completed. Digital map data file was created using a digital data file, which was scanned from negative film by IGAC. And aerial photo index map was delivered to IGAC with overlaying a satellite image.

After the Draft Final meeting, Minutes of Meeting on Draft Final Report was prepared and signed between IGAC and the JICA Study Team on October 22, 2007. The copy of Minutes of Meeting is shown in Appendix 4.

3.6 Dealing with flexibility

Beside from official meetings and discussions, the JICA Study Team and IGAC had frequent meetings to discuss technical issues and exchange opinions. The JICA Study Team tried its best to deal with requirements from IGAC in flexible manner. For instance, IGAC requested the JICA Study Team to change map symbols even after they were officially determined in February 2006. The JICA Study Team discussed the issue with IGAC and did its best to incorporate such changes.

CHAPTER 4 DESCRIPTION OF IGAC

In order to make plan for technology transfer, to analyze self sustainability of the 1/2,000 scale mapping program as well as to make plan for the promotion of GIS, it was necessary to understand the characteristics and capability of IGAC. This chapter summarizes the information collected by the JICA Study Team on IGAC.

4.1 Organization of IGAC

4.1.1 History of IGAC

IGAC is the national survey and mapping organization of Colombia and a leading geographic institute in Central and South America. The institute was established in 1935 as Geographical Military Institute, an organization affiliated to the Colombian military. In 1940, the institute was renamed as Geographical Military and Cadastral Institute and belonged to the Ministry of Treasury and Public Credit. From 1999, by the Resolution 1174 of 1999/6/29, the institute belongs to DANE. Current legal background of IGAC's activities is Decree 208 of 2004.

While IGAC is an independent institute, its management is supervised by a board which consists of representatives of other ministries and public agencies. Member of the board area as follows:

- DANE (Departamento Administrativo Nacional de Estadistica)
- Ministerio de Medio Ambiente, Vivienda y Desallojo Territorial
- Ministry of Defense
- DNP (Departamento Nacional de Planeacíon)
- Presidential office

4.1.2 Organizational structure of IGAC

IGAC consists of three divisions and one research and development institute.
Organization chart of IGAC is as shown in Figure 4-1.

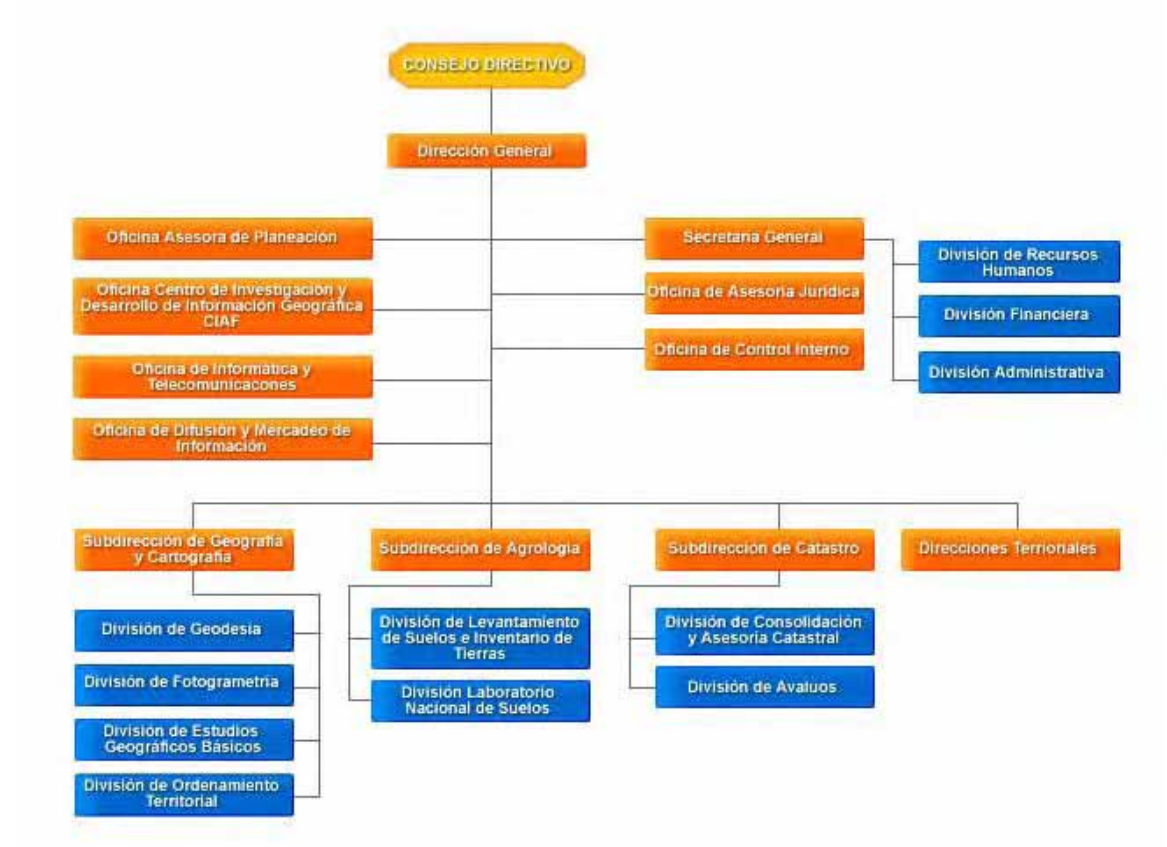


Figure 4-1 Organization chart of IGAC

CIAF stands for Center for Interpretation of Aerial Photographs. As the name indicates, CIAF was a specialized institute within IGAC responsible for aerial photo interpretation. Current official name of the institute is “Centro de Investigacion y Desarrolo de Information Geografica”, but traditional name of CIAF is still being used.

CIAF is responsible for technical research and development within IGAC. The institute is also expected to lead the construction of national spatial infrastructure of Colombia. CIAF also has many training courses in geodesy, photogrammetry, remote sensing and mapping. Lecturers are recruited from various sources including universities and former IGAC engineers.

4.1.3 Role of IGAC

As the organization chart indicates, IGAC has five major roles.

- Production of maps and geographic information
- Maintenance and management of cadastral data
- Production of soil data
- Research on the use of GIS

- Research and development of technologies in geodesy, photogrammetry, remote sensing and the use and management of geographic information.

As for the cartographic work, IGAC is responsible for the production of 1/1,500,000, 1/500,000, 1/100,000, 1/50,000, 1/25,000, 1/10,000 and 1/2,000 topographic maps of Colombia.

National survey and mapping institute in the world can be divided into two types. One group has capability to produce maps by themselves. The other group contract out map production to a private sector. IGAC has characteristics of the both groups.

One unique feature of IGAC is that IGAC is not only responsible for topographic map production but also for the maintenance and management of cadastral data. This fact seems to be related to the contents of field identification survey. In IGAC's field identification survey wider variety of data is collected comparing to the survey for ordinary topographic mapping work.

4.2 Operation Plan

According to Report of the Management Plan published by IGAC in February 2006, pre-conditions of IGAC's five years plan covering 2005 - 2010 were as follows:

- Budget from the central government shrunk and introduction of modern mapping technologies is delayed. However, IGAC has to carry out its mission.
- After 1994, IGAC is updating maps according to the budget, but still parts of the country are not yet updated.
- Since 1997 IGAC has been the leader of ICDE (Infrastructura Colombiana de Datos Espaciale). The purpose of ICDE is to promote the production of geographic information as well as the access and usage of geographic information.
- Make development plan according to "Hacia un Estado Comunitario"
- Innovate organization according to the Decree 208 of 2004.
- Make necessary maps by DANE-IGAC program for Year 2005 Census.
- Modernize cadastral management with the assistance from IDB.
- Activate mapping system with the assistance from EU.
- Make quality control mechanism to get ISO9001:2000 certificate.

In consideration of the above listed conditions in which IGAC exists, IGAC sets practical goal and strategy for map and GIS data production as shown on Table 4-1.

Table 4-1-1 Objective of IGAC for the Year 2006

Purpose and Strategy	
1. Production and updating of basic digital geographic data at national level	
1.1	Implementation of projects concerning the production of geographic data, maps, agrology, and cadastral data for national development
1.2	Strengthening production facilities (Strategic partnership)
1.3	Increase income to cover production costs of basic geographic information
2. Construct geographic information management model of IGAC and promote the use and exchange of spatial data infrastructure technology	
2.1	Implement survey and development projects on high priority issues of IGAC
2.2	Transfer technology on geographic information through knowledge management programs.
2.3	Lead the establishment of standard for the production of geographic information.
2.4	Promote the development of spatial data infrastructure at organizational, national and international level.

Table 4-1-2 Objective of IGAC for the Year 2007

Purpose and Strategy	
1. Produce and upgrade basic digital geographic information covering the nation	
1.1	Implement project for the production of geographical, cartographic, agrological and cadastral information for the integral development of the country
1.2	Strengthen production infrastructure
1.3	Generate revenues for the financing of the production of basic geographic information of the country.
2. Implement the management model of geographic information of IGAC and promote them	
2.1	Carry out IGAC's high priority projects of investigation and development
2.2	Adapt, transfer and promote knowledge in management of the geographic information
2.3	Lead the establishment and application of standard of geographic information
2.4	Implement development and infrastructure of space data in the environment of national and international institute

Objectives of IGAC for 2006 and 2007 are basically equal. From the fact that "Strengthen production infrastructure" is listed again in 2007, it is understood that IGAC is continuously improving its production capacity.

4.3 Budget

Total budget of IGAC for the year 2005, 2006 and 2007 are as follows:

2005: CO$84,260,264,321

2006: CO$53,166,500,053

2007: CO$72,823,500,000

Year 2005, 2006 and 2007 budget for mapping are as shown on Table 4-2. In Year 2005, special budget for DANE mapping is included.

Table 4-2 Mapping Budget of IGAC Year 2005, 2006 and 2007(CO$)

Cost Item	2005	2006	2007
Total mapping budget	26,187,569,000	480,000,000	8,443,000,000
1. Production and updating of general maps	300,000,000	300,000,000	4,108,000,000
2. DANE	10,987,569,206	0	0
3. Contract with other ministries	0	0	4,280,000,000
4. System modernization	14,900,000,000	180,000,000	55,000,000

IGAC has three sources for its budget.

- Budget of the central government (Ministry of Treasury)
- Budget comes from the contract with other ministries such as DANE
- Budget from IGAC's own income generated by selling its products

Budget changes according to the policy of central government. For instance, in 2007 IGAC's map production capabilities have to be concentrated on the production of 1/25,000 scale topographic maps. Incidentally, for the basic operational costs and for strategic project costs, budget from the central government is allocated.

IGAC's budget preparation procedure is as follows:

(1) Preliminary discussion on next year's budget starts before September between IGAC and DNP

(2) Preliminary budget plan is made in September and October based on the results of preliminary discussions between IGAC and DNP.

(3) Around end of October, DNP presents its budget plan to IGAC.

(4) IGAC will revise its original budget plan according to DNP plan in November and December.

(5) End of December, IGAC submits its final budget plan to DNP.

(6) End of March, DNP starts to send budget to IGAC

4.4 Income

IGAC makes efforts to promote the sale of its products. New types of products are being produced at rapid pace. Revenue from the sale of the products was CO$7,127,400,000 in 2005 and CO$8,034,000 in 2006.

Income from the sale of the products is relatively small in comparison with the expenditure of IGAC but it is important because IGAC has control over the use of the income.

4.5 Situation of map and geographic information production

1/100,000 scale map production was completed in 2006. Production of 1/2,000 and 1/25,000 scale maps being implemented and budget is needed. Summary of the coverage of maps of Colombia is as summarized on Table 4-3.

Table 4-3 Map Coverage

Scale	Coverage as of July 2007
1/1,500,000	100%
1/500,000	100%
1/100,000	100%
1/50,000	Approx. 20%(Analogue)
1/25,000	Approx. 70%(Analogue), 5% (Digital)
1/10,000	Approx. 30% (Analogue), 5% (Digital)
1/2,000	251 Municipalities, 48,000ha in 2007

4.6 Production capacity of the Division of Photogrammetry

For the production of photogrammetric maps and basic GIS data, there are two divisions under the Sub Directorate of Geography and Cartography. They are:

- Sub Division of Photogrammetry
- Sub Division of Geodesy

Their capacity is as described below.

4.6.1 Number of staff

First of all, IGAC staff is classified under the following categories.

(1) Administrative staff

- Director
- Sub-Director（Currently there are three sub-directors）
- Adviser: Consultants
- Chiefs of office and/or Chiefs of Division (15 people)

(2) Technical staff

- Coordinators
- Professionals
- Technicians

"Coordinators" are technical staff almost equal to Chief Engineers of other country. Although IGAC has very sophisticated system of planning and approval, recently efforts are being made to speed up decision making by simplifying reporting and approval process.

Number of staff working at Bogotá headquarters is 290 and those of regional office are 646. Number of staff of Sub Directorate of Geography and Cartography is as listed in Table 4-4. All of them work at the headquarters.

Table 4-4 Number of staff of the Sub Directorate of Geography and Cartography (2007)

	Coordinators		Professionals		Technicians	
	Officials	Contractor	Officials	Contractor	Officials	Contractor
Geodesia	2	0	18	10	1	17
Fotogrametria	3	0	8	8	14	25
Estudio Geograficos	1	0	9	3	4	4
Ordenamiento Territorial	1	0	8	0	14	0

It is clear that many Contractors are working as Professionals and Technicians. Since they are basically hired for specific projects for a limited length of time, their status is relatively unstable compared to Officials and it is also worried that part of technologies and experience gained by Contractors may not become the asset of IGAC. While the reducing the number of officials contributes to make a small government, it affects IGAC negatively as far as technical development or improvement is concerned.

Further, according to IGAC, total number of professional photogrammetrists of IGAC is about 30. This number is small if a large quantity of mapping work has to be implemented in relatively short period of time. This implies that using the production capacity of private firms seems to be imperative.

4.6.2 Training of technical staff

Various training courses are available at CIAF. Every year CIAF makes annual training program and send it to each Sub Directorate. Heads of the Sub Directorates select their staff who are going to take the training courses that year. Trainees need not pay tuitions. Also, if IGAC staff wishes, they are given opportunities to take higher academic degree at universities or institutes. However, it should be noted that above mentioned training opportunities are open only for legitimate staff of IGAC and not available to CONTRADISTA or temporary employee.

In addition to regular training courses given at CIAF, some software companies make their technical staff stationed within IGAC headquarters to provide on the job technical advice and instructions.

These kinds of training opportunities are not fully available to the staff of regional offices. While IGAC headquarters send its technical staff to local offices as instructors for training, regional offices seem to have more frequent or longer training programs.

4.6.3 Instruments and equipment

IGAC started digital mapping in 1990 when encoder was attached to Wild B8 analogue plotting machine. Analytical plotter Leica SD2000 and KERN DSR15 were introduced to IGAC in 1994. In 1999 the first soft copy stereo restitution machine was installed. And since 2005 IGAC was rapidly changing its photogrammetric mapping instruments to soft copy machines. JICA also provided an aerial triangulation system, a digital mapping system, a digital editing system and a GIS software in this study. Survey and mapping instruments of IGAC as of July 2006 are as listed on Table 4-5.

Table 4-5 Survey and Mapping Instruments of IGAC

Type of Instruments	Manufacturer	Name/Model	Type	Year procured	Con-dition	Qty
1. Field Survey Instruments.						
1) GPS	Leica	System500	520	1998	G	11
	Trimble			2001	R	1
	Leica			2002	N	1
	Leica			1999	G	1
2) Level	Leica	NA3	Geodetic	2005	G	3
3) Distance meter	Leica	702	Geodetic	2005	G	3
2. Aerial Photography						
1) Camera	WILD	RC-30		1994	G	1
	Vexel	Ultracam D		2007	G	1
2) Navigation System	IGI	CCNS 4		2003	G	1
3) Photo processing	COLEX	RTBW	12360	2005	G	1
4) Scanner	VEXCEL	UltraScan Manual and Automatic	5000	2005	G	2
3. Photogrammetry						
1) Aerial triangulation	BAE systems	SOCETSET MATCH AT		2000-2005		3
2) Restitution	INPHO	Summit Evolution		2006		3
	Leica	LPS		2005		5
	DVP	DVP		2006		8
	BAE systems	SOCETSET		2006		5
3) Editing	ESRI Bentley	ArcGIS MicroStation		2000-2005		25
4) DTM generation	BAE systems INPHO	SOCETSET MATCH-T		2004-2006		2
5) Orthophoto production	BAE systems INPHO	SOCETSET Ortovista		2004-2006		2

4.6.4 Assistance from other donors

EU, U.S.A., Sweden, and France were providing technical support to IGAC in various fields of survey, photogrammetry, remote sensing and GIS. Table 4-6 summarizes their activities.

Table 4-6 Summary of activities of donors other than JICA

Donor name	Main component of the project
E U	**Project Title:** Improvement Systems of Cartography of the Colombian Territory **Project Period:** 2003 – June 2007 **Objectives:** • Increase technical capacity of Colombia for the production and use of geographic information obtained by remote sensing techniques. **Contents:** • National Image Bank is constructed. • Procurement of hardware and software for digital basic and thematic mapping. • Consulting service for mapping process improvement. • Study on the marketing of cartographic products. • Training of government officers in remote sensing and digital mapping in collaboration with universities in Colombia.
U.S.A (NGA)	**Project Title**: Cartography Production **Objectives:** Exchange of products and services of mapping, photography and remote sensing between IGAC and NGA. Topics such as geographical names, geodesy and photogrammetry are also included. **Contents:** • Updating of 1/100000 scale Department Maps of Arauca and Casanare and also updating of vector data of 4 sheets of 1/100000 scale maps of Department of North of Santander.
Sweden	**Project Title:** GIS for Land Classification **Objectives:** Make conceptual and methodological design of GIS for national land classification.
France French Fund for World Environment (FFEM)	**Project Title:** Corine Land Cover Mapping **Objectives:** Production of CORINE Land Cover map at the scale of 1/100,000 for CORMAGDALENA. The project completed in May 2007.

4.7 Situation of IGAC regional offices

Currently, the productions of 1/2,000 scale digital maps are being handled by the headquarters of IGAC. Field work such as ground control point survey and field identification survey need large budget. If IGAC territorial offices can take over some part of the field work currently being carried out by the personnel of IGAC headquarters, cost saving is possible.

Also, the involvement of territorial office personnel who know their territory very well is the big benefit for the mapping work. With this hypothesis, the situation of territorial offices was surveyed. Offices in Cartagena, Santa Marta, Barranquilla, Cali, Manisalez and Perelia were visited.

4.7.1 Role of IGAC territorial offices

IGAC has total 22 territorial offices. They are under the Sub-Directorate of Cadastre. Their main role is the management of cadastral data including data updating. Territorial offices sell cadastral maps and data to the public. Currently, their involvement in topographic mapping is limited but IGAC is trying to train territorial office staff in field surveys for topographic mapping.

4.7.2 Technical capacity

Regional offices are equipped with cadastral GIS with the assistance from IDB. For cadastral data updating and management, every office has 2 to 3 field surveyors and 2 to 3 cartographic and GIS staff.

4.7.3 Issues

Most offices visited by the JICA Study Team feel that more comprehensive training in GIS is required for their staff. Particularly, more formal education and training will be required to handle problems associated with digitizing maps of unknown parameters or changing projection system from one to the other.

Further, most of the regional offices do not have experience in photogrammetric mapping. Therefore, training and education will be required in this field, too, if regional office staff is involved in topographic mapping process.

CHAPTER 5 1/2,000 MAPPING AND BASIC GIS DATA PRODUCTION IN THIS STUDY

In this chapter, the 1/2,000 scale maps and basic GIS data production processes employed in the study are described. As for very important things, they are summarized in Chapter 8.

5.1 Preparatory work in Japan

Information and material collected by the Preliminary Study Team and also by the JICA Study Team were analyzed in order to make basic strategy for the Study. Particularly the following two thins were analyzed.

(1) IGAC's method of 1/2,000 scale digital maps and basic GIS data. Also, the present situation of the use of maps and GIS data.

(2) Contents of POT. Particularly, contents of maps, GIS data and data catalogue required for POT.

Plan for aerial photography and ground control point survey were also prepared. Although aerial photography and ground control point surveys were to be undertaken by IGAC, the JICA Study Team made its own plan in order to estimate the total volume of work. The JICA Study Team used basic information and maps collected by the preliminary study team.

Results of the preparatory work listed above, the JICA Study Team compiled its implementation plan as Inception Report.

5.2 Aerial photography and scanning

5.2.1 Aerial photography

Aerial photography and scanning of the aerial photos were undertaken by IGAC before the JICA Study Team visited Colombia in August 2005. Plan for aerial photography was also made by IGAC.

(1) Specifications of aerial photography

Scale:	1/10,000
Forward overlap:	80%

Side lap:	30%
Type of photos:	Black and white photos
Method:	Kinematic GPS photography

IGAC tried to use Kinematic GPS aerial photography method. However, in Cartagena area, GPS receiver on a ground station was unstable and could not get useful data.

Further, IGAC has been reviewing percentage of forward overlap by referring to specifications used in other countries. And IGAC decided to use 80% overlap from the aerial photography for this Study.

(2) Instruments used in the aerial photography

Aerial camera:	Zeiss RC30
Lens:	15/4 UAG-S with focal length of 152.49 mm
Navigation system:	CCNS

(3) Accuracy control

IGAC checked the quality of the aerial photos based on its own standard and the results of the inspection were compiled on accuracy control sheets. Items inspected were flight altitude, flight course, forward and lateral overlap, tilting, cloud coverage and image quality including existence of halation (Figure 5-1).

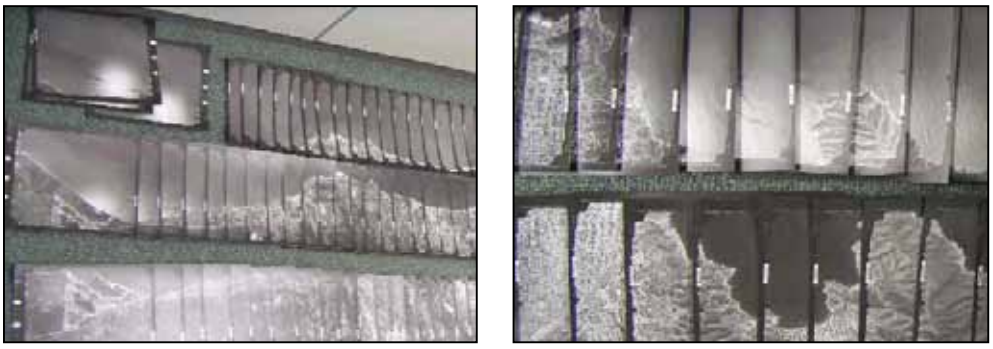


Figure 5-1 Aerial photos

(4) Results (Number of photos)

Santa Marta area:	Approximately 330 photos
Cartagena area:	Approximately 380 photos
Metropolitan area of Barranquilla:	Approximately 620 photos

The flight index map is shown in the Figure 5-2.

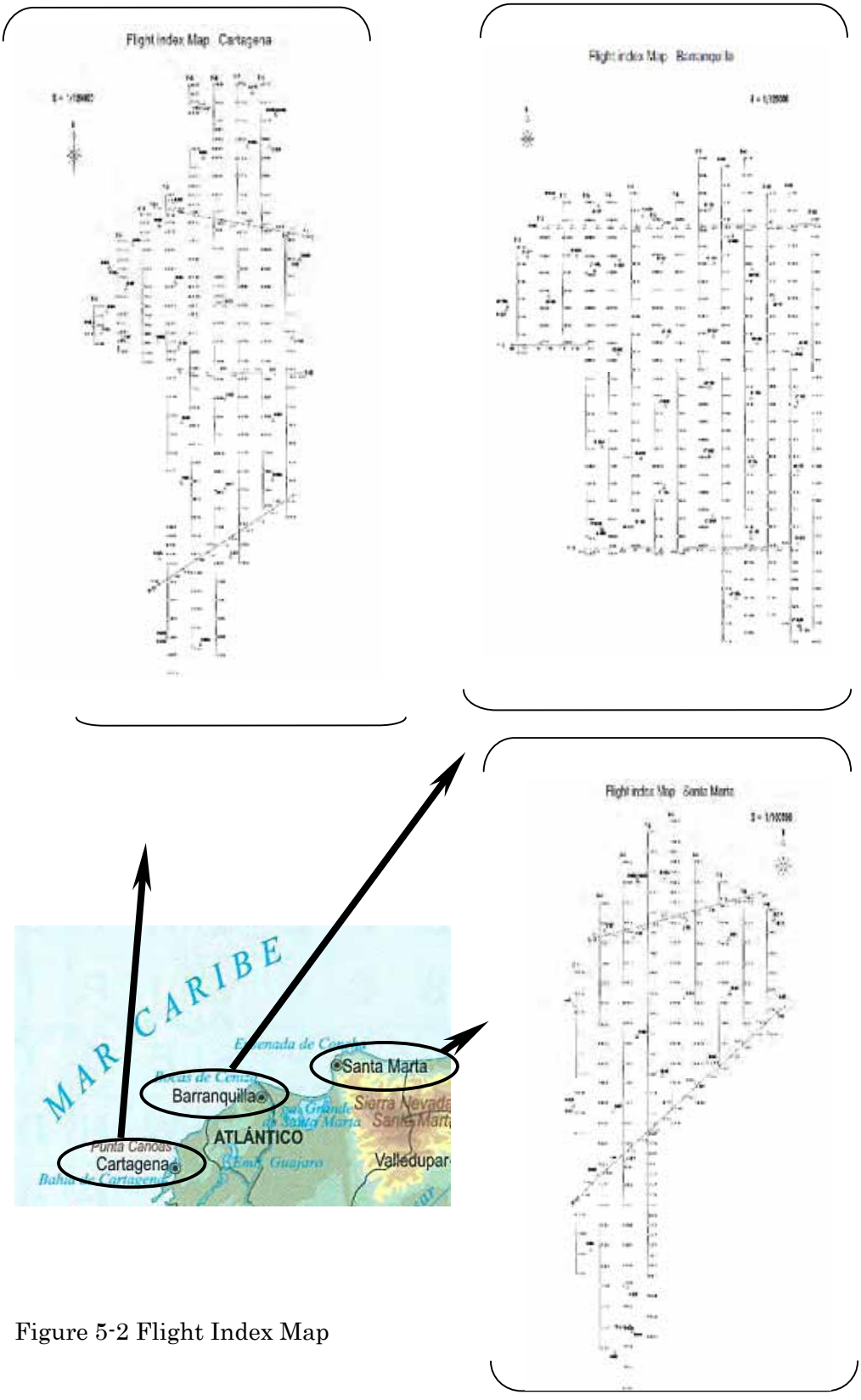


Figure 5-2 Flight Index Map

5.2.2 Scanning of aerial photos

IGAC made digital images of the aerial photos in TIFF format, by using VEXEL Ultrascan5000. Setting selected by IGAC for scanning was:

Gray scale: 256 levels
Scanning resolution: 15 microns (Approx. 1600dpi)

Size of one image file was 221MB. These image files were provided to the JICA Study Team. The JICA Study Team also rented original negative film from IGAC and brought it back to Japan. The reason for renting negative film is as follows:

- Usually, aerial film scanning is carried out under strict quality control such as scanner calibration and placing a scanner on a very stable bench.
- This kind of trouble is detected during aerial triangulation process by large residual error in the distance between fiducial marks or by the trouble that elevation measurement is impossible.
- If this kind of trouble happens, film must be scanned again.

5.3 Ground control point survey

5.3.1 Collection of data on existing GPS points and bench marks

The JICA Study Team collected information required for the subsequent survey and mapping work from IGAC. They are basic parameters for survey and specifications for 1/2,000 scale mapping and also the coordinates of existing geodetic control points to be used in ground control point survey.

(1) Basic specifications for survey

Like in Japan, in Colombia, a new geodetic system based on ITRF and old system exist. Old system uses Heyford as reference ellipsoid. Old system is called BOGOTA and the new system is called MAGNA=SIRGAS. Existing topographic maps made before the establishment of MAGNA-SIRGAS are based on BOGOTA system. The topographic maps made in the study are based on MAGNA-SIRGAS.

Table 5-1 shows the difference in the coordinates of origins in each zone between MAGNA-SIRGAS and BOGOTA.

Table 5-1 Origins of MAGNA-SIRGAS and BOGOTA

Las coordenadas MAGNA de los origenes Gauss-Kruger en Colombia corresponden con:

Origen	Coordenadas Elipsoidales		Coordenadas Gauss-Kruger	
	Latitud(N)	Longitud(W)	Norte(m)	Este(m)
Bogotá-MAGNA	4°35′46.3215″	74°04′39.0285″	1 000 000.0	1 000 000.0
Este Central-MAGNA	4°35′46.3215″	71°04′39.0285″	1 000 000.0	1 000 000.0
Este Este-MAGNA	4°35′46.3215″	68°04′39.0285″	1 000 000.0	1 000 000.0
Oeste-MAGNA	4°35′46.3215″	77°04′39.0285″	1 000 000.0	1 000 000.0
Oeste Oeste-MAGNA	4°35′46.3215″	80°04′39.0285″	1 000 000.0	1 000 000.0

Las coordenadas en Datum BOGOTA de los origenes Gauss'-Kruger en Colombia corresponden con:

Origen	Coordenadas Elipsoidales		Coordenadas Gauss-Kruger	
	Latitud(N)	Longitud(W)	Norte(m)	Este(m)
Bogotá-BOGOTA	4°35′56.57″	74°04′51.30″	1 000 000.0	1 000 000.0
Este Central-BOGOTA	4°35′56.57″	71°04′51.30″	1 000 000.0	1 000 000.0
Este Este- BOGOTA	4°35′56.57″	68°04′51.30″	1 000 000.0	1 000 000.0
Oeste- BOGOTA	4°35′56.57″	77°04′51.30″	1 000 000.0	1 000 000.0
Oeste Oeste-BOGOTA	4°35′56.57″″	80°04′51.30″	1 000 000.0	1 000 000.0

As the above table shows geographic coordinates of origins changed by changing geodetic system from BOGOTA to MAGNA-SIRGAS. Therefore, when topographic maps made previously are overlaid onto the maps made in this Study, coordinate transformation is required. Parameters defined by IGAC for 1/2,000 scale topographic maps are as follows:

- Geodetic system: MAGNA-SIRGAS
- Reference ellipsoid: GRS80
- Origin of horizontal position: Bogotá origin
- Origin of vertical position: 2,579.118 m

(2) Coordinate System

Colombia has two types of coordinate systems. One is for small scale maps and the other is for large scale maps.

1) For small scale maps

Coordinate system for small scale maps covers Colombia by dividing the country by total five 3

degree width zones, namely, WW, W, Bogota, E and EE. The study areas belong to zone Bogota.

XY coordinates of origin of each zone are defined as 1,000,000 meters respectively. Scale factor is 1.0000. This coordinate system is supported by GIS software such as ArcGIS.

2) For large scale maps

For large scale maps such as 1/2,000 scale maps, IGAC sets local coordinate system for almost every municipalities or local areas. This means almost every city has coordinate origin in their geographical centers. Therefore, the number of local coordinate system is very large. Coordinate value of each origin is not (0,0) but given the same coordinate value of the coordinate system for small scale maps.

Projection method of the local coordinate system is Cartesian. However, IGAC employs a special projection method where projection plane does not touch the surface of ellipsoid. The distance between the projection place and ellipsoid is adjusted according to average elevation of terrain in each coordinate system.

Distortion becomes large if the distance from the origin exceeds around 10 kilometers. However, according to IGAC, size of most of local cities in Colombia are within 10km x 10km. In the past, coordinate origins were moved according to the expansion of urban areas.

5.3.2 IGAC's Specifications for GPS survey

Ground control point allocation plan was made by the JICA Study Team for the mapping areas planned by IGAC.

Numbers of ground control points (GPS points) were, 24 points for Cartagena, 31 points for Barranquilla and 19 points for Santa Marta. Total number of the point is 74. The team also planned that length of direct leveling was 86 km for Cartagena, 158 km for Barranquilla and 95 km for Santa Marta. Total length of the planned leveling survey was 339km. Based on these figures, the team estimated that total 35 days and 4 survey teams would be required to complete the ground control point survey.

However, after arriving at Colombia and had a meeting with IGAC on technical specifications for the survey and mapping, the JICA Study Team found that IGAC usually does not use direct leveling method to measure the elevation of ground control points which are within 10

kilometers distance from the known points. The JICA Study Team also confirmed that the total volume of work for ground control point survey would not change too much. Therefore, the JICA Study Team agreed to carry out only GPS survey for the ground control point survey.

5.3.3 Selection of ground control points

The JICA Study Team explained the ground control point allocation plan prepared in Japan to IGAC. The point allocation plan was for block adjustment. GPS locations were marked on contact prints. Since aerial photos were taken with 80% overlap, every even number or odd number photos were used for this marking.

When the ground control point survey was started, mapping areas were already in rainy season and some GCP locations planned in Bogota were inundated. Therefore, new locations had to be found.

5.3.4 GPS observation

GPS survey was carried out by using Leica System500 receivers following IGAC's specifications for ground control point survey for 1/2,000 scale mapping. First, reference points were established. Then, by using two reference points a triangle was formed with a new point. Length of one side of the triangle was approximately 10 kilometers. And GPS observation was carried out on the three points to determine the coordinate of a new point. This session was repeated. Relative accuracy of the length measurement may be lower in this method than computing coordinates of survey points by network analysis. Advantage of this method is that total number of days for GPS observation is shorter because simultaneous observation by all the survey teams is not necessary. Also, even with this method, the accuracy is better than the specified level, H=V=0.25m.

In addition to the GPS survey, direct leveling was carried out between existing bench marks and pricking points for the purpose of checking the accuracy of elevation data measured by GPS survey.

Locations of ground control points are shown in Figure 5-3. Scene of the survey work is shown in Figure 5-4.

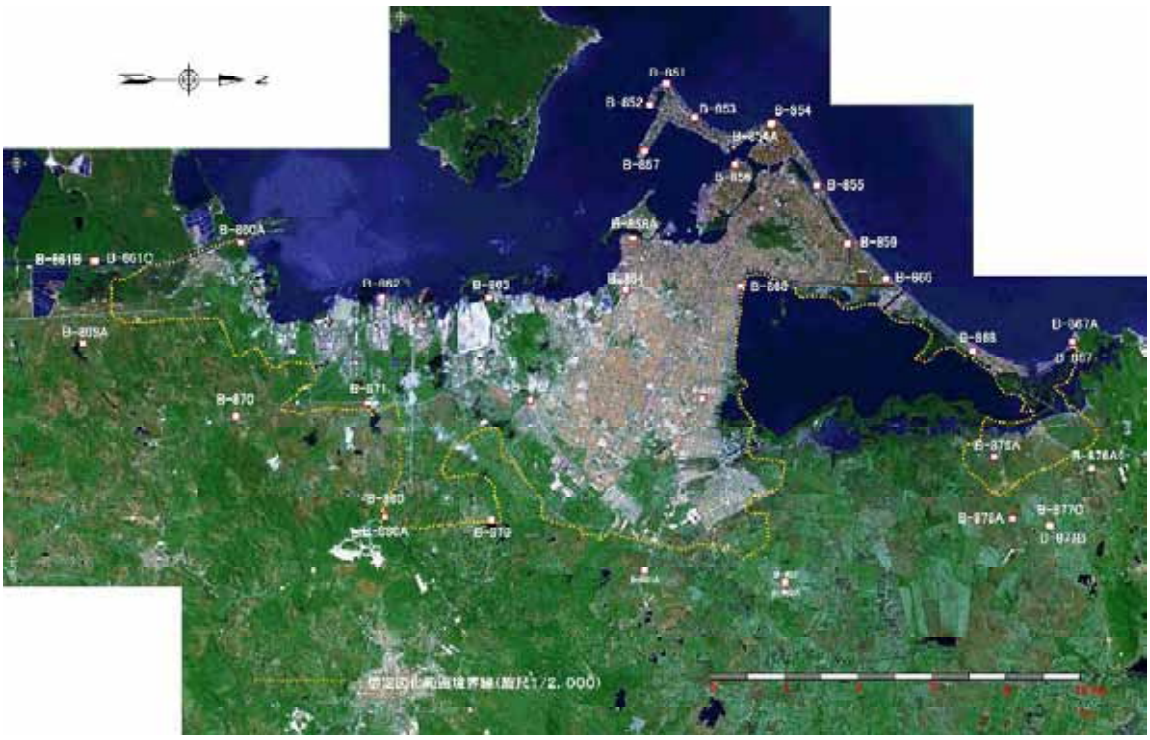


Figure 5-3-1 Location of GCP (Pricking points) Cartagena area

Figure 5-3-2 Location of GCP (Pricking points) Barranquilla metropolitan area

Figure 5-3-3 Location of GCP (Pricking points) Santa Marta area

GCP survey

Confirmation of point location

GPS observation

GPS observation at existing control point

Checking of elevation data by direct leveling

Figure 5-4 Ground Control Point Survey

5.3.5 Pricking of GCP's and making description of points

IGAC usually use pricking method to identify the locations of GCP's on aerial photos. Aerial signals are not established before aerial photography. Pricking method is also employed in this study.

Pricking is a very important process which determines the accuracy of the mapping. The JICA Study Team confirmed that there were no pricking points whose locations causes problems in subsequent mapping process.

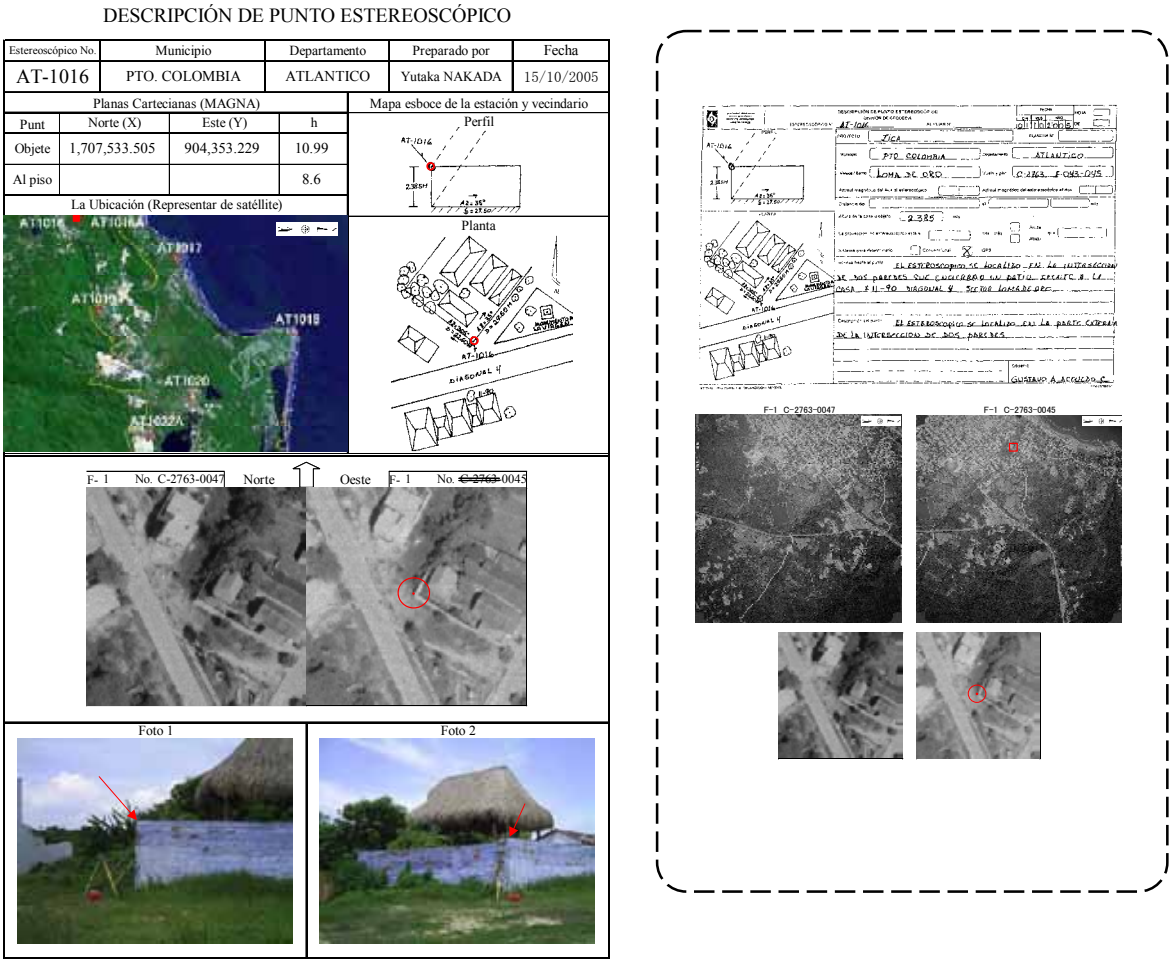
However, there were some ground control points whose elevation recorded on the coordinate list were doubtful. For these doubtful points, their elevation were examined by using ground elevation, GPS antenna height and sketches recorded on the description of points.

IGAC use contact prints for the pricking. However, the JICA Study Team recommended using enlarged photos to secure higher accuracy in the pricking. In the Study, 2 times enlarged image was made from scanned aerial photos and used for the pricking.

As for the point description of GCP's, two types of description were made. One follows IGAC method and the other one follow the design proposed by the JICA Study Team.

The JICA Study Team proposed to use satellite image obtained from WWW as background image so that relative locations of GCP's are easy to understand. Further, the team took photos of GCP's and their surrounding areas from relatively close distance and paste the image on the description. This image makes it easy to understand the elevation of the GCP's when aerial triangulation is carried out.

Description of control point was made by using a method widely used in Japan. (Figure 5-5)



DESCRIPCIÓN DE PUNTO ESTEREOSCÓPICO

Estereoscópico No.	Municipio	Departamento	Preparado por	Fecha
AT-1016	PTO. COLOMBIA	ATLANTICO	Yutaka NAKADA	15/10/2005

Planas Cartecianas (MAGNA)			Mapa esboce de la estación y vecindario
Punt	Norte (X)	Este (Y)	h
Objete	1,707,533.505	904,353.229	10.99
Al piso			8.6

La Ubicación (Representar de satéllite)

Perfil

Planta

F- 1 No. C-2763-0047 Norte Oeste F- 1 No. C-2763-0045

Foto 1 Foto 2

Japanese point description IGAC's point description

Figure 5-5 Point Description designed by the JICA Study Team (Left)

5.3.6 Computation of GCP coordinates

According to IGAC's work flow, computation of coordinates after GPS observation is not carried out while the survey team is still in the survey area. Field survey team brings back the GPS observation data to IGAC headquarters in Bogota and coordinate computation is done by engineers in charge of computation. One potential problem of this method is that if GPS data have some problem, the survey team has to go back to the field again.

Further, IGAC usually uses precise ephemeris for GPS coordinate computation and it takes about 15 days. The JICA Study Team proposed to use broadcasted ephemeris because the purpose is the calculation of ground control points for photogrammetric mapping. IGAC agreed and broadcasted ephemeris was used.

5.3.7 Quality control

All the GPS surveys were conducted according to IGAC's technical specifications and the results of the baseline analysis computation for all of the three mapping areas were within the specified limits. That is,

- Sigma value of the final computation was 0 – 2mm for horizontal and 1 – 5 mm for vertical.
- All the points pricked on photos were objects clearly identifiable on photos.

Aerial triangulation was carried out by using the results of the GCP surveys. No problem was observed in the identification of ground control points.

5.3.8 Output

Results produced in this process are as follows:

- Description of points of GCP's: 2 types
- Results of GPS computation: Coordinate list and accuracy table
- GCP location map

5.4 Aerial triangulation

The JICA Study Team carried out aerial triangulation in Japan.

5.4.1 Data used

- Aerial photo image data files
- Flight index maps
- Ground control point survey results (Coordinate list and point description)
- Camera parameters

5.4.2 Instruments used

- Observation of fiducial marks, GCP's and pass points: SocetSet
- Adjustment (Bundle block adjustment): In-Block

5.4.3 Procedures

Procedure of aerial triangulation is as shown in Figure 5-6.

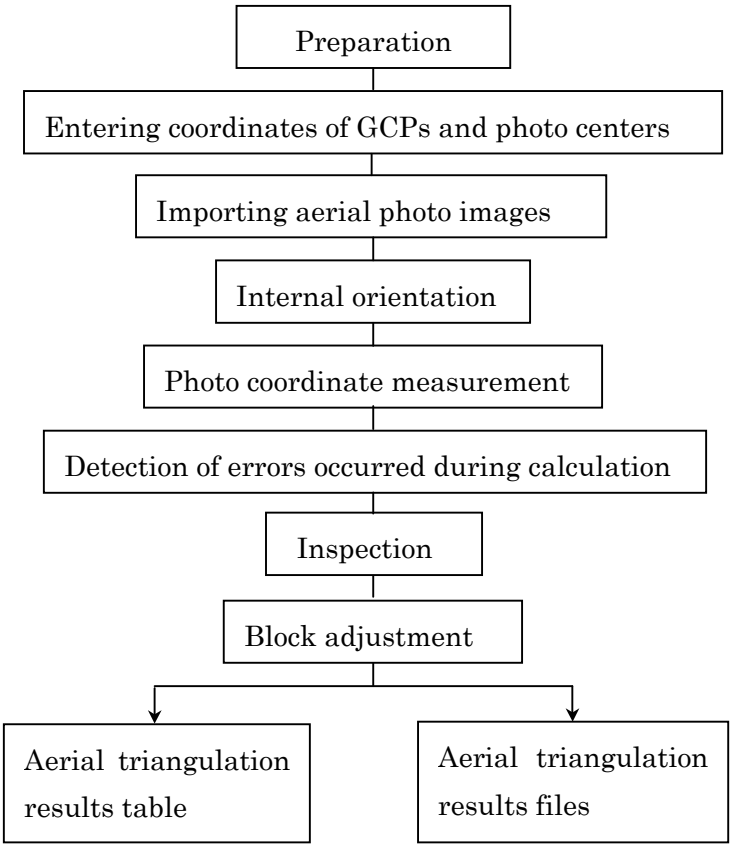


Figure 5-6 Procedure of aerial triangulation

5.4.4. Quality Control

Required accuracy was set as follows according to IGAC's technical specifications for aerial triangulation.

Residual of control points: For both vertical and horizontal +/-0.5m for 90% of the points.

The results were as listed below. The results of all of the three areas satisfied this accuracy requirement.

【Cartagena】 Models：198 Courses：12

Adjustment method: Bundle block adjustment

Number of control points		Number of points excluded		Residuals of control points				Bundle method	
Horizontal	Elevation	Horizontal	Elevation	Horizontal (m)		Elevation(m)		Horizontal(mm)	
				SD	Max	SD	Max	SD	Max
38	38	0	0	X=0.018	0.048	0.018	0.046	X=0.005	0.024
				Y=0.015	0.039			Y=0.005	0.022

【Barranquilla Metropolitan area】 Models：331 Courses：17

Adjustment method：Bundle block adjustment

Number of control points		Number of points excluded		Residuals of control points				Bundle method	
Horizontal	Elevation	Horizontal	Elevation	Horizontal(m)		Elevation(m)		Horizontal(mm)	
				SD	Max	SD	Max	SD	Max
41	42	0	0	X=0.233	0.554	0.191	0.469	X=0.005	0.027
				Y=0.183	0.401			Y=0.005	0.030

【Santa Marta area】 Models：175 Courses：11

Adjustment method：Bundle block adjustment

Number of control points		Number of points excluded		Residual of control points				Bundle method	
Horizontal	Elevation	Horizontal	Elevation	Horizontal(m)		Elevation(m)		Horizontal(mm)	
				SD	Max	SD	Max	SD	Max
26	26	0	0	X=0.253	0.646	0.291	0.628	X=0.004	0.024
				Y=0.175	0.367			Y=0.005	0.020

5.5 Digital Orthophoto Production

Orthophoto mosaic which were used in the confirmation of the extent of mapping areas and also in recording the results of field identifications survey was made by the JICA Study Team in Japan.

5.5.1 Generation of digital terrain model (DTM)

30 meter mesh DTM which is required to make orthophoto was generated by stereo matching method.

5.5.2 Orthophoto projection and mosaicing

Orthophoto was produced by using digital image of aerial photos, aerial triangulation results and DTM. Orthophoto was made for each model. They were put together and cut into the size of 1/2,000 scale map sheet. Orthophoto was used to determine the areas of maps produced in this study, to compile the results of field identification survey and also to check if every necessary geographic feature is checked in field identification survey.

5.6 Digital mapping

Digital mapping was carried out in Japan by using the results of field surveys conducted in Colombia.

5.6.1 System and data used

(1) System

- Zuka meijin (System developed by Asia Air Survey)
- SocetSet (BAE systems)
- Summit Evolution (INPHO)
- MicroStation V.8 (Bentley)

(2) Data

- Digital image of aerial photos
- Aerial triangulation results
- Description of ground control points

(3) Reference material

- CAD data file of annotation

- Map symbol and map style of IGAC (Version 2.0)

5.6.2 Results of digital restitution

Result of digital mapping was made in MicroStation DGN file format.

5.6.3 Identification of unclear items

The following items were listed to make material to be used in field identification survey.

- Items difficult to identify on aerial photo image during digital mapping process
- Geographic features which are not defined by IGAC's map symbol and map style.

5.7 Field identification survey

Field identification survey was carried out in three steps.

- Confirmation of IGAC's specifications and method
- Inventory survey
- Field survey

5.7.1 Confirmation of IGAC's specifications and method

(1) Specifications

There are three technical specifications of IGAC on field identification survey

Annex 2: Field identification survey

Annex 6: Unico de model

Annex 7: Map symbol

There are some inconsistencies among these three types of documents IGAC and the JICA Study Team agreed to carry out the field identification survey for the Study following Annex 2. However, two modifications were made. One is the use of orthophoto and the other is the use of GPS data recorder.

1) Field identification survey using orthophoto

Usually, enlarged aerial photos are used in field identification survey. However, often features located near the edge of each photo are left unchecked. One solution will be to reduce the number of photo sheet. The JICA Study Team used orthophoto assembled together to cover the same area of each map sheet.

Usually enlarged photos are used in field identification survey. However, if a large number of photos are used a chance of forgetting to write down the survey results

2) Use of GPS installed data recorder (RECON)

Main part of the field identification survey is the collection of annotation information. IGAC proposed to use data recorders with GPS in the field identification survey and the JICA Study Team agreed to try to use it. Since IGAC did not have experience in using the recorder, the JICA Study Team and IGAC counterpart engineers developed a method to use the recorder. Setting up of coordinate system, use of GPS function and record of collected data were checked. Training was also conducted.

(2) Procedures

IGAC's standard method for field identification survey is as described below.

1) Preparatory work

First the boundaries of the survey area are drawn on aerial photos. Then, geographic features to be checked in the field are marked. This process is called ILUMINACION. Geographic features marked will be waterways, road, railways, cultural facilities (schools, hospitals, churches and resort facilities). Annotations which were collected from existing information are also drawn. Aerial photos of odd number are used for this ILUMINACION work. Photos of even numbers are used in the field.

2) Field work

- Survey of geographic features

Illuminated features are checked in the field and the results of checking are written down on photos.

- Annotation survey

Road names are checked by referring to road signs. As for schools, if a building is shared by school and other user, then that building is not annotated as school. Major water bodies, mountains, hills, places and any other natural topographic features are emphasized. Churches are not classified according to religious sect.

- Colors used in the field identification survey

Blue:	Water body
Green:	Vegetation
Red:	Descriptive notes on the survey results
Purple:	Abandoned buildings or buildings with no walls
Black:	Names

Figure 5-7 shows the general workflow of field identification survey.

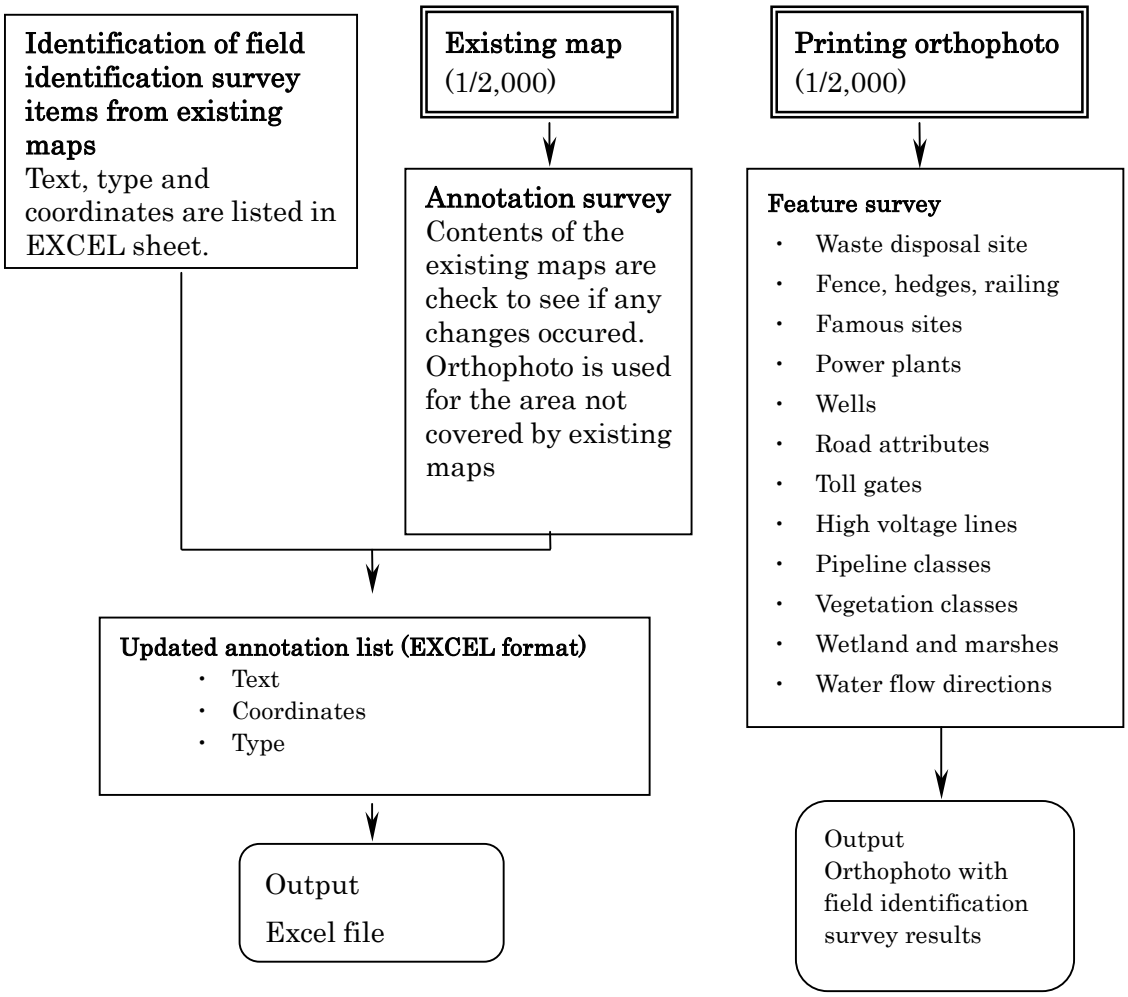


Figure 5-7 Field identification survey procedure

3) Provided material

Sample of place names list.

5.7.2 Inventory survey

In inventory survey the following information was collected. With this inventory work, the volume of field work is estimated.

- Existing maps and statistical data
- Name of administrative area and location of administrative boundaries
- Name and type of road and rivers
- Name and type of public facilities and major buildings
- Other relevant data

5.7.3 Field survey

Actual field identification survey was carried out by IGAC staff. Code numbers were used to show the results of field identification survey so that Japanese map editing staff can understand the kind of geographic features identified in the field. As for the annotation information, the JICA Study Team and IGAC agreed that IGAC makes complete dataset so that the JICA Study Team can use it without any further checking or modification. Procedure of the field identification survey is as shown in Figure 5-7.

(1) Inspection

Orthophoto with the result of field identification were inspected by the JICA Study Team members to check to see if any modification or improvement is required in survey method. Data collected by RECON were downloaded to PC for each map sheet and the JICA Study Team member checked the accuracy of location data. During the early stage of the survey, some unreliable data were identified. But with the progress of the work, data quality increased.

(2) Data compilation

Collected annotation data were converted into Shape File format for each map sheet. Then the data were displayed on monitor screen to make corrections. For the area where RECON was not used, location of annotation points marked on orthophotos were digitized and compiled as Shape File format.

(3) Output

Results of the field identification survey for each municipality are summarized on a Table 5-2.

Table 5-2　Output (Barranquilla, Cartagena, Santa Marta)

Output	Barranquilla	Cartagena	Santa Marta
Orthophoto with survey results	196　sheets	120　sheets	103 sheets
Annotation data（Shape file）	196　files	120　files	103 files

5.8 Digital editing

Original data made by digital mapping were editing according to Map Symbol rules.

5.8.1 System and data used

(1) System used:　MicroStation J

(2) Data used:

- List of geographic features

- Orthophoto with field identification survey results
- Digital mapping results

5.8.2 Digital editing procedures

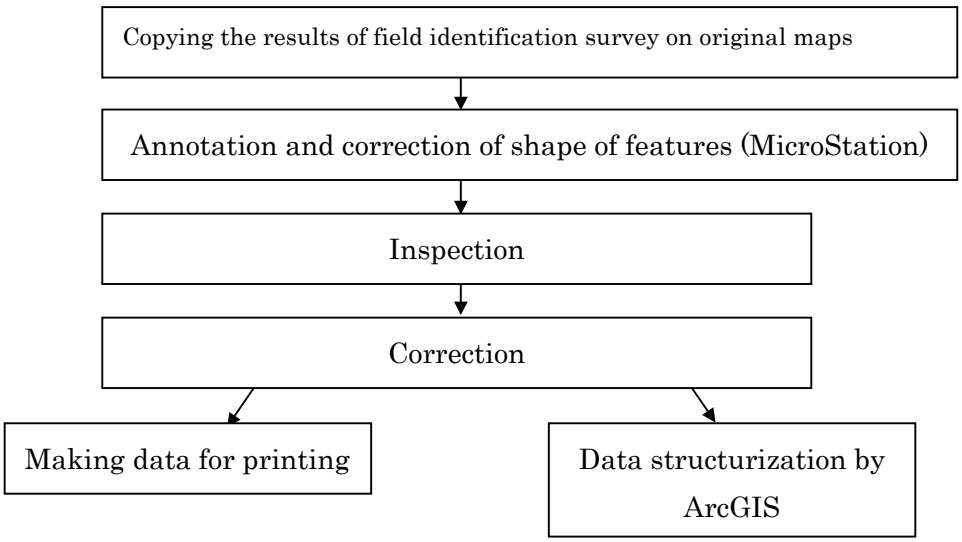


Figure 5-8 Map editing procedures

5.8.3 Quality control

Edited map data were plotted out on paper sheet and the following factors were checked.

(1) Completeness: All the geographic features are drawn according to map feature catalogue.

(2) Data acquisition rules: Data are captured according to the rules specified in the specifications.

(3) Accuracy of location: Positional accuracy of features drawn on the map is high

(4) Accuracy of classification: Correct classification of road and geographic features.

5.8.4 Output

Map data file. MicroStation DGN file format

5.9 Field completion survey

IGAC does not carry out Field Completion survey. In the Study, the JICA Study Team proposed

IGAC to add this process in order to introduce a Japanese method to IGAC.

The purpose of the filed completion survey was to check these items which found unclear even after map editing process. Items to be surveyed in the field completion survey were carefully checked and selected by IGAC surveyors and only those items which are really necessary to check for the 1/2,000 scale mapping were checked in the field. The results of the field completion survey were directly drawn on paper maps and brought back to Japan. As for annotation information, the JICA Study Team asked IGAC to review the spelling.

5.10 Editing after field completion survey

Second map editing work was carried out from late October 2006 based on the results of the field completion survey. Two major elements of the second editing were:

- Correction of geographic features and map symbols
- Correction of features which were not clear during digital restitution process
- Correction of marginal information whose contents were changed

5.10.1 Systems and data used in the editing

(1) System: MicroStation J

(2) Data

- List of geographic features (result of field completion survey)
- Results of field completion survey compiled on orthophoto
- Digital map data

5.10.2 Quality Control

It was checked if all the unclear parts were clarified and all the necessary corrections were made. If uncorrected items were found they were corrected during the inspection process.

5.11 Symbolization

After the digital edit was completed, topographic map data were compiled by modifying the position of place names and annotations to make map data for printing.

5.11.1 Systems and data used

(1) System: MicroStation

(2) Data: Edited map data

(3) Specifications: Map Symbol and Map Style (IGAC Version 2.0)

5.11.2 Quality Control

After modification for making map data for printing map, each sheet was inspected. Any mistakes found in the inspection were sent back to digital mapping or digital editing process and corrected.

5.11.3 Output

- Data file for map printing
- MicroStation DGN file and its plot file in Adobe Portable Document（Acrobat PDF）format

5.12 Issues and solutions

During the process of the Study some issues were found. The JICA Study Team provided solutions or advice to IGAC. And by the end of the Study, IGAC changed or improved its production method or process to avoid such problems.

5.12.1 Incomplete models

Some of the photos covering water areas in Cartagena and Santa Marta areas were found not to be correlated. In other words, there were some incomplete models. For example, sand bars in Cartagena were not covered by single course. For “Incomplete Models”, elevation of the water body was estimated from the elevation of nearby land area.

5.12.2 Numbering of photos

It was found that numbers of photos which were generated automatically by aerial camera, point number of airborne GPS data and file number of digitized aerial photos were not co-related. This caused much confusion in preparatory stage for aerial triangulation. It is recommended to review numbering rules or at least make some relational table.

5.12.3 Position of cross strips

IGAC flew cross strips which connect main flight courses. However, the positions of cross strips were not in designed in a way to reduce the number of ground control points.

5.12.4 Quality of the image of aerial photos

(1) Contents of the problem

After the JICA Study Team started aerial triangulation in Japan, it was found that color tone in some digital image was not continuous. Details are as follows:

- By enlarging the image up to pixel level, it was found that color tone of neighboring pixel is not continuous.
- In areas such as roof of buildings or surface of roads where color tone should be almost the same, color one of neighboring pixel changes randomly.

Because of these problems, it was very difficult to measure the elevation of flat surface such as rooftop and road surface during stereoscopic restitution process. Incidentally, this problem was not caused by shifting or scanning line usually caused by vibration during scanning process. After carefully examining the image, the JICA Study Team concluded that it would be possible to continue aerial triangulation and digital mapping with the scanned aerial photos provided by IGAC.

The JICA Study Team has never experienced the tone discontinuity problem before. For this reason, the JICA Study Team made scanned data in Japan from negative film by using the same type of Vexel Scanner. The result was satisfactory as shown in Figure 5-9.

Figure 5.9 Comparison of IGAC image and image scanned by JICA Study Team in Japan

The JICA Study Team concluded that some irregularity happened during film scanning process at IGAC and decided to check the scanning process at IGAC.

(2) Inspection of scanning process at IGAC

During the period the JICA Study Team stayed in Colombia between January and February 2006, the JICA Study Team checked IGAC film scanning process. The result was as described below (Figure-5-10):

- Vexel UltraScan 5000 was introduced by EU but IGAC staff did not receive sufficient training to use the machine.
- Aerial photo image scanned by IGAC for other project also had similar image problem.

And after observing the scanning method, it was found that IGAC operator set the scanning speed at the maximum level and also the operator set image resolution manipulation mode ON.

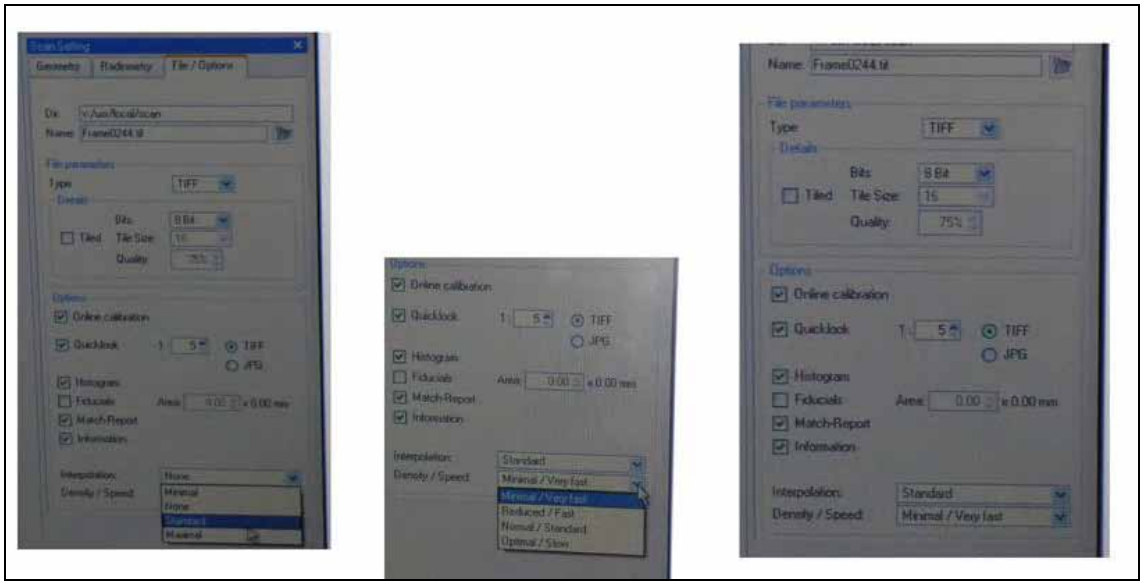


Figure 5-10 Setting of scanner

Usually it is not recommended to manipulate image resolution by interpolation method but nobody at IGAC knew about it. Also after some experiment it was confirmed that best quality image could not be obtained if scanning speed was set at maximum level.

The JICA Study Team advised IGAC operator to find the most suitable level of scanning speed by considering both image quality and scanning time.

CHAPTER 6. INSTRUMENTS AND EQUIPMENT PROCURED BY JICA

JICA donated to IGAC the following instruments and equipment including software required for technology transfer.

- Aerial triangulation system (Software)
- Digital mapping system (Software)
- Digital editing system (Software)
- Data structurization system (GIS Software)
- Networking equipment
- Printer
- Plotter

6.1 Procurement process

Donated systems and equipment were procured by JICA Colombia office by tendering. The JICA Study Team prepared a draft technical specification for the instruments and equipment. The preparation of the draft was done in three steps:

- Investigation of equipment of IGAC as well as its modernization plan
- Survey of price, method of procurement and possibility of maintenance of instruments and equipment listed as candidates
- Preparation of final specification sheet

6.1.1 Investigation of IGAC's equipment

Inventory of IGAC's photogrammetric equipment was made during the year 2005. It was found that:

- IGAC has more than one type of photogrammetric mapping system
- IGAC is still in the process of evaluating different types of photogrammetric mapping systems and has not reached any conclusion yet as for the selection of one particular system

After the investigation, the JICA Study Team decided to employ the following criteria in the determination of specifications for the procurement.

(1) In order to carry out technology transfer in very limited time, time required for learning basic operational skill of a system (software) should be minimized. For this reason, systems (software) should be selected among from the systems (software) already installed in IGAC.

(2) Systems and equipment to be procured should be the one which are suitable not only for technology transfer but also for actual map and GIS data production at IGAC.

6.1.2 Survey of price and availability of technical service

The JICA Study Team prepared a preliminary list of systems and equipment which can satisfy the selection criteria. Then, the information on sales agent, price and availability of technical maintenance services in Colombia were collected.

6.1.3 Preparation of draft specifications for JICA

It was the best if systems IGAC had already chosen were procured. JICA Study Team asked IGAC about the selection of systems. However, as for photogrammetric mapping work IGAC was still in the process of evaluating various different systems in the year 2005. Therefore, the JICA Study Team decided not to specify any particular system except for small parts of the system.

The name of the brand the JICA Study Team judged to specify and the reason for the selection is explained below.

(1) CAD software: Bentley MicroStation

- Bentley MicroStation is one of the most commonly used CAD software in photogrammetric mapping industry. All the digital photogrammetric mapping system the JICA Study Team listed as candidates uses MicroStation as CAD software to draw or edit vector data
- IGAC also was using MicroStation for map editing and IGAC cartographers were familiar with this software

(2) Word Processing, Spread Sheet、Database and Presentation software : Microsoft Office Professional Edition

- Widely used in Colombia and IGAC counterparts

(3) Software for editing and viewing raster image file：Adobe Photoshop CS 2

- Widely used in IGAC

(4) Software for editing and viewing large size graphic file (Drawing software) : Adobe Illustrator CS

- Widely used in IGAC

(5) GIS software: ESRI ArcInfo ver.9

- Widely used in IGAC and introducing other system will cause much confusion

The JICA Study Team made draft specification sheet and submitted it to JICA. The JICA Study Team added a note on the draft specification that as for aerial triangulation and digital mapping systems, hardware and software should be procured from one vendor otherwise system may not function properly.

6.2 Procured systems and instruments

As the results of tender by JICA Colombia office, the following systems and instruments were procured and installed in IGAC.

◆ Aerial triangulation system: One set
- ・LPS Stereo
- ・LPS Core
- ・LPS ATE
- ・LPS TE
- ・ORIMA TE GPS for LPS
- ・Hardware HP Workstation XW6200

◆ Digital mapping system: One set
- ・LPS Stereo
- ・LPS Core
- ・PRO600 FOR LPS/DPW
- ・MicroStation
- ・Hardware HP Workstation XW6200

◆ Digital map editing system: One set
- ・MicroStation
- ・Hardware HP Workstation XW4300

Digital editing system

◆ GIS

・ArcInfo9.2

・Hardware HP Workstation XW4300

◆ Printing devices

➢ Large format (A0 size) Color Plotter

・HP DESIGNJET 1055CM PLUS

HP DESIGNJET 1055CM PLUS

➢ Laser printer（Mono chrome laser printer）

・Epson Laser Printer 2420DN

Laser 2420DN

Other image processing software

・Microsoft Office Professional Edition

・Adobe Photoshop CS 2

・Adobe Illustrator CS

CHAPTER 7 TECHNOLOGY TRANSFER

Basic objective of this Study is to transfer technology for digital mapping and basic GIS data construction from the JICA Study Team to IGAC. However, being quite different from other survey and mapping organizations, IGAC staff already had experience and basic skills in operating digital photogrammetric instruments and software. Therefore, the JICA Study Team decided to provide advice mainly on the improvement in the efficiency of production.

As for survey and mapping work which IGAC carried out in Colombia for the Study, the JICA Study Team provided technical advice while working together with IGAC staff in Colombia.
As for some elements of map production which the JICA Study Team implemented in Japan, the JICA Study team members in charge of each process visited IGAC to review IGAC's method and to provide necessary advices.

7.1 Aerial triangulation and digital mapping

During the first field work in Colombia in 2005, the JICA Study Team explained the ground control point allocation plan for bundle block adjustment method before the start of ground control point survey.

The JICA Study Team member in charge of digital mapping visited IGAC from October 2006 for one month. And the member in charge of digital mapping reviewed IGAC's aerial triangulation and digital mapping process and found that IGAC operators had no problem in digital mapping. As for aerial triangulation, the member in charge of digital mapping concluded that by using automatic correlation function of software IGAC could carry out aerial triangulation without problem. Therefore, the member in charge of digital mapping taught IGAC staff a method to carry out aerial triangulation with manual correlation to deal with cases where automatic correlation is difficult.

7.2 Digital editing and symbolization

IGAC can carry out digital editing without any problem. So a JICA Study Team member in charge of digital editing and symbolization spent his time mostly in the discussion with IGAC on defining symbols for the 1/2,000 scale mapping for the three municipalities. The details of the discussion on the specifications for symbolization are summarized in Chapter 8.

7.3 Data structurization and making plot files

A JICA Study Team member in charge of data structurization and plot file production visited IGAC for one month from October 2006. He analyzed IGAC's structurization and plot file making processes and proposed data structurization plan. IGAC and the JICA Study Team had a series of discussion on the subject and decided the data structurization rule for the study. The specifications for data structurization are described in Chapter 8.

CHAPTER 8. DISCUSSION ON IMPORTANT TECHNICAL SUBJECTS

After reviewing IGAC's photogrammetric map production process, the JICA Study Team understood that training in the operation of mapping software and hardware is not necessary. IGAC already had operational skill for most of mapping systems or technical staff of software vendors who are stationed at IGAC was providing necessary assistance. For this reason, the JICA Study Team spent most of the time in discussion with IGAC on very fundamental rules of survey and mapping as well as on technical specifications. This chapter describes the discussion on important technical subjects.

8.1 Coordinate system employed by IGAC

The JICA Study Team understood IGAC's coordinate system as follows.

8.1.1 IGAC's local coordinate system

(1) Almost all of the 1099 municipalities have each own origin of coordinates.

(2) Previously, coordinates of these origins were unique to each coordinate system. But now, values of the coordinates of these local origins are set to the same VALUE of the coordinate system for smaller scale survey and mapping. This is confusing because it is difficult to tell if a set of coordinates of a point is of local coordinate system or that of small scale coordinate system.

(3) Basically earth surface is projected to a plane which touches the earth surface at one point. However, considering large difference in altitude in some areas, a plane is LIFTED from the earth surface.

(4) IGAC set a scale factor as 1.0000. Therefore, this local coordinate system can use within an area about 10km by 10km. This implies that in large cities, more than one local coordinate system is required.

8.1.2 Issues

The JICA Study Team assumes that this local coordinate system cause the following inconveniences.

(1) If many local coordinate systems exist for one area, ordinary users of geographic information will be confused.

(2) If many local coordinate systems exist, GIS software manufactures hesitate to make conversion program. Or, does IGAC have a plan to distribute conversion software to general public?

In case of ArcGIS Ver.9.1, the situation is as described below:

- ArcGIS has a number of projection parameters. One of them is "LOCAL (Cartesian)". This seems to be the closest parameters applicable to the situation of local coordinate system of Colombia. However, ArcGIS cannot deal with the vertical shifting of plane which is done by IGAC according to the average elevation of terrains.

(3) After checking some GIS data made by IGAC, it was found that parameters of ellipsoid used were different from that of GRS80. It seems that change of the size of ellipsoid is used as a substitute to the vertical shifting of planes. For ordinary GIS users, this kind of solution may be difficult to understand.

(4) In the future, geodetic control point network will be established in many municipalities. If coordinates changes over a short period time due to the move of origin, management of survey data will be very complicated.

One of the purposes of making GIS data and using GIS is to share geographical information by using the same coordinate system. Existence of multiple coordinate systems in small areas will make the use of geographic information difficult.

(5) Coordinate value of origin of local coordinate system are the same with the coordinate value of the coordinate system for small scale mapping. Coordinate values of both coordinate systems are identical at the origin of local coordinate system. Although coordinate values of the two coordinate systems are identical only at the origin of the local coordinate systems, this system is quite confusing for ordinary map users because it is difficult to identify the type of coordinate system only from coordinate values of points on maps.

8.2 Use of GPS installed data recorder (RECON)

IGAC used GPS installed data recorder for the first time in field identification survey. Advantages and disadvantage of the use of the recorder were clarified during the field identification survey. In future field identification survey it will be necessary to make work plan by taking considerations of both advantages and disadvantages of the recorder.

Good point of the recorder is that coordinates and text information on collected data stored in digital form and therefore can be transferred to mapping system with further digitization.

Disadvantage is that the system does not support Cartesian projection. Also, since GPS installed in the recorder measure the location of the receiver only by single positioning mode, positional accuracy is not so high.

By considering above discussion, the JICA Study Team recommends IGAC to use the recorder in the following manner.

- Type of work suitable for using the recorder: National Census in which the quantity of data collection is large and also every building or household must be visited.
- Type of work not suitable for using the recorder: Identifying and drawing items which are not clearly visible on aerial photos.

8.3 Data Catalogue

IGAC published various catalogues on geographic features. The JICA Study Team collected such catalogues and specifications and try to understand the relationship between them. However, after worked with IGAC counterparts, the JICA Study Team realized that actual survey and mapping work had not been implemented according to existing catalogue and specifications. Data catalogue is the base of map making and also deeply related to the construction of GIS data. Followings are the understanding of the JICA Study Team on catalogues and also issues the JICA Study Team recognized on catalogue.

8.3.1 Type of Catalogues

Since the start of the project the JICA Study Team collected the following data catalogue available at IGAC.

(1) Modelo de datos Catalogo de Objetos CO-25 ver2(1995)..... A
This is a catalogue of geographic information and map symbols basically for 1/25,000 mapping.

(2) Modelo de datos urbano catalog de objectos CO-U y Catlogo de simbolos CS-2000 (1996) ..... B
This catalogue was published by Subdireccion Cartografia.（In this report, we call this catalogue as CO-U catalogue and CS-2000 symbol data.）

(3) PROYECTO DE NORMA TÉCNICA NTC COLOMBIANA 2001-04-11
CATÁLOGO DE OBJETOS GEOGRÁFICOS BÁSICOS C
Este proyecto de norma técnica será sometido a consulta pública en el primer semestre de 2001.

(4) Unico de modelo ..... D

(5) GEODATABASE catalogue made in April 2006 ..... E

8.3.2 Purpose and characteristics of these catalogues

The JICA Study Team analyzed the characteristics of these catalogues. As the result of our analysis the JICA Study Team thinks that the characteristics of each catalogue is as follows.

- A and B has a characteristic of Inventory Catalogue which covers geographic information made or possessed and managed by four sub directorates of IGAC.

- A and B do not have any explanation on how to handle data on a specific software to be used in data production. These documents are made based on ATOKIS of Germany.

- C was made in the movement of standardization of geographic information based on ISO.TC211. For the production of this catalogue C, organizations other than IGAC also participated.

- D and E looks like catalogues used in IGAC for data production.

- As for catalogue D, the JICA Study Team thinks that D was made based on B. That is, D extracted only mapping items and attributes of B for the purpose of map production.

- Based on these catalogues, materials such as map feature code table, code table for editing (Symblogia2000ParaMicrostation), etc. were prepared for each part of the map production process by adding information necessary for each process. The types of information added are: Information required to be used by a specific type of software; selection of map features for each mapping scale; map symbols, etc.

- Until 2006, catalogue D had been used in actual map production process. However, attribute code of this catalogue covers features which are not necessary for topographic mapping. For this reason, if field identification survey is carried out based on this catalogue D, field survey

team collects information which is not necessary for the topographic mapping.

- One thing should be noted that, we explained in the above that catalogue D might have made based on catalogue B. However, most of the IGAC staff who participates in topographic mapping work by using catalogue D told that they had never seen catalogue B.

- Catalogue E was made by IGAC by rearranging the contents of catalogue D when IGAC changed its map editing tool from MicroStation to ArcGIS. Data specifications are for ArcGIS Geodatabse. Structures of data specified in this catalogue E are for the editing of mapping symbols of 1/2,000 topographic maps rather than for the definition of general spatial data infrastructure (SDI).

8.3.3 Suggestion of the JICA Study Team

- As for A and B, they are already obsolete and therefore the team feels it not necessary to improve them.

- However, from a point of view of utilization of geographic data, it will be necessary or at least useful for IGAC to make a catalogue like A or B. The reason to suggest such an activity is that discussions participated by various sub-directions and divisions of IGAC will give IGAC staff a good opportunity to think about the concept of basic GIS data which contribute to the efficient and reliable territorial planning.

- Catalogue E specifies data structure for only one type of GIS software – ArcGIS. And the catalogue E seems to be made to be used in map symbol editing work. It is possible for users outside IGAC use the catalogue. But the JICA Study Team feels that catalogue E may not be the most convenient model of geographic data to be used by many different types of users outside IGAC.

- Basic GIS data or Spatial Data Framework proposed by the JICA Study Team in October 2006 has data structure which is easily used by users of various different purposes.

- Catalogues D and E do not have the definition of geographic features. No documents which explain the definition of geographic feature were found. Clear definition of geographic features is necessary to make high quality data efficiently. If the mapping work proceeds with unclear definition of geographic features, much confusion occurs. Actually, the JICA Study Team was also annoyed by the unclear definition of geographic features made by IGAC. If

IGAC plans to subcontract out mapping to local contractors, it is the responsibility of IGAC to provide contractors with very clear mapping specifications.

Incidentally, there are following two types of specifications in the technical specifications IGAC uses for the work subcontracted out to local private firms.

Annex No.6 Modelo de datos
Annex No.7 Symobologia

Items checked during field identification survey were listed based on the data model rules specified in Annex 6. However, there are some geographic features which are not covered by this data model. Also, symbolization rule is specified in Annex 7 but some of them do not match with data model described in Annex 6. Further, some parts of the feature classification rule of this Annex 6 found to be not so logical.

It is understandable that this kind of confusion occurs because IGAC was in the process of constructing data model. It is recommended to review the structure of data model and also make data model and symbols consistent with each other.

Further, data model of Annex 6 were designed to deal with any map scale. However, it was found that some data items were specific only to certain map scale. Relation between data and scale is not clear and this makes surveyors participating in field identification survey confused. Data items which the JICA Study Team judges to be cadastral data are also included in the model. The JICA Study Team feels that it would be better not to include them in the data model for “topographic maps”. If information on cadastre should be collected or identified during field identification survey, the efficiency of “topographic mapping” cannot be maximized.

8.4 Data Structurization

The JICA Study Team and IGAC spent long time to discuss on the data structure of GIS data. The JICA Study Team assumed that Basic GIS Data should be basic framework which can be used in almost any kind of thematic maps. IGAC’s concept of Basic GIS Data included data items which the JICA Study Team classified as the data for thematic maps. The JICA Study Team and IGAC spent long time to discuss the definition of basic GIS data.

8.4.1 Structure of data structurization implemented by IGAC

IGAC’s method of data structurization changed after the Study was started in 2005.

The difference is summarized on Table 8-1.

Table 8-1 Change in IGAC's Data Structurization Method

	Digital Mapping Software	Software for data editing and structurization	Data output format
After Autumn of 2006	INPHO, LPS, DVP, All with CAD MicroStation	ArcGIS Ver9.1	Geodatabase, Shape File, Dxf
Before Autumn of 2006	INPHO, LPS, DVP, LPS, SocetSet with interposes to MicroStation	ArcGIS, ArcInfo, Workstation and occasionally MicroStation	Geodatabase, ArcInfo coverage, Shape File, Dxf

(1) Process

IGAC's data structurization process can be described as follows:

- Bentley MicroStation is used in digital mapping. Output of digital mapping is in DGN format. This will be converted into DXF format before to be imported into ArcGIS. Import of DXF to Geodatabase of ArGIS is done layer by layer.

- After the completion of restitution, data connectivity, continuity and closure or polygons are checked manually on CAD files. Further, when DXF files are converted into Geodatabase, data is also checked by pre-determined topological rules.

(2) Contents of the data structurization

IGAC made a new data model after it decided to use ArcGIS for map editing and data structurization. The JICA Study Team recognized that this new data model is not only for producing GIS data but also for making data for map printing. For this reason, IGAC requested the JICA Study Team to make topographic map data by using ArcGIS.

However, the JICA Study Team was using MicroStation as CAD software to make map data file in DGN format as agreed in 2005. IGAC first thought that MicroStation could not make complete geometry and topology. The JICA Study Team explained that making complete geometry and topology was possible by using MicroStation Geographics and IGAC agreed to receive map data in DGN format.

On the other hand, the JICA Study Team assumed that Basic GIS Data would be as follows:

1) Purpose

Purpose of making Basic GIS Data is the provision of accurate and reliable geographic data which can be used as the standard in overlaying more than one type of spatial information.

2) Contents

Framework information such as road, water line and building, which can be used as positional reference when thematic data are added.

3) Data structure

Basic GIS data have universal data format and structure which are not dependent on specific software and therefore can be used by a wide variety of users. On the contrary, IGAC wanted to include every feature drawn on the map in Basic GIS Data.

For the topographic mapping in the Study, every feature which can be identified on aerial photos is to be drawn. However, features such as electric poles or manholes are not easy to identify on photo images and therefore it is impossible to make complete database. If database is incomplete, it will make the user of GIS data confused.

Further, on topographic maps, shorelines are divided into more than one class such as artificial coastal line or natural coastline. It is much more convenient for GIS users if these lines are combined together to make one single line.

As the result of discussions mentioned above, IGAC and the JICA Study Team agreed as follows on the data strucutrization.

1) Every data except for annotation and symbols are included in Basic GIS Data. Road names, river names and elevation height are included.

2) Feature class

Basically the data are classified into 5 groups and then each group is divided into point, line and polygon data.

- Datos Basicos (Consisting of 12 feature classes)
- Elemento Divisorio (Consisting of 2 feature classes)
- Urbano (Consisting of 4 feature classes)
- Relive (Consisting of 2 feature class)
- Infrastructure (Consisting of three feature classes)

3) Attribute information

Road names, river names, spot heights and elevation value of contour lines are registered as attribute information. If there are both official name and common name for roads and rivers, both of them are registered.

4) Method of grouping

Geographic features of 1/2,000 scale topographic maps are re-classified into feature models of basic GIS data. If necessary, geometry is also changed in this process. Result of re-classification is expressed using UML Class diagram. Each geographic feature is expressed as CLASS and each theme is expressed as PACKAGE which combines classes.

- Classes
  - ✧ Light blue： Geographic features drawn on 1/2,000 scale topographic maps are directly imported into basic GIS data.
  - ✧ White： Geographic features of water bodies are combined together.
  - ✧ Gradation of white and blue： Geographic features whose geometry has to be changed in order to be implemented as Geodatabase.

- Packages
  - ✧ Pale pink： Package which is mainly used as basic geographic data.
    - Water line package
    - Administrative boundary package
    - Water flow and waterways (single line rivers and water ways) package
    - Single line road package
    - Railway package
    - Road edge package
    - Package for structure in the water
    - Road center line package
  - ✧ Green： Data which are mainly used in urban planning and land use planning including POT. To be used in urban planning together with data in Pink package
    - Public building package
    - Land cover and land use package
    - Site package
  - ✧ Magenta： Boundary data required in cadastral surveys
    - Package for cadastral survey
  - ✧ Yellow： Terrain conditions (Contour lines and spot height)

- Terrain conditions package

✧ Red : Control points. (Ground control points and tie points of aerial triangulation.)
Control points package

✧ Black : Geographic features which are drawn on 1/2,000scale maps but not registered as basic GIS data. (Electric poles and manholes for which complete data should be obtained from utility companies who own them.)

When the data are implemented in Geodatabase, basically this package becomes feature dataset. Master file is one Geodatabase. When data is delivered to the users of GIS outside IGAC, only necessary information is exported from master data.

Data structures on Geodatabase are explained by diagrams in Figure 8-1 - Figure 8-7.

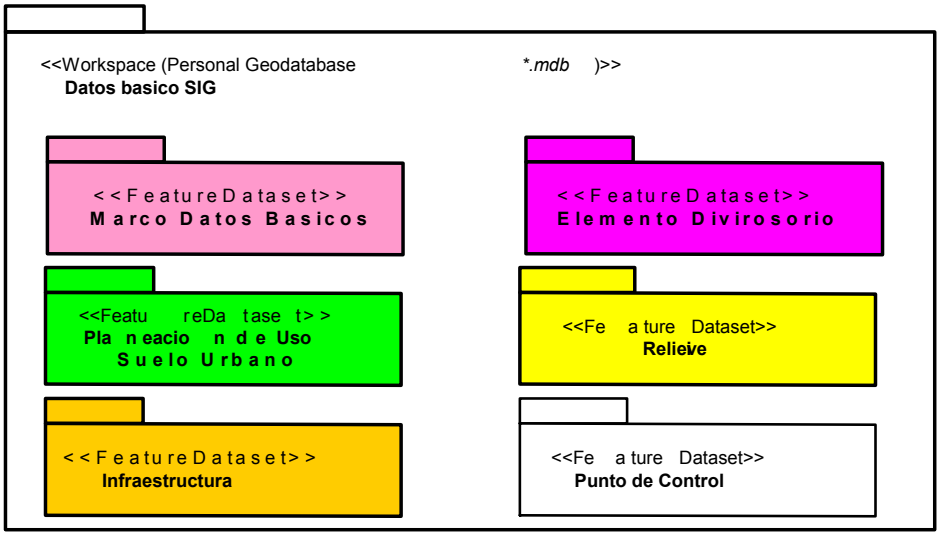


Figure 8-1 Database structure of Geodatabase

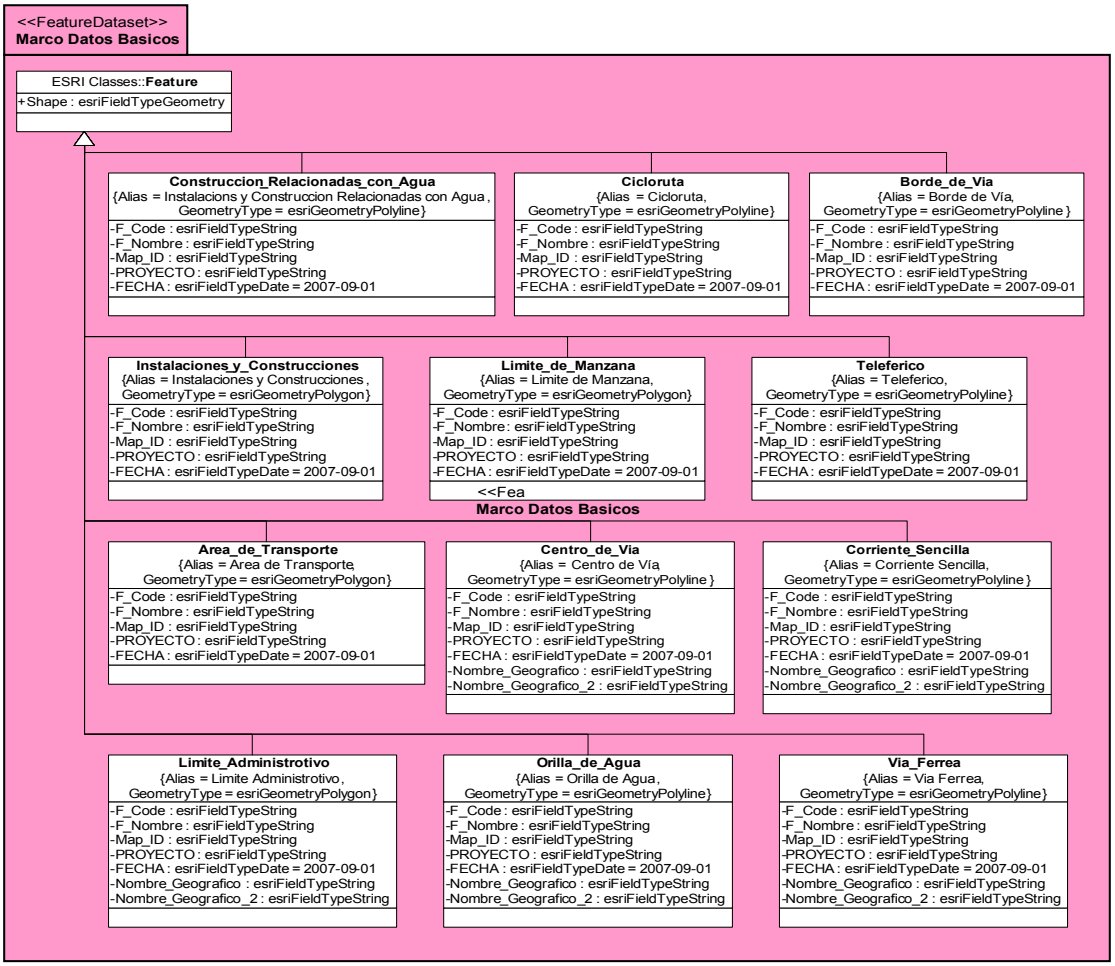


Figure 8-2 Feature classes of Feature Dataset of Marco Datos Basicos

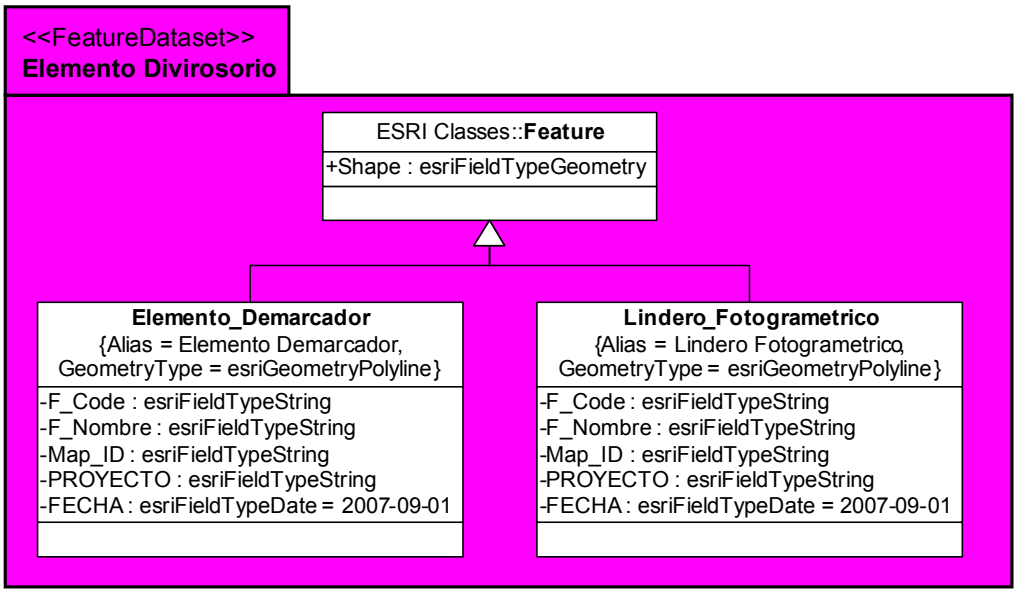


Figure 8.3 Feature classes of Feature Dataset Elemento Divirosorio

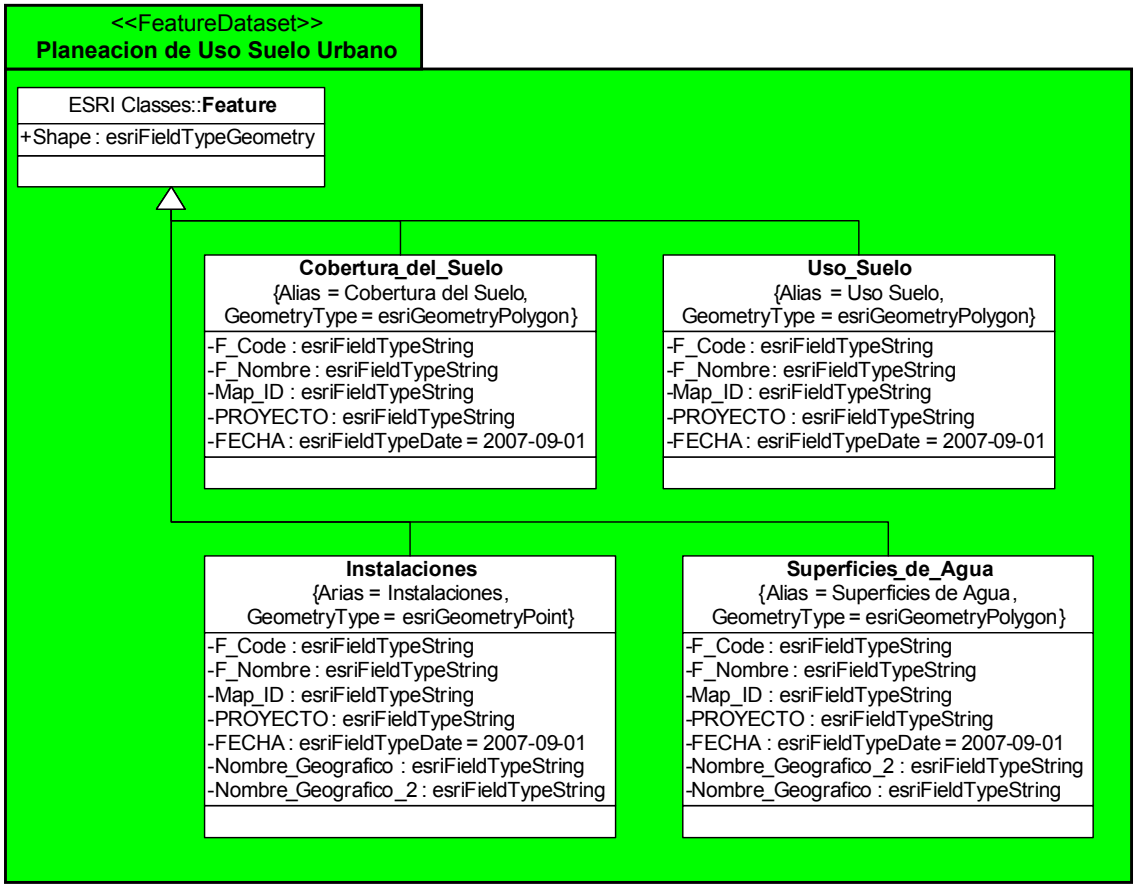


Figure 8-4Feature classes of Feature Dataset Suelo Urbano

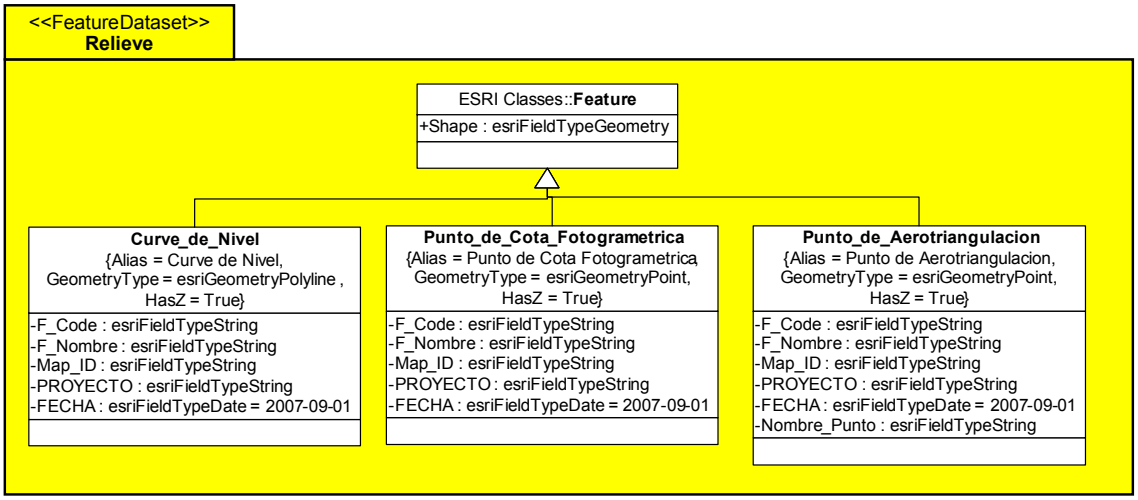


Figure 8-5 Feature classes of Feature Dataset Relieve

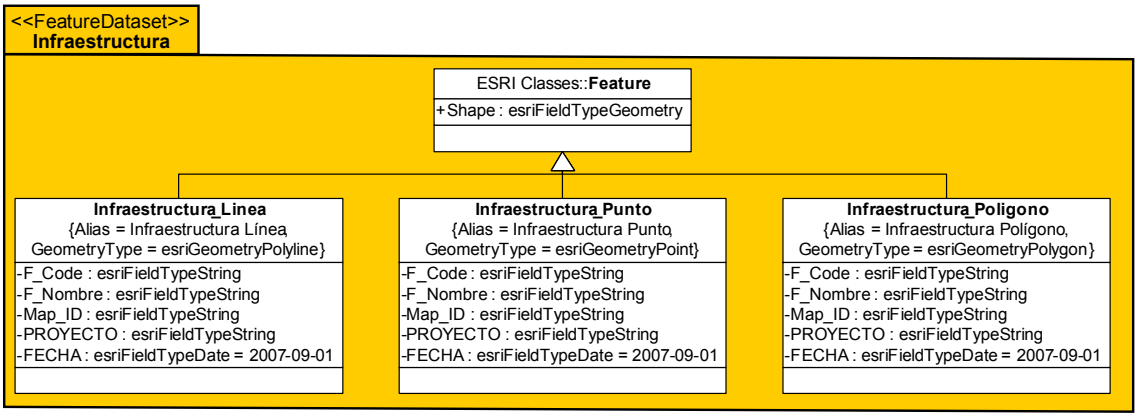


Figure 8-6 Feature classes of Feature Dataset Infrastructure

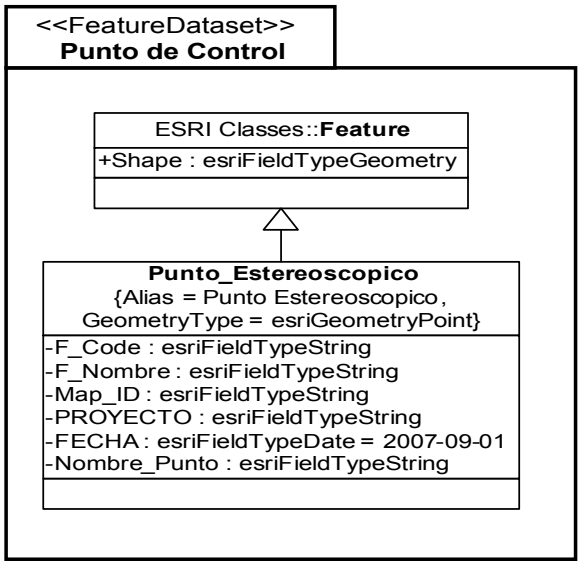


Figure 8-7 Feature classes of Feature Dataset Punto de Controll

CHAPTER 9 PROMOTION OF THE USE OF GEOGRAPHIC INFORMATION

It is necessary to understand the current situation of users of geographic information in order to promote the use of geographic information made and supplied by IGAC. For this purpose, municipalities of Cartagena, Barranquilla and Santa Marta were visited and various types of thematic maps used in POT making were collected. The collected maps and material were analyzed to understand the quality and accuracy of the information. Further, answers to questionnaire were also collected from 48 municipalities listed in the 100 municipalities. Municipalities of Cali, Manizales and Perelia were also visited to collect information on the current use of geographic information.

9.1 Current situation of the use of geographic information

In Colombia each municipality is responsible to make its own POT. This means there is a clear need for reliable geographic information.

However, answers from the 48 municipalities indicates that municipalities which do not have human resources or equipment to make thematic maps to be used to make POT are naturally still in a very primitive stage as far as the use of geographic information. And most of the municipalities do not have any resources to handle geographic information.

9.1.1 Thematic mapping for POT

Municipalities are trying to make various maps because by LAW388 each municipality has to make its own POT.

Cities which are the target of the mapping in this study, namely, Cartagena, Barranquilla and Santa Marta, are well ahead of other majority of municipalities in terms of mapping and POT making. Their resources are summarized on Table 9.1.

Table 9-1 Mapping capability of the three municipalities (2005)

Item	Cartagena	Barranquilla	Santa Marta
Hardware	N/A	PC：2	PC：1
Software	MicroStation（Quantity unknown）	AutoCAD ArcView	AutoCAD ArcView3.1
I/O device	N/A	A0 Color inkjet plotter: 1 Digitizer: 1（Not working）	
Staff to maintain	N/A	2 persons	No person

POT			
Surveyor	N/A	2 persons（One of them is basically an engineer of urban planning and can use GIS to some extent）	1 person (Engineer in construction）
GIS engineer	N/A	1	None
System Engineer	N/A	None	None

9.1.2 Thematic maps to make POT

Each municipality has its own development program and therefore types of maps to be used in POT making are different. In general maps required for making POT can be divided into the following categories.

- Public administration maps: Administrative boundaries, etc.
- Land use management maps: Current land use; land use plan for various sectors; zoning plan which consists of master plan
- Social infrastructure maps: Road, water, sewerage, electricity, gas and other utilities
- Environment management maps: Conservation areas; nature ecosystem protection areas, etc.
- Hazard prevention maps: Inundation areas; areas of high possibility of landslides; steep slope areas, etc.

Maps and documents collected from Cartagena, Barranquilla and Santa Marta are as listed on Table 9-2 and Figure 9-1. Most of them are based on IGAC or DANE maps. However, they have problems such as different scale, difference in production year, changes over time, inaccuracy in positions. If these maps are to be used in urban or regional planning, their compatibility with new data or maps should be carefully examined.

Table 9-2 Maps and material collected from the three municipalities (2005)

Item	Cartagena	Barranquilla	Santa Marta
Maps	-POT map: 85 files (dgn file: 84	-POT map: 176 -Map for updating: 1 (AutoCAD) -DANE topographic map: 1 (AutoCAD) -AAA topographic map: 193 (AutoCAD) - Thematic maps from CRA: 152 (AutoCAD and Shape)	-POT PDF: 44 -POT maps: 327 files (DWG, DXF, shp, bmp, doc, ppt, pdf)
Document	-POT text documents: 9	-POT text documents: 7	-POT text documents 38
Others		- POT digital maps and documents (Malambo, Puerto Colombia and Soledad): 180	

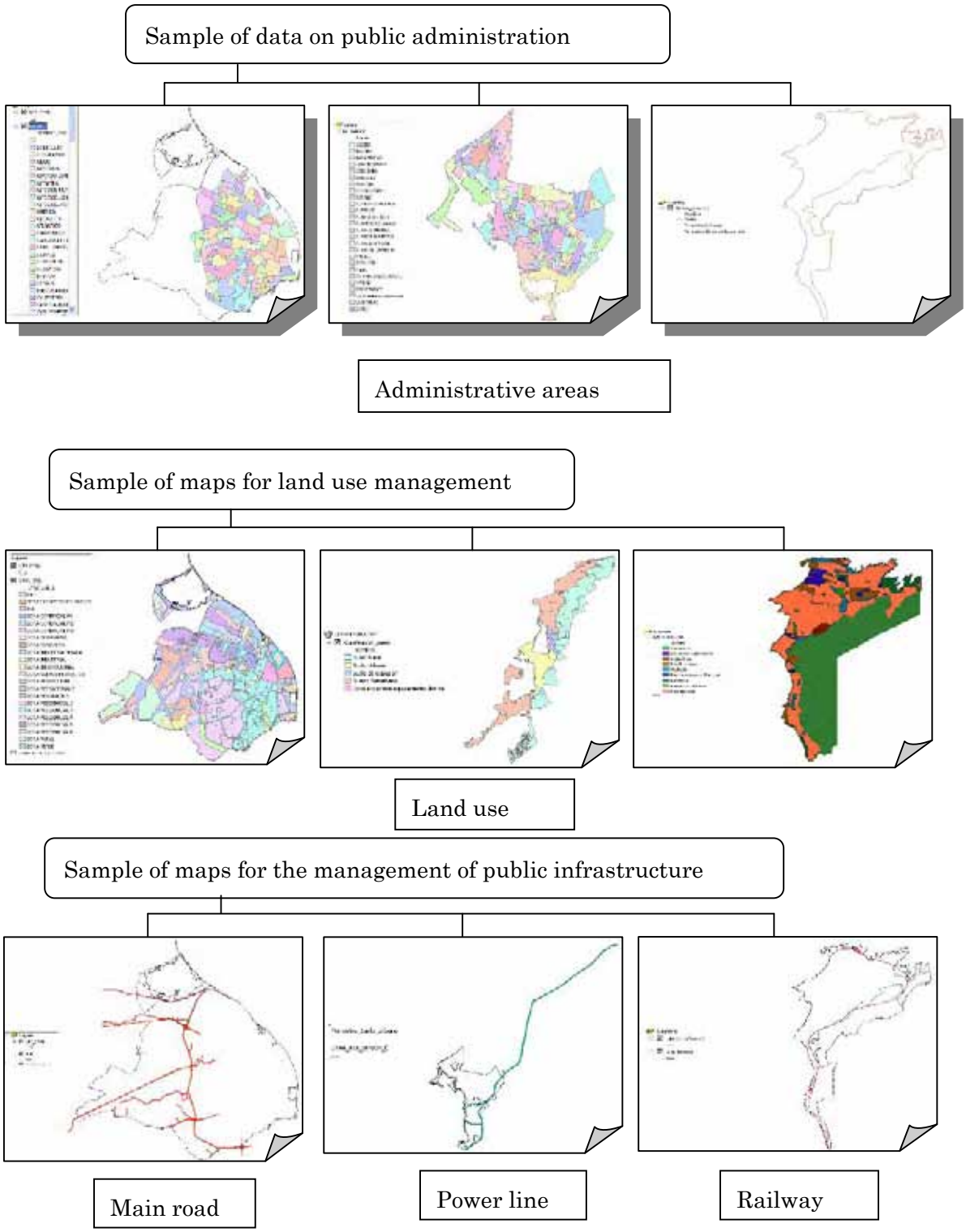


Figure 9-1-1　Samples of collected maps（1）

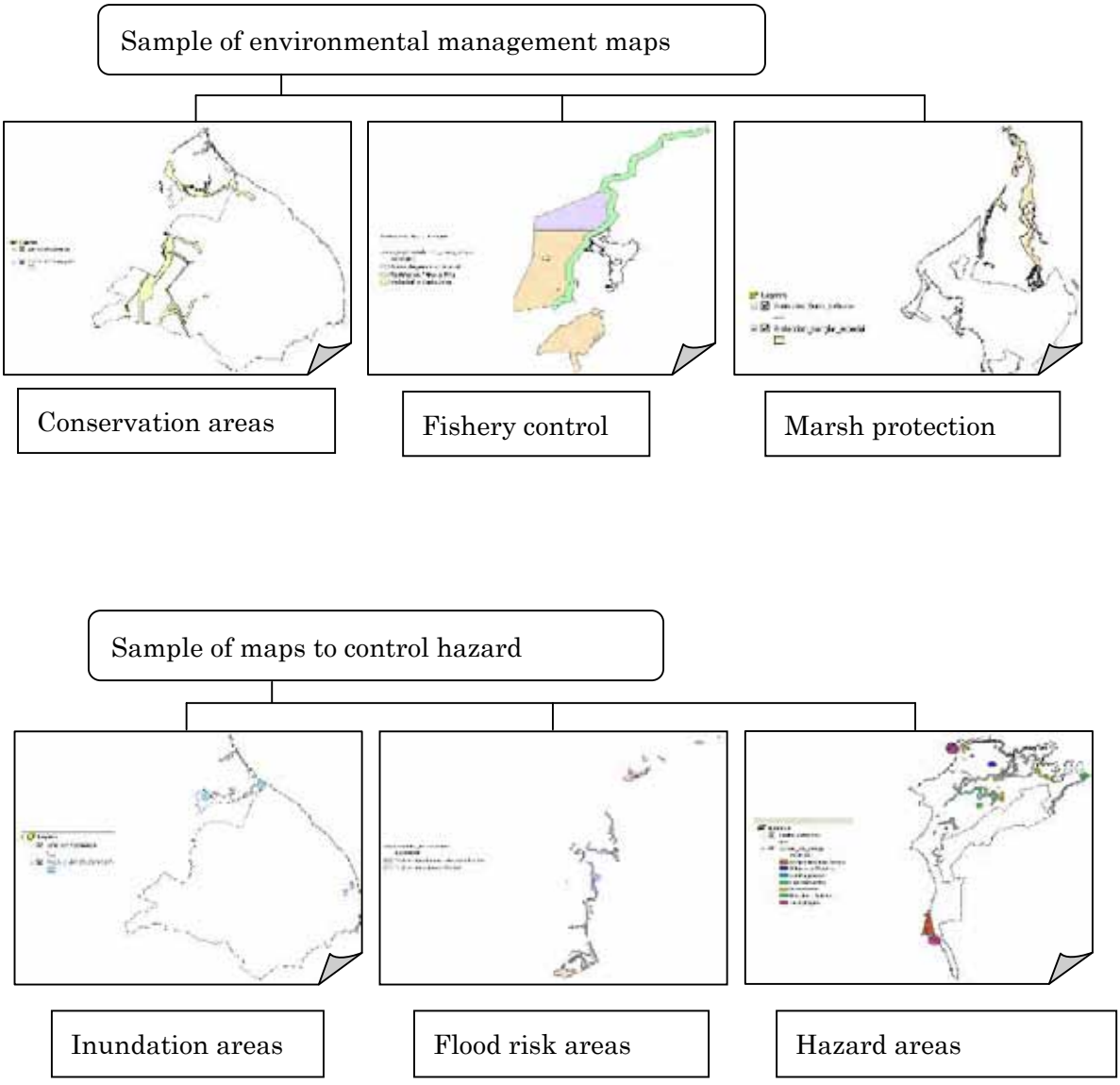


Figure 9-1-2　Sample of collected maps（2）

9.1.3 Issues in POT

The main objective of geographic data supplied by IGAC is to promote the making or updating of POT. However, some problems have to be solved before IGAC data are widely used.

(1) Making standard for POT maps

Most of the thematic maps used in making POT use IGAC or DANE topographic maps as their base. However, both maps are different in scale, production year and accuracy. Therefore, if they are overlaid, geographic features such as roads and buildings do not match. The maximum difference was 20 meters in Barranquilla and 15 meters in Santa Marta (Figure 9-2). Some maps cannot overlay because they are twisted.

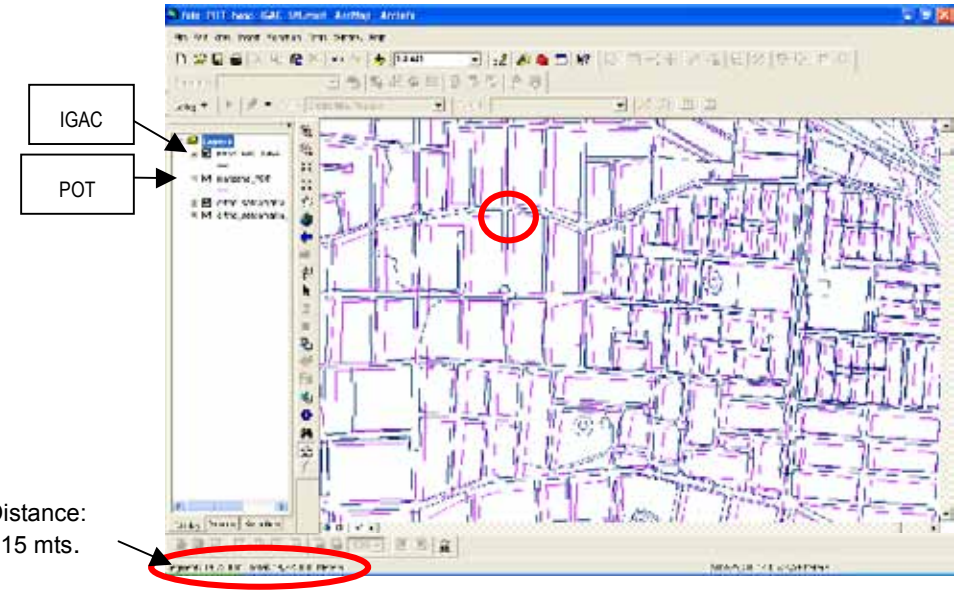


Figure 9-2 Overlaid of new and old (1994) maps of Santa Marta

(2) Management of POT maps

Once maps are produced they have to be updated constantly because geographic features changes over time. However, POT maps are not updated due to the shortage of budget or because municipality staff are not well aware of the fact that geographic features on maps changes over time.

In Barranquilla, the municipality was trying to update POT by using DANE maps of 2004 and the maps made by water works organization AAA. Santa Marta was also updating POT data but they were not using IGAC map because they could not wait until the most recent version is published. Cartagena was waiting for IGAC map.

(3) Standardization of POT making method

Various types of thematic maps are required to make POT. Although IGAC has a guideline to make thematic maps, details of the map making have not yet been standardized.

9.2 Technical problem in the promotion of geographic information and GIS

Small local municipalities do not have human resources, organization and budget to use GIS. The problems associated with the promotion of the use of GIS are summarized as follows:

(1) Review of geographic feature catalogues

Geographic feature catalogue which defines geographic features to be mapped and their code is very important document in making a GIS database. However, current catalogue of IGAC is mainly aimed at the management of cadastral data and not suitable for general purpose GIS database. It is necessary to redefine geographic features and their attributes for GIS database which is used as basic framework for various types of thematic map production.

On the other hand, IGAC has urban data model CO-U and symbol catalogue CS-2000 to manage urban land and cadastral data. They are made by referring to geographic information standard but they are not related to POT.

(2) Making guidelines

As a base map for POT maps, maps of IGAC or DANE are used. However, mixing use of more than one type of base map causes troubles because of difference in scale, map legends and accuracy. These problems prevent ordinary planners or GIS users from using maps or geographic information more extensively. It is necessary to make a guideline for the production of basic geographic data.

(3) Budget

Under the Law 388, municipalities have to make POT. However, most of the municipalities do not have enough budgets to make good quality POT. However, if reliable geographic data are provided, preparation of thematic maps and POT will become much easier than now. In order to avoid redundant investment in geographic data production, it is recommended to use high quality maps and geographic information to be supplied by IGAC.

(4) Institutions

IGAC makes map by receiving orders from municipalities. However, IGAC does manage maps

made by municipalities. On the other hand, municipalities cannot have their own organization to handle geographic information particular GIS data. Some municipalities hire temporary staff to operate GIS but after the contract is terminated they leave the organization and the municipality cannot keep the know how in using geographic information and GIS. It will be beneficial for municipality to utilize the capacity of IGAC territorial offices to fill the shortage in technical capacity.

CHAPTER 10 GIS MODEL SYSTEM

10.1 Purpose of the development of a model system

The purpose of GIS model system development is to make a tool which can be used in making various development plans including but not limited to POT and which can also be used in introducing the merit of GIS to potential users.

10.2 Policy in the development of a GIS model system

10.2.1 GIS model system to support POT making

GIS model to be made in the study needs to support thematic map production for POT and the promotion of the use of geographic information. For this reason, it was determined to use only basic functions of ArcGIS without adding any software. Data format is Geodatabase and operation manual was made in Spanish.

10.2.2 Functions of the GIS model system

GIS model system is designed to run on ArcGIS9.1.

For the purpose of the promotion of the use of GIS, the following functions were developed. With these functions a manual was made to experience the following things:

- Tool for decision making (Introduction of GIS by showing the process to select a new park area)
- Introduction of user friendly GIS for tourists

In all the system have the following functions.

- Thematic mapping and updating
- Coordinate conversion (convert to Cartesian coordinate)
- Data editing
- Thematic map viewing
- Thematic map printing

(1) Thematic mapping and updating function

Editing point, line and polygon features for making thematic maps. Also, data record of geographic features are managed and updated.

- Management of road name and attribute related to road network

- Data management related to map annotation
- Data management related to geodetic control points
- Management of other type of information

(2) Coordinate transformation function

Map data existing in the three cities use special coordinate system and not easy to use for ordinary GIS users. Therefore, a command to carry out coordinate conversion with simple operation was made.

(3) Data editing and viewing function

Displaying and editing function was prepared. By using this function you can overlay the thematic maps on the screen and edit the data.

(4) Thematic map printing

After creating layout on the screen you can print them on a paper. You can select layout which is store as a template also.

10.3 Contents of GIS model system

IGAC should lead activities to promote the use of GIS in various fields.
As the use of GIS increase, the necessities of the GIS from municipalities and from the private company will become more sophisticated.

And interest will expand not only for POT but applications such as the prevention of disaster or for the planning purpose using standard specifications.

Content of GIS model system and the use of SIG are shown in Figure10-1, 10-2, 10-3.

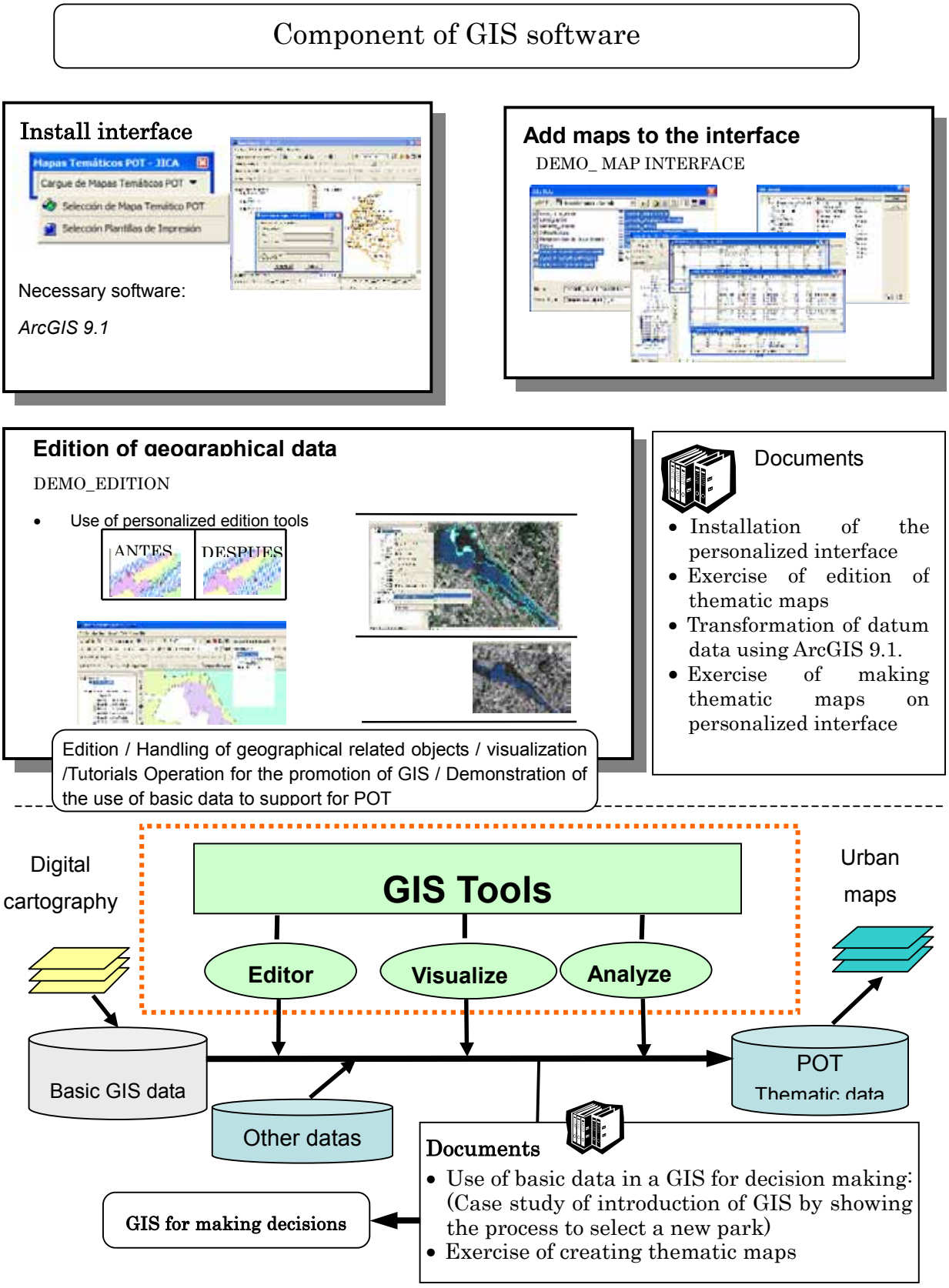


Figure 10-1 Components of GIS software

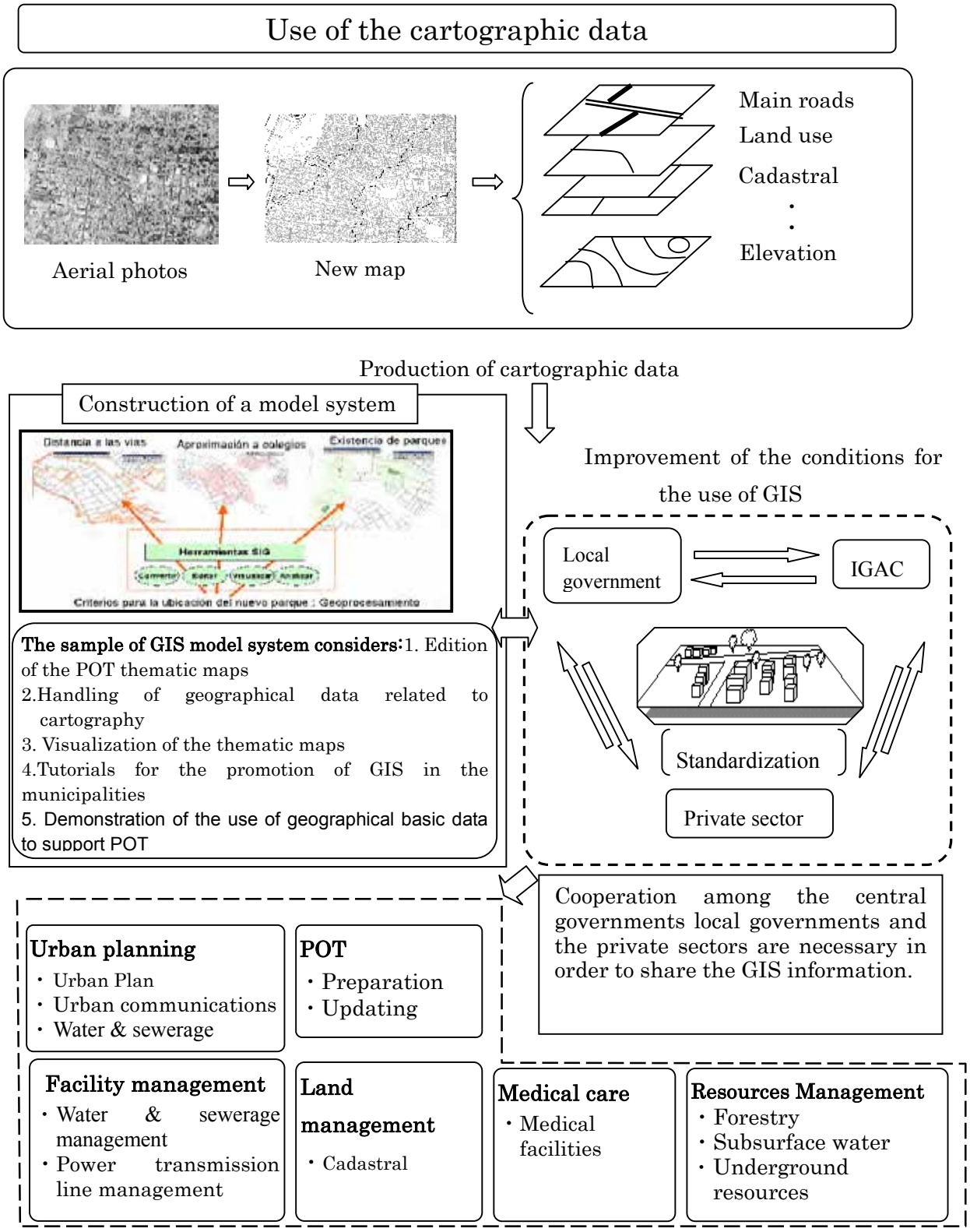


Figure 10-2 Data processing with special information

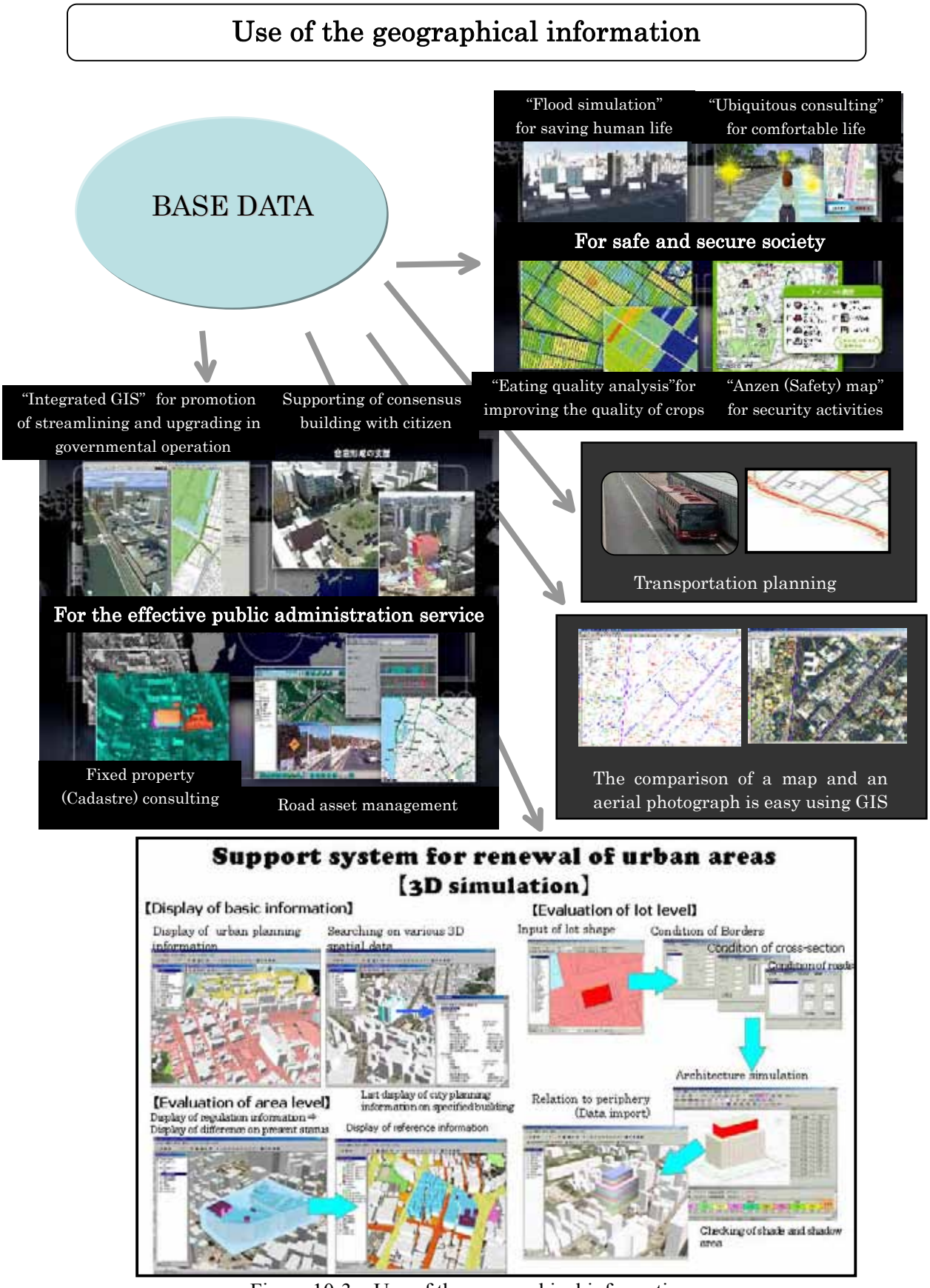


Figure 10-3 Use of the geographical information

CHAPTER 11 SELF SUSTAINABILITY ANALYSIS

11.1 Purpose and method

11.1.1 Purpose

The purpose of the analysis is to examine if IGAC can produce 1/2,000 digital maps and basic GIS data of 100 municipalities based on its technical capacity and also utilizing technologies transferred through the study.

11.1.2 Method of Analysis

The subject of self-sustainability analysis is the IGAC's program to make 1/2,000 scale digital maps and basic GIS data of the 100 municipalities. Three factors determine the level of the self-sustainability after the completion of the JICA project.

- Combined production capacity of IGAC and private sector
- Budget to make basic GIS data of the 100 municipalities
- Results of the technical transfer program of JICA

Figure 11-1 shows the relation among above three factors as well as items of information collected and analyzed. The figure does not show the structure of the report.

11.1.3 Data Collection

Information on IGAC was collected by the interview with IGAC staff, questionnaire, observation of production processes and analysis of existing documents. IGAC regional offices in Santa Marta and Cali were visited.

As for the survey of the situation of 100 municipalities, a questionnaire was prepared and distributed to the 100 municipalities through IGAC regional offices and collected by the same IGAC offices.

Further, since the period of survey for self-sustainability study in Colombia was 40 days in the first year and 30 and 60 days in the second year. To supplement these relatively short working days in Colombia, results of activities of other JICA Study Team members were also used in the analysis.

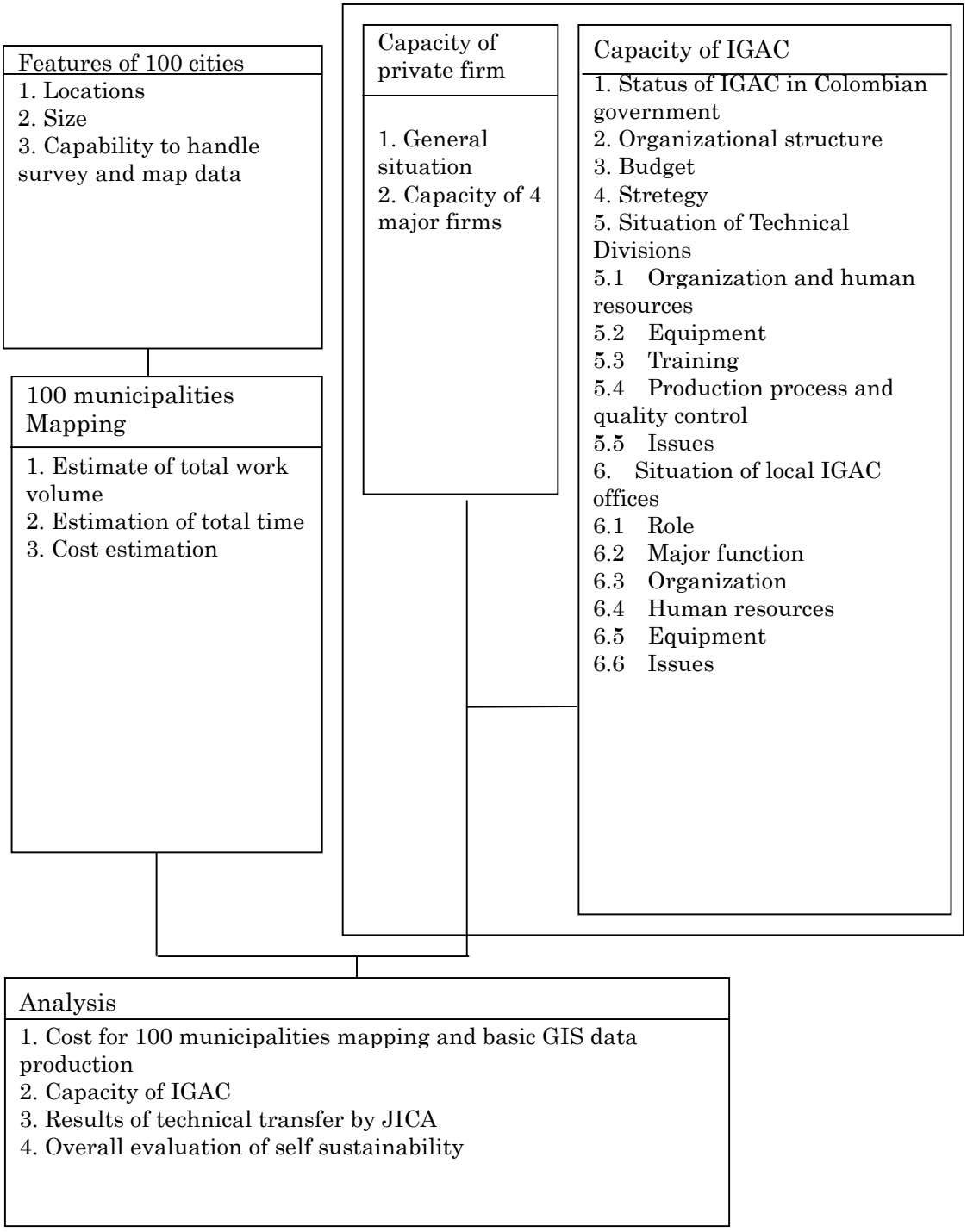


Figure 11-1 Self Sustainability Analysis Components

11.2 Chronological record of activities

11.2.1 Work in Colombia (January – March 2006)

(1) Explanation of the purpose of the study as well as the contents of self-sustainability analysis to IGAC

It was found that IGAC had misunderstood that JICA would continue to produce maps and basic GIS data of the 100 municipalities after the completion of the geographic data for the three Atlantic coastal cities. JICA Study Team explained IGAC that the objective of the study is to assist IGAC establishing modern mass production process of digital maps and basic GIS data through the JICA study. The team also explained that IGAC should be responsible for the 100 municipalities and that is why Self Sustainability Analysis would be important.

(2) Analysis of IGAC's current conditions and issues

Information on the present situation of IGAC was collected by interviewing IGAC staff and questionnaires. The information was used to understand IGAC's organization, policy, major activities and overall capacity for large scale digital mapping and GIS data construction. Similar information was collected also at regional offices of Santa Marta and Cali.

(3) Collection of basic data to make tentative work and cost plans

In order to calculate total working volume of the 1/2,000 scale digital maps and basic GIS data of the 100 municipalities, typical working rate of IGAC, volume of work being contracted out to private sector and other relevant data were collected.

(4) Selection of the 100 municipalities

IGAC made the original list of the 100 municipalities when the Scope of Work for the study was signed. IGAC changed the list at the end of 2005. The reason for this change was that some municipalities in the former list were covered by 1/2,000 scale maps. The list was further modified according to changes in priority.

The final list of the 100 municipalities is shown as Table 11-1.

Table 11-1 100 Municipalities List (Part I)

No	Departamento	Municipio	respuesta	No.	Departamento	Municipio	Respuesta
1	ATLÁNTICO	CAMPO DE LA CRUZ		26	BOLIVAR	HATILLO DE LOBA	○
2	ATLÁNTICO	CANDELARIA		27	BOLIVAR	MAHATES	
3	ATLÁNTICO	JUAN DE ACOSTA		28	BOLIVAR	MARGARITA	
4	ATLÁNTICO	LURUACO	○	29	BOLIVAR	MORALES	
5	ATLÁNTICO	MANATI	○	30	BOLIVAR	PINILLOS	
6	ATLÁNTICO	POLONUEVO	○	31	BOLIVAR	REGIDOR	
7	ATLÁNTICO	PONEDERA		32	BOLIVAR	RIO VIEJO	
8	ATLÁNTICO	REPELON		33	BOLIVAR	SAN CRISTOBAL	
9	ATLÁNTICO	SANTA LUCIA		34	BOLIVAR	SAN ESTANISLAO	○
10	ATLÁNTICO	SUAN	○	35	BOLIVAR	SAN FERNANDO	○
11	ATLÁNTICO	TUBARA		36	BOLIVAR	SAN JACINTO	
12	ATLÁNTICO	USIACURI		37	BOLIVAR	SAN JUAN NEPOMUCENO	
13	BOLIVAR	ACHI		38	BOLIVAR	SAN MARTIN DE LOBA	○
14	BOLIVAR	ALTOS DEL ROSARIO		39	BOLIVAR	SAN PABLO	○
15	BOLIVAR	ARENAL		40	BOLIVAR	SANTA CATALINA	
16	BOLIVAR	ARJONA	○	41	BOLIVAR	SANTA ROSA	○
17	BOLIVAR	ARROYOHONDO	○	42	BOLIVAR	SIMITI	
18	BOLIVAR	BARRANCO DE LOBA		43	BOLIVAR	SOPLAVIENTO	○
19	BOLIVAR	CALAMAR		44	BOLIVAR	TALAIGUA NUEVO	
20	BOLIVAR	CANTAGALLO		45	BOLIVAR	TIQUISIO	
21	BOLIVAR	CICUCO		46	BOLIVAR	TURBANA	
22	BOLIVAR	CLEMENCIA		47	BOLIVAR	VILLANUEVA	○
23	BOLIVAR	CORDOBA		48	BOLIVAR	ZAMBRANO	
24	BOLIVAR	EL GUAMO		49	CALDAS	ARANZAZU	○
25	BOLIVAR	EL PEÑON		50	CALDAS	FILADELFIA	○

Table 11-1 100 Municipalities List (Part II)

No	Departamento	Municipio	respuesta	No.	Departamento	Municipio	Respuesta
51	CALDAS	LA MERCED	○	76	CUNDINAMARCA	ZIPACON	
52	CALDAS	MANZANARES	○	77	LA GUAJIRA	ALBANIA	
53	CALDAS	MARMATO		78	LA GUAJIRA	BARRANCAS	○
54	CALDAS	MARQUETALIA	○	79	LA GUAJIRA	DIBULLA	○
55	CALDAS	MARULANDA	○	80	LA GUAJIRA	DISTRACCION	○
56	CALDAS	PENSILVANIA	○	81	LA GUAJIRA	EL MOLINO	○
57	CALDAS	RIOSUCIO	○	82	LA GUAJIRA	FONSECA	○
58	CALDAS	SALAMINA	○	83	LA GUAJIRA	HATONUEVO	○
59	CALDAS	SAMANA	○	84	LA GUAJIRA	LA JAGUA DEL PILAR	
60	CALDAS	SUPIA	○	85	LA GUAJIRA	MANAURE	
61	CALDAS	VICTORIA	○	86	LA GUAJIRA	SAN JUAN DEL CESAR	○
62	CAQUETÁ	FLORENCIA	○	87	LA GUAJIRA	URIBIA	○
63	CAUCA	POPAYAN	○	88	LA GUAJIRA	URUMITA	○
64	CUNDINAMARCA	AGUA DE DIOS	○	89	LA GUAJIRA	VILLANUEVA	
65	CUNDINAMARCA	ALBAN		90	META	VILLAVICENCIO	○
66	CUNDINAMARCA	ANOLAIMA	○	91	RISARALDA	APIA	
67	CUNDINAMARCA	CACHIPAY		92	RISARALDA	BELEN DE UMBRIA	
68	CUNDINAMARCA	JERUSALEN	○	93	RISARALDA	GUATICA	
69	CUNDINAMARCA	LA MESA		94	RISARALDA	LA VIRGINIA	
70	CUNDINAMARCA	NILO	○	95	RISARALDA	MARSELLA	
71	CUNDINAMARCA	QUIPILE	○	96	RISARALDA	MISTRATO	
72	CUNDINAMARCA	RICAURTE	○	97	RISARALDA	QUINCHIA	
73	CUNDINAMARCA	TOCAIMA	○	98	RISARALDA	SANTUARIO	○
74	CUNDINAMARCA	VILLETA		99	TOLIMA	IBAGUE	○
75	CUNDINAMARCA	VIOTA		100	VALLE DEL CAUCA	CALI	○

11.2.2 Work in Colombia (June – July 2006)

(1) Recovery of the answers to the questionnaire

Total 40 municipalities sent their answers back before the end of July 2006. JICA Study Team decided to wait until the end of August.

(2) Analysis of collected answers

Collected answers were compiled by entering them into EXCEL formats.

(3) Calculation of the volume of GIS data production

Data on the size and population of the municipalities were collected from existing material. They were used in the estimation of total cost for the 100 municipalities mapping program. Detailed calculation was made by IGAC while the JICA Study Team used data from the production of digital maps for 65 municipalities. Two results were compared to check their validity.

(4) Analysis of the role of IGAC territorial offices

At first, the target of the self-sustainability analysis was the section of IGAC headquarters in charge of photogrammetric mapping. However, after the completion of the first year's study, it was realized that IGAC regional office would have potential capacity to play an important role in field survey works for mapping. Also, IGAC regional office would be important to make data users understand the value of basic GIS data.

For this reason, it was decided to investigate the situation of regional offices. Santa Marta and Cali offices were visited for this purpose.

11.2.3 Work in Japan (August 2006)

(1) Recovery of answers

As of early August 2006, answers were received from 48 municipalities. Request to answer the questionnaire started in late July by IGAC.

(2) Pre-processing of collected answers

Contents of the collected answers were entered into one table format. Judging from their area size, population density and from land use pattern shown on existing aerial photos, it was determined that these 48 municipalities can represent the 100 municipalities.

(3) Calculation of work volume of 1/2,000 scale digital mapping of the 100 municipalities

Total size of the 100 municipalities mapping area is approximately 562 km2. Although the total size is not large, mapping areas are scattered around the country. At the beginning the team was planning to categorize municipalities according to the priority of mapping. However, later it was realized that for the sake of work efficiency, nearby municipalities should be grouped together.

(4) Collection and analysis of additional information
Information and material to understand IGAC's work and map production capacity were collected in the first year. However, since IGAC renewed some of its manual and specifications, additional data were collected.

Also, further analysis was made on issues identified by the JICA Study Team.

11.2.4 Second Work in Colombia of the 2nd year (Sept – Nov, 2006)

(1) Planning of the 100 municipalities mapping
Based on the information collected in the second year, 100 municipalities mapping plan was reviewed.

(2) Collection of additional information on IGAC's situation and working procedures.
In 2005 and 2006, IGAC introduced modern photogrammetric equipment in a rather fast pace mainly with the support from foreign donors. This means IGAC's production method and procedures changed over a very short period of time. Particularly, since

IGAC shifted the digital editing software from MicroStation to ArcGIS, completely new analysis of work flow became necessary.

(3) Visit to IGAC territorial offices
Territorial offices in Manizales and Pereira were visited to know the technical capacity of IGAC's regional offices.

(4) Confirmation of the results of technical transfer and provision of recommendations
Considering a long blank between the Year 2006 work and the Year 2007 work in Colombia, a wrap-up meeting was held in IGAC to summarize the findings of the JICA Study Team and important things in making basic GIS data of 100 municipalities .

11.3 Results

11.3.1 100 municipalities survey

(1) Outline of the 100 municipalities

In the 100 municipalities , five large cities, namely, Cali, Ibague, Villavicencio, Popayan and Florencia are included. Since their area size and population are both far larger than those of the remaining 95 cities, the analysis of characteristics of “the 100 municipalities ” was made on “95” municipalities. Table 11-2 shows the population and area size of the 95 municipalities

Table 11-2 Size, population and population density of 95 municipalities .

Percentile	Size of urban area (ha)	Population	Population density
10%	47.20	2,216.80	16.64
20%	88.80	4389.40	28.74
30%	108.60	5,280.20	37.78
40%	136.00	6331.00	43.26
50%	167.00	7,764.00	48.33
60%	203.80	9117.80	56.16
70%	251.00	10751.80	65.91
80%	336.20	13,395.20	78.96
90%	486.40	18702.60	102.51
100%	1,154.00	50,351.00	272.00

Total size of 95 municipalities is 21,610ha and average size of the one municipality is 227.39ha. Average population is 530.000 and average population density is 2.86 person per ha.

99 of the 100 municipalities are already covered by aerial photos. Sample aerial photos of four municipalities are shown on next pages. As these sample photos shows, urban areas of most municipalities can be covered by a few models of aerial photos (Figure 11-2, 11-3).

Figure 11-2 Existing aerial photos of Santa Catalina, Bolivar

Figure 11-3 Existing photos of Marulanda, Caldas

Since only 48 of the 100 municipalities sent their answer back to the JICA Study Team, it was necessary to examine if these 48 municipalities can represent the 100 municipalities .Actually, five municipalities , namely, Cali, Ibague, Villavicencio, Popayan and Florencia, are different from other 95 municipalities in terms of its size. Therefore, in this examination the five municipalities were excluded. As for 48 cities please refer to Table 11-1.

Table 11-3 shows area size and population of 95 municipalities – the five large municipalities were excluded. The five large municipalities were also among 48 municipalities who provided answers to the questionnaire. Therefore, in this examination, they were excluded from 48 municipalities . This makes the number of municipalities who replied to the questionnaire as 43 instead of 48.

Table 11-3 Statistics of 95 municipalities

		Area size（ha）	Population
Standard Deviation	43 municipalities	242.55	8,581.65
	52 municipalities	154.90	6,793.97
	95 municipalities	203.78	7,666.20
Median	43 municipalities	208.00	8,150.00
	52 municipalities	136.00	6,944.50
	95 municipalities	167.00	7,764.00
Average	43 municipalities	273.58	10,062.30
	52 municipalities	189.19	9,231.06
	95 municipalities	227.39	9,607.31

The table shows that area size and population of 52 municipalities who did not send back their answers are smaller than the average of the 43 and the 95 municipalities.

The team concluded that area size and population of the 43 municipalities which sent back answer are practically almost equal to that of 95 municipalities. Therefore, the team judged that the 43 municipalities could be regarded as representative of the 100 municipalities .

(2) Summary of the survey of the 48 municipalities

Answers to questionnaire collected from 48 municipalities are summarized as follows. Since the survey was conducted by indirect method, there is a possibility that some of the questions were not correctly interpreted by municipality staff who answered them. However, from the collected answers, approximate characteristics of the 48 municipalities can be estimated.

1) Existence of maps for POT: Existing 42, Not existing 5, No reply 1.

2) As for municipalities who answered "Existing" in above question:

- Map scale: Scale varies between 1:1,750 and 1:110,000. 18 cities have maps smaller than 1/10,000. Replies from 6 cities were null.
- Production year of the maps; 9 cities did not reply. One city: 1961. The maps of the cities were made between 1981 and 2006.
- Map producer: 10 cities did not reply. 11 cities replied "IGAC". The rest of the cities replied "Regional autonomous corporations" or Mayoralty's office.
- Cost of map making: No replies from 35 cities. The rest of the cities, except for one, replied "between 2,000,000 and 57,000,000 Colombian Pesos.
- Issues related to maps: 19 cities replied "no problem". No reply from 15 cities. The rest of the cities listed "outdated" and "inaccurate" as the problems.

3) Existence of units specialized in mapping or GIS

Only 3 cities replied that they had such a section.

4) If the answer to the above question is Yes:

- Number of technical staff: 1 to 3
- Major instruments: Only one city has digitizer. One city does not have any plotter.

5) Major industry: Agriculture and livestock farming.

6) Population

Population varies from 2,691 to 2,423,381. Only 5 cities have population over 110,000.

7) Size of area designated as urban area: No reply from 11 cities. Size and definition are various.

8) Number of school

Less than 10	23 cities
11-20	9 cities
21-30	2 cities
31-40	4 cities
41-50	3 cities
51-100	1 city
more than 100	3 cities
No reply	4 cities

9) Existence of POT

48 cities reply that they had POT. Year of the production of POT ranges from 1998 to 2005.

10) Organization who made POT:

44 cities replied. Most of them replied that consultants made POT. In 15 cities a planning division of city made POT.

11) Thematic maps made for POT

42 cities replied. Since multiple thematic maps are made, total number of thematic maps is 455 Table 11-4).

Table 11-4 Thematic maps made for POT

Major thematic maps		Number
1	Water supply, sewerage and housing	26
2	Public facilities	51
3	Road, communication, transportation	37
4	Environment, Natural environment, forests	41
5	Land use, soil type	66
6	Danger, risk, vulnerability	62
7	Geology and limnology	12
8	Geomorphology and topography	22
9	Homogeneous areas	14
10	River, precipitation and water system	22
11	Political and administrative boundaries	53
12	Other items difficult to classify	49
	Total	455

12) Time required to make POT: 41 cities reply. 3 – 60 months.

13) Cost to make POT

28 cities replied.

- CO$500,000 以下 1 city
- CO$5,000,000～CO$10,000,000 6 cities
- CO$10,000,001～CO$20,000,000 6 cities
- CO$20,000,001～CO$50,000,000 11cities

- CO$50,000,0001～CO$100,000,000 3 cities
- CO$100,000,001～CO$1,000,000,000 1 city

CO$1,000,000,001 以上 1 city

14) Data sources to make POT

Major sources are data of DANE, IGAC, SISBEN and Regional Autonomous Corporations. Some cities mentioned the problem of obsolete or unreliable maps.

15) Problems of POT database

14 cities replied no problem. 6 cities replied that they do not have database. Cities who owns database pointed out that they were old.

16) Relation with Law 388

39 cities replied that they made POT based on Law 388.

17) Standardization of data sources for the construction of spatial information.

10 cities replied that there would be no need.

18) Standardization of specifications for POT making

32 cities replied. Most of them aid that standardization of the specifications is important.

19) Amount of subsidy budget for the maintenance of POT

35 cities replied. If subsidiary money is available for the POT maintenance, the amount required by municipalities ranged from CO$2,000,000 to CO$30,000,000.

20) Cooperation between cities, state or with central government on the maintenance of POT data

40 cities replied. Most of them have some kind of cooperation agreement with other public organizations.

21) Existence of development plan

44 cities replied that they had development plan.

22) Important subject in city development

- Education
- Housing development

- Water resource development
- Agricultural development
- Road network
- Water supply
- Sewerage

23) Annual budget / Amount of budget varies. Roughly between CO$2,000,000,000 and CO$16,000,000,000.

The following is the summary of the replies from 48 cities.

- Major industries are agriculture and cattle breeding in most municipalities. This implies that land use pattern is also almost identical.
- Majority of the 48 cities listed "old and inaccurate map" as the problem for POT making.
- Many cities think that making standard for POT is important.
- Only three cities have special section in charge of survey or GIS. However, even such cities number of technical staff is between one and three. This means most of the 48 cities do not have capability to handle survey data, maps and GIS data.

11.3.2 Costs to make maps and basic GIS data for 100 municipalities

Cost estimation was made in order to compare the total cost of the 100 municipalities mapping with ordinary budget of IGAC.

Two estimations were made. One estimation was based on unit prices IGAC uses in estimating budget for contracts with private firms.

The other estimate was based on the contract amount of 65 municipalities mapping project undertaken by private firms in 2006.

(1) Cost estimation by using IGAC unit price

To make individual cost estimation for each city is very time consuming. For this reason, originally it was planned to divide 100 municipalities into several groups according to their characteristics such as major industry and land use. However, after checking answers to questionnaire from 48 cities, it was concluded that in general all the cities except 5 large ones are identical and cannot be divided into groups based on their characteristics.

So, grouping was made based on their location. Grouping by location is important from the standpoint of view of minimizing costs for field surveys. As the results, 100 municipalities were divided into 10 groups. And for each group, time and costs for ground control point survey, field identification survey, aerial triangulation and photogrammetric mapping were estimated.

1) Work volume of 100 municipalities mapping

- Mapping Area size: 56,210 ha
- Models: 646 models
- Control points: 723 points

2) Work speed

- Ground control point survey: 4 points/day/team
- Field identification survey: 130ha/day/team
- Aerial triangulation: 10 model/man/day
- Digital mapping: 200ha/man/month
- Digital editing: 600ha/man/month

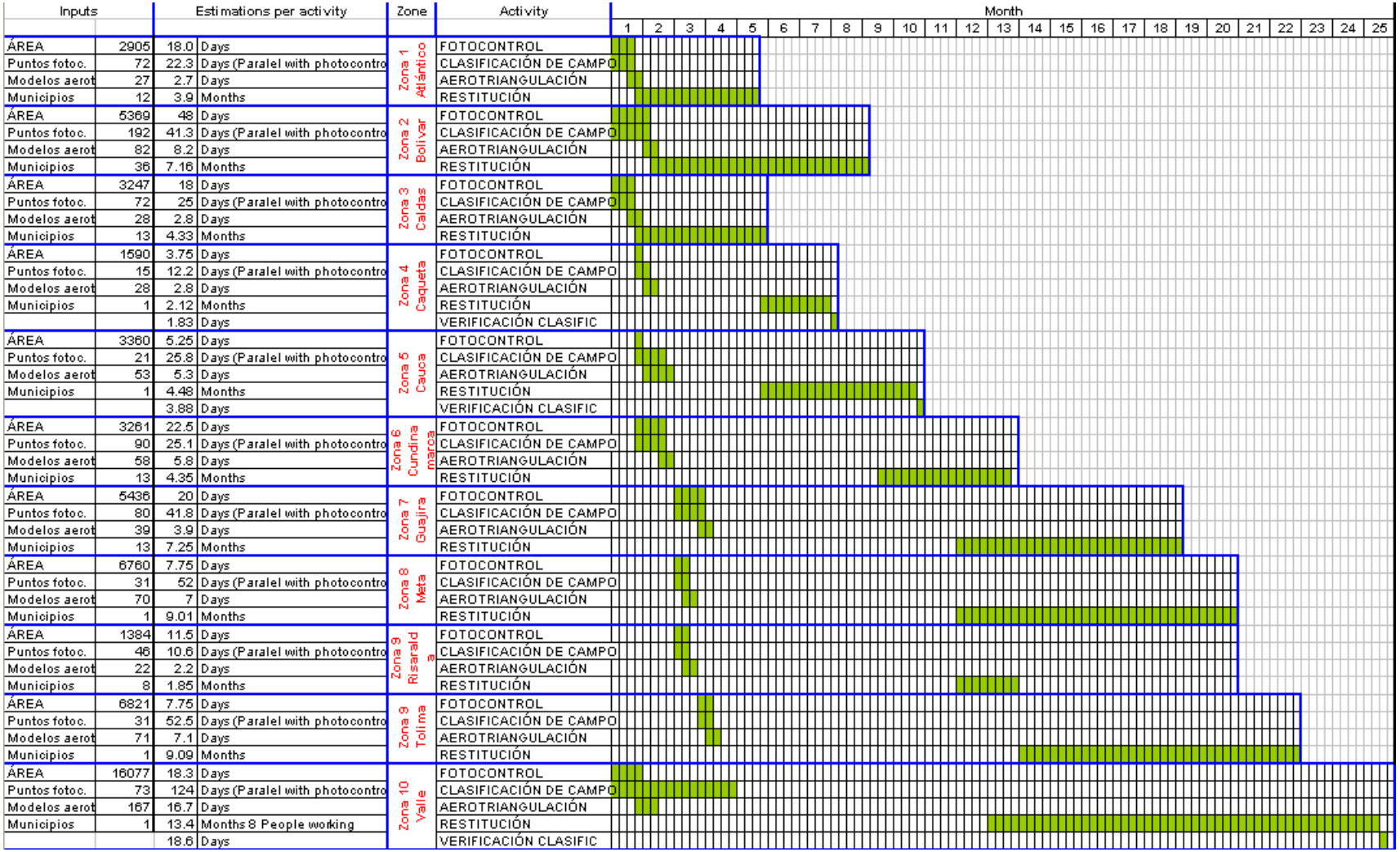
As Table 11-5 shows, total length of work is 25 months.

3) Costs

a） Ground control point survey：	CO$549,480,000
b） Field identification survey：	CO$224,840,000
c） Aerial triangulation：	CO$81,719,000
d） Digital mapping and editing：	CO$2,810,500,000
e） Field completion survey：	CO$56,210,000
Total：	CO$3,694,766,000

Table 11-5 Schedule of 100 municipalities mapping

Inputs		Estimations per activity		Zone	Activity
ÁREA	2905	18.0	Days	Zona 1 Atlántico	FOTOCONTROL
Puntos fotoc.	72	22.3	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	27	2.7	Days		AEROTRIANGULACIÓN
Municipios	12	3.9	Months		RESTITUCIÓN
ÁREA	5369	48	Days	Zona 2 Bolivar	FOTOCONTROL
Puntos fotoc.	192	41.3	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	82	8.2	Days		AEROTRIANGULACIÓN
Municipios	36	7.16	Months		RESTITUCIÓN
ÁREA	3247	18	Days	Zona 3 Caldas	FOTOCONTROL
Puntos fotoc.	72	25	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	28	2.8	Days		AEROTRIANGULACIÓN
Municipios	13	4.33	Months		RESTITUCIÓN
ÁREA	1590	3.75	Days	Zona 4 Caqueta	FOTOCONTROL
Puntos fotoc.	15	12.2	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	28	2.8	Days		AEROTRIANGULACIÓN
Municipios	1	2.12	Months		RESTITUCIÓN
		1.83	Days		VERIFICACIÓN CLASIFIC
ÁREA	3360	5.25	Days	Zona 5 Cauca	FOTOCONTROL
Puntos fotoc.	21	25.8	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	53	5.3	Days		AEROTRIANGULACIÓN
Municipios	1	4.48	Months		RESTITUCIÓN
		3.88	Days		VERIFICACIÓN CLASIFIC
ÁREA	3261	22.5	Days	Zona 6 Cundinamarca	FOTOCONTROL
Puntos fotoc.	90	25.1	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	58	5.8	Days		AEROTRIANGULACIÓN
Municipios	13	4.35	Months		RESTITUCIÓN
ÁREA	5436	20	Days	Zona 7 Guajira	FOTOCONTROL
Puntos fotoc.	80	41.8	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	39	3.9	Days		AEROTRIANGULACIÓN
Municipios	13	7.25	Months		RESTITUCIÓN
ÁREA	6760	7.75	Days	Zona 8 Meta	FOTOCONTROL
Puntos fotoc.	31	52	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	70	7	Days		AEROTRIANGULACIÓN
Municipios	1	9.01	Months		RESTITUCIÓN
ÁREA	1384	11.5	Days	Zona 9 Risaralda	FOTOCONTROL
Puntos fotoc.	46	10.6	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	22	2.2	Days		AEROTRIANGULACIÓN
Municipios	8	1.85	Months		RESTITUCIÓN
ÁREA	6821	7.75	Days	Zona 9 Tolima	FOTOCONTROL
Puntos fotoc.	31	52.5	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	71	7.1	Days		AEROTRIANGULACIÓN
Municipios	1	9.09	Months		RESTITUCIÓN
ÁREA	16077	18.3	Days	Zona 10 Valle	FOTOCONTROL
Puntos fotoc.	73	124	Days (Paralel with photocontro		CLASIFICACIÓN DE CAMPO
Modelos aerot	167	16.7	Days		AEROTRIANGULACIÓN
Municipios	1	13.4	Months 8 People working		RESTITUCIÓN
		18.6	Days		VERIFICACIÓN CLASIFIC



These costs are calculated based on the assumption that all the work is sub-contracted out to local private firms. IGAC often uses local survey firms for their mapping work if its own capacity is not sufficient. A cost estimated on this assumption is the maximum costs IGAC will need to make topographic maps of 100 municipalities.

(2) Cost estimation by referring to 65 municipalities mapping project

Contract amount of the 65 municipalities mapping with a total area of 65,000ha which IGAC contracted out to Colombian private firms is CO$4,500,000,000. On the other hand total size of the 100 municipalities mapping is 56,210ha.

By using these data of the mapping work already carried out, costs for the mapping of 100 municipalities were estimated.

Two calculations were made. In one case it was assumed that no fixed cost exists. In the other case, percentage of fixed cost and percentage of variable costs were assumed 10% and 90%.

If 10% of the contract amount is the fixed cost, total cost for the 100 municipalities mapping can be estimated by the following formula.

（CO$4,500,000,000×10%）＋（CO$4,500,000,000×90%）/65,000ha×56,210ha
＝CO$3,952,315,385

And if the percentage of the fixed cost is 0$ the total price will be CO$3,891,461,538.

Since it is unlikely that the entire contract price consist of variable cost, for the purpose of this approximation, the price estimated with 10% fixed cost, that is, CO$3,952,315,385, is used

(3) Evaluation of the two estimations

Costs estimated by two methods are as follows:

IGAC estimation:	CO$3,694,766,000
Estimation from previous contract:	CO$3,952,315,385

The difference is 7%. Judging from the fact that both calculation were not made based on exact number of control points or the shape of mapping areas, the JICA Study Team regard this 7% difference not significant. Conclusion of these estimations is that 100 municipalities mapping will be able to be done if approximately CO$4,000 million budget is available.

It should be noted that these figures are based on the assumption that existing aerial photos are used for the mapping.

In the Table 11-6, the estimated cost could be compared with IGAC budget. IGAC's budget directly related to mapping is as follows.

Table 11-6 Estimated mapping cost compared with IGAC budget

Cost Item	2005	2006	2007
1. Production and updating of general maps	300,000,000	300,000,000	4,108,000,000
2. DANE	10,987,569,206	0	0
3. Contract with other institutions	0	0	4,280,000,000

The Amount of mapping budget changes drastically from one year to the other. Basically the mapping budget for the year 2007 is for the production of 1/25,000 maps. But if this size of budget is allocated for the 1/2,000 scale mapping, total cost of mapping CO$3,952,315,385 can be easily covered.

11.4 Capacity of IGAC in map and GIS data production

11.4.1 IGAC's own resources and capability

Type and number of instruments and number of technical staff of the division of photogrammetry and division of geodesy are described in Chapter 6.

Overall resources of IGAC in the production of 1/2,000 scale digital maps and basic GIS data can be summarized as follows:

(1) Instruments and technical staff

As of July 2007, the Division of Photogrammetry has total 21 digital plotting systems and 25 digital map editing systems. As for the number of operators, it is possible for IGAC to hire contractors if the needs to increase production capacity arise. Therefore, IGAC has sufficient number of technical staff for photogrammetric mapping.

As for ground control point survey, Division of Geodesy has enough number of GPS and levels and operators to carry out field works.

(2) Operational skill of photogrammetric mapping systems:

Full scale conversion from analytical plotters to soft copy mapping systems started almost two years ago. And by July 2007, all the operators of conventional analytical plotters had been

trained to use soft copy machines. So, IGAC has no problem in the operations of individual mapping and editing system.

(3) Experience in photogrammetric mapping

IGAC has enough experience in stereo restitution and editing. The same is also true for aerial triangulation, ground control point survey and field identification survey.

(4) Capability to make basic GIS data

Since 2005 IGAC was studying the use of ArcGIS for map data editing and in 2006 a new data model was announced. Although the JICA Study Team and IGAC had a series of discussion on the definition and contents of basic GIS data, the JICA Study Team judges that IGAC has capability to produce GIS data from topographic map data.

(5) Issues and technology transfer

The JICA Study Team identified some issues in IGAC's map production method or rules. Particular concern was that communication between each technical group seems not be sufficient. Shortage in communication appeared in various process by taking different forms. One example is that ground control point allocation plan was not fully understood by photographic flight planner. Another example is unclear definition of data catalogue to be used in field identification survey.

Other minor issues include, but not limited to, map sheet layout which changes with the expansion of the size of each municipality.

All these issues identified by the JICA Study Team were checked and reviewed by IGAC. And some of the suggestions made by the JICA Study Team have already been accepted by IGAC and IGAC changed its previous method. Particular importance is IGAC is now trying to improve communication between different technical groups.

11.4.2 Capacity of Colombian private mapping firms

In 2006, IGAC made a contract with Colombian private mapping firms to make 1/2,000 scale digital maps of 65 municipalities. Capacity of private sector will be important in making 1/2,000 scale digital maps and basic GIS data in a short period of time. 4 major private mapping firms were visited to know their capacity

- FAL LTDA
- GEOVITAL

- GEOSISTEMAS
- ATLAS INGENIERIA

All of the four firms have some relation with IGAC. For example, former IGAC staff is working as top management in some firms. Although photogrammetric instruments of most of the firms are not as new as those of IGAC, all of them have sufficient capability to produce digital maps.

1) FAL

Established in 1980. Only mapping company in Colombia which has ISO certificate. FAL has its own aircraft Cessna 206. Photogrammetric instruments of FAL are as follows:

- PG2 × 4 sets
- Topocarto D × 1 set
- Planicomp × 1 set
- Aerial triangulation software: PAT-M

Presently, City of Bogotá is making 1/1000 scale topographic maps and groups of private firms are carrying out the work. FAL is working as the leader of a group of private firms. In 1/2,000 scale topographic mapping of 65 municipalities, which IGAC is subcontracting out to private firms, FAL is responsible for the mapping of 28 municipalities together with other firms.

2) ATLAS INGENIERIA

President of Atlas Ingeniería Mr. Ricardo Galindo was educated in ITC and the USA and was working as an instructor at CIAF. Further, Atlas has its own training school of photogrammetric operators. The company owns its own Cessna 206TU. They have the following photogrammetric instruments.

- DVP × 6 sets
- DVP for training × 6 sets
- Aerial triangulation system: SPACE-M

3) GEOVIAL

Many former IGAC staffs are working at this company. Major equipment is as follows:

- TOPOCARTO D (with encoder) × 3 sets
- CADMAP（Intergraph）＋INPHO × 1 set
- MicroStation
- ArcInfo Aerial triangulation software: Simultaneous Block Adjustment of DMA

4) GEOSISTEMAS

All staff except for the president is former staff of IGAC. Usually the firm has only 4 members. When the firm gets the contract, temporary employees are employed. Major photogrammetric instruments are as listed below:

- PG2 ＋ CADMAP × 3
- Imagestation（Intergraph） × 2
- AU3-WIN × 1
- MicroStation V8 ArcInfo

11.5 Results of the self sustainability analysis

As explained previously, self sustainability of IGAC's 1/2,000 scale maps and basic GIS data production program is judged by three factors as follows:

- Combined production capacity of IGAC and private sector
- Budget to make basic GIS data of the 100 municipalities
- Results of the technology transfer program of JICA

11.5.1 Combined production capacity of IGAC and private sector

By July 2007 IGAC has almost completed to equip itself with full digital photogrammetric production line. Operators of old analytical plotting machines were all trained to use softcopy restitution and editing instruments. On the contrary private firms are still using analytical plotters in addition to modern digital mapping instruments. But their final products comply with IGAC specifications.

By combining both capacities, it will not be difficult to make maps of 100 municipalities.

11.5.2 Budget to make basic GIS data of the 100 municipalities

IGAC's annual budget is CO$ 72.823 Million in the fiscal year of 2007. Total budget to be used for general mapping is CO$8.388 Million. On the other hand, budget required to make 1/2,000 scale maps and basic GIS data for 100 municipalities is approximately CO$3.694 Million. Therefore, if all of mapping budget is used for the 100 municipalities mapping, it can be completed in almost two years. Of course, IGAC has to make maps of other scales and other products, using all the mapping budget for the 1/2,000 scale mapping is impossible. However, considering the size of the cost of the 1/2,000 scale mapping and total size of IGAC budget, it will be concluded that with proper budget IGAC can complete the 100 municipalities mapping in relatively short period of time.

11.5.3 Results of the technology transfer program of JICA

As already mentioned in Chapter 7, the JICA Study Team contributed in reviewing and modifying IGAC's production methods for better results. The modification contributes to improve efficiency in 1/2,000 scale photogrammetric map production.

11.5.4 Overall evaluation of self sustainability

By combining all the factors mentioned above the JICA Study Team concludes as follows:

(1) IGAC has enough resources to produce 1/2,000 scale digital photogrammetric maps and basic GIS data of the 100 municipalities in reasonable timeframe. If IGAC'S own production resources are occupied with other mapping projects, then Colombian mapping firms can fulfill the shortage in resources.

(2) However, IGAC has gone through very drastic modernization process in the past three years and the process has just been completed. Many new methods were introduced. Although IGAC has acquired enough skill in the operation of each production system, such as soft copy mapping system, there still is uncertainty in combining all the new systems into one unit of digital map production.

(3) Furthermore, there are still some items which need further examination as to whether modification or improvement is required or not. One example is the local coordinate system now being used by IGAC for the mapping of local municipalities. As recorded in Chapter 8, the JICA Study Team argued that current Cartesian coordinate system of IGAC was not easy to understand for ordinary GIS users. While the JICA Study Team understands that the system has long been used in Colombia and was chosen over other method because of certain advantages of the system, the team thinks it is worthwhile for IGAC to review the coordinate system again from the point of view of the promotion of GIS data. One of the most difficult parts of using GIS for ordinary GIS users is the conversion of coordinate system or projection system. If each municipality has its own coordinate system, the chance that ordinary GIS users are confused.

Another example of items which has potential needs for review and improvement is the technical specifications for geographic features which should be interpreted and drawn on maps. IGAC has published data catalogues but the JICA Study Team thinks that definition of geographic features is not necessarily clear enough. Unclear definition of geographic features is potential cause of confusion in restitution and field identification.

(4) By combining above arguments, the JICA Study Team judges that IGAC is basically self sustainable in the production of 1/2,000 scale digital maps and basic GIS data of the 100 municipalities if sufficient budget is allocated. However, further technical review and improvement will be required to eradicate potential causes of confusions such as local coordinate systems and data catalogues.

CHAPTER 12 Proposal to IGAC

The JICA Study Team has summarized its recommendations to IGAC as described below from the implementation of the study.

12.1 IGAC's own resources and capability

(1) Instruments and technical staff

As of July 2007, the Division of Photogrammetry has total 21 digital plotting systems and 25 digital map editing systems. As for the number of operators, it is possible for IGAC to hire contractors if the needs to increase production capacity arise. Therefore, IGAC has sufficient number of technical staff for photogrammetric mapping.

As for ground control point survey, Division of Geodesy has enough number of GPS and levels and operators to carry out field works.

(2) Operational skill of photogrammetric mapping systems:

Full scale conversion from analytical plotters to soft copy mapping systems started almost two years ago. And by July 2007, all the operators of conventional analytical plotters had been trained to use soft copy machines. So, IGAC has no problem in the operations of individual mapping and editing system.

(3) Experience in photogrammetric mapping

IGAC has enough experience in stereo restitution and editing. The same is also true for aerial triangulation, ground control point survey and field identification survey.

(4) Capability to make basic GIS data

Since 2005 IGAC was studying the use of ArcGIS for map data editing and in 2006 a new data model was announced. Although the JICA Study Team and IGAC had a series of discussion on the definition and contents of basic GIS data, the JICA Study Team judges that IGAC has capability to produce GIS data from topographic map data.

12.2 Evaluation of self sustainability

(1) IGAC has enough resources to produce 1/2,000 scale digital photogrammetric maps and basic GIS data of the 100 municipalities in reasonable timeframe. If IGAC's own production resources are occupied with other mapping projects, then Colombian mapping firms can fulfill the shortage in resources.

(2) IGAC has gone through very drastic modernization process in the past three years and the process has just been completed. Many new methods were introduced. Although IGAC has acquired enough skill in the operation of each production system, such as soft copy mapping system, there still is uncertainty in combining all the new systems into one unit of digital map production.

(3) The current Cartesian coordinate system of IGAC was not easy to understand for ordinary GIS users. While the JICA Study Team understands that the system has long been used in Colombia and was chosen over other method because of certain advantages of the system, the team thinks it is worthwhile for IGAC to review the coordinate system again from the point of view of the promotion of GIS data.

12.3 Mapping Technique and Specification of IGAC

The JICA Study Team judged that the mapping technique and specification of IGAC had some problem.
The contents of discrepancy were explained and it has advised by the JICA Study Team.

(1) Incomplete model
Some of the photos covering water areas in Cartagena and Santa Marta areas were found not to be correlated. In other words, there were some incomplete models. For example, sand bars in Cartagena were not covered by single course.
For “Incomplete Models”, elevation of the water body were estimated from the elevation of nearby land area.

Although the height of the water surface was deduced from the height of nearby land on the model and it corresponded by giving height in the incomplete model.
The JICA Study Team guessed that IGAC was almost inexperienced in 1/2,000 topographical mapping near coast, so the JICA Study Team guided IGAC for the future photography method.

(2) The numbering rule of a photograph
It was found that numbers of photos which were generated automatically by aerial camera, point number of airborne GPS data and file number of digitized aerial photos were not co-related. This caused much confusion in preparatory stage for aerial triangulation. It is recommended to review numbering rules or at least make some relational table.

(3) Position of cross strips

IGAC flew cross strips which connect main flight courses. However, the position of cross strips was not in designed in a way to reduce the number of ground control points.

The purpose of the cross strips was explained and the correspondence to a future photography plan was guided.

(4) Quality of the image of aerial photos

1) Contents of the problem

Color tone in some digital image which IGAC created was not continuous.

- By enlarging the image up to pixel level, it was found that color tone of neighboring pixel is not continuous.
- In areas such as roof of buildings or surface of roads where color tone should be almost the same, color one of neighboring pixel changes randomly.

2) Inspection of scanning process at IGAC

Usually it is not recommended to manipulate image resolution by interpolation method. Also after some experiment it was confirmed that best quality image could not be obtained if scanning speed was set at maximum level. The JICA Study Team advised to find the most suitable level of scanning speed by considering both image quality and scanning time.

12.4 Subject about improvement in staff technologic abilities

(1) Management of a topographical map and a GIS database

One of the requests from a municipality was the necessity of updated maps. Because there is no updated maps and they feel inconvenience for planning purpose.

But when the data of three cities is completed IGAC will offer a set of data to three cities. These data is expected to be used effectively in various scenes.

However, update of data will become a big problem in future. So it is necessary to find a way to perform data update. Utilize the staff of IGAC regional office for data update is recommended.

(2) IGAC regional office training

IGAC is the national survey and mapping organization of Colombia and a leading geographic institute in Central and South America.

For staff education various training courses about a survey, photogrammetry, remote sensing for mapping are available at CIAF.

However, these kinds of training opportunities are not fully available to the staff of regional offices. While IGAC headquarters send its technical staff to local offices as instructors for training, regional offices seem to desire more frequent or longer training programs.

Currently, their involvement in topographic mapping is limited but IGAC is trying to train regional office staff in field surveys for topographic mapping. Therefore it is important to think about their training in this field positively

12.5 Review IGAC's production process

(1) A production process and specification review from a different viewpoint from IGAC.
IGAC is a survey department with more than 70 years of history.
Therefore some production process has changed and it is necessary to review a work process, but in some case review is not performed.

The JICA Study Team was able to review specifications from the viewpoint that was different from IGAC in a production process and reported the result.

However, the JICA Study Team thinks it is necessary to increase opportunities of information exchange between sections in order to handle mass production in future. In addition, it is necessary to bring up the manager who can look around the whole process.

(2) Advice to IGAC from an investigating commission

- Aerial triangulation and digital mapping
  IGAC operators had no problem in digital mapping. As for aerial triangulation the JICA Study Team concluded that by using automatic correlation function of software IGAC could carry out aerial triangulation without problem. Therefore, the JICA Study Team taught IGAC staff a method to carry out aerial triangulation with manual correlation to deal with cases where automatic correlation is difficult.

- The contents and the subject of a coordinate system employed by IGAC
  Almost all of the 1099 municipalities have each own origin of coordinates. As a result, coordinate system of Colombia causes the following inconveniences.

1) If many local coordinate systems exist for one area, ordinary users of geographic information will be confused.

2) If many local coordinate systems exist, GIS software manufactures hesitate to make conversion program. Or, does IGAC have a plan to distribute conversion software to general public?

3) In the future, geodetic control point network will be established in many municipalities. If coordinates changes over a short period time due to the move of origin, management of survey data will be very complicated.

One of the purposes of making GIS data and using GIS is to share geographical information by using the same coordinate system. Existence of multiple coordinate systems in small areas will make the use of geographic information difficult.

4) Coordinate value of origin of local coordinate system are the same with the coordinate value of the coordinate system for small scale mapping. Coordinate values of both coordinate systems are identical at the origin of local coordinate system. But coordinate values of the two coordinate systems are identical only at the origin of the local coordinate systems, this system is quite confusing for ordinary map users because it is difficult to identify the type of coordinate system only from coordinate values of points on maps.

12.6 Verify Specification of IGAC in the Same Position as Subcontract

The survey and a field survey were performed without carrying the survey technique of Japan, but by respecting the specification of IGAC. So the JICA Study Team had to confirm specifications of IGAC in detail, and as a result the JICA Study Team was able to point out a reexamine point to IGAC. It will be important to explain the reexamine result to the people in IGAC.

(1) Data catalog

IGAC has published various catalogs on geographic features.

There are following two types of specifications in the technical specifications IGAC uses for the work subcontracted out to local private firms.

Annex No.6	Modelo de datos
Annex No.7	Symobologia

Items checked during field identification survey were listed based on the data model rules specified in Annex 6. However, there are some geographic features which are not covered by this data model. Also, symbolization rule is specified in Annex 7 but some of them do not match with data model described in Annex 6. Further, some parts of the feature classification rule of this Annex 6 found to be not so logical.
It is understandable that this kind of confusion occurs because IGAC was in the process of constructing data model. It is recommended to review the structure of data model and also make data model and symbols consistent with each other.

12.7 Proposal of New Technique to Field Survey Method Which IGAC is Performing

IGAC is now shifting from analog method to digital method.
Therefore, the contents expected to be helpful in the future have a strong posture taken in positively.

Introduction of RECON and orthophotograph is a concrete example, and it also considers it to be an important subject to connect to the mass production organization which is less experienced by IGAC.

(1) Use of a data recorder (RECON) with GPS
IGAC proposed to use GPS installed data recorder in field identification survey. Advantages and disadvantage of the use of the recorder were clarified during the field identification survey. In future field identification survey it will be necessary to make work plan by taking considerations of both advantages and disadvantages of the recorder.

Good point of the recorder is that coordinates and text information on collected data stored in digital form and therefore can be transferred to mapping system with further digitization.

Disadvantage is that the system does not support Cartesian projection. Also, since GPS installed in the recorder measure the location of the receiver only by single positioning mode, positional accuracy is not so high.

By considering above discussion, the JICA Study Team recommends IGAC to use the recorder in the following manner.

- Type of work suitable for using the recorder: National Census in which the quantity of data collection is large and also every building or household must be visited.

- Type of work not suitable for using the recorder: Identifying and drawing items which are not clearly visible on aerial photos.

CHAPTER 13 Recommendations for the Use and Application of digital data created by the Project

The recommendations for the use and application of digital data created by this project are summarized below.

13.1 Role of IGAC on the use of GIS

The potential role of the digital data created by this project can be used for updating of POT. But once the digital data are created, these data need maintenance. So IGAC should act more as a top manager in dissemination of information.

(1) Conceptualization of some of the tasks
Conceptualizations of some of the tasks are documented below.

1) IGAC should be responsible for coordinating, integrating, and monitoring GIS activities in the Colombia.

2) IGAC should provide technical assistance and training at various stages of the project execution using GIS, and also act as an information center.

3) IGAC should play a central role in advising government and municipality on issues of geographic information policy, such as standards, exchange formats, data charging and data collection units, legal issues.

4) Until the municipalities are able to fully undertake the job themselves, IGAC should be responsible for the update and integration of the digital data.

5) Provide functional standards and guide line for:

- Data collection methods and survey protocol
- Validation of data
- Documentation and quality assurance
- Analysis and modeling
- Reporting and product development
- Data audits

Figure 13-1 show a type of GIS user and a role of IGAC as data provider.

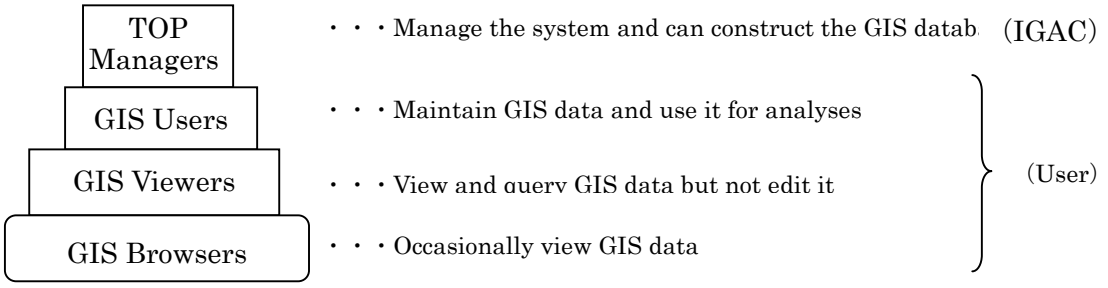


Figure 13-1 Type of GIS User and their role

(2) Training specially for mapping purpose

1) Train the GIS user

2) Training for operations personal (i.e. data collection and entry)

3) Training for viewers

4) Training Users (i.e. decision makers)

13.2 GIS data base User

Basic GIS Data is the provision of accurate and reliable geographic data which can be used as the standard in overlaying more than one type of spatial information, such as road, water line and building.

Many GIS users use existing basic GIS data from IGAC etc. And add other type of data if required for actual use. Therefore reliability of GIS data base is important.
Actually the following user exists in Bogotá (Table 13-1).

Table 13-1 GIS data base User

No	Name	Comments	Jurisdiction
1	DANE - Departamento Adminstrativo Nacional de Estadistica	Statistical data producer	National
2	Ministerio de Ambiente, Vivienda y Desarrollo Territorial	Ministry of the Environment, Housing and territorial development	National
3	ECOGAS - Empresa Colombiana de Gas	Gas company	National
4	IDEAM - Instituto de Hidrología, Meteorología y Estudios Ambientales	Institute for hidrology, meteorology and environmental studies	National
5	DNP - Departamento Nacional de Planeacion	National Planning Department	National
6	Bogota Municipality - Alcaldia de Bogota	(*) In general, institutions of Bogota do not use IGAC-produced data for their tasks.	Local (Bogota)
6.1	DAPD Departamento Administrativo de Planeacion Distrital	Planning Office	Local (Bogota)
6.2	IDRD Instituto Distrital de Recreacion y Deporte	Recreation - Sports	Local (Bogota)
6.3	IDU Instituto de desarrollo urbano	Urban development	Local (Bogota)
6.4	DACD Departamento Administrativo del Catastro Distrital	Cadaster	Local (Bogota)
6.5	CVP- Caja de vivienda popular	Popular Housing	Local (Bogota)
6.6	DABS- Departamento Administrativo de bienestar social del distrito	Social welfare	Local (Bogota)
6.7	DADEP - Departamento administrativo defensoria de espacio publico	Public spaces	Local (Bogota)
6.8	DAMA - Departamento administrativo del Medio Ambiente	Environment	Local (Bogota)
6.9	Empresa de renovacion urbana	Urban renewal	Local (Bogota)
6.10	ETB - Empresa de telecomunicaciones de Bogota	Telecomunicactions	Local (Bogota)
6.11	BSH - Bogota sin hambre		Local (Bogota)
6.12	Canal Capital	Television channel	Local (Bogota)
6.13	FAVIDI - Fondo de ahorro y vivienda distrital	Housing fund	Local (Bogota)
6.14	DPAE - Departamento Administrativo La Dirección de Prevención y Atención de Emergencias de Bogota	Emergencies prevention & attention	Local (Bogota)
6.15	Metrovivienda	Social housing	Local (Bogota)
6.16	Secretaria de educacion	Secretary of Education	Local (Bogota)
6.17	Secretaria de hacienda	Secretary of	Local (Bogota)
6.18	Secreatria de gobierno	Secretary of government	Local (Bogota)
6.19	Secretaria de obras	Secretary of public infrastructure	Local (Bogota)
6.20	Secretaria de salud	Secretary of health	Local (Bogota)
6.21	Secretaria de transito y transporte	Secretary of transportation	Local (Bogota)
6.22	Transmilenio	Transmilenio Transportation system	Local (Bogota)
6.23	Empresa de Acueducto de Bogota	Aqueduct	Local (Bogota)
7	Corporación Autónoma Regional de Cundinamarca (CAR)	Cundinamarca environmental regional office	Regional (Cundinamarca)

13.3 Specific use of GIS data

(1) Preparation of basic GIS data and special data

The JICA Study Team assumed that there are two types of GIS data required for project. Spatial data which is a basic GIS data commonly necessary for formulation of various projects and other types of data required for actual projects (Table 13-2).

Table 13-2 Specific use of GIS data

		Road construction	Agriculture	Industry	Fisheries	Housing	Tourism	Disaster	Environmental preservation
Spatial data	Road, railroad	○				○	○	○	○
	Coastline	○		○	○				○
	Water area (river, lake)	○	○				○	○	
	Geographical feature (elevation, contour line)	○	○	○		○			
	Control point	○				○		○	
	Vegetation						○		○
	Public facility					○		○	
	Name of a place						○	○	
Other	Land use	○	○	○		○		○	○
	Soil		○						
	Geology	○		○				○	
	Disaster history	○				○	○	○	

(2) Use of GIS according to a purpose

The GIS database created by covers all the contents indicated to "spatial data." However, the information above including land use, soil, geology, a disaster history, etc., raised to "others" will be collected if required.

Table 13-3 shows the data for main project arranged.

Table 13-3 Use of GIS data according to a purpose

Field	Summary	Data to use
Urban Planning	City planning decision, Urban planning control	Road, River, Boundary (administration boundary), Contour line, Control point Land use, Educational facilities
Facility management	Sewer pipe management Power transmission	Drainage canals, such as a pipeline, water supply plant information, a pump place, and beneficiary information

Land management	Land ownership management tax property evaluation	Lot number, a house, present condition classification of land, structure, etc.
Resources management	Agriculture, Agricultural management, Soil diagnostic, Underground resources (groundwater, various ores, etc.)	Farming person, area, crop inclination soil, slope, geology

Urban Planning：

The information necessary for city planning decision, urban planning control and city planning support, etc includes road, river, boundary and facilities etc. Also statistical information such as population etc. is necessary.

Facility management：

Many information's to be collect and requires lot of time for data construction. Especially the accuracy of position of piping network data is a big key to a success and quantity of work will become huge.

Land management：

IGAC is already using computer for cadastral. To prepare the necessary data cadastral survey is necessary. Also the boundary of the land and the name of the land owner as annotation information. For this 1/2,000 scale information are adequate to indicate each house definitely.

Resource management：

For farming project topographic map scale of 1/2,000 are adequate to indicate each crop. Attribute data of land owners should be attached as annotation.

CHAPTER 14 CONCLUSION

The study was implemented in July 2005 when The JICA Study Team started its preparatory work in Japan. And the study was completed in December 2007 when the JICA Study Team delivered the final output to JICA Tokyo office.
In Colombia, aerial photography, film scanning, ground control point survey and field identification survey were planned and implemented by IGAC. The JICA Study Team provided various advices on aerial photography, film scanning, ground control point survey and field identification survey.

Since IGAC technical staff already had knowledge in the operation of digital mapping instruments, technology transfer was made mainly as a form of technical discussions rather than giving instructions on the operation of instruments. A series of discussions were made to check problems of current production process and exchange opinion on production techniques. These discussions are aimed for the strengthening the production capacity in IGAC.

The production of 1/2,000 scale digital maps are being handled by the headquarters of IGAC. If territorial offices can take over some part of the field work carried out by the IGAC headquarters, cost saving is possible. But currently main role of regional staff is the management of cadastral data including data updating. So most of the regional offices do not have experience in photogrammetric mapping. Therefore, if regional office staff is going to involved in topographic mapping process, training and education will be required in this field.

If territorial offices can take over some part of the field work, not only cost saving but also the involvement of territorial office will be a big benefit for the mapping work.

The mapping budget for the year 2007 is mainly for the production of 1/25,000 maps rather than 1/2,000. But the JICA Study Team judges that IGAC is basically self sustainable in the production of 1/2,000 maps for the 100 municipalities. If production resources are occupied for the production of 1/25,000 maps, Colombian mapping firms can fulfill the shortage in resources.

Finally, the JICA Study Team wishes to express sincere appreciation for the great support and cooperation rendered, during the period of implementation of the Study, by the Director General of IGAC, IGAC counterparts, the Japanese Embassy in Colombia and the JICA Colombia office.