JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
SURVEY OF KENYA (SOK)

THE STUDY
FOR
THE ESTABLISHMENT OF THE SPATIAL DATA FRAMEWORK
FOR
THE CITY OF NAIROBI
IN
THE REPUBLIC OF KENYA

FINAL REPORT

FEBRUARY 2005

JICA STUDY TEAM

KOKUSAI KOGYOU CO., LTD.

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Preface

In response to a request from the Government of the Republic of Kenya, the Government of Japan decided to conduct the Study for the Establishment of the Spatial Data Framework for the City of Nairobi in the Republic of Kenya, and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA dispatched a study team headed by Mr. Akira Nishimura of Kokusai Kogyo Co. Ltd. to the Republic of Kenya, six times between December 2002 and March 2005.

The team held discussions with concerned officials of the Government of the Republic of Kenya, including the Survey of Kenya, Ministry of Lands and Housing and Nairobi City Council, and conducted field surveys in the study area. Upon returning to Japan, the team conducted further studies and prepared this report.

I hope that this report will contribute to the establishment of spatial data infrastructure and the development of various GIS in the Republic of Kenya in the future, and to the enhancement of friendly relations between our two countries.

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

February 2005

Mr. Kazuhisa Matsuoka
Vice-President
Japan International Cooperation Agency

Letter of Transmittal

Mr. Kazuhisa Matsuoka
Vice-President
Japan International Cooperation Agency

It is a great honor to submit herewith the report of the Study for the Establishment of the Spatial Data Framework for the City of Nairobi in the Republic of Kenya. This report was prepared, incorporating the suggestions received from the Japan International Cooperation Agency (JICA) and concerned authorities, as well as the agencies concerned of the Government of the Republic of Kenya including the Survey of Kenya, Ministry of Lands and Housing and Nairobi City Council.

During the Study, spatial data infrastructure for the City of Nairobi, which forms a part of the national spatial data infrastructure of Kenya, was established, and the techniques concerned with this work were transferred to the Survey of Kenya. Furthermore, various GIS databases (public facilities, roads, water supply and sewerage, cadastral) were constructed from this spatial data infrastructure, to support administration of Nairobi City. The team also developed GIS model systems that use these databases, and provided them as a tool to solve urban problems faced by the city. Regarding the GIS model systems, techniques for GIS use, including those for database construction, were transferred to the Survey of Kenya and Nairobi City Council with successful results.

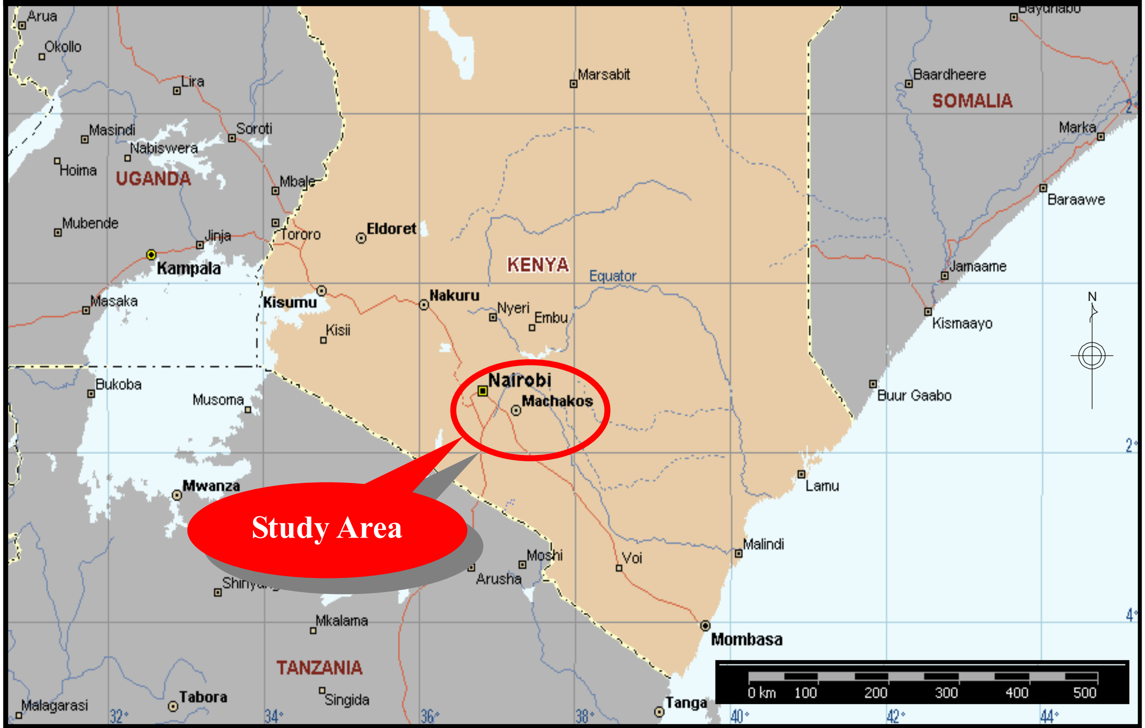
In the final chapter of this report, specific recommendations are made based on the results of the study. From the viewpoint of maintaining and developing the results of the study, I hope that these recommendations are promptly implemented by the agencies concerned of the Government of the Republic of Kenya.

On behalf of the team, I would like to express my sincere gratitude to JICA, the Ministry of Foreign Affairs, the Ministry of Land, Infrastructure and Transport, and agencies concerned for the valuable advice and cooperation they provided us during the implementation of this study. I would also like to express my deep appreciation to the agencies concerned of the Government of the Republic of Kenya, including the Survey of Kenya, Ministry of Lands and Housing and Nairobi City Council, for their generous assistance and cooperation during our stay in Kenya.

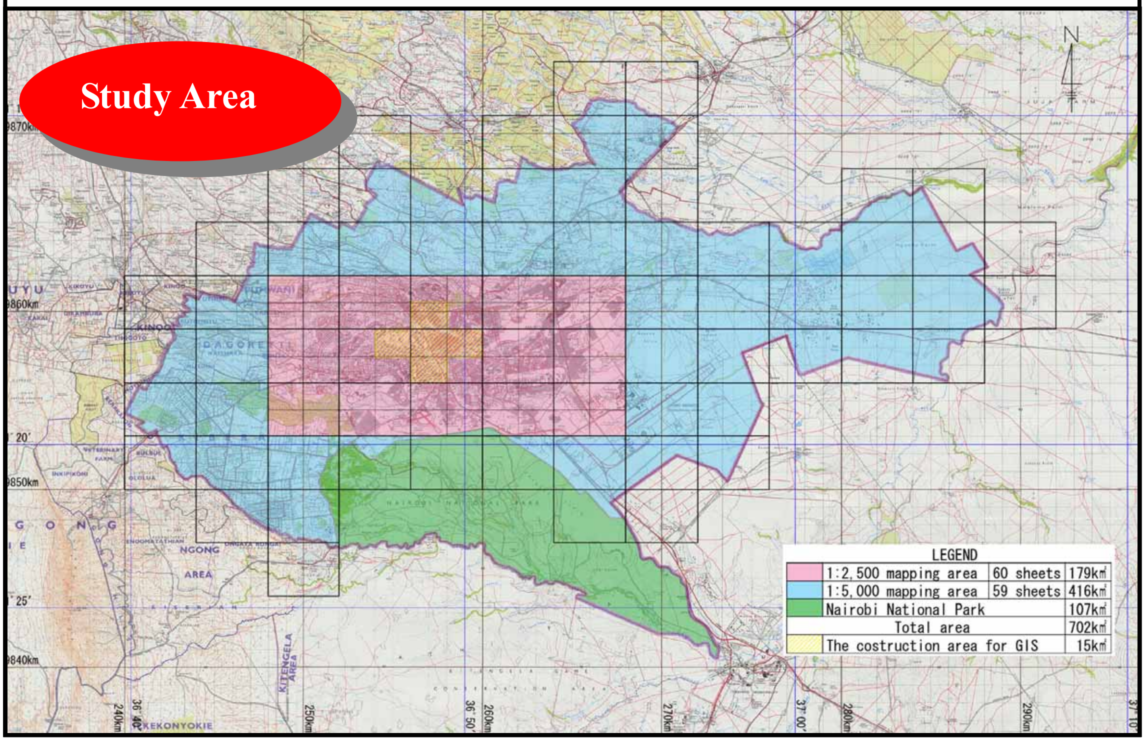
February 2005

Akira Nishimura
Team Leader
The Study for the Establishment of the Spatial Data Framework for the City of Nairobi in the Republic of Kenya

Location Map of Study Area



Republic of Kenya



Photographs

Nairobi City

Nairobi City

Nairobi City

Nairobi City

Nairobi City

Nairobi City

Photographs

Survey of Kenya

Survey of Kenya

Plotting

Plotting

Computer Room

Printing Machine

Photographs

Nairobi City Council

Nairobi City Council

Nairobi City Council

Nairobi City Council

GPS Survey

GPS Survey

Photographs

Levelling

Levelling

Aerial Photography

Aerial Photography

Aerial Photography

Aerial Photography

Photographs

Field Identification

Field Identification

Supplementary Field Identification

Supplementary Field Identification

Technology Transfer

Technology Transfer

Photographs

Technology Transfer

Technology Transfer

Technology Transfer

Technology Transfer

Technology Transfer

Technology Transfer

Photographs

Inception Report Meeting

Inception Report Meeting

Progress 1 Report Meeting

Interim Report Meeting

Interim Report Seminar

Interim Report Seminar

Photographs

Progress 2 Report Meeting

Draft Final Report Meeting

Technology Transfer Seminar

Technology Transfer Seminar

Technology Transfer Workshop

Technology Transfer Workshop

Final Report

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Chapter 1 Summary of the Study

1.1 Background

In recent years, the City of Nairobi in the Republic of Kenya (hereinafter referred to as "Kenya") has experienced rapid growth due to an inflow of people from rural areas, and the city cannot effectively manage its infrastructure (water and sewerage, land management, waste disposal, health and sanitation, etc.) to meet the growing demand. Moreover, the city lacks up-to-date geographic information essential to deal with this serious problem.

The 1:2,500-scale topographic maps of Nairobi, which are the most basic geographic information, were produced by the Survey of Kenya (SOK) in analogue format over 30 years ago. However, the maps cover only a portion of the urban area and have not been updated or expanded.

As part of the effort to establish the latest geographic information in digital format, SOK has been promoting a plan to develop National Spatial Data Infrastructure (NSDI).

Under the above circumstances, the Government of Kenya made a request in 2001 to the Government of Japan for technical cooperation regarding "The Study for the Establishment of the Spatial Data Framework for the City of Nairobi in the Republic of Kenya" (hereinafter referred to as "the Study").

In response to the request, the Government of Japan dispatched a preliminary study team in September 2002 to confirm the content of the request, the scope and content of the study, implementation conditions, etc., and the Scope of Work (S/W) and Minutes of Meeting (M/M) were signed and exchanged.

The Study was implemented in accordance with the S/W and M/M

1.2 Objectives

The aim of the Study was to construct GIS model systems and to establish spatial data infrastructure, which are shown in the following, and to transfer the techniques applied in those processes. Particular emphasis was placed on the transfer of technology.

(1) Transfer of technology (main objective)

(2) Construction of GIS model systems

(3) Establishment of spatial data infrastructure at a level of 2500 and 5000

1.2.1 Technology Transfer

The primary objective of the Study was to transfer technology so that SOK and Nairobi City Council (NCC) would be able to construct GIS, establish spatial data infrastructure and carry out operation and maintenance work independently after completion of the Study.

1.2.2 Construction of GIS

The Study aimed to construct the following GIS:

Construction of GIS model systems to contribute to solving urban problems

Construction of databases for use on the GIS model systems

1.2.3 Establishment of Spatial Data Framework

The Study aimed to establish the following spatial data infrastructure:

2500-level spatial data infrastructure (179.22 km^2)

5000-level spatial data infrastructure (416.60 km^2)

1.3 Study Area

The areas targeted for the respective works in the Study were as follows.

(1) Target area for acquisition of aerial photo image data

Aerial photo image data was acquired for the entire City of Nairobi (702km^2). (Refer to Figure 1.1 Aerial photography study area)

(2) Target area for aerial triangulation

Aerial triangulation was carried out for the entire City of Nairobi, excluding Nairobi National Park, which was not to be mapped (595.82km^2). (Refer to Figure 1.2 Aerial triangulation area)

(3) Target area for the establishment of 2,500- and 5,000- level spatial data infrastructure

The new sheet division for 2500 and 5000 level data was set, and the target area was determined in sheet units giving first priority to the city boundary.

a. <u>2500 level</u>

The 2500-level data was established for an area of 179.22km^2 in 60 sheets (2 km x 1.5 km/sheet). (Refer to Figure 1.3 Mapping area & sheet index)

b. <u>5000 level</u>

The 5000-level data was established for an area of 416.60km^2 in 59 sheets (4km x 3km/sheet). Refer to Figure 1.3 Mapping area & sheet index)

(4) Target area for the construction of GIS databases

GIS databases were constructed for the 15km^2 area (5 sheets) most suitable for application of the GIS model system within the area covered by 2500-level data.

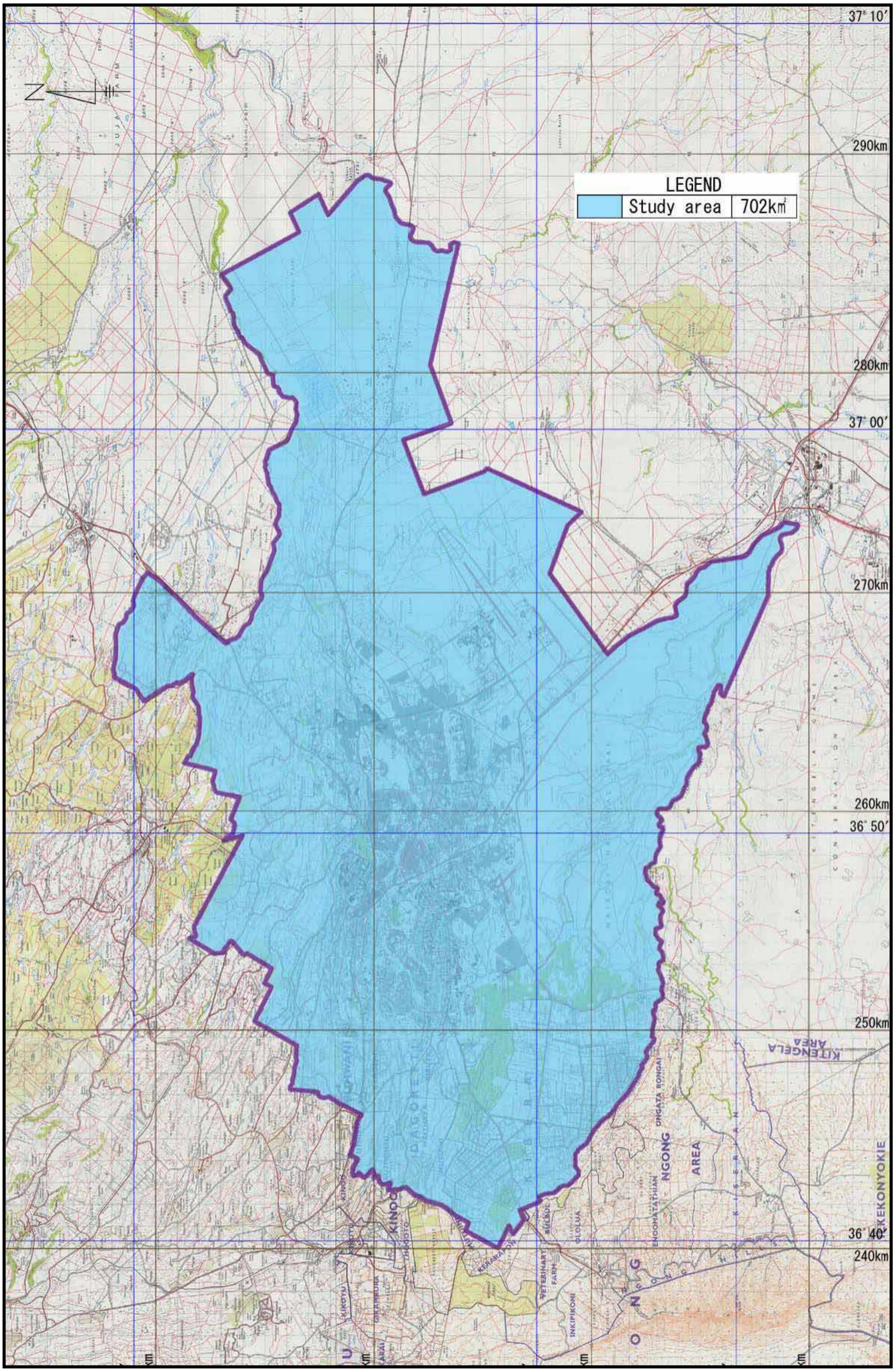


Figure 1.1 Aerial photography study area

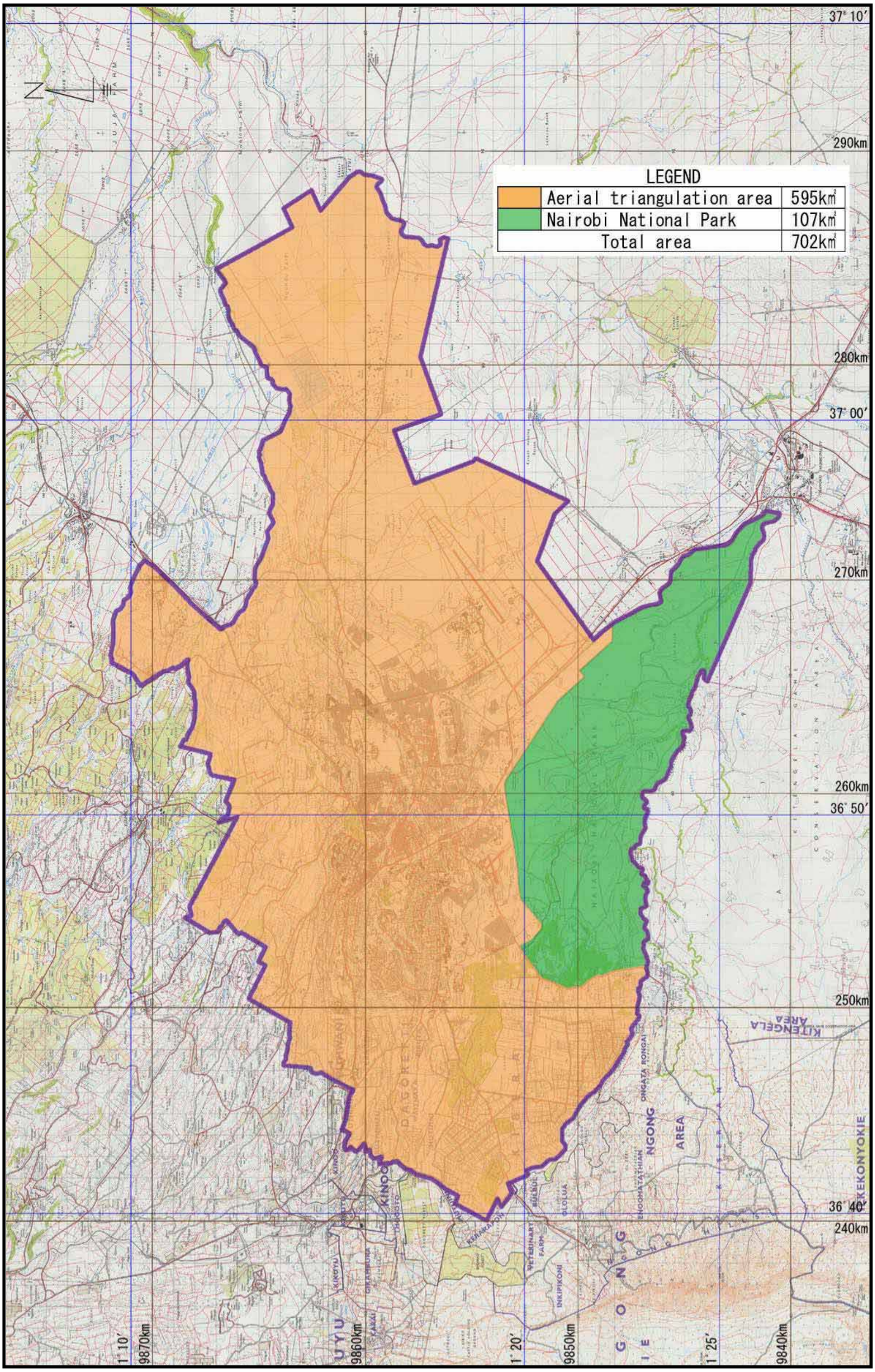


Figure 1.2 Aerial triangulation area

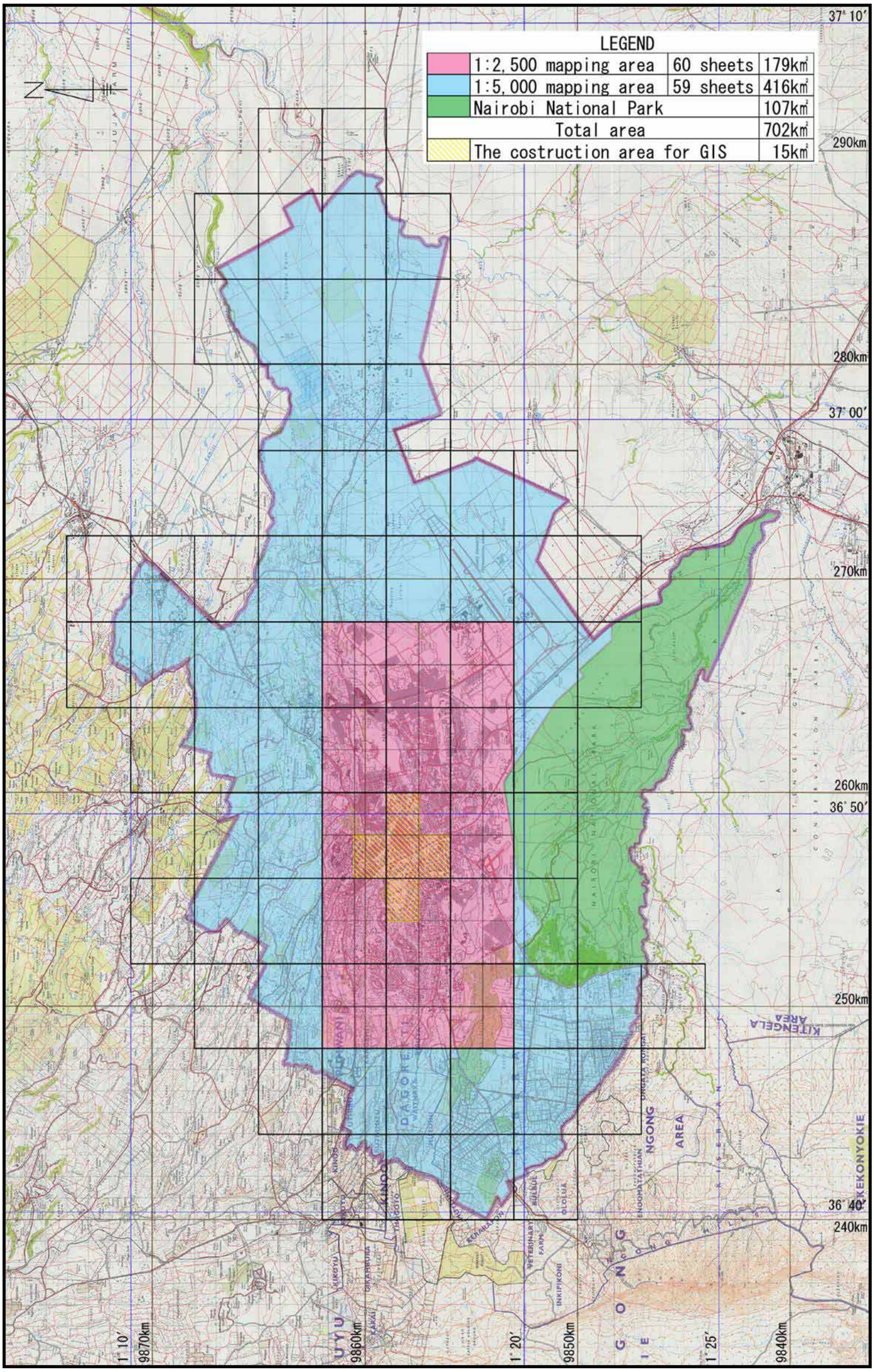


Figure 1.3 Mapping area & sheet index

1.4 Contents of the Study

1.4.1 Contents and Volume of Work

(1) Technology transfer

The technology transfer implemented in the Study was divided into the following two main fields:

- ♦ Technology transfer for GIS construction
- ♦ Technology transfer for the establishment of spatial data infrastructure

a) Technology transfer for GIS construction

The transfer of technology in this field covered the following items:

- ♦ Construction of GIS databases
- ♦ Construction of topographic databases
- ♦ Operation and maintenance of GIS

b) Technology transfer for the establishment of spatial data infrastructure

The transfer of technology in this field covered the following items:

- ♦ GPS survey
- ♦ Ordinary leveling
- ♦ Pricking
- ♦ Field identification
- ♦ Aerial triangulation
- ♦ Digital plotting and compilation
- ♦ Supplementary field identification
- ♦ Production of topographic map data

The work related to technology transfer was implemented according to the flowchart shown in Figure 1.4.

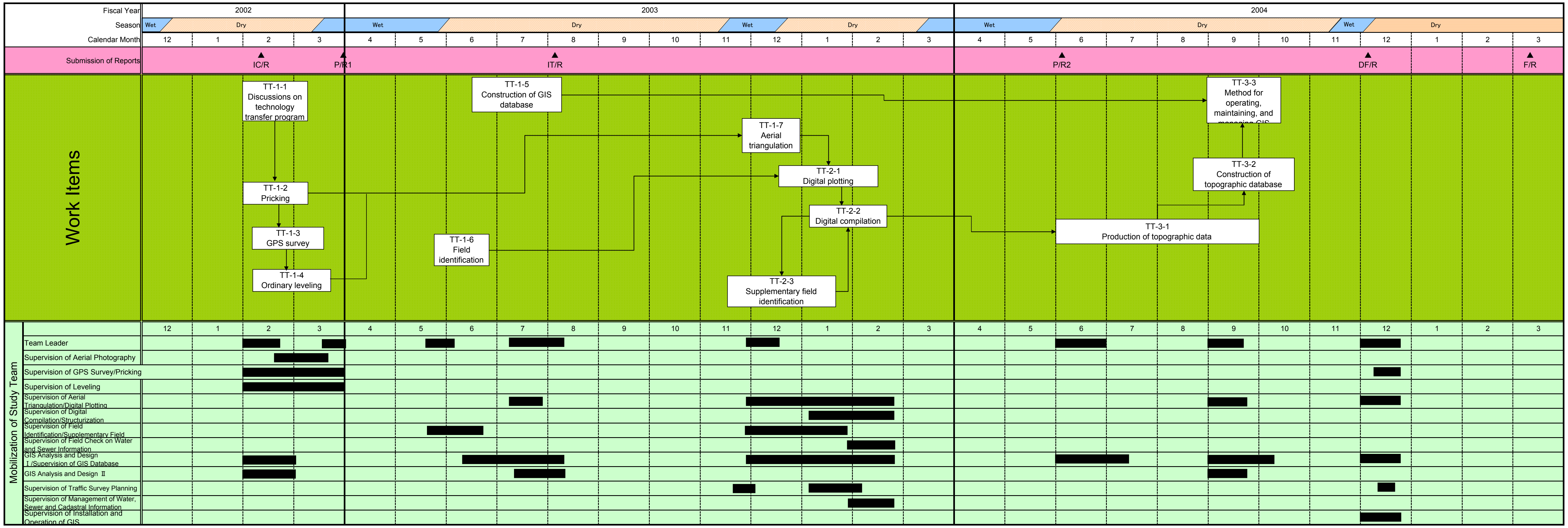


Figure 1.4 Flowchart of Technology Transfer

(2) Construction of GIS

The contents and volume of work related to GIS construction are summarized in Table 1.1.

Table 1.1 Contents and volume of work for GIS construction

Category	Work Item	Description	Volume
Joint Work	Consultations on works related to GIS	A survey on work that could be targeted for GIS and a survey on requested GIS functions and database items/material was conducted.	1 set
	Discussions/determination on target works and target area of GIS	The target work and target area of GIS was discussed with the Counterpart and decided on.	1 set
	Discussions on GIS specifications	Based on the items discussed and decided on above, the functions and database items was discussed and determined.	1 set
	System/database verification 1 and 2	The constructed GIS model systems were verified to be running in accordance with the specifications.	1 set
Construction of GIS databases	Collection of administrative data (by SOK)	Administrative data corresponding to the database items decided on were collected.	1 set
	Construction of GIS databases (by SOK)	The various GIS databases were constructed from the collected administrative data.	$15km^2$
	Construction of topographic database	The topographic database was constructed from the topographic map data.	$15km^2$
	Traffic volume survey (by subcontractor)	Three types of traffic volume surveys were conducted.	1 set
	Field verification of information on water and sewer facilities (by subcontractor)	Information (location, etc.) on water and sewer facilities (manholes, valves, etc.) were verified in the field.	$15km^2$
Construction of GIS system	System construction	Based on the results of the consultations on GIS related work, a system equipped with various functions was constructed.	1 set

(3) Establishment of spatial data infrastructure

The contents and volume of work related to the establishment of 2500- and 5000-level spatial data infrastructure are summarized in Table 1.2.

Table 1.2 Contents and volume of work for the establishment of spatial data infrastructure

Category	Work Item	Description	Volume
Joint Work	Preparatory work in Japan	The preparations necessary for Study implementation were made.	1 set
Establishment of 2500/5000 level spatial data infrastructure	Discussions and determination on the area targeted for the establishment of spatial data infrastructure	The area targeted for the establishment of the spatial data infrastructure were discussed and decided on with the Counterpart agency.	1 set
	Discussions and determination on the specifications for the establishment of spatial data infrastructure	The specifications for establishing the spatial data infrastructure were discussed and decided on with the Counterpart agency.	1 set
	Aerial photography (by subcontractor)	1:15000-scale color aerial photos were taken	702 km^2
	Ground control point survey (by SOK)	A photo control point survey by GPS and ordinary leveling was conducted.	22 points 247 km
	Pricking (by SOK)	Using the aerial photos taken, pricking of photo control points and elevation points by ordinary leveling was carried out.	22 points 247 km
	Aerial triangulation	Using the results of the ground control point survey, the elements of orientation required for digital plotting were obtained through computer processing.	250 models
	Field identification (by SOK)	The information (place names, annotations, etc.) that could not be obtained through photo interpretation using the aerial photos taken was collected in the field.	585.82 km^2
	Digital plotting/compilation (done in part by SOK and subcontractor)	The 2500 and 5000 level topographic and planimetric features were digitally plotted and compiled using the results of aerial triangulation and field identification.	585.82 km^2
	Supplementary field identification (by SOK)	Any questionable items that arose during digital plotting/compilation were verified in the field	585.82 km^2
	Supplementary digital compilation (done in part by SOK)	The results of the supplementary field identification were digitally compiled to produce digitally compiled data.	585.82 km^2
	Establishment of topographic map data (done in part by SOK)	Topographic data suitable for producing output maps were generated from the digitally compiled data, and reproduction film for printing was made.	585.82 km^2
	Production of printed maps (by SOK)	Printed maps were produced using the reproduction film.	119 sheets 1020 copies
Other	Technical transfer seminar	The process and results of the Study were announced and dissemination of the products of the Study was promoted. The outcome of the technology transfer was also reviewed.	1 set

The work related to the construction of GIS and the establishment of 2500- and 5000-level spatial data infrastructure was implemented in accordance with the flowchart shown in Figure 1.5.

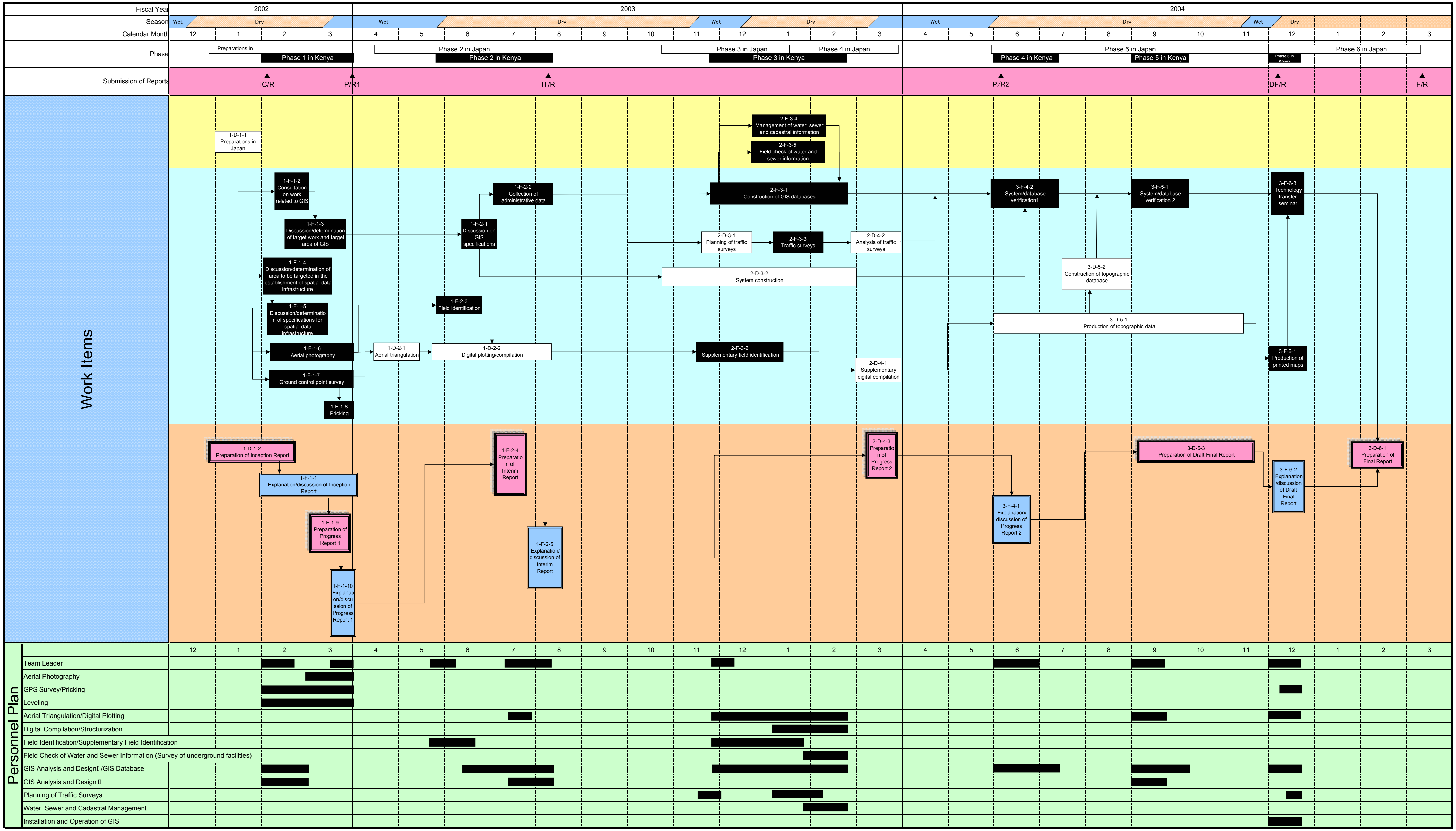
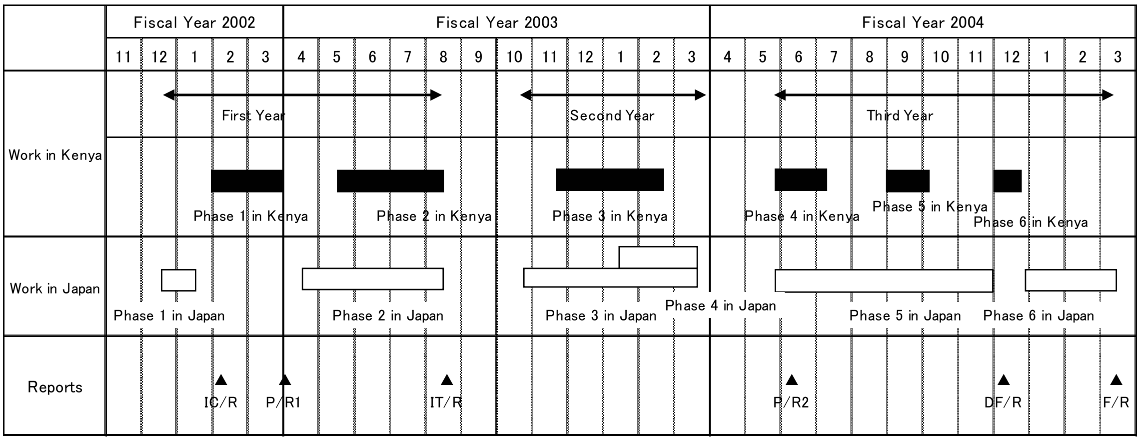


Figure 1.5 Flowchart for GIS construction and establishment of spatial data infrastructure

1.4.2 Implementation Schedule

(1) General schedule

The general schedule of the Study was as follows:



The Study commenced at the end of December 2002 and was completed at the middle of March 2005.

(2) Detailed schedule

The detailed schedule was divided into technology transfer and GIS construction/establishment of 2500- and 5000- level spatial data infrastructure (refer to Table 1.3 Detailed schedule).

The schedule of the subcontracted work is shown in Table 1.4. The time the work was contracted out (▲) and time of quality and flow control (△) are indicated by their respective symbols.

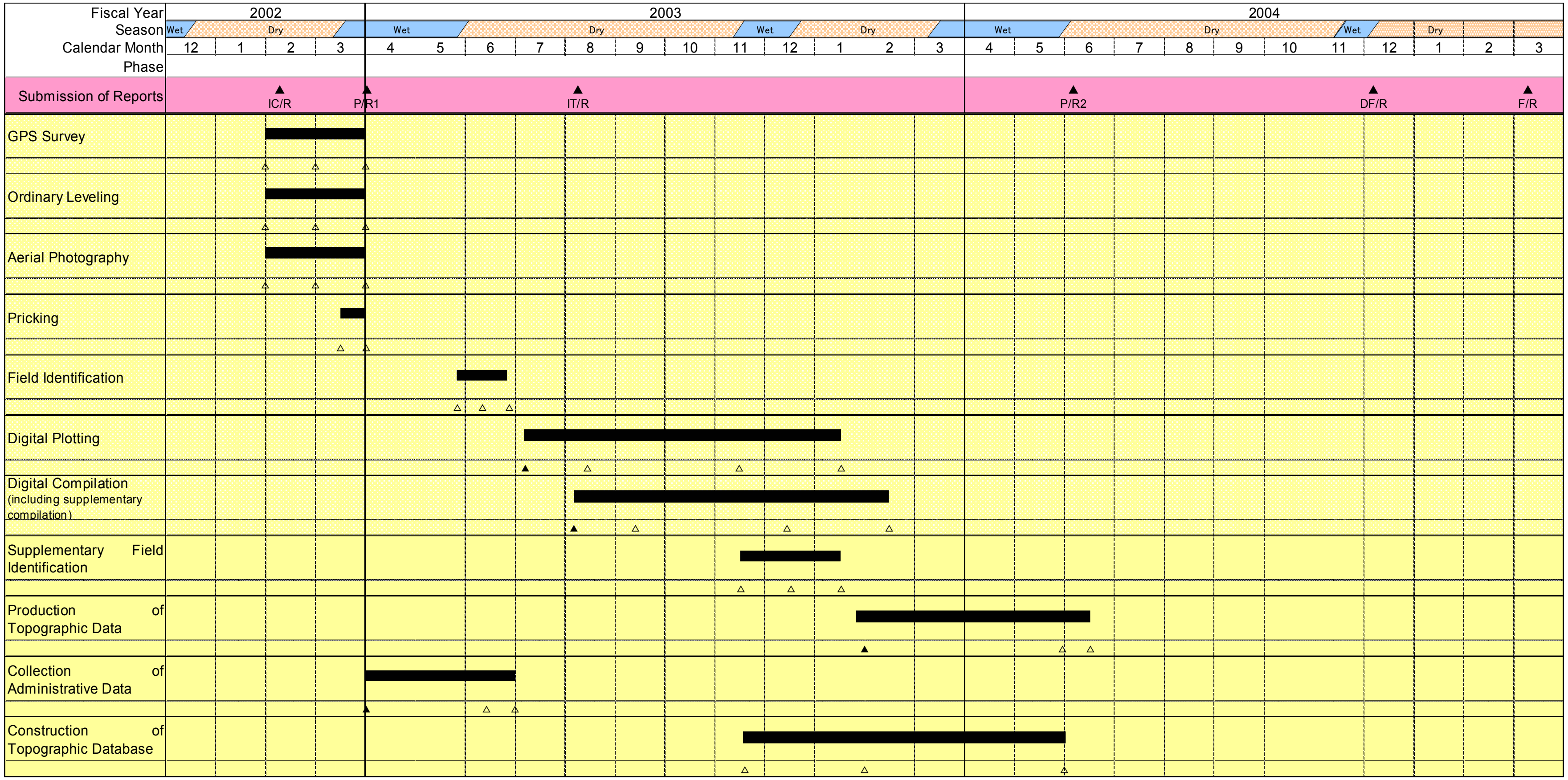
Table 1.3 Detailed schedule

Fiscal Year	2002				2003												2004											
Season	Wet / Dry				Wet / Dry / Wet / Dry												Wet / Dry / Wet / Dry											
Calendar Month	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Phase	Preparations in Japan; Phase 1 in Kenya				Phase 2 in Japan; Phase 2 in Kenya; Phase 3 in Japan; Phase 3 in Kenya; Phase 4 in Japan												Phase 4 in Kenya; Phase 5 in Japan; Phase 5 in Kenya; Phase 6 in Kenya; Phase 6 in Japan											
Submission of Reports			IC/R	P/R1					IT/R										P/R2						DF/R			F/R

Year	Group	Code	Activity
First Year			First Year
	Technology Transfer	TT-1-1	Discussions on technology transfer program
		TT-1-2	Pricking
		TT-1-3	GPS survey
		TT-1-4	Ordinary leveling
		TT-1-5	Construction of GIS database
		TT-1-6	Field identification
	Phase 1 in Japan		Phase 1 in Japan
		1-D-1-1	Preparatory work in Japan
		1-D-1-2	Preparation of Inception Report
	Phase 1 in Kenya		Phase 1 in Kenya
		1-F-1-1	Explanation/discussion of Inception Report
		1-F-1-2	Consultation on work related to GIS
		1-F-1-3	Discussion/determination of target work and target area of GIS
		1-F-1-4	Discussion/determination of area to be targeted in the establishment of spatial data infrastructure
		1-F-1-5	Discussion/determination of specifications for spatial data infrastructure
		1-F-1-6	Aerial photography
		1-F-1-7	Ground control point survey
		1-F-1-8	Pricking
		1-F-1-9	Preparation of Progress Report 1
		1-F-1-10	Explanation/discussion of Progress Report 1
	Phase 2 in Japan		Phase 2 in Japan
		1-D-2-1	Aerial triangulation
		1-D-2-2	Digital plotting/compilation
	Phase 2 in Kenya		Phase 2 in Kenya
		1-F-2-1	Discussion on GIS specifications
		1-F-2-2	Collection of administrative data
		1-F-2-3	Field identification
		1-F-2-4	Preparation of Interim Report
		1-F-2-5	Explanation/discussion of Interim Report
Second Year			Second Year
	Technology Transfer	TT-1-7	Aerial triangulation
		TT-2-1	Digital plotting
		TT-2-2	Digital compilation
		TT-2-3	Field identification
	Phase 3 in Japan		Phase 3 in Japan
		2-D-3-1	Planning of traffic surveys
		2-D-3-2	System construction
	Phase 3 in Kenya		Phase 3 in Kenya
		2-F-3-1	Construction of GIS database
		2-F-3-2	Supplementary field identification
		2-F-3-3	Traffic surveys
		2-F-3-4	Management of water, sewer and cadastral information
		2-F-3-5	Field check of water and sewer information
	Phase 4 in Japan		Phase 4 in Japan
		2-D-4-1	Supplementary digital compilation
		2-D-4-2	Analysis of traffic surveys
		2-D-4-3	Preparation of Progress Report 2
Third Year			Third Year
	Technology Transfer	TT-3-1	Establishment of topographic data
		TT-3-2	Construction of topographic database
		TT-3-3	Method for operating, maintaining and managing GIS
	Phase 4 in Kenya		Phase 4 in Kenya
		3-F-4-1	Explanation/discussion of Progress Report 2
		3-F-4-2	System/database verification 1
	Phase 5 in Japan		Phase 5 in Japan
		3-D-5-1	Establishment of topographic data
		3-D-5-2	Construction of topographic database
		3-D-5-3	Preparation of Draft Final Report
	Phase 5 in Kenya		Phase 5 in Kenya
		3-F-5-1	System/database verification 2
	Phase 6 in Kenya		Phase 6 in Kenya
		3-F-6-1	Production of printed maps
		3-F-6-2	Explanation/discussion of Draft Final Report
		3-F-6-3	Technology transfer seminar
	Phase 6 in Japan		Phase 6 in Japan
		3-D-6-1	Preparation of Final Report

Legend: ■ Work in Kenya □ Work in Japan

Table 1.4 Schedule of subcontracted work



Legend: ▲ Procurement of servcies , △ Quality/flow control

・The study team implemented quality and flow control of work by local subcontractor while in Kenya.
・Quality and flow control of work by SOK in the technology transfer was implemented during the technology transfer.
・Flow control by e-mail was carried out along with the execution of works .

1.5 Study Outputs

1.5.1 Study Outputs

The outputs of the Study are as follows:

(1) Reports

①Inception Report	20 copies
②Progress Report 1	20 copies
③Interim Report	20 copies
④Progress Report 2	20 copies
⑤Draft Final Report	
Main Report	20 copies
Summary	20 copies
⑥Final Report	
Main Report	20 copies
Summary	20 copies

(2) Products

①Aerial Photography	
♦ Negative film	1 set
♦ Diapositive film	1 set
♦ Contact prints of aerial photos	1 set
♦ Photo index map	1 set
②Results of control point survey	1 set
③Results of aerial triangulation	1 set
④1:2500 and 1:5000 topographic maps	
♦ Reproduction film for printing	1 set
♦ 1:2500 and 1:5000 printed topographic maps	1,000 sets
♦ 1:2500 and 1:5000 digital topographic map data	20 sets
⑤Guidelines	10 copies ea.
⑥Digital data for GIS (database)	2 sets

1.5.2 Results of Technology Transfer

(1) Results of technology transfer for GIS construction

a) Techniques for construction of GIS database

Techniques for the construction of databases necessary for GIS, according to their specifications, were transferred to SOK and NCC.

NCC mainly acquired techniques for collecting and arranging basic data for database construction and for determining the appropriateness of the data collected

SOK mainly acquired techniques for the construction of databases according to specifications using the data collected.

b) Techniques for construction of topographic database

SOK acquired techniques for the construction of a topographic database from topographic map data for use in GIS

c) Techniques for operation and maintenance of GIS

Techniques for operation of the four individual systems constructed were transferred mainly to NCC. Techniques for operation and maintenance of the databases were transferred to NCC and SOK.

(2) Results of technology transfer for the establishment of spatial data infrastructure

a) Ground survey techniques

Techniques for “GPS survey”, “ordinary leveling”, “pricking”, “field identification” and “supplementary field identification” were transferred to SOK through on-the-job training (OJT).

b) Digital photogrammetric techniques

Techniques for “aerial triangulation”, “digital plotting/compilation” and “production of topographic map data” were transferred to SOK through lectures and practical training on basic techniques followed by OJT.

1.5.3 Results of GIS construction

The study team conducted consultations with NCC on work related to GIS. Based on the results, the following three basic policies for GIS construction was determined:

- ♦ Construction of GIS databases for spatial data infrastructure

- Construction of GIS databases to support the work of NCC
- Construction of GIS model systems to solve urban problems in Nairobi
- From the basic polices mentioned above, specifically, the following databases and model systems were constructed:
- GIS databases for spatial data infrastructure
- GIS databases to support the work of NCC
- GIS model systems

(1) GIS databases for spatial data infrastructure

A database composed of 11 main layers was constructed from the topographic map data. Each main layer contains sub-layers and the various features are defined by polygon, line and point data.

(2) GIS database to support the work of NCC

This database is composed of 14 layers and was constructed in the form of polygon data, line data and point data, in consideration of the shape of each feature. The data is linked to the various attribute data obtained from NCC.

(3) GIS model systems

A GIS model system consisting of the following four model systems was constructed.

- Model system to support water management
- Model system to support sewerage management
- Model system to support cadastre management
- Model system to support road management

Each system has basic functions, analytical functions and its own specific functions.

(4) Coverage of GIS databases

The databases targeted a 15 km^2 area, covered by five sheets of the 1:2500 topographic map, in the central part of Nairobi.

1.5.4 Results of the Establishment of Spatial Data Infrastructure

The following works were implemented in the course of establishing spatial data infrastructure.

- Discussion and determination of standards, specifications, and target area.
- Aerial photography

- Control point survey
- Field identification
- Aerial triangulation
- Digital plotting/compilation
- Production of printed maps
- Production of topographic map data

(1) Discussion and determination of standards, specifications and target area

Survey standards: The existing reference ellipsoid (Clark 1880 modified) and projection method (UTM) were adopted.

Specifications: Specifications for each work were discussed and decided on. All specifications were finally arranged in "Work Regulations for the Establishment of Spatial Data Infrastructure".

Target area: 2500 level spatial data infrastructure was to be established for 60 sheets covering 179.22km^2 in the central part of the city.
5000 level spatial data infrastructure was to be established for 59 sheets covering approximately 416.60km^2 in the central part of the city.

(2) Aerial photography

Aerial photography was subcontracted out to the South African company Digital Topographical Mapping (D.T.M); 305 color photos were taken at a scale of 1:15000 along 15 flight lines.

(3) Control point survey

Fourteen (14) observation sessions, GPS survey of 25 points, and 247km of leveling (using an electronic level) were conducted with the full cooperation of SOK.

(4) Field identification

Field identification (1:2500 scale: 30km^2, 1:5000 scale: 24km^2) by aerial photo and supplementary field identification (1:2500 scale: 179.22km^2, 1:5000 scale: 416.60km^2) using output maps were conducted with the full cooperation of SOK.

(5) Aerial triangulation

Aerial triangulation was carried out in digital format, targeting 15 flight lines and 250 models.

(6) Digital plotting/compilation

Digital plotting and compilation work was divided among SOK (1:5000: 74.87km^2, 1:2500: 15.00km^2), the subcontractor (1:5000: 103.49km^2) and work in Japan (1:5000: 238.24km^2, 1:2500: 164.22km^2).

(7) Production of printed maps

Using SOK's printer, 1025 copies of sixty 1:2500 sheets and fifty-nine 1:5000 sheets respectively were printed.

(8) Production of topographic map data

Topographic map data was produced from the compiled data in accordance with the specifications.

Chapter 2 Study Objectives and Implementation Policy

2.1 Objectives

The aim of the Study was to construct GIS model systems and to establish spatial data infrastructure, and to transfer the techniques applied in those processes. Particular emphasis was placed on the transfer of technology.

The three objectives of the Study were as follows:

(1) Technology transfer (main objective)

(2) Construction of GIS model systems

(3) Establishment of spatial data infrastructure (2500 and 5000 level)

2.1.1 Technology Transfer

The primary objective of the Study was to transfer the following technology so that SOK and NCC would be able to construct and establish (including revision of secular change) similar products and carry out operation and maintenance work independently after completion of the Study.

Technology transfer was implemented through lecture-style and on-the-job OJT) training.

(1) GIS construction

Technology transfer for GIS construction included the following specific techniques:

a. Techniques for construction of GIS database:

Collection and arrangement of source material, construction of database according to specifications and updating, operation and maintenance of database

b. Techniques for construction of topographic database:

Construction of topographic database from topographic map data

c. Techniques for operation and maintenance of GIS:

Operation of GIS model systems constructed and operation and maintenance of GIS databases

(2) Establishment of spatial data infrastructure

Technology transfer for the establishment of spatial data infrastructure by photogrammetry included the following techniques:

a. GPS survey: Planning, observations, analysis techniques, evaluation of analysis results
b. Ordinary leveling: Planning, observations, analysis techniques (using electronic level)
c. Pricking: Pricking techniques, preparation of description sheets of pricked points
d. Aerial triangulation: Planning, preparations, analysis, evaluation techniques (for digital aerial triangulation) (including techniques for digitization of aerial photos)
e. Field identification: Preparations, field identification using aerial photos, arrangement of results
f. Digital mapping/compilation: Use of digital plotter and compiler
g. Supplementary field identification:
Preparations, supplementary field identification using output map, arrangement of results
h. Production of topographic map data:
Techniques for the production of topographic map data

The technology transfer for establishment of spatial data infrastructure and GIS construction also aimed to contribute to enhancing technical capacity and human resources capacity to enable NSDI to expand national spatial data infrastructure in the future.

2.1.2 GIS Construction

The Study aimed to construct GIS, which consisted of the following items:

a. Construction of GIS model systems to contribute to solving urban problems:
Construction of GIS model systems equipped with various functions
b. Construction of databases for operation in GIS model system:
Construction of graphics and attributes databases to implement the various functions

The Study also aimed to realize full-scale operation of the GIS model systems through construction of the systems and databases.

2.1.3 Establishment of Spatial Data Infrastructure

The Study aimed to establish 2500 and 5000 level spatial data infrastructure, which consisted of the following items:

a. Establishment of 2500 level spatial data infrastructure ($179km^2$) and production of printed maps (60 sheets, 1025 copies)
b. Establishment of 5000 level spatial data infrastructure ($416km^2$) and production of printed maps (59 sheets, 1025 copies)

Spatial data infrastructure was established at a specified level and area in order to transfer all the techniques required for the establishment of spatial data infrastructure.

2.2 Basic Policies and Approaches

2.2.1 Basic Policies and Approach for Technology Transfer

(1) Basic policies

The basic policies for technology transfer were as follows:

a) Technology transfer for database construction

b) Technology transfer for the operation and maintenance of GIS

c) Transfer of the latest techniques for establishing spatial data infrastructure

d) Establishment and evaluation of the objectives of the transfer

e) Preparation of regulations and manuals

f) Human resource development

(2) Approach

The approach to technology transfer was as follows:

a) Technology transfer for GIS database construction

- ♦ The technology transfer should include some degree of academic training in the form of lectures.
- ♦ Practical manuals for database construction and textbook-like teaching material should be prepared for use in the technology transfer.

b) Technology transfer for operation and maintenance/management of GIS

- ♦ Guidelines for the maintenance/management of GIS (system and database) should be prepared based on past experience and discussions with the concerned agencies, and technology transfer should be implemented in line with the content.
- ♦ An operational handbook should be prepared for the technology transfer aiming at the daily operation of GIS. Based on the results of daily operation, some helpful advice for developing a plan to expand use should be given.

c) Transfer of the latest technologies for establishing spatial data infrastructure

- ♦ The individual technologies such as for GPS surveying should be transferred mainly through OJT based on the experience and requests of the Counterpart
- ♦ Techniques for planning and managing projects for establishing spatial data infrastructure by means of photogrammetry should also be transferred to the Counterpart to enable them to administer this type of original project.

d) Establishment and evaluation of the objectives of the transfer

- Specific objectives of each technology transfer should be established based on discussions with the Counterpart.
- Whether the established objectives have been achieved or not should be verified and evaluated.

e) Preparation of regulations/manuals

- Systematic regulations taking the concept of ISO into consideration should be made in order to standardize the quality of products.
- Manuals for the technology transfer should also be prepared using the manuals of equipment to be used in the technology transfer as a reference to ensure effectiveness.

f) Human resource development

- From the standpoint of human resource development, the series of technologies in each field should be systematically transferred.
- From the standpoint of human resource development, this technology transfer should include content that can be incorporated into the technical training curriculum.
- Based on the outcome of this technology transfer, the academic training and practical training should be systematized and institutionalized, aiming to play a part in the "African Institute for Capacity Development" in the area of human resource development regarding the establishment of spatial data infrastructure and GIS construction.
- From the standpoint of human resource development, tours of concerned agencies to observe progressive programs, such as the programs of the "African Institute for Capacity Development" should be examined.

2.2.2 Basic Policies and Approach for GIS Construction

(1) Basic policies

The basic policies for the construction of GIS were as follows:

a) Feasible technical specifications

b) Ensuring the common use of databases

c) Introduction of a system that can be operated and maintained

(2) Approach

The approach to GIS construction was as follows:

a) Adoption of technical specifications likely to be applied

The technical specifications for introducing a GIS suitable for independent operation by the City of Nairobi should be closely and carefully examined and decided on as follows:

- Consultation on GIS related work should be conducted with all concerned departments and agencies in the City of Nairobi to grasp their awareness of and intent to use GIS
- Based on the above information, the functional requirements and ease of operation and maintenance should be examined to establish basic technical specifications.

b) Ensuring the common use of databases

As the effective use of GIS at a variety of agencies is hoped for, the following approaches should be taken.

- In the consultation on work related to GIS, the required databases should be clarified.
- From the required databases, the ones that are likely to be shared should be identified aiming to keep the database construction load at a minimum.

c) Introduction of a system that can be operated and maintained

With respect to the present conditions of Nairobi City and coping with the urban problems faced by the municipal government, the following approaches should be taken.

- In order to cope with the numerous urban problems, a multifunctional GIS is required. However, the functions of the model system to be introduced should be basic and educational placing importance on one that can be independently operated and maintained by SOK and the City of Nairobi in order to have a maximum effect.
- A manual for the daily operation of GIS should be prepared incorporating the know-how obtained through the technology transfer.

2.2.3 Basic Policies and Approach for the Establishment of Spatial Data Infrastructure

(1) Basic policies

The basic policies for the establishment of 2500 and 5000 level spatial data infrastructure were as follows:

a) Adopting technical specifications that meet user needs

b) Establishment of spatial data for general use

c) Ensuring technical sustainability

(2) Approaches

a) Adoption of technical specifications that meet user needs

- Close discussions should be held with SOK on the technical specifications of the spatial data infrastructure based on the topographic map data and its use on the GIS in Nairobi City, and the results should be reflected in the specifications and work regulations.

b) Establishment of spatial data for general use

- As wide-ranging use of the spatial data infrastructure through GIS is expected, it should be that which can be applied and generally used as common data infrastructure.

c) Ensuring technical sustainability

- The know-how obtained through the work of establishing the spatial data infrastructure should be reflected in the manual to enable SOK to deal with similar projects and updating work on its own.

2.2.4 Basic Policies and Approach to Management of the Study

(1) Basic policies

The basic policies for operation of the Study were as follows:

a) Detailed preparations

b) Flexible schedule

c) Close consultation with concerned agencies

d) Exhaustive safety measures

e) Thorough compliance

f) Utilization of results

g) Adequate quality control and flow control of subcontracted work

(2) Approaches

a) Thorough preparations

- Material for the many discussions to be held during the Study should be prepared in advance.
- Many items will be discussed and decided on based on information collected in fieldwork during the Study. However, alternative plans based on past experience should be prepared in case for some reason the information cannot be obtained or the party to be consulted cannot be determined.

b) Flexible schedule

- The aerial photography work schedule should be flexible to cope with delays due to the weather, etc. If the work is not complete within six months, it should be extended within the limit of an additional six months.
- As pricking work requires aerial photographs, the use of existing aerial photographs and topographic maps, drawings, and site photos should be considered.
- Adequate flow control of subcontracted work should be conducted to promptly detect and cope with any delays in work and the cause.

c) Close consultation with concerned agencies

- Close consultation including technical matters should be held with SOK, NCC and other concerned agencies to deepen understanding of and cooperation in the Study.
- Discussions should be held on the configuration of equipment to be used in the technology transfer and the method/time of introduction.

d) Exhaustive safety measures

- All work in the Study should be implemented during the day while it is light out.
- Outdoor work by the Study Team alone should not be conducted
- Travel outside should always be done by car and in groups of at least two.
- Study Team members should always carry a means of communication such as a mobile phone in case of an emergency.
- The equipment used in the Study (i.e. GPS receivers, levels, personal computers, etc.) should not be left outside. (A guard must always be posted)
- In case of an accident, safety manuals should be prepared and thoroughly explained to the team members.

e) Thorough compliance (obeying laws)

- When driving a vehicle, traffic laws such as the speed limit should be obeyed.
- When hiring locally, the concerned laws should be obeyed.
- In regards to selecting and contracting local subcontractors, the concerned laws should also be obeyed.
- The treaty for combating bribery of foreign public officials to ensure fairness in international trade should be observed.

f) Utilization of Results

- In the final stage of the Study, a homepage for the Study should be set up on the Internet, and various kinds of information necessary for utilizing the work results and products should be posted there.

g) Adequate quality control and flow control of subcontracted work

Of the subcontracted work to be done in connection with the technology transfer, quality control and flow control should be conducted on the following items at the appropriate times, as they are also to be implemented outside the period of implementation of work in Kenya.

- Digital plotting
- Digital compilation (including supplementary digital compilation)
- Establishment of topographic map data
- Construction of topographic database

Chapter 3 Results of Implemented Work

3.1 Results of Implemented Work and Period of Implementation

3.1.1 Implemented Work

(1) Phase 1 in Japan

a) Other work

1-D-1-1: Preparatory work in Japan

1-D-1-2: Preparation of Inception Report

(2) Phase 1 in Kenya

a) Work related to technology transfer

TT-1-1: Discussions on technology transfer program

TT-1-2: Pricking

TT-1-3: GPS survey

TT-1-4: Ordinary leveling

b) Work related to the construction of GIS

1-F-1-2: Consultation on works related to GIS

1-F-1-3: Discussions/determination of target works and target area of GIS

c) Work related to the establishment of spatial data infrastructure

1-F-1-4: Discussions/determination of the area targeted for the establishment of spatial data infrastructure

1-F-1-5: Discussions/determination of specifications for the establishment of spatial data infrastructure

1-F-1-6: Aerial photography

1-F-1-7: Ground control point survey

1-F-1-8: Pricking

d) Other work

1-F-1-1: Explanation/discussions of Inception Report

1-F-1-9: Preparation of Progress Report 1

1-F-1-10: Explanation/discussions of Progress Report 1

(3) Phase 2 in Japan

a) Work related to the establishment of spatial data infrastructure

1-D-2-1: Aerial triangulation

1-D-2-2: Digital plotting/compilation

(4) Phase 2 in Kenya

a) Work related to technology transfer

TT-1-5: Construction of GIS database

TT-1-6: Field identification

b) Work related to the construction of GIS

1-F-2-1: Discussions on GIS specifications

1-F-2-2: Collection of administrative data

c) Work related to the establishment of spatial data infrastructure

1-F-2-3: Field identification

d) Other work

1-F-2-4: Preparation of Interim Report

1-F-2-5: Explanation/discussions of Interim Report

(5) Phase 3 in Japan

a) Work related to the construction of GIS

2-D-3-1: Planning of traffic volume survey

2-D-3-2: System construction

(6) Phase 3 in Kenya

a) Work related to technology transfer

TT-1-7: Aerial triangulation

TT-2-1: Digital plotting

TT-2-2: Digital compilation

TT-2-3: Supplementary field identification

b) Work related to the construction of GIS

2-F-3-1: Construction of GIS databases

2-F-3-3: Traffic volume survey

2-F-3-4: Management of water, sewer and cadastral information

2-F-3-5: Field verification of location of water and sewer facilities

c) Work related to the establishment of spatial data infrastructure

2-F-3-2: Supplementary field identification

(7) Phase 4 in Japan

a) Work related to the construction of GIS

2-D-4-2: Analysis of traffic volume survey

b) Work related to the establishment of spatial data infrastructure

2-D-4-1: Supplementary digital plotting

c) Other work

2-D-4-3: Preparation of Progress Report 2

(8) Phase 4 in Kenya

a) Work related to the construction of GIS

3-F-4-1: Verification 1 of system/database

b) Other work

3-F-4-2: Explanation/discussions of Progress Report 2

(9) Phase 5 in Japan

a) Work related to the construction of GIS

3-D-5-2: Construction of topographic database

b) Work related to the establishment of spatial data infrastructure

3-D-5-1: Production topographic map data

c) Other work

3-D-5-3: Preparation of Draft Final Report

(10) Phase 5 in Kenya

a) Work related to technology transfer

TT-3-1: Production of topographic map data

TT-3-2: Construction of topographic database

TT-3-3: Method for operation and maintenance of GIS

b) Work related to the construction of GIS

3-F-5-1: Verification 2 of system/database

(11) Phase 6 in Kenya

a) Work related to the establishment of spatial data infrastructure

3-F-6-1: Production of printed maps

b) Other work

3-F-6-2: Explanation/discussions of Draft Final Report

3-F-6-3: Technology transfer seminar

(12) Phase 6 in Japan

a) Other work

3-D-6-1: Preparation of Final Report

3.1.2 Implementation Period

The implementation period of the various works were as follows:

Phase 1 in Japan:	December 24, 2002	-	January 31, 2003
Phase 1 in Kenya:	February 1, 2003	-	April 1, 2003
Phase 2 in Japan:	April 2, 2003	-	August 13, 2003
Phase 2 in Kenya:	May 20, 2003	-	August 10, 2003
Phase 3 in Japan:	October 11, 2003	-	March 12, 2004
Phase 3 in Kenya:	November 17, 2003	-	February 24, 2004
Phase 4 in Japan:	February 24, 2004	-	March 12, 2004
Phase 4 in Kenya:	June 1, 2004	-	July 12, 2004
Phase 5 in Japan:	July 13, 2004	-	November 30, 2004
Phase 5 in Kenya:	September 1, 2004	-	October 9, 2004
Phase 6 in Kenya:	December 1, 2004	-	December 21, 2004
Phase 6 in Japan:	December 22, 2004	-	March 22, 2005

3.2 Results of Technology Transfer

The technology transfer was divided into two fields: GIS construction and the establishment of spatial data infrastructure. Prior to implementation, the technology transfer program was discussed in respect to the following items:

- ♦ Schedule of the technology transfer
- ♦ Items targeted in the technology transfer
- ♦ Participants of the technology transfer
- ♦ Method of the technology transfer

The technology transfer was implemented based on the results of the discussions above.

3.2.1 Results of Technology Transfer for GIS Construction

(1) Technology transfer program

The technology transfer program was discussed in line with the objectives of the technology transfer for GIS construction.

The contents, implementation period and number of participants of the program decided on are as shown in Table 3.1.

Table 3.1 Contents of technology transfer

Contents	Period of Implementation	No. of Participants
・Set up of hardware ・Installation of GIS software and other software ・Explanation of GIS software functions ・Practice with sample data	Jul - Aug 2003 (Actual Period: Jul 15 - Aug 1, 2003)	From SOK: 5 From NCC: 5
・Review of previous training ・Preparation of database specifications ・Data conversion ・Setting/conversion of projection method ・Construction of new database ・Editing of database ・Production of new graphic data ・Editing of new graphic data ・Input from external database ・Output to external database	Dec 2003 - Feb 2004 (Actual Period: Dec 8, 2003 - Feb 13, 2004)	From SOK: 10 From NCC: 10

Contents	Period of Implementation	No. of Participants
・Review of previous training ・Data display ・Geometrical correction/georeferencing ・Data conversion ・Attribute data analysis ・Spatial search ・Vector data creation ・Spatial analysis ・3D analysis	Jun - Jul 2004 (Actual Period: Jun 7 - Jul 2)	From SOK: 10 From NCC: 10
・General review ・Review of functions for ArcMap ・Review of functions for ArcCatalog ・Review of functions for ArcToolbox ・Review of spatial analysis ・Review of 3D analysis	Sep - Oct 2004 (Actual Period: Sep 6 - Oct 1, 2004)	From SOK: 10 From NCC: 10
・Review of previous training ・Method for operation and maintenance of GIS ・Exam	Dec 2004 (Actual Period:Dec 7 - 10, 2004)	From SOK: 10 From NCC: 10

a) Schedule of the technology transfer

The technology transfer for GIS construction was implemented in four periods as shown in Table 3.1above.

b) Items targeted in the technology transfer

The items targeted in the technology transfer were divided into four main parts.

- ♦ Basic knowledge and set up of hardware and software necessary for GIS
- ♦ Knowledge and techniques necessary for construction of GIS database and topographic database
- ♦ Knowledge and techniques for analysis using GIS functions
- ♦ Knowledge and techniques for operation and maintenance of GIS

c) Participants of the technology transfer

In consideration of the continued and widespread use of GIS, the participants of the technology transfer were to include five staff members from SOK and NCC respectively.

d) Method of the technology transfer

The technology transfer for GIS construction was to be implemented through a combination of lecture-type and on-the-job training, using the manuals that came with the hardware and software to be employed. Detailed manuals were to be prepared if necessary.

(2) Implementation of the technology transfer

Technology transfer in the field of GIS construction was implemented as planned with respect to contents and schedule.

As for the number of participants, technology transfer in the first period was carried out as planned (5 participants from SOK and 5 from NCC), using provided equipment. However, from the second period onward, technology transfer was implemented using AICAD facilities targeting 10 staff from SOK and NCC respectively for effectiveness.

a) Goal

The aim of technology transfer for the various items was as follows:

* Basic knowledge and techniques of hardware and software necessary for GIS

  The goal was to acquire basic knowledge and techniques concerning the hardware and software to be used in the technology transfer for GIS construction. This included:

  - ♦ Understanding of the physical setting up of hardware and software (connection, etc.)
  - ♦ Acquisition of the method for installing and uninstalling GIS software
  - ♦ Acquisition of the basic functions of GIS software
  - ♦ Application of basic functions on sample data

* Knowledge and techniques necessary for the construction of GIS database and topographic database

  The goal was to acquire knowledge and techniques necessary for construction of the various databases. This included:

  - ♦ Systematic understanding of GIS software
  - ♦ Acquisition of the method for configuring GIS software necessary for construction of each database
  - ♦ Understanding and acquisition of various coordinate conversion and projection methods necessary for construction of each database
  - ♦ Acquisition of techniques for handling attribute data necessary for construction of each database
  - ♦ Database design based on GIS software

* Knowledge and techniques for analysis using GIS software functions

  The goal was to acquire basic knowledge and techniques of analysis functions of GIS software. This included:

- ♦ Acquisition of basic knowledge and techniques for spatial analysis using GIS software
- ♦ Acquisition of basic knowledge and techniques for 3-D analysis using GIS software
- ♦ Acquisition of techniques for construction of GIS topographic database

* Knowledge and techniques necessary for operation and maintenance of GIS

The goal was to acquire knowledge and techniques necessary for daily operation and maintenance of the GIS model systems to be introduced. This included

- ♦ Acquisition of necessary knowledge and techniques for daily operation of the GIS model systems constructed
- ♦ Acquisition of the techniques for operation and maintenance of the GIS databases constructed.
- ♦ Acquisition of knowledge and techniques for updating the GIS databases constructed.

b) Method

In the first period, the technology transfer was conducted using loaned equipment. However, in order to increase effectiveness, from the second period onward technology transfer was carried out using AICAD facilities enabling each individual participant to operate equipment

The technology transfer was conducted mainly through lectures, using both the manuals that came with the hardware and GIS software and materials specially prepared for the technology transfer.

The technology transfer for operation of the GIS model systems constructed was implemented targeting expected work.

c) Evaluation of the results

* Basic knowledge and techniques for hardware and software

SOK and NCC staff were able to fully understand the physical set up of hardware by participating in the actual setting up of equipment used in the technology transfer.

The method for installing GIS software and other software was transferred by OJT through the actual installation of software. As the procedure was simplified, the counterparts were able to gain full understanding. The method for uninstalling software was also transferred through OJT and the counterparts were able to gain an understanding.

The importance of computer managers was explained through lecture style training but it became a major concern by the final stage of the technology transfer.

The technology transfer for basic functions of GIS software was carried out through lectures and practice using sample data. It is judged that the trainees understood the basic techniques for using GIS software.

∗ Knowledge and techniques necessary for construction of GIS database and topographic database

Although the degree of understanding by SOK and NCC staff of the systematic concepts of ArcGIS software including ArcCatalog, ArcMap and ArcToolbox varied, all participants were able to understand the basic concepts.

They also gained an understanding of the basic method for operating software necessary for database construction.

Regarding coordinate conversion and projection methods (a part of GIS software), the technology transferred focused on methods adopted in Kenya and the participants gained an understanding of the methods. In practical training using actual data, the participant acquired the techniques, although there was a slight difference in skill level.

∗ Knowledge and techniques for analysis using GIS software

Here, the basic operation of ArcMap, ArcCatalog and ArcToolbox was reviewed, and all trainees understood the operating method and concept of these applications. The basic concept and operating method of spatial analysis and 3D analysis, which are extension programs, were also explained, and all the trainees gained an understanding of overlay analysis using various data, and the method for constructing digital topographic data (elevation, slope, aspect) using contour data.

∗ Knowledge and techniques for operation and maintenance of GIS

In the final technology transfer, lectures were held on the operation and maintenance of the GIS model systems constructed, and all the trainees gained a deeper understanding of the importance of this.

In addition, the method for operating the GIS model systems was explained mainly to staff of corresponding departments of NCC through workshops and they all understood the basic items though their was a difference in the degree of individual understanding.

3.2.2 Results of Technology Transfer for the Establishment of Spatial Data Infrastructure

(1) Technology transfer program

a) Schedule for the technology transfer

Technology transfer for the establishment of spatial data infrastructure was implemented according to schedule.

GPS survey (including pricking, aerial photo signals):	Feb 12 - Mar 27, 2003
Ordinary leveling (including pricking):	Feb 12 - Mar 27, 2003
Field identification:	May 26 - June 13, 2003
Supplementary field identification:	Dec 8, 2003 - Feb 20, 2004
Digital photogrammetry	
(aerial triangulation, digital plotting/compilation, other):	Dec 8, 2003-Feb 20, 2004
	Sep 6 - 22, 2004

b) Items targeted in the technology transfer

The items targeted in the technology transfer were as follows:

- Pricking
- GPS survey
- Ordinary leveling
- Field identification
- Supplementary field identification
- Aerial triangulation
- Digital plotting
- Digital compilation
- Other digital photogrammetric techniques

c) Participants of the technology transfer

The participants of the technology transfer were to be selected mainly from KISM graduates by SOK. The selection was done well in advance of the commencement of each technology transfer and the number of participants was determined based on discussions with the Study Team, in consideration of the volume of available equipment.

As a result, there were four (4) participants for GPS survey, three (3) for ordinary leveling, five (5) for field identification, and ten (10) for supplementary field identification. For the transfer of photogrammetric techniques, there were five (5) participants and two (2) observers who attended on occasion.

d) Method of the technology transfer

The Study Team proposed to conduct the technology transfer through OJT accompanied by some lecture style training, and agreement by SOK was obtained. The Study Team also prepared manuals and work regulations as supplementary teaching material and SOK agreed to their use.

(2) Implementation of technology transfer

a) Goal

The aim of the technology transfer for the various technical items was as follows.

* Pricking:
  - ♦ Acquisition of techniques for pricking photo control points on aerial photos and for preparing description sheets of the pricked points
  - ♦ Acquisition of techniques for pricking elevations points while carrying out observations in ordinary leveling

* Aerial photo signals:
  - ♦ Understanding the relationship between photographic scale and the size of aerial photo signals
  - ♦ Acquisition of techniques for installing aerial photo signals and for preparing description sheets

* GPS survey:
  - ♦ Acquisition of techniques for preparing a point distribution and observation plan
  - ♦ Acquisition of techniques for observations and analysis of observation data (baseline analysis, net adjustment)
  - ♦ Acquisition of techniques for evaluation of results of analytical computations

* Ordinary leveling:
  - ♦ Method of planning for ordinary leveling
  - ♦ Method of inspecting and adjusting the level
  - ♦ Acquisition of techniques for observations, computational processing, etc.

* Field identification:
  - Method for conducting field identification using aerial photos enlarged to the plotting scale
  - Acquisition of techniques for arranging the results of field identification on the aerial photos

* Supplementary field identification:
  - Understanding of the aim and procedures of supplementary field identification
  - Understanding of the method of planning/preparing for supplementary field identification
  - Acquisition of the method of using the handbook for aerial photo interpretation
  - Acquisition of the method for conducting supplementary field identification
  - Acquisition of techniques for arranging the results of supplementary field identification

* Aerial triangulation (digital method):
  - Acquisition of techniques for operating a film scanner
  - Acquisition of techniques for digitization of aerial photos using a film scanner
  - Acquisition of techniques for carrying out digital aerial triangulation
  - Acquisition of the method for evaluating the results of digital aerial triangulation

* Digital plotting
  - Acquisition of techniques for operating a digital plotter
  - Acquisition of techniques for carrying out digital plotting
  - Acquisition of techniques for handling digitally plotted data

* Digital compilation
  - Acquisition of techniques for operating a digital compiler
  - Acquisition of techniques for carrying out digital compilation
  - Acquisition of techniques for handling digitally compiled data

* Other digital photogrammetric techniques
  - Acquisition of techniques for operating a map scanner
  - Acquisition of techniques for digitizing topographic maps
  - Acquisition of techniques for producing orthophotos
  - Understanding of a network system

- ♦ Understanding of ISO standards

b) Method

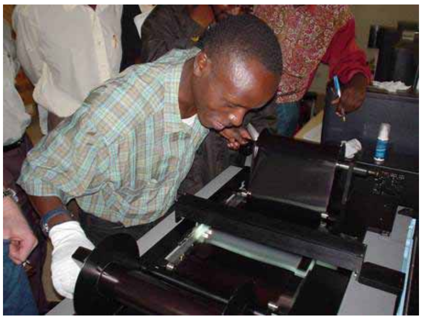
The various technology transfers began with lecture style training, followed mainly by OJT. However, for setting up the level and performing observations, a practice run was conducted prior to OJT.

Furthermore, the technology transfer for digital photogrammetric techniques was divided into four modules, i.e. basic operation, practice, applied techniques and other relevant techniques, as shown below.

∗ Basic operation module

Techniques for operating the scanner (film and map), digital plotter and digital compiler and for basic operation of the software installed in that equipment were explained to the participants.

∗ Practice module



Based on the results of the basic operation module, technology transfer was carried out as follows.

In "aerial triangulation", the counterpart digitized about 40 models of aerial photos using a film scanner, targeting the region of subsequent digital plotting and compilation work of SOK. Digital aerial triangulation was then carried out using the digital data.

In "digital plotting", 1:2,500 scale topographic maps were digitally plotted using the results of aerial triangulation mentioned above.

In "digital compilation", digital compilation including symbols, annotations, adjoining adjacent map sheets, etc. was carried out using the data obtained in the above digital plotting. Furthermore, the method of data cleaning through structurization (building topology) of the compiled data and for the representational setting of plotter output was transferred to the participants.

In addition to the above, techniques for outputting the data obtained and accuracy control were also transferred.

∗ Applied technology module

Making good use of the features of digital photogrammetric equipment, techniques for establishing spatial data other than topographic maps, such as DEM and orthophoto data, were transferred to the counterpart.

∗ Other relevant techniques

As part of learning the latest photogrammetric techniques, the counterparts were made to understand the concepts of product specifications in conformance with international standards (ISO standards), setting of metadata profiles and data updating.

Techniques for management of the network computer (the "server"), one of the equipment used in the technology transfer, were also transferred.

c) Evaluation of the results

The results of each technology transfer were evaluated as follows:

∗ Pricking:

The results of this technology transfer were evaluated based on the accuracy of the pricked locations carried out in OJT.

The pricking of photo control points in locations where many features were clearly identifiable in the photos was carried out with sufficient accuracy. However, the counterparts still need to enhance their capacity for pricking in locations with few identifiable features. The pricking of elevation points was mainly carried out on roads, where there were many features that could be identified in the photos. Therefore, the work was carried out accurately.

Based on these results, it is determined that SOK has acquired ordinary pricking techniques but needs to build on their experience.

∗ Aerial photo signals:

The relationship between photographic scale and size of aerial photo signals was explained through lecture style training and although SOK's theoretical understanding was not adequate, they were able to grasp the size of aerial photo signals corresponding to photographic scales required in actual work.

As for the installation of aerial photo signals and the preparation of description sheets, these techniques were successfully transferred to SOK through OJT. However, SOK staff needs to build on its experience and reinforce the skills it has acquired in the future.

∗ GPS survey:

The selection of GPS photo control points was conducted through OJT based on the point distribution map prepared by the Study Team. Thus, SOK was able to acquire the skills for point selection and can implement such work independently.

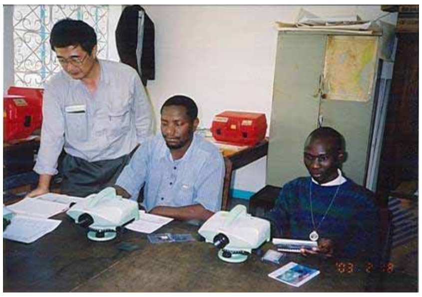
Based on the results of the point selection above, a new point distribution map and observation plan were prepared in cooperation with SOK. Through this process, SOK adequately acquired the techniques for preparing a point distribution and observation plan in consideration of the equipment it possesses.

On this occasion, 14 observation sessions were carried out and through the OJT conducted in the process, SOK was able to adequately acquire techniques for carrying out observation.

The majority of the baseline analysis from the observation data of the 14 sessions was carried out by SOK. Moreover, the check computations and net adjustment following the baseline analyses were conducted through OJT, and SOK obtained the same results as the supervisor from the Study Team. Therefore, it is determined that SOK has acquired the techniques for carrying out analytical computations.

Based on these results, it is clear that SOK is capable of carrying out general baseline analysis, check computations, and net adjustment independently.

∗ Ordinary leveling:



SOK was able to gain an adequate understanding of the significance of ordinary leveling in photogrammetry through lecture-style training.

The method for inspecting the level was also carried out repeatedly so SOK was able to master this technique.

Regarding the observation plan (establishing of leveling routes), SOK acquired the techniques for formulating a plan independently based on their understanding of the significance of ordinary leveling in photogrammetry.

SOK also acquired techniques for observations using an electronic level through OJT. However, SOK is expected to improve their ability to carry out observations more quickly through further practice.

Analysis and computations of observation data were carried out with the attached package software and net adjustment program. These techniques were also transferred to SOK through OJT. SOK is expected to apply the techniques they have acquired in future SOK projects.

* Field identification:

Prior to conducting field identification using aerial photos, technology transfer for preparing for the field survey and for the application of symbols was carried out through lecture-style training. In the lecture-style training, SOK understood the need to prepare the aerial photos to be used in the field identification for each topographic map sheet and for members of the field study to have a standard interpretation in the application of symbols.

Since SOK did not have experience with field identification using aerial photos, technology transfer was carried out by showing them the results of actual field identification by this method and then by conducting the field identification with all participants of the technology transfer.

The technology transfer for field identification was carried out through OJT with the participants organized into four groups. As a result, it is determined that SOK gained a fair understanding of the method of field identification using aerial photos However, SOK is still not capable of arranging the results of the field study so that it can be effectively utilized in subsequent works. SOK also lacks experience with prioritizing the targets of the field study. Furthermore, comments have not been obtained from the plotter operators who will use the study results. As a result, SOK needs to obtain feedback from the plotter operator and continue to build on their practical experience.

* Supplementary field identification:

As the ten participants were from different sections (i.e. Land Survey, Photogrammetric, and Mapping), their technical experience and capability for field identification varied, and this was apparent in the evaluation of the final outcome of the technology transfer.

Technology transfer for planning and preparations was mainly carried out through lecture-style training. However, as planning was a completely new task for the SOK, they need to obtain some practical experience in the future. In regard to preparations, OJT was conducted and it is determined that they understood and acquired the method.

In the technology transfer for photo interpretation using the Aerial Photo Interpretation Handbook, which was conducted through OJT, the technical experience of the participants had a big effect on the outcome. The participants from the Photogrammetric Section were quick to understand and implement actual work, and have reached the target level. On the other hand, participants from the other sections need further practical experience to reach the target level.

In the technology transfer for confirming administrative names and boundaries, the technical experience of the participants greatly influenced the outcome. Those from the Mapping Section were able to reach the target level. As for the other participants, although they acquired the method for carrying out this work, checks and revisions through adequate quality control are necessary.

In the technology transfer for supplementary field identification, which was conducted through OJT with participants in groups of two, the level to which the participants acquired the techniques varied. Although there was no great difference in the level of understanding of the symbols regulations, which serve as the standard for supplementary field identification, in actual application their performance varied greatly due to their individual ability and technical experience. About a third of the participants' performance level was low and they are expected to continue to receive similar training from the other participants who adequately acquired the techniques

In the technology transfer for arranging the results of the supplementary field identification, the technical experience of the participants was a major factor. Those from the Mapping Section were able to reach the target level. However, the others were not able to arrange the results in a way that was understandable to a third person. They are expected to receive training from the other participants to improve their skills.

∗ Digital photogrammetric techniques:

The results of the technology transfer for the set of digital photogrammetric techniques, which was conducted through lectures and OJT, were evaluated as follows:

- Regarding techniques for the digitization of aerial photos and subsequent digital aerial triangulation, the quality of work by the counterpart was verified by comparing it with the results of aerial triangulation carried out by the Study Team. As a result, the work by the counterpart was found to be of equal quality to that of the Study Team, Therefore, it is determined that SOK has reached a level where they can carry out such works independently
- The data plotted by SOK was visually compared to that done by the Study Team. As a result, the difference in horizontal positions and code numbers of the topographic and planimetric features plotted were found to be within the permissible level. Therefore, it is determined that the counterpart has reached a level where they can carry out such work independently.
- As with digital plotting, the data complied by the counterpart was visually compared to that done by the Study Team, and a logical check was also conducted. As a result, the discrepancies and occurrence of logical errors were within the permissible level. Therefore, it is determined that the counterpart has achieved the target technical level

Based on the evaluation above, it is judged that SOK has achieved a technical level where they are capable of carrying out work from digital aerial triangulation to digital compilation on their own.

3.3 Results of GIS Construction

3.3.1 Current Situation of GIS at NCC

For construction of the GIS model systems, consultations on work related to GIS were conducted in order to assess the current situation of GIS at NCC.

(1) Objective of consultations on work related to GIS

Nairobi is faced with various urban problems and Nairobi City Council (NCC) is pressed to formulate plans and take immediate measures to improve or resolve such problems.

In this Study, GIS was to be introduced to serve as a tool to facilitate the swift formulation of plans to enhance the efficiency of city management and to improve or resolve the city's problems. When introducing GIS, it is necessary to conduct studies on current conditions to determine the target of GIS and to identify the problem points.

Based on the above, consultations on work related to GIS were conducted to determine the work content, problems, maps produced/utilized, etc of the various departments and agencies of NCC.

(2) Implementation of consultations on work related to GIS

a) Departments visited

The NCC departments (sections shown in parentheses) targeted in the consultations on work related to GIS are as follows: (Attachment 1:List of attendants of meetings at each department/agency, Attachment 2:List of materials collected from each department)

- City Planning (Building Survey, Forward Planning, Research, Development Control, Land Survey, Urban Design and Development)
- Town Clerk (Land Valuation)
- City Treasurer (Rates)
- Environment
- Water (Cooperate Account, System Administration, Planning & Design

Construction, Project Implementation) & Sewerage

- City Engineer (Road, Traffic management & transportation, Operations & Services, Estate Development & Control, Engineering Survey)
- City Inspectorate (Headquarter)
- Medical Officer of Health (MOH)
- Social Service & Housing (SS&H)
- Education

b) Contents of consultations on work related to GIS

The contents of consultations on work related to GIS were as follows. Consultations were carried out through interviews using questionnaires.

- General understanding of the main duties of each department
- Understanding of the relationship among NCC departments and with external organizations
- Understanding of the use conditions of geographic information
- Identification of problems in the execution of duties
- Understanding of the thematic maps each department would like established
- Understanding of the plan for GIS use of each department

(3) Results of consultations of work related to GIS

The results of the consultations on work related to GIS were as follows: (Attachment 3: Answers to questionnaire from each section)

a) Outline of main duties of each department

The main duties of each department are outlines in Table 3.2.

Table 3.2 Main duties of various departments in NCC

<u>*City Planning*</u> *Planning and management of urban development to support a sustainable society, economy and environment*
<u>*Town Clerk (Land Valuation)*</u> *Estimation and management of fixed property tax, general property and land management*

City Treasurer (Rates) *Management of land registered under the jurisdiction of NCC (leasehold, freehold property, titled property), taxation and tax collection concerning plots in Githurai-Karen, Ruai-Kinoo, and Karura Forest-Kitengela areas*
Environment *Environmental planning and environmental management such as land, air and water quality*
Water and Sewerage *Planning, design , construction, and operation & maintenance of water supply facilities and charge and collection of water use fee*
City Engineer *Establishment, maintenance and management of urban infrastructure (roads, drainage system, street lights, etc.)*
City Inspectorate *Enforcement of byelaws of Nairobi City and laws related to the administration of Nairobi City*
Medical Officer of Health *Improvement of health conditions of citizens through the promotion of health and sanitation, disease prevention, administration of health care centers and medical facilities, collection of information on disease and experimental research*
Social Service & Housing *Management of public tenements and NCC run public facilities (community centers, municipal offices, city markets), eradication of slums, and promotion of social welfare*
Education *Promotion of the provision of quality basic education at the preschool/elementary level for all children*

b) Relationship among departments and with external organizations

The cooperative relationship among various departments in NCC and with external organizations are shown in Table 3.3.

* Regarding the relationship among the departments in NCC, City Planning works in coordination with all other departments. Town Clerk (Land Valuation), Water & Sewerage, and City Engineer work in coordination with many other departments.
* Few departments work in coordination with SOK, mainly because up-to-date topographic maps are not available. This is also why use of maps produced by SOK is stagnant.
* Power and Lighting Co. and Telekom, which are concerned with City Engineer, are private companies that provide electricity and communications services. These companies independently create and accumulate information and GIS data. NCC expects to build a cooperative relationship with these companies and share this information.

Table 3.3 Relationship among departments and with external organizations

	City Planning	Town Clerk (Land Valuation)	City Treasurer (Rates)	Environment	Water & Sewerage	City Engineering	City Inspectorate	MOH	SS&H	Education	Power and Lighting Co.	Telekom	SOK	National Police	KEMRI	Ministry of Agriculture	Ministry of Environment	Ministry of Health	Ministry of Education	WHO
City Planning	*	●	○	○	●	●	○	○	●	●			○							
Town Clerk (Land Valuation)	●	*	●		○	○														
City Treasurer (Rates)	●	●	*		○															
Environment	●			*	●	●	○		○								○			
Water & Sewerage	●	○	○		*								●							
City Engineering	○	○			△	*					△	△								
City Inspectorate	●			○		●	*							○						
MOH	●							*						○	○	○	○	○		○
SS&H	●	○	●	○		○	○		*		○									
Education	●	○		●	●	●	○			*									●	

● = Day to day cooperation
○ = Time to time cooperation
△ = Lack of cooperation

c) Geographic information and conditions of use

A list of geographic information used by the various department is shown in Table 3.4. In particular, the geographic information that is commonly used by many of the departments are the topographic maps and thematic maps shown below.

Topographic maps: general topographic maps - Entire Nairobi City (1:50,000)
City of Nairobi (1:20,000)
Topographic maps of various scale

Thematic maps: cadastral related - Cadastral Map (1:10,000)
Valuation Map (independently produced and used by Land Valuation section)
Deed Map (provided by SOK)
Survey Map (provided by SOK)
Registry Index Map (provided by SOK)

Zoning Map (independently produced by City Planning section)
Constituency Map (1:50,000-scale map sheets produced by SOK, indicating the boundaries and names of the election districts within the city)

Table 3.4 Geographic information and conditions of use

Abbreviation of Data Source SOK= Survey of Kenya NCC= Nairobi City Council MLS=Min of Lands and Settlement MPE=Min of Planning and Economic Development	Nairobi and District 1:2,500	Nairobi and District 1:5,000	Entire Nairobi City 1:50,000	Zoning Map 1:50,000 (=Land use Map)	Constituency Map (8 sub-division boundaries)	Area Policy Plan Map 1:5,000	Structure Plan	Valuation Map (Property Map)	Deed Map	Survey Map	Registry Index Map 1:2,500 1:1,000	Map Sheet (from UK colonial period) 1:1,250	Nairobi City 1:5,000	Topographic Map KENYA 1:100,000	National Atlas of Kenya	Nairobi and Environs 1:100,000	City of Nairobi 1:20,000	Nairobi and District 1:2,500	Nairobi City Center 1:5,000	Nairobi and Environs 1:25,000	Water System Detailed Map 1:500	Water Network Map 1:2,500 (printed & CAD)	Sewer line Network Map 1:500	Sewerage / Road Profile	Road Schemes (developed by City Engineer)	Register of Roads (documents&sketches)	City of Nairobi 1:10,000	Proposed Traffic Signals Junctions Layout Plan	Central Area Off-Street Car Parks and One Way Traffic System	Cadastral Map 1:10,000	Demography Map 1:20,000
Map Series# / T=Thematic	SK13	SK14		T	T	T	T	T			SK64	T	SK66	Y633		SK58	SK46	SK13	SK59	SK20	T	T	T	T	T	T	SK88	T	T	SK7	
Data Source	SOK	SOK	SOK	NCC	NCC	NCC	NCC	NCC	MLS	MLS	SOK		SOK	SOK	SOK	SOK	SOK	SOK	SOK	SOK	NCC	NCC	NCC	NCC	NCC	NCC	SOK	NCC	NCC	SOK	MPE
City Planning	O	O	O	O	O	O	O	O	O	O	O		O	O			O	O	O	O							O			O	O
Town Clerk (Land Valuation)	O			O	O			O	O	O	O	O																		O	
City Treasurer (Rates)								O																							
Environment					O									O	O	O	O	O	O	O											
Water & Sewerage (Water)				O	O					O	O										O	O								O	
Water & Sewerage (Sewerage)					O			O															O	O							
City Engineer	O			O	O		O	O	O	O	O		O				O				O	O	O	O	O	O	O	O	O		
City Inspectorate			O		O																										
MOH			O		O																										
SS&H																															
Education			O		O																										

The departments that often use topographic and thematic maps for carrying out their duties are City Planning, Town Clerk (Land Valuation), Water & Sewerage and City Engineer (Road).

* The geographic information most commonly used by the four departments mentioned above is cadastral related maps (Valuation Map, Deed Map, Survey Map, Registry Index Map). The reason for their frequent use is because cadastral related maps are updated whenever necessary so they are very reliable and because land related information is essential when planning and constructing urban facilities. The next most commonly used geographic information is the Zoning Map. This map indicates information required for the planning and construction of urban facilities such as water supply and sewerage, roads, and so on. It is also used by the Land Valuation to verify land prices
* The map most commonly used by all the departments is the Constituency Map. The compilation of statistical data and duties of Nairobi City Council are managed by election district so all departments frequently use the Constituency Map as a reference.
* The maps frequently used to get a general view of the entire city are Entire Nairobi City (1:50,000), City of Nairobi (1:20,000), and Cadastral Map (1:10,000).

d) Problems in the execution of duties

The problems in the execution of duties given by each department are shown in Table 3.5.

* The four problems that are in greatest demand for improvement are the up-dating of topographic maps, the computerization of work (introduction of computers), the building of networks (including not only computer networks but also telephone and wireless networks and networks to coordinate between departments), and improvement of the system for managing registers and maps.
* The need for education and training of NCC staff is recognized by most departments and is strongly requested.

Table 3.5 Problems in the execution of duties

	Need for updated maps	Not Adequate Map Scale	Poor management of maps, documents and information	Lack of departmental inter-linkage	Poor accessibility of information by the public	Need for computerization	Need for networking	Need for capacity building	Insufficient budget	Enhancement of revenue collection
City Planning	●	●	●		●	●	●	●		●
Town Clerk (Land Valuation)	●		●			●	●	●		
City Treasurer (Rates)	●		●		●	●				●
Environment	●			●		●	●	●		●
Water & Sewerage (Water)	●		●	●		●	●	●	●	●
Water & Sewerage (Sewerage)	●					●	●	●		
City Engineer	●		●	●	●	●	●	●	●	
City Inspectorate	●		●			●	●	●		
MOH	●		●	●		●	●	●	●	
SS&H	●		●	●		●			●	
Education	●		●		●	●	●			

e) Thematic maps that the various departments would like established

The thematic maps that the various department would like established are shown in Table 3.6.

* The thematic maps that most departments would like established are those related to natural resources such as land use maps, vegetation maps, soil maps, geological maps, and river and lake maps.
* The thematic maps desired by most departments also include population distribution maps. This because they recognize that information on population density and population structure is essential in the planning and construction of urban facilities and in the management of existing municipal facilities.

∗ The departments responsible for maintaining, managing, and expanding urban facilities, that is City Planning, Water & Sewerage, and City Engineer, recognize the need for maps of underground facilities possessed by the private companies, Kenyan Power and Telecom.

Table 3.6 Desired thematic maps

	Comprehensive map including all development changes	Land Use Map	Soil Type Map	Topographic Map (contours, control points)	Geological Map	Rainfall Data	Location of Natural Water Resources	Location of Street Furnitures	Location of Natural Earth Drains	Location of Public Services	Map of Natural Resources (tree coverage, vegetation type, water etc.	Population Distribution Map	Cartographic Map	Map of Underground cables network (by Kenyan Power & Telekom)
City Planning	○	○	○	○	○						○	○	○	○
Town Clerk (Land Valuation)														
City Treasurer (Rates)														
Environment		○									○			
Water & Sewerage (Water)			○	○	○		○		○		○			○
Water & Sewerage (Sewerage)			○	○	○						○			
City Engineer			○	○	○	○	○	○	○	○	○			○
City Inspectorate												○		
MOH												○		
SS&H		○						○		○		○		
Education	○		○		○		○			○		○		

f) Plan for GIS use

The plan for GIS use put forward by each department is shown in Table 3.7. One point that many departments have in common is the plan to utilize GIS to interlink the records and relevant maps held by each department. It is expected that by creating such a link, the efficiency and accuracy of daily work will be improved.

Table 3.7 Plan for GIS use

City Planning *Interlinked GIS system will enhance the production of updated maps and policy plans that will lead to better planning and service delivery *Location map of advertisements along roads with their size information linked to billing & revenue data (currently in paper-based)
Town Clerk (Land Valuation) *GIS system linked with Valuation Book (currently developing Access database) *Digitized map and property record = GIS database, computerized property records = relational database -> Land Information System
City Treasurer (Rates) *GIS networking system with Valuation *GIS system showing location and detailed information of the leasehold, freehold and titled plots of NCC
Environment *GIS for illegal dumping management *Spatial analysis of relationship between income level and type of solid waste disposal, population distribution and urban vegetation, pollution level and its distribution *Spatial analysis for allocation of road cleaning staffs, allocation of dumping sites *Assessment of revenue collection, vegetation distribution *landscape deigning
Water and Sewerage *GIS leakage control system (water) *GIS system linking digitalized topographic maps, water network and customer's property details which will assist accurate and quick billing (water) *Revitalizing system that will incorporate existing digital maps (water) *Sewerage GIS system integrating Nairobi Sewerage Master Plan
City Engineering *Centralized GIS & database system with collaboration of other departments for enhancement of informed and consultative decision makings on current and future development *Road maintenance GIS with information of road surface condition and necessary information (cost, material etc.) for road maintenance
City Inspectorate *GIS system aimed for identification of specific areas for the purpose of law-enforcement, for identification of population density and crime-prone-areas *Tracking system of officers working in the field *GIS for identification of specific areas of operations easier *Shortest rout finder for emergency
Medical Officer of Health *GIS for medical facility allocation based on population distribution and existing medical facilities *Pattern analysis of parasitic disease dispersion with relation to population distribution
Social Service & Housing *GIS showing location and situation of the existing physical establishment - houses, markets, social halls
Education * GIS for allocation of new schools with relation to population distribution *School mapping (location of existing schools and detailed information linked to location)

3.3.2 Basic Policies for Construction of GIS Model System and Selection of Target Area

(1) Basic policies

Based on the results of the consultations on works related to GIS (study to assess the current situation regarding GIS at NCC), the basic policies for construction of the GIS model system were discussed and decided on with SOK and NCC at KISM on February 19, 2003 (refer to memorandum). The three policies decided on are shown below. A conceptual diagram of the basic policies is shown in Figure 3.1.

To construct a GIS database of spatial data infrastructure
To construct a GIS database to support the tasks of NCC
To construct a GIS model system to solve urban problems in Nairobi

a) GIS database of spatial data infrastructure

The GIS database of spatial data infrastructure is to be constructed by converting the topographic map data produced in the Study into data for use in GIS. Although the data in this GIS database is topologically structured, no attribute information other than the feature code was added to the individual feature data.

b) GIS database to support the tasks of NCC

This GIS database is to be constructed to support the tasks of the various departments of NCC. The majority of the database (i.e. administrative data, road network data, facility distribution data, etc.) will be constructed using the GIS database for spatial data infrastructure in a). However, a portion of the database (i.e. cadastral data) needs to be newly established. Detailed attribute data will also be added to this GIS database.

c) GIS model system to solve urban problems in Nairobi

Specialized GIS model systems will be constructed to deal with the problems (traffic, slums, environment, etc) faced by NCC. Based on the results of discussions with SOK and NCC and in consideration of existing materials/data and scope, the model systems are to support road management, cadastre management and water and sewerage management.

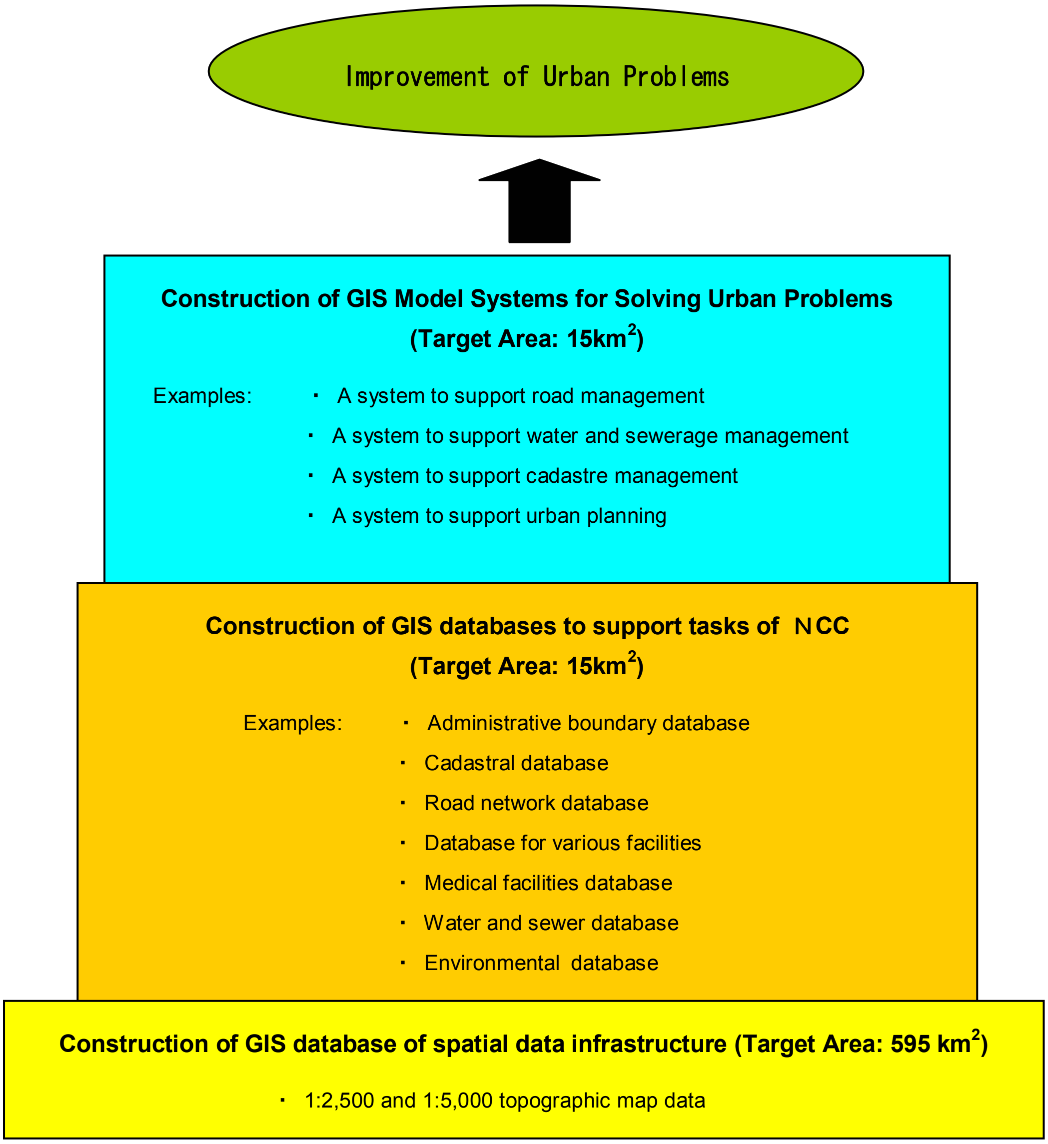


Figure 3.1 Basic policies for construction of GIS databases and GIS model systems

(2) Selection of target areas

a) Target area for construction of GIS database for spatial data infrastructure

As mentioned in (1), this database will be constructed from spatial data (topographic map data. Therefore, this database should cover the same area targeted for the construction of spatial data infrastructure, which is the entire city of Nairobi excluding Nairobi National Park (595km^2).

b) Target area for construction of GIS database to support the tasks of NCC

Based on discussions with NCC and available information (maps, attributes), this GIS database is to cover the following five sheets of the 1:2,500 topographic map to be produced in the Study: 69-III, 78-II, 79-I, 79-II and 79-III (37-III-EG). The total area covered was 15km^2 and is shown in Figure 3.2.

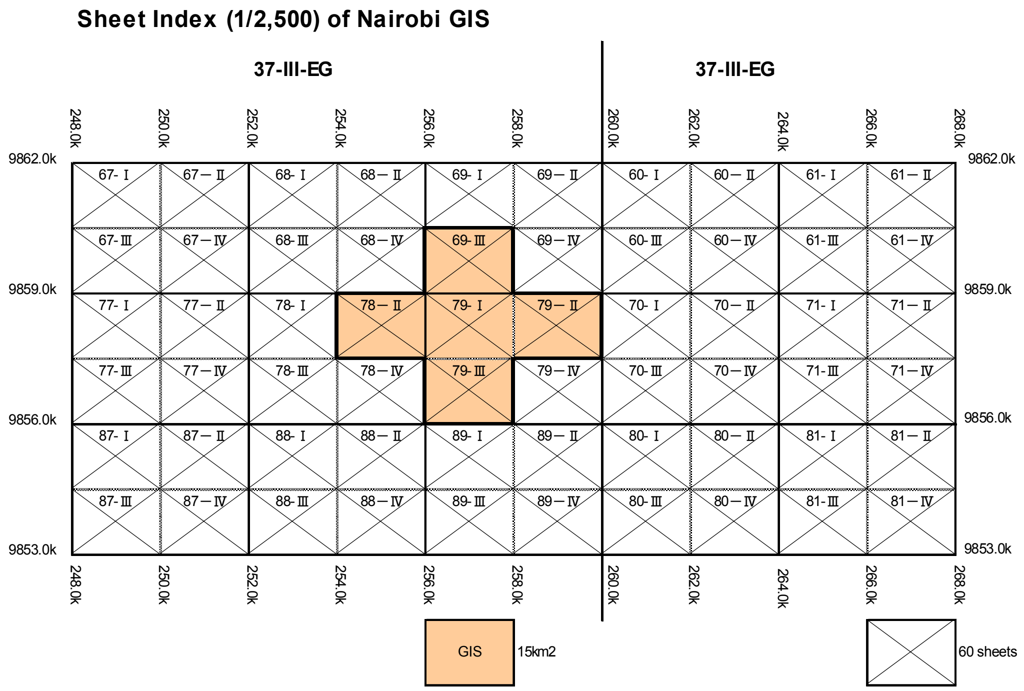


Figure 3.2 Sheet index (1:2,500) of Nairobi GIS

c) Target area for construction of GIS model systems to solve urban problems in Nairobi

The GIS model systems are to be constructed using the GIS database to support the tasks of NCC mentioned in b). Therefore, the GIS model systems should cover the same area targeted for the construction of that GIS database, as shown in Figure 3.2.

3.3.3 Construction of Database for GIS Model Systems

(1) Discussions on GIS database specifications

Based on the basic policies in 3.3.2, the following two types of GIS databases were constructed.

- GIS database of spatial data infrastructure
- GIS database to support the tasks of NCC

The final specifications for the GIS databases mentioned above were discussed and decided on with NCC and SOK. The GIS database specifications are shown in the documents at the end of the report.

a) GIS database of spatial data infrastructure

The GIS database of spatial data infrastructure is composed of the following 11 main layers. Furthermore, each layer contains sub-layers and stores the various types of feature data.

① Administrative boundary
② Transportation
③ Buildings
④ Small Objects
⑤ Water areas
⑥ Surround
⑦ Open spaces
⑧ Vegetation
⑨ Topographic features
⑩ Control points
⑪ Others

This GIS data is defined in the form of polygon data, line data or point data based on the characteristics of the target feature. The feature code number is added as attribute data.

b) GIS database to support the tasks of NCC

The GIS database to support the tasks of NCC is composed of the following 15 layers.

① Administrative boundary
② Road network
③ Intersection
④ Property boundary
⑤ Water supply line
⑥ Chamber
⑦ Water meter
⑧ Sewage line
⑨ Manhole
⑩ Educational facility

⑪ Medical facility

⑫ Social facility

⑬ Vegetation

⑭ Wetland

⑮ Land use

These data will be constructed in the form of polygon data, line data or point data depending on the shape of the feature, and the information concerned with these data will be added as attribute data. The attribute data will be constructed using database development software (Microsoft Access).

The specific contents of the layers are described below.

① Administrative boundary

Administrative boundary data is constructed as polygon data. The administrative boundary code number, administrative name, area, total population, population by gender, population by age, etc, are attached as attribute data. This attribute data is established based on the census.

② Road network

The road network data is constructed as single-line data by obtaining the centerline of roads. The intersections will be represented as nodes. The road code number, road name, road width, no. of lanes, road length, traffic volume (by time and by vehicle type), start and end points, surfacing (asphalt, concrete, etc.), surface conditions (paved, not paved), type of drainage, accident history, etc. are attached as attribute data.

③ Intersection

Intersection data is constructed as point data. Signal information (present or not) and type of intersection (intersection, rotary) are attached as attribute data.

④ Property boundary

Property boundary data is constructed as polygon data. The land reference number, area, name of ratable owner, address, telephone number, value of property, type of land use, tenure, lease term, serial number, situation, valuation book number, etc, are attached as attribute data.

⑤ Water supply line

The water supply line data is constructed as line data. Furthermore, the water supply line between chambers is constructed as single line data. The length, width, material, gradient, covered zone, construction records, etc. are attached as attribute data.

⑥ Chamber

Chamber data is constructed as point data. The type of chamber, location and status are attached as attribute data.

⑦ Water meter

Water meters are constructed as point data. The type, meter number and size are attached as attribute data.

⑧ Sewage line

As with water supply line data, sewage line data will be constructed as line data, and the sewage line between manholes will be constructed as single line data. The length, diameter, material, gradient, covered zone, construction records, etc. will be attached as attribute data.

⑨ Manhole

Manhole data is constructed as point data. The inver level (I.L.), ground level (G.L.), type of manhole, etc. are attached as attribute data.

⑩ Educational facility

Educational facility data is constructed as point data to make the location of the facility known. The facility name, situation, address, telephone number, FAX number, type (national, public, private, etc.), number of faculty members, number of students (by gender and by grade), number of toilets, etc. are attached as attribute data.

⑪ Medical facility

As with educational facility data, medical facility data is constructed as point data to make the location of the facility known. The facility name, situation, address, telephone number, fax number, type (national, public, private), specialty (general, surgical, internal medicine, pediatric, etc.), number of doctors, number of beds, number of medical staff, etc., are attached as attribute data.

⑫ Social facility

Social facility data is constructed as point data to make the location of the facility known. The facility name, situation and type are attached as attribute data.

⑬ Vegetation

Vegetation data is constructed as polygon data, using the vegetation data of the spatial infrastructure GIS data. The area, situation and type are attached as attribute data.

⑭ Wetland

Wetland data is constructed as polygon data or line data using the wetland and water area data of the spatial infrastructure GIS data. The area, situation and type are attached as attribute data.

⑮ Land use

Land use data is constructed as polygon data using information obtained from land use maps possessed by NCC and spatial infrastructure GIS data. The area, situation and type are attached as attribute data.

(2) Collection of administrative data

The necessary information (maps, records, etc.) for construction of the GIS database to support the tasks of NCC was collected with the cooperation of NCC and SOK. (Refer "List of administrative data collected" included in the Annex.)

a) Collection of information on water and sewer lines

The positional and attribute information of facilities such as lines and manholes, necessary to construct the database for the model system to support water and sewer management, was collected with full cooperation of NCC. The verification work was carried out mainly by NCC staff who are participating in the technology transfer by the Study Team.

Table A Design / Development

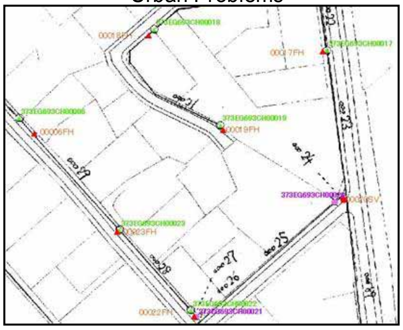
ID	Unique ID numbers
LENGTH	Length (m)
DIAMETER	Diameter (feet & inch)
MATERIAL	Material
GRADIENT	Gradient (by ratio, i.e. 1:200)
ZONE	Service coverage by zone
RECORD	Construction date

ID	Unique ID numbers
MATERIAL	Material
TYPE	Type (Reducer, Hydrant, Sluice valve etc.)
LOCATION	
STATUS	

- Information on water lines

All the attribute information (Table A) and positional information of water lines are indicated on the map entitled "Nairobi Water Supply Distribution System" (1:2,500; produced by NCC in 1986). The map has been revised to reflect changes since the map was produced. However, because the maps have not been well preserved (blue prints, mylar sheets) and they are lent out to other departments and work sites when needed, the verification work was difficult.

Figure A Improvement of Urban Problems



Orange: obtained in field check

The Study Team reported the results of the field check on water line information to the responsible staff at NCC. The positional information and classification of water lines determined from the map were not consistent with the results of the field check (Figure A). The responsible staff at NCC was consulted and it was agreed that in general, the positional information verified in the field check and the classification determined from the map would be adopted.

♦ Information on sewer facilities

All the attribute information (Table B) and positional information of sewer lines and manholes are indicated on the map entitled "Nairobi Hill Area SEWAGE PHASE III"(Cross Section: 1:500 in horizontal direction, 1:100 in vertical direction; Layout: 1:2,500; produced by NCC in 1980).

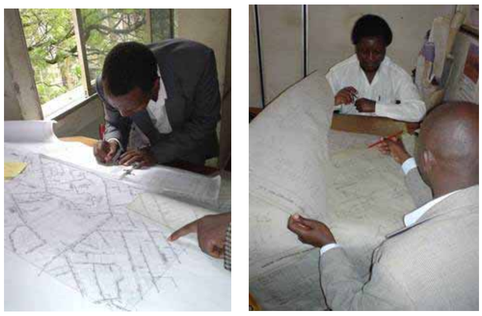
Table B Sewer (lines)

ID	Unique ID numbers
SR	SR number
LENGTH	Length (m)
DIAMETER	Diameter (feet & Inch)
MATERIAL	Material
GRADIENT	Gradient (by ratio, i.e. 1:200)
ZONE	Service coverage by zone
RECORD	Construction date

Sewer (manholes)

ID	Unique ID numbers
IL	Invert level
GL	Ground level
TYPE	Type

Figure B Verification work by NCC staff



The map has been revised to reflect changes since the map was produced. However, because the maps have not been well preserved (ordinary paper, mylar sheets) and they are lent out to other departments and work sites when needed, the verification work was difficult.

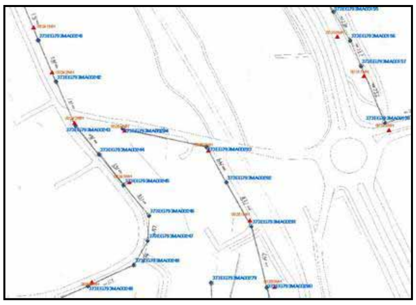


Figure C Disparity between positions obtained in field check and from the map

The Study Team reported the results of the field check on sewer facility information to the responsible staff at NCC. The positional information of manholes determined from the map was not consistent with the results of the field check (Figure C). The responsible staff at NCC was consulted and it was agreed that in general, the positional information verified in the field check would be adopted

b) Collection of cadastral information

The attribute data (Table C) is included in the MSAccess database constructed from the Valuation Book, and is managed by a unique Land Reference Number (LRN) assigned to each property. As for positional information, it was initially agreed to obtain it from the Town Clerk's "Valuation Map" map (1:1,250), produced and used daily in the Valuation Section. However, when preparing input maps for digitization, it was found that the shapes of roads and buildings on the Valuation Map greatly differed from present conditions and that the property boundaries were not consistent with existing land boundaries. In order to solve this problem, cooperation from SOK, which maintains the land register, was requested. As a result, SOK staff carried out verification work based on the "Topo-Cadastral Map" (1:2,500, produced by SOK), and produced input maps (5 sheets covering the entire target area of the model systems) reflecting the positional information of property boundaries for digitization.

c) Field check of information on water and sewer facilities:

In order to upgrade the quality of the information (particularly positional information) on water and sewer facilities, the information was verified in the field by a subcontractor.

- ♦ Selection of local subcontractor

  The field check of information on water and sewer facilities was to be conducted by a local subcontractor. Therefore, advice was obtained from SOK and a tender was held.

  As a result, HIGHLAND SURVEYORS was selected as the local subcontractor.

- ♦ Target area

  The field check was conducted on a 15 km^2 area in the city center, covered by the following five sheets of the 1:2500-scale topographic map.

  EG-69-3, EG-78-2, EG-79-1, EG-79-2, EG-79-3

♦ Implementation period

The work was implemented from December 10, 2003 to February 10, 2004. The actual verification in the field was done over Christmas and New Year's vacation when there were few cars.

♦ Implementation of work

Facilities (manholes, valves, lines, etc.) were recorded on a 1:2,500-scale base map, based on documentation of water and sewer systems.

Using the base map, the position and, to the extent possible, the type of facility were verified by plane table survey, total station, and visual check

The results (facility position and type) of the field check were recorded on a 1:2500-scale topographic map. The survey team was able to verify the positions of 1911 water and sewer facilities in the field.

d) Traffic survey

Traffic surveys were conducted as part of the collection of administrative data.

♦ Objective

The aim of the traffic surveys is to gain an understanding of current traffic conditions and causes of congestion in Nairobi in order to obtain basic data for planning measures to alleviate congestion.

♦ Type of survey

In order to achieve the objective, the following three types of traffic surveys were planned. Each type of survey was for a 12-hour period (weekday, 7:00 - 19:00) and was to be carried out twice.

∗ Traffic flow survey

This survey studies the volume of vehicles by direction and by vehicle type that pass through an intersection, targeting 21 intersections within the city.

∗ Survey of turning movement at intersections

This survey studies the volume of vehicles by turning movement and by vehicle type that pass through an intersection, targeting the 21 intersection mentioned above.

* Survey of traffic conditions at intersections

In this survey, the length of the traffic jam at an intersection and the time required to reach to stop line of the intersection are measured, targeting six of the 21 intersections mentioned above.

■ Survey method

* Traffic flow survey

Monitors are stationed at the specified survey points, and the number of vehicles that pass through the intersection is counted by vehicle type.

The counts are recorded by vehicle type, at 30 minute intervals.

The vehicles are classified into the following four groups:

- Small: Sedan, 4WD, PickUp
- Bus
- Lorry
- Matatu

* Survey of turning movement at intersections

Monitors are stationed at the specified survey points, and the number of vehicles that pass through the intersection is counted by turning movement (through, right, left), vehicle type, and time.

The counts are recorded by turning movement (through, right, left) and vehicle type at 30 minute intervals.

The vehicles are classified into the same four groups as the traffic flow survey.

* Survey of traffic conditions at intersections

The length of the traffic jam at an intersection and the time required to pass were monitored.

For the traffic jam length, the length from the stop line to the end of the traffic jam was measured every hour to the nearest 10 meters.

For the time required to pass, the time a given car arrives at the back of the line of traffic and the time it reaches the stop line are recorded. This is done for five vehicles every hour.

The survey was conducted at six intersections in the center of the city.

♦ Field investigation

A field investigation was conducted to determine whether or not the planned traffic surveys could adequately achieve their objectives.

As a result, the planned surveys were judged to be suitable for achieving the objectives.

The planned survey points were checked in the field. Some were found to be unsuitable for assessing traffic volume and were also expected to be difficult spots for conducting a proper survey. They were therefore changed.

As for the planned method, discussions were held with potential contractors during the tender and the survey days, time period and stationing of monitors were decided on.

- Selection of local subcontractor

As the traffic surveys were to be conducted by a local subcontractor, advice was obtained from SOK and NCC and a tender was held.

As a result of the tender evaluation, ITEC ENGINEERS LTD was selected to carry out the traffic surveys.

- Target points of traffic surveys

The following three types of surveys were conducted at the points shown below and in the following table.

Survey 1:Traffic flow survey	21 intersections
Survey 2:Survey of turning movement at intersections	21 intersections
Survey 3:Survey of turning movement at intersections	6 intersections

As a results of the field investigation, survey point No.9 (MOI AVENUE) of the traffic conditions survey was changed to No.2 (UHURU HIGHWAY).

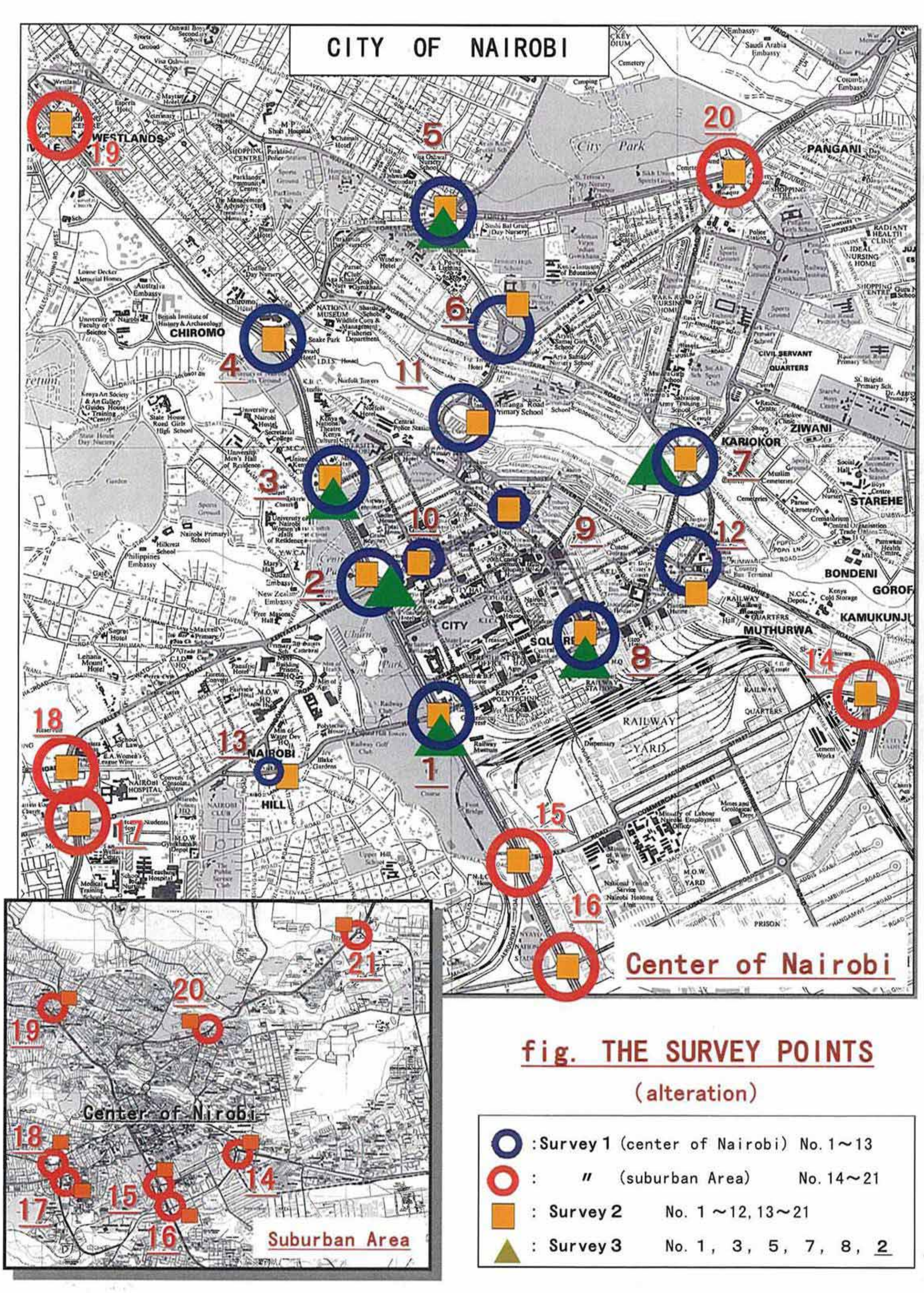
Table 3.8 List of traffic survey points

	Site	1st Survey (1/13-15)			2nd Survey (1/27-29)		
		Survey 1	Survey 2	Survey 3	Survey 1	Survey 2	Survey 3
1	City Center	○	○	○	○	○	○
2		○	○		○	○	○
3		○	○	○	○	○	○
4		○	○		○	○	
5		○	○	○	○	○	○
6		○	○		○	○	
7		○	○	○	○	○	○
8		○	○	○	○	○	
9		○	○	○	○	○	
10		○	○		○	○	
11		○	○		○	○	
12		○	○		○	○	
13		○	○		○	○	
14	Suburb	○	○		○	○	
15		○	○		○	○	
16		○	○		○	○	
17		○	○		○	○	
18		○	○		○	○	
19		○	○		○	○	
20		○	○		○	○	
21		○	○		○	○	
Total	-	21	21	6	21	21	6

Survey 1: Traffic flow survey

Survey 2: Survey of turning movement at intersections

Survey 3: Survey of turning movement at intersections


CITY OF NAIROBI
Center of Nairobi
Suburban Area
Center of Nirobi
fig. THE SURVEY POINTS
(alteration)
:Survey 1 (center of Nairobi) No. 1～13
: 〃 (suburban Area) No. 14～21
: Survey 2 No. 1～12, 13～21
: Survey 3 No. 1, 3, 5, 7, 8, 2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
WESTLANDS
CHIROMO
PANGANI
KARIOKOR
ZIWANI
STAREHE
BONDENI
KAMUKUNJI
MUTHURWA
RAILWAY YARD
City Park

♦ Scheduled day of traffic surveys

The traffic surveys were implemented twice for a 12-hour period (7:00～19:00) on a weekday.

Survey 1: January 13 (Tue) - 15 (Thu)

Survey 2: January 27 (Tue) - 29 (Thu)

♦ Implementation of traffic surveys

- Implementation of Survey 1
  Four monitors were stationed at the target intersections on the vehicle approach side of the street, and the volume of vehicles was recorded by vehicle type (4 types), at 30 minute intervals.
- Implementation of Survey 2
  Three monitors were stationed at the target intersections and the number of vehicles was recorded by turning movement (through, right, left) and by vehicle type (4 types), at 30 minute intervals.
- Implementation of Survey 3
  For the study of traffic jam length, one monitor was stationed at the specified intersections. The stop line and the end point of the traffic jam were plotted on a 1/2500 topographic map to the nearest 10 m every hour. The length of the traffic jam was also recorded. As for the delay time at the intersection, the same monitor responsible for traffic jam length recorded the time a given vehicle arrived at the end of the traffic jam and the time it took to reach the stop line. This study was carried out on five cars every hour.

(3) Construction of GIS database

Prior to construction of the GIS database, the hardware and software required for this work was introduced. The hardware and software introduced is shown in the following table.

Table 3.9 Hardware and software required for GIS

Hardware	*Desktop PC Client* ・ *CPU:Pentium4 2.8GHz* ・ *Main Memory:1GB* ・ *HDD:120GB* ・ *DVD-ROM, CD-RW* ・ *Network Interface*	*2 sets*
	20 inch TFT monitor	*2 sets*
	Permanent power supply	*2 sets*

Software	*ArcGIS (ArcInfo 9.0)* *Spatial Analyst* *3D Analyst* *ArcSDE* *Windows 2000* *Microsoft Office 2000 Pro.* *Antivirus software*	*2 sets* *2 sets* *2 sets* *1 set* *2 sets* *2 sets*

The GIS databases were constructed in accordance with the database specifications based on the results of consultations on work related to GIS and discussions with NCC. The databases constructed are as follows:

- ♦ GIS database of spatial data infrastructure
- ♦ GIS database to support the tasks of NCC
- ♦ Database for the four GIS model systems to be constructed

a) GIS database of spatial data infrastructure

This is the so-called topographic database and is constructed from structured topographic map data. This database can be used for background maps and also includes data (administrative boundaries, educational facilities, social facilities, vegetation, wetlands) that form a portion of the other two databases, the "GIS database to support the tasks of NCC" and the "database for the four model systems constructed".

b) GIS database to support the tasks of NCC

- ♦ Graphic database

In principle, the necessary graphic databases were constructed according to the database specifications, using the graphic data from the "GIS database to support the tasks of NCC" and the "database for the four model systems constructed". However, a portion of the graphic data (land use) specific to this database was produced from materials and information provided

- ♦ Attribute database

From the information collected, the attribute data specific to this database was recorded in data input sheets according to the specifications for the database to support NCC tasks. Then, the database was constructed according to specified format.

c) Databases for the four GIS model systems constructed.

- ♦ Graphic databases

From the collected information, the graphic data (pipe, facility, property boundary, etc.) specific to the four model systems was plotted on output maps of the topographic maps produced in this study and digitized according to the database specifications for the four model systems. Then, the database was constructed by converting the digitized graphic information to the specified data shape (point, line, polygon) and format.

♦ Attribute databases

From the collected information, the attribute data (diameter and type of pipe, type of facility, etc.) specific to the four model systems was recorded in data input sheets according to the specifications for the database for the four model systems. Then, the database was constructed according to the specified format.

d) Construction of database of the traffic survey results

The results of the traffic survey were developed into a database so that it could be used as one of the databases for the GIS model system to support road management.

♦ Counts of traffic survey

Basic counts were carried out in each survey.

- Traffic flow survey
  The number of passing vehicles was tabulated by vehicle type every 30 minutes at each survey point (street).
- Survey of turning movement at intersections
  An intersection diagram was prepared and the number of vehicles was tabulated by turning movement and by vehicle type every 30 minutes at each survey point (intersection).
- Survey of traffic conditions at intersections
  The length of traffic and the average delay time were tabulated every hour at each survey point (congested street).

♦ Database construction

In order to construct the database for the GIS model system to support traffic management, a road network model and the corresponding traffic survey results and analysis results were developed into a database.

- Road network model
  A simple model of the road network consisting of road section (arcs) and major intersections (nodes) was developed. In this model, character data as

attribute information can be linked to the corresponding graphic data (nodes and arcs).

- Database construction

  The traffic survey results and analysis results were developed into a database so that they can be linked to the arcs and nodes.

・Attribute data linked to nodes:	Results of survey on turning movements at intersections
	Diagram of intersections
	Tabulation results
	Analysis results
・Attribute data linked to arcs:	Results of traffic flow survey
	Inflowing/outflowing traffic volume
	Traffic volume at intersections
	Analysis results
	Results of survey on traffic conditions at intersections
	Traffic jam length (km)
	Delay time at intersections (min)
	Analysis results

3.3.4 Construction of GIS Model System

Discussions were conducted with NCC on the target field of the GIS model systems, based on the basic policies for construction of GIS model systems prepared based on discussions with NCC.

In the discussions, the effectiveness as a tool to improve or solve urban problems and the degree and feasibility of construction of the required databases were examined and it was agreed with NCC to construct the following four model systems.

- ♦ GIS model system to support road management
- ♦ GIS model system to support water management
- ♦ GIS model system to support sewerage management
- ♦ GIS model system to support cadastre management

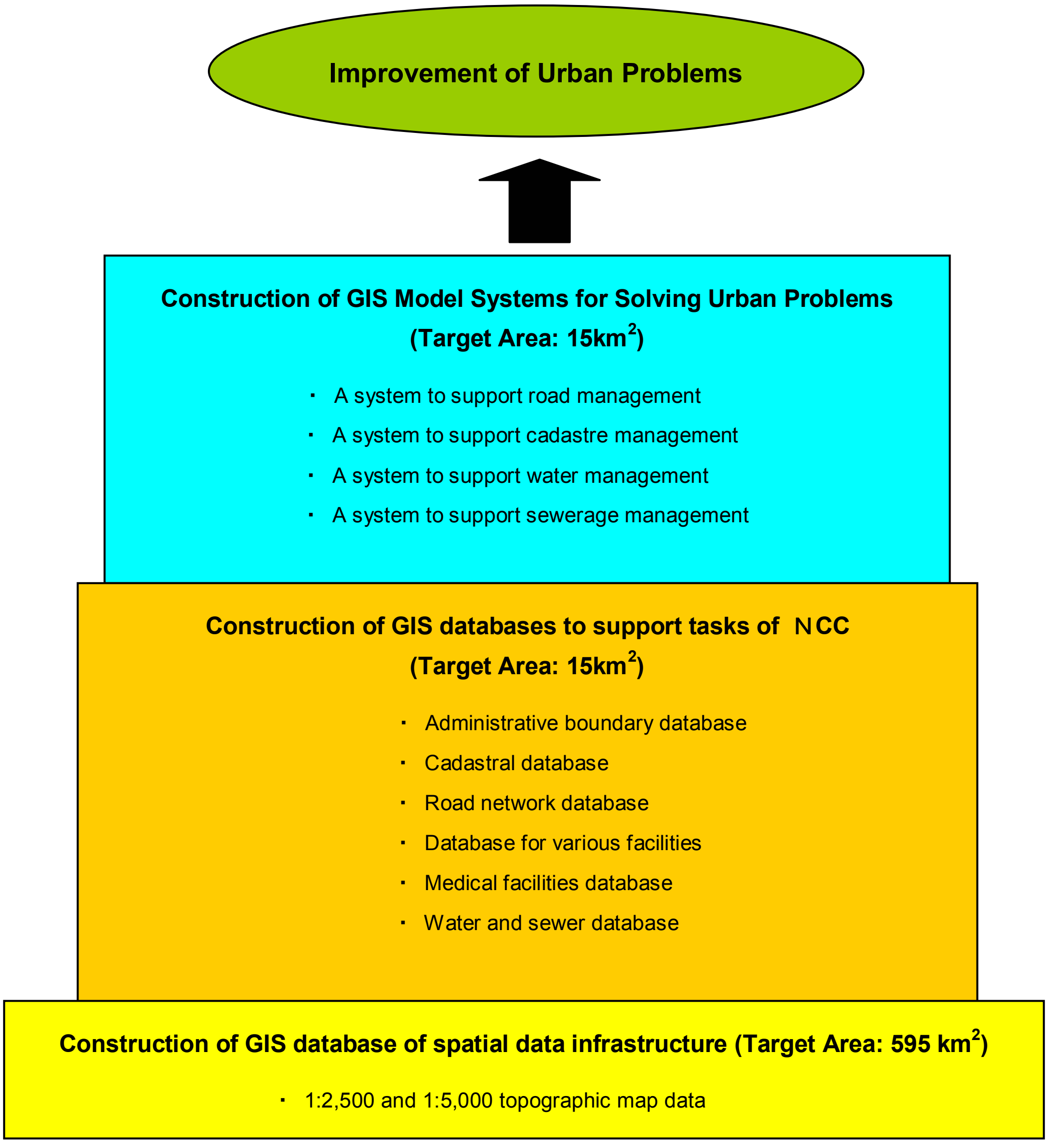


Figure 3.3 Agreement concerning the construction of GIS databases and GIS model systems

(1) Definition of required functions of GIS model systems

After the above four GIS model system were specified, discussions were held with NCC on the definition of their functions.

a) Definition of functions of GIS model system to support road management

The primary objective of this GIS model system was to make it possible to visually grasp the traffic conditions of each road by direction (inbound/outbound lane), time and vehicle type and to instantly access information such as traffic volume of each road at different times of day. Therefore, road network data, road width data, road length and traffic volume data was established.

In addition, by utilizing this system, it is possible to identify where the problems in traffic management are and to formulate improvement plans, such as installing signal lights at intersections, and plans to widen roads and build new ones (bypass) in order to reduce traffic in certain areas. This system also allows you to layer road network data, cadastral data, and land use data in order to instantly display cadastral and land use information in areas where roads are to be widened

Considering the objective of this system, based on discussions with NCC, the main functions required for the GIS model system to support traffic management were as follows:

- Various search functions by road name, width, etc
- Search, display and print out function for digital land register
- Display function indicating the traffic congestion
- Overlay analysis function for various data (spatial analysis function)
- Counting function coupled with conditional expressions
- Function for outputting display and analysis results
- Data import function
- Data export function
- Editing function for graphic data (add, edit, delete)
- Editing function for attribute data (add, edit, delete)

b) Definition of functions required for GIS model system to support water management

At present, existing information on water facilities in Nairobi City is outdated and deficient. As a result, damage to underground water lines during road construction work is frequently seen.

Based on this background, existing maps of water networks were obtained and a GIS model system to support water management was constructed. This GIS system allows you to accurately grasp the position of water lines and by attaching attribute information, to have instant access to the material and diameter of pipes and construction records. It is also possible to search and edit maps, clip specific areas, print out maps, and so on in order to support NCC tasks.

Considering the objective of this system and based on discussions with NCC, the main functions required for this GIS model system were as follows:

- Digital mapping function (editing of graphic data)
- Search function of various types of information (location, material of pipe, diameter of pipe, etc.)

- Map output function
- Clipping function
- Edit function for attribute data
- Function to zoom in/out
- Scroll function
- Output function for digital forms

c) Definition of functions required for GIS model system to support sewerage management

At present, existing information on sewer facilities in Nairobi City is outdated. It is also inadequately managed so necessary data cannot be quickly retrieved.

Based on this background, existing sewer line maps and information on manhole locations, etc. were obtained and a GIS model system to support sewerage management was constructed. This GIS system allows you to accurately grasp the position of sewer lines and by attaching attribute information, to have instant access to the material and diameter of pipes and construction records. It is also possible to search and edit maps, clip specific areas, print out maps, and so on in order to support NCC tasks.

Considering the objective of this system and based on discussions with NCC, the main functions required for this GIS model system were as follows:

- Digital mapping function (editing of graphic data)
- Search function of various types of information (location, material of pipe, diameter of pipe, etc.)
- Map output function
- Clipping function
- Edit function for attribute data
- Function to zoom in/out
- Scroll function
- Output function for digital forms

d) Definition of functions required for GIS model system to support cadastral management

When consultations on works related to GIS were conducted with NCC, a large amount of property maps and records were found. The maps, in particular, were produced quite some time ago and many were deteriorated. Also, NCC staff has to search through piles of records to locate those of a property on a map. In order to improve work efficiency, it is necessary to find a way to access this information quickly

Based on the situation of NCC, the construction of a GIS model system that links property maps and property information to support cadastral management will lead to an improvement in work performance and efficiency. Construction of such a GIS system also makes it possible to develop an efficient scheme for collecting fixed property tax in the future.

Considering the objective of this system and based on discussions with NCC, the main functions required for the GIS model system to support cadastral management were as follows

- ♦ Input function for cadastral boundaries
- ♦ Edit function for cadastral boundaries
- ♦ Search function by cadastral information (lot number, address, owner, etc)
- ♦ Search function by map sheet number, etc.
- ♦ Map output function
- ♦ Clipping function by address
- ♦ Edit function for cadastral attribute data (add, edit, delete)
- ♦ Function for overlay analysis with various data
- ♦ Search and analysis function by conditional expression

(2) Construction of GIS model systems

The GIS model systems were implemented based on the results of consultations on work related to GIS and discussions on GIS specifications.

The systems constructed were the four GIS systems decided on in discussions with NCC. However, the GIS model system to support water and sewerage management was divided into two systems so the following four were constructed. GIS databases for spatial data infrastructure and to support the tasks of NCC were also constructed.

- ♦ GIS model system to support road management
- ♦ GIS model system to support water management
- ♦ GIS model system to support sewerage management
- ♦ GIS model system to support cadastre management

a) Constraints in system construction

The hardware and software that could be utilized in the system design and database design of the four GIS model systems mentioned above were as follows:

- ♦ Hardware
  - Desktop PC
  - TFT monitor
  - A0 color plotter

- A0 black and white scanner
- A4 black and white printer

♦ Software

- OS : Windows XP Professional
- GIS engine : ArcGIS 9.0 (ArcInfo, Spatial analyst, 3D analyst)
- Microsoft Office XP Professional
- Anti-virus software

b) System design

The design of the four GIS model systems consisted of a function design and a database design.

* Function design

The required functions for the four GIS model systems were “common basic functions”, “common analysis functions” and “ specific functions”. The details of the various functions are summarized in the attached document, “GIS Model System Requirements Definition”.

* Database design

The databases required for the four GIS model systems and the database to support the tasks of NCC consist of graphic data and attribute data. The respective data items were designed based on the system functions and existing information and are summarized in the attached documents.

c) Construction of GIS model system

The existing functions in the GIS engine to be used were not sufficient to meet the requirements of the four GIS model systems. Therefore, some of the required functions were customized using “Arc/Info”.

* Common basic functions

The basic functions required for the four model systems were analyzed and those common to the four respective systems were identified. The basic functions required when starting the model systems, such as display, reading of data, etc., were also determined.

The common basic functions are shown below and were established with existing

"Arc/Info" functions and customized functions.

- ♦ System start up (including menu display)
- ♦ Reading of various data on start up
- ♦ Data layer management
- ♦ Manipulation of topographic map data
- ♦ GIS database management (edit, output, etc. of data)
- ♦ Image data output
- ♦ Data format conversion

∗ Common analysis functions

As with the basic functions, the analysis functions required for the four model systems were analyzed and those common to the various systems were identified.

The analysis functions were established with mainly existing "Arc/Info" functions.

- ♦ Spatial search function (Search for specific data in the topographic database from various keys)
- ♦ Attribute search function (Search for specific data in the attribute database from various keys)
- ♦ Thematic map creation function
- ♦ Function for tabulation of selected features (Mainly to tabulate statistics of the attribute data of various features)

∗ Specific functions of the model systems

Of the required functions of the model systems determined in discussions, those that could not be classified as common basic functions or common analysis functions were constructed as specific functions for each model system.

The specific functions were established with existing "Arc/Info" functions and customized functions.

The specific functions of the respective model systems are mainly as follows:

- ♦ GIS model system to support road management
  - Display of traffic survey results
  - Cost simulation for road construction

- ♦ GIS model system to support water management
  - Cost simulation
  - Network analysis

- ♦ GIS model system to support sewerage management
  - ３D display
  - Cost simulation for laying sewer lines

- ♦ GIS model system to support cadastre management
  - Area value calculation
  - Raster analysis

- ♦ Other

  Regarding the model systems and their respective databases, the data requirements, security requirements and operation and maintenance requirements were defined when the systems were being constructed, and smooth and safe operation of the systems was realized.

d) Verification of the systems and databases

The systems constructed were verified with users using the databases constructed. In the verification process, whether the defined functions were functioning properly, whether the users were satisfied with the various displays, and whether the operational procedures were simple and convenient were checked.

Based on the verification results, the model systems were modified and improved and the flaws in the databases were corrected. After that, a final verification was carried out and the four GIS model systems were completed.

3.4 Results of the Establishment of Spatial Data Infrastructure

3.4.1 Target Area of Spatial Data Infrastructure

(1) Sheet size and sheet division

In this Study, it was necessary to establish spatial data infrastructure as well as produce printed maps. Therefore, sheet size and sheet division were discussed based on global standards, and the following was decided.

a) Sheet size

The sheet size of both the 2500 and 5000 scale level printed maps was to be 80cm x 60cm.

b) Sheet division

It was decided that the sheet division for the 5000 scale level printed maps was to be every 4km in the east-west direction and every 3km in the north-south direction from the origin of coordinates.

For the 2500 scale level printed maps, the sheet division was to be a quarter of the 5000 scale level printed map sheets (refer to Figure 3.4)

(2) Target area of the 2500 and 5000 scale level spatial data infrastructure

The area to be targeted in the establishment of spatial data infrastructure of both scale levels was discussed based on the principle that no gaps occur in the 5000 scale level printed maps due to the production of 2500 scale level printed maps and that the central part of Nairobi City is covered by 2500 scale level printed maps. The following was decided.

a) Target area for 2500 scale level spatial data infrastructure

The target area was approximately 179.22km^2 covered by 60 sheets as shown in Figure 3.4.

b) Target area for 5000 scale level spatial data infrastructure

The target area was approximately 416.60km^2 covered by 59 sheets as shown in Figure 3.4.

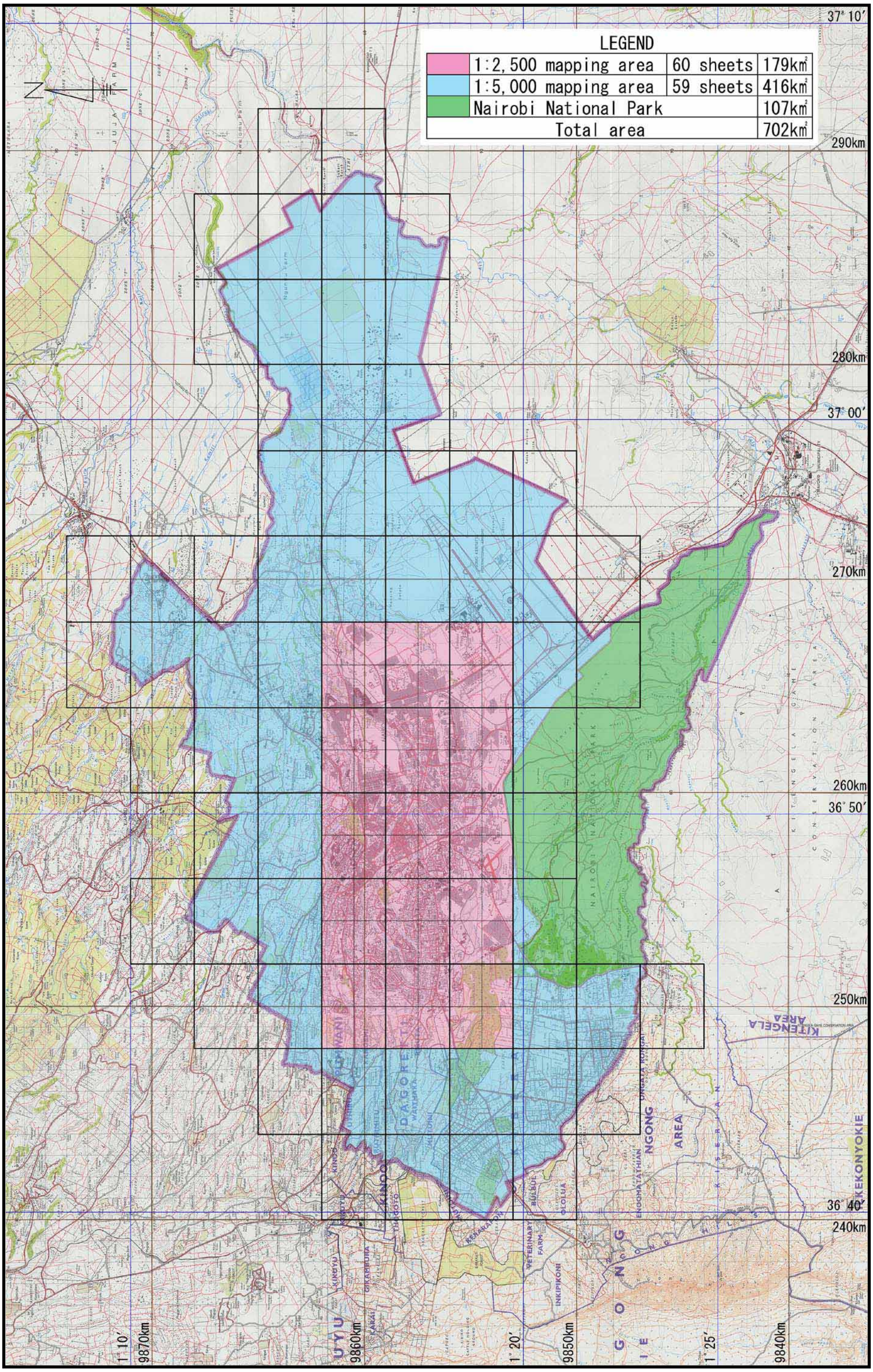


Figure 3.4 Scope of digital mapping/sheet division

3.4.2 Specifications for Spatial Data Infrastructure

In the establishment of spatial data infrastructure, specifications were discussed and decided on.

(1) Survey standards

Based on the existing survey standards, the following was decided on.

Reference ellipsoid: Clarke 1880 (modified)

Projection method: U.T.M (Universal Traverse Mercator) Zone37

Point of origin: Intersection point of 39° east longitude (central meridian) and the equator

Scale factor at the central meridian: 0.9996

(2) Work specifications for the establishment of spatial data infrastructure

The work specifications for establishing spatial data infrastructure include a wide range of techniques. Therefore, the specifications were to be discussed and decided on as the Study progressed. The "Work Specifications for the Establishment of Spatial Data Infrastructure (Draft)" were to be prepared in the final stage of the Study.

The technical items and main specifications discussed and decided on are as follows:

a) Aerial photography

The specifications for the performance of the aircraft, aerial camera and photographic film used and for shooting conditions, development/printing, and cloudiness in the aerial photos taken were established.

An example of the specifications for aerial photography is as follows:

1) Overlap should be 55% - 65%.
2) Sidelap should be 10% or more.
3) The photo swing (κ) should be less than 10 degrees.
4) The photo swing (Φ, ω) should be less than 5 degrees.

b) Photo control point survey by GPS

The specifications for the performance of the GPS receivers used, the method and time of observations, and the analysis results were established.

An example of the specifications for observation method and photo control points is as follows:

1) The observation method should be static. The observation time should be 1 hour with a data acquisition interval of less than 15 seconds.
2) Regarding the accuracy of photo control points after adjustment computations, the standard deviation should be less than ±0.5m for the horizontal position and less than ±0.3m for the elevation.

c) Ordinary leveling

The specifications for the performance of the level used, method of observation, and computation results were established.

The following are the respective margins of error for the computation results of the observation method.

1) The error of closure between known points must be within 50mm$\sqrt{S}$ (km).
2) The error of closure of loop must be within 40mm$\sqrt{S}$ (km).
3) The discrepancy between duplicate observation values must be within 40mm$\sqrt{S}$ (km).

d) Data specifications

"Spatial Data Infrastructure/Data Specifications (Draft)" were prepared, aiming at the following:

- Specifications that can be used for the GIS database without making major modifications.
- Logical data structure, e.g. node matching, in consideration of GIS use
- For digital data, realization of conventional topographic map representation to the extent possible
- Data structure and data format that can be utilized on general purpose systems

The features of the data specifications prepared in consideration of the above points are as follows:

- The extent of specific sites (such as for public facilities, schools, medical facilities, roads, rivers, airports, railway, parks, golf courses, quarries, cemeteries, grounds, etc.) can be identified in the GIS database.
- A single data set contains a set of features that are associated by meaning and features

that share common spatial relationships.

- For producing topographic maps, the files are composed per map sheet.
- Expression Codes are defined to maintain the continuity of planimetric features while realizing topographic map representation, and to assign multiple data structures (point, line) to a single planimetric feature.
- As for the data structure, the data is defined by points, line segments and continuous lines (including closed figures) so that it can be widely used.
- The data format is DXF.ver11 in consideration of wide use.

Annex IV

Digital Map Symbols for Scale Level 2500 and 5000

Category	Feature Class	Class Code	Item Code	Expression code	Feature Item	Figure	Data Type	Line Width (mm)	Color
Symbols for Open Spaces	Symbols for Open Spaces	62	21	00	Crater	0.4 1.8	Line		Black
Vegetation	Vegetation	63	01	00	Vegetation Boundary	0.5 0.5	Line	0.1	Black
		63	02	00	Cultivated Land Boundary	1.0 3.0	Line	0.1	Black
		63	11	00	Rice Field	Rice Rice 1.5	Line		Black Green
		63	13	00	Cultivated land	CULT CULT 1.5	Line		Black Green
		63	17	00	Coffee Plantation	C C 1.4	Line		Black Green
		63	18	00	Sisal Plantation	$ $ 1.4	Line		Black Green
		63	19	00	Sugar Plantation	Su Su 1.4	Line		Black Green

Regulations for Map Symbols

3.4.3 Aerial Photography

Aerial photography was carried out by a local subcontractor.

(1) Preparation and approval of specifications

Specifications for the local subcontractor were prepared based on the section in the "Work Specifications for the Establishment of Spatial Data Infrastructure (Draft)" on aerial photography, and approval by JICA was obtained.

(2) Selection of local subcontractor

A tender was held using the approved specifications. The three companies that participated in the tender were evaluated based on their technical capabilities and overall capacity.

As a result, the company below was selected as the local subcontractor, and JICA's approval was obtained:

Digital Topographical Mapping Services (DTM) (South Africa)

(3) Permission for aerial photography

After selecting the local subcontractor, applications for aerial photography permits were submitted to the concerned agencies with the full cooperation of SOK. Permits were obtained from the Department of Defense on February 6, 2003, the Kenya Association of Air Operators on February 12, 2003, and Kenya Civil Aviation Authority on February 17, 2003.

(4) Implementation of aerial photography

The aircraft arrived at Wilson Airport in Nairobi on February 18, 2003. All preparations were made by February 20, 2003. The aerial photos were shot on that same day (February 20) and the film was developed.

(5) Results of aerial photography

The development of the film and printing of color photographs was conducted in South Africa. At the same time, black and white contact prints were produced and used to inspect the results of aerial photography. The following items were checked to make sure they were in accordance with the specifications:

a) The specified coverage
b) The overlap and sidelap
c) The swing and tilt of the aerial photographs
d) Cloudiness

All the aerial photographs were found to be acceptable and, therefore, all of them were used. The aerial photography used consisted of 305 photographs (contact prints) taken in 15 flight strips (refer to Figure 3.5).

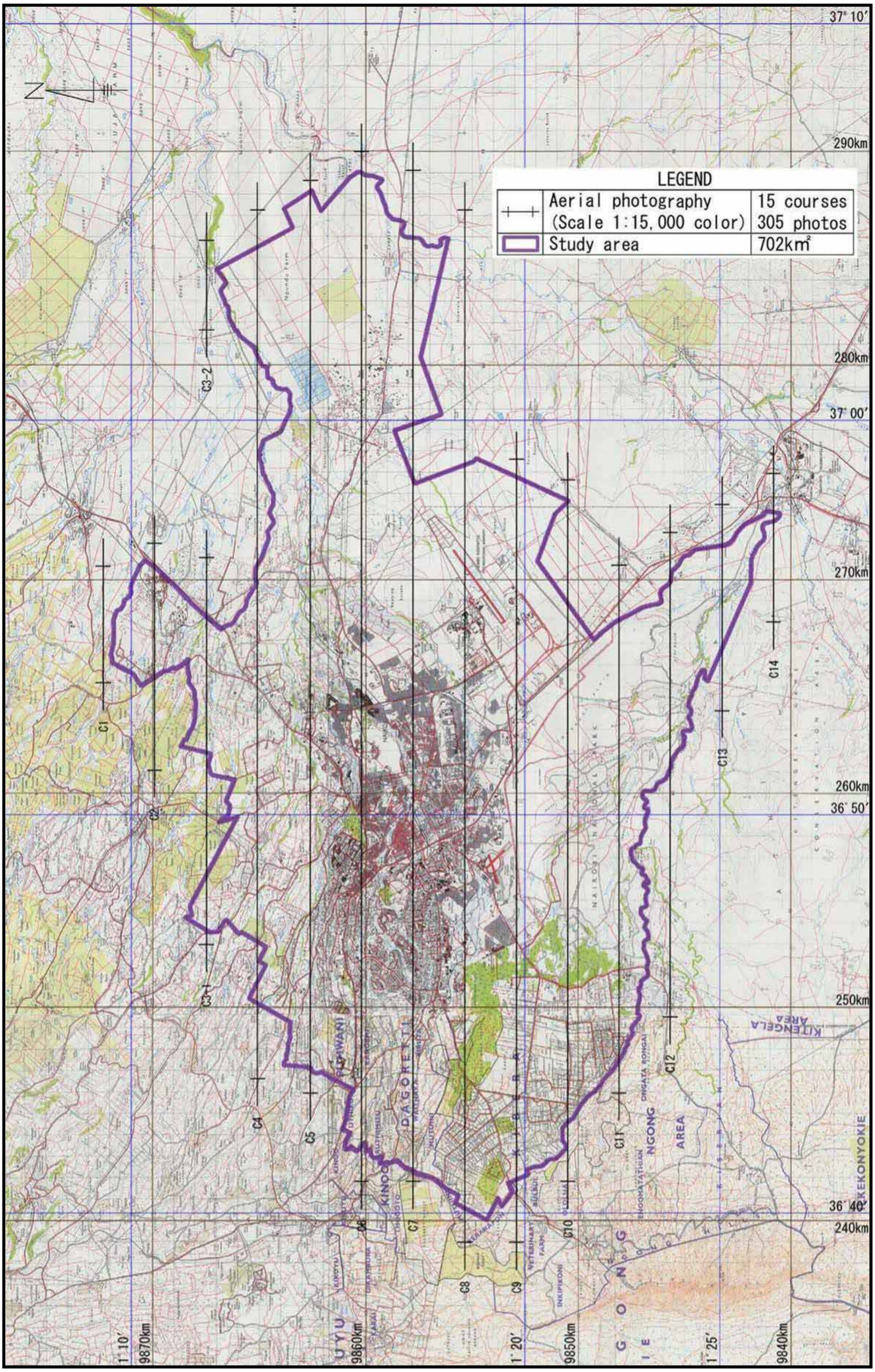


Figure 3.5 Aerial photography

3.4.4 Pricking

Pricking work was divided into the pricking of photo control points and the pricking of elevation points in ordinary leveling.

(1) Pricking of photo control points

Twenty-two (22) photo control points selected at locations that would appear clearly in the aerial photos were pricked on the contact prints. All the photo control points were clearly identified in the contact prints. Description sheets for all the pricked points were also prepared. The pricked points were transferred from the contact prints to the description sheets using photographs enlarged eightfold.

(2) Pricking of elevation points

The pricking of elevation points is normally carried out while conducting observations in ordinary leveling. However, on this occasion, the following two methods were adopted in view of the period of aerial photography.

1. Sketches of the elevation points to be pricked are prepared and used for the pricking the contact prints.
2. As usual, elevation points are pricked while performing observations.

Using the two methods mentioned above, elevation points were pricked on the contact prints at a standard interval of approximately 500m.

3.4.5 Ground Control Point Survey

The ground control point survey was divived into a GPS photo control point survey and ordinary leveling.

(1) GPS photo control point survey

The GPS control point survey was to be conducted to establish photo control points by GPS method with horizontal positions and heights required for aerial triangulation.

a) Field reconnaissance of existing triangulation points

A field reconnaissance of existing triangulation points was conducted based on the GPS photo control point survey plan formulated in the work in Japan.

The field reconnaissance was carried out using the triangulation point descriptions. However, of the 13 points investigated only three were verified. Furthermore, the four-foot concrete pillars of the three verified triangulation points were destroyed with only the base stones remaining.

Seven of the 13 points were in the northwest area but not a single one could be verified. This is due to the fact that most of those points were installed underground (after monumenting, the point is buried) and there were no point descriptions of them.

b) Selection and monumentation of photo control points

Photo control points were selected based on the photography flight plan and the planning map for the GPS photo control point survey.

The positions of photo control points were selected assuming that aerial photo signals would not be installed. Therefore, objects that could be clearly identified in the aerial photos (bridges, corners of large manholes, roofs of houses, etc) were targeted.

The results of point selection were satisfactory in the western area, as there were many objects that could be clearly identified in the aerial photos. However, it was difficult in the eastern area since there were few objects clearly indicated in the photos.

The 22 photo control points that were selected included what is known as the origin of longitude and latitude, which was installed through assistance from the Japanese government in 1989.

After point section was complete, the photo control points were monumented using metal markers. As a result, markers were installed on rooftops at three points, using concrete posts at five points and directly installed at 13 points. (A marker was not installed at the origin of longitude and latitude.)

c) Observations

The observation plan was determined taking into account the draft plan prepared in advance, the results of the field reconnaissance on existing triangulation points, the results of photo control point selection, and the number of GPS receivers available for observations.

The observations were carried out using four GPS receivers (Leica SR520).

It was composed of 14 sessions and there were a total of 12 common sides.

(Figure 3.6 Observation plan)

Prior to performing each observation session, test GPS observations were conducted to confirm the GPS satellites and obtain the almanac data.

Analysis of the GPS satellite data from the test observation confirmed that the GPS satellites were flying well and that the distribution conditions would be good all day

Therefore, two sessions were performed per day, one in the morning (10:00 - 11:30) and one in the afternoon (14:30 - 16:00).

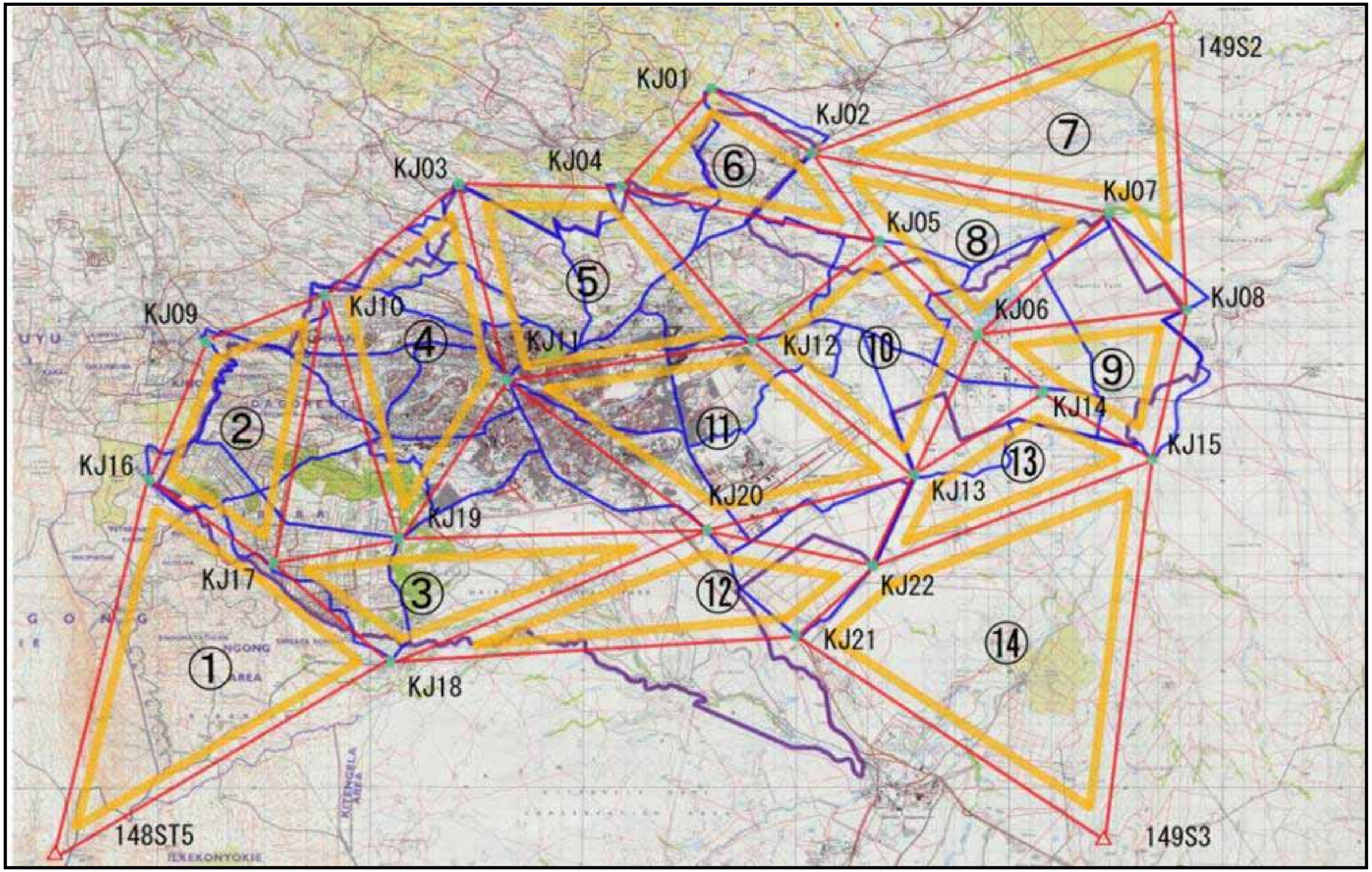


Figure 3.6　Observation plan

Four groups were organized to perform the observations, each group consisting of a technical expert, an assistant, a helper, a driver, a set of GPS receivers and a vehicle.

The 14 observation sessions were conducted based on the group organization and observation plan above. The groups contacted each other by mobile phone to report the start and end time of the observations and the security situation.

d) Analytical computations of observation data

The analytical computations performed on the observation data included baseline analysis, check computations, and net adjustment. As a rule, Leica's processing software "SKI-PRO" was used for all the work.

Baseline analysis was carried out for each baseline in the 14 sessions and a solution was obtained, indicating there were no problems with the observations.

Using the results of the baseline analysis, the check computations were carried out.

The results of the check computations that compare overlapping sides showed that they all were within the 45mm limit set in discussions with SOK. The maximum discrepancy of overlapping sides was as follows

$\triangle X$=35mm $\triangle Y$=34mm $\triangle Z$=19mm

The results of the check computations on the closure error in a given polygon showed that the closure error of all polygons was within the limit (45mm x $\sqrt{\ }$no. of sides) set in discussions with SOK.

After the above analysis, three-dimensional net adjustment was carried out to determine the coordinates of each photo control point. In the net adjustment, the coordinates of the newly installed photo control points were determined by using the three existing triangulation points as fixed points.

The standard deviation of all the newly installed photo control points' final coordinates was within the limit set in discussions with SOK (standard deviation of longitude and latitude: 15cm, standard deviation of height: 30cm).

The maximum standard deviation of each point was as follows:

$\triangle B$ (latitude) maximum value = 34mm

$\triangle L$ (longitude) maximum value = 41mm

△H (height) maximum value = 108mm

(Table 3.10 Results of check calculations, Table 3.11 List of newly installed photo control points)

e) Preparation of point descriptions and final results table

The pricking of newly installed photo control points and results of analytical computations were arranged, and point descriptions and a final results table were prepared.

The point descriptions and final results table were prepared in a digital format that is convenient for storing and easy to search and revise (Figure 3.7 Point description).

3-65

Table 3.10 Results of check calculations

Project name	The Republic of Kenya	Area	Nairobi Area	Planning agency	Japan International Cooperation Agency	Executing agency	Kokusai Kogyo Co., Ltd.	Project leader	Akira NISHIMURA
Objectives	The Establishment of The Spatial Data Framework	Period	2003/02/01～2003/04/01			Work quantity	22 points	Responsible engineer	Satoru NISHIO

Standard deviation of new points						
New point No.	ΔB		ΔL		ΔH	
	Residual	Tolerance	Residual	Tolerance	Residual	Tolerance
KJ01～22	max 0.034	0.150	max 0.041	0.150	max 0.108	0.300

Inspection										
Point name		ΔX(Tolerance0.045)			ΔY(Tolerance0.045)			ΔZ(Tolerance0.045)		
From:	To:	Observed values	Adopted value	Discre-pancy	Observed values	Adopted value	Discre-pancy	Observed values	Adopted value	Discre-pancy
148ST5	KJ18	-9,514.139	-9,514.168	0.029	13,000.160	13,000.140	0.020	10,522.977	10,522.989	-0.012
KJ02	KJ05	-2,017.392	-2,017.368	-0.024	2,500.989	2,500.991	-0.002	-4,121.131	-4,121.130	-0.001
KJ02	KJ07	-8,574.774	-8,574.777	0.003	11,175.760	11,175.758	0.002	-2,668.505	-2,668.507	0.002
KJ03	KJ11	-1,598.411	-1,598.423	0.012	1,660.504	1,660.495	0.009	-9,310.664	-9,310.658	-0.006
KJ05	KJ06	-2,981.792	-2,981.777	-0.015	3,770.240	3,770.248	-0.008	-4,333.953	-4,333.946	-0.007
KJ09	KJ10	-3,396.645	-3,396.655	0.010	4,415.343	4,415.335	0.008	2,183.558	2,183.577	-0.019
KJ09	KJ16	1,467.799	1,467.816	-0.017	-2,308.103	-2,308.091	-0.012	-6,637.564	-6,637.574	0.010
KJ09	KJ17	-2,150.011	-2,150.014	0.003	2,348.768	2,348.749	0.019	-10,447.535	-10,447.544	0.009
KJ10	KJ16	4,864.460	4,864.495	-0.035	-6,723.417	-6,723.427	0.010	-8,821.134	-8,821.150	0.016
KJ11	KJ12	-7,034.283	-7,034.285	0.002	9,303.571	9,303.561	0.010	1,852.842	1,852.844	-0.002
KJ12	KJ13	-4,735.489	-4,735.470	-0.019	6,052.150	6,052.159	-0.009	-6,389.674	-6,389.677	0.003
KJ14	KJ15	-3,146.975	-3,146.961	-0.014	4,011.443	4,011.462	-0.019	-3,227.321	-3,227.318	-0.003
KJ15	KJ22	7,812.950	7,812.951	-0.001	-10,334.946	-10,334.936	-0.010	-4,982.957	-4,982.952	-0.005
KJ16	KJ18	-7,113.060	-7,113.075	0.015	8,939.388	8,939.374	0.014	-8,465.644	-8,465.627	-0.017
KJ17	KJ18	-3,495.223	-3,495.224	0.001	4,282.505	4,282.539	-0.034	-4,655.668	-4,655.672	0.004
KJ18	KJ20	-8,799.694	-8,799.689	-0.005	11,837.238	11,837.237	0.001	6,364.031	6,364.029	0.002
KJ21	KJ22	-2,118.791	-2,118.798	0.007	2,932.325	2,932.316	0.009	3,402.514	3,402.523	-0.009

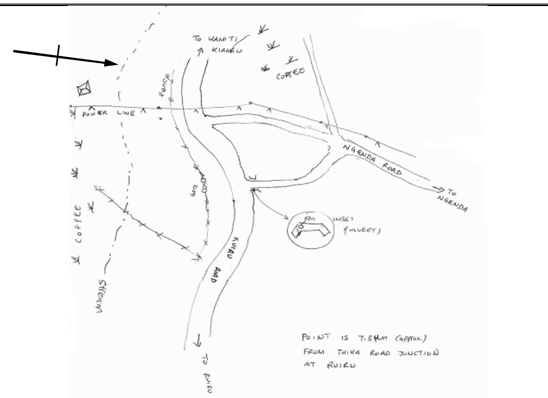
Names and numbers of main instruments		
Leica SR520 4 sets		
Permanent monuments		
Category	Number	Shape
Comments		
Observation method: Static		

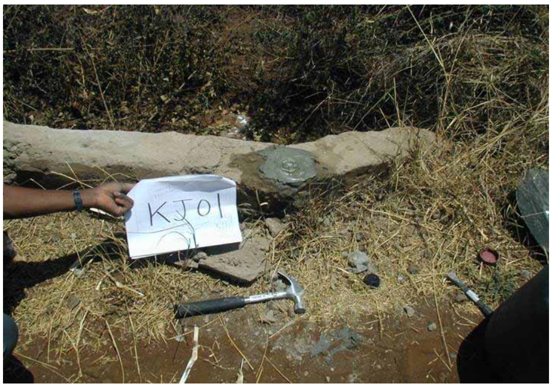
Table 3.11 List of newly installed photo control points

Point ID	B	L	X	Y	Ell(m)	Alt(m)	Geoid H.(m)	Remark
148ST5	1° 29' 17.70455" S	36° 37' 01.93966" E	9,835,375.070	234,861.940	1,751.642			
149S2	1° 06' 01.51548" S	37° 06' 44.49970" E	9,878,315.023	289,949.592	1,389.794			
149S3	1° 28' 07.08874" S	37° 03' 44.64762" E	9,837,592.787	284,419.100	1,727.096			
KJ01	1° 08' 53.64349" S	36° 53' 53.69124" E	9,873,011.157	266,117.332	1,454.634	1,564.493	109.859	
KJ02	1° 10' 38.75232" S	36° 56' 19.18118" E	9,869,785.482	270,618.912	1,429.742	1,539.473		Calculation by the interpolation
KJ03	1° 11' 18.23361" S	36° 47' 25.83794" E	9,868,559.858	254,126.032	1,646.087	1,755.926	109.839	
KJ04	1° 11' 24.58187" S	36° 51' 32.45660" E	9,868,370.837	261,753.130	1,518.012	1,627.743		Calculation by the interpolation
KJ05	1° 12' 52.94674" S	36° 58' 03.03261" E	9,865,665.450	273,833.428	1,407.386	1,517.117		Calculation by the interpolation
KJ06	1° 15' 14.07097" S	37° 00' 38.43740" E	9,861,333.871	278,642.179	1,387.763	1,497.649	109.886	
KJ07	1° 12' 05.67685" S	37° 03' 54.68593" E	9,867,125.458	284,706.218	1,363.585	1,473.010	109.425	
KJ08	1° 14' 32.80888" S	37° 05' 52.12847" E	9,862,608.535	288,340.853	1,377.832	1,487.417	109.585	
KJ09	1° 15' 23.26364" S	36° 41' 01.85797" E	9,861,021.492	242,256.828	1,834.370	1,943.979	109.609	
KJ10	1° 14' 12.26252" S	36° 44' 01.97427" E	9,863,207.837	247,825.540	1,703.072	1,812.803		Calculation by the interpolation
KJ11	1° 16' 21.43488" S	36° 48' 39.80047" E	9,859,246.533	256,421.085	1,561.377	1,671.208	109.831	
KJ12	1° 15' 21.16614" S	36° 54' 56.97341" E	9,861,107.686	268,083.412	1,473.976	1,583.897	109.921	
KJ13	1° 18' 49.21307" S	36° 59' 05.44134" E	9,854,722.673	275,771.774	1,471.391	1,581.122		Calculation by the interpolation
KJ14	1° 16' 38.51834" S	37° 02' 11.71732" E	9,858,741.974	281,528.489	1,386.312	1,496.106	109.794	
KJ15	1° 18' 23.61464" S	37° 04' 56.57494" E	9,855,517.537	286,628.400	1,365.482	1,475.109	109.627	
KJ16	1° 18' 59.41044" S	36° 39' 33.64896" E	9,854,377.754	239,534.745	1,782.569	1,892.106	109.537	
KJ17	1° 21' 03.48035" S	36° 42' 44.30843" E	9,850,571.212	245,434.915	1,752.437	1,862.168		Calculation by the interpolation
KJ18	1° 23' 35.16717" S	36° 45' 42.90531" E	9,845,915.976	250,962.559	1,624.835	1,734.577	109.742	
KJ19	1° 20' 24.79077" S	36° 45' 56.42869" E	9,851,765.427	251,375.325	1,684.073	1,793.781	109.708	
KJ20	1° 20' 08.02429" S	36° 53' 39.89564" E	9,852,293.211	265,707.212	1,525.040	1,634.834	109.794	
KJ21	1° 22' 56.55056" S	36° 56' 00.62238" E	9,847,119.741	270,063.268	1,507.525	1,617.329	109.804	
KJ22	1° 21' 05.76944" S	36° 57' 57.59399" E	9,850,526.016	273,677.291	1,495.617	1,605.348		Calculation by the interpolation
						Ave.	109.731	

PHOTO CONTROL POINT DESCRIPTION **SOK/JICA**

Point ID	**KJ01**		**Operator**	Charles O. GAYA		
Signal shape	----	**Bench-mark distance**	Signal-Hight from Ground	----	**Inspector**	Satoru NISHIO
	----		Below Signal	----		
Color	----		Above Ground	0.15	**Date of installation**	25-Feb-03
Coordinate Zone	UTM-37	**B (X)**		**L (Y)**	**H**	
Point Coordinates (Clarke 1880)	**Main point**	1° 08' 53.64349" S		36° 53' 53.69124" E	Ell (m)	1,454.634
		9,873,011.157		266,117.332	Alt (m)	1,564.493
	Eccentric point	----		----	Ground Hight (m)	1,564.343

Schematic map	**Map 1:50 000 : KIAMBU Map sheet No: 148/2**
	

Close range photograph	**Long range photograph**
	

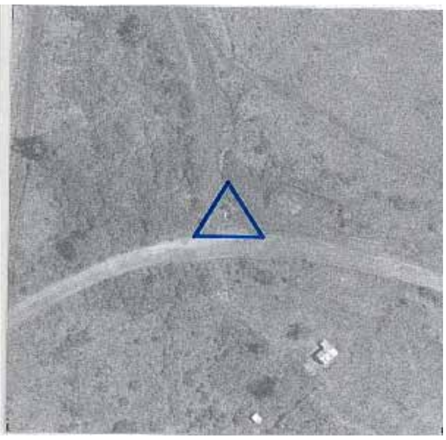
Left Photo (C-1 , No. 1,179)	**Right Photo (C-1 , No. 1,180)**
	

Figure 3.7 Point description

(2) Ordinary leveling

Ordinary leveling was implemented to perform observations at and establish elevation points with height information required for aerial triangulation, as well as to determine the heights of photo control points.

a) Field reconnaissance of established benchmarks

A field reconnaissance of established benchmarks in and around Nairobi City was conducted using the point description data for first and second order benchmarks available at SOK and other agencies.

Most of the established benchmarks were lost due to road repair work, etc, or were difficult to locate due to temporal changes in the terrain. However, the following 11 benchmarks were verified in and around the city.

V/6(h=1661.837m), V/20(h=1894.686m), IN/11(h=1649.843m)
IN/37(h=1794.851m), IV/10(h=1636.665m), 3N/52(h=1659.788m)
LXI/4(h=1596.980m), LXI/6(h=1560.013m), LXI/7(h=1533.415m)
MT3(h=1611.336m), KISM7(h=1592.530m)

Elevations of benchmarks indicated in feet were converted to meters by the equation 1 meter = 3.280840 feet.

b) Deciding on routes for ordinary leveling

The routes for ordinary leveling were determined based on the planned routes, the photography flight plan map, 1:15,000 scale aerial photographs and the results of the field reconnaissance mentioned above. The following was also considered:

- Position of verified established benchmarks
- Position of newly installed photo control points
- Form of the network
- Aerial triangulation
- Safety

It was decided that ordinary leveling would consist of three types of routes: routes forming a loop, routes closed on established benchmarks, and open routes. It was also decided that the heights of 15 of the 22 newly installed photo control points would be determined by leveling. The total length of the routes was approximately 247km (Figure 3.8).

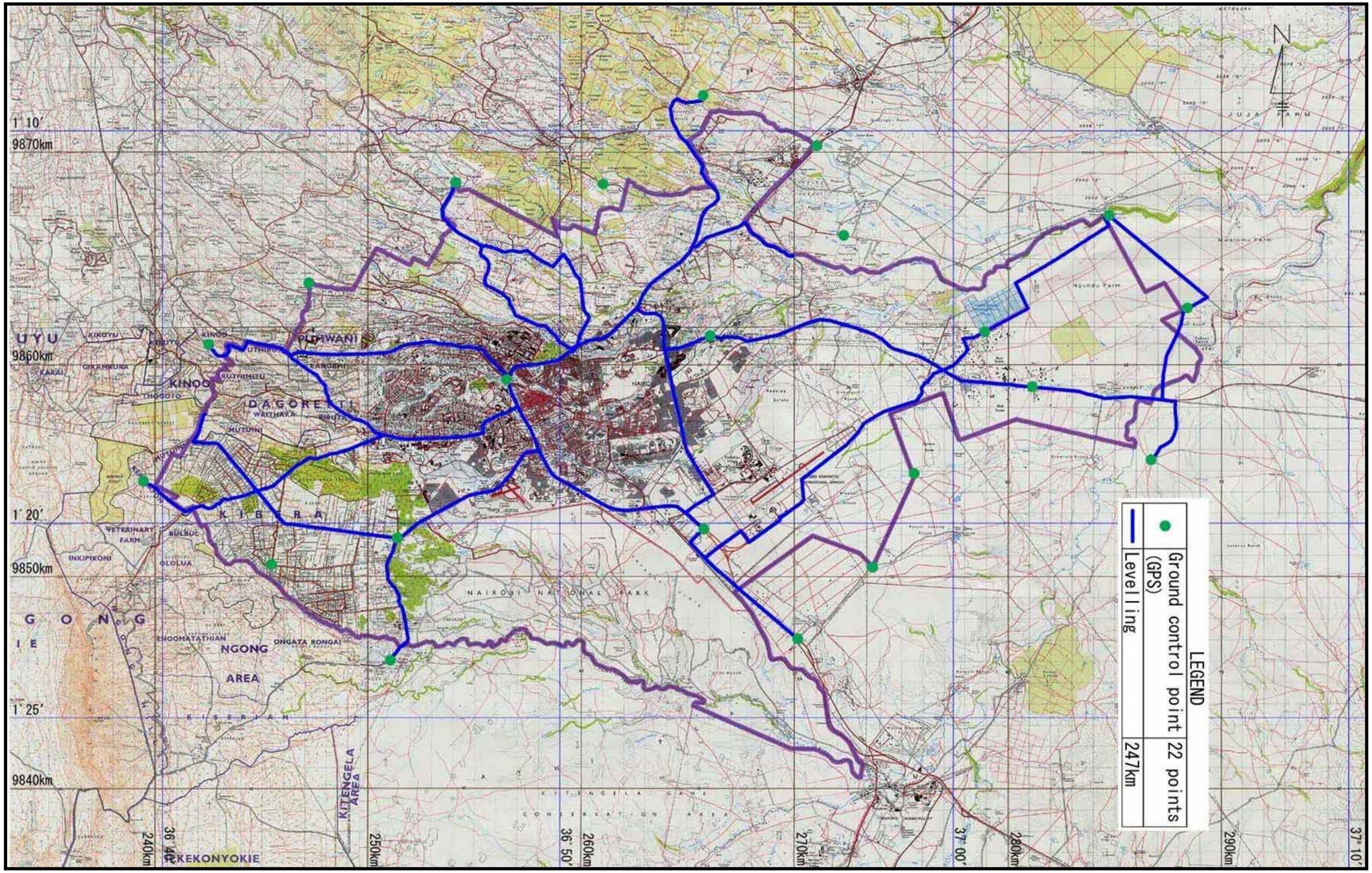


Figure 3.8 Map of leveling routes

c) Observations

After deciding on the routes for ordinary leveling, three groups were organized to perform observations.

Prior to performing observations, the levels were inspected and adjusted (collimation axis, etc.).

Observations were carried out according to the following specifications:

- Length of sight (distance from the level to the staff): within 90m
- Difference between the length of sight of foresight and back sight: within 60m
- Observed value: average of 3 readings
- Position of fixed point: leveling routes intersections and major road intersections
- Position of pricking point: positions that can be identified in aerial photos such as road intersections and bridges

The group organization and the equipment used were as follows:

- Survey engineer: 1 person
- Staff man: 2 persons
- Assistant: 1 person
- Level (LEICA: DNA10): 1 unit
- Staff (Myzox: GKNL4C): 2 units
- Foot plate: 2 units

d) Computational processing and arrangement

Computational processing: Computational processing of observation data was carried out for all leveling routes (loop routes, closed routes, and open routes). In the computation processing for the various routes, the quality of the observation data was first checked in the field or in the work indoors, and the routes for which observations needed to be re-performed were identified. At the same time, accuracy control tables were prepared (Figure 3.9, Table 3.2).

Then, for the routes with adequate observation data, the heights of fixed points and pricking points were determined using LEICA's processing software "Level Pack Pro" (Figure 3.10).

As for the seven photo control points whose heights could not be established by ordinary leveling, their heights were determined by interpolation from the established geoid model using the results of the photo control points whose heights could be established by ordinary leveling.

Arrangement: The heights of the pricking points determined by computational processing were arranged in meters on the contact prints to the second decimal place.

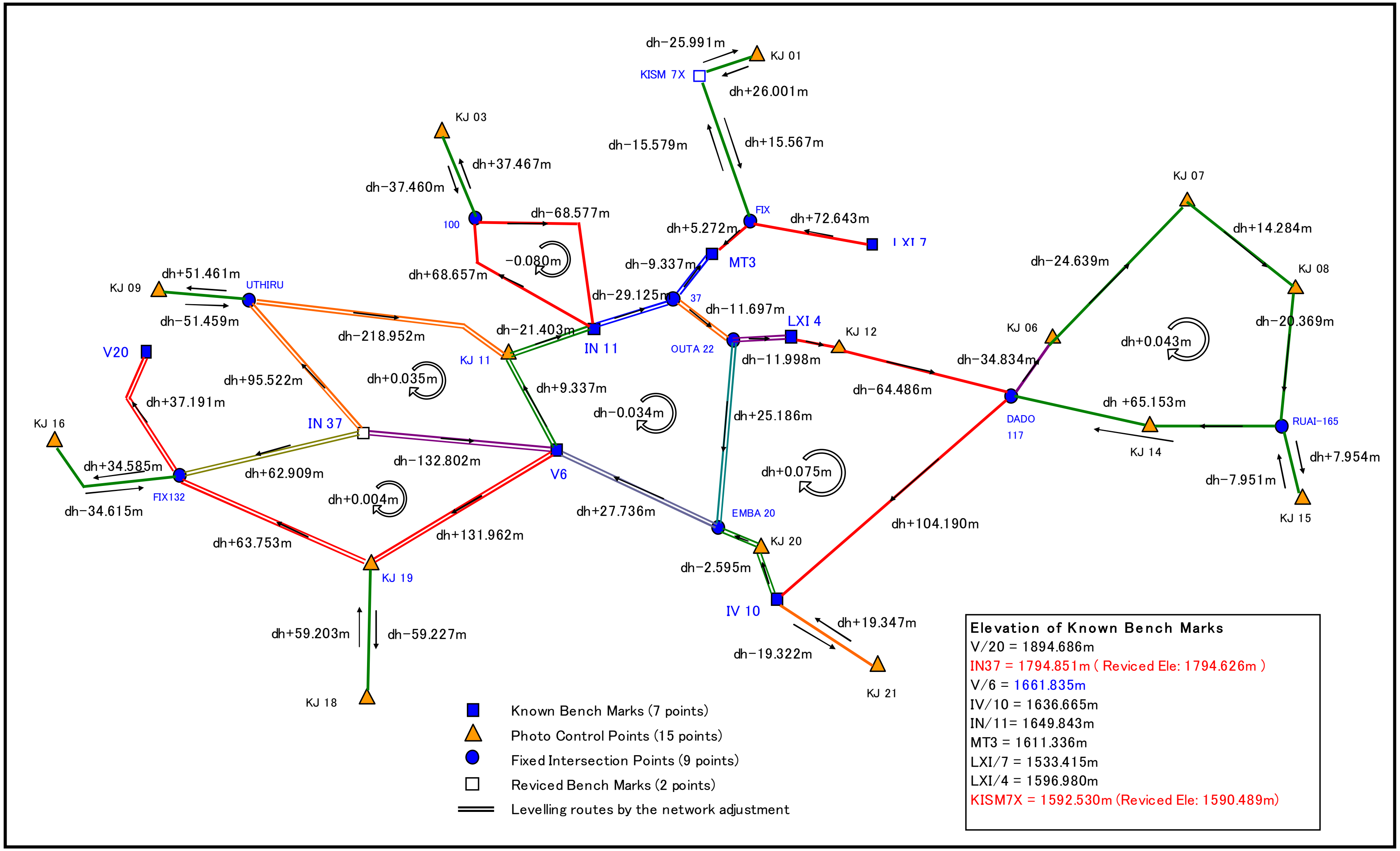


Figure 3.9 Accuracy control map

Table 3.12 Accuracy control table

Project name	Nairobi Mapping	Area	Nairobi City	Planning agency	JICA and Kokusai Kogyo	Executing agency	SOK	Project leader	(Signature) A. Nishimura
Objectives	Mapping	Period	from 1st Feb. 2003 to 1st Apr. 2003 (60 days)			Work quantity	Approx. 247km	Responsible engineer	(Signature) K.Ishizuka

Route No.	Distance	Error of closure limit	Error of closure	Comments	Route No.	Distance	Error of closure limit	Error of closure	Comments	Name of instrument
	km	cm	cm			km	cm	cm		LEICA DNA10
Link routes between known points					Going/Backing routes					(S/No. 331026)
V/6 → IN/11	7.0	13.2	7.4	within limit	FIX → KJ01	10.3	12.8	0.2	within limit	(S/No. 331020)
IN/11 → MT3	5.7	11.9	4.5	within limit	100 → KJ03	5.0	8.9	0.7	within limit	(S/No. 331110)
MT3 → LXI/7	7.0	13.2	0.6	within limit	UTHIRU → KJ09	5.5	9.3	0.2	within limit	
IV/10 → V/6	10.5	16.2	2.9	within limit	FIX132 → KJ16	6.0	9.7	3.0	within limit	
LXI/4 → IV/10	27.0	25.9	1.9	within limit	KJ19 → KJ18	6.5	10.1	2.4	within limit	
V/6 → V/20	21.0	22.9	5.5	within limit	IV/10 → KJ21	8.0	11.3	2.5	within limit	
					RUAI165 → KJ15	4.0	8.0	0.3	within limit	
Loop route from known point										
IN/11 → IN/11	16.0	16.0	8.0	within limit						
Link routes between fixed point and known point										
OUTA22 → LXI/4	2.5	6.3	0.6	within limit						
V/6 → 132	14.0	14.9	3.5	within limit						
Link routes between fixed points										
37 → EMBA20	11.7	13.6	8.8	within limit						
IN/37 → KJ11	17.0	16.4	1.7	within limit						
Loop route from fixed point										
DADO117 → DADO117	35.0	23.6	4.3	within limit						

Error of Closure Limit
- Route between known points: within 50mm√S
- Loop route: within 40mm√S
- Going/Backing route: within 40mm√S

(S: Distance in Km)

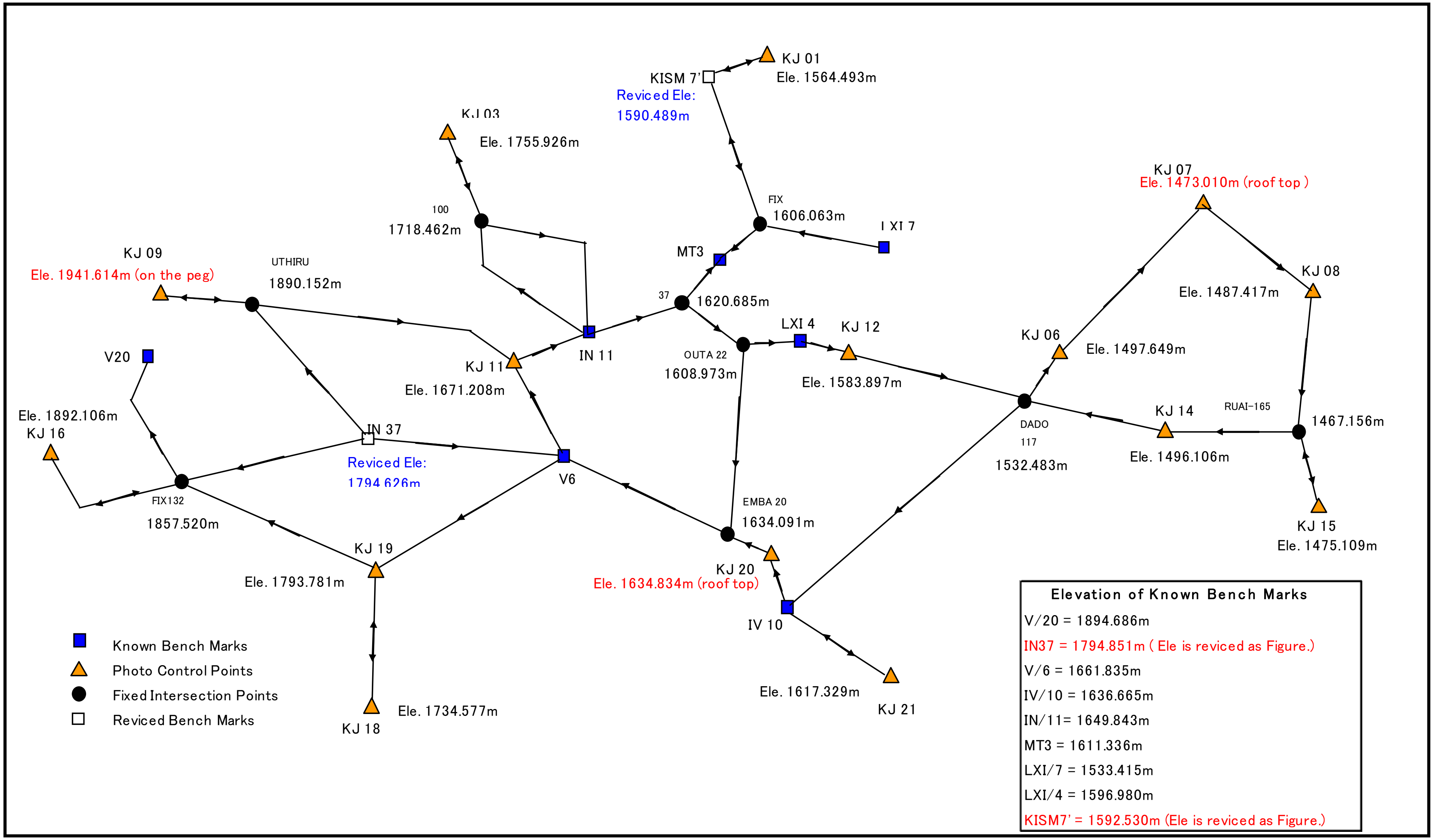


Figure 3.10 Calculation results

3.4.6 Field Identification

(1) Objective

The objective of field identification was to transfer the techniques for conducting field identification using mainly aerial photographs to SOK. Furthermore, it was decided that the results obtained through OJT in this technology transfer were to be used in the subsequent digital plotting/compilation works.

(2) Scope and period of work

a) Scope

The scope of field identification implemented through OJT included the central urban area of Nairobi City, the wealthy residential area, the slum area, the new residential area, and various vegetative areas (Refer to Figure 3.11). Because the objective of this field identification was to transfer technology and the period was short, only a small portion of the target area was covered.

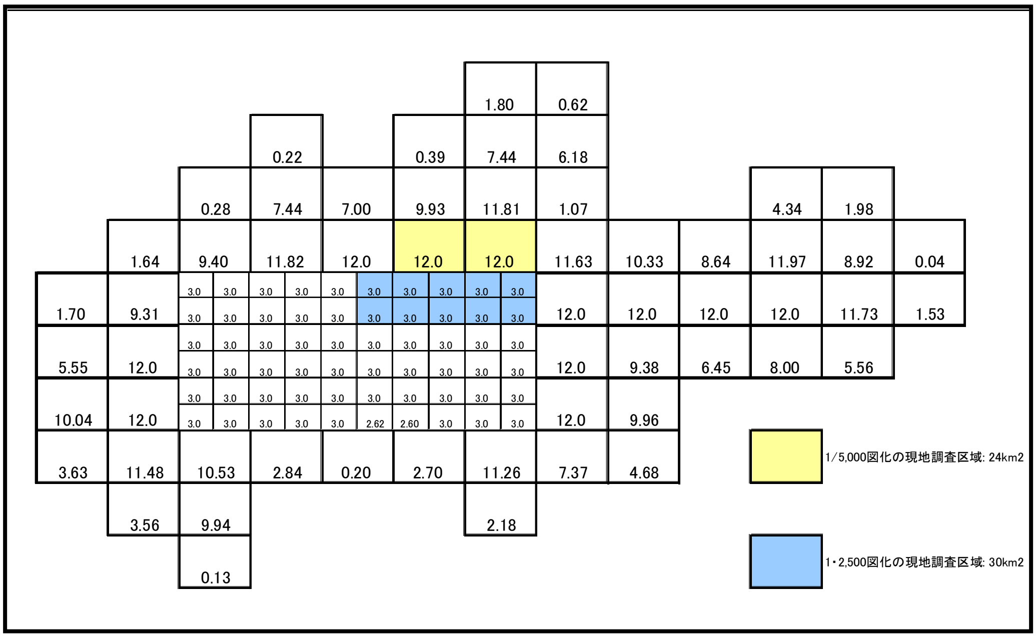


Figure 3.11 Scope of field identification

b) Period

The field identification was implemented through OJT from May 22 to June 16.

(3) Field identification

The aerial photographs covering the target area were enlarged to the same scale as that of the spatial data infrastructure to be established, and used in field identification. In field identification, the topographic items in line with the map symbols regulations were surveyed and the results were arranged on the aerial photographs.

(4) Aerial photo interpretation handbook

During the field identification, information was collected in line with the topographic features in the map symbols regulations to prepare an aerial photo interpretation handbook (collection of actual interpretations to serve as a reference for photo interpretation in digital plotting/compilation).

(5) Acquisition of existing information

In addition to carrying out field identification by OJT in a confined area, information related to topographic maps (i.e. administrative boundaries, administrative names, names of roads, etc.) required for the establishment of spatial data infrastructure was collected. The specifications for scanning were as follows:

1/2500 topographic maps	14 originals, 53 copies
1/5000 topographic maps	14 originals, 42 copies
1/10000 topographic maps	14 original, 1 copy
Data on administrative names and boundaries	1 set (ArcView format)

3.4.7 Aerial Triangulation

Aerial triangulation was carried out to determine the elements of orientation and the geodetic coordinates of pass points necessary for digital plotting by computational processing.

(1) Digitization of aerial photographs

In order to carry out aerial triangulation in a digital format, the negative films were scanned to produce image data of the aerial photos. The specifications for scanning were as follows

- Resolution: 1270dpi
- No. of aerial photos: 305

(Image data of aerial photos covering the entire city including Nairobi National Park was produced in consideration of producing digital orthophotos for all of Nairobi City.)

The resulting image data of aerial photos covering the entire city was approximately 120 GB. The data was stored on a portable hard disk.

(2) Aerial triangulation

This work was carried out by the analytical method, in consideration of flexibility in the selection of equipment for digital plotting. After calculating the results, the data of the aerial triangulation results was converted and processed into a general format, in consideration of digital plotting by digital plotter.

The results satisfied the required accuracy for producing 1: 2,500 and 1: 5,000 topographic maps. The work volume was as follows.

- No. of flight lines: 15
- No. of models: 250

3.4.8 Digital Plotting/Compilation

(1) Digital plotting

Spatial data infrastructure, on which the topographic and GIS databases are based, was established using a digital plotter and an analytical plotter. The data established was stored in a layer structure and file structure suitable for the processing and updating of data in accordance with the "Spatial Data Infrastructure・Data Specifications". The layer sets and their requirements are described below.

Table 3.13 Layer sets and their requirements

Layer set	Contents	Order of priority regarding topographic map representation	Requirements
admin	Administrative districts	2	● Node matching required (topology check) ● Closed area should be formed
boundary	Land use boundaries	9	● Node matching required (topology check) ● As a rule, places obscured by other features. should maintain continuity ● Closed area should be formed
centerline	Center lines of roads	-	● Not displayed ● Node matching required (topology check)
facilities	Road, railway, and river facilities	4	● Node matching between features not required (representation only) ● Within the same feature, there are restrictions such as closed figures (i.e. inbound and outbound roads of tunnels), etc.

Layer set	Contents	Order of priority regarding topographic map representation	Requirements
railway	Center line of railway tracks	9	● Node matching required ● Continuity required
building	Buildings and building symbols	4	● Node matching between features not required ● Within the same feature, there are restrictions such as closed figures (i.e. buildings), etc. ● Overlapping of same features is unacceptable ● As a rule, buildings and symbols should have topology (The symbol should be placed within the building)
Small Object	Small objects and small object symbols	3	● Node matching between features not required ● Within the same feature, there are restrictions such as closed figures (i.e. buildings), etc. ● Overlapping of same features is unacceptable ● As a rule, buildings and symbols should have topology (The symbol should be placed within the building)
surround	Artificial topographic features	5	● There is a topological relationship within a feature (i.e. the top and bottom of a revetment) ● Symbolization required in topographic map representation
openSpace	Open space symbol	3	● Symbols should be laterally distributed in topographic map representation
vegetation	Vegetation symbol	7	● Symbols should be laterally distributed in topographic map representation
topographic	Topographic representation	8	● Contour lines should be 3-dimensional
geographic	Natural topographic features	6	● There should be a topological relationship within a feature (i.e. the top and bottom of a revetment) ● Symbolization required in topographic map representation
gcp	Ground control points	1	● Those with results should be 3-dimensional
annotation	Annotation	1	● Two-line representation, etc. should be carried out for printed data, and significant letter strings should be maintained on topographic map data.

(2) Digital compilation

The various files by layer structure and by sheet unit obtained in digital plotting were processed using a digital compilation system. The processing procedure was as follows:

- Graphic compilation:

  The compilation of graphic shapes, including line-node matching, mistaken graphical overlays, hidden line processing, appropriate distribution of symbols, etc. was carried out.

- Input of administrative boundaries, etc.:

  Additional graphic information, such as administrative boundaries obtained from existing map sheets and existing data other than aerial photos, was input and compiled.

- Input of annotations:

  The input of annotations was conducted based on the photo interpretation results, constituting a portion of the technology transfer results, and existing maps.

- Graphic compilation between layer sets:

  The processing of the minimal displacement and sections of graphic overlapping required for topographic representation was conducted. Topological compilation such as node matching for the graphics between data sets was not required.

- Sheet joining:

  The joining of adjacent sheets was conducted for each layer set. In this work, graphics were joined and the feature codes aligned.

(3) Logical check

A complete check was conducted on the digitally compiled data for topological consistency and the correctness of classification, using a logical check program. The discovered errors were corrected, compiled and rechecked for assurance. The items checked are described below.

- Consistency check of topology

  Regarding the interrelated features mentioned in the specifications (for example, admin layer), a logical check was conducted on the geometric figures. The following items were checked.

Item	Description
Joining	Check for any unjoined elements
Undershoot	Take particular note of this because the process is difficult.
Overshoot	Check for dangling nodes (less than 1.25m)
Overlapping polygons	Check for unacceptable overlapping of houses, etc.
Consistency of land classification	Check for multiple land use (vegetation, etc.) not allowable for a single area. Check whether classification is consistent between maps sheets.
Loops	Check for lines that intersect themselves
Twisted polygons	Check for polygons with missing nodes
Overlapping of data	Check for overlapping lines

- Correctness check of classification

  A logical check on the items below was conducted for all layers and items.

Item	Description
Appropriateness of the feature code	Check whether or not the layer name is within the defined area
Appropriateness of the data type	Check whether or not it is the defined data type

(4) Accuracy control

In addition to the logical checks, visual checks using output maps were conducted as follows.

- ♦ A check was conducted after the completion of each digital plotting and digital compilation process.
- ♦ Each stereo model was checked for digital plotting, and each map sheet for digital compilation.
- ♦ The mistaken entries and omissions on each layer were compiled, clearly indicated on the check sheets and corrected.

3.4.9 Supplementary Field Identification

Supplementary field identification was conducted on the 179 km^2 area of the 1/2500-scale topographic map and the 417 km^2 area of the 1:5000-scale topographic map, using output maps of the compiled data.

(1) Planning/preparations

a) Planning

A detailed plan of the procedures and schedule of supplementary field identification was prepared.

b) Preparations

The following maps and materials were prepared:

(Map for arranging the results of the field survey)

- Compiled manuscripts at a scale of 1:2,500 with overlays: (60 sheets)
- Compiled manuscripts at a scale of 1:5,000 with overlays: (59 sheets)

(Map for the field survey)

- Compiled manuscripts at a scale of 1:2,500: (60 sheets)
- Compiled manuscripts at a scale of 1:5,000: (59 sheets)

(Existing relevant materials)

- Data of administrative names and boundaries(Arc View shp file)

- Topo-cadastral maps at a scale of 1:2,500 in 1958/60 (65 sheets)
- Topo-cadastral maps at a scale of 1:5,000 in 1958/60 (42 sheets)
- Topo-cadastral maps at a scale of 1:10,000 in 1958/60 (5 sheets)
- City of Nairobi map and Guide at a scale of 1:20,000 in 1995
- Nairobi Parliamentary Constituencies Map at a scale of 1:50,000 in 2002
- Nairobi AZ a Complete Guide (Fourth Edition) in 2002

(Other necessary materials)

- Contact prints at a scale of 1:15,000
- Enlarged aerial photos used in field identification
- Index map of new and old neat lines
- Photo interpretation key

(2) Implementation of supplementary field identification

a) Revision of administrative names and boundaries based on existing materials and information

The existing materials and data on administrative boundaries were at a scale level of 1:50,000, which was not adequate for the accuracy of the plotting scales (1:2,500 and 1:5,000) of the maps to be produced. Therefore, boundaries along features such as roads, rivers, etc were modified and adjusted to follow their shape. In addition, other uncertain boundaries were verified at the District Offices and Location or Semi-location Offices in Nairobi and revised on the supplementary field identification map.

b) Recording and checking of names of places, roads, rivers, etc. of existing materials and information

The names of places, roads, rivers, etc. from the annotation information of the existing Topo-Cadastral Map (Scale: 1:2,500, 1:5,000, 1:10,000), "City of Nairobi Map and Guide" produced by KISM in 1995, and "Nairobi AZ: A Complete Guide", were indicated on the supplementary field identification map, and checked in the field during the supplementary field identification.

Items not covered by the existing material were directly inspected and verified in the field.

c) Verification of uncertainties during plotting and compilation

Any uncertainties regarding the topographic and planimetric features and/or place names encountered during plotting and compilation were indicated on the output map for the supplementary field identification in advance and then inspected and verified by aerial photo interpretation or in the field.

d) Implementation of supplementary field identification

Sections that were difficult to interpret or plot, such as roads or houses in densely forested areas, were surveyed using the plane-table method or portable GPS receivers (positional accuracy by single positioning: within 2m. Pylons, in particular, were difficult to interpret and plot and their positions were confirmed by portable GPS.

Furthermore, the positions of the established first and second order bench marks (9 points), confirmed in ordinary leveling, were reconfirmed by portable GPS.

e) Verification of interpretation of vegetation by aerial photo

The vegetation interpreted based on the photo interpretation handbook and the sections that could not be identified were checked and confirmed in the field.

(3) Arrangement and inspection of the results

The results of the supplementary field identification were arranged on the overlay of the supplementary field identification map using a drawing pencil, in accordance with the simplified symbols produced for the survey based on the symbols regulations.

After the results were arranged, the work was inspected to ensure that there were no omissions, that the results were adequately transferred from the map used for the field survey to the overlay, and that the adjacent map sheets were properly joined.

(4) Supplementary digital compilation

According to the output map of digitally compiled data and the supplementary field identification results arranged on the overlay, the final digital compilation covering the entire scope of plotting was implemented as follows:

- ♦ Addition of administrative boundaries
- ♦ Correction and addition of place names/annotations
- ♦ Correction and addition of representations in sections that were difficult to interpret such as forested areas

- Reclassification of features that are difficult to identify except in the field, such as road class.
- Optimal representation of sections that need to be expressed with symbols such as slum areas, etc.

In the last stage of supplementary digital compilation, the sheets were adjoined numerically.

3.4.10 Production of Data for Printing Topographic Maps

Data for printing topographic maps was produced by deleting the data thought to be unnecessary for printing maps from the topographic database constructed.

Specifically, the data obtained for printing maps was adjusted (line width, color, symbols, annotations, etc.) based on the symbols specifications and converted to a Macintosh application format for producing printed maps. In addition, as the converted data was still in the layer structure of the topographic database, the positional relationship of the layers was revised according to the appearance of a topographic map.

As for marginal information, one set each (1:2500 scale, 1:5000 scale) was produced using Macintosh application software. Then, the topographic map was inserted in a copy of that, and the sheet numbers and coordinate values were input in the respective sheets.

3.4.11 Production of Printed Topographic Maps

After the data for printing was completed, films were output. As the topographic map consists of five colors (grey and the four process colors), five films were output.

For the final check, the output films were individually overlaid on an output map and inspected for defects. As no problems were found, the reproduction film for printing was produced.

3.5 Outputs of the Study

3.5.1 Reports

a.	Inception Report	20 copies (prepared in February 2003)
b.	Progress Report 1	20 copies (prepared in March)
c.	Interim Report	20 copies (prepared in August 2003)
d.	Progress Report 2	20 copies (prepared in March 2004)
e.	Draft Final Report (prepared in December 2004)	
	Main Report	20 copies
	Summary	20 copies
f.	Final Report (prepared in March 2005)	
	Main Report	20 copies
	Summary	20 copies
	CD-ROM	2 sets

3.5.2 Outputs of Technology Transfer

The various technology transfers were implemented using manuals that came with the equipment and software and specially prepared manuals.

The types of manuals specially prepared for the technology transfer are as follows:

a.	GPS survey manuals	1 set
b.	Ordinary leveling manuals	1 set

3.5.3 Outputs of GIS Construction

In GIS construction, four model systems for administrative support were constructed. The outputs include the following:

a.	GIS model system and database to support road management	1 set
b.	GIS model system and database to support water management	1 set
c.	GIS model system and database to support sewerage management	1 set
d.	GIS model system and database to support cadastre management	1 set
e.	Topographic database	2 sets
f.	Guidelines for the various GIS model systems (User’s manual)	10 sets ea.

3.5.4 Outputs of Work Related to the Establishment of Spatial Data Infrastructure

The outputs of the establishment of spatial data infrastructure are as follows.

a. Aerial photography
   - ♦ Negative film 1 set
   - ♦ Diapositive film 1 set
   - ♦ Contact prints of aerial photos 1 set
   - ♦ Photo index map 1 set

b. Results of ground control point survey 1 set

c. Results of aerial triangulation 1 set

d. 1/2500 and 1/5000 topographic maps
   - ♦ Reproduction film for printing 1 set
   - ♦ 1:2500 and 1:5000 printed topographic maps 1,000 sets
   - ♦ 1:2500 and 1:5000 digital topographic map data 20 sets

Chapter 4 Current Situation and Issues

4.1 Assessment of Current Situation

4.1.1 Technical Capacity

(1) Ground survey

The various techniques for ground survey including the installation of aerial photo signals, pricking, GPS survey (point selection, observations, analytical computations), ordinary leveling (observations, computations), field identification, and supplementary field identification were transferred to SOK staff. Although the results of these technology transfers were described in "Results of Technology Transfer", they are examined once again in order to assess the current technical capacity of SOK.

a. Installation of aerial photo signals

In the technology transfer, an aerial photo signal was installed once for practice through OJT and at that time, SOK staff were determined to have acquired this technique. However, as SOK staff have not had practical experience since then, there is no assurance that they have maintained this technique.

b. Pricking

In the technology transfer, SOK staff carried out the pricking of 22 photo control points and hundreds of points in ordinary leveling through OJT and were determined to have acquired this technique. However, as with the technique for installing aerial photo signals, SOK staff have not had subsequent work experience so there is no assurance that they have maintained this technique.

c. GPS survey

In the technology transfer, the techniques for point selection, observations, and analytical computations were transferred to SOK staff through the implementation of a GPS survey to establish 22 photo control points. As some of the SOK staff had already acquired these techniques, the technology transfer went smoothly. In addition, with the provision of equipment, SOK has been carrying out small scale GPS surveys. Therefore, they have maintained the techniques for observations and analytical computations. However, SOK still lacks experience in the planning and implementation of large scale GPS surveys to form large networks and training is needed.

d. Ordinary leveling

In the technology transfer, approximately 250km of ordinary leveling was carried out using an electronic level through OJT. At that time, SOK staff were judged to have acquired the techniques for observations and computations. However, as they have not carried out such works since then, there is no assurance that they have maintained these techniques.

e. Field identification/supplementary field identification

The technology transfer for field identification was conducted in a model area, while that for supplementary field identification was conducted through OJT covering the entire target area. Although this has produced some positive results, SOK staff have not had carried out such works since then so there is no assurance that they have maintained these techniques.

(2) Photogrammetry

In the Study, techniques for scanning aerial photographs and maps, digital aerial triangulation, digital plotting and compilation, orthophoto production and ISO standards were transferred to SOK. After the technology transfer, the technical capacity of SOK for such techniques was evaluated to assess its current situation.

a. Computerization of photogrammetric works

Until now, PC terminals have been used for inputting various types of data. However, SOK seems to have a good grounding for full-scale computerization of photogrammetric works in regard to the following points.

Increase in work efficiency:	Techniques for carrying out efficient data sharing in a server/client environment have been acquired. In addition, large-scale digital photogrammetric works by more than one engineer/PC are now possible.
System manager:	Minimum security has been ensured by making it possible to manage network resources, assess user conditions, and take measures against computer viruses by the system manager.
Basic knowledge of PC users:	PC users now follow basic rules (understanding of user rights, handling problems) when utilizing the network. As a result, the overall network is now operated safely and efficiently.

Data storage: SOK is now capable of regularly backing up data and taking appropriate measures when there is trouble with equipment.

b. Scanning of aerial photographs

SOK is now capable of establishing specifications for a purpose and digitizing aerial photographs. Therefore, they can be applied to different scales and products (e.g. topographic maps, orthophotos).

c. Aerial triangulation

SOK had previously acquired the capability for carrying out aerial triangulation with analogue equipment. However, this technique requires a high level of skill and can only be done by veteran engineers.

Because the participants in the technology transfer have adequately acquired basic techniques for aerial triangulation by digital photogrammetry and for operating the system, the situation is has changed in regard to the following points.

Development of technically capable staff:

With the digital method, if basic knowledge of aerial triangulation and knowledge of how to operate a digital photogrammetric system is achieved, a high level of skill is not required for operation of the system. Therefore, the staff who participated in the technology transfer are at a technical level where further development of others in the department is expected.

Quality improvement: As the participants of the technology transfer have reached a level where there are capable of objectively evaluating the results of aerial triangulation in digital format, it is thought that the quality of work is greatly improved.

d. Plotting/compilation

SOK staff have reached a level where they understand a spatial data model and its concept, assuming use in GIS, and can carry out plotting according to that requirement. However, in order to improve their plotting skills, SOK staff need continued guidance through OJT.

SOK has the capability for editing data structure to a certain level assuming not only compilation for printed maps. but also use in GIS. SOK is also capable of partially carrying out logical checks on data, according to the structure of the spatial data model.

e. Generation of digital terrain models

SOK has adequate understanding of the settings required for automatically generating detailed digital terrain models and can make full use of the system.

f. Generation of orthophotos

SOK has a general understanding of the knowledge required for generating orthophotos and has reached a level where it can adequately use the system. In addition, SOK already had a certain level of skill for peripheral techniques such as image processing, so there is good potential for producing orthophoto products.

g. Design of spatial data models

SOK has gained a certain level of understanding of the concept of spatial data models, assuming data use mainly in GIS not in paper maps. However, training in object-oriented language, etc, is necessary to reach a level where it can design spatial data models on its own.

h. Collaboration with staff concerned with GIS and printing work

In SOK, collaboration between staff engaged in work using GIS software and digital printing equipment and those engaged in photogrammetric works was extremely rare. This is mainly due to the administration of SOK as well as the fact that the there were no areas of technical overlap.

As the photogrammetric techniques transferred in this project include techniques for image processing and generating print format data, the Photogrammetric Section now has the grounding for carrying out work in collaboration with staff using GIS software and printing staff.

Basic techniques for image processing and generating print format data to fill the gap between printing work and photogrammetric work have been acquired.

Techniques for spatial data compilation using GIS software have also been acquired. Thus, spatial data will be constructed in consideration of the requirements for use in GIS.

(3) GIS

The technology transfer for GIS was conducted for SOK and NCC staff through lectures and hands-on training. The current technical capacity of each organization in regard to GIS is summarized in the table below.

Current situation of SOK and NCC in regard to GIS

Items	SOK	NCC
Setting up of hardware (connection)	Technology transfer for setting up (connecting) hardware was conducted for SOK staff. Since SOK staff have many opportunities to handle hardware such as computers and plotters in their daily work, the majority of those who participated in the technology transfer were able to understand how to set up the hardware.	Technology transfer for setting up (connecting) hardware was conducted for NCC staff. Because there are almost no computers in any of the NCC departments, the majority of NCC staff who participated in the technology transfer had no experience in setting up hardware. However, they were able to acquire this technique through the technology transfer so there should be no particular cause for concern.
Installing and uninstalling of software	Technology transfer for installing/uninstalling ArcGIS software was conducted for SOK staff. At this time, there is no particular cause for concern with this technique.	Technology transfer for installing/uninstalling ArcGIS software was conducted for NCC staff. It was the first time for the majority of NCC staff to carry out such work but because it was interactive, there were no significant problems. Therefore, there should be no cause for concern with this technique
Operation of Windows	Technology transfer for operating Windows (start up, shut down, file copying, delete, etc.) was conducted for SOK staff. Although there was a difference in individual level, there is no particular cause for concern regarding these techniques/ know-how.	Technology transfer for operating Windows (start up, shut down, file copying, delete, etc.) was conducted for NCC staff. However, because many of the staff do not use computers in their daily work, a few participants were still not able to adequately operate Windows at the time the technology transfer was completed.
Matters concerning ArcGIS	Technology transfer for the ArcGIS applications, ArcMap, ArcCatalog, and ArcToolbox, was conducted for SOK staff. Overall, they were able to acquire basic techniques such as data display, layout creation, georeferencing, data conversion, spatial search, 3D analysis and spatial analysis. However, their understanding of logical operations that require mathematical elements is still insufficient.	Technology transfer for the ArcGIS applications, ArcMap, ArcCatalog, and ArcToolbox, was conducted for NCC staff. Unlike SOK, many NCC staff do not have a background in mapping and survey techniques so their technical capability for georeferencing and data conversion in particular seems to be inadequate. However, they had a basic understanding of data display, layout creation, 3D analysis and spatial analysis techniques. In addition, like SOK, NCC staff's understanding of logical operations that require mathematical elements is still insufficient.

4.1.2 GIS Model System

The following factors must be carefully considered when operating and managing GIS as a sustainable system. None of these factors must be lacking and all must be maintained in good balance.

- Database
- System
- Equipment (software, hardware)
- Personnel
- System operation (organization, finance)

Firstly, the current situation of the GIS model system is analyzed, and then the challenges are identified and suggestions of implementable projects are made.

(1) Database

a) Coverage

In developing the GIS database, it was decided that the basic policy is to support the tasks of NCC. The coverage of NCC management is the entire Nairobi City of 702 km^2 ($595km^2$, excluding the Nairobi National Park). However as is described, the target area of the GIS model system only covers $15km^2$ (1:2,500*5sheet) in the central part of the City.

b) Contents

The sources of information used to establish the database were the paper maps and documents that are utilized in the respective departments at NCC for daily works. However some were produced as far back as the 1970’s and very few of them have been systematically revised and maintained. Though accuracy and reliability of the data sources remains questionable, the study team utilized those maps and documents to develop the GIS database.

c) Design

In the process of database design, the study team and NCC conducted a series of meetings in order to discuss the fields, contents, structure, and future possible use of the data. Only the databases which could be established within a financial, time, and technical framework of a model system were realized. In practical usage of the database, additional layers and attribute fields should be added.

(2) System

a) System development environment

【Development Policy】

- User friendly interface
- Compliant with GIS database
- Extensible in the future

【Development Environment】

- Microsoft Windows XP Professional
- ArcObjects
- VB Script
- Visual Basic 6.0 SP6

b) Extensibility of functions

The GIS software adopted in the project is ArcGIS (ESRI Inc., hereafter ESRI). The extensibility of its functions is assured under the development environment of Visual Basic for Applications (VBA), which is embedded in ArcGIS Desktop (ArcMap, ArcCatalog, etc.), as well as use of Component Object Model (COM) components developed by major computer languages (Visual Basic, Visual C++, Visual J++, etc.). In this system development, Visual Basic is adopted to create COM components (ActiveX DLL) instead of VBA since there is a need for more developing flexibility than VBA can offer, such as creating original windows (dialogue windows). The COM components are automatically loaded when ArcGIS starts and all the customized functions are activated in ArcGIS.

In this model system, seventeen functions as common basic and analysis functions and two functions for each of the four model systems as specific analysis functions were created, based on the result of discussions with NCC and the study team.

(3) GIS software and hardware

a) GIS software

ArcInfo, ArcGIS series (ESRI Inc.), the software adopted for this model system, is one of the most powerful and widely used software. A variety of functions are prepared such as overlay, neighbor analysis, generalization, adjoining map sheets, coordinate conversion, file format conversion, etc.

Also, Spatial Analyst (raster data analysis functions) and 3D Analyst (3D data display and analysis functions) were added to ArcInfo as additional modules. The products of ESRI expand functionality by adding modules according to users' needs. In this project, the above two modules were added by considering the tasks of NCC.

As with all other kinds of software, new versions of GIS software are released day after day. In case of the products of ESRI, any version ups and technical help are supported within a year from the day of purchase. However, it is necessary to pay the cost and make a contract of software maintenance for version ups and technical support from the second year.

b) GIS hardware

The set of GIS equipment provided to NCC is the minimum set of equipment necessary for GIS utilization. Because it is necessary to process large volume data such as images and raster data with GIS, the study team selected high performance equipment. The introduced personal computer is going to function both as a GIS license server and a GIS client computer for the time being. A scanner mandatory for the digitalization of paper maps and a plotter for printing large size maps such as A0 are also introduced. The diagram (Figure 4.1) shows the provided components of GIS equipment, and their detailed specifications are described in the Annex.

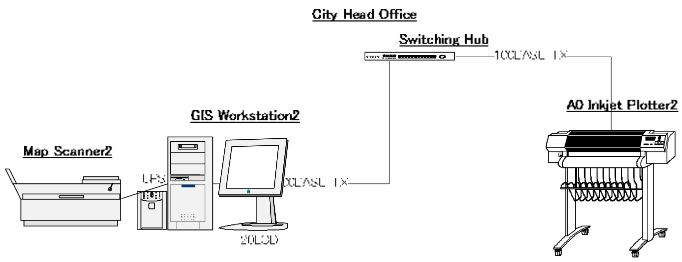


Figure 4.1 Equipment for NCC

(4) Personnel

As is mentioned earlier, the participants of the GIS training from NCC and SOK acquired the techniques and skills of GIS basic operation, editing, converting, spatial analysis, 3D analysis etc. The trainees were selected from those departments in which GIS can be effectively utilized. The professional level of the trainees varies, so that not only juniors who actually work on operations but also seniors who make decisions will grasp the capability of GIS and the possibility of its use. In this way, the study team hopes that the sustainability of GIS will be assured technically and organizationally.

City Engineer	3 trainees: Development, maintenance, and management of city infrastructure
City Planning	3 trainees: City planing, development, building permit contact
Town Clerk (Valuation)	2 trainees: Valuation and collection of property tax, property and land management
Nairobi Water & Sewer Co., Ltd.	2 trainees：management, operation, and development of water and sewer network

The trainees of the GIS training worked at the same time as a cross sectional task force group which cooperated in data collection, and discussion about database design and model system development and contributed to incorporate ideas and needs from the point of daily works.

(5) System operation (organization, finance)

a) Organization

NCC consists of eleven departments, each responsible for a particular public services. Among them, the City Planning department actively committed and cooperated in this project (highlighted in red in the Figure 4.2). The City Planning department cooperates with other departments in daily works and its connection with others greatly contributed to this project. However, it is beyond the City Planning department's mandate to cross sectionally organize and progress the GIS initiative within NCC and cannot act as a leading body continuously after the project period.

On the other hand, there is Computer section in City Treasurer department (highlighted in yellow in the Figure 4.2) which provides computer-related services to all the NCC departments. The main tasks currently are to issue various taxation bills (water, sewerage, rates, benefit), calculate cost, maintain account books, and prepare payrolls of NCC personnel. In completion of those tasks, the computers used at the relevant departments are networked by LAN, so that all the data management and calculation are centralized at the Computer section. Other than that, all the computers used in the rest of the departments and sections are either stand-alone computers or networked internally within the department, not networked throughout all of NCC.

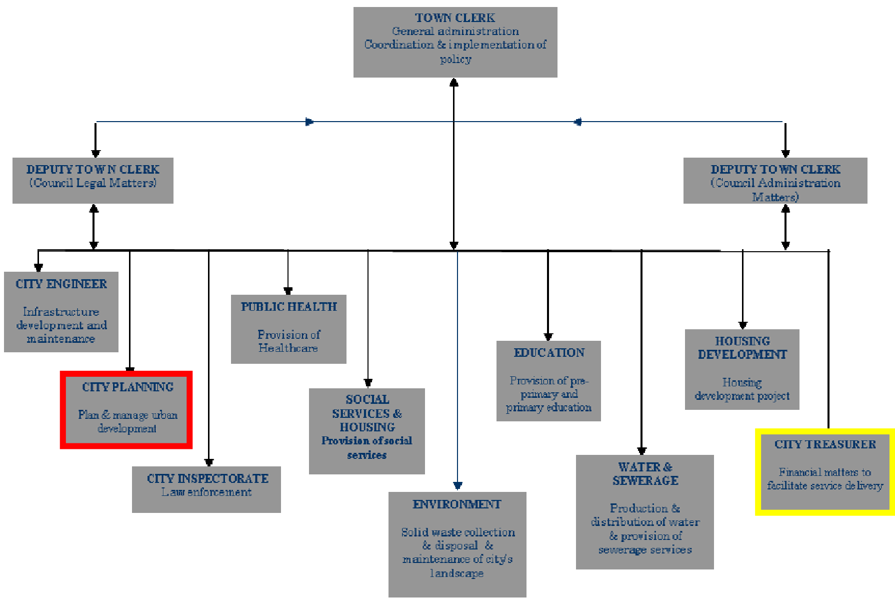


Figure 4.2 NCC organization chart

b) Finance

Financial backup is essential in operating sustainable GIS. It is costly just to maintain hardware, software, database, human resources, supplies etc., and often the case in the developing countries, it is a heavy burden to finance all these expenses especially when the equipment is the latest model. The current financial status of NCC is extremely severe where revenue (mainly rates) generation cannot keep up with the total expenses.

Under this condition, it is quite difficult to allocate budget since introduction of GIS is not something directly producing or generating revenues for NCC. Therefore, understanding and cooperation of all the departments are mandatory. It is important to analyze and calculate the actual benefit expected to be delivered by the use of GIS, gain full understanding of the senior staffs, and continuously allocate budget for GIS operation and maintenance.

4.1.3 Spatial Data Infrastructure

In the Study, specifications for spatial data infrastructure were discussed and decided on with SOK in accordance with ISO standards. Furthermore, 2500 and 5000 level spatial data infrastructure covering Nairobi City was established by the digital photogrammetric method in accordance with these specifications.

The features of the products and product specification of the spatial data infrastructure established are as follows:

a. Description standards of specifications

The product specification adopts (in part) the description standards specified in the ISO 19100 series (Geographic Information).

One example is Application Scheme corresponding to conventional map symbols. By adopting these description standards, the manufacturer can describe the specifications more objectively and the user can understand the specifications more objectively.

b. Data structure/included items

Considering the importance of the demand for printed topographic maps and the users who are accustomed to conventional topographic map representation, the specification for data structure and included items pursues the following:

Increased value of data: Specifications that enable use of data in GIS with as little modification as possible.

Follow the representation of conventional topographic maps:

Although data use is a top priority, by realizing a representation close to conventional topographic maps, it will be easy for previous users to get used to

c. Data format

The format adopted is AutoCAD DXF, which is a defacto standard used in GIS and CAD software. GIS users who use major GIS software such as ArcGIS and technical experts, such as civil engineers, who use CAD software such as AutoCAD can utilize this data with an easy conversion process.

d. Use of established spatial data

As it stands, as with the printed topographic maps, the spatial data will be sold but there is no concrete plan for data use.

4.2 Issues

4.2.1 Technical Capcity

(1) Ground survey

Issues concerning technical capacity for ground surveys are considered in terms of the following.

* Ground survey techniques mainly for establishing spatial data infrastructure, which were targeted in the technology transfer
* Ground survey techniques necessary for building the national geodetic network

a. Ground survey techniques mainly for establishing spatial data infrastructure, which was targeted in the technology transfer

The techniques necessary for establishing spatial data infrastructure were covered by the ground survey techniques targeted in the technology transfer. As a result of the technology transfer, SOK acquired those techniques. However, as mentioned in the assessment of the current situation, in consideration of conditions after the technology transfer was completed, it is essential for SOK to build on its practical experience for each technique, excluding GPS survey.

♦ Technical issues in actual work

In the technology transfer conducted in the Study, various manuals were used and the participants took a considerable amount of notes. In applying the acquired techniques to actual work, SOK must find a way to effectively use these manuals and notes.

Another important challenge is to transfer the acquired techniques to other engineers through work to be carried out in the future.

b. Ground survey techniques necessary for building the national geodetic network

In the technology transfer for GPS survey, the techniques for a relatively small-scale GPS survey based on the existing geodetic network were transferred. However, SOK intends to build a national geodetic network based on international standards. This requires techniques for network planning and analysis of long baseline, which were not adequately covered in the transfer. A major issue for SOK is how to acquire these techniques.

(2) Photogrammetry

Issues faced by the Photogrammetric Section in SOK regarding technical capacity are as follows:

a. Promotion of the transition towards digitization in the Photogrammetric Section

In the Photogrammetric Section, there are works that can be improved in terms of efficiency and level by introducing digital techniques, other than the topographic mapping work covered in the technology transfer. At present, there exists both analogue and digital technologies and equipment. However, in view of improving the efficiency and capability of the staff, a gradual transition to digital methods should be made.

Digitization of existing work: Particularly in the production of cadastral maps, data entry should be simplified and digitized by replacing mapping work using enlarged photos with digital orthophotos.

Internet connection: Internet access from the office will become increasingly necessary along with digitization. Software maintenance, queries about the system via e-mail, computer virus countermeasures, etc. are required.

b. Continued OJT for digital photogrammetric techniques

With little opportunity for actual work, it will be difficult to deepen understanding of the wide range of digital photogrammetric techniques acquired and to keep up them up to date.

Training projects: The Photogrammetric Section should independently implement various case projects using past aerial photographs, etc.

Trial project for digitization of existing work:
A trial project should be launched for digitizing existing works such as the production of cadastral maps as mentioned in the previous section.

c. Dissemination of techniques

Key photogrammetric techniques such as aerial triangulation should be disseminated among more engineers in order to share knowledge and information. The following is expected to be implemented.

Work execution system: Establishment of a system for executing work based on a combination of staff experienced in analogue techniques

	and those who acquired digital techniques in the technology transfer.
Internal work manuals:	Preparation of work manuals based on personal work experience.

d. Integrity of digital data

Safe storage of spatial data:	Once all the works are digitized, it will be much more important to backup data. Recovery from data loss requires a lot of money and time.

The establishment of a safe system for regularly backing up data is an urgent task.

e. Collaboration with other sections

Collaboration among staff in the various sections in SOK in the past has been rare. This was often due to the fact that it was difficult for the respective staff to acquire overlapping techniques. However, the digital photogrammetric techniques acquired include some that overlap with techniques used in printing and GIS related works and full-scale collaboration is expected as follows.

Printing work:	Smooth transition to map printing by digital method
GIS related work:	Capacity building for data conversion and input of attributes

f. Continued software maintenance

In digital photogrammetry, software is the core component that replaces traditional photogrammetric equipment. The latest logic and software technology has been provided and in order to get the maximum benefit, maintenance is important to ensure effective use.

g. Role of promoting the advanced use of spatial data

Until now, the role of the Photogrammetric Section was limited to the production of topographic maps. However, it should gradually take on the additional task of promoting the advanced use of spatial data.

Setting up of data center:	The data center will serve as a clearing house for data distribution.
Improvement of consulting capacity:	
	Capacity to provide consulting services to users for

advanced use of spatial data should be improved.

h. New products

New products that can be produced using digital photogrammetric techniques should be introduced as standard output.

DEM:	Standard data product providing 3D data
Orthophotos:	Provision of maps overlain with various thematic maps and NSDI orthophoto image data as a part of NSDI

(3) GIS

Technology transfer for GIS was implemented five times from July 2003 to December 2004 (Refer to Table 3-1). In consideration of the current capacity of SOK and NCC for GIS based on the results of the technology transfer, the issues for both organizations are described below.

a. Survey of Kenya (SOK)

a.1 Solid acquisition of basic GIS techniques

In the case of SOK, because the staff carries out mapping work using GIS, image processing software and computers on a daily basis, they have the capacity for basic GIS techniques. However, it is uncertain as the whether all staff in relevant sections have achieved this level. Therefore, it is necessary for those who participated in the technology transfer in the Study to serve as instructors in conducting GIS training for other staff, in order to develop the capacity of all staff. As a result, those who act as instructors will be able to review the techniques they have acquired while those who are receiving training for the first time will be able to learn the latest GIS techniques and trends. In the end, this will lead to the strengthening of the overall technical capacity of SOK from the bottom up and the development of skills for the efficient production of spatial data.

Based on the above, reinforcement of basic GIS techniques is the primary task.

a.2 Acquisition of GIS application techniques (3D analysis, spatial analysis)

In the technology transfer conducted in the Study, SOK staff learned basic functions for 3D and spatial analysis. Based on these basic techniques, SOK needs to acquire techniques for producing new types of topographic maps (e.g. 3D topographic maps) and thematic maps (e.g. poverty map produced using overlay analysis of various data). For that purpose, new technology transfer training for advanced 3D and spatial analysis is necessary.

b. Nairobi City Council (NCC)

b1. Solid acquisition of basic GIS techniques

The issues concerning this are the same as SOK. Of the NCC ten staff who participated in the technology transfer, three are of a relatively high level. The remaining seven acquired basic techniques but have not yet mastered them. Therefore, the three staff should serve as instructors in implementing technology transfer training for other NCC staff. This will lead to developing the basic technical capacity of NCC staff, including those of the instructors.

b2. Acquisition of operation and application techniques for GIS model systems

In the Study, four GIS model systems were constructed to support the tasks of NCC (cadastre, water, sewer and road). In order to make full use of the model systems, basic techniques and application techniques of ArcGIS are necessary. In addition, in order to expand the functions and coverage of the model systems, basic techniques and application techniques of GIS are essential.

Therefore, NCC is faced with the task of maintaining and sustaining the basic GIS techniques acquired in the Study as well as acquiring new application techniques.

b3. Acquisition of techniques for operation, maintenance and management of GIS

In general, digitization of the various departments in NCC has not progressed so the staff are not used to working with computers. Therefore, acquisition of techniques for operation and maintenance of the GIS hardware and software introduced is urgent. It is also necessary to develop staff with the capacity to manage GIS equipment.

4.2.2 GIS Model System

As described in the basic policy of the GIS model system, the system aims to support the tasks of the departments in NCC and also to support finding measures for improving and solving urban problems (traffic, slum, etc.).

Based on the analysis of the current condition, the future challenges for NCC to realize the above aims of the model system through the use of GIS can be summarized as follows.

1) Database

a) Coverage

The target are of the model system was 15km^2 so it is necessary to expand the data coverage.

b) Contents

The accuracy and reliability of the data sources were questionable so it is necessary to verify if the database can be utilized for the practices at NCC.

c) Design

It is necessary to modify data structure and add contents based on the needs of the users in the practices. It is also necessary to shift from Personal GeoDatabase to Multiuser GeoDatabase in case of a substantial increase of data volume or change of editing environment from stand-alone to network.

2) System

a) System development environment

In developing the system, the adopted development environment may change in future such as release of new version of development language or operation system and it will be a challenge to make adjustments to those changes.

b) Extensibility of functions

It is necessary to add more functions and change software interface in order to make the model system become more practical and useful in the practices by programming. It may also be necessary to rewrite the program codes when the new version of GIS software is released.

3) GIS software and hardware

a) GIS software

Since the maintenance contract to assure new releases and technical support of GIS software is expensive, it will be a challenge to manage financing for it.

b) GIS hardware

In order to maintain equipment and purchase supplies such as plotter ink and papers, it is necessary for NCC to finance it for sustainable use of GIS.

4) Personnel

As an achievement of GIS training, all the trainees acquired knowledge and techniques of GIS operation. However, the opportunity for them to use computers in the daily work is very limited or none existed, and it is a challenge to sustain their achievement after completing the project. Also, as the database expands and the GIS editing environment changes, it will be a challenge to secure professionals of programming and database management.

5) System operation

a) Organization

In order to use and develop GIS database and system cross-sectionally at NCC, it is necessary to establish an organizational setup which centralizes all the works related GIS and serves all the NCC departments. Currently there is nothing like it; however it will be a key how to cooperate with Computer section in the City Treasurer department which overseas all the IT related works. Cooperation with the Computer section or establishing a new unit under it should be carefully considered.

b) Finance

The financial condition of NCC is very severe now. The major reasons why revenue cannot be secured to meet the expenses is its weak financial foundation and lack of accurate and efficient tax billing and collection. On the other hand, at least minimum budget is necessary to sustain and manage GIS equipment, database and system provided by the project. This will be a challenge for NCC to generate these budgets under this situation.

4.2.3 Spatial Data Infrastructure

In the Study, specifications for spatial data infrastructure were determined based on the experience of the Study Team and discussions with SOK, and spatial data infrastructure was established based on those specifications. As a result, the following items need to be considered.

a. Reflection of user requirements in the data specifications

The current product specification of spatial data infrastructure should be considered as a "transitional" product specification pursuing both data users and printed topographic maps. As the existence value of a product is usually substantiated by the users, reflecting the users' requirements in the data specification to a greater degree should lead to further use. Therefore, the following issues need to be considered.

Breaking away from topographic maps:

Topographic maps represent a large number of features on paper, as they are designed to be of general use for a variety of purposes and users. On the other hand, as topographic maps do not consider use by specific users, when users utilize such maps, they frequently need to add information or make modifications (it is the same with paper maps).

Required accuracy: In general, the accuracy of a topographic map depends on the method used to produce it. The accuracy should essentially be defined by that required for the feature to be used by the user.

Place importance on regular users of topographic map:

Particular importance should be placed on spatial data requirements for work in public institutions, i.e. departments in NCC that use topographic maps on a daily basis for specific tasks. It is necessary to collect the requirements of such users.

Responding to the many other users:

The activities at NSDI conferences need to be further broken down into working group activities for reflecting users requirements in the specifications.

Reflection of requirements in product specification:

Application of the collected requirements in product specification should be examined in consideration of technical aspects and cost.

b. Updating of data

In terms of using GIS data, it is more important that the data is up-to-date than with paper maps. Even if a user has the latest attribute information, it cannot be utilized as data unless there is spatial data associated with it. Therefore, the following items should be considered:

Establishment of update cycles:

Topographic maps of urban areas are generally updated 3-5 times a year. However, in the use of GIS data, it is ideal to update urban areas more frequently. On the other hand, data users do not always require all features to be up-to-date. For instance, a person using data to mange sewer facilities pays close attention to changes in the shape of roads but not to vegetation. To take another example, a person using data for road planning expects the 3D terrain models and buildings to be updated but not the annotations. Therefore, while gradually reflecting the user requirements in the product specifications, it is necessary to set an appropriate update cycle for each of those features (obtained features).

Use of various data sources:

Aerial photography is high costing work but it is an essential means for updating all data features. However, in consideration of the cost, it is necessary to use effective data sources including not only aerial photography but also existing materials, field surveys and other easy survey methods in order to examine the adequate update cycles for each feature mentioned above.

Consideration of inexpensive and easy update method:

The method selected for updating data will have a big impact on the cost. The precise method of photogrammetry is very expensive. Therefore, it is necessary to consider a simple and easy method for updating data, taking into account the features to be obtained and the required accuracy. For example, single image digitization of orthophotos by automatic processing is slightly less accurate than the photogrammetric method but requires only half the cost and time (excluding the shooting of aerial photographs).

c. Expansion of the coverage of spatial data infrastructure

Meet the potential need to expand the coverage of spatial data infrastructure to include other urban areas faced with the same urban problems as Nairobi City.

d. Release of information on available spatial data

Information on spatial data needs to be made public so that users can know what spatial data is available, how up-to-date is it, what features are covered, etc. It is also necessary to establish an easy system to verify the information, such as through the Internet. This will further bring out potential user needs.

f. Copyright (legal aspect)

Spatial data serves as social infrastructure and should be freely available for public use. For commercial use as well, a license should be available at a reasonable cost in order to promote its use.

On the other hand, because digital data is easy to reproduce, it is often pirated or illegally used. Therefore, it is necessary to take the following copyright protection measures.

Basic policy:Basic copyright policy for NSDI/spatial data infrastructure should be established, and the rights and obligations of the user should be specified.

Concrete steps: Concrete steps in accordance with the basic policy should be taken; for example, establishing guidelines and a system for the distribution and sale of data, or releasing documents specifying the rights and obligations of users.

g. Copyright (technical aspect)

In order to implement copyrights based on the basic policy and concrete steps, technical backing is essential. In general, there are two techniques for protecting copyrights: active protection and passive protection. Both techniques are required. A copyright of vector data is technically difficult to protect so comprehensive measures in terms of legal and technical aspects are necessary.

Active protection: The are a number of ways to actively prevent the illegal use of data. For example,

- ♦ Encryption: Data is converted into an unreadable format. A secret key or password is required when distributing the data.
- ♦ Rasterization: Vector data is converted into raster image data to prevent unauthorized use of information. The distribution of maps through the Internet is generally done in this format.
- ♦ Intentionally degradation of data: The positional accuracy of products is intentionally degraded at random to lower the value of the product in order to prevent illegal use.
- ♦ Robust digital watermarks: Digital watermarks are embedded in digital data to identify it, in order to protect copyrights and property rights. With spatial data, digital watermarks need to be robust against manipulations of the data. In addition to protecting copyrights, digital watermarks can serve other purposes such as media links, and thus give added value to a product.

Passive protection:

- ♦ Robust digital watermarks: Robust watermarks can verify whether or not data has been manipulated. They can also certify that the spatial data is an original copy and identify the source when unauthorized use is detected.

Chapter 5 Recommendations to Counterpart Agency

5.1 Future Image and Plans

5.1.1 Technical Capacity

(1) Land survey

The counterpart agency connected with this technology is mainly SOK, and the future image of SOK in this field is described below.

a. Future image

The present state of technology in this field and related problems in SOK which have been so far described will be overcome, and land survey technology related to the establishment of the spatial data infrastructure will come into common use. The technology in these fields will be utilized in accordance with the annual programs based on the long-term plan, while OJT courses to increase the numbers of engineers will be planned and implemented by the SOK staff.

Work will begin on the development of a national geodetic network, moving gradually from higher-order control points to lower-order control points in accordance with the world geodetic system or the East Africa geodetic system to be established in the near future. The existing control points will be subject to coordinate conversion using the parameters obtained during the development of the new national geodetic network.

Then, work will start on the important task of the coordinate conversion of the huge volume of accumulated cadastral data, with a view to data management under a standardized coordinate system.

b. Future plans

On the basis of the above future image, the following plans are conceivable:

- ♦ Land survey for the development of spatial data infrastructure

  The land survey program in accordance with the future plans described in "(2) Photogrammetry" below will be one future plan in this field.

Establishment of the national geodetic network

The present geodetic standard is based on Clarke 1880, but the national geodetic network will be based on the East Africa Geodetic Standard (World

Geodetic System WGS 84 or ITRF 1998). The following future plans are conceivable:

Establishment of 0-order control points (about 5 points)

Establishment of 1st-order control points

Establishment of 2nd-order control points

Coordinate conversion of existing control points

- ♦ Integrated management of cadastral data

  The cadastral data based on several types of survey standard will be subject to coordinate conversion and re-survey based on the standardized geodetic system to be established in accordance with the national geodetic network that will be established.

(2) Photogrammetry

The Photogrammetry Group of SOK is the only organization that can create spatial data by itself and is also an organization that has very little potential. This Group is expected and required to have the capability to maintain NSDI as the national land infrastructure. The future image and plans it is hoped to realize in stages are described below.

a. Future image

In 3 years: Fully digital photogrammetric technology - The photogrammetric works within SOK will be fully digitized to allow the advanced and efficient development of spatial data.

In 5 years: Setup of spatial data center - The development of meta-data and the foundation of a clearinghouse will be in progress in order to promote the effective use of the spatial data accumulated in various fields. In addition, this center will function as a base for data entry to support the construction of various types of thematic data.

In 10 years: Spatial data consulting - Professional technology in spatial data development will be acquired and will reflect the requirements of governmental agencies and city councils for spatial data. When the GIS is constructed, consulting in data supply, entry and updating will be possible.

b. Future plans

In 3 years: Expansion of city areas in which the spatial data infrastructure is established and coverage of the entire country with digital national topographic maps.

In 5 years: Preparation of meta-data for the spatial data infrastructure based on the

Internet environment, creation of a clearinghouse, dissemination of data, and the preparation, through the use of professional technology in spatial data development, of the various thematic data required by government agencies and municipalities.

In 10 years: Consulting in GIS development - Not only data supply but also entry of thematic data for ministries and agencies that plan to construct a GIS using the spatial data infrastructure. Performance of consulting services for system maintenance and operation, including entry, supply and updating of data.

(3) GIS

The counterpart agencies concerned with GIS technology are SOK and NCC. The future images and plans for SOK and NCC are described below.

a. Survey of Kenya (SOK)

a1. Future image

The future image of SOK is described on the assumption that the problems with the GIS of SOK described above will be cleared.

All the members of SOK staff concerned with the GIS will master the basics of ArcGIS and applied technologies, and will make full use of them in their daily work. Those staff members who joined technology transfer training in this Study will take the lead in regularly transferring the basic and applied technologies to those SOK staff members who do not fully understand them, thereby ensuring the bottom-up training of all staff members in GIS technology.

In this Study, a topographic map GIS database was constructed covering the entire city of Nairobi (with the exception of the Nairobi National Park). In the future, the basic and applied GIS technologies that the SOK staff has mastered will be used to expand the coverage of this topographic map database to the major cities of Kenya. Eventually, a topographic map database covering the entire Kenya will be developed.

In addition, the GIS Model System for a cadastral map for the Nairobi City Council (5 map sheets on a scale of 1/2,500) was constructed in this Study. Since the cadastral map is administered by SOK, the acquired GIS technology will be used to constructed the cadastral GIS database covering major local cities and eventually the cadastral GIS database will be expanded so as to cover the entire Kenya.

a2. Future plans

①Based on the above future image of SOK, the following future plans are conceivable

- Constructing of a topographic map GIS database for major cities (at the 1/5,000 to 1/10,000 level)

  A topographic map GIS database for major cities (including Mombasa, Nakuru and Kisumu) will be constructed in accordance with the specifications of the topographic map GIS database.

- Construction of a topographic map GIS database covering the entire Kenya (at the 1/250,000 to 1/500,00 level)

  After a topographic map GIS database for major cities has been constructed, a topographic map GIS database covering the entire Kenya will be constructed.

- Construction of a cadastral GIS database for major cities (at the 1/5,000 to 1/10,000 level)

  A cadastral GIS database for major cities will be constructed using the cadastral data to be acquired in the land survey as described above.

- Construction of a cadastral GIS database covering the entire Kenya (at the 1/250,000 to 1/500,00 level)

  After construction the cadastral GIS database for major cities, a cadastral GIS database covering the entire Kenya will be constructed.

b. Nairobi City Council (NCC)

b1. Future image

The future image of NCC is described on the assumption that its problems with GIS described above will be cleared.

All the staff of each NCC department will fully master the basics of ArcGIS and applied technologies, and will make full use of them in their daily work. The GIS Center (provisional naming) will be set up and the first Administrator of the Center will be selected from among the trainees in the technology transfer training of this Study. The trainees, including the Administrator, will carry out regular training of GIS operators through GIS technology transfer training.

At the same time, the NCC staff will also master the technology to expand the coverage and functions of the 4 GIS Model Systems developed in this Study, making use of the basic and applied GIS technologies they have acquired. In addition, there are hopes for the development of a GIS system to resolve new city problems (such as environmental pollution, hygiene and poverty).

b2. Future plans

- Setup of GIS Center

  The GIS Center will be set up within the city council building where the GIS database will be constructed and data management implemented. In the future, terminals will be installed in each department and section and the development of a network will make the use of GIS possible throughout the city council building. For this purpose, NCC staff will be trained in networking technology.

- Regular technology transfer training

  At present, NCC does not have sufficient equipment to carry out training in GIS technology transfer. Therefore, regular GIS technology transfer training will be furnished using facilities that have GIS equipment, such as AICAD and RCMRD.

- Acquisition of technical capacity to expand the function of the GIS Model System

  In order to expand the function of the GIS Model System, it is necessary to master the technology to allow customization of the GIS. This means that the programming technology necessary for customization must be acquired, and technology transfer training will be conducted by experts in this field.

- Acquisition of spatial analysis and 3D-analysis technologies

  It is desirable for training by experts in applied technology in spatial analysis and 3D spatial analysis be implemented in the future, in order to allow the development of a GIS Model System to resolve new city problems.

This training will transfer to the NCC staff technologies such as overlap analysis of various types of information, and analysis for the selection of optimum locations via logical operations.

5.1.2 GIS Model System

It will not be easy to overcome the various challenges and introduce GIS efficiently. Figure 5.1 describes the process and also the checkpoints at each process based on the experience of the municipalities and local authorities in Japan when introducing GIS. It is hoped that NCC refers to those checkpoints at each process of implementing GIS in the future.

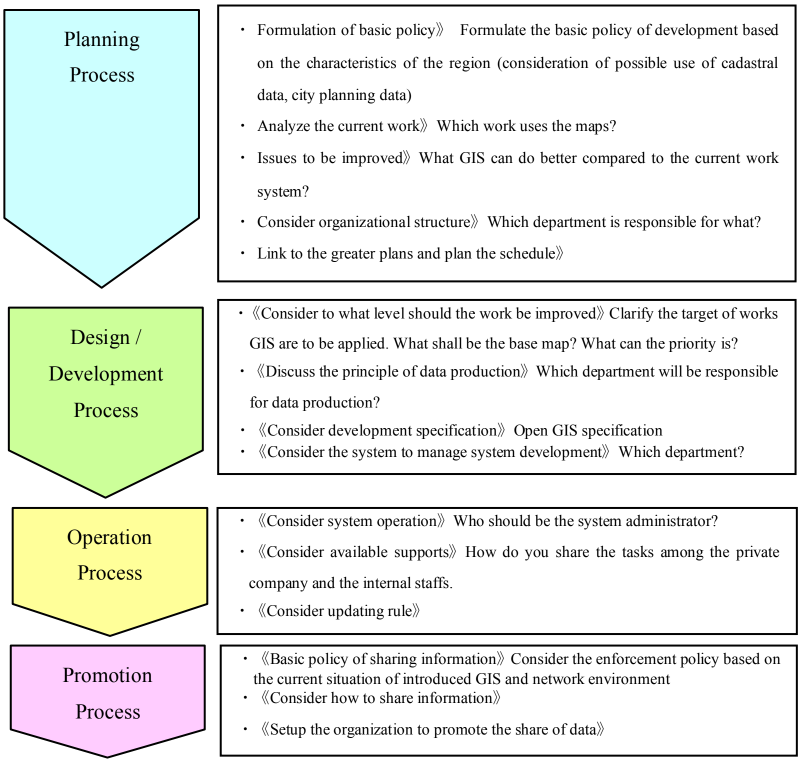


Figure 5.1 Process and checkpoints of GIS introduction

As for NCC, the minimum complete set of GIS is provided for the first time through this project, such as equipment, training, data, and system. It can be said that the trainees / task force group were engaged from the planning process to design/development process and operation through GIS model system development. However, it is still a prototype and the real challenge for NCC to implement GIS has just started.

Thus, the study team suggests the introduction of GIS to NCC as shown below (Figure 5.2) followed by detailed description of each stage.

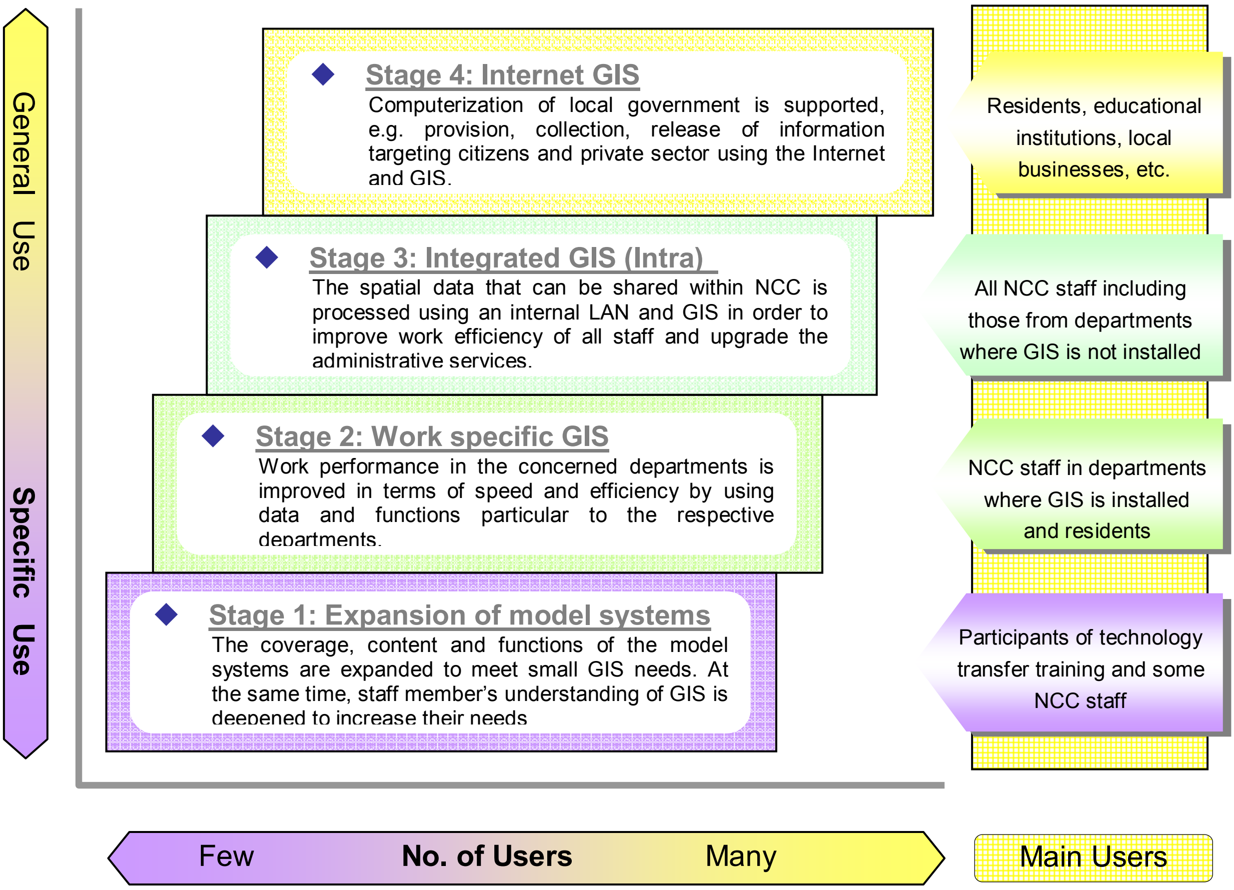


Figure 5.2 Introduction of GIS to NCC by stage

Fist Stage: Expansion of data coverage and functions of the model system

At this stage, the NCC personnel who received the GIS technical transfer training take the initiative and use the provided equipment, to focus on expanding the model system. NCC staffs construct the database from the area of importance and priority and expand the data coverage. At the same time, they verify the constructed database from the point of geographic location and contents and update it. They also analyze necessary functions for the use in professional practices and add them to the model system. Above all, the most important thing at this stage is to further the understanding of the NCC personnel who had no opportunity to know GIS to increase their potential needs of the use of GIS for making their work more efficient and effective. The fruits of the first stage lead to the second stage: Establishment of Work Specific GIS. The detailed proposals for the fist stage are described in the next chapter five.

Second Stage: Establishment of Work Specific GIS and Establishment of Common Data Infrastructure

《Establishment of Work Specific GIS》

At this stage, it is assumed that the understanding of GIS by NCC personnel is matured and it is expected that the needs for introducing GIS to their practices have increased. It is then ready to establish work specific GIS at this stage. The purpose is to improve the speed and efficiency of works by utilizing the GIS system and database that are especially designed and customized for each of the needs of professional practices; That is, to construct an individual complete GIS system and database each for cadastre management, road management, water network management, sewer network management, and so on. These systems are no longer a model system but are scaled up to enterprise level that should computerize and automate the current daily work cycle. These systems should reduce cost, improve accuracy and efficiency of service delivery, and contribute to maximize revenue generations.

As with NCC, forty percent of revenues are dependent on property tax and this situation is causing a huge risk on NCC's financial status for being dependent on one income resource. Base on this background, the study team suggests prioritizing and implementing the GIS Cadastral Management System. Needless to say that it is effective in increasing revenue generations but also it is also most versatile and can be widely used since cadastral information is the key to all other urban infrastructure management.

When planning the introduction of GIS Cadastral Management System, the following key points should be considered.

When planning the introduction of GIS Cadastral Management System, the following key points should be considered.

- Keys of Data
  Be flexible about data accuracy as long as it is within the minimum accuracy requirement and has no problem in using it in practices since the source of data varies and the accuracy varies at the same time.
- Keys of System
  Construct a user-friendly system which does not require complicated computer operations
- Keys of Equipment
  It is important to look toward the Integrated GIS which will be implemented in the

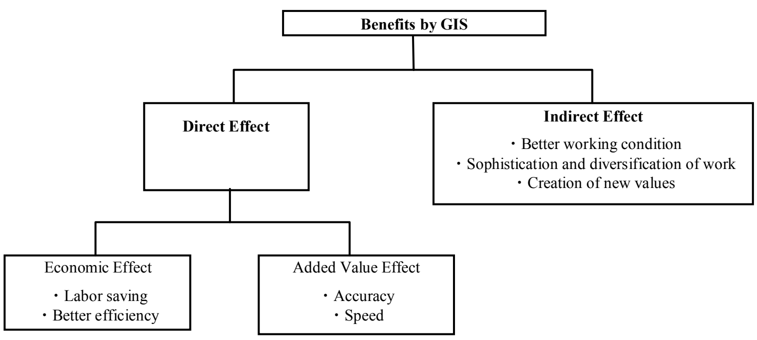


Figure 5.3 Groups of benefits gained by GIS

next stage; however, at this stage, consider the minimum investment to realize the work specific GIS and try not to overreach to the fully networked environment etc. which will be very costly and may lead to suspension of the entire GIS initiatives.

- Keys of Organization and Operation
  It is important to clarify the purpose of the use of GIS and analyze quantitatively the benefit of introducing GIS to the work cycles so that it will be more persuasive in budgeting for GIS. Follow Figure 5.3 which shows the group of benefits expected to gain from introduction of GIS and clarify the factors of expected effects. For each identified factor, set specific targets for achievement and estimate the effect by comparing the factors before and after.

《Development of Common Data Infrastructure》

While promoting the introduction of work specific GIS, it is important to develop data infrastructure and manage various kinds of GIS database for use in future stages. It is sometimes the case that duplicated investments are made on the same database development when work specific GIS are introduced. In order to avoid this duplication of effort, it is crucial to identify the data which shall be shared and commonly used among the departments and develop and maintain this data infrastructure as common property by the initiative of cross sectional GIS organization in NCC.

When developing common data infrastructure, the budget of construction cost should be allocated from NCC's general fund since it is not targeting a specific department but is to be utilized by the entire Council in the future. Another way of securing budget is to a collect small amount from each department by the basket system so that all the stakeholders at NCC share the cost and the benefits.

As a reference, the data items specified by the Japanese government for the local authorities as "common spatial data" (1:2,500 level or larger) is listed in the Annex. Looking into each of the data items, some are similar to those established by this project as the spatial data infrastructure (DXF format) and the topographic GIS database (ESRI Geodatabase) at 1:2.500 and 1:5,000. The corresponding code numbers of the topographic GIS database are shown also in the same list.

《Establishment of GIS unit》

While pursuing the development of work specific GIS, it is essential to establish an organizational set-up to support the development of common data infrastructure and promote cross departmental cooperation. The proposal is to establish a GIS unit under the Computer Section in the City Treasurer Department (highlighted green in the Figure 5.4) so that the following functions can be centralized and strengthened. The GIS unit serves as an inter-departmental organization which provides database and technical support and adjusts and harmonizes the development of work specific GIS with a view of the intranet GIS in the next stage.

- Adjustment among various departments and promotion for diverse application to the work
- Determination on the data specification of common data infrastructure and database development
- GIS technical support (maintenance and management of system, database, software, equipment)
- Assistance in utilizing private companies in database and system development

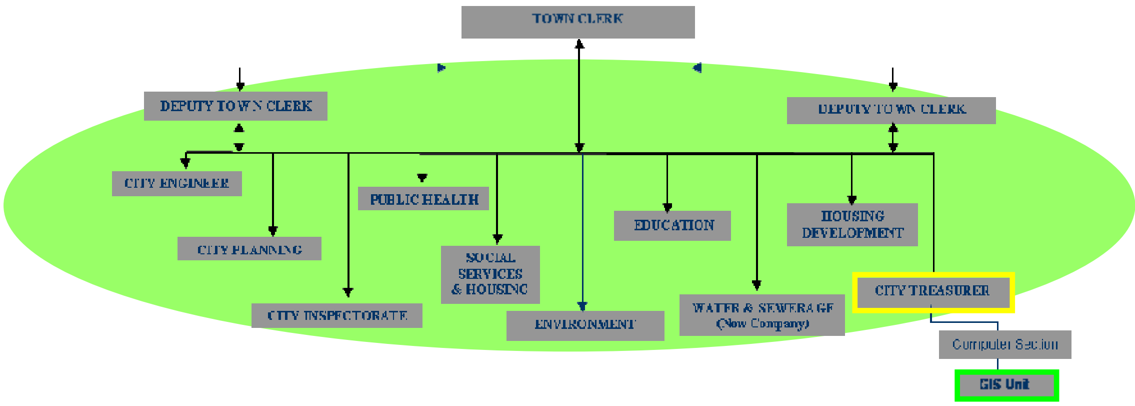


Figure 5.4 GIS unit within NCC

Third Stage: Development of Intranet GIS (Integrated GIS)

Integrated GIS is defined as follows.

Identify the Figure B Verification work by NC staff

Orange: obtained in field check
Blue: obtained from map

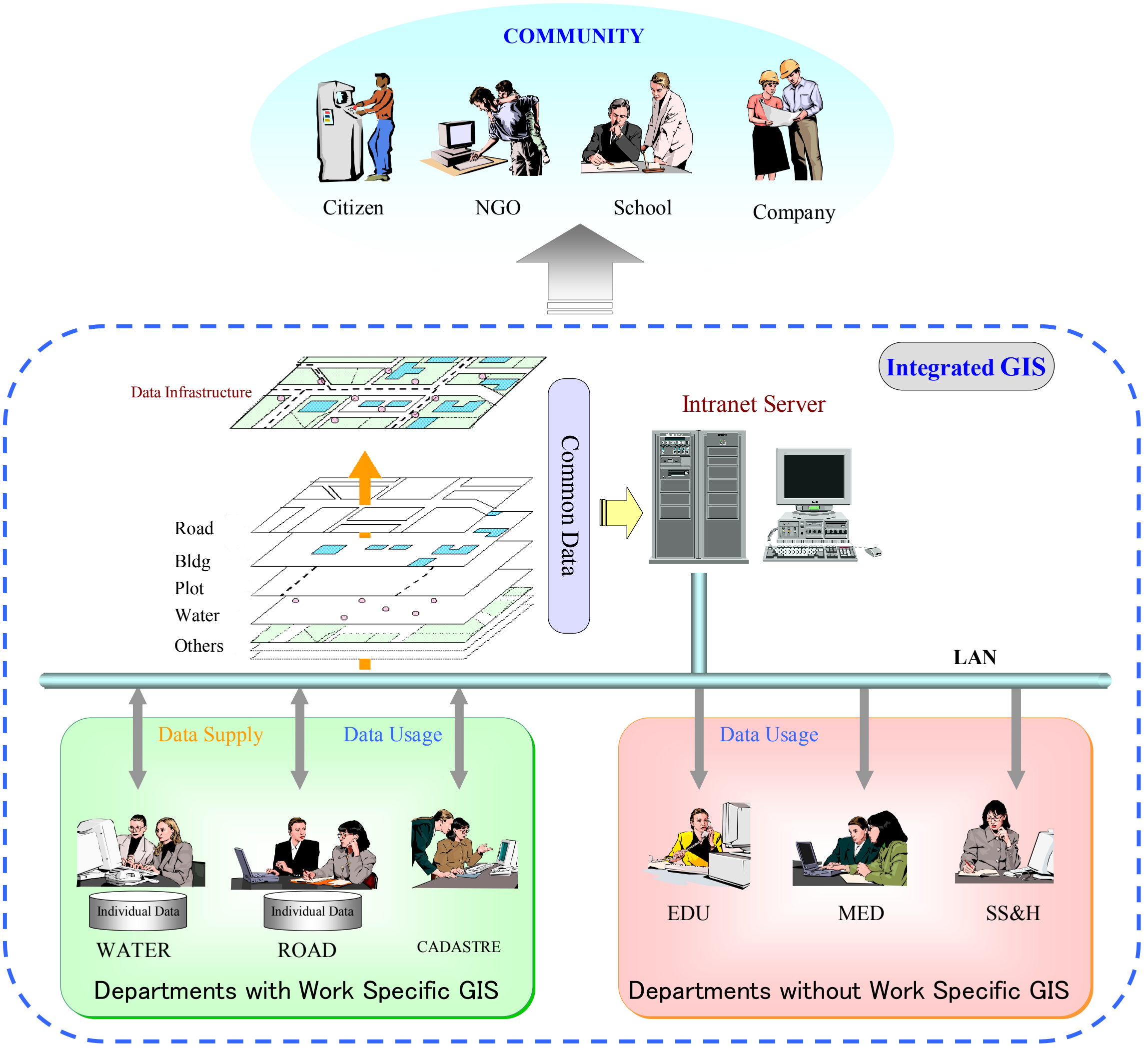


Figure 5.5 Integrated GIS

In the second stage, the personnel who use work specific GIS in the respective departments and those who work for the GIS unit are the only GIS users at NCC. However, in this third stage, the goal is to allow the rest of the departments to access GIS through LAN and acquire necessary maps and attribute information to utilize in their works.

It is the precondition that LAN is established in NCC and client computers of each department are networked and work specific GIS is performing stably at the respective departments. Also common data infrastructure should be developed by the GIS unit.

Since GIS is a part of the IT world, it is crucial to incorporate with IT policy of NCC and the Kenyan government and develops GIS as a part of the whole IT strategy. The details are described in the Annex in relation to NCC strategic plans (DRAFT STRATEGIC PLAN 2004-2009, April 2004) as reference.

Forth Stage: Development of Internet GIS

At this stage, NCC staffs promote the concept of e-government, collect, and disclose information to citizens, private companies, etc. by use of the internet and GIS. Other than NCC staffs, the major users vary such as governmental organizations, citizens, educational institutes, private companies and etc.

In the previous stage, the purpose is to build an integrated GIS for the cross-departmental use of GIS within NCC. In this stage, it is expected to expand the internal use of GIS to broader use throughout the internet. GIS is a technique that can improve the efficiency and speed of conventional activities and also create a variety of value added services in the field of administration, industries, and citizens' lives.

There are many preconditions to realize the internet GIS, such as construction of communications infrastructure, dissemination of IT use among the citizens, development of spatial data infrastructure, and progress in research and development of GIS application by the private companies in a variety to fields. Strong initiative by the government is crucial. However, it is not too early for the NCC to start considering what kind of information and services they should provide to the rest of the world once the future vision becomes true.

5.1.3 Spatial Data Infrastructure

The future image and plans for the spatial data infrastructure as described below are derived from present conditions and problems mentioned previously:

a. Future image

- ♦ Practical policy for NSDI

  The comprehensive NSDI framework will be clarified and various types of spatial data infrastructure will be designed and constructed based on that framework.

- ♦ Usage

  The use of the GIS will be promoted, thereby making paper maps almost unnecessary. The data specifications will be modified in stages on the assumption that the data will be put to active use.

- ♦ Compatibility with Internet environment

  As use of the Internet environment spreads, data retrieval and access will make more extensive use of the Internet.

b. Future plans

- Specific policy for NSDI

  The project to prepare the spatial data infrastructure for major cities will be implemented as part of the expansion of the spatial data base. The spatial data development project will also be implemented as an alternative to the topographic maps covering the entire Kenya.

  The comprehensive framework of NSDI will be clarified and various types of spatial data infrastructure will be designed and constructed based on that framework.

- Usage

  Change from transitional specifications to specifications for full use of digital data: User requirements will be incorporated in stages and the specifications will be modified for the use of digital data.

  Extensive use within the government: The data will regularly be updated, as the GIS will be used more extensively in the work of the Government and the municipalities such as Nairobi City.

- Compatibility with Internet environment

  Meta-data development: The meta-data of all the NSDI will be prepared and maintained.

  Creation of clearinghouse: Clearinghouse nodes will be set up at SOK and NCC.

5.2 Recommendations to NCC

5.2.1 Overview of Plans for Priority Projects

As is suggested earlier in 5.1.2, GIS should be introduced to NCC in stages. In this section, the proposals for expanding data coverage and system functions in the first stage are summarized based on the discussion with NCC personnel. For each model system, 1) data coverage, 2) scale, 3) accuracy, 4) update frequency, 5) additional attributes, 6) additional layers, and 7) additional functions are discussed in the following.

It is supposed that all the proposed work including data collecting, organization, and GIS data entry will be completed by the respective personnel of NCC by use of the equipment provided by this project. Please refer to the Annex for the details.

1) Cadastre Model System

The GIS database developed in relation to cadastral management is Property Polygon. This was constructed by digitizing the valuation maps, creating polygons, and attaching the attribute information provided in the form of MS Access Database by Valuation section.

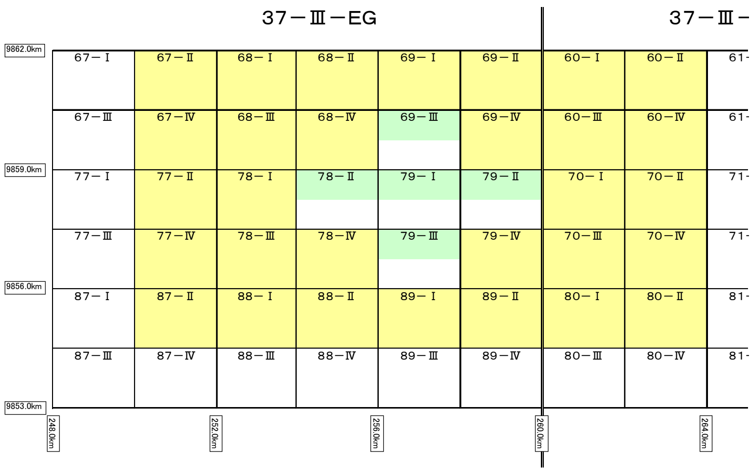


Figure 5.6 Data coverage of property polygon

① Data coverage

The data coverage is expanded from the current 15km^2 (shown blue in the figure 5.6) to the area of 105 km^2 (shown yellow in the same).

② Scale

The data scale is maintained at the level of 1:2,500. This is not large enough to precisely measure area on GIS. However Property Polygon should be used as an index map and the details such as surveyed area and other personal information related to property is stored as the attributes of the polygons. When necessary, 1:500 level database shall be developed only for the densely urbanized area in the future.

③ Accuracy

It is necessary to conduct field surveys to verify geographic position and confirm cadastre attribute information by the NCC personnel.

④ Update frequency

At minimum, the data should be verified and updated once a year.

⑤ Additional attributes

Target layer : Property_pol

In order to accurately charge and collect property tax, two attribute fields, Term of lease and Commencement, shall be added. In addition, the attribute fields which are already prepared but to be filled in prior to others are the followings; Tenure, Lease, Situation.

Graphic type : polygon

Scale of the original maps : 1:1,250 (Valuation Map)

Reference material : Title Deeds,Certificate of Lease

Attribute fields: Term of lease, Commencement, Tenure, Lease, Situation

(Refer to the Annex for more details)

⑥ Additional layers

Additional layer : Planning Zones

This is the zoning map showing the planning zones. Its attributes include building code which are derived from the month notices and all kinds of details about the zones and are utilized in land development, land valuation, city planning, and taxation purposes.

Graphic type : polygon

Scale of the original maps : 1:2,500 (Zoning Map)

Reference material : Zoning Table, Planning Policies

Attribute fields: Refer to the Annex for more details

Additional layer : Outdoor Advertisements

This is the point data showing the outdoor advertisements such as signboards, billboards and advertisement towers which NCC generates advertising rates. This data will help generating accurate and efficient collection of the licensing fees.

Graphic type : point

Scale of the original maps : 1:100 - 1:250 (Approved Plans)

Reference material : Licenses, Policies

Attribute fields: Refer to the Annex for more details

⑦ Additional functions

No additional functions are necessary for now.

2) Road Model System

The GIS database constructed for road management indicates the road network (line) and intersections (point). The road network was generated from the center line of the spatial data infrastructure (1:2,500) by converting it to GIS database and appending the attribute information. The intersection data was generated by automatically creating nodes at the intersecting point of the roads and attribute information is appended.

① Data coverage

Data coverage is extended from the current 15km^2 (blue in the figure 5.7) to 400km^2 (circled orange in the same figure, EAST 267,000m, WEST 247,000m, NOTRH 9,868,250m, SOUTH 9,848,250m) which is proximately 26 times as large as the model system coverage. It is going to cover 20km x 20km including the central part of the city.

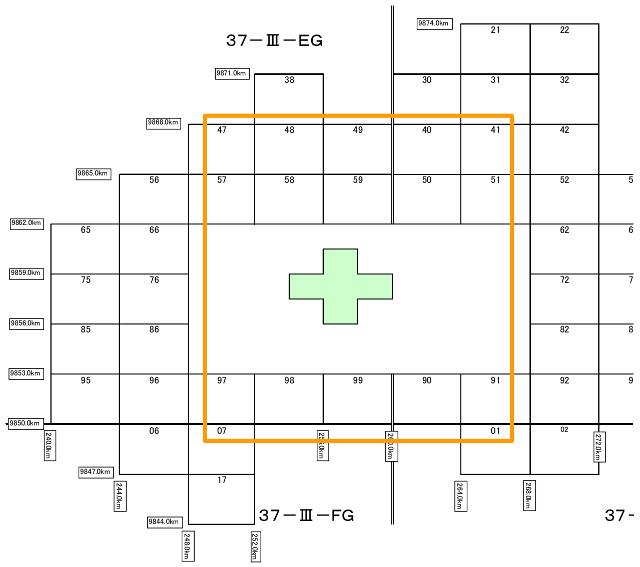


Figure 5.7 Road/intersection data coverage

② Scale

The data scale is maintained at the level of 1:2,500. However the area for which the 1:5,000 topographic data was produced will adopt 1:5,000 level.

③ Accuracy

Field survey should be conducted to verify the road condition and positional accuracy.

④ Update frequency

At minimum, the data should be verified and updated once every 6 months.

⑤ Additional attributes

Target layer: Road_lin_macro

In order to be used for the additional faction of “Display Road Congestion Indicator”, the maximum number of cars that a road is capable of handling is added as an additional attribute. For the purpose of road planning and maintenance, the estimated cost and actual cost of road construction are input as the attributes of mcost_est and mcost_act. In addition, the attribute fields which are already prepared and to be filled in prior to others are the following; Lane, Parking, Authority.

Graphic type : line

Scale of the original maps : 1:2,500 and 1:5,000 (Topographic Map)

Attribute fields: MaxVol, mcost_est, mcost_act, lane, parking, authority

(Refer to the Annex for more details)

⑥ Additional layers

Additional layer: Street_Lighting

This is a point data showing the location of the equipment related to roads such as street lights. It is to be used in managing and planning for them.

Graphic type : point

Scale of the original maps : To be specified

Attribute fields: Refer to the Annex for more details

⑦ Additional functions

Display Road Congestion Indicator

To color classify the road network by current road congestion condition using the result of traffic volume survey and the maximum road capacity of each road segment. In Japan, the maximum road capacity is specified per lane per day or 12 hours and varies depending on the number of lanes. This information is useful for understanding the congestion situation and also planning new road developments. The necessary attribute value (MaxVol) should be prepared in using this function.

(Refer to the Annex for more details)

3) Water Model System

The GIS database constructed for water management includes the water network (line) and chambers (point). The water network was digitalized by scanning the network maps (1:2,500) provided by NCC. The attributes of the water network was summarized by reading information on the maps into the attribute inventory. The chamber points were also created in the same way as the water network. In February 2004, the study team conducted a series of field surveys and the survey results are also incorporated in the GIS database.

① Coverage

Data coverage is extended from the current 15km^2 (light blue in the Figure 5.8) to 588km^2 (blue in the same figure, EAST Kayole Estate, WEST Kangemi Estate, NORTH Kimathi Estate, SOUTH Nairobi National Park, which is approximately 39 times as large as the model system coverage.

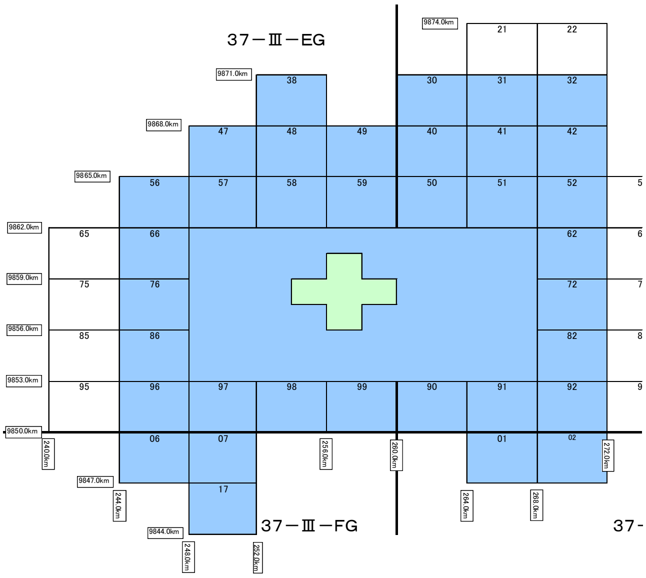


Figure 5.8 Water network line/chamber point data coverage

② Scale

The data scale is maintained at the level of 1:2,500. This is not large enough to perform precise measurements on GIS. However, Water Network and Chamber should be used as an index map and the details are stored as the attributes of the lines and points. The printout of this database is expected to be used on the field.

③ Accuracy

In order to improve data reliability, GIS database should be verified by field surveys and updated frequently. Especially when a new water pipe or a chamber point is established, this field identification is essential.

④ Update frequency

It is ideal if data update is performed as a part of daily activities. However, due to financial restrictions, data update should be done once a year at minimum.

⑤ Additional attribute

<u>Target layer: water_lin</u>

In practice, it is important to maintain information of water supply zones so it is to be added.

Graphic type : line

Scale of the original maps: 1:2,500

Attribute fields: Zone_

(Refer to the Annex for more details)

⑥ Additional layers

Additional layer: Nodes

Irrespective of availability of water facilities, this point data shows the location of connecting location of the pipes.

Graphic type: point

Scale of the original maps: 1:2,500

Attribute fields: To be decided

(Refer to the Annex for more details)

⑦ Additional functions

Simulate Construction Cost for Water Network 

The "Simulate Construction Cost" function was created in order to calculate the installation cost when laying new pipe lines. The user inputs parameters and draws a line on the screen so that the system calculates the cost of construction based on the length of the line and the given parameters.

The proposal is to add one more parameter to be given by the user. The cost is largely affected by the size of the pipe so the parameter of the pipe size is added. However in actual calculation, the additional parameter will not be counted but just to be displayed on the result window.

(Refer to the Annex for more details)

4) Sewerage Model System

The GIS database constructed for sewer management includes the sewer network (line) and manholes (point). The sewer network was digitalized by scanning the network maps (1:2,500) provided by NCC. The attributes of the sewer network were summarized by reading information on the maps into the attribute inventory. The manhole points were also created in the same way as the sewer network. In February 2004, the study team conducted the series of field surveys and the survey results are also incorporated in the GIS

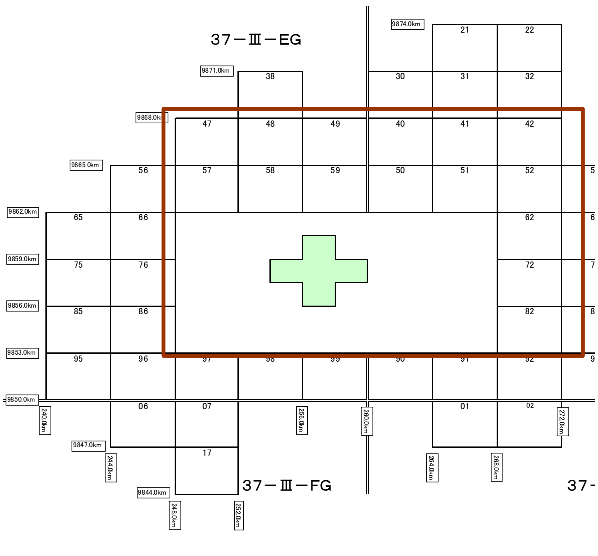


Figure 5.9 Sewerage network line/manhole point data coverage

database.

① Coverage

Data coverage is extended from the current 15km^2 (light blue in the Figure 5.9) to 391km^2 (circled brown in the same figure, EAST 270,000m,WEST 247,000m, NORTH 987,000m, SOUTH 985,300m) which is proximately 26 times as large as the model system coverage.

② Scale

The data scale is maintained at the level of 1:2,500. This is not large enough to perform precise measurements on GIS. However, the sewer network and manholes should be used as an index map and the details are stored as the attributes of the lines and points. The printout of this database is expected to be used on the field.

③ Accuracy

The location of the manholes should be identified on field by less than 1 meter accuracy. Also, attribute information should be verified and updated.

④ Update frequency

It is ideal if data update is performed as a part of daily activities. However, due to financial restriction, data update should be done once a year at minimum.

⑤ Additional attributes

<u>Target layer: sewer_lin</u>

It is important to maintain information on what material is used in the sewer surrounds for the purpose of maintenance and new development so the new attribute field is added.

Graphic type: line

Scale of the original maps: 1:2,500

Attribute fields: Pipe_surr (type of sewer pipe surrounds)

(Refer to the Annex for more details)

<u>Target layer: manhole pnt</u>

In order to maintain and develop new manholes, it is necessary to know what kind of material is used for the existing ones so the new attribute field is added.

Graphic type: point

Scale of the original maps: 1:2,500

Attribute fields: Design (materials used for manholes)

(Refer to the Annex for more details)

⑥ Additional layers

No additional layer is necessary for now.

⑦ Additional functions

Simulate Excavation Cost for Sewerage Network 

The “Simulate Excavation Cost” function was created in order to calculate the excavation cost when laying new pipe lines. The user inputs parameters and draw a line on screen so that the system calculates the cost of construction based on the length of the line and the given parameters.

The proposal is to add one more parameter to be given by the user. The cost is largely affected by the size of the pipe so the parameter of the pipe size is added. However in actual calculation, the additional parameter will not be counted but just to be displayed on the result window.

(Refer to the Annex for more details)

Find the Nearest Manhole

When a new building is constructed, the drain outlets of the building have to be connected to the existing sewer network. In deciding which manhole to be connected to the drain outlets, it is necessary to simulate the cost of laying a new pipe at minimum cost. This additional function enables the user to search for the closest manhole from the location where the user indicates as a drain outlet. It is possible to find the closest manhole and simulate its excavation cost by combining it with Simulate Excavation Cost function.

(Refer to the Annex for more details)

5.2.2 Improvements for Realization of Plans

Because it requires vast time and cost to introduce GIS at the early stage, it is quite difficult to reach the point where GIS is successfully in operation. As with the local authorities in Japan, there are cases when they had to withdraw from GIS activities because the cost expanded much more than the estimate or it took so long to complete the database and system development that the information was already outdated and became of no use.

Here, the challenges that need to be overcome in order to successfully realize the plan are discussed, focusing on organizational structure, system operation, and finance.

(1) Organizational structure

At the end of the project, all the GIS equipment including hardware, software, plotter, and scanner, and GIS model system and database will be placed in the room of GIS Center which was provided by the Town Clerk. This room is to be utilized as a GIS Center for all the GIS users at NCC to edit data, create maps, and print maps. Until the GIS unit is established under the Computer Section, this GIS Center will take the initiative to expand data coverage, content, and function of the model system. It should also meet small GIS needs and actively hold activities and trainings to deepen understandings and needs of GIS of NCC personnel.

(2) System operation and management

For the time being, the computers are not networked within NCC, so it is not possible to use GIS through LAN from the client computers. Therefore, the users have to come to GIS Center to use GIS. In such environment where many NCC personnel come to GIS Center to access GIS databases for a variety of purposes, it is essential to clearly define the task and responsibility of the administrator and the users and operate the system systematically.

The discussions and suggestions for the GIS Center regarding 1) data management and 2) system operation are summarized below.

1) Data management

[Data hierarchy]

It is assumed that when the system is first introduced, the users will have little understanding of the data except for those who received training. Therefore, consideration must be given to avoiding corruption of the system and data due to operational errors by setting the data hierarchy with four levels and restricting data accessibility. (Refer to the Annex for more details)

1. Master geodatabase: The geodatabase constructed and delivered by the JICA side will be the master geodatabase when the system is in operation.
2. Edited geodatabase: The changes made in routine work will be updated to a geodatabase, which will be maintained as the edited geodatabase.
3. Working database: A portion or all of the data is extracted for carrying out various analysis work and data processing.
4. System setting database: This database will maintain the various setting information required to execute the program. It will only be accessed from the program and it is assumed that the users, including the system manager, will not modify it directly.

[Data maintenance responsibility]

It is very important to clarify the responsible department in maintaining databases for sustainable GIS operation. Table 5.1 lists the datasets developed for the GIS model system and also the appointed responsible departments respectively. (Refer to the Annex for more details)

Table 5.1 Appointment of responsibilities

Dataset	Contents	Appointment of Responsibility
administration	Admin boundary (for each administrative level)	Survey of Kenya
transportation	Road network	City Engineer
	Intersection	
	Road map index	
property	Property plot	Valuation Section
	Valuation map index	
water	Water network	Water and Sewer Company
	Water facilities	
	Water meter	
	Water map index	
sewage	Sewer network	Water and Sewer Company
	Manhole	
	Sewer map index	
education	Educational facilities	Education
medical	Medical facilities	Public Health
social	Social facilities	Social Services & Housing
vegetation	Vegetation	Survey of Kenya
wetland	Waters	Survey of Kenya
landuse	Landuse	City Planning

[Data backup]

It is the most basic yet definite way to back up data in order to recover from un-recoverable corruption of database. Since several different levels of databases are created, custodians for each data group must be clearly identified and their responsibility must be well recognized by all.

(Refer to the Annex for more details)

[Data Security]

The system is designed in order to suit the current IT environment at NCC (computers not networked, stand-alone GIS hardware and software for the time being). However, in order to increase the security of the system, consideration has to be given to the following issues.

(Refer to the Annex for more details)

- Physical settings (Lock on the door of the GIS Center)
- Login settings (Password request when logging in the GIS server computer)
- Software settings (Password requested when starting to edit master database)

2) System operation

As is described in the previous section, the model system maintains the hierarchy of database so that data integrity shall be secured. In relation to this, users should also be grouped by their responsibility and data accessibility. The following describes the roles of administrators, editors, and viewers of the data and system. Considering the condition of available hardware, software, human resources at NCC, details at STAGE 1 and FUTURE perspectives are discussed. How the system should be operated at NCC is illustrated in the Figure 5.10 below. (Refer to the Annex for more details)

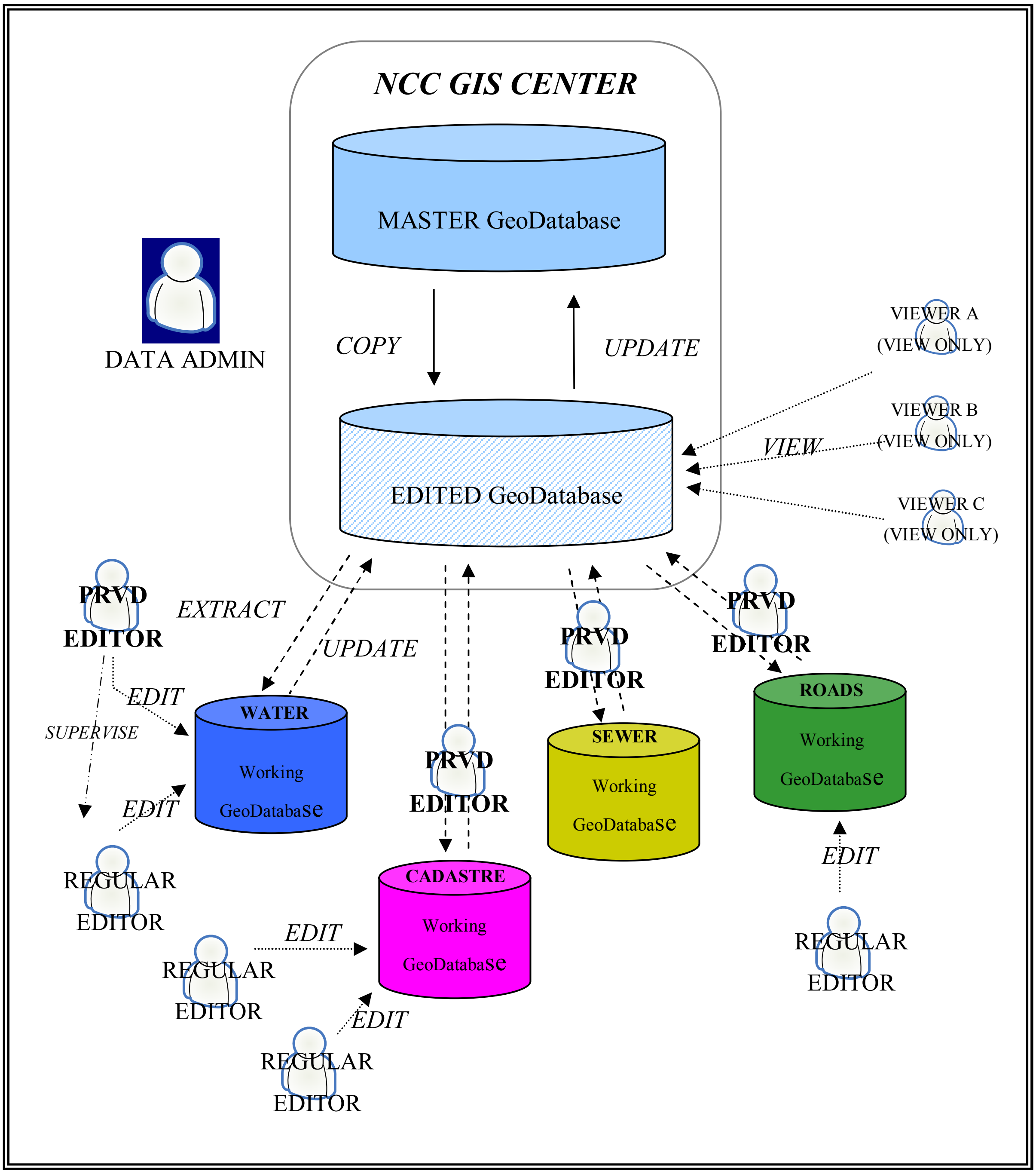


Figure 5.10 System operations at NCC

(3) Finance

The investment in data development is the heaviest and generally accounts for 70-80 % of the total cost. The cost of hardware and software is falling but is still are very expensive in Kenya. Also the cost for human resources is not negligible.

In regard to maintenance cost, it is generally said that the cost of upgrading hardware and software is 5 % of the initial investment. On the other hand, the maintenance cost of the database is totally different, ranging from a few percent of the initial investment to the total replacement.

As with NCC, the current situation is that a minimum set of hardware and software, database, and system is installed and 10 personnel received the GIS training, which means a long way is still ahead and the initial investment is yet to be made.

1) Cost estimates

[Hardware maintenance cost]

It is a worldwide trend that the rate of hardware is dropping, however it is necessary to annually allocate the budget of 2-6% of the initial cost of purchase in order to maintain the equipment at minimum. Table 5.2 shows the maintenance cost of the provided equipment in case of the purchase of equipment of the same performance level in Japan. The local cost in Kenya must be confirmed, but it is calculated that 69,400Ksh to 162,000Ksh may be annually necessary for maintaining the provided equipment.

Table 5.2 Estimate of hardware maintenance cost

(Based on the 2-6% of the cost of purchase)

Hardware	2%	6%
Scanner	23,200	69,600
Plotter	43,050	86,100
GIS Workstation	3,150	6,300
TOTAL (Ksh)	**69,400**	**162,000**

[Software maintenance cost]

Other than GIS, there are many types of software that should be maintained such as Windows, MicrosoftOffice, antivirous software, etc. Fortunately other than GIS software, it is possible to download patch and upgrade programs from the internet at no cost. Regarding GIS software, there is most likely to be a charge

ESRI Inc. charges for the maintenance contract from the second year of the purchase in order for them to upgrade the software and provide technical support. The contract is made annually and should be continuous. Table 5.3 shows an estimate of the maintenance cost offered by the ESRI representative in Kenya (Oakar Services Ltd.). Based on this, it is required for NCC to allocate 371,200Ksh annually for the maintenance cost of the GIS software.

Table 5.3 Estimate of maintenance cost of GIS licenses for July 7, 2004 to July 6th, 2005

Description	Qnt	Unit Price	Total
Primary Maintenance on ArcInfo Floating License	1	Ksh 240,000	Ksh 240,000
Primary Maintenance on ArcGIS 3D Analyst Concurrent Use License	1	Ksh 40,000	Ksh 40,000
Primary Maintenance on ArcGIS Spatial Analyst Concurrent Use License	1	Ksh 40,000	Ksh 40,000
		VAT 16%	**51,200**
		TOTAL(Ksh)	**371.200**

[Database development cost]

Figure 5.11 shows the estimated man-hours for the proposed database expansion described as priority project in 5.2.1. This estimation is made based on the experience of developing a similar GIS database of the model system done by the study team and only for the workload of GIS data entry. In the complete work flow of GIS database construction, there are more processes as shown in Figure 5.11 and this estimation is made just for those colored blue in the figure. It is assumed to require almost the same amount of work to collect data, create the base maps for data entry and create the attribute inventories.

Table 5.4 Estimate of cost for expanding GIS database

Model	Layer	Type	Attribute Field	Updated Items	A: Area	B:Work days	C: Cost	D:TOTAL	E:	F:
Cada	Property_pol	Polygon	ALL	Expand the area (spatial&attr)	90	120	60000		6	20
			Term of Lease	Input additional attributes	105	35	17500		7	5
			Commencement	Input additional attributes	105	35	17500		7	5
	Planning_zones	Polygon	ALL	Input additional layers (spatial&attr)	105	21	10500		7	3
	Outdoor_advertizements	Point	ALL	Input additional layers (spatial&attr)	105	35	17500	123000	7	5
Road	Road_lin_macro	Line	ALL	Expand the area (spatial&attr)	385	513	256667		26	20
			MaxVol	Input additional attributes	400	267	133333		27	10
			mcost_est	Input additional attributes	400	53	26667		27	2
			mcost_act	Input additional attributes	400	53	26667		27	2
	Street_Lighting	Point	ALL	Input additional layers (spatial&attr)	400	213	106667	550000	27	8
Water	Water_lin	Line	ALL	Expand the area (spatial&attr)	573	764	382000		38	20
	Nodes	Point	ALL	Input additional layers (spatial&attr)	588	314	156800	538800	39	8
Sewer	Sew er_lin	Line	ALL	Expand the area (spatial&attr)	391	521	260667		26	20
			Pipe_surr	Input additional attributes	376	201	100267		25	8
	Manhole_pnt	Point	Design	Input additional attributes	376	201	100267	461200	25	8

A: Additional data coverage (km^2)

B: Necessary work days (days ; in case a single operator does the work)

C: Personnel cost (Ksh ; multiplying B days and 500 Ksh assuming 500ksh per day is the average operator cost at NCC)

D:TOTAL (Ksh ; total cost per model)

As reference

E: Additional area is XX times as large as $15km^2$

F: Work days need to complete similar data development of the size of $15km^2$ by the JICA study team (days ; in case a single operator does the work)

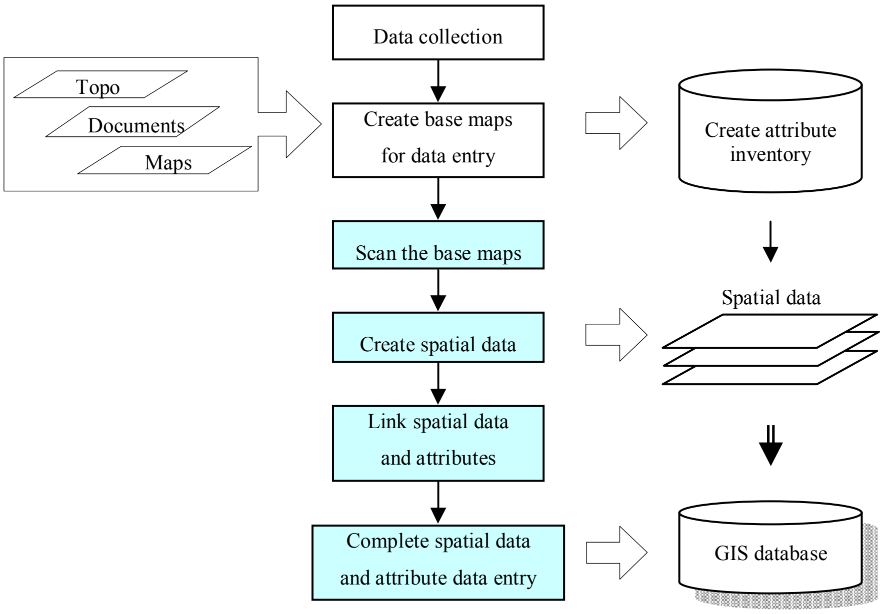


Figure 5.11 Work flow of GIS database development

[Human resources cost]

The technical skills and fields are different from each implementation stage of GIS and consequently the cost of human resources varies. Generally speaking, when the local authority fully introduces GIS, it is common to engage with a private consulting company to plan, design, and construct the system and database in the beginning.

As for NCC, it is proposed to expand the model system as the first stage (shown in the Figure 5.2) by using the provided equipment with the initiative of the trainees who received the GIS technical transfer training. The aim is to further develop the database and the functions by the own effort of the NCC personnel. The most important part of this stage is to make as many NCC staffs as possible aware that GIS is a practical tool to assist their works and effective service delivery and lead them to develop the work specific GIS which meets specific needs of the departmental duties. After completing the fist stage, now NCC personnel will be able to analyze the users' needs and adequately incorporate them into the data specification.

It is assumed that as many as NCC personnel as possible will be trained, so the provided equipment may not be enough. In this case, it is proposed to utilize the African Institute for Capacity Development (AICAD) GIS facility. From the experience of the study team using their GIS lab, it is ideal for training and data development since it has 10 ArcGIS licenses with a full set of extension modules and networking environment. Table 5.5 shows the rate of the use of GIS computer lab at AICAD.

Table 5.5 AICAD Rates for GIS computer lab(Aug 2004)

Facility	Facility Description	Remarks	Rate Per Day
Computer Lab	Desktop top computer: PACKAGE PER PERSON	Only for computer use	700
	ArcGIS: PACKAGE PER PERSON	Only for ArcGIS license use	3,500
		TOTAL (Ksh)	**4,200**

The benefit of using AICAD's computer lab is not only for the training but also to maximize the work efficiency to expand the database of the model system with the maximum 10 trainees / operators. Any of the trainees who participated in the technical transfer training can be a trainer now. It is expected that a few personnel should be trained as GIS data operator from the departments that are appointed to be responsible for maintaining the database. If 10 personnel are trained and engaged in the data entry for two weeks, the cost of using AICAD GIS computer lab will be 420,000Ksh, which is equivalent to completing 100 person / day of data entry.

2) Secure financial resources

To summarize the above estimates, the approximate cost to maintain GIS at NCC after the completion of the project is as follows.

[Hardware maintenance cost] 162,000Ksh
[Software maintenance cost] 371,000Ksh
[Database development cost] 3,346 (person/day) = approx. 1,673,000 Ksh
[Human resources cost] 420,000Ksh (10 personnel engaged for 2 weeks at AICAD)

It will not be easy for NCC to mange to raise the budget for those costs in view of the recent financial status. It is essential to consider it as a prior investment that will improve work efficiency and service provision, manage to collect more revenues, and eventually improve financial status of NCC. With full understanding and united motivation, the budget should be allocated to cover the costs for GIS related activities.

A brief suggestion to raise the needed budget is as follows.

① Provide small services to the department of NCC using GIS and generate revenue

Using the provided scanner, scan the paper maps and create a library of the map images. Plot the scanned image of the maps with the plotter on demand and collect small revenues. In this way, it may cost less than making large size copies at the copy shops, which reduces the expense of the departments of NCC. Also, the revenue can be used for operating and maintaining the GIS Center. The followings are some examples of services that the GIS Center can provide to the other departments.

- Map scanning and large size printing
- Creating thematic maps
- Information search and creating report

② Collect small budget from the respective departments

The GIS model system was designed to be as versatile as possible and be utilized by many departments. Also, GIS enables us to perform information search and map creating that is not possible with paper maps. It is proposed that this common resource with full potential needs to be carefully maintained and expanded by the assistance of the departments that share these visions. The database and system developed jointly with the departments should be shared and utilized for their own purposes.

③ Allocate budget to the GIS Center as one of the indirect departments

As is the case with the Computer Section in the City Treasurer department, it is proposed to NCC to allocate budget for the maintenance and operation of the GIS Center. As the legitimate reason, it is important to quantitatively analyze and clarify the benefit of having the GIS Center such as improved efficiency, reduction of expenses, reduction of labor cost, etc. By referring to the description of the establishment of work specific GIS in the second stage in 5.1.2, it is strongly recommended that NCC estimates the benefits expected to gain by the use of GIS quantitatively.

5.3 Recommendations to SOK

5.3.1 Overview of Plans for Priority Projects

a. Establishment of national geodetic network based on the World Geodetic System

A priority project for SOK to tackle based on the results of technology transfer and the future image and plans that were clarified in this Study, is to change the standard geodetic system as the base for future survey activities from the present Clarke 1880 to one based on the World Geodetic System. For this purpose, as a first step the 0-order control point network will be planned and implemented.

Purpose:	5 0-order control points based on the World Geodetic System will be set up within Kenya as the geodetic points for the setting-up of the 1st-order or lower control points.
Planning:	The 0-order control points will be selected in the room using the existing small-scale maps and the distribution maps of existing control points. In point selection, the existing control points will be used as far as possible. The observation planning map will be prepared by checking and using the locations of existing IGS points. The adjustment plan map will also be prepared taking the existing IGS points into consideration.
Selection of points:	The locations of selected points on the planning map will be verified in the field. If the existing points are usable, they will be used and if unusable, the locations of new points will be selected.
Monumenting:	In setting up new 0-order points, new control points will be built in accordance with prescribed rules.
Observation:	Observation for 60 hours or more will be made using 5 GPS receivers simultaneously. The observation interval will be 15 sec.
Analytical calculation:	Software allowing the super-long baseline analysis (BERNESE software) will be used for the analytical calculations. In the first step of analysis, each baseline will be analyzed while the observed data of the IGS points that are to be used in the observation plan will be acquired via the Internet. After completion of the baseline analysis, the duplicated lines

and the closure errors in the minimum polygons will be checked to verify that there was no problem in the observation results.

Before the adjustment calculations are made, the determined coordinates of the IGS points will be converted into the coordinate values at the time of observation because of plate movements, and these will be used as the given control points for the adjustment calculations. The 0-order adjusted coordinate values obtained from the adjustment calculations will be converted to the coordinate values at the same time as the determined coordinate values of the IGS points taking plate movement into consideration.

In this way, the coordinate values of the 0-order control points will be determined based on the World Geodetic System.

For the detailed materials including the planning map and the cost estimates, refer to the Appendices.

When the above work has been completed, the 1st-order or lower control points can be set up without any technical problems, using the results of the technology transfer in this Study.

b. Establishment of spatial data infrastructure

The priority project for SOK to tackle based on the result of technology transfer in this Study and the future image and plans is the project to establish a spatial data infrastructure for Mombasa City, the second largest city in Kenya after Nairobi City. If the specifications of the national spatial data infrastructure (NSDI) have been established when this project is started, the project will conform to these specifications. The scale level will be 2,500 or 5,000, the same as for Nairobi City.

Purpose: The spatial data infrastructure will be established as a tool to formulate the city plan and resolve the problems of Mombasa City.

Planning: Plans will be drawn up for aerial photography, control point surveys, neatline divisions, digital plotting and compilation, etc.

Land survey: Various land surveys will be carried out using the results of the technology transfer in this Study, and using the procured equipment provided in this Study.

Photogrammetry: This work will also be done using the results of technology

	transfer in this Study and will be implemented digitally using the procured equipment provided in this Study.
Data development:	If the specifications of the national spatial data infrastructure have been established at this time, the project will conform to those specifications. If not, the specifications of the spatial data infrastructure adopted in this Study will be applied.

c. Constructing of topographic map database for GIS

The topographic map database for cadastral management will be constructed at the same time that the Mombasa City spatial data infrastructure is established.

Purpose:	The topographic map database will be constructed to manage the cadastral information of Mombasa City.
Planning:	The state of preparation of the cadastral map of Mombasa City and the functions required for the cadastral GIS will be investigated. Based on the investigation results, a topographic map database for the cadastral GIS will be designed.
Data construction:	The topographic map database will be constructed in accordance with the cadastral GIS specifications based on the prepared Mombasa City spatial data infrastructure.

5.3.2 Improvements for Realization of Plans

From an understanding of the present conditions and problems in SOK, the following items for improvement should be considered in the implementation of the work described above:

- ♦ Rational planning
- ♦ Strong initiative for implementing plans
- ♦ Raising of necessary expenses for implementing plans
- ♦ Establishment of a technical base (including preparation of equipment and materials)

a. Items for improvement needed for establishment of national control point network

- ♦ Rational planning

  The detailed materials for this project are included in the Appendices. However, this project is still in the planning stage, with no experience in the field. No detailed schedule is given. Therefore, the control point distribution plan must be reviewed with reference to actual field conditions at the time these recommendations are received by SOK, and a detailed schedule drawn up before the improvement work is implemented.

- Strong initiative for implementing plans

  It is necessary to assign as the leader for this project an engineer who is familiar with the technical and managerial aspects, has a powerful sense of mission, and can demonstrate the strong initiative and leadership needed to implement the project successfully. In particular, initiative and leadership are indispensable factors in this kind of pioneering project. One of the most important improvement items is the securing and appointment of such an excellent leader.

- Procurement of necessary expenses for the project

  It is self-evident that any project requires considerable expense. In this project, fortunately, the observation equipment that has been procured in this Study or that is in the possession of the counterpart agencies can be used. The cost of purchasing the super-long baseline analysis software, the traveling costs of SOK staff members and the expense to secure vehicles and fuel for them, will inevitably be required for this project.

  These costs and expenses should naturally be secured from the annual budget of SOK. It is recommended that SOK cope with the work of raising the cost from the budget in cooperation with other agencies that will be beneficiaries of the national control point network to be established; or that the budget (costs and expenses) should be secured through a hitherto unknown concept, that the project should be implemented by sharing the costs and expenses jointly with other beneficiaries.

- Establishment of technical base (including preparation of equipment)

  The equipment and materials procured in this Study as mentioned above can be appropriated to the observation work. The monumenting and control point observation technology poses no basic problems as the results of the technology transfer will be applied.

  It is necessary to connect the SOK-owned equipment to the Internet in order to download from the Internet the observed data of IGS points. However, this is not a great problem.

  Another problem is how to do the super-long baseline analysis. There are two solutions to this problem: one is for SOK staff members to master for themselves how to run the purchased super-long baseline analysis software and use that, and the other is for the analysis work to be referred to the Geographical Survey Institute of Japan through the JICA's long-term expert dispatched to SOK at present.

Another problem is how to execute the somewhat complicated processes related to the adjustment calculations. One solution to this problem would be for SOK staff members to understand the complicated processes as they familiarize themselves with how to use the purchased software for super-long baseline analysis. Or, as with the super-long baseline analysis work, the complicated processes could be referred to the Geographical Survey Institute of Japan through the JICA's long-term expert working with SOK at present.

The implementation of the above 4 items may be considered essential for the successful implementation of the project.

b. Establishment of spatial data infrastructure and construction of the topographic map database for GIS

♦ Rational planning

The detailed materials for this project are included in the Appendix. In this project, the distribution of photo control points is absolutely theoretical, and does not reflect conditions in the field. In carrying out the work, it will be necessary to modify the plans rationally so as to reflect actual conditions in the field.

It will also be necessary to draw up plans to construct a more efficient database, based on the experience of constructing the cadastral management database in this Study.

♦ Securing the engineers capable of doing the above work is one more item for improvement.

♦ Strong initiative for implementing the plans

These plans involve work similar to ordinary photogrammetric work and the work of database constructing in this Study. However, as with the work to establish the national control point network, it will be necessary to employ an engineer capable of demonstrating strong initiative and leadership in the implementation of the works. Securing such an excellent leader will be an important improvement item.

♦ Procurement of necessary costs for implementation of the plans

The traveling costs for SOK staff members and expenses for securing vehicles and fuel in these plans will be required. At the same time, with the exception of the expenses needed for new aerial photography, it will be possible to implement the plans using the equipment and materials provided in this Study.

These necessary costs and expenses may be appropriated from the revenues of the sale of existing printed maps and the spatial data (including printed maps) developed in this Study. Of course the proceeds from the sale of existing topographic maps goes into the national treasury, and it will be necessary to modify the system so that the proceeds become special-purpose income for SOK.

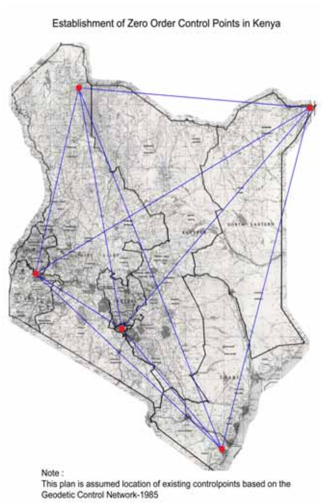
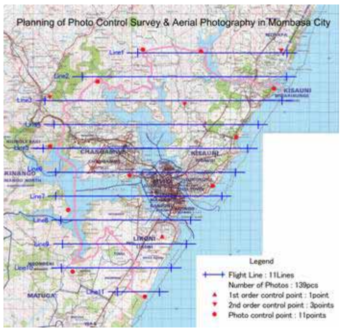
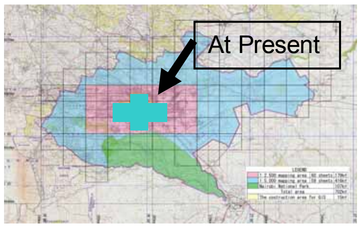
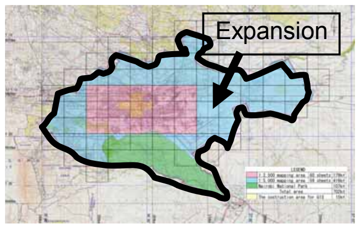
♦ Establishment of technical base

The technical base to implement these plans has been established through technology transfer and the construction of the GIS database in this Study. However, the assistance of an appropriate adviser is needed for the plans to be implemented smoothly. With regard to the functions required for the Mombasa City cadastral GIS, the consulting technology to define the functions and the GIS technology to realize those functions, and the securing of engineers specialized in these technologies, are important improvement items.

5.4 Summary of Recommendations to SOK and NCC

5.4.1 Summary of Recommendations

The recommendations made to SOK and NCC in 5.2 and 5.3 are summarized in the table below in respect to their priority, costs and required equipment.

	Establishment of national geodetic network	Establishment of spatial data infrastructure in Mombassa City	Expansion of the GIS model systems in Nairobi City
Summary of Recommendation	 • To establish a new national geodetic network based on the World Geodetic System • To establish five 0 order control points based on the World Geodetic System within Kenya	 • To establish spatial data infrastructure covering all of Mombassa City based on the same specifications as Nairobi City • To produce printed maps	  • To expand the database coverage and data items of the existing GIS model systems (4 systems) • To strengthen the functions of the existing GIS model systems (4 systems)
Main equipment Required	• GPS receivers: 5 units • Analytical software BERNESE: 1 set • Personal computers for analysis: 2 units	• Aerial photos (scale: 1:15,000) covering all of Mombassa City • Film scanner 1 unit • Plotter 2 units • Compiler 3 units	• Map scanner 1 unit • Digitizer 3 units • Compiler 3 units • Personal computer 4 units
Cost	Approx: US$67,000	Approx: US$292,000	Approx: US$21,000
Priority	1st priority	3rd priority	2nd priority

5.4.2 Contribution to the Development of Economic Infrastructure

(1) Establishment of spatial information

Topographic maps and land-related information, that is to say spatial information, are basic information essential for the development of economic infrastructure. However, Kenya is not in a situation where this spatial information can readily contribute to such development. Under such circumstances, the establishment of spatial data infrastructure for the City of Nairobi helped to meet this need. Moreover, the plan for establishing spatial data infrastructure for the City of Mombassa based on the same specification, as proposed in the previous section, will further the establishment of spatial information necessary for the development of economic infrastructure.

It is also important that the geodetic system, on which the spatial information is based, is in accordance with global standards or the Africa geodetic system. Thus, the establishment of a national geodetic network, as proposed in the previous section, is an urgent task.

The recommendations up until the previous section do not include specific mid and long term plans for the establishment of spatial information (including the training of human resources). From the standpoint of developing economic infrastructure, the formulation of such mid and long term plans is a matter that cannot be overlooked.

(2) Contribution to poverty reduction

Considering the development of economic infrastructure in respect to poverty reduction, water and sewerage, which are closely related to the daily lives of the citizens, are important factors.

The establishment of adequate water and sewerage facilities is indispensable to improving the living standards of the citizens, and formulation and implementation of a rational water and drainage plan is one policy for poverty reduction. From this point of view, the GIS model system constructed in the Study to support management of water and sewerage and the plan for its expansion are significant.

Also, the GIS model system constructed in the Study to support cadastral management can enable the rational management of certain land-related information. The clarification of land use and ownership in poor regions can help those regions to formulate policy for eradicating poverty. Therefore, the plan for expansion of the system proposed in the previous chapter will contribute to poverty reduction.

In addition to the above, if a study on the system for sales and registration of land in Kenya can be conducted, and taxation on properties can contribute to tax revenues, which is the basis of national finances, an adequate financial base for poverty reduction can be secured. In respect to that, the expansion of the GIS model system constructed to support cadastral management and the establishment of a land information system through the development of that system, can be used not only as a tool to formulate poverty reduction policy, but also as a tool to support the equitable taxation of property, which will serve as a revenue source for poverty reduction.

(3) Coordination of SOK with AICAD and KISM

The organization responsible for the extensive spatial information in Kenya is considered to be SOK. Therefore, SOK must play a leading role in realizing the establishment of spatial information to contribute to the development of economic infrastructure, as mentioned above.

However, SOK, which has enhanced its technical capacity through the technology transfer in the Study, cannot carry out the task of establishing the vast amount of spatial data infrastructure and cadastral information on its own. This task must be realized through coordination with KISM, which has great technical potential in this field, and AICAD, which has an abundance of equipment and is responsible for its use and training activities. In addition to contributing to the rational establishment of spatial data infrastructure and cadastral information, it is expected that such coordination, through the participation of many concerned institutions, will help raise public awareness of its importance.

5.5 Importance of Strengthened Cooperation

5.5.1 Survey of Kenya and Nairobi City Council

Prior to commencement of this Study, there was no point of contact between SOK and NCC other that the sale and purchase of topographic maps. However, it is important that they strengthen cooperation in the future in regard to the following

- ♦ Provision of geographic information such as the latest topographic maps, aerial photos, and orthophotos
- ♦ Provision of Topo Cadastre Map reflecting changes in property boundaries consequent upon the division of plots
- ♦ NSDI activities for standardization of geographic information and promotion of advanced use
- ♦ Among the data items included in the common data infrastructure of NCC, those that SOK are responsible for should be maintained and provided.
- ♦ Sharing information regarding the development of cadastral GIS system and database

5.5.2 NSDI

a. Present Status of NSDI

The NSDI (National Spatial Data Infrastructure) was conceived in 2001 and organized by the beneficiary agencies, of which SOK is the main agency. The first workshop was held in November 2001, and since then, several workshops have been held so far.

The NSDI consists of three hierarchical organizations. The Executive Committee, consisting of the heads of the beneficiary agencies, is at the top; the Steering Committee, consisting of those departments of the beneficiary agencies that deal with NSDI, come next, and at the bottom are four working groups that actually construct and operate the NSDI.

At present, the four working groups (1: standardization, 2: legislation, 3: education and 4: dissemination) have been organized and have started their respective activities. However, none of the four working groups is yet in a position to undertake real activities or obtain effective results.

b. Strengthened Cooperation with NSDI

In this Study, the specifications of the spatial data infrastructure were determined through discussions with SOK, that plays a central role in NSDI. This Study was completed in accordance with these specifications. It is desirable that the specifications for the spatial data infrastructure adopted in this Study will be reported to the relevant working group as an example of NSDI standardization, and subjected to discussion. It is also hoped that the process of the establishment of the spatial data infrastructure and the experiences in the technology transfer related to that, will be reported and that this will strengthen the activities of the working groups. The spatial data infrastructure of this Study will then contribute to the national spatial data infrastructure.

As one of the counterpart agencies for this Study, SOK needs to maintain regular communications with the other beneficiary agencies (through the use of the Steering Committee and the working groups), based on their experience in the establishment of the spatial data infrastructure in this Study. In view of this, it is necessary for NSDI activities (conferences and meetings for discussion at each level) to be implemented on a regular basis and for the cooperative relationship between the beneficiary agencies to be strengthened, to meet their demands for the establishment of a national spatial data infrastructure.

5.5.3 Related Agencies

(1) AICAD (African Institute for Capacity Development)

AICAD possesses eleven licenses for the latest version of ArcGIS 9.0 plus all the extensions, and has a GIS-dedicated computer laboratory. Therefore, AICAD is certainly an essential organization from which the staff of SOK and NCC will be able to receive training in up-to-date GIS technology; and thus it is important for SOK and NCC to maintain strengthened relationship with AICAD.

In order to strengthen and maintain the relationship with AICAD, mutual cooperation is essential. For instance, the dispatch of lecturers by SOK when AICAD conducts technical training in GIS; and the lease of the necessary GIS data from SOK or NCC when AICAD requires various types of data.

A short term expert has been dispatched to AICAD from February to March 2005, to provide assistance in “the formulation of a utilization plan for GIS facilities”. At present, the expert is collecting information (implementing agency, description and instructors of the training, curriculum, etc.) on existing GIS training programs and institutions using GIS in Kenya, Tanzania and Uganda, together with the counterpart and the long term expert in the second phase of the AICAD project, in order to formulate a plan for AICAD to launch its own activities, while transferring the technical skills and knowledge concerned with such work to the counterpart.