JAPAN INTERNATIONAL COOPERATION AGENCY
DEPARTMENT OF LANDS AND SURVEYS (DL&S)

THE STUDY

FOR

ESTABLISHMENT OF GEOGRAPHIC DATABASE

IN

THE REPUBLIC OF THE GAMBIA

FINAL REPORT

(SUMMARY)

JANUARY 2003

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Preface

In response to a request from the Government of the Republic of Gambia, the Government of Japan decided to conduct the Study for Establishment of Geographic Database in the Republic of Gambia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Akira Nishimura of Kokusai Kogyo Co., Ltd to Gambia, four times between March 2001 and January 2003.

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

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

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

January 2003

Takao Kawakami
President
Japan International Cooperation Agency

Letter of Transmittal

Mr. Takao Kawakami
President
Japan International Cooperation Agency

It is a great honor to submit herewith the final report of the Study for Establishment of Geographic Database in the Republic of the Gambia.

The study team, led by myself, implemented the study from March 2001 to January 2003 in accordance with the contract established with the Japan International Cooperation Agency (JICA).

The study team held discussions with the concerned officials of the Government of the Republic of the Gambia, and carried out field work, e.g. aerial photography, field identification, ground control point survey, technology transfer, etc., at the site. In Japan, aerial triangulation, digital plotting and digital compilation were carried out to produce topographic map data and 1/50,000-scale printed topographic maps. This report compiles the details of the study and its results, and offers suggestions to solve future issues.

On behalf of the study team, I wish to express my heartfelt appreciation to the concerned officials of the Government of the Republic of the Gambia and the concerned agencies for the warm friendship and cooperation they have extended to us during our stay in the Gambia.

I also wish to express my sincere gratitude to JICA, the Ministry of Foreign Affairs, the Ministry of National Land and Transportation, and the Embassies of Japan in Senegal, as well as the government authorities concerned for the valuable advice and cooperation they have provided us during the implementation of this study and the preparation of the reports.

January 2003

Akira Nishimura
Study Team Leader
Study for the Establishment of Geographic Database in the Republic of the Gambia

The Study for Establishment of Geographic Database in the Republic of the Gambia Location Map

Photography

Banjul City

Banjul City

Main Street in Banjul

Main Street in Banjul

Rice field of the Suburbs of Janjangbure

River Gambia near by Temdaba

Photography

The Entrance of DL&S

The Entrance of DL&S

National Control Point

National Control Point and Photo Signal

GPS Survey for National Control Point

GPS Survey for Photo Control Point

Photography

Field Identification

Supplementary Field Identification

The Lecture of Technology Transfer

Technology Transfer of GPS Survey

The Technology Transfer of Field Identification

The Technology Transfer of Photo Interpretatior

Photography

The Presentation of Inception Report

The M/M Meeting of Inception Report

The Presentation of Progress Report

The M/M Meeting of Progress Report

The Presentation of Draft Final Report

The M/M Meeting of Draft Final Report

Photography

Technology Transfer of GPS Software

Technology Transfer of GPS Software

Technology Transfer of Map Revision

Technology Transfer of Map Revision

Technology Transfer

Technology Transfer

Photography

Technology Transfer

Technology Transfer

Technology Transfer

Technology Transfer

Technology Transfer

Technology Transfer

Abbreviations

C/P:	Counter Part
B/W:	Black And White Film
DF/R:	Draft Final Report
DL&S:	Department of Lands & Surveys
DTM:	Digital Terrain Model
F/R:	Final Report
GAMTEL:	Gambia Telecommunications Co., Ltd.
GIS:	Geographic Information System
GPS:	Global Positioning System
GPTC:	Gambia Public Transport Corporation
GUI:	Graphical User Interface
IC/R:	Inception Report
IGS:	International GPS Service
IEC:	Independent Election Committee
ITRE2000:	International Terrestrial Reference Frame 2000
JICA:	Japan International Cooperation Agency
M/M:	Minutes of Meeting
NAWEC:	National Water and Electricity Company Ltd.
NEA:	National Environment Agency
OJT:	On the Job Training
PM:	Permanent Munumentation
RINEX:	Receiver Independent Exchange Format
PR/R:	Progress Report
S/W:	Scope of Work
TIFF:	Tag Image File Format
USAID:	United States Agency International Development
WGS-84:	World Geodetic System 1984

Preface

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Study Area Map

Photography

Abbreviations

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1. Summary of the Study

1.1 Background and Objectives of the Study

(1) Background of the Study

In 1999, the Republic of the Gambia (hereinafter referred to as "the Gambia") drew up "VISION 2020", which laid down the nation's long-term economic goals. However, up-to-date maps needed to formulate and implement the development programs in this vision were not available. The production of digital topographic maps at a scale of 1:50,000 and the construction of databases operable on a geographic information system (hereinafter referred to as "GIS") thus became a pressing issue.

Meanwhile, the Department of Lands and Surveys (hereinafter referred to as "DL&S"), the agency responsible for generating geographic information in the Gambia, was faced with the important task of training its staff in techniques for generating and revising geographic data and GIS.

Based on the above background, the Government of the Gambia made a request to the Government of Japan in July 1999 for the production of national base maps covering the entire country and the transfer of the technology used in the production of national base maps. In response to this request, the Government of Japan dispatched a preliminary study team, and the S/W was signed and exchanged on December 18, 2000.

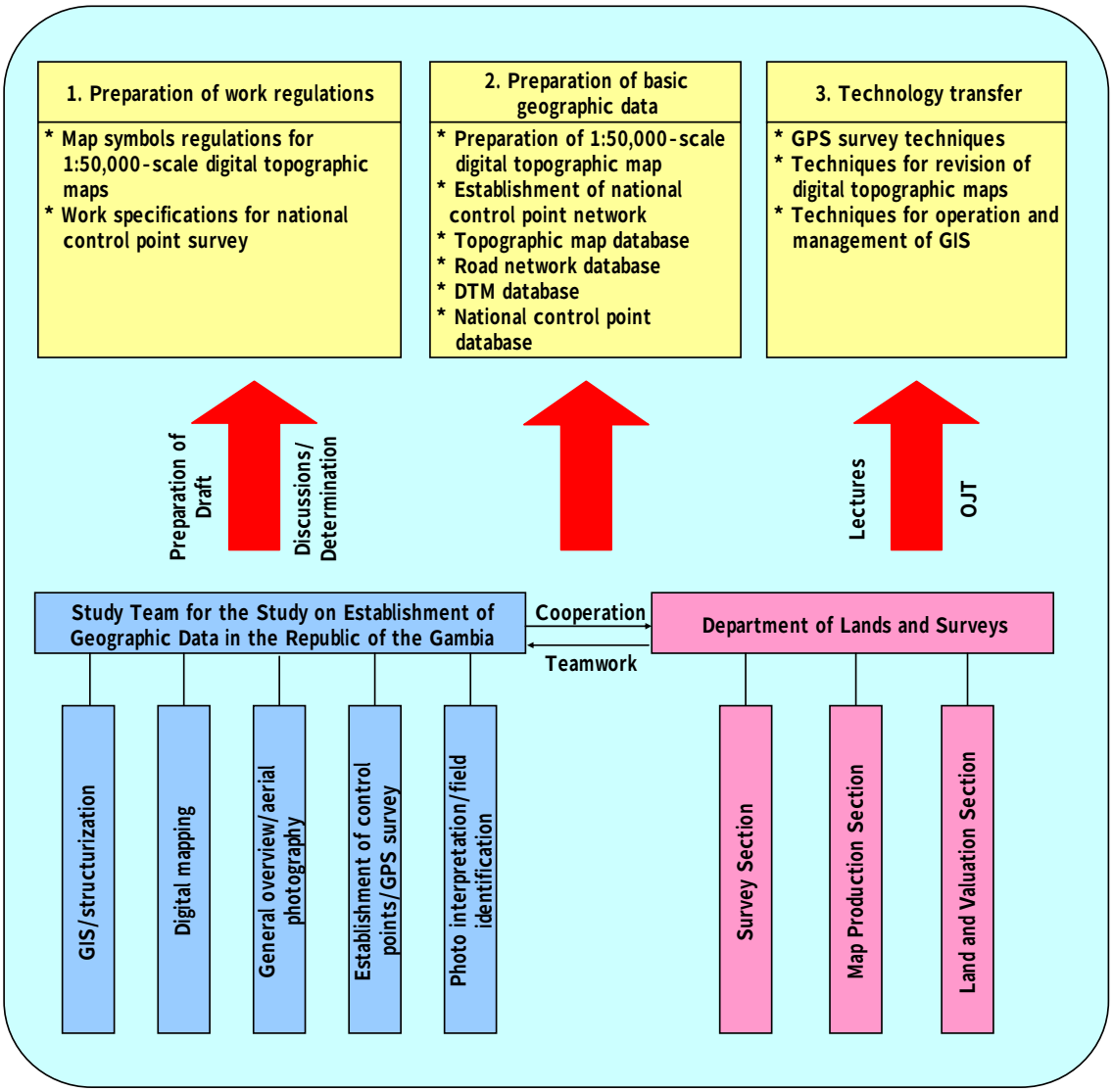
(2) Objectives of the Study

The objectives of the Study were as follows:

- ♦ To produce digital topographic maps (national base maps) at a scale of 1:50,000 and basic GIS data.
- ♦ To transfer technology related to the Study to DL&S

1.2 Overall Frame of Study Works

The Study Works were implemented as described in the frame below:



1.3 Study Area

The Study Area included all of the Gambia, an area equivalent to about 11,295km^2. (Refer to the location map on the opening page)

1.4 Contents of the Study

1.4.1 Outline of work content and volume

An outline of the content and volume of the works implemented in the Study are summarized by year in Table 1.1.

Table 1.1 Outline of Work Content and Volume

Year	Phase	Work Item	Description	Work Volume
First Year	Preparations in Japan	a-1: Collection/arrangement of relevant documents/information	Existing documents and other relevant data was collected, partly from the Internet, and then arranged.	
		a-2: Examination of specifications for digital map symbols and GIS data	The specifications for digital map symbols of the 1/50,000-scale topographic maps and GIS data were examined.	
		a-3: Examination of equipment for technology transfer	The equipment to be used in technology transfer was examined.	
		a-4: Planning of the national control point network and ground control point survey	The national control point and ground point surveys were planned.	
		a-5: Formulation of the Inception Report	The Inception Report, which included the entire contents of the Study, was prepared.	20 copies in English
Second Year	Phase 1 in Gambia	b-1: Explanation/discussion of the Inception Report	Meetings were held in Gambia to explain and discuss the entire contents of the Study, and an agreement was reached.	
		b-2: Assessment of the current situation relevant to the preparation of geographic information	DL&S' current operation and management of geographic information was assessed.	
		b-3: Discussions on technical specifications	Discussions were held with DL&S on technical specifications for control points, etc.	
		b-4: Selection/monumentation of national control points and selection of ground control points	National control points were selected and monumented and ground control points were selected.	17 national control points, 11 ground control points
		b-5: Discussions on the equipment used in the transfer of map revision techniques	Discussions were held with DL&S on the equipment to be used in the transfer of map revision techniques.	15 GPS benchmarks
	Phase 2 in Gambia	c-1: Observations and computations of national control points	GPS observations were performed on national control points（with the cooperation of DL&S）.	17 national control points
		c-2: Ground control survey	GPS observations, and simple leveling when necessary, was carried out on the ground control points（with the cooperation of DL&S）.	11 ground control points, 15 GPS benchmarks
		c-3: Aerial Photography	B/W aerial photos at a scale of 1/50,000 were taken（local subcontractor）。	Approx. 11,295km^2
		c-4: Discussions on specifications for map symbols and GIS data	The specifications for map symbols and GIS data were discussed with DL&S.	
		c-5: Photo interpretation and field identification	Photos were interpreted and field identification was conducted.	Approx. 11,295km^2
	Phase 1 in Japan	d-1: Formulation of manuals for technical transfer	A manual for the transfer of map revision techniques was prepared.	
		d-2: Aerial triangulation	The coordinates of pass points and tie points required for digital plotting were computed.	456 models
		d-3: Formulation of Progress Report	The Progress Report including the results of the study work in the first and second years was formulated.	20 copies in English
Third Year	Phase 2 in Japan	e-1: Digital Plotting	Topographic and planimetric features were digitally plotted.	Approx. 11,295km^2
		e-2: Digital compilation（Encoding）	The data obtained from digital plotting was compiled in accordance with the map symbols	Approx. 11,295km^2
		e-3: Proposal of geographic information applications system	A proposal was formulated after examining the results of （b-2）.	
	Phase 3 in Gambia	f-1: Explanation/discussion of Progress Report	Meetings were held with DL&S to explain and discuss the Progress Report and an agreement was reached	
		f-2: Discussions on contents of technical transfer seminars	The contents of the technical transfer seminars were examined and discussed with DL&S and then decided on.	
		f-3: Field completion	Items that were obscure in the digital plotting/compilation work were investigated in the field, and the administrative boundaries and names were finalized.	Approx. 11,295km^2
	Phase 3 in Japan	g-1: Supplementary digital compilation	The results of the field completion were digitally compiled.	Approx. 11,295km^2
		g-2: Preparation of GIS data	Several GIS databases were prepared	Approx. 11,295km^2
		g-3: Creation of data for printed maps	Data for printed maps were created in sheet units	Approx. 11,295km^2
		g-4: Production of printed maps	Plate films were created and 1/50,000-scale topographic maps were printed.	27 sheets at a scale of 1/50,000
		g-5: Formulation of the Draft Final Report	The Draft Final Report including the results of all the study work and proposals for DL&S was formulated.	20 copies in English
	Phase 4 in Gambia	h-1: Transfer of Technology	Mainly map revision techniques were transferred.	
		h-2: Technical transfer seminar	The seminar presented the contents of the Study and the technologies that were transferred, as well as the possibilities of GIS.	
		h-3: Explanation/discussions on Draft Final Report	The Draft Final Report was explained to and discussed with the DL&S, and an agreement was reached.	
	Phase 4 in Japan	i-1: Formulation of Final Report	The Final Report was formulated taking into consideration the opinions of the DL&S.	20 copies in English

1.4.2 Schedule of Study Work Implemented

The flow chart of all the works implemented in the Study is shown in Figure 1.1.

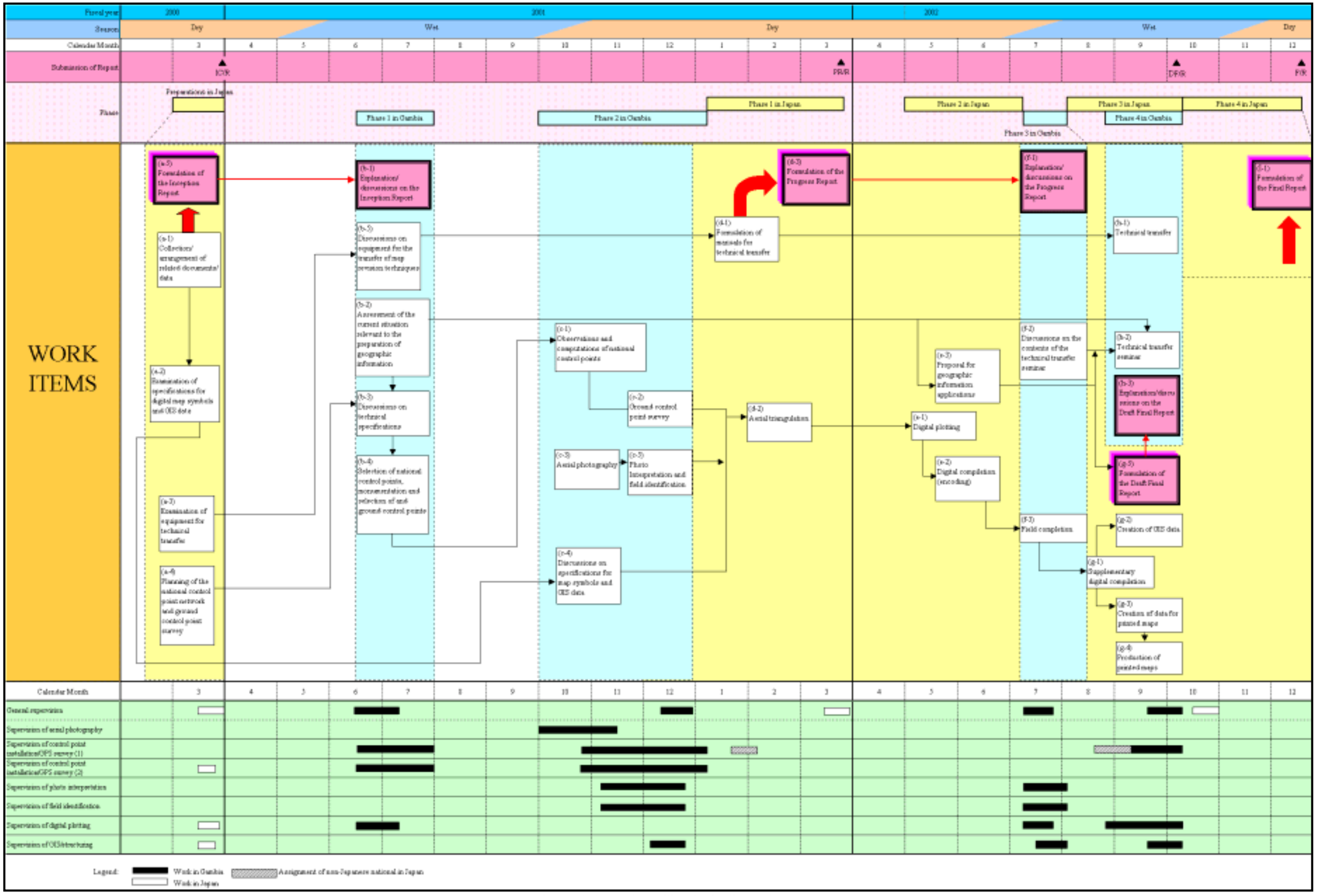


Figure 1.1 Flow Chart of All Works

1.5 Results and Significance of Study Works

Through implementation of the Study Works, the following significant results were obtained.

Results	Specification of results	Features and significance of results
1. Preparation of basic geographic data		
* Digital topographic map (including topographic map database)	Scale: 1:50,000, 27 sheets (Printed maps and digital data)	Topographic maps expressing the latest geographic information were obtained in the existing printed map form as well as in digital form to replace the existing topographic maps. As the topographic maps were produced in digital form, the updating of geographic information corresponding to developments and changes in land use is much simpler, and DL&S is more likely to update topographic maps independently. Also, the services that use geographic information based on GIS spatial data shall be greatly broadened.
* Establishment of national control point network	First order national control points: 17 points	A new national control point network, tied to the World Geodetic System with WGS84 as the reference ellipsoid, was established by GPS surveying to replace the existing control point network. By doing so, all geographic information in the Gambia can be tied to the World Geodetic System and 2 (of the 17) control points, which are of particularly high accuracy, can be used as reference control points for the World Geodetic System in West Africa.
* Preparation of various databases	Road network, DTM, and national control point databases	The road network and DTM databases were constructed using the topographic map database. These are basic databases that are expected to be used for road administration and disaster simulation. With the national control point database, the national control points, which were managed by an analogue base in the past, can now be managed in digital format. In future, by successively inputting control points determined by the new geodetic standard, it is possible to consolidate management of geographic information.
2. Technology transfer GPS survey techniques		GPS survey techniques, from observation planning to analysis, were transferred mainly through OJT; DL&S is now able to carry out such works on their own. In future, based on this outcome, the densification of control points based on the new geodetic system can be expected.
Revision techniques for digital topographic maps		The technology transfer was conducted focusing on digital compilation, and digital data on topographic and planimetric features can now be handled at DL&S. In future, DL&S will be able to carry out the digitization of topographic maps and revision of digital topographic maps independently based on these techniques.
Techniques for the operation and maintenance of GIS		Basic techniques for the operation and maintenance of the GIS using the various databases constructed were transferred to DL&S. This was the first step in the practical operation and maintenance of GIS, and the use at DL&S is likely to broaden.

Results	Specification of results	Features and significance of results
3. Preparation of work specifications	Map symbols regulations for 1:50.000-scale digital topographic maps, work specifications for national control point survey	Two work specifications (drafts) were prepared based on the digital topographic maps (1:50,000) and GPS control point survey carried out in the Study. In future, DL&S shall carry out works based on these drafts, and the details and results shall be examined to create official regulations.

2． Basic Policies and Implementation of Study Work

2.1 Basic Policies and Approaches of Study Work

(1) Basic technical policies

The basic policies from a technical aspect were established as follows:

- ♦ Preparation of basic geographic data for general use
- ♦ Preparation of technical specifications and work regulations
- ♦ Thorough quality and accuracy control
- ♦ Implementation of hands-on technology transfer
- ♦ Proposals on the operation/maintenance, applications and long-term plans of geographic information

(2) Technical approaches

The approaches based on the basic policies were as follows:

①Preparation of basic geographic data for general use

Basic geographic data shall be generated through the production of digital topographic maps at a scale of 1:50,000 and the establishment of national control points.

②Preparation of technical specifications and work regulations

Technical specifications and work regulations shall be prepared for national control point surveys and digital topographic maps at a scale of 1:50,000.

③Thorough quality and accuracy control

Quality and accuracy control suitable to the technical content shall be implemented.

④Implementation of hands-on technology transfer

Technologies related to the Study shall be transferred to DL&S in the form of lectures and OJT.

⑤Proposals on the operation/maintenance, applications and long-term plans of geographic information

Proposals shall be made on the operation/maintenance, applications and long-term plans of geographic information after assessing the current situation.

(3) Basic Operational Policies

The basic policies from an operational aspect were established as follows:

- ♦ Close interaction with all concerned agencies
- ♦ Flexible schedule to cope with unexpected situations
- ♦ Detailed preparations
- ♦ Active promotion of the products of the Study
- ♦ Exhaustive safety measures

(4) Operational Approaches

The approach based on the basic policies were as follows:

①Close interaction with all concerned agencies

Discussions shall be held with DL&S and all other concerned agencies regarding the Study to ensure smooth operation of works.

②Flexible schedule to cope with unexpected situations

The schedule shall be revised if there are any delays in individual works in order to minimize the effect.

③Detailed preparations

Detailed preparations for the various works shall be made in advance in an effort to move up the work schedule.

④Active promotion of the products of the Study

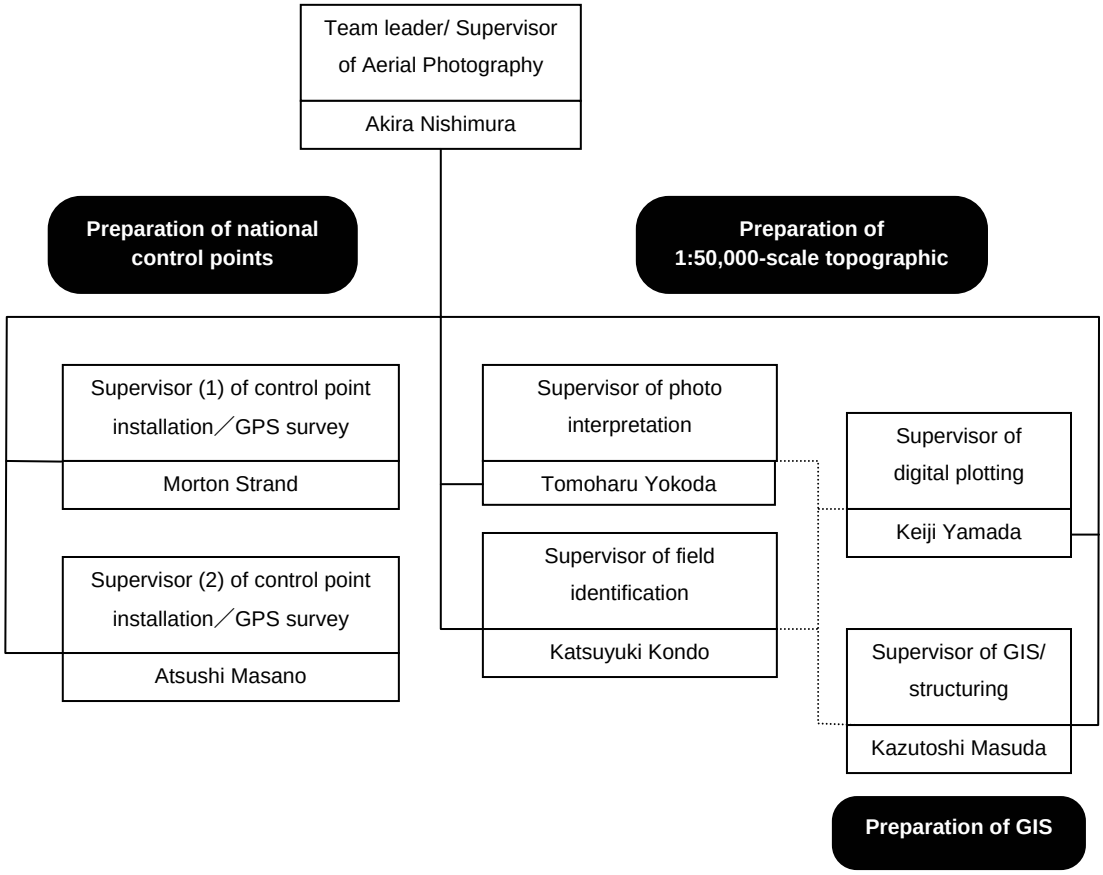
The products of the Study shall be actively promoted among the concerned agencies through technology transfer seminars.

⑤Exhaustive safety measures

Information on safety and security shall be obtained and a means of communication shall be secured prior to implementation of the Study.

2.2 System and Period of Study Work Implementation

2.2.1 System of Study Work Implementation



Study Team for the Project to Establish a Geographic Database in the Gambia

2.2.2 Organization and Work Allocation of Study Team

(1) Organization of the Study Team

The study team was organized as follows:

Title	Name
Team Leader/ Supervisor of Aerial Photography	Mr. Akira Nishimura
Supervisor (1) of Control Point Installation/GPS Survey	Mr. Morten Strand
Supervisor (2) of Control Point Installation/GPS Survey	Mr. Atsushi Masano
Supervisor of Photo Interpretation	Mr. Tomoharu Yokoda
Supervisor of Field Identification	Mr. Katsuyuki Kondo
Supervisor of Digital Plotting	Mr. Keiji Yamada

Title	Name
Supervisor of GIS/Structuring	Mr. Kazutoshi Masuda
Coordinator (1)	Mr. Masahiko Takahashi
Coordinator (2)/Database	Ms. Chiyo Kigasawa

2.2.3 Schedule of Implemented Study Work

The details of the study schedule are as follows:

First year:	「Preparations in Japan」	Mar 8 - Mar 22, 2001
Second year:	「Phase 1 in Gambia」	Jun 13 - Jul 30, 2001
	「Phase 2 in Gambia」	Oct 2, 2001 - Jan 10, 2002
	「Phase 1 in Japan」	Jan 11 - Mar 29, 2002
Third year:	「Phase 2 in Japan」	Jul 1 - Jul 12, 2002
	「Phase 3 in Gambia」	Jul 13 - Aug 14, 2002
	「Phase 3 in Japan」	Aug 15 - Aug 22, 2002
	「Phase 4 in Gambia」	Aug 23 - Oct 13, 2002
	「Phase 4 in Japan」	Oct 14, 2002 - Jan 8, 2003

3． Results of Study Work

3.1 Details and Results of Study Work

3.1.1 Preparatory Work

(1) Preparations for creation of 1:50,000-scale topographic maps

In preparing for the creation of topographic maps, drafts for digital map symbols (method of symbol representation, additions to/changes in represented features) and map sheet division were formulated.

(2) Preparations for GPS survey

In preparing for the GPS survey, plans for the national control point survey, ground control point survey and aerial photography were formulated.

(3) Preparations for GIS databases

In preparing for the GIS databases, the databases to be constructed were determined and specifications (draft) for them were examined.

(4) Preparations for technology transfer

In preparing for the technology transfer, the techniques to be transferred were determined and the equipment to be used was examined.

(5) Preparations for assessing the current situation of geographic information and proposal

The content of the survey for assessing the current situation and for the proposal were examined based on the information collected on geographic information.

3.1.2 Establishment of National Control Point Network

(1) Determination of specifications for national control points

In the determination of specifications, the positioning of national and ground control points, the method of tying the national control points and ground control point network to IGS points, as well as the observation time and computation method were discussed and determined.

Discussions on specifications

As for the survey standard, the reference ellipsoid was changed from Clarke 1880 to WGS-84 in order to tie to the World Geodetic System.

Furthermore, an original standard for monumentation was proposed and agreed upon

(2) Point selection and monumentation

①Point selection

Of the 17 zero and first order control points, existing control points were to be used in their present condition for 10, re-monumented or reinforced control points were to be used for 4, and the remaining 3 were to be newly established points.

As for the 26 ground control points, existing control points were to be used in their present condition for 11, and natural targets were selected for the remaining 15.

②Monumentation

Four (4) of the existing control points were reinforced, and the three newly established control points were monumented in accordance with the monumentation standard decided on in the discussions on specifications.

(3) GPS Survey

①Zero order control point survey

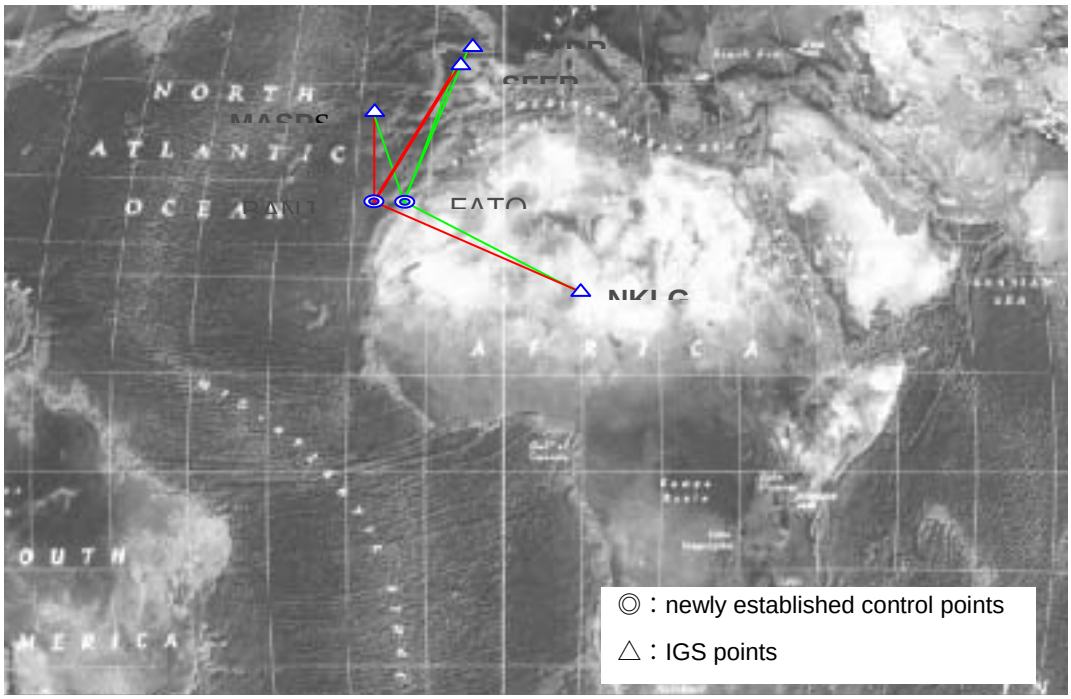


Figure 3.1　Observation Map for Zero Order Control Point Survey

In the zero order control point survey, observations were performed at Banjul and Fatoto and observation data was obtained from IGS points in the vicinity to carry out the analysis computations. (Refer to Figure 3.1 for the observation map) The divergence in the baseline analysis and the final values for the zero order control points are shown in Table 3.1 and Table 3.2.

Table 3.1　Divergence

Site	X(ECEF)	Y(ECEF)	Z(ECEF)
N2（BANJ）	10.7mm	6.2mm	3.1mm
N17（FATO）	5.3 mm	8.2mm	2.3mm

Table 3.2　Final Values

Site	Latitude（N）	Longitude（W）	Ell.Hgt.
N2（BANJ）	13 ° 27 ′ 08.56154	16 ° 35 ′ 22.27207	37.863
N17（FATO）	13 ° 24 ′ 22.30210	13 ° 53 ′ 29.64585	67.147

②First order control point survey

Figure 3.2 Observation Map for First Order Control Point Survey

The first order control point survey was conducted using zero order control points (N2, N17) as known points. (Refer to Figure 3.2 for the observation map)

As for the results of the analysis computations, the mean square error of all the control points was less than a few centimeters. (Refer to Table 3.3.)

Table 3.3 First Order Control Point Adjustment Results

Point Id	Class	Latitude	Longitude	Ellip Hgt	Sd. X	Sd. Y	Sd. Z
N2	Control	13° 27' 08.56154" N	16° 35' 22.27207" W	37.8630	0.000	0.000	0.000
N17	Control	13° 24' 22.30210" N	13° 53' 29.64585" W	67.1468	0.000	0.000	0.000
L1	Adjusted	13° 28' 52.33167" N	16° 40' 50.54748" W	44.2311	0.018	0.006	0.005
N1	Adjusted	13° 05' 55.57910" N	16° 45' 49.03416" W	35.7217	0.016	0.005	0.005
N10	Adjusted	13° 46' 59.13647" N	14° 59' 33.45374" W	45.1392	0.023	0.007	0.007
N11	Adjusted	13° 32' 50.63285" N	15° 01' 14.98621" W	58.5378	0.022	0.007	0.006
N12	Adjusted	13° 33' 11.36680" N	14° 44' 54.04608" W	50.9523	0.023	0.007	0.007
N13	Adjusted	13° 37' 30.89831" N	14° 30' 57.18141" W	75.9958	0.021	0.006	0.006
N14	Adjusted	13° 18' 58.72146" N	14° 31' 42.63683" W	58.6953	0.022	0.006	0.006
N15	Adjusted	13° 30' 07.56842" N	14° 12' 22.68712" W	76.8046	0.018	0.005	0.005
N16	Adjusted	13° 13' 09.81567" N	14° 11' 15.11171" W	89.7529	0.020	0.006	0.006
N3	Adjusted	13° 10' 04.52137" N	16° 24' 59.74873" W	56.0345	0.016	0.005	0.005
N4	Adjusted	13° 31' 43.12949" N	16° 10' 36.05240" W	62.6834	0.017	0.005	0.005
N5	Adjusted	13° 13' 42.41408" N	16° 05' 48.31298" W	44.5012	0.018	0.006	0.005
N6	Adjusted	13° 14' 50.70676" N	15° 50' 06.57357" W	41.1258	0.021	0.007	0.006
N7	Adjusted	13° 34' 15.15276" N	15° 48' 41.35211" W	59.3074	0.023	0.007	0.007
N8	Adjusted	13° 44' 18.16614" N	15° 23' 46.85361" W	55.4986	0.023	0.007	0.007
N9	Adjusted	13° 23' 51.97874" N	15° 23' 28.20885" W	42.6921	0.023	0.007	0.007

③Ground control point survey

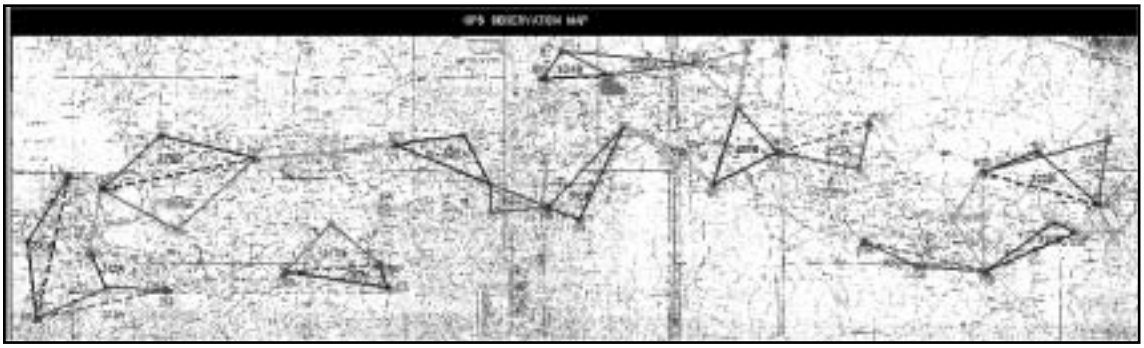


Figure 3.3 Observation Map for Ground Control Point Survey

The ground control point survey was conducted using zero and first order control points as known points. (Refer to Figure 3.3 for the observation map) The results of the analysis computations are shown in Table 3.4.

Table 3.4 Coordinate and Standard Deviation of Ground Control Points

Point Id	Latitude	Longitude	Ellip Hgt	φ(m)	λ(m)	ELL HT(m)
G1	13° 18' 34.34069" N	16° 47' 09.28606" W	39.169	0.013	0.013	0.037
G2	13° 35' 23.69764" N	16° 25' 20.69608" W	67.857	0.014	0.018	0.136
G3	13° 10' 43.94695" N	15° 48' 32.13743" W	43.476	0.029	0.033	0.157
G4	13° 21' 34.69058" N	15° 17' 50.97591" W	75.788	0.011	0.013	0.124
G5	13° 44' 52.52519" N	15° 16' 42.06503" W	73.488	0.010	0.011	0.065
G6	13° 27' 48.10335" N	14° 56' 24.51859" W	65.087	0.012	0.014	0.094
G7	13° 45' 37.70286" N	14° 51' 56.25512" W	78.051	0.087	0.299	0.427
G8	13° 14' 21.06039" N	14° 23' 14.18069" W	63.248	0.027	0.037	0.252
G9	13° 32' 52.75088" N	14° 03' 18.56270" W	79.198	0.018	0.021	0.216
G10	13° 20' 06.85477" N	13° 56' 34.87234" W	45.654	0.014	0.015	0.131
G11	13° 32' 58.68276" N	13° 53' 25.40467" W	47.534	0.034	0.051	0.207
L2	13° 17' 10.05005" N	16° 37' 05.55770" W	44.735	0.027	0.072	0.155
L3	13° 10' 48.20742" N	16° 34' 31.91352" W	46.080	0.009	0.012	0.077
L4	13° 19' 59.77416" N	16° 23' 04.23327" W	32.574	0.028	0.035	0.267
L5	13° 21' 07.03308" N	15° 58' 02.08557" W	58.238	0.038	0.033	0.227
L6	13° 33' 27.73807" N	15° 54' 53.16970" W	56.373	0.023	0.023	0.158
L7	13° 23' 02.64002" N	15° 31' 47.65292" W	62.730	0.021	0.028	0.202
L8	13° 27' 31.78708" N	15° 32' 09.18157" W	61.390	0.019	0.025	0.18
L9	13° 34' 33.95901" N	15° 36' 16.27877" W	54.103	0.027	0.035	0.253
L10	13° 36' 52.20314" N	15° 10' 14.97213" W	41.517	0.021	0.029	0.144
L11	13° 40' 39.38941" N	14° 52' 27.40182" W	46.606	0.022	0.024	0.165
L12	13° 30' 10.50734" N	14° 29' 58.47598" W	54.375	0.035	0.057	0.168
L13	13° 22' 12.35086" N	14° 17' 03.92469" W	53.717	0.030	0.047	0.191
L14	13° 21' 32.59331" N	14° 00' 18.47807" W	77.030	0.021	0.022	0.188
L15	13° 19' 35.36952" N	13° 50' 57.55162" W	86.247	0.015	0.016	0.152

(4) Determination of Elevation

The elevations of national control points and ground control points were determined based on the following methods:

- ♦ Elevation determined by the height data of existing control points
- ♦ Elevation determined by direct leveling
- ♦ Elevation determined by a geoid map

The horizontal coordinates, ellipsoid height, geoid height and standard height of the sought after points are indicated in Table 3.5.

Table 3.5 List of Horizontal Coordinates, Ellipsoid Height, Geoid Height and Standard Height

Pt Name	Easting	Northing	Ellip Hgt	Geoid Hgt	Std Hgt
N1	308799.219	1448725.639	35.722	28.407	7.315
N2	327928.009	1487718.776	37.863	28.879	8.984
N3	346472.130	1456138.196	56.035	28.756	27.279
N4	372666.538	1495903.916	62.683	29.460	33.223
N5	381169.728	1462659.470	44.501	29.322	15.179
N6	409521.854	1464648.187	41.126	30.055	11.071
N7	412204.125	1500414.022	59.307	30.177	29.130
N8	457149.764	1518827.885	55.499	30.475	25.024
N9	457649.364	1481157.992	42.692	30.858	11.834
N10	500797.061	1523737.746	45.139	30.282	14.857
N11	497746.273	1497671.793	58.538	30.650	27.888
N12	527228.063	1498322.651	50.952	30.624	20.328
N13	552364.257	1506333.514	75.996	30.398	45.598
N14	551063.985	1472164.243	58.695	31.112	27.583
N15	585895.847	1492801.327	76.805	30.475	46.330
N16	588029.867	1461540.536	89.753	31.344	58.409
N17	620008.084	1482325.174	67.147	30.810	36.337
NJAU	479607.344	1520876.709	62.568	30.383	32.185
G1	306547.815	1472061.137	39.169	28.519	10.650
G2	346109.606	1502822.728	67.857	29.213	38.644
G3	412339.469	1457057.969	43.476	30.106	13.370
G4	467786.374	1476926.421	75.788	30.901	44.888
G5	469908.035	1519865.574	73.488	30.435	43.053
G6	506478.609	1488378.896	65.087	30.793	34.294
G7	514526.023	1521240.123	78.051	30.271	47.780
G8	566381.948	1463667.654	63.248	31.280	31.968
G9	602234.832	1497934.247	79.198	30.356	48.842
G10	614470.385	1474452.402	45.654	31.027	14.627

Pt Name	Easting	Northing	Ellip Hgt	Geoid Hgt	Std Hgt
G11	620064.028	1498191.396	47.534	30.322	17.212
L1	318075.898	1490973.347	44.231	28.806	15.425
L2	324701.271	1469346.574	44.735	28.691	16.044
L3	329251.811	1457583.142	46.080	28.643	17.437
L4	350051.664	1474409.202	32.574	28.978	3.596
L5	395255.825	1476261.667	58.238	29.754	28.484
L6	401023.572	1498996.793	56.373	29.970	26.403
L7	442625.444	1479670.258	62.730	30.780	31.950
L8	441995.882	1487940.015	61.390	30.813	30.577
L9	434598.239	1500926.843	54.103	30.554	23.549
L10	481522.051	1505099.172	41.517	30.596	10.921
L11	513595.509	1512075.367	46.606	30.420	16.186
L12	554155.858	1492807.918	54.375	30.663	23.712
L13	577483.305	1478175.884	53.717	30.910	22.807
L14	607732.424	1477058.794	77.030	30.946	46.084
L15	624623.727	1473530.128	86.247	31.051	55.196

3.1.3 Production of 1:50,000-scale Topographic Maps

(1) Determination of specifications for 1:50,000-scale topographic maps

①Determination of the standards for production of topographic maps

The standards (i.e. projection method, UTM zone, origin of coordinates and their values and scale factor) for the production of topographic maps were decided on.

②Digital map symbols

The digital map symbols were created based on the 1:50,000-scale analog map symbols. The digital map symbols were arranged and published in the “National Base Map Symbols Regulations (Draft)”

③Marginal information

As a rule, the marginal information was to be created in the same form as the analog maps. DL&S also agreed that the following English text would be indicated on the printed maps as part of the marginal information:

“This map was prepared jointly by the Japan International Cooperation Agency (JICA) under the Japanese Government Technical Cooperation Program and the Government of the Republic of the Gambia”

④Sheet division

A sheet division plan covering the entire country with 27 maps each 15' x 15' in size was adopted.

(2) Aerial Photography

①Selection of subcontractor

The following South African company was selected as the subcontractor:
Digital Topographic Mapping Services (D.T.M.)

②Aerial photo signalization

Prior to the taking of aerial photos, aerial photo signals were installed at a total of 28 points (15 control points and 13 ground control points). Pricking was performed for the remaining 2 control points and 13 ground control points. The specifications for the aerial photo signals are shown in Table 3.6.

Aerial Photo Signal (Y type)

Pricking of Natural Marker (Well)

Table 3.6 Specifications for Aerial Photo Signals

Form	Y type (3 wing)	＋type (4 wing)	T type (3 wing)	□type (square)
Color	White	White	White	White
Size	1m×3m（1wing）	1m×3m（1wing）	1m×3m（1wing）	3m×3m

③Permit for Photography

Applications for landing and airport use permits as well as photography permits were filed at the concerned agencies (Department of Aviation, Ministry of Defense, Government of Senegal) in both Gambia and Senegal. All permits were obtained.

④Aerial Photography

a. Taking of photos

Aerial photography work began on November 7, 2002 and photos were taken on the 12th, 13th, and 14th.

b. Inspection of photos

After being developed and printed, the photos taken were inspected. All were adopted thus completing the aerial photography work.

c. Permit to take out photographic film

As the photographic film was to be used in subsequent works, a permit was obtained from DL&S to take the film to Japan.

(3) Field Identification/ Aerial Photo Interpretation

①Field identification

The field identification was conducted using existing maps, on which the results were indicated. After obtaining the aerial photos, the results were also indicated on the contact print overlays.

②Aerial photo interpretation

The aerial photo interpretation was performed using the "Aerial Photo Interpretation Handbook" prepared based on the information gathered in the field identification. The results were indicated on the contact print overlays.

Sample of Aerial Photo Interpretation Handbook

(4) Aerial Triangulation

①Aerial triangulation

Aerial triangulation was carried out based on the WGS-84 coordinate system.

a. Scope of aerial triangulation

Aerial triangulation covered the entire country of the Gambia.

b. Control points used for adjustment computations (horizontal positions and heights)

Point selection

All control points planned for use in adjustment computations were employed.

Pricking

c. Method of adjustment

Adjustment computations were carried out by the bundle method for which the whole area was handled as one block.

d. Results of adjustment computations

The residuals of the control points after the adjustment were within the given limit, thus ensuring the required accuracy.

Film scanner

②Raster conversion of aerial photos

The rasterization of aerial photos was performed after deciding on the resolution, data format and other specifications. The scope of raster conversion was equal to that of aerial triangulation.

(5) Digital Plotting/Digital Compilation

①Digital plotting

Digital plotting was carried out using the results of the field identification and aerial triangulation, while referring to the "Aerial Photo Interpretation Handbook".

The implemented work volume and equipment used were as follows:

Digital plotting

Plotted area： 11,375.6km^2

Equipment used： P2, P3 Planicomp Analytical Plotter

②Digital compilation (Encoding)

Using the results of digital plotting and field identification and the "Photo Interpretation Handbook" as a reference, digital compilation (encoding) was carried out in compliance with the digital map symbols regulations.

The implemented work volume and equipment used were as follows:

Digital compilation

Compiled area：	11,375.6km^2
Software used：	Micro Station 95
	TNT mips

(6) Field Completion Survey

Any uncertainties that arose concerning the position and/or representation of building symbols, power lines/radio towers, etc during digital plotting and digital compilation were confirmed in the field completion survey. The information was also collected and verified indoors. Furthermore, surveys were conducted to confirm any secular change occurring after compilation work was completed. The results of the field completion were indicated on two output maps.

Using these results, supplementary digital compilation work was carried out to produce map data in sheet units.

(7) Production of Printed Maps

①Sheet division

The plan to produce 27 sheets, each 15' x 15' in size based on "(1) Determination of specifications for 1:50,000-scale topographic maps, ④ Sheet division" (i.e) was formulated.

②Marginal information

The digital marginal information was created based on the existing 1:50,000-scale analog maps. Discussions were held to determine the position and coloring of the marginal information.

③Collection of data on marginal information

The map names and magnetic declination based on the new sheet division were obtained from DL&S and true north was recalculated.

④Production of printed map data

The newly created marginal data and map data generated from the supplementary digital compilation were combined and processed to produce printed map data in sheet units.

⑤Production of films for printing

From the produced printed map data in sheet units, reproduction films of each color (5 colors) were produced.

⑥Printing

Aluminum plates were produced with the reproduction film to carry out printing. For each sheet, 1003 copies were made.

3.1.4 Construction of GIS Databases

(1) Examination/discussions/determination of databases to be constructed

①Examination of GIS databases to be constructed

The GIS databases expected to be effectively used in the Gambia were identified as follows:

- ♦ Topographic map database
- ♦ Road network database
- ♦ Digital terrain model (DTM) database
- ♦ National control point database

②Examination of specifications for GIS databases (draft)

The specifications for the GIS databases were examined using the topographic map data specifications as a reference.

(2) Discussions/Determination of Specifications for GIS Data

Discussions on the specifications for the databases specified in (1) were held with DL&S with the following results:

①Specifications for topographic map database

The topographic and planimetric features in the topographic map database were to be structured (data topology) and a systematic code number was to be attached to each one.

②Specifications for road network database

The necessary data was to be extracted from the topographic map database in order to construct the road network database, and a 4-digit attribute code number was to be attached to each of the data.

③Specifications for DTM database

The DTM database was to be constructed with mesh at 50m intervals.

④Specifications for national control point database

The positions of national control points were to be prepared as point data. The results of the nation control points (X.Y.H) and the point descriptions were to be prepared as attribute data.

(3) Construction of GIS Database

The "topographic database", "road network database", "DTM database" and "national control point database" were constructed based on the results of discussions with DL&S.

①Topographic map database

The topographic map database was constructed from the digital topographic map data by structuring the digital data in accordance with database use and attaching a systematic code to the topographic and planimetric features.

②Road network database

The road network database was constructed by extracting the centerlines of the road data from the constructed topographic map database mentioned above, tying the data in sheet units to it, and attaching an attribute code number.

③DTM database

The DTM database was constructed by creating 50 m interval mesh data from the contours and spot elevation data of the constructed topographic map database mentioned above, and by indicating elevation values on each mesh.

④National control point database

The national control point database was constructed with text information (i.e. the coordinate values of newly established national control points, the dates they were installed, etc) as text attribute data and image information (i.e. photos of site conditions) as image attribute data.

3.1.5 Technology Transfer

(1) Method and Objective of Technology Transfer

①Method

Technology transfer was implemented in the form of lectures, on-the-job training (OJT) and technical transfer seminars.

②Objective

The objective of technology transfer was to enable the counterparts to apply and administer the technologies independently.

(2) Target of Technology Transfer

The targets of the technology transfer were as follows:

- ♦ GPS surveying (the candidates were 3 technical experts from DL&S)
- ♦ Field identification and photo interpretation (the candidates were 2 technical experts from DL&S)
- ♦ Map revision

(3) Technology Transfer for GPS Survey

①Theory and Planning of GPS surveys

The technology transfer for the general theory and planning of GPS surveys was carried out in the form of lectures.

As a result, they were for the most part able to master planning techniques.

Scene from lecture

②Point selection and monumentation

The technology transfer for point selection and monumentation was carried out in the form of OJT while point selection was being implemented based on the planning map.

As a result, the counterparts acquired the ability to carry out point selection and the monumentation of common control points in GPS surveys on their own.

③Aerial photo signalization

The technology transfer for aerial photo signalization was carried out in the form of OJT during Study implementation. The technology transfer regarding the relationship between signal size and photo scale as well as in signal shapes was carried out in the form of lectures in a previously arrangement.

As a result, the counterparts reached a level where they were able to independently install aerial photo signals suitable to conditions.

④Observations

The technology transfer for observations using GPS receivers was carried out in the form of OJT during Phase 1 and Phase 2 in the Gambia.

The counterparts were able to completely master the techniques by the end of Phase 2 in the Gambia securing DL&S with the capacity to perform observations on their own.

⑤Analytical computations

The technology transfer for analytical computations was carried out in the form of lectures and OJT while analytical computations on the observation data were being performed.

As a result, DL&S acquired the skills to independently process data, from baseline analysis to 3-dimensional net adjustment computations.

(4) Technology Transfer for Field Identification/Aerial Photo Interpretation

①Field identification

The transfer of field identification techniques was conducted in the form of lectures and on-the-job training

As a result, the counterparts reached a level where they were generally able to identify topographic and planimetric features based on the map symbols regulations and select the features that should be represented on the 1:50,000-scale topographic maps.

②Aerial photo interpretation

Aerial photo interpretation techniques were to be transferred during the first field identification. However, as the counterpart's technical level in aerial photography was lower than anticipated, the expected results would not have been obtained. The technology transfer was thus implemented after the "Aerial Photo Interpretation Handbook" was prepared so that it could be used in training. Because experience is essential in mastering photo interpretation technique, it is expected that the counterparts shall continue to build on this experience using the "Aerial Photo Interpretation Handbook" based on the technology transfer, and their technique will improve.

(5) Technology Transfer for Map Revision

①Determination of technologies to be transferred

It was decided that the following techniques would be transferred: a. techniques for digitizing existing maps, b. techniques for revising digitized topographic maps and c. basic digital techniques.

②Preparation of manuals

The following three types of manuals were prepared based on the map revision procedures and the configuration of the equipment used in the technology transfer: a. work

specification manuals, b. work method manuals and c. manuals for the use equipment in the technology transfer.

③Technology transfer for map revision

The transfer of map revision techniques was implemented in the form of lectures and on-the-job training. The targets of the technology transfer were six persons recommended by DL&S.

a. Items of the technology transfer

The specific items of the technology transfer were set as follows:

- Training in the set-up of hardware/software used in technology transfer
- Training in the basic operation of hardware/software used in technology transfer
- Training in the basic techniques for the revision of 1:50,000-scale topographic maps
- Training in advanced/application techniques for map revision software

b. Training in the set-up of hardware and software

The technology transfer implemented included checking the working voltage of the various hardware, the method of physically connecting the hardware, the method of network construction, as well as the installing, uninstalling and reinstalling of software.

c. Training in basic operation of hardware and software

Techniques for the basic operation of hardware such as the starting up and shutting down of equipment were transferred using the manuals prepared. At the same time, techniques for the basic operation of the following software were also transferred using the manuals prepared.

- TNTmips
- Photoshop
- Illustrator

d. Training in basic techniques for the revision of 1:50,000-scale maps

Using the prepared TNTmips manual, the techniques for revising the marginal information (e.g. margins, sheet name, sheet number, edition number, index to boundaries, legend, magnetic declination, etc) on topographic maps and the topographic maps themselves (e.g. topographic and planimetric features) were transferred.

e. Training in advanced/application techniques for map revision software

TNTmips has various functions other than the basic functions mentioned above. It is

believed that it can be effectively used in map revision and with GIS. The following techniques were transferred.

- ♦ Data input/output for GIS databases
- ♦ Basic analysis of GIS databases
- ♦ Handling of aerial photo data
- ♦ Handling of 3-dimensional data
- ♦ Production of bird's eye view

(6) Technology transfer concerning GIS

The transfer of technology concerning GIS was mainly implemented in the form of on-the-job training. The targets of the technology transfer were three engineers from DL&S who had some amount of experience.

The main items of the technology transfer implemented were as follows.

- ♦ An overview of GIS
- ♦ An explanation of the basic functions of ArcView GIS
- ♦ Creating new GIS data (i.e. polygon, line, point)
- ♦ Setting map projection and transformation
- ♦ Creation of attribute tables and map revision
- ♦ Calculating polygon areas and line lengths
- ♦ Linking graphic data to the existing database
- ♦ Linking graphic data to image data
- ♦ Data input/output
- ♦ Input of image data and geometric correction

3.1.6 Current Situation of Geographic Information

(1) DL&S organization and their services

DL&S is a government agency under the Department of State for Local Government and Lands.

①DL&S Organizations

DL&S has its head office in the capital of Banjul and plans to set up branches in the principal cities throughout the country.

The head office in Banjul is composed of an administrative section and the following three technical sections.

Survey Section

Map Production Section

Land and Valuation Section

At the time the Study began (June 2001), DL&S had a total of 84 employees, although there have been some slight personnel changes due to retirement, etc.

The staff has been ranked from Grade 1 to Grade 11, Grade 11 being top level. (as of June 2001)

The personnel organization of section is as follows (As of June 2001):

Administration Section:	13 employees, including the director
Survey Section:	40 employees, including the section chief
Map Revision Section:	18 employees, including the section chief
Land and Valuation Section:	13 employees, including the section chief

(2) Geographic Information

①Control points

The national control points with Clarke1880 as the reference ellipsoid were established in the 1960's, and as they have not been maintained, many are thought to have been lost. The data prepared on the control points includes a point distribution map (scaled at 1:50,000), a control data list and point descriptions.

②Aerial photographs

There exist 1:50,000-scale and 1:25,000-scale aerial photos covering the entire country and larger-scale aerial photos that cover sections of the country. The photos are available for general sale but are in fact difficult to obtain as the developing equipment is superannuated.

③Topographic Maps

Small-scale maps (1:250,000, 1:50,000) covering the whole country as well as medium-scale maps (1:25,000, 1:10,000) and large-scale maps (1:5,000, 1/2,500, 1:1,250) have been produced.

In addition to the topographic maps, photomaps and orthophotos have also been produced. However, all the above data, including the topographic maps, was produced before the 1980`s and have not been revised according to secular change.

(3) Actual Conditions of GIS Use

The study on the actual conditions of GIS use was implemented through interviews. The main questions asked in the interviews were as follows:

Q1: Which products of the Project do you expect to be useful for your service?
(Aerial photos; results of GPS survey; printed topographic maps scaled 1:50,000; digital map images; GIS data)

Q2: How do you think the newest topographic map information will be used in your field?

Q3: Please give any information on your experience in GIS.

Q4: Please give information on the ongoing projects and important tasks or problems, if any.

3.1.7 Formulation of Reports and Explanation/Discussions

(1) Formulation of Reports

The following four reports were formulated in the Study:

- ♦ Inception Report
- ♦ Progress Report
- ♦ Draft Final Report
- ♦ Final Report

①Inception Report

The aim of this report was to give an understanding of the general outline and flow of the entire Study.

②Progress Report

This report included a chronological account of the study work until the end of the second years in order to give an understanding of the progress and results of the study work.

③Draft Final Report

This report included the progress of all the works implemented under the Study as well as their results and products. It also included a proposal for DL&S based on the experience and knowledge obtained from the Study.

④Final Report

The above report was revised to formulate the Final Report, which included comments by

DL&S concerning the Draft Final Report, the transfer of map revision techniques and the results of the technology transfer seminars.

(2) Explanation/Discussions

①Explanation of and discussions on Inception Report

On June 20, 2001, a meeting was held at the DL&S office to explain and discuss the Inception Report. The details of the explanation and discussions were recorded in the minutes of the meeting, which was signed on June 22.

②Explanation of and discussions on Progress Report

On July 17, 2002, a meeting was held at the DL&S office to explain and discuss the Progress Report. The details of the explanation and discussions were recorded in the minutes of the meeting, which was signed on July 23, 2002.

③Explanation of and discussions on Draft Final Report

On October 3, 2002, a meeting was held at the DL&S office to explain and discuss the Draft Final Report. Due to personnel changes at DL&S, one top official and the targets of the technology transfer took part in the explanation and discussions. The details of the explanation and discussions were recorded in the minutes of the meeting, which was signed on October 8, 2002.

3.1.8 Technology Transfer Seminar

(1) Objective

The technology transfer seminar was held in order to announce the products of the Study work and to promote their effective use.

(2) Dates and participants

The technology transfer seminar was held over a two-day period from October 8 to9.

The number of participants was 77 and 66, respectively, including staff from ministries and governmental agencies in Gambia and local governing bodies, private companies, donors from various countries and concerned persons from NGOs.

(3) Contents

In two-day technology transfer seminar, the progress and results of the Study work as well as the products were announced. Demonstrations of the products were also given and the basics

of GIS and its applications were explained.

3.2 Results of the Study

3.2.1 Products of the Study

The following products were generated in the Study

＊Reports

♦	Inception Report	30 copies in English（10 for JICA）
♦	Progress Report	30 copies in English（10 for JICA）
♦	Draft Summary Report	
	Main Report	30 copies in English（10 for JICA）
	Summary	30 copies in English（10 for JICA）
		10 copies in Japanese
♦	Final Report	
	Main Report	30 copies in English（10 for JICA）
	Summary	30 copies in English（10 for JICA）
		10 copies in Japanese

＊Final Products

♦	Aerial Photography	
	Negative film	1 set
	Contact prints	1 set
♦	Result of control point survey	
	Results of national control points	1 set
	Description of national control points	1 set
	Results of GPS survey	1 set
	Adjustment computation sheets	1 set
♦	Results of aerial triangulation	1 set
♦	1:50,000-scale topographic maps	
	Printed maps	1003 sets, 27sheets/set
		(3 sets for JICA)
	Films for printing	1set
♦	1:50,000-scale topographic map data	23 sets (3 sets for JICA)
♦	1:50,000 topographic map database	23 sets (3 sets for JICA）

- ♦ Other GIS databases 1 set
- ♦ Metadata 1 set

3.2.2 Results of the Study

(1) Results accompanying the production of 1:50,000-scale topographic maps

①Up-to-date 1:50,000-scale topographic maps (printed maps) covering the entire country were produced.

②Up-to-date digital topographic data covering the entire country were produced

③An up-to-date digital topographic database covering the entire country was constructed

④GIS databases covering the entire country were constructed.

⑤Up-to-date aerial photos (scaled at 1: 50,000) covering the entire country were generated.

⑥A total of 17 national control points based on the world geodetic system were established within the country.

(2) Results of technology transfer

①Aerial photo signalization techniques were transferred to DL&S so that they are now able to apply the techniques independently.

②GPS surveying techniques were transferred to DL&S so that they are now able to conduct GPS surveys independently using the equipment provided

③Techniques of compiling digital topographic map data (digital compilation), which is concerned with map revision, were transferred to DL&S so that they are now able to carry out digital compilation independently using the equipment provided.

(3) Equipment provided

Upon completion of the Study, the following equipment will be handed over to DL&S who are expected to be able to operate the equipment independently.

- ♦ GPS receivers 3 units
- ♦ GPS survey software 1 set (including 1 personal computer)
- ♦ Digital compilation system 1 set（including all hardware and software）

4. Proposals for DL&S

4.1 Reinforcement of DL&S Organization

4.1.1 Reinforcement of organization

(1) Reinforcement of the administration section

This section should be a base of activity for the administration of geographic information by allowing it to function as a staff section for DL&S. In order to do so, adequate human resources should to be secured to formulate long-term plans for DL&S and to examine its external policy (i.e. negotiations with concerned foreign aid organizations; public policy and sales strategy for geographic information; and negotiations with higher ranking agencies on budget and staff).

(2) Reinforcement of technical sections

It is now time to thoroughly examine the present organization of the technical sections with the development of technologies concerning geographic information. The immediate task should be to investigate and examine the services of each section and reshuffle personnel accordingly.
The sections should also be strengthened by organizing teams responsible for GPS surveys, digital photogrammetry and GIS within the sections to cope with technical advances.

(3) Establishment of public relations section

Due to a lack of publicity activities concerning geographic information, a section in charge of public relations shall be established within DL&S. Also, the available geographic information and how to obtain it shall be open to the concerned agencies, educational institutions and general public.

4.1.2 Reinforcement of Technical Capacity

At present, DL&S possess various kinds of equipment for generating geographic information. Technical capabilities regarding geodetic surveying, digital photogrammetry and GIS should be reinforced through the utilization of the equipment.

4.2 Proposals for geodetic surveying

4.2.1 Establishment of control point survey work specifications

The National Control Point Survey Work Specifications (Draft) were prepared after examining the accuracy, etc. obtained in the GPS survey implemented in the Study. Based on these Work Specifications (Draft), the official national control point survey work specifications should be established, taking into consideration the present conditions of the Gambia and DL&S.

4.2.2 Densification of national control points

In the Study, a first order control network was established with points spaced at 40km intervals. However, the national control points should be densified by establishing a second order control network with points spaced at 20km intervals through GPS surveys. DL&S should also endeavor to maintain and disseminate GPS survey techniques through such work.

4.2.3 Transformation of Coordinates

There exist many control points based on the old reference ellipsoid in the Gambia. In order to adjust these points to the newly established national control points, it is necessary to either resurvey the points or recalculate the results (coordinate values). For the time being, the old results will be converted based on the coordinate transformation parameters established in the Study by a method that is neither costly nor time-consuming.

4.3 Proposals for photogrammetry

4.3.1 Establishment of topographic map symbols regulations

In the Study, the "National Base Map Symbols Regulations (Draft)" containing of the digital map symbols and rules of application discussed with DL&S were prepared. The official symbols regulations for digital topographic maps scaled at 1:50,000 should be established based on these regulations (draft).

4.3.2 Revision and Generation of Topographic Maps

(1) Revision of Topographic Maps

Preparations should be made for the revision of the 1:50,000-scale digital topographic maps produced in the Study, by collecting information on secular change. Moreover, revision work based on secular change to all analog topographic maps beginning with the 1:25,000-scale maps

should be implemented simultaneously with digitization work using the aerial photos taken in the Study.

(2) Generation of Topographic Maps

1:250,000-scale topographic maps covering the entire country, which are in demand, should be produced from the 1:50,000 topographic map data generated in the Study through reduction compilation. The products of the Study should also be used to produce 1:5,000-scale topographic maps of the principle cities.

4.4 Proposals for GIS

From the databases constructed in the Study Works, the following GIS applications are possible.

Field of application	Produced data to be used	Additional data required for GIS use	Expected results/significance
Socio-economics	Administrative boundary data	Attribute data of administrative boundary units ♦ Population ♦ Income ♦ Products	It is possible to grasp the characteristics of local communities in order to formulate industrial policy and welfare measures
Public Transport	Road network data, DTM database	♦ Data on bus service ♦ Traffic volume ♦ Data on land prices	It is possible to manage an efficient bus route that can be expected to improve convenience; it can also be used to plan road routes in consideration of the environment and budget
Disaster Management	DTM database, river data, road network database	♦ Precipitation ♦ River facilities	Areas inundated by floods can be simulated and places of refuge identified in order to formulate measures to deal with natural disasters
Agriculture	DTM database, river data, road network database	♦ Soil map ♦ Traffic volume ♦ Duration of sunshine	From databases such as those mentioned on the left it is possible to select land suitable for agricultural use using the spatial and geographical analysis function of GIS
Medicine	Topographic map database	♦ Medical care facilities ♦ Data concerning malarial mosquitoes (i.e. data on rivers, lakes and marshes; meteorological data; statistical data)	Medical institutions for malaria can be publicized; it can also be utilized to formulate plans to eradicate malaria.

4.5 Operation of GIS databases

Tasks in various fields concerning the topographic map, road network, and DTM databases constructed in the Study have been mentioned. However, it is necessary to establish a system of implementation and administration for when it comes to actually carrying out such tasks. DL&S must not only participate in the system along with the concerned government agencies, but also play a guiding role.

4.6 Operation and Maintenance/Application of Study Results

4.6.1 Survey Products

(1) Printed topographic maps scaled at 1:50,000

It is expected that the 1:50,000-scale topographic maps produced in the Study will be widely and generally sold at an appropriate price based on policy for the commercial sale of geographic information. Storage facilities should also be built to adequately manage the stock of printed maps. Through the sales of such products, the organization and expansion of public relations and sales sections as well as the raising of awareness of their profitability is expected.

(2) Digital data

It is expected that the topographic data and various GIS databases will be appropriately used at DL&S and related government agencies by devising a means for copyright protection. Further, as with the printed topographic maps, the wide and general sale of the topographic data at an appropriate price is projected.

(3) National Control Point Results

The “National Control Point Management System” should be effectively used to maintain the control point results.

(4) Aerial Photography

The aerial photos taken in the Study should be used for the various types of photo interpretation. They should also be widely and generally sold at a suitable price as with the printed maps.

4.6.2 Equipment Provided

(1) Equipment for GPS Survey

It is expected that the GPS equipment provided (GPS receiver, analytical software, etc.) shall be appropriately managed and used in the densification of national control points and cadastral surveys.

(2) Equipment for Topographic Map Revision

As with the equipment for GPS surveying, it is expected that the equipment for revising topographic maps shall be appropriately managed and regularly serviced. In addition, the equipment should be used to produce 1:250,000 topographic map data (including output maps) from the 1:50,000 topographic map data by means of reduction compilation.