Japan International Cooperation Agency (JICA)

Geographic Institute of Mali,
Ministry of Equipment, National Development, the Environment
and Urban Planning, Republic of Mali (IGM)

THE NATIONAL TOPOGRAPHIC MAPPING OF THE REPUBLIC OF MALI IN THE KITA AREA

FINAL REPORT
(SUMMARY)

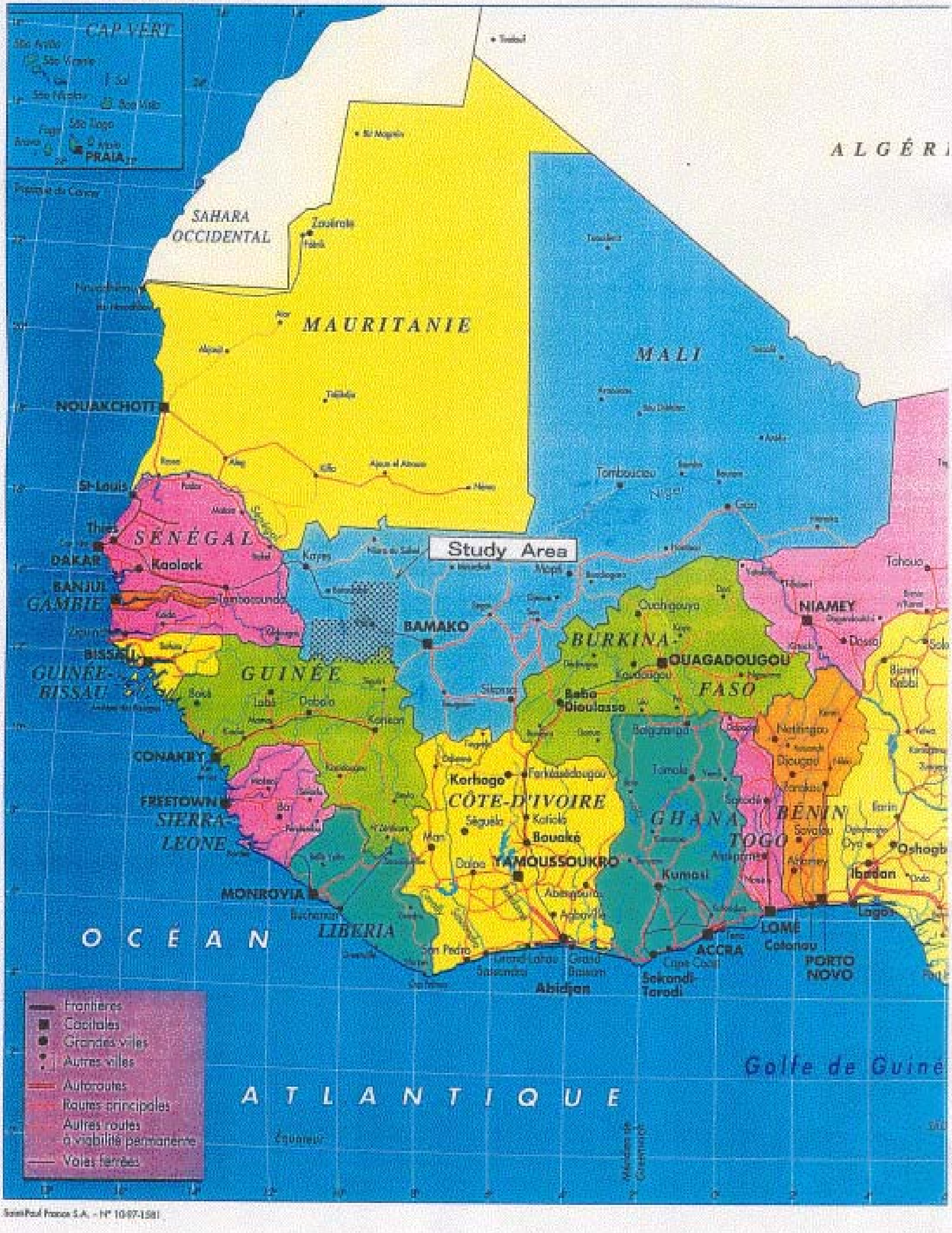
OCTOBER 2001

ASIA AIR SURVEY CO., LTD.

For currency conversion, in case necessary,
Exchange rate in August 2001 may be applied:

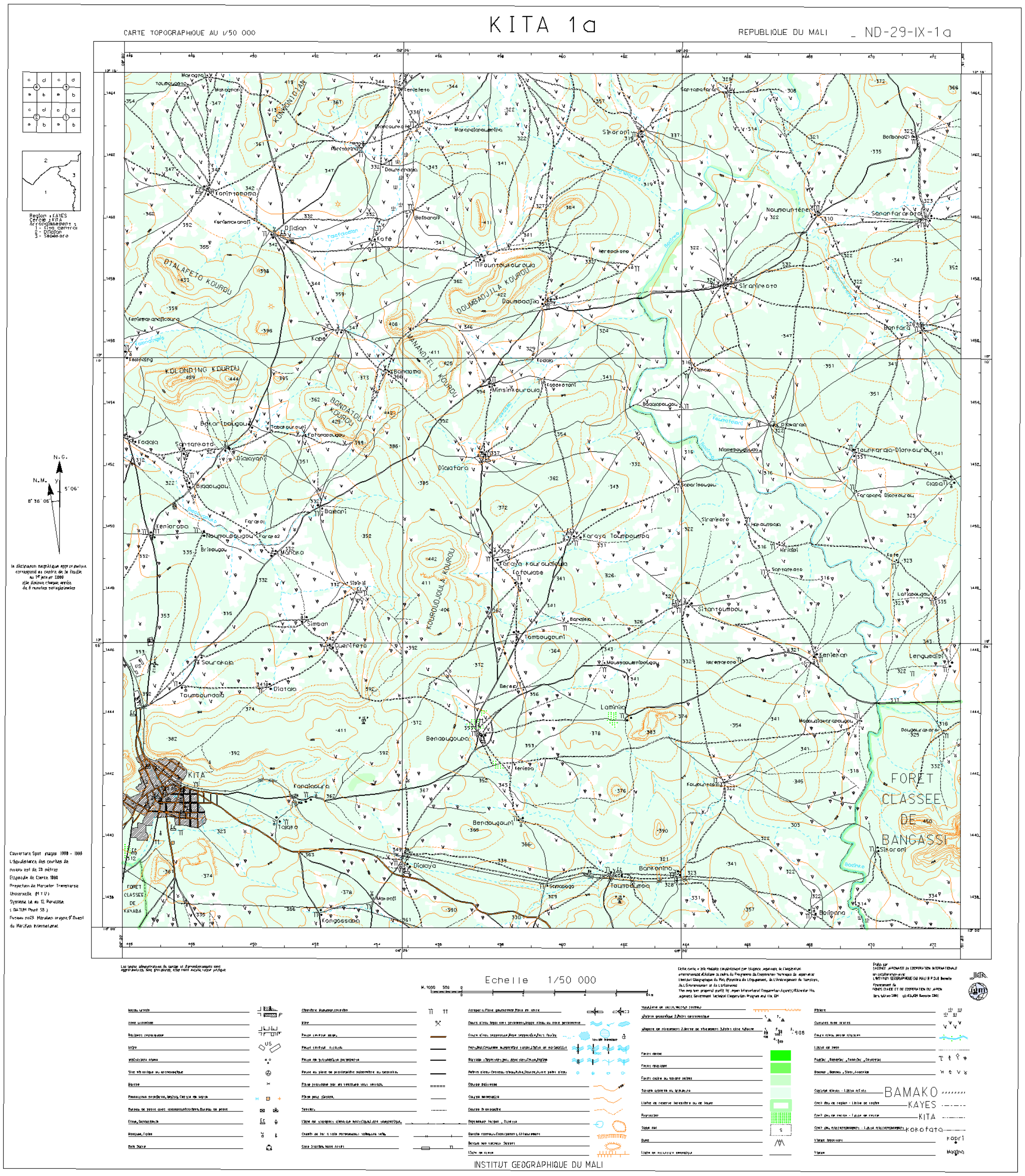
100JPY=612.745F CFA

Project site location map

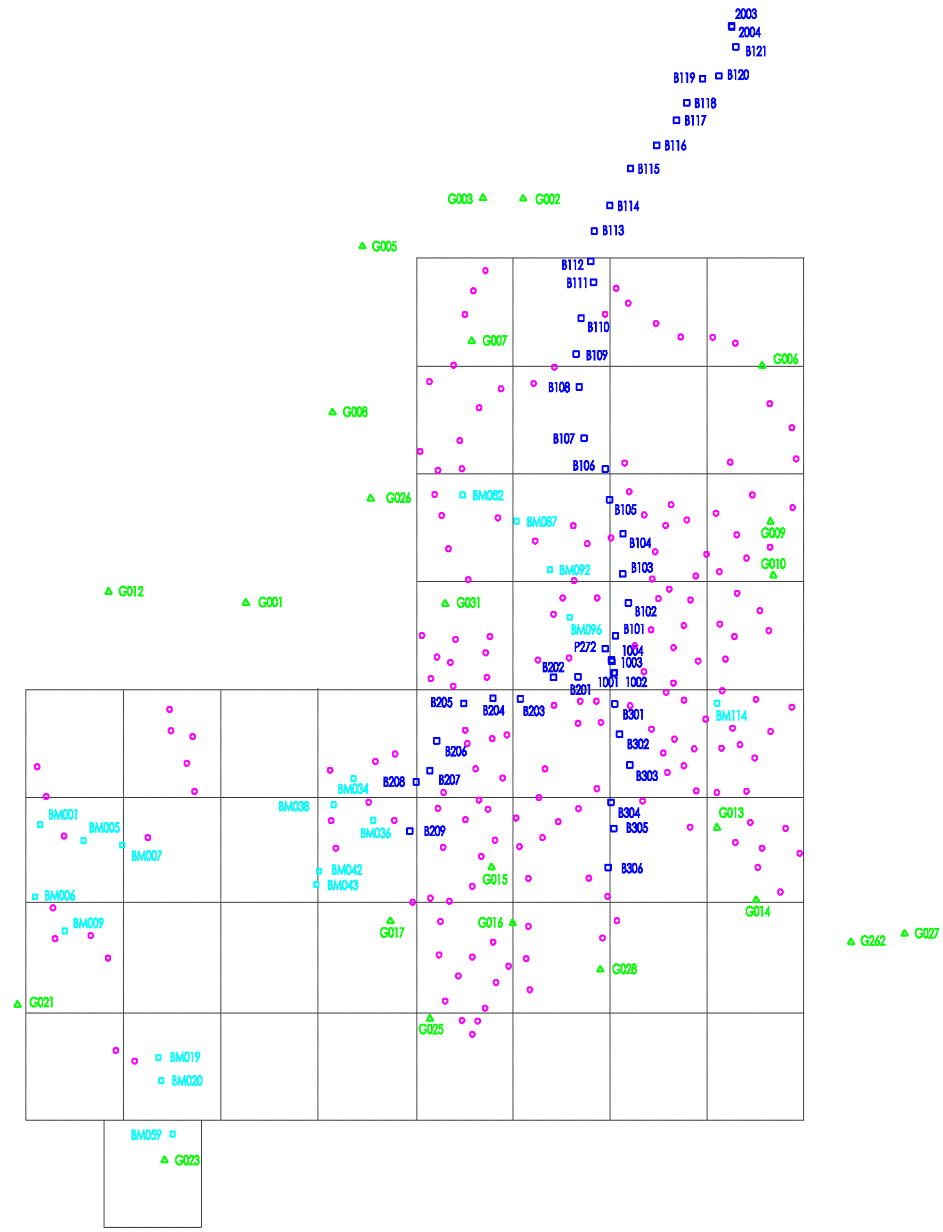


Saint-Paul France S.A. - N° 10-97-1581

Sample print (reduced scale)



Ground control point location map



△ GPS Point

□ Bench mark

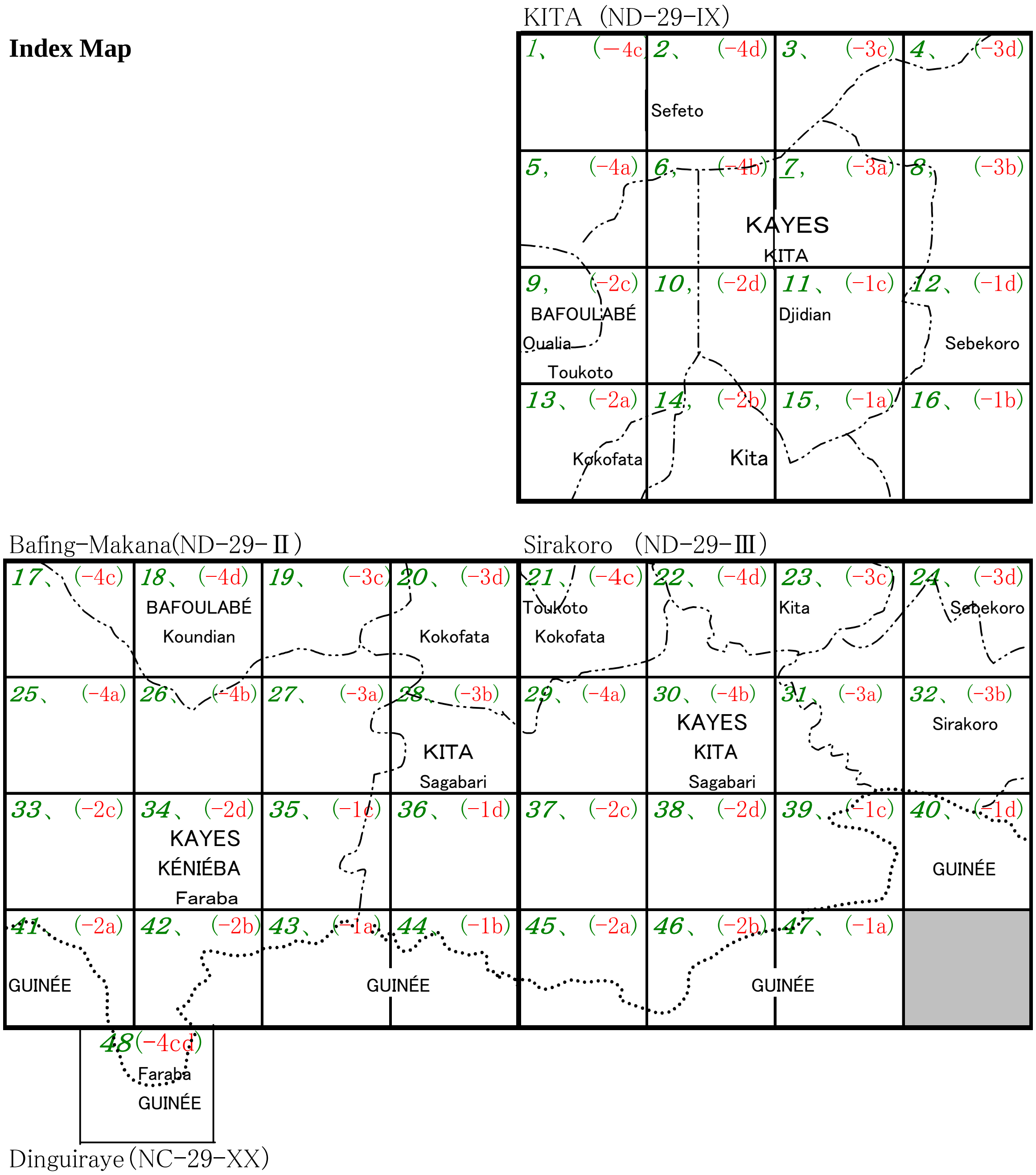
□ Leveling point

○ Point for correction of height

Index Map

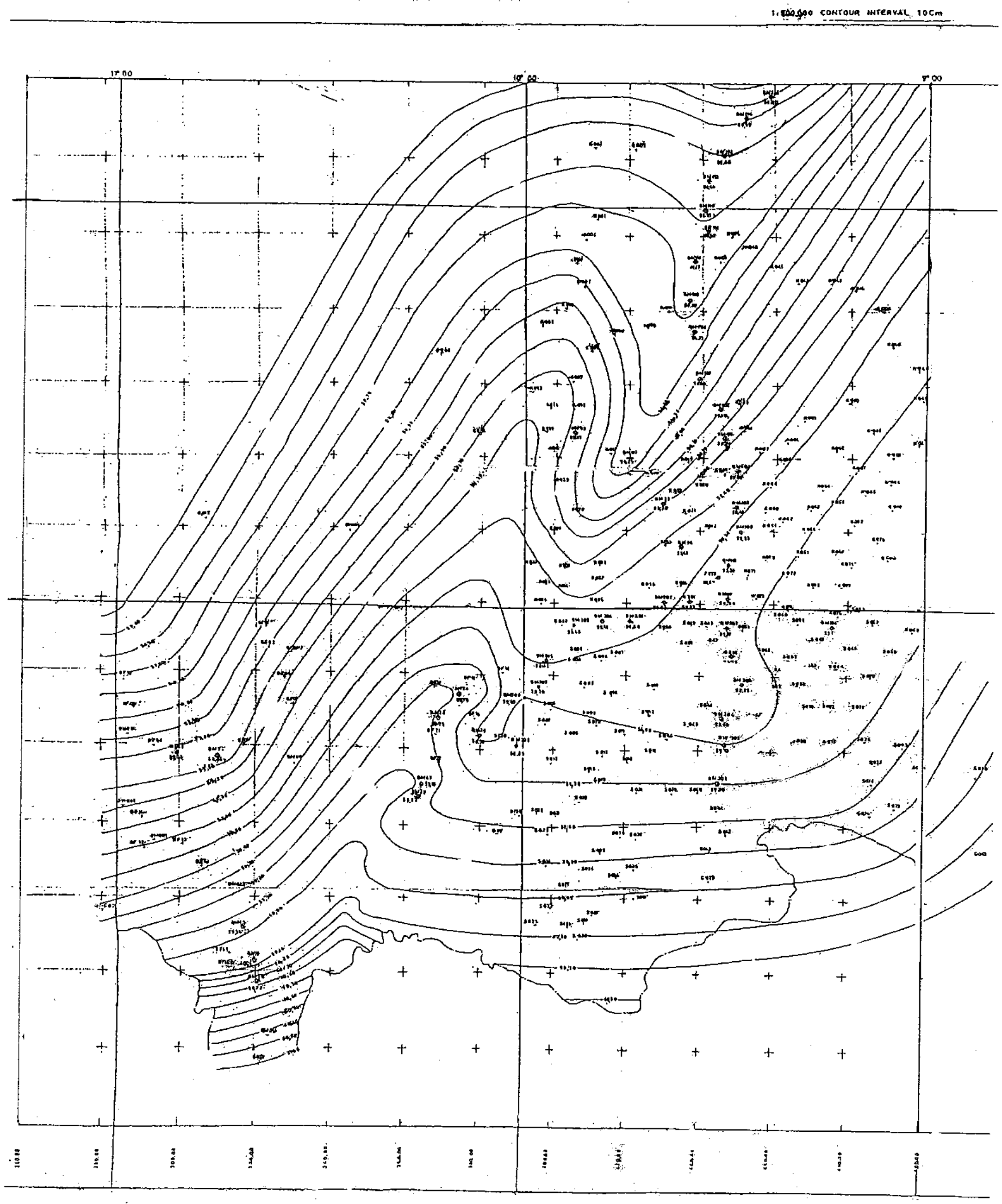
Carte D'index

Index Map



Geoid map

Geoid map GEOIDAL UNDULATION MAP IN KITA SIRAKORO AND BAFING MAKANA ARERS



PREFACE

In response to the request from the Government of the Republic of Mali, the Government of Japan decided to conduct the study on The National Topographic Mapping of the Republic of Mali in the Kita area and entrusted the study to the Japan International Cooperation Agency (JICA).

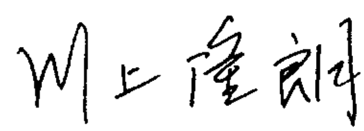
JICA selected and dispatched a study team headed by Mr. Junichi Koseki of Asia Air Survey Co. Ltd. to Mali, four times between October 1998 and August 2001.

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

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

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

October 2001



Takao Kawakami
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

October,2001

Mr. Takao Kawakami
President
Japan International Cooperation Agency

Dear Mr. Kawakami:

It is my great pleasure to submit herewith the Final Report of the Study of National Topographic Mapping in the Kita area of the Republic of Mali.

The study team which consists of the Asia Air Survey Company Limited (AAS) conducted surveys in the Republic of Mali over the period between October 1998 and September 2001 as per the contract with the Japan International Cooperation Agency.

The findings of this study, which are compiled in this report, were fully discussed executed with Geographic Institute of Mali (IGM) of the Republic of Mali.

On behalf of the study team, I would like to express my heartfelt appreciation to the IGM, the Ministry of the Equipment, National Development, the Environment and Urbanization of the Republic of Mali, for diligent cooperation and assistance and for the heartfelt hospitality which they extended to the study team during our stay in Mali.

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

Yours faithfully,

Junichi Koseki
Team Leader for the Study Team

CONTENTS

1. Outline of the Study

1.1 Objectives of the Study

This Study had the objectives to create the 1/50,000-scale topographic map covering the area of 31,000 km^2 including Kita City in Mali and the mapping data for that map and to transfer the technology of topographic mapping to the counterparts in Geographic Institute of Mali (IGM) that is the implementing agency in Mali to implement this Study jointly during the period of 36 months from October 1998 to October 2001.

1.2 Considerations for Implementation of the Study

In this Study, the efficient, low-cost study method and scheme using the up-to-date technology was adopted aiming at producing the topographic maps with the high accuracy compared to the conventional mapping method and at low cost for the minimum time. The following working methods were adopted and conducted for this Study:

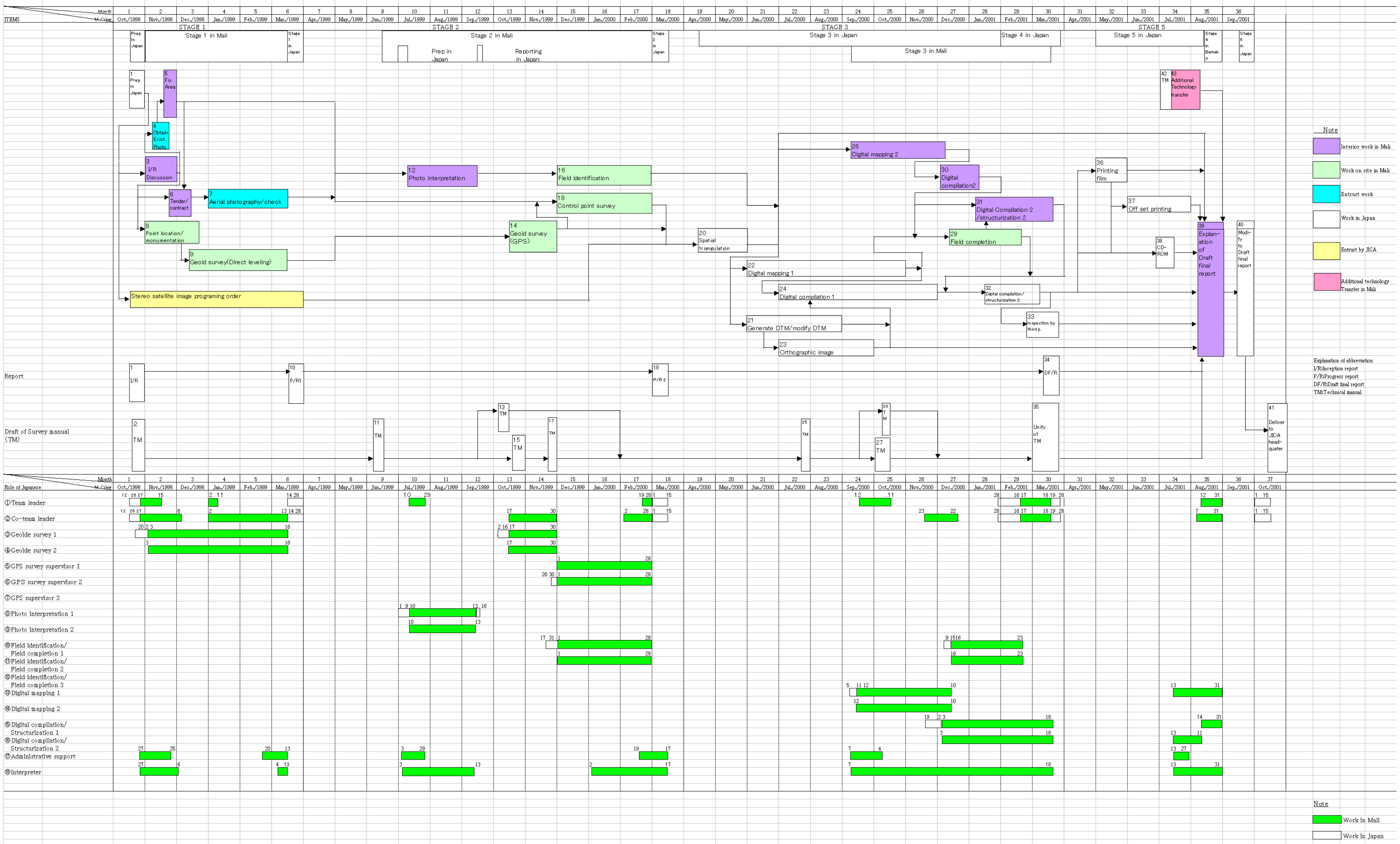
(1) Leveling by digital levels
(2) Ground control point survey using GPS
(3) Elevation measurement by GPS survey
(4) Map data acquisition using SPOT satellite images
(5) Production of ortho-photos and automatic creation of contours using DTM
(6) Digital plotting and compilation and production of printed manuscripts using a digital compilation system

1.3 Specifications of the Study

Type of Work		
Leveling	Third order leveling	Discrepancy between back-and-forth leveling 10mm $\sqrt{S}$ Error of circuit closure 15mm $\sqrt{S}$
GPS survey	First order ground control point survey	Use of 2-frequency receiver and translocation method
Symbol specifications	Symbolization	Digital symbolization

1.4 Table of yearly work schedule

FLOWCHART AND JAPANESE COUNTERPART ASSIGNMENT



1.5 Work Types and Volumes

Item	Sub-item	Description	Remarks
1.Point selection and Monumentation		36 points	
2. Leveling		360km	
3. Aerial photography	Scale of photography	1:50,000	Entrust to MAPS Geosystems
	New photographed area	10,600km^2	Based on photo inspection
	New photographs	334 sheets	
	New photography strips	22 strips	
4.Photo processing	Existing contact prints	596 sheets	Entrust to MAPS Geosystems
	Existing photography strips	44 strips	
	Two times enlarged photos	596 sheets	
	Four times enlarged photos	82 sheets	
5.Reproduction of satellite image	Stereo scenes	20 scenes *2	
	1:100,000 image output	20 sheets	
6. GPS observation	On leveling route	80 points	
	Surrounding areas	24 points	
7. Photo interpretation	Aerial photos	596 sheets	
	Satellite images	19 sheets	
	Quality control sheet	1 set	
8. Ground control point survey	Horizontal plane	54 points	
	Elevation	272 points	
9. Field identification		31,000km^2	
10. Spatial triangulation	Spatial triangulation	19 scenes	1 scene: outside the target area
	Quality control sheet	1 set	
11. Generation of DTM	DTM intervals	100 m	
12. Satellite ortho-image production	Ortho-image production	48 sheets	
13. Digital plotting 1/2	Digital plotting 1	46 sheets	Japan
	Digital plotting 2	2 sheets	Mali
	Creation of contours	48 sheets	Japan
	Production of base maps for data acquisition	48 sheets	2 sheets in Mali
	Digital mapping data files	48 files	2 files in Mali
	Quality control sheet	1 set	
14. Digital compilation 1/2	Digital compilation 1	46 sheets	Japan (29,500km^2)
	Digital compilation 2	2 sheets	Mali (1,500km^2)
	Scale	1:50,000	
	Total area	31,000km^2	
	Contour lines	Main: 20m Index: 100m	Averaging and tree height correction
	Quality control sheet	1 set	
15. Field completion	Total area	31,000km^2	
16. Supplementary compilation and structuralization 1/2	Supplementary compilation and structuralization 1	46 sheets	Japan

	Supplementary compilation and structuralization 2	2 sheets	Mali
	Adjoining compilation	48 sheets	2 sheets in Mali
	Topographic map (structuralized) data files	1 set	2 files in Mali
	Quality control sheet	1 set	
17. Inspection by third party	Visual inspection	46 sheets	Japan
	Logical inspection	48 sheets	Japan
18. Production of printing films	EPS files	48 sheets * 4 files	Japan
	Mapping data files	1 set	2 files in Mali
19. Printing	Offset printing	503 sheets/map	Japan
	Quality control sheet	1 set	
20. Topographic map (structuralized) data file	CD-R	53 sets	Japan
	Quality control sheet	1 set	Japan
21. Reports and others	Inception Report	1 set	Japan
	Progress Report 1	1 set	Japan
	Progress Report 2	1 set	Japan
	Draft Final Report	1 set	Japan
	Overall Manual	1 set	Japan
	Final Report	1 set	Japan
	Symbols and marginal information	1 set	Japan

1.6 Plans and Implementation

Table 1.6 Comparison Table of Planned and Implemented Works

Item	Planned	Implemented	Remarks
1. Point selection and monumentation	36 points	36 points	
2. Leveling	360km	360km	
3. Aerial photography			
Photograph scale	1:50,000	1:50,000	Black/white
New photographed area	5,500km^2	10,600km^2	On photo inspection
New photographs	224 sheets / 2 copies	334 sheets / 2 copies	1 copy: Japan 1 copy: Mali
New photography strips	13 strips	22 strips	
4. Photo processing and reproduction			
Existing contact prints	592 sheets	596 sheets	Incl. photos for inspection (Mali)
Existing aerial photography strips	44 strips	44 strips	
Two times enlarged photo	592 sheets	596 sheets	296 sheets: Mali
Four times enlarged photo	80 sheets	82 sheets	For description of control point
5. Satellite image copying		20 scenes * 2	
Satellite images	20 scenes * 2	20 scenes * 2	Digital data

1:100,000 image output	20 sheets	20 sheets	Mali
6. GPS observation			
On leveling route	70 points	80 points	
Surrounding area	7 points	24 points	
7. Photo interpretation			
Aerial photos	592 sheets	596 sheets	
Satellite images	20 sheets	20 sheets	Mali
Quality control sheet	1 set	1 set	
8. Ground control point survey			
Horizontal plane	50 points	54 points	
Elevation	250 points	272 points	
9. Field identification			
Field identification	31,000km^2	31,000km^2	Field identification of photos in Japan
10. Spatial triangulation			
Spatial triangulation	19 scenes	19 scenes	1 scene: outside the target area
Quality control sheet	1 set	1 set	
11. Generation of DTM			
DTM intervals	200m	100m	
12. Satellite ortho-image production			
Ortho-image creation	48 sheets	48 sheets	Mali
13. Digital plotting 1/2			
Digital plotting 1	46 sheets	46 sheets	Japan
Digital plotting 2	2 sheets	2 sheets	Mali
Contour line creation	48 sheets	48 sheets	Japan
Creation of base maps for data acquisition	48 sheets	48 sheets	2 sheets: Mali
Digital mapping data files	48 files	48 files	2 files: Mali
Quality control sheet	1 set	1 set	
14. Digital compilation 1/2			
Digital compilation 1	46 sheets	46 sheets	Japan (29,500km^2)
Digital compilation 2	2 sheets	2 sheets	Mali (1,500km^2)
Scale	1:50,000	1:50,000	
Total area	31,000km^2	31,000k m^2	
Contour lines	Main: 20m Index: 100m	Main: 20m Index: 100m	Averaging and tree height correction
Quality control sheet	1 set	1 set	
15. Field completion			
Total area	31,000km^2	31,000k m^2	Original (Japan) Copy (Mali)
16. Supplementary compilation and structuralization 1/2			
Supplementary compilation and structuralization 1	46 sheets	46 sheets	Japan
Supplementary compilation and structuralization 2	2 sheets	2 sheets	Mali
Adjoining compilation	48 sheets	48 sheets	2 sheets: Mali

Topographic (structuralized) data files	1 set	1 set	2 files: Mali
Quality control sheet	1 set	1 set	
17. Inspection by third party			
Visual inspection	46 sheets	46 sheets	
Logical inspection	48 sheets * 4 files	48 files	
18. Production of printing films			
EPS files	48 sheets * 4 files	48 files * 4 files	
Topographic data files	1 set	1 set	2 files: Mali
19. Printing			
Offset printing	503 sheets/map	503 sheets/map	3 copies: JICA
Quality control sheet	1 set	1 set	
20. Topographic (structuralized) data file			
CD-R	53 sets	53 sets	3 sets: JICA
Quality control sheet	1 set	1 set	
21. Reports and others			
Inception Report	1 set	1 set	
Progress Report 1	1 set	1 set	
Progress Report 2	1 set	1 set	
Draft Final Report	1 set	1 set	
Overall Manual	1 set	1 set	
Final Report	1 set	1 set	
Symbols and marginal information	1 set	1 set	

1.7 Technical Meetings

This Study was implemented over a long period of 4 years. Therefore, the technical meetings were held at the beginning and at the end of the study work in each fiscal year. Furthermore, the plan of operation, work manuals (drafts) and technology transfer plans were prepared at the beginning of the study work in each fiscal year, which were discussed and confirmed at the technical meeting on the work for each fiscal year before the study work was conducted. The items discussed and confirmed at the technical meeting in each year will be described below.

(1) First Year

Plan of operation

Ground control point installation: Technology transfer plan; Survey manual

Aerial photography

Geoid survey (leveling): Technology transfer plan; Survey manual

Photo interpretation: Technology transfer plan; Survey manual

Symbols and application rules for map symbols

(2) Second Year
Progress Report 1
Plan of operation
Geoid survey (GPS survey)
Ground control point survey: Technology transfer plan; Survey manual
Field identification: Technology transfer plan; Survey manual

(3) Third Year
Progress Report 2
Plan of operation
Digital plotting: Technology transfer plan; Survey manual
Digital compilation: Technology transfer plan in structuralization; Survey manual
Field completion: Technology transfer plan; Survey manual

(4) Fourth Year
Additional technology transfer
Draft Final Report
Combined binding of survey manuals
Submission of Final Report

1.8 Cooperation with and Training of Counterparts

The Study Team consisted of Japanese engineers and counterparts of Geographic Institute of Mali (IGM) and the counterparts were trained for the technology of field identification work under the supervision of Japanese engineers while they conducted the work together with Japanese engineers. The counterparts that participated in the technical discussions and work of this Study were as follows:

1. Mr. Issa COULIBALY	Directerur de l'IGM
2. Mr. Diakalia OUATTARA	Directeur Ajoint
3. Mr. Aliou COULIBALY	Chef Division Infrastructure de Base
4. Mr. Silamakan TRAORE	Ingenieur Photogrammetre
5. Mr. Chaka FORE	Technicien des Constructions civiles
6. Mr. Modibo CAMARA	Ingenieur Topographe
7. Mr. Bakary COULIBALY	Ingenieur Topographe
8. Mr. Soboua TRAORE	Technicien des Constructions civiles
9. Mr. Yala SIDIBE	Technicien des Constructions civiles
10. Mr. Cheickna KOUMARE	Technicien des Constructions civiles

11. Mr. Mamadou CAMARA Ingenieur Photogrammètre
12. Mr. Alassane BA Docteur Ingenieur Cartographe
13. Mr. Modibo DIAKITE Technicien des Constructions Civiles
14. Mr. Bakari DIARRA Technicien Superieur photogrammètre
15. Mr. Amadou DIALLO Technicien Superieur photogrammètre
16. Mr. Bourama KONTA Technicien Superieur photogrammètre

1.9 Individual Training of Counterparts

The counterparts received the on-the-job training during the study period in Mali and the counterparts as listed below visited Japan to participate in the individual training in Japan.

The trainees received the training for the works conducted in Japan. In addition, they visited the Geographical Survey Institute, Japan Association of Surveyors, Japan Map Center and other related organizations to understand the Japanese system related to surveys and receive the explanation of the services provided and the equipment used by those organizations.

Name	Training Period	Item of Training
Modibo CAMARA	13/9/1999 ～ 9/10/1999	Survey Situation in Japan
Amadou DIALLO	17/7/2000 ～ 14/9/2000	Plotting, Aerial Triangulation and Data Applications
Silamakan TRAORE	31/7/1999 ～ 2/7/2000	Group training
Aliou Coulibaly	15/6/2001 ～ 14/7/2001	Printing technology Confirmation of final print

Three counterparts that participated in the training in Japan shared the central roles in the works of this Study and fulfilled the effective functions in the technology transfer through interpretation of technical terms. The effects of training in Japan were proven to be large.

1.10 Role of JICA Study Team and Period of Dispatch

The role of the JICA Study Team and the period of dispatch to Mali are as follows:

JICA Study Team	Assignment	Working in Bamako	Fiscal Year
Junichi KOSEKI	Team leader	27/10/1998-15/11/1998	First year
		02/01/1999-11/01/1999	First year
		13/07/1999-27/07/1999	Second year
		20/02/2000-28/02/2000	Second year
		16/09/2000-09/10/2000	Third year
		18/02/2001-16/03/2001	Third year
		13/08/2001-28/08/2001	Fourth year
Nobuo SHIMIZU	Sub-team leader,	27/10/1998-06/12/1998	First year
	Management of sub-contract	02/01/1999-13/03/1999	First year
		18/10/1999-28/11/1999	Second year
		24/11/2000-20/12/2000	Third year
		18/02/2001-16/03/2001	Third year
		08/08/2001-29/08/2001	Fourth year
Hajime GOTO	Control point survey supervisor 1	03/11/1998-16/03/1999	First year
	GPS supervisor 1	18/10/1999-26/02/2000	Second year
Hitoshi KOAMI	Control point survey Supervisor 2	03/11/1998-16/03/1999	First year
	GPS supervisor 2	18/10/1999-26/02/2000	Second year
Toshiyuki FUJIOKA	GPS supervisor 3	18/10/1999-26/02/2000	Second year
Hiromi Ogawa	Photo interpretation supervisor 1	13/07/1999-11/09/1999	Second year
	Field identification supervisor 1	02/12/1999-26/02/2000	Second year
	Field completion supervisor 1	18/12/2000-21/02/2001	Third year
Kenji NAMIKI	Photo interpretation supervisor 2	13/07/1999-11/09/1999	Second year
	Field identification supervisor 2	02/12/1999-26/02/2000	Second year
Kenji SUZUKI	Field identification supervisor 3	02/12/1999-26/02/2000	Second year
Tetsuzo YAMAMOTO	Field completion Supervisor 2	18/12/2000-21/02/2001	Third year
Tsuneo TERADA	Digital plotting supervisor 1	16/09/2000-08/12/2000	Third year
		14/07/2001-29/08/2001	Fourth year
Chugo ODAKA	Digital plotting supervisor 2	16/09/2000-08/12/2000	Third year
Toru WATANABE	Compilation/structuralization	03/12/2000-16/03/2000	Third year
	Supervisor 1	15/08/2001-29/08/2001	Fourth year
Yoshiteru MATSUSHITA	Compilation/structuralization	03/12/2000-16/03/2000	Third year
	Supervisor 2	16/07/2001-09/08/2001	Fourth year
Ichiro NONAKA	Coordination	27/10/1998-25/11/1998	First year

		06/07/1999-27/07/1999	Second year
		08/09/2000-02/10/2000	Third year
		16/07/2001-27/07/2001	Fourth year
Manabu KAWAGUCHI	Coordination	20/02/1999-13/03/1999	First year
Norio YOKOKAWA	Interpreter	27/10/1998-06/12/1998	First year
		02/01/1999-13/03/1999	First year
		06/07/1999-27/07/1999	Second year
		08/09/2000-16/03/2001	Third year
		14/07/2001-29/08/2001	Fourth year

1.11 Significance of the Results Obtained in the Study

(1) Standardization of survey results

The Government of Mali has planned to establish the ground control point network in the nationwide standardized coordinate system. The control point survey that was made with high accuracy under the cooperation by the US Defense Mapping Agency (DMA) was the 12th parallel survey. The control point network was based on traversing points 58 made by this survey. In this Study, the control points were also surveyed relative to these control points obtained in that survey. Therefore, the control points established in this Study can also be used as part of the national standardized control point network.

(2) Use of topographic maps

This Study completed a total of 48 sheets of 1/50,000-scale topographic maps covering the Kita, Sirakoro and Bafing-Makana areas that are covered by the 1/200,000 topographic maps. (See Fig. 2 “Sheet Index Map”.) These topographic maps may be used for planning and formulating the future agricultural, industrial and mining development programs.

(3) Use of geoid maps

As the conversion parameters from the WGS84 into the CLARKE1880 and the geoid maps (see Fig. 3 “Geoid Map”.) were produced, the positions and orthometric elevations on the CLARKE 1880 reference ellipsoid that is governed in Mali can easily be obtained by making the GPS survey in the study area of Kita, Sirakoro and Bafing-Makana covered by the 1/200,000 topographic maps.

The program that enables the results of this Study to be easily used was also developed.

2. Contents of the Study

In this Study, 48 sheets of the 1/50,000-scale topographic maps covering the Kita area for which the future agricultural, industrial and mining developments are expected, and the mapping data to be usable for GIS were produced.

The work processes to obtain these products in this Study will be described below.

2.1 Work Plans

(1) Confirmation of survey specifications

The following survey specifications were confirmed before beginning the Study:

- Reference ellipsoid: CLARKE 1880
  Semi-major axis: 6,378,249.145m; Flattering : 1/293.465
- Standard of position: Point 58
  Latitude 13° 5' 40.629" N; Longitude 9° 30' 43.2326" W
- Standard of elevation (Origin at Dakar)
  The elevation value of the existing benchmark was used.
- Map projection
  UTM Zone 29
- Symbols
  The symbols were determined through discussions based on the existing maps.

(2) Collected materials

The materials collected and used to implement this Study are as follows:

- 4 sheets of 1/200,000 topographic maps (Kita, Sirakoro and Bafing-Makana, Dinguiraye)
- Existing 1/50,000 topographic maps
- Existing 1/20,000 topographic maps (Bamako, Nord-est, Nord-ouest, Sud-est, Sud-ouest)
- Astronomic point table and description of control point
- 12th parallel survey material
- Symbol specifications
- Magnetic bearings
- 1/200,000-scale map sheet index maps
- Statistic data of population of Kita District
- Electric transmission line location map
- Road construction plan map
- Others (to be added)

(3) Borrowed materials

- SPOT image data (20 scenes of stereo image data)

2.2 Discussions on Symbols and Marginal Information

The items to be included in the topographic maps and mapping data were determined through discussions with the counterparts in Mali. Basically, these items were determined on the conditions that they would have integrity with those in the existing 1/50,000 topographic maps and that they would be applicable to digital processing. In determining these items, the symbols (draft) were prepared by the Study Team, based on the existing materials and, incorporating the opinions of the counterparts of Mali, the sample symbol figures were depicted in accordance with the symbol specifications of Mali. Then, the final symbols for the topographic maps were determined. After that, the samples using the data actually acquired were produced with some corrections in color or character size. The marginal information (draft) was also prepared by the Study Team, based on the existing examples and finally determined through discussions with the counterparts of Mali.

Existing materials used

- Existing map: 1/50,000 KHOSSANTO
- Existing map: 1/20,000 BAMAKO NORD -EST
- Carte de France 1:50,000 Edition 1980

2.3 Acquisition of SPOT Images and Aerial Photography

The map data for the study area was basically acquired from the SPOT images. As it was difficult to acquire the detailed information from the SPOT image data with the resolution of 10m, the 1/50,000 aerial photographs were used as the materials for detailed interpretation.

(1) Satellite image photography

For the SPOT image photography, JICA made its direct instructions and purchased the necessary equipment, which was lent to the Study Team. The study area was covered with 20 models.
The satellites SPOT No.1, No.2 and No.4 were used for photography. As the image format from SPOT No.4 was changed, the data collected from the different types of sensor on SPOT No. 1 and SPOT No.2 was combined as a stereo pair, resulting in some troubles in software operation.

There were some scenes of which 3-dimensional photography was not available due to the halation of clouds, shadows or water area that appeared in part of those scenes. Since these scenes would affect the subsequent processes including stereo matching, ortho-photo production and digital plotting, resulting in lower accuracy of photography, the defective positions in these scenes were recorded for later supplementary use of the existing materials such as the topographic maps and aerial photos.

(2) Aerial photography

There were the existing 1/50,000 aerial photos of a part of the study area that were taken in 1995 under Germany's assistance. These photos were photographed under the specifications: Overlap 50% and side-lap 0%. It was found that these photos could be used for this Study though some scenes include clouds partly. Thus, the usable ones were selected from these photos and it was decided to newly conduct the aerial photography of the lacking areas. Each photo was two times enlarged for use in photo interpretation.

Item	Existing photos	New photography
Type of camera	Zeiss RMK TOP15	Zeiss RMK TOP15
Photo size	230 x 230	230 x 230
Focal distance	154.401mm	154.401mm
Number of photography strips	44	22
Number of photos	596	334

2.4 Photo Interpretation

As the SPOT images had low resolution, making direct interpretation and depiction difficult in digital plotting, the items to be included in the maps were examined in photo interpretation on the existing and new aerial photos and the field identification was made in advance to prepare the necessary materials.

(1) Verification of study area
(2) Verification of aerial photos covering each map sheet
(3) Creation of photo interpretation keys
(4) Photo interpretation
(5) Checking and inspection

2.5 Field Identification

The field identification work was conducted to identify the unclear points in the photo interpretation and to collect the information available only from the field. In addition, the secular changes in the roads and power transmission lines that had been newly constructed were also surveyed.

The field identification was conducted in the following steps:

(1) Preparation of overlays

Polyester-based overlays were prepared on the two times enlarged photos used in the photo interpretation and the results of photo interpretation were transferred on the overlays. These overlays were brought to the field for field identification.

1) The administrative boundaries, major terrains and public facilities were transferred from the existing materials onto the overlays.
2) The names and categories of villages and hamlets were examined on the existing materials and identified in the field.

(2) Field identification

1) Examination of the unclear points in the photo interpretation.
2) Identification of the results of photo interpretation
3) Identification of new public and governmental facilities
4) Identification of tree heights for contour line correction
5) Identification of types of cultivated land

(3) Arrangement of the results of field identification

In the field identification, additions, deletions and modifications to the items filled onto the overlays in photo interpretation were made and arranged.

(4) Checking and inspection

The arranged field identification maps were checked and inspected, and the results were arranged as the Quality control sheet in the same form of the photo interpretation results.

2.6 Geoid Survey

In this Study, the survey using the GPS was made. The GPS is configured adopting the earth ellipsoid centering the gravity center of the earth (WGS-84). However, the topographic maps produced in this Study adopted the reference ellipsoid (CLARKE 1880) as specified by Mali.

For this purpose, the parameters to obtain the orthometric elevations from the coordinate transformation between ellipsoids and the ellipsoidal elevation measured by the GPS were required. The survey to obtain these parameters is called “geoid survey”.

2.6.1 Transformation of Ellipsoid

To obtain the parameter for transformation of two ellipsoids, the ground control point having the 3-dimensional coordinate values of both ellipsoids are required. In this Study, the point P272 located at approximately 5 km northwest of the Kita City that was used in the 12th parallel survey was adopted as the ground control point for coordinate transformation. The coordinate values of both ellipsoids around the point P272 are shown below.

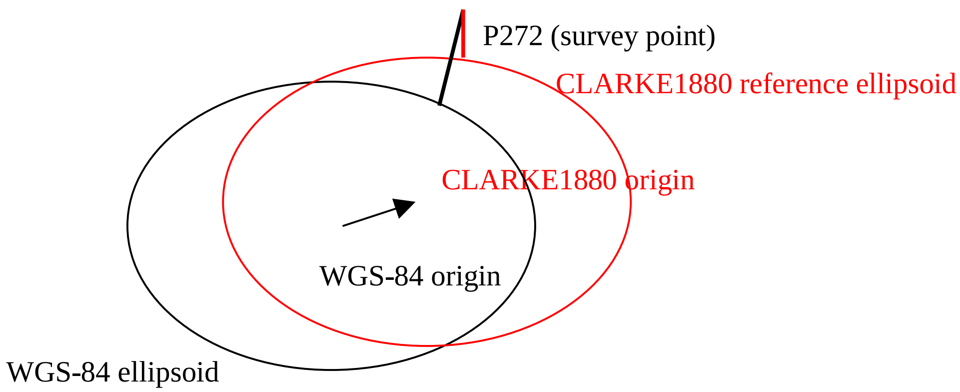


Fig.2-6-1 Model diagram of transformation between ellipsoids

The steps to obtain the parameters for transformation between the ellipsoids will be described below.

① Obtain the 3-dimensional coordinates of the earth center from the latitude, longitude and ellipsoid elevation as measured on the WGS-84 ellipsoid.

② Obtain the 3-dimensional coordinates of the same point from the latitude, longitude and elevation values on the CLARKE 1880 ellipsoid.

③ Obtain the difference between both 3-dimensional coordinate values, which are the shift values of origins (X, Y, Z).

Table 2-6-1 Calculations of Parameters for Transformation between Ellipsoids

Item	WGS-84	CLARKE1880
Semi major axis (m)	6378137.000	6378249.145
Flattering	1/298.257223563	1/293.465
Latitude	13° 5' 41.5754"	13° 5' 40.629"
Longitude	-9° 30' 43.2326"	-9° 30' 38.238"
Elevation (m)	453.399	393.87
X (m)	6128357.0205	6128456.1142
Y (m)	-1026855.7584	-1026719.7991
Z (m)	1435733.8248	1435563.5443
ΔX (m)	99.094	
ΔY (m)	135.960	
ΔZ (m)	-170.281	

2.6.2 Geoid Elevation

As shown in Fig. 2-6-2, the elevation measured by the GPS survey is the height above the ellipsoid. As the ellipsoidal plane is not coincident with the geoidal plane in principle, it is impossible to obtain the orthometric elevation that can be obtained in leveling. Thus, it is necessary to make the geoid survey to know how far the geoidal plane is from the ellipsoidal plane. In this Study, the height above the ellipsoid measured by GPS survey and the elevation measured by leveling are obtained and the undulation on the geoid from the CLARKE 1880 ellipsoid were presumed.

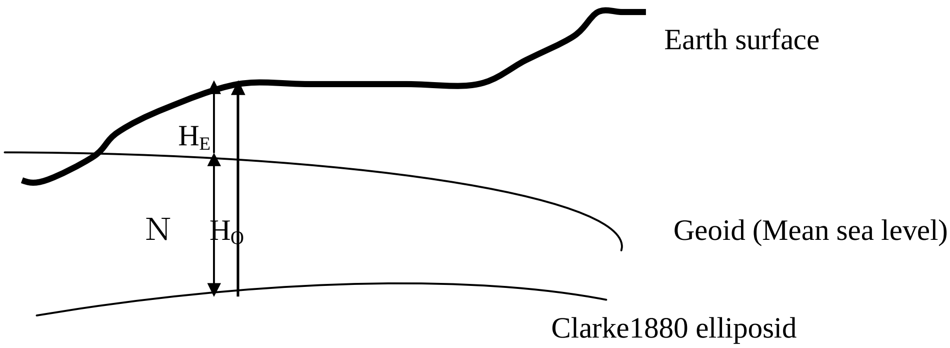
The steps for this procedure are as follows:

① Make the GPS survey on the benchmark and obtain the 3-dimensional coordinates on WGS-84.

② Transform the coordinates from WGS-84 into CLARKE 1880 and obtain the height above the ellipsoid (H_E) on the CLARKE 1880 ellipsoid.

③ Obtain the geoid elevation (N) at the point from the difference between the height above the ellipsoid and the orthometric elevation (H_0) measured by leveling.

④ Conduct this measurement in the entire target area, plot the geoid elevation at each point on the 1/50,000 topographic map and represent the undulation as the contour line to create the geoid map.



H_0: Orthometric height

N: Geoid elevation

H_E: Height above ellipsoid

$H_O = H_E + N$

Fig.2-6-2 Height above ellipsoid and geoid elevation

The actual work was conducted in the following steps:

(1) Reconnaissance of existing benchmark (first-year work)

The railway runs from east to west through the Kita area located at the center of the study area. Along this railroad, the first order leveling route extends and the second order leveling route runs outside the study area in the north, and the third order leveling route passes around Manantali dam in the west of the study area. Therefore, it was decided to set the leveling routes in the north and the south where the road extends to the north from Kita and along the road running in the southwest direction. There was a benchmark Mle103 in the vicinity of the planned leveling route around Kita. As the result of measuring this point and the adjacent benchmark Mle104, the measuring error was only 1 mm. Therefore, the point Mle103 was adopted as the origin for this area. The route bound for Diéma in the north was set as Route 1 and the benchmark 28-T on the leveling route passing through Diéma was set as the end of the route. As the result of measuring the benchmark 28-T and the adjacent benchmark 27-T, the measuring error was 21 mm. The route connecting from Kita to the southwest was set as Route 2 with the end set to the third order benchmark 36 in Bantakoto. The adjacent benchmark 37 to this point 36 was measured, resulting in the measuring error of 7 mm. The route from Kita to Gale in the south was set as Route 3. There was no existing benchmark at the end of this route so that the route could not be enclosed at any benchmark. As this survey was aimed at obtaining the geoid undulation, the benchmark obtained by round-trip survey was adopted.

(2) Monumentation of benchmarks (first-year work)

On Route 1 from Kita to Diéma in the north, 21 benchmarks were established in about 10-km intervals over the distance of 200.1 km, 9 benchmarks in about 10-km intervals over the distance of 55.6 km on Route 2 up to Bantakoto, and 6 benchmarks over the distance of 88.4 km on Route 3 up to Galé. The specifications of monument of stones as the benchmarks are shown as follows. In addition, 4 benchmarks were laid each in Kita City and in the City of Diéma for the purpose of use for the future city development.

(3) Third order leveling (first-year work)

On three routes Route 1, Route 2 and Route 3 on which benchmark stones were laid, the third order leveling was conducted over the total distance of 376.9 km.

(4) GPS survey on benchmarks and pricking (second-year work)

The GPS survey was conducted on the points where leveling was made to obtain their geoidal elevations and on the existing benchmarks.

(5) Calculations and indication of geoidal elevations

The results of the GPS survey made on the benchmarks were transformed into the CLARKE 1880 reference ellipsoid as specified by Mali and the geoidal elevations were obtained from the elevation difference between the heights above the ellipsoid and those measured by leveling.

It was clear that the geoidal plane in the study area was located 59.446 m in average above the CLARKE 1880 ellipsoid.

(6) Production of geoid maps (second-year work)

The geoidal elevations obtained as above were plotted on the 1/50,000 topographic maps. The maximum value of the geoidal elevations was 61.000 m and the minimum value was 57.929 m , and the distance between both points was about 280 km. As described above, it was clear that the geoidal undulation in this study area rose gradually by 2.5 m over 280 km, namely about 10 cm in 10 km intervals. Therefore, the contour lines were depicted in 10 cm intervals to complete the geoid map. The heights above the ellipsoid that were obtained by GPS survey could be corrected with the geoidal correction values that were easily obtained by plotting the measuring points and could also be transformed into the elevation values obtained by leveling.

2.7 Ground Control Point Survey

The ground control points were set at the adequate positions to conduct the spatial triangulation using the SPOT images and the coordinates of these ground control points were measured by GPS survey. The steps of this work will be outlined below.

(1) Reconnaissance of existing ground control points
(2) Selection of ground control points
(3) GPS survey and pricking
(4) Calculations and arrangement
(5) Preparation of Quality control sheet
(6) Products

2.8 Survey of Supplementary Elevation Points

Since the elevation values in the SPOT images had no sufficient accuracy to depict the 20m-contour lines, about 273 additional elevation points (including 24 ground control points) were surveyed in order to enhance the elevation accuracy. Care was taken to distribute these supplementary elevation points uniformly across the entire study area. The results of GPS survey were transformed into the coordinates on the CLARKE ellipsoid and corrected using the geoid map in order to obtain the elevations. The obtained elevations were used as the check data for the contour lines depicted in the digital plotting process.

2.9 Spatial Triangulation

The index elements of each SPOT image were obtained to execute the digital plotting using the SPOT images. 20 scenes of stereo images were lent by JICA to the Study Team, of which it was confirmed that 19 scenes could cover the entire study area. Therefore, spatial triangulation for the 19 scenes of SPOT images was executed to determine the index elements of each image and the coordinates of pass points and tie points. The spatial triangulation was conducted in Japan.

The actual work of spatial triangulation was carried out in the following procedure:

(1) Preparation

First, the density of the satellite images was adjusted to standardize the density of each image scene using the filtering function of the image processing software PHOTOSHOP.

Then, the ground control point file was made up, in which the ground control points were divided into the control points with XYH coordinates obtained in the GPS observation and the benchmarks having only the heights.

(2) Point selection and observation

From the images for which the density was adjusted, the ground control points and pass points were selected and relative orientation was made using these points. For transcription of the ground control points, the satellite images on which the description of points (GPS points and benchmarks) and pricking were made were referred to. Furthermore, 3 or more tie points were added between courses to strengthen the connections of these.

(3) Adjustment

All the scenes of the satellite images were subject to the absolute orientation using the spatial triangulation software for satellite images as described below to perform adjustment calculations.

The result of adjustment was verified and the ground control points with large residual errors were checked and re-measured, and it was verified that the residual errors were within the limits before the adjustment was finished.

The system and software used were as follows:

SOCET SET (Leica Helva, Switzerland)
VirtuoZo (Supresoft, China)

(4) Conclusion

The orbit element was recorded on the header of each satellite image and there were 19 scenes that were acquired on the same orbit element. Therefore, the spatial triangulation software for satellite images that can incorporate the orbit elements in the adjustment calculations was also used in this project.

The number of points used for the adjustment and the overall standard deviations are as follows:

Pass points = 547 points
Ground control points on horizontal plane = 23 points
Ground control points on vertical plane = 43 points
Tie points = 102 points

Standard deviations X = 9.558 m
Y = 14.228 m
Z = 5.095 m

2.10 Creation of Digital Terrain Models

The results of spatial triangulation and the SPOT satellite images were used to create the digital terrain models (DTMs) with 100m grids using the Supresoft automatic DTM generation program. The steps to create the DTMs will be described below.

(1) Inner-model Measurement

The automatic DTM generation was performed using the stereo matching method. As the unclear points and the uneven texture fields in the images had poor matching accuracy, the 3-dimensional models were generated using a digital plotter and the elevations were measured by manual operation.

As the tops of trees were measured in the forest fields, the ranges of tree heights were defined. The measured heights of trees were corrected in accordance with the defined ranges to determine the ground height.

(2) DTM data integration

The DTMs created for each model were merged to one DTM file.

(3) Acquisition of break lines

To depict the contour lines that could represent the terrain accurately, the major roads, rivers, ridgelines and swamp lines were acquired as break lines (topographic lines).

(4) Creation of DTMs

The 100m-inerval DTMs were created from the merged DTM file, and the break line data was combined to the DTMs to create the topographic data.

2.11 Creation of Ortho-Photo Images

The results of spatial triangulation, 100m-grid DTMs and SPOT images were used to create the ortho-photo images.

(1) Creation of ortho-image per scene

Using the ortho-photo image generation software of SupreSoft make, the ortho-images were generated with the same resolution of 10 m as the SPOT images. The satellite ortho-images are usually generated from either of the left and right images. In this Study, the image with higher quality and clear pattern were selected from the left and right images.

(2) Connection of scenes

The ortho-images generated for each scenes were integrated to make one ortho-image file.

(3) Filing of each map sheet

An ortho-image was cut out of the generated ortho-image file to fully cover each map sheet in a square extent and stored in a file.

(4) Printing in CD-ROM

Each ortho-photo image file for each map sheet was printed and stored in a CD-ROM.

2.12 Digital Mapping

The digital mapping for 2 map sheets in Mali and for 46 map sheets in Japan was carried out in the following steps:

(1) Acquisition of planimetric features

1) Production of base maps for data acquisition

A polyester-based overlay was put on each ortho-photo image per map sheet and the information including the roads, railways, rivers, small objects and administrative boundaries that were obtained in photo interpretation and field identification was arranged and transcribed on the overlay. The base map was generated in this process.

2) Acquisition of planimetric data

The base map was A/D-converted with a scanner and the ortho-photo image and the base map data were displayed on the computer monitor. The positions of the data on the base map were adjusted to coincide with the horizontal positions of the planimetric features to obtain the vector data of the planimetric data. The crack lines running along the geological strata within the project area were represented as geological lineaments, which were acquired as the planimetric features that had no impact on the contour lines. In the data acquisition, a digital compilation system was used. The acquired data was recorded as digital mapping data.

The order of data acquisition was as follows:

① River
② Railway
③ Road
④ Artificial structure

⑤ Small object
⑥ Vegetation
⑦ Boundary of protected district
⑧ Geological lineament
⑨ Annotation

(2) Acquisition of topographic data

The 20m main contour lines and the 100m index contour lines were generated from the DTM file using contour generation software. To enhance the contour accuracy, the special topographic lines (break lines such as cliff lines, ridge lines and valley lines) and single points were measured on the 3-dimensional models based on the satellite images. In the case the contour line was 5 cm or more on the map in a flat terrain, supplementary contour lines were added. In the case the forms of some topographic features were deemed to be special, their special forms were added as they are. The acquired data was stored in a contour data file per map sheet.

The data of the 2 map sheets to be processed in Mali was sent to Mali after the data adjoining process was carried out. Then, the same work was conducted in Mali.

(3) Doubtful points and quality control

After the end of digital mapping, the digital mapping data was outputted for checking and correction. The final edition was inspected and the result of inspection was filled in the quality control sheet.

The doubtful and unclear points found in the inspection were indicated on the output maps and arranged as the field completion material.

2.13 Digital Compilation

The digital mapping data and the contour file were outputted and inspected on the integrity with the ortho-photo images. The output data was corrected so that no discrepancy between the planimetric features and the contour liens appeared, and the digital compilation data was produced.

In the digital compilation, the following jobs were carried out:

① Verification of road codes
② Verification of names of villages
③ Categorical processing of wadis
④ Others

The results of digital compilation were outputted and inspected, and the final edition was further inspected and the quality control sheet was made up.

2.14 Field Completion Survey

The doubtful, unclear points and secular changes that were found in digital plotting and compilation were verified through field completion survey.

The points that could be interpreted referring to the materials were discussed and settled with the CP agency.

The secular change data on newly constructed roads, electric transmission lines and substations, and public facilities was made available from the related agencies that controlled the information and materials on the data. In addition, these secular changes were verified and surveyed in the field.

The annotations such as names of villages, rivers and mountains were verified on the formal names and spellings in the field survey.

The results of the field completion survey were arranged, checked and inspected on the digital compilation maps and the inspected results were filled in the quality control sheet.

2.15 Structuralization and Compilation Based on Field Completion

Based on the results of field completion survey, additions and corrections were made to the digital compilation data and the compilation for adjoining the map sheets was carried out. In addition, some errors in structuralizing points, lines and polygons in the digital plotting process were checked and corrected to complete the digital compilation data (topographic mapping (structuralized) data). In particular, the priority order of the duplicated data and which data is to be represented, were checked and corrected in regard to the structures (the upper and lower relations of data to represent points, lines and polygons) for producing the printed maps.

The items to be structuralized were determined considering the plotter outputs and printing as follows:

Point data: Ground control point, independent house and its symbol, annotations, point-like planimetric features, single point of elevation, vegetation symbol and target objects.

Line data: Single-line road, single-line river, railway, electric transmission line, contour line, special topographic lines such as cliff, and geological lineament

Polygon data: Vegetation field (including plantations), dual-line road, dual-line river, lake and swamp, protected districts (for animals and plants, national parks), generalized representation of built-up area, and sandy area

2.16 Production of Printing Films and Printing of Topographic Maps

The topographic mapping data were divided into 4 colors, yellow, magenta, cyan and black, to produce the EPS files for the reproduction film. After color separation, each color block was output for checking and inspection. Overprint processing was carried out and the topographic mapping data were rechecked. The data were then printed out and the final EPS data produced.

Color-separated printing film is produced on basis of EPS data. The film was checked and corrected to complete the final printing film. Using this printing film, 500 copies of each of the 48 map sheets for the Kita area were printed.

2.17 Production of Topographic Map Data Files

The structuralized topographic map data files were stored in a CD-ROM.

The overview of the created data is as follows:

Road length:18,773km

River length:4,732km

Public facilities

Schools:115 Hospitals:1

3. Considerations and Recommendations

3.1 Use of Ground Control Points

In this Study, 52 new ground control points were established. The ground control points that had been established in Mali so far in the past were only the astronomic points installed for producing the existing 1/200,000 topographic maps and the traversing points installed in the 12th parallel survey implemented late in the 1960's. Under these circumstances, the ground control points installed with high accuracy using the GPS in this Study will form the foundation of the ground control point network to be established in Mali in the future. Thus, it is expected that further efforts will be made to expand the survey network conducted independently by Mali itself using the GPS survey technology transferred in this Study.

3.2 Use of Mapping Data

In this Study, also, the mapping data to ensure the output of the 1/50,000 topographic maps by plotter were created. This data can be output in the format to ensure it to be imported into the usual GIS software. In Mali, currently, the projects to digitize the geographic information that the map-user agencies possess individually and to build the GIS combined with maps are being promoted, and the World Bank and some assisting organizations in Europe and the U.S.A. are also positively considering similar projects. Thus, the application of these topographic maps will be increased and expanded in the future. The mapping data created in this Study covered only 48 map sheets of 2000 map sheets that can cover the entire national land in terms of the 1/50,000 topographic map. However, the mapping data is expected to be positively used not only for the development programs in the Kita area but also for the spatial analysis in the development of the surrounding areas in an integrated form.

3.3 Use of Supplied Equipment

In this Study, the following equipment was supplied to Mali:

(1) Work vehicles
TOYOTA Land Cruiser 4 units

(2) GPS sets and accessories
Leica GPS Survey Set 4 sets

(3) Digital mapping system
The digital mapping system introduced in this Study consists of the following major equipment

and the software to operate it:

① Server (PC) 1 unit
② Client (PC) 3 units
③ Laser printer (B/W) 1 unit
④ Digitizer 2 units
⑤ Image scanner (B/W) 1 unit
⑥ UPS 1 unit
⑦ Transformer 1 unit

In the case that similar surveys are planned and implemented in the future, the GPS survey sets will effectively be used for installation of ground control points and acquisition of initial data. The digital plotting and compilation system will be very useful for data editing and production of study products. It is, therefore, expected that the equipment supplied in this Study will greatly contribute to the future socioeconomic development of Mali.

3.4 Technology Transfer and Future Response of IGM

In this Study, the transfer of technology in all the processes involved in the topographic mapping should have been conducted, but it was thought to be advisable that the process of securing equipment and materials necessary for topographic mapping and the processes requiring high costs of maintenance and management, such as aerial photography, aerial triangulation, data acquisition by plotter and printing, should be implemented on a contract basis. Thus, these processes were excluded from the items of technology transfer, but the technology in all other processes was transferred to the counterparts of Mali. In this scope, the transfer of technology in all the processes from the receipt of documents and materials to production of topographic maps was implemented.

(1) Computer literacy

Computers have been used as OA equipment in IGM, but not in the mapping and survey fields so far. In the technology transfer in this Study, computers were used in many processes. Many of counterparts had slight knowledge of computers. In fact, much time was spared for basic matters such as computer operation and data management through time should have originally been used for operation of topographic mapping software programs. In addition, as the arrival of the supplied equipment was delayed, alternative equipment was used for training, so that the technology transfer took much time. It is expected, therefore, that the environment to enhance the computer literacy (basic knowledge) will be created in IGM.

(2) Survey manuals

The survey manuals were prepared before the technology transfer and modified in the course of the actual works. These manuals were completed with the great efforts of the counterparts using French terminology and aiming at the practical use, so that they will be used as the glossary at hand. It is also expected that the future works will be carried out based on these manuals and that the revised editions of those manuals will be prepared.

(3) Transfer of technology concerning supplied equipment

As the supplied equipment was installed the last month of the third year, the transfer of technology using the supplied equipment was not sufficiently conducted. Especially, the training for the operation and system management of the peripheral equipment such as the scanner, digitizer and plotter could not be carried out. This equipment was necessary for production of initial data and checking of the produced data. It was especially useful because it is provided with high efficiency in data creation different from the use of a small LCD display. In addition, the software system introduced in this Study was only the basic tools to produce the topographic maps. Thus, the future introduction of Word, Excel and image processing software is necessary for the effective use of the system.

3-5 Present Status of IGM

DTGC was renamed IGM in January 2001. The new name was intended to: ① define IGM as an agency dedicated to services related to topographic maps, and ② enable it to raise funds independently as an independent corporate entity.

Based on this view, IGM plans to be a pioneer in the GIS field in Mali, including production of digital basic maps, creation of GIS data for other ministries and agencies, support for GIS construction and training of GIS engineers. For this purpose, IGM is making efforts to fortify its position domestically, based on its mapping department, and strengthen its cooperative relationship with other ministries and agencies.

(1) Budget and personnel

IGM's annual budget for the past five years increased substantially in 1998 and 1999 as shown in Table 3.5.1. Personnel shows a slight decrease after 1997, but remains virtually unchanged. It can be assumed, therefore, that the project costs increased. The organization chart of IGM is shown in Fig. 3.5.2. As there is no evident increase in personnel, the transfer of personnel to the new computer mapping department is expected to meet the change in IGM's role.

Table 3.5.1 Budget and personnel by year

Year	Budget Amount	Personnel
1997	217 million Fcfa	145
1998	250 million Fcfa	135
1999	350 million Fcfa	134
2000	471 million Fcfa	133
2001	501 million Fcfa	132

Source: IGM

(2) IGM's revenue sources

IGM obtains its income from the sale of resources such as maps and data in its possession, and technical services for surveying and mapping, as shown in Table 3-5-2. As can be seen from the table, map sales are high and mapping and survey services are the main external source of income.

Table 3.5.2 Main IGM revenue sources

Revenue source	Average income amount
Sale of maps	28.5 million Fcfa
Sale of geodetic survey results	0.1 million Fcfa
Sale of data	2.0 million Fcfa
Sale of photographs	2.4 million Fcfa
Survey services	90.0 million Fcfa
Mapping work	300 million Fcfa

Source: IGM

(3) Equipment owned by IGM

IGM possesses equipment for use in its survey, photography and mapping operations. As shown in Table 3-5-4, it is an extremely poor range of equipment for undertaking mapping work.

Table 3.5.3 Equipment possessed by IGM

Department	Equipment	Quantity
Geodetic survey department	Level	5
	Theodolite	12
	Range finder	2
	Plane table	2
	GPS	3
Photogrammetry department	Plotter	1
Mapping department (GIS)	Personal computer	4
	Digitizer	2
	Drawing board	2
Photograph processing department	Rectifier	1
	Photo copier	1
	Contact camera	2
	Blueprinted	5

Source: IGM

(4) Projects undertaken by IGM

IGM is engaged in the following projects at present:

1) Sadiola area 1/50,000 topographic mapping project

This project was implemented with the aim of developing and mapping the national territory from 1995 to 1996. Mapping work was carried out using digital photogrammetry, and Arc/View GIS software digitizers, scanners and printers were introduced.

2) Project for the return of Mali national maps owned by France

This project is being implemented from 1996 to 2002. 136 topographic maps of Mali on a scale of 1/200,000, geodetic survey results and aerial photos in the possession of France were returned to Mali. Following this, a system capable of digitizing, storing and printing the topographic maps was introduced. The system consisting of a micro-station, geomedia, printer and scanner was installed in August 2000.

3) National border fixing project

The territory of Mali is bordered by 7 countries with which Mali is working to fix the borders. The survey is being conducted using GPS.

4) Cadastral survey

A cadastral survey on a scale of 1:5,000 of an area of 66,000 km^2 including the cities of Bamako and Kati is in progress. 200 ground control points were established by GPS survey to implement this project.

5) Decentralization project

To promote decentralization, a database was created including administrative boundaries and public facilities, based on existing materials. The database is stored on a CD-ROM.

6) Other projects

In addition the following projects are planned:

· 1/50,000 topographic map of Nielle area (8 map sheets)
· 1/50,000 topographic map of Sikasso cotton plantation area (40,000 km^2)
· 1/50,000 topographic map of Kossanto area (5 map sheets)
· Tourist map of Dogon plateau
· Revision of 1/2,000,000 general maps of Mali
· Revision of 1/20,000 tourist maps of Bamako city

3.6 Recommendations to IGM

(1) Effective use of equipment procured by JICA

The vehicles, GPS units, map compilation system and other survey equipment introduced into Mali for this study will certainly be put to effective use to meet growing expansion in the survey and mapping field in Mali which only has very poor equipment. It is expected that IGM will make effective use of the procured equipment and transferred technology to promote the projects mentioned above.

(2) Building a LAN within IGM

Building an intra-agency LAN to connect the system procured by JICA with IGM's existing system will promote joint use of data and peripheral equipment and make effective use of resources owned by IGM.

(3) Promotion of GIS

A Central Geographic Information Committee has been established in Mali to promote smooth exchange of GIS-related information among ministries and agencies. It is recommended that IGM plays a central role in this committee to promote various activities such as monitoring the need for GIS data by other agencies and creating data on high priority areas.

In addition, IGM should undertake the training of GIS engineers and encourage especially those engineers trained in this and previous studies to pursue higher technology,.

(4) Publicizing of IGM's activities

Since IGM is the agency responsible for surveys and maps, it is recommended to spread its knowledge to public users through display of mapping processes, samples of various products and equipment used for surveying and mapping.