HUNTING Technical Services

THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF NATURAL RESOURCES AND TOURISM

THE WORLD BANK

National Reconnaissance Level Land Use and Natural Resources Mapping Project

DRAFT FINAL REPORT

VOLUME 1 : MAIN REPORT

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NATIONAL RECONNAISSANCE LEVEL LAND USE AND NATURAL RESOURCES MAPPING PROJECT

(A component of the World Bank-assisted Forest Resources Management Project)

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Date : 15 June 1997

Mr J W A Musokwa
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Dear Sir

DRAFT FINAL REPORT

In accordance with the provisions of the contract between Ministry of Natural Resources and Tourism, Government of the United Republic of Tanzania, and Hunting Technical Services Limited of the UK, dated 15th April 1994 (with Addendum authorised 20th June 1996) and issued under IDA Credit CR 2335-TA, we take pleasure in submitting six copies of the Draft Final Report of the above Project. Each copy is in two volumes; Volume 1, the Main Report and Volume 2, the Data Dictionary.

We hope that the contents may be discussed with the World Bank and comments referred to our head offices in the UK during the next four weeks so that these may be incorporated into the final version.

We look forward to your comments in due course.

Yours sincerely,

David Smith
Project Manager

ACKNOWLEDGEMENTS

ACKNOWLEDGEMENTS

The outputs of this Project are the result of the efforts of many people, including the personnel of institutions external to the consultancy team. Our thanks are due in particular to the following :

The Government of the United Republic of Tanzania for the recognition of the importance of forest and other natural resources that led to the commissioning of the Forest Resources Management Project, of which this project has been a part.

The Project Coordinating Committee, for policy direction; the Technical Committee for technical direction; and the Project Coordinator and core staff of FRMP, for the provision of administrative assistance.

The Director and specialist staff of the Institute of Resource Assessment, University of Dar es Salaam, for continuous input into the derivation of an appropriate classification, the quality control of imagery used for interpretation, and the general verification of land cover distribution resulting from this work and field-checking exercises.

The Director and technical staff of the Surveys and Mapping Division (SMD), Ministry of Lands (ML), for the completion of the topographic series and the provision of topographic bases to the thematic series; for the provision of access to the national aerial photographic archive; for the delineation and authorisation of current administrative area boundaries (Regions and Districts); and for the final proofing of the printed thematic map series.

The Director and technical staff of the Forestry and Beekeeping Division (FBD), Department of Forestry, Ministry of Natural Resources and Tourism (MNRT), for the provision of access to the national archive of gazetted Forest Reserve and other designated area boundary information, and for the systematic authorisation of boundaries transferred to the thematic map series by the project team.

The Director of Wildlife (MNRT) and the Director of the Tanzania National Parks Authority (TANAPA), for granting free access to protected and conserved areas throughout the country for the purpose of the field verification of image interpretation.

A wide variety of individuals from Regional and District Forest Offices, the offices of Regional and District Commissioners, research organisations, Non-Governmental Organisations and conservation groups, who have willingly given time and/or information in support of the project effort.

Finally, but by no means least, the Tanzanian members of the consultancy team - in the most part, seconded from their substantive positions within FBD and SMD - for un-stinting committment to the project effort, their sufferance of occasional hardship when in the field, and for the provision of invaluable local knowledge and expertise.

ABBREVIATIONS

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Abbreviations and acronyms commonly appearing in the text are explained as follows :

The Project	National Reconnaissance Level Land Use and Natural Resources Mapping Project
FRMP	Forest Resources Management Project
IBRD	International Bank for Resconstruction and Development (the World Bank)
IDA	International Development Administration
GoT	Government of the United Republic of Tanzania
MNRT	Ministry of Natural Resources and Tourism (formerly, the Ministry of Tourism, Natural Resources and Environment)
ML	Ministry of Lands (formerly, the Ministry of Lands, Housing and Urban Development)
FBD	Forestry and Beekeeping Division
SMD	Surveys and Mapping Division
DoW	Department of Wildlife
TANAPA	Tanzania National Parks Authority
GIS	Geographic Information System
GPS	Global Positioning System
HTS	Hunting Technical Services Limited
TANRIC	Tanzania Natural Resouces Information Centre
IRA	Institute of Resource Assessment (UDSM)
UDSM	University of Dar es Salaam
NCA	Ngorongoro Conservation Area
NGO	Non-Governmental Organisation
ha	hectare(s)
km	kilometre(s)
sq km	square kilometre(s)
ONC	
UTM	Universal Transverse Mercator

EXECUTIVE SUMMARY

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E.1 INTRODUCTION

E.1.1 Reason for the Project

Statistics gathered during the 1980's indicated that, although the consumption of timber resources throughout Tanzania appeared to be within the natural increment, areas with high population density were characterised by increasing pressure upon vegetation resources, largely as a result of expanding settlement and agriculture. This was particularly noticeable in areas of natural woodland, customarily exploited for domestic fuelwood and for tobacco curing.

This identified gap in location-specific wood energy balances attracted the attention of UNDP and the World Bank and led to the formulation in 1984 of an Energy Sector Management Assistance Programme (ESMAP). ESMAP produced woody biomass inventory and trends data from four sample areas in Tanzania (1988-89) and its output contributed to the preparation of a Tropical Forestry Action Plan (TFAP) for Tanzania. TFAP possessed a much broader scope and addressed additional policy and institutional constraints to the sustainable management of the nation's forest resources.

The intiatives proposed in TFAP included the investigation of, and recommendations for, advantageous forest policy reform and feasible strengthening of the capability of forest management institutions. One implementation of these proposals was the creation in 1993 of the Forest Resources Management Project (FRMP).

FRMP possesses four inter-linked components :

- A forest management component,
- a land cover and land use mapping component,
- a national GIS natural resources data base (TANRIC), and
- a land policy reform component.

This report relates the progress and output of the land cover and land use mapping component. Its outputs were intended to provide inputs, in the first instance, to both the management component (by illustrating the spatial coverage of principal woody biomass resources throughout the nation) and to TANRIC, by providing an up-to-date land cover data base in a compatible digital format. Arguably, the output of the mapping component also provides wider benefit by furnishing the most current and complete combined thematic and topographic map series at a scale suitable for planning purposes at the national and regional levels.

E.1.2 The Project Team

The contract to provide consultancy services to the mapping component of FRMP was awarded to Hunting Technical Services Limited, UK, 15 April 1994, under IDA Credit CR 2335-TA.

From the outset, one intention was to maximise the benefit derived by Tanzania from the Project and from the potential for technology transfer inherent within it. To this end the

Project team was structured to emphasise the participation of both Tanzanian specialists and institutions, as exemplified below :

- Expatriate consultant inputs were confined to four core staff, assisted by four short term specialist consultants.
- The bulk of the team concerned with the derivation of an appropriate classification; image interpretation; field verification; and cartography were Tanzanian specialists (seven long-term and two short-term), who were seconded from their regular employment by key concerned institutions - FBD (Ministry of Natural Resources and Tourism) and SMD (Ministry of Lands).
- The majority of Tanzanian team members would return to their substantive posts, taking the acquired experience with them.
- The Project was located within the premises of the Institute of Resource Assessment (IRA), University of Dar es Salaam (UDSM), allowing continuous interaction with the Director and senior staff of IRA who were the designated technical arbiters of the thematic work of the Project.
- Key Tanzanian institutions were involved throughout the Project, in practical as well as consultative ways. SMD completed and provided the topographic base to the thematic series. SMD also researched, drafted and authorised all administrative boundaries included upon the final maps. FBD assisted in the research, delineation and authorisation of all Forest Reserve, Game Reserve and National Park boundaries included upon the final maps.
- The intended inter-component linkages within FRMP worked very well, particularly with the management component and with TANRIC, which is now institutionalised within the IRA and commences to function as the national natural resources data base.

The outputs of this Project were truly the result of a team effort.

E.1.3 Project Objectives

The objectives of the Project (Terms of Reference, Appendix A) were to :

- Provide country-wide baseline forest resource information regarding forest areas and forest types.
- Provide baseline information about other land uses, particularly agriculture.
- Facilitate an assessment of natural resource and land use change over time, relating the changes to possible causes, and
- Develop the framework for natural resource monitoring.

E.2 APPROACH AND METHODOLOGY

E.2.1 Choice of Map Presentation

Two alternative forms of map presentation were considered :

- A line presentation overlaying a half-tone reproduction of the corresponding satellite image, with mapping units identified by alpha-numeric coding, or,

- A full colour and symbolised presentetion, but without the underlying imagery.

The first option would be the simpler to produce, but it was felt that the second option would result in a more user-friendly map that allowed more ready appreciation of the distribution of the land cover classes shown. The second option - a full colour presentation - was preferred.

E.2.2 Choice of Imaging System and Imagery

The choice of imaging system to provide the main interpretation medium was driven by two principal criteria :

- The need to utilise the most up-to-date imagery within as narrow a time-frame as possible (essentially, all imagery was to be acquired within the life of the contract) and,
- the desirability that all acceptable coverage for the entire country be sourced from one system.

Original proposals were to use imagery acquired by the Landsat 6 satellite, to be launched in August 1993. Unfortunately, this platform failed to achieve orbit at launch. The remaining feasible alternatives were :

- Landsat 5-TM (American)
- SPOT (French)
- JERS-1 (Japanese)
- Indian and Russian systems

Indian and Russian systems had no proven track record of commercially available acquisitions over Tanzania. The French SPOT system, whilst able to furnish high resolution imagery, is very expensive in terms of cost per unit area covered. The competition was reduced to two systems - Landsat 5-TM and JERS-1.

The two systems possess similar specifications for resolution and spectral range, but Landsat 5-TM is more cost effective, has a shorter (16 day) repeat cycle, and is a proven system that images continuously. JERS-1 (at the time of Project commencement) was an experimental, programmable system with a two-year design life and an unproven track record of data acquisition and processing.

The main argument against Landsat 5 was that its on-board recorders had become non-functional. Thus, acquired image data could only be down-loaded in real-time to receiving stations within line of sight. In the case of Tanzania, only the southern two-thirds of the country could be imaged in this way, from the South African receiving station.

One proposal was to complete nationwide coverage using Landsat-TM in combination with JERS-1 imagery (to fill-in the northern gap), but this was rejected on the grounds of non-compliance with the second of the driving criteria.

Fortunately, assurance was obtained (from TELEOS) that a mobile station would operate from Kenya during the life of the Project which would allow the northern part of the country to be imaged by Landsat 5. This system, therefore, ultimately complied with all criteria and it was selected to provide the image requirements of the Project.

Image data acquired for the Project was to be as current and as cloudfree as possible (no more than 10 per cent overall on any one scene). For nationwide coverage to be obtained within the life of the Project, it was necessary to accept that the acquisitions would be multi-seasonal (ie from the dry seasons pre- and post- main rains).

For the purpose of optimal discrimination of vegetation types, Landsat-TM bands 4, 3 and 5 were chosen to create the false colour image maps.

E.2.3 Approach to Interpretation

The alternatives were whether to interpret the acquired satellite imagery manually, or to adopt a system of automatic classification (whereby land areas with reflection signatures falling within a given spectral range are given the same class name). The advantage of automatic classification systems is speed, but they are only applicable reliably in those cases where the relationship between spectral reflectance and ground truth is very consistent. This is very rare in the case of interpretation for vegetation / land cover, particularly when imagery may be acquired from different seasons of the year. Local knowledge, ground truthing and reference to secondary data become important inputs and manual interpretation becomes the only realistic option.

E.2.4 The Selection of Information to be Presented

The information to be presented upon the final maps results from a balance drawn between the information content of the interpreted medium, on the one hand, and end-user aspirations on the other. In this case, the main limitations were (a) scale (1:250,000) and (b) system resolution for themes other than land cover.

The smallest area that may be realistically drawn and labelled in practice is about 4mm square. At the presentation scale of 1:250,000 this equates to a land area of 1km square, so medium sized farms, plantations, water bodies, etc., with areas below this were unlikely to be shown as discreet units.

Further, the system resolution allows the discrimination of only substantial infrastructure and, as many roads (for example) are made of natural materials with similar reflectance to surrounding land, the image information content for infrastructure was very variable. It was decided that the information to be presented upon the final maps would be driven primarily by the information content of the satellite imagery.

E.2.5 The Collection of Ground Truth

The approach to ground truth information employed two routines :

Field Traverses : These were conducted throughout the road network of Tanzania. Starting from a known point, entry and exit from land cover units were recorded (on dictaphone cassette) and logged against vehicle speedometer readings. The geo-references of each start point, interim way-points and the end point of each traverse were recorded using Magellan GPS. All recorded traverses were written up in hard copy and used to verify final interpretation.

Sample Site Descriptions : Along traverses, sample sites were selected for more detailed description. At each (geo-referenced) site, the profile of the land cover formation was sketched, dominant species from the tree, bush and herb layers were recorded, and notes were compiled on the site characteristics and observed land use.

E.2.6 The Approach to Cartography

Initial proposals were to adopt traditional cartographic techniques as these were well understood and employed in Tanzania. Traditional techniques are employed mostly on hard-copy materials. Colours, symbols and annotations are created by cutting out screens and wax pulls which are then applied to the appropriate separations. The approach relies very heavily upon the drawing and scribing skills of the cartographer and upon efficient reprographics facilities, and the time taken is directly related to the complexity of the work.

After a reasonable amount of image interpretation and field-verification work had been completed it became evident that (a) the information content of the Landsat TM imagery for land cover was very high and that (b) the mean distribution of land cover units on the ground was intricate. Interpretation compilations for land cover were complex, with many small and/or narrow units, and it was clear that cartography under the traditional approach would be a very labourious task and could not be completed in time with the staff resources committed. An alternative approach was looked for.

Computer technology improves rapidly, and the up-dating of hardware and software in the consultants' head offices raised the feasibility of adopting an almost wholely digital approach to cartography. This would allow the computer-assisted plotting of line work, the automatic allocation of selected colours and symbols to land cover units, and the creation of separations for final printing using modern film writing technology. Benefits inherent in this alternative approach included additional technology transfer and the provision of digital data products which would allow more efficient and flexible future use. This proposed alternative was adopted as the approach to cartography.

E.3 IMAGE ACQUISITION AND IMAGE MAP PRODUCTION

The territorial area of Tanzania is covered by a total of 48 Landsat TM scenes (Figure 3.1), although only 42 of these are whole scenes (the remainder being covered by quarter scenes, or quadrants). Image acquisition was constrained mainly by season. Landsat TM is an optical system and registers the presence of cloud, and the shadows cast by this upon the ground. Only imagery that is totally cloudfree, or only minimally effected, was deemed acceptable. Most of Tanzania experiences two dry seasons during which there exists a good chance of acquiring high quality, cloudfree, imagery - from about June to October and (in some parts) from January to March.

The western side of the country proved to be the easiest to image in these terms, the first batch of acceptable scene data being acquired in August 1984. The Southern Highlands and the coastal region are more persistently cloud-affected and the last of the Landsat TM scenes covering the mainland were not acquired until September 1995. Nevertheless, image data for the mainland was acquired almost within one year - complying with the stipulation for acquisition within the life of the Project, and rather better than anticipated. Significant delay was experienced, however, in obtaining delivery of some of this later scene data. The TELEOS - operated station in Kenya ceased operations in late 1995. Their data archive was data handed to EOSAT, who experienced technical difficulties in reading it. This caused some knock-on delays in image map production for the consultants.

Obtaining coverage of the islands of Pemba, Zanzibar and Mafia provided another protracted problem. Only Mafia fell within the footprint of the South African receiving station, and the TELEOS facility in Kenya had closed before acceptable imagery of the northern islands could be acquired. With the consent of the Client, a programming request was lodged with SPOT and quality imagery of all islands was eventually obtained in April and June, 1996. The SPOT data were mosaiced with the adjoining Landsat TM data, as part of the processes described below.

Raw scene data are inappropriate for cartography. The requirement was to convert the raw scene coverage (of about 48 scenes) to a scale-controlled format matching the 64-sheet layout of the national 1:250,000 scale topographic series (Figure 3.2) by producing corresponding image maps. This was acheived using the following processes.

Geometric correction of raw scene data was conducted in two stages (at the consultants' head offices in the UK). After downloading of acquired scene data into the image processing system, tie-points within the overlap common to adjacent scenes were identified and the data manipulated to ensure the best fit. Secondly, another set of geo-referenced tie-points were selected from a sample of the extant 1:50,000 scale topographic series and used to warp the scene data to fit this control.

Contrast enhancement was carried out to provide optimum highlighting of interpretable information and to ensure maximum consistency between scenes. This was acheived by apply a space-variant contrast stretch to scenes to be mosaiced together.

Selected groups of scenes were then **mosaiced**, allowing the limits of the 1:250,000 map series to be superimposed and then the individual **image map data** to be edited from the whole.

Once all the stages of image processing had been completed, the enhanced digital data were written to film and the master negatives thus produced were used to develop the hard copy image maps delivered to the Project team in Tanzania.

E.4 CLASSIFICATION AND LEGEND

The Classification, and thereby the information presented upon the maps, was driven by a number of considerations, principally :

- The expectation of potential end-users for certain types of information to be presented on the finished maps.
- The information content of the satellite imagery at the presentation scale of 1:250,000.
- Constraints to the above brought about by the need to acquire multi-season imagery in order to minimise the time frame over which data were collected.
- The selection of the approach to classification, the discriminative criteria to be applied and the system of nomenclature to be used.

Vegetation and land use classifications employed previously in the East African region were researched. These earlier classications fell into three main categories of approach - Hierarchical, Physiognomic and Ecological - and these were investigated for suitability a basis for the Project clasification.

Consultations were held with potential end-users of the thematic map series to canvass preferences. The outcome was in favour of a classification system based upon a purely physiognomic approach, unaffected by considerations of floristic distinction, the use of vernacular or local terms, or by a unit's apparent position within the ecological succession. The Institute of Resource Assessment compiled a logical framework for the classification of land cover (Figure 4.1) which received general approval.

The Classification grew from this framework, influenced by observations of land cover characteristics and variety collated during reconnaissance and verification field missions. It comprises five main vegetative land cover types (Formations) - Forest; Woodland; Bushland; Grassland; and Cultivated Land; plus additional classes for Open Land, Water Features and Urban Areas. The Formations are sub-divided into Sub-Formations according to relative canopy density, combination with other Formations, or wetlands status. The final classification represents 35 classes, or mapping units, and is shown in Figure 4.1.

Current land use is more difficult to **map**. Some uses (such as hunting and recreation) do not have recognisable (and therefore un-mappable) boundaries. Others (such as fuel-wood harvesting, or agriculture) may embrace a number of adjacent but different land cover units. The classification for land use has been **implied**, therefore, from that for land cover (also indicated in Figure 4.1). Thus, whilst accurate area statements may be derived from the mapping of land cover, the extrapolation of such figures to indicate the distribution of land use would be less reliable.

E.5 INTERPRETATION AND FIELD VERIFICATION

Apart from the very early stages of the Project when footprint (raw scene) imagery was used during field reconnaissance, all interpretation was carried out upon clear acetate (inktake) overlays to the scale-controlled image maps. The following procedures were used to arrive at the final compilations :

A **Preliminary Interpretation** was carried out to identify major topographic features (assisted by paper copies of the topographic base maps) and the general distribution of land cover types. One main purpose was the identification of areas of certainty and uncertainty - ie those areas where land cover types could be recognised upon the imagery with a high degree of confidence, and those areas where identification was in some doubt.

This work was carried out for each image map sheet as they arrived on-Project from the UK and, once a number of adjacent sheets had accumulated, was used to direct the **Field Verification** exercises.

Field teams were organised such that field work in the area of a given map sheet(s) was carried out by the same specialists who had carried out the preliminary interpretation and would ultimately complete the final interpretation. Teams comprised two specialists - generally one expatriate and one Tanzanian. Each team was responsible for planning the itinerary of their field mission, based upon the questions raised by the preliminary interpretation. Fieldwork was carried out in Project FWD vehicles each with a driver, allowing the specialists to concentrate wholely on field verification.

Field Traverses were conducted as per the approach (E.2.5, above). The main routes for which detailed traverse notes were collected are indicated in Figure 5.1. Nearly 20,000 km of traverse was described in this way, representing about 30,000 land cover units observed and located.

Periodically, **Sample Sites** were described in greater detail. The selection of the location of sample sites was not wholely random, but directed largely by the results of the preliminary interpretation and by the intention to sample the full range of the land cover classification as equitably as possible (although Cultivated Lands - generally very obvious upon the imagery - were sampled with less frequency).

At each Sample Site, the following information was recorded :

- Sample Site identification.
- A sketched profile of the vegetation cover.
- Dominant tree, bush and grass species.
- The geographical co-ordinates of the Site.
- Site elevation.
- 1:250,000 map sheet reference.
- Land Form at the Site.
- Land Cover unit identification and code.
- (Arboreal) cover density.
- Observed land use.

In addition other site parameters were recorded (sometimes requiring reference to secondary data) including : soil type; rainfall; geology; Gillman vegetation unit; Land Status (eg whether reserved or not); and the Region and District of location.

Examples of the record forms used for field traverses and sample site descriptions are given in the main text, Figures 5..2 and 5.3.

The gathered field data were used to assist the **Final Interpretation** of each image map. This was further supported by reference to available secondary data. Reference was made to previous studies, reports and cartography, but the key support to final interpretation was through reference to the national aerial photography archive. Access to this archive was kindly granted by Surveys and Mapping Division, Ministry of Lands.

In addition to interpretation for land cover, the decision was taken to interpret **surface drainage** from the imagery also. This was because it was discovered that rivers shown upon the existing 1:250,000 topographic map series (which would provide the topographic base to the thematic series - see E.6, below) did not always exactly register with riparian-associated land cover units derived from image interpretation. Interpretations for drainage were compiled as separate overlays to each image map.

The interpretation compilations were completed by edge-matching to adjacent compilations prior to being pssed to the cartographers for digitising.

E.6 THEMATIC CARTOGRAPHY

E.6.1 General

The following data sets were needed to complete the maps as envisaged :

- Land Cover polygons
- Surface Drainage alignments
- Forest Reserve boundaries
- Game Reserve boundaries
- National Park boundaries
- Administrative Area boundaries
- Basic topographic detail

Under the agreed digital approach to cartography (E.2.6), all data sets with the exception of the topographic detail were to be digitised. The topographic base to the thematic maps was prepared as a set of film positives, and this is discussed later.

All digitising, data manipulation (editing) and data retrieval was carried out using the ARC/INFO system. Three copies of licenced PC software were purchased for the Project, including manuals and dedicated licence keys (dongles). Hardware comprised three digitising stations - Calcomp A1 digitising tablets linked to PC processers. Peripherals included two further lap-top computers (on loan from the consultants), a Hewlett-Packard Laser Jet IV printer, an 8-pen colour draft plotter and tape drives for data back-up storage. All systems were protected by in-line voltage regulators and uninterruptable power supplies but, nevertheless, considerable down-time was experienced due to occasional cuts in the mains power supply.

The digitising procedure was fundamentally the same for all data sets. Once the corner marks of each map sheet had been registered as longitude and latitude values, all internal information may be recorded as x,y coordinates relative to these benchmarks. Points may be joined to form lines (arcs) and arcs may be closed to form shapes (polygons). Arcs and polygons may be attributed names, codes, colours or symbols, by using appropriate software routines (Appendix B). The enclosed area of digitised polygons may be similarly computed.

For all the digitised data sets, the following processes had to be completed :

- Creation of raw digitised coverage
- Cleaning of the coverage (identifying errors)
- Editing of the coverage (correcting errors)
- Transformation of the coverage to UTM projection
- Checking for sliver polygons and editing-out
- Coding of polygons
- Clipping of the coverage (to allow edge-matching to adjacent sheets)
- Edge match editing
- Production of a draft colour plot and checking
- Generation of the final coverage and copying.

In addition, the UTM grid and master border for each final map sheet were created.

Specific issues concerning the compilation of the individual thematic data sets are commented upon briefly in the following sections.

E.6.2 Land Cover

The land cover data set was prepared for the cartographers in the form of hand-drawn and coded compilations on clear inktake film (overlays to each of the 64 image maps comprising the series). Digitising of the land cover data set was a major exercise. On average, each map sheet was comprised of some 700 polygons (about 40,000 in total for the series). During digitising each polygon was given a sequential number which was then encoded to match the interpretation compilation. The encoded data files were used to produce draft colour plots for interim checking and, later (after further editing) for the allocation of colours and symbols during the production of the final quality-control inkjet plots.

E.6.3 Drainage

The surface water drainage network was traced from the image maps on a separate clear inktake overlay and digitised by the cartographers as a separate coverage for each map sheet. It was only possible to trace rivers where channelisation was clearly shown on the imagery (often, rivers disappear into areas of seasonal or permanent swamp). Consequently, the drainage network represented upon the final maps is a combination of clear river alignments joined to ribbon-like polygons of riparian-associated land cover units. This approach was necessary, but did create problems - digitised coverages for drainage had to be very accurately "cut-back" so as to meet, but not overlap, land cover boundaries.

E.6.4 Designated Areas

Designated Areas include Forest Reserves, Game Reserves, Conservation Areas and National Parks. There are about 500 Designated Areas in Tanzania. The authorised boundary for each was researched by Project cartographers from archives held by the Department of Forestry (FBD), the Department of Wildlife, and the Tanzanian National Parks Authority (TANAPA). Researched boundaries were transferred by scale-drawing to transluscent overlays to each image map. Supporting data sets such as land cover, drainage and topographic detail were referred to throughout this process in order to ensure that known boundary coincidences (eg, with major rivers or roads) were met. Draft compilations were checked and authorised on a sheet-by-sheet basis by a senior official of FBD. All source data were recorded and archived.

Authorised compilations were passed to the cartography section for the digitising of boundary information. This process was complicated by the need to call-up other coverages for each map sheet (such as drainage or administrative boundaries) in order to ensure that the identified boundary coincidences were accurately reflected within the digital data.

E.6.5 Administrative Areas

Administrative Area boundaries, in the context of this Project, include the International, Regional and District boundaries. The boundaries shown upon the 1:250,000 topographic series were out-of-date, being on occasion omitted, mis-aligned or mis-classified. These errors affected about two-thirds of the 64-map sheet series. The consultants identified apparent anomalies by reference to more recent cartography (at both lesser and larger scales) and provided notes to the Boundary Section of SMD who drafted up-to-date and authorised boundaries upon paper plan copies of each map sheet, provided by the Project.

This information was transferred to the stable topographic base film positives prior to digitising. Again, boundary coincidences with other data sets (principally, rivers and Designated Area boundaries) had to be accommodated. Once this digital data set was complete for each map sheet, all previous boundary information appearing upon the topographic base films was erased. In common with all other digitised data sets, the adminstrative boundaries were edge-matched to adjacent map sheets.

E.6.6 The Topographic Base

The topograhic base is the only non-digitised data set used in the production of the final maps. It exists as a set of 64 film positives prepared by SMD, with assistance from the Project, and is comprised of information combined from the Black and Brown plates used in the production of the national 1:250,000 scale topographic map series (Blue plate information showing rivers and water bodies was deliberately excluded form this combination following the identification of occasional mis-registration with associated image data).

The option of preparing a generalised topographic base from image interpretation was considered but was discarded on the grounds that the imagery provided insufficient infrastructural information to meet the requirements of the ToR, if used as the sole source. Utilising selected information from the national topographic series, however, also possessed some disadvantages to be overcome :

- Approximately one-third of the 1:250,000 scale topographic series had never been published, and this had to be completed before the thematic series could go into full production.
- Some of the information presented was out-of-date.
- Although only two plates were selected to provide a satisfactory topographic base to the thematic maps, the data content of most map sheets was too great to digitise within the resources of the Project.

The first issue was overcome by assisting SMD to complete the topographic series, at least to the level required by the Project. The second issue was partially resolved by updating the topographic information (wherever possible and reliable) via image interpretation and reference to relevant secondary data sources, carried out by the Project cartographers. The third point was accommodated by incorporating the topographic film positives into final map production at the reprographics stage.

E.6.7 Map Design

Map design was directed towards the maximisation of information content and compliance with the cartographic standards and conventions consonent with a national map series, but with emphasis upon the clarity with which map information is presented to the end-user. To these ends, the following characteristics were included in the design of the maps :

- Land cover Formations were each assigned a colour broadly representative of their appearance in reality.
- Symbols used to discriminate between land cover Sub-Formations were chosen to reflect relative canopy density, propensity for water-logging, or the organised nature of cultivated lands, for example.
- Where Formations are sub-classified according to the same criteria, the same overlying symbol was used (eg Dense Woodland shares the same symbol with Dense Bushland, although their Formation-level colours are different).
- The majority of symbols were printed in half-tone, to reduce potential obscuring of topographic information.
- Keys were established to discriminate between the different classes of shared Designated Area boundaries (eg a given Forest Reserve may lie adjacent to another Forest Reserve, or a Game Reserve, or the two may share all or part of the same land area).
- Master border information was compiled to provide complete thematic and topographic legends, grid and magnetic data, sheet layout and data source information, accreditation and compilation notes, all in a manner consonent with the national map series.

Map design is considered in more detail in Section 6.3 of the main text.

E.7 COMPUTATION OF CURRENT LAND COVER DISTRIBUTION AS A BASIS FOR MONITORING CHANGE

The planning for future natural resources management requires an accurate inventory of current resources and an appreciation of present trends in their status. One fundamental purpose of the Project was to provide an inventory of one aggregation of renewable resources (in this case, land cover - natural vegetation modified by land use), derived within as narrow a time-scale as possible, in order to form the basis for future trends-monitoring and evaluation.

The mapping exercise, - whose stages are described in the preceding sections - would result in a series of thematic maps illustrating the spatial distribution of land cover units according to the derived classification. Implicit in the ToR for the Project, however, was the additional requirement to provide statistical data for this distribution in the form of area statements in respect of each of the 64 map sheets; each of the ~~26~~ Regions comprising the Republic; each of the ~~99~~ Districts comprising the Regions; and for the Nation as a whole.

Once the digital data describing land cover unit boundaries were satisfactorily captured, the generation of area statements was facilitated by the provisions of the ARC/INFO software and by employing the routines given in Appendix B. The software provided for the automatic calculation of the area represented by any individual map unit, or for the aggregate total of similar units within a given overall area. For individual map sheets with pre-determined dimensions, the process was relatively straightforward. For Districts and Regions, however, it was complicated by the need to mapjoin the map sheet coverages embracing the area in question. In the case of a large Region, for example, half-a-dozen individual map coverages may need to be joined to cover the Region. The Regional boundary would then be superimposed upon this joined coverage, followed by the isolation of the land cover information within it. Only then could the area statements be generated. This procedure had to be followed similarly for every Region and for each District within each Region. The process was complicated further by the inability of the computer software to cope easily with the geometrical distortions inherent at UTM Zone boundaries (Tanzania falls within three UTM Zones). The "easiest" way to deal with this problem was to treat Regional and/or District areas falling across a zonal boundary as two separate polygons (one East and one West), compute the areas for each, and then sum them to provide the final statement.

The required area statements are presented in Volume 2, the Data Dictionary.

The framework for the future monitoring of land cover and land use change has been established by the documentation of the procedures used during the course of the Project; the training of key Tanzanian staff who have returned to their substantive posts and retain the skills acquired, and by the legacy of an equipped and functional facility (presently within IRA, UDSM). All processes are fully replicable. Future monitoring and evaluation will require merely the organisation of the repetition of Project work, either holistically or in selected sample areas across Tanzania.

E.8 FINAL PROCESSING

The digitising work described above, and carried out by the Project team in Tanzania, resulted in the output of dedicated files describing all of the coverages and attributes comprising each map sheet. These were copied to floppy diskette as export files and sent to the consultants' head offices in the UK for initial processing using the more powerful computer facilities there.

Initial processing began with the conversion of the export files to a SUN UNIX format compatible with the SUN SPARCstation 10 Workstation installed at the consultants' head offices. Preliminary editing, including further edge-matching and combination of coverages, was carried out in the UK prior to plotting inkjet proofs. These proofs were sent back to Tanzania for combination with the topographic base film and checking against a pro-forma checklist. The completed checklists, annotated inkjets, and corresponding topographic bases were then returned to the UK for final editing and correction.

The process of final editing was linked to the decision by the Client to have the final maps printed in the UK, as referred to in the following section. Attached to this decision was the requirement ~~for an independent cartography specialist to~~ supervise the final editing and map printing on behalf of the Client, giving particular emphasis to the adherence to cartographic standards and conventions. This valuable input assisted in final cartographic correction, improving the legibility of the maps in detail, and ensuring that the final products were of the standard required by the Client.

Final, detailed corrections were incorporated into the relevant coverages and the maps were replotted as final inkjets. These were checked to ensure that all identified corrections had been incorporated satisfactorily before the map data were exported as Postscript .eps files to be used in the reprographics stage.

E.9 REPROGRAPHICS AND PRINTING

Reprographics refers to the preparation of negative film separations for each of the four process colours required to print each map sheet, followed by the preparation of corresponding printing plates, used in the final stage.

E.9.1 General

From the outset, the aspiration was to print the final maps in Tanzania, with SMD (the Government ~~printer~~) being the preferred sub-contractor. This proposal was clearly favoured by the Client. The negotiations towards finalisation of the printing sub-contract were protracted, however, due in part to the need to cost for the refurbishment of the presses and dark room facilities at SMD, and the apparently high labour cost of printing at SMD (which needed re-negotiating).

Inspection of the presses at SMD by a specialist engineer revealed that only the Duffa flatbed press was functioning reliably. This press is not designed for large print runs and, of the installed machines that are, only the Roland Rekord was in a condition worth repairing.

The repair of this machine was contracted by FRMP under separate funding. The work was intended to be completed by August 1996 but due to delays in the selection of the contractor, the issue of contract documents, the procurement and shipping of spare parts and the mobilisation of the engineer, the repair of the Roland Rekord was not completed until early December, 1996. At this point it was possible to test the machine by printing proof copies of selected map sheets - in this case, those for Tabora, Bukene and Rungwa. The negative separations required had been prepared in the UK, but printing plates and other requisites were purchased locally in Dar es Salaam. The printing plates were prepared at SMD from the imported separations. The Tabora sheet was printed from plates used for earlier proofing of the Duffa flatbed press. These had become damaged in storage and the printed proofs were very smudgy as a result. The Bukene sheet printed with very inconsistent black detail across the sheet - attributed to poor exposure of the Black plate during plate-making. Greater attention to plate-making for the Rungwa sheet resulted in a very much improved proof. This was sufficiently good to reinforce confidence in printing at SMD, although some reservations remained concerning the likely consistent quality of printing plates.

Discussions between the consultants and senior officials at SMD arrived at an arrangement whereby the consultants would purchase all required materials and arrange for the preparation of colour separations and plate-making in the UK, all to be delivered to SMD in Tanzania who would remain responsible for map printing to specification.

By mid-January 1997, sufficient printing paper had been purchased and one third of the total had been air-freighted to Dar es Salaam. Negative film separations had been prepared for 16 sheets (of the 64-sheet series) and plates had been made for half of these. In addition, 260 unexposed plates had been purchased and cut to a size to fit the Roland Rekord press at SMD. It was clear, however, that it was becoming increasingly unlikely that the contracted deadline of 31 January 1997 would be met. Strategies for completing the Project were compiled and discussed in Technical Committee, and reviewed following the findings of a small appointed working group. This review coincided with protracted power and water shortages in Dar es Salaam and the Client decided (22 January 1997) that printing outside Tanzania may prove more secure. The consultants were instructed (5 February 1997) to seek for alternative printers in the UK.

E.9.2 Reprographics

The final output from the consultants head offices was the postscript.eps files containing the digital information needed to produce the colour separations for each map sheet. Separations production and plate-making were conducted ex-house because of the specialised equipment and software used. The first stage in the process required the conversion of the postscripted data to a language that is compatible with the current generation of film writers. The image setter language used in this case was TYPAN RIP.

Once in TYPAN, the data for each map sheet were imported to an Agfa Advantra 44 film writer. This is one of the larger film writers with a 44" x 36" format. The majority of printing in the UK today is carried out from positive separations. In this case, however, the Client was quite specific that negative separations and plates should be produced. To this end, the following stages were gone through for each of the 64 map sheets in the series.

- A family of four negatives (Black, Cyan, Magenta and Yellow) were produced from the Advantra.
- One positive was produced for the Black plate from its negative.
- This positive was then combined with the topgraphic base positive and exposed together to form a combined negative (a "new" fourth negative).
- From these four negatives, the plates for printing each sheet were prepared.

In addition, four positive separations were prepared for each of eight sheets selected for sample checking by Cromalin proofing.

E.9.3 Printing

A UK printer was found possessing a press taking plates that were just slightly larger than those used by the Rekord, thereby retaining the possibility of further future use on the Rekord after minor trimming (the Roland 6000, a more modern version of the Rekord. Following an inspection of the printing facilities (accompanied by the cartography consultant) and an examination of similar work carried out previously, an order for the printing of the maps was placed.

Sets of printing plates were provided in batches of between 10 and 20. This facilitated the setting up of fairly large runs at one time, on one machine, with one operator and thereby reducing some of the variables that might be introduced - such as different ambient temperatures, or different colour perception on the part of the operator(s).

Production control at this stage was largely the responsibility of the printer with periodic supervision from the consultants. As batches were printed, however, specimen maps were delivered to the consultants for final checking.

Examples of the maps as they were being printed were sent to FRMP Tanzania for review and comment (the first batch of 3 sheets at the end of March 1997 and a further batch of 10 sheets in early May). Received comments were satisfactory and complimented the high standard of the printing.

After printing and trimming, each map sheet in 500 copies was wrapped in protective kraft paper ready for freighting to Tanzania.

E.9.4 Quality Control Procedures

The digital map data (postscript.eps files) output from the consultants head offices was authorised via the checking of inkjet plots produced from the data, in combination with the topographic base film positives (Section 8).

There are three main process stages between that point and sight of the finally printed maps, however :

- Separations production
- Plate-making, and
- Printing.

The technologies and methodologies employed at each of these stages were well-tried and robust, but the potential for something to go wrong always exists and it was important to monitor each stage and be able to react quickly to solve any identified problems before they continued further into the production run.

The production of separations was monitored by checking Cromalin proofs produced from positives of the separations. Cromalins are one-off prints and are expensive to produce, so a sample of eight map sheets (12.5 per cent of the series) was selected to represent as much variation in land cover as possible (and therefore in colour and symbols). Cromalins prepared for these eight map sheets (Kabale, Kahama, Arusha, Uvinza, Tabora, Sumbawanga, Kazimoto and Liwale) were checked by the consultants for completeness of information content, accuracy of registration, correctness and consistency of colours, clarity of symbolisation, and legibility of annotations.

Plate-making was monitored by checking Ozalid prints prepared from the Black and Cyan plates of each map sheet (most of the information making up the maps is contained on these two plates). An Ozalid was prepared for each of the 64 map sheets prior to printing. The black and white presentation allowed further checking of registration, symbolisation and annotations. It also allowed examination of the percentage dot screens transferred from separation to plate, and thereby producing some assurance that the desired colours would be created at printing.

E.10 PROJECT OUTPUTS AND HANDOVER

The project objectives were met by the following Project outputs :

- Digital products for each satellite image scene.
- Digital and hard copy products for each scale-controlled image map.
- Film positives of the completed 1:250,000 topographic bases
- Interim products including
    - Land cover interpretation overlays to each map sheet.
    - Drainage cover interpretation overlays to each map sheet.
    - Authorised Forest Reserve and other Designated Area boundary overlays to each map sheet.
    - Authorised Regional and District boundaries (on paper copies) for each map sheet
    - Flight indices for all aerial photographic surveys accessed in the course of interpretation, for each map sheet.
    - All (interim) digital cartographic data on hard disk.
- 500 approved copies for each of the 64 map sheets within the 1:250,000 scale thematic map series.
- Finalised (corrected) digital cartographic data (on CD ROM).
- Colour separations (repromats) to accompany each map sheet.
- Baseline statements of land cover distribution, according to the approved classification, and by map sheet, District, Region, and for the Nation as a whole.
- A Data Dictionary describing each of the mapping units.
- Quarterly Progress, and Final Reports.
- A consolidated and operational facility, with trained and experienced Tanzanian expertise, that may be utilised to facilitate the future monitoring of land use change, within a framework developed by the Project's sister component, TANRIC.

MAIN REPORT

1. INTRODUCTION

1. INTRODUCTION

1.1 THE GENESIS OF THE PROJECT

1.1.1 Woody Biomass, Forestry and Energy

Tanzania possesses a territorial area of about 945,000 sq km. Statistics gathered during the 1980's indicated that almost half of the country - some 440,000 sq km - remained wooded to one degree or another. However, only about 4 per cent of this area was classified as forest or closed woodland, the remainder being more open formations represented very largely, but not exclusively, by the *Brachystegia sp. / Julbernardia sp.* association referred to locally as "Miombo".

Total exploitation of forest production was estimated at that time to amount to some 28 million cubic metres per annum, well within the estimated increment for the natural resource of about 70 million cubic metres per annum (TFAP in World Bank, 1991).

Most of this exploitation, however, was identified as being for domestic fuelwood consumption and tobacco curing (in the north and west of the country), and although the relationship between exploitation and growth rates for the nation as a whole may be within balance, concern began to be focussed on specific areas of the country where this balance might be being reversed.

In locations of high population density, Tanzania's wood resources have been increasingly pressurised by the demands of expanding agriculture, urbanisation and the increasing domestic energy requirements of a growing population (exacerbated in recent years by the hospitality offered by Tanzania to refugees fleeing conflicts in neighbouring countries). It was this identified gap in the location-specific wood energy balances that intially attracted the attention of UNDP and the World Bank (in 1984) and led to the formulation of an Energy Sector Management Assistance Programme (ESMAP).

1.1.2 ESMAP and the FRMP

ESMAP arose from an energy assessment of Tanzania produced by UNDP and the World Bank in 1984. This report expressed the need to formulate and implement comprehensive woodfuel development strategies in specific target areas throughout Tanzania. A mission carried out in 1986 (reporting in 1987) identified the options for the alleviation of woodfuel shortages. The mission also highlighted the need for the updating of information on the nature and extent of woody biomass resources, particularly in peri-urban and tobacco-growing areas.

This intiative to update woody biomass data led to a study targetting four sample areas in Tanzania (Tabora-Mwanza; Iringa; Arusha; and Dar es Salaam). The selected methodology involved the establishment of a workable classification, followed by the interpretation and field verification of some 38 SPOT satellite images covering the four selected sample areas, for land cover distribution. This work was conducted by specialsists from the Institute of Resource Assessment, University of Dar es Salaam, in preparation for the organisation of sample inventories to be conducted within the target areas. This work took place mostly during 1988 and 1989.

The outputs from ESMAP drove, to some extent, the preparation of a Tropical Forestry Action Plan (TFAP) for Tanzania, which possessed a much broader scope and addressed additional policy and institutional constraints to the sustainable management of the nation's forest resources.

It is out of the TFAP that the present Forest Resources Management Project (FRMP) has grown.

1.1.3 The Project within FRMP

By 1993, FRMP was already intiated, but was not fully functional until early 1994.

The brief of FRMP includes :

- The strengthening of mechanisms for natural resource use monitoring and the formulation of forest policy,
- The strengthening of institutions concerned with land policy and its reform,
- The strengthening of Regional and District forest services (intially in Tabora and Mwanza Regions).

To implement this brief, FRMP comprises four components, each of which possess particular Terms of Reference, but which complement one another through their outputs.

1) **The Forest Management component :** This operates as a pilot project in the Regions of Tabora and Mwanza. It is directed at establishing and testing revised institutional systems and practices for forest management, for improving the revenue base from the exploitation of forest resources, and for the systemised involvement of local communities in the management of forest resources.

2) **The Land Cover and Land Use Mapping component :** This component is directed at the production of an up-to-date series of vegetation and land use maps covering the entire country, at 1:250,000 scale, together with computed area statements for the distribution of the mapped units. This component is intended to furnish a useful tool for the planning of forest resources management at the Regional level, and to provide a baseline for the future monitoring of land use change. It is this component of FRMP that is the subject of this report.

3) **The Tanzania Natural Resources Information Centre (TANRIC) :** TANRIC is institutionalised as the National natural resources data base. This component of FRMP has been responsible for setting-up the facility, systems and staff training required to allow the continued operation of a Geographic Information System (GIS) that will capture and analyse natural resources (including forest resources) data, for feed-back into the planning cycle.

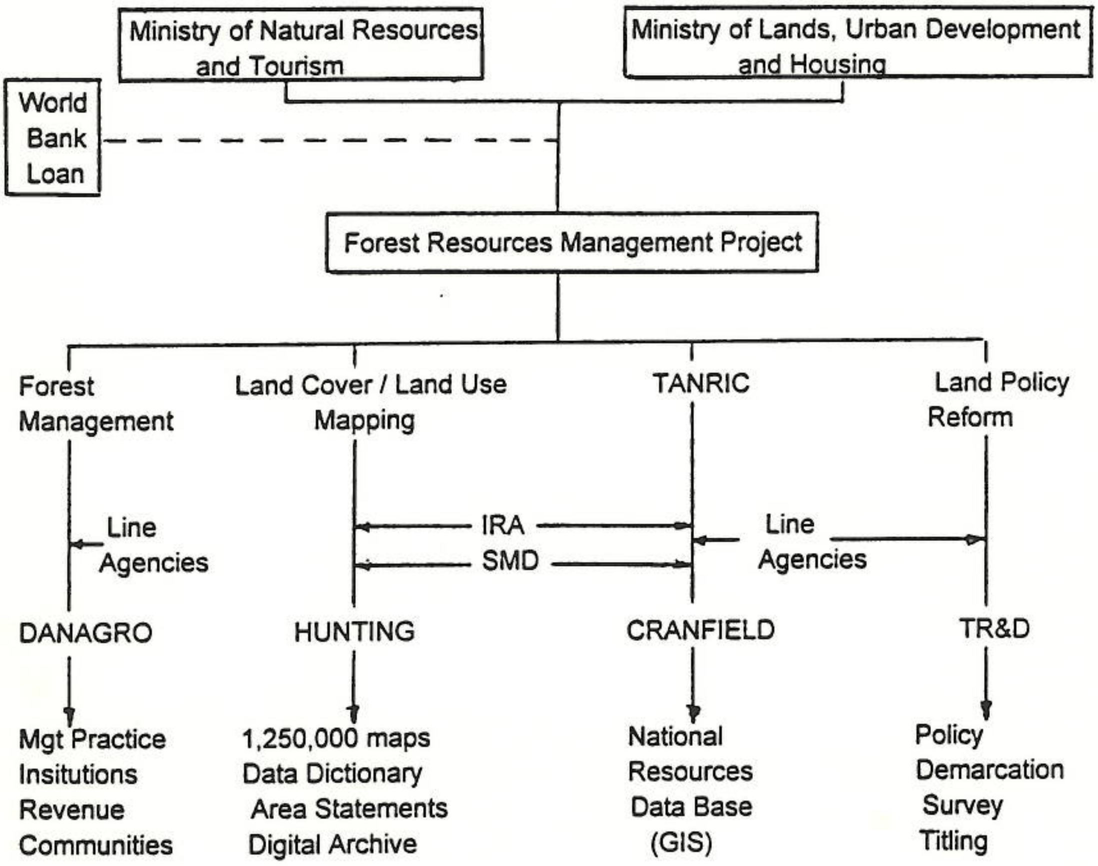
4) **The Land Policy Reform component :** This has comprised short-term consultancy assistance to on-going Government intiatives to rationalise land tenure and land policy throughout Tanzania. Practical intiatives include policy formulation, the demarcation and surveying of land parcels, and the formalisation of rights of tenure and usufruct. This is an important input to forest management, particularly in areas where rights boundaries may be in dispute.

The organisation of these components within FRMP is shown in Figure 1.1.

FIGURE 1.1 THE PROJECT WITHIN FRMP

NATIONAL RECONNAISSANCE LEVEL LAND USE AND NATURAL RESOURCES MAPPING PROJECT

ORGANISATION



FRMP, therefore, is responsible to two ministries (Ministry of Natural Resources and Tourism, and the Ministry of Lands).

Project policy is decided by a Project Coordinating Committee, upon which both ministries are represented by their respective Principal Secretaries.

The programme for technical implementation is directed by a Technical Committee, chaired by the Project Coordinator and comprised largely of Departmental heads and technical officers from the main concerned line agencies and institutions - Surveys and Mapping Division (SMD), Forestry and Beekeeping Division (FBD), and the Institute of Resource Assessment (IRA).

It is within this organisational context that the National Reconnaissance Level Land Use and Natural Resources Mapping Project (the Project) has operated.

1.1.4 The Contracted Consultancy Team

Invitations to tender for consultancy services to the land cover and land use mapping component were issued by the (then) Ministry of Tourism, Natural Resources and Environment in mid-1993.

Following submissions and negotiations, the contract to provide these services was awarded to Hunting Technical Services Limited of the UK, 15 April 1994, under IDA Credit CR 2335-TA.

Once contract documents were finalised and exchanged, the Project was mobilised in Tanzania, mid-September 1994.

From the outset, the Project has been seen as a vehicle for institutional development, including training and technology transfer. To this end, the composition of the consultancy team has emphasised heavily the participation of qualified Tanzanian consultants, drawn in the main from Government line agencies. In this way, the experience and expertise acquired in the course of the Project could be expected to remain in Tanzania and to be utilised for the future benefit of the Nation's development. The composition of the team has varied as the Project has progressed through its technical phases. The participating individuals are identified in Table 1.1, below :

TABLE 1.1 THE CONSULTANCY TEAM

EXPATRIATE	POSITION	TANZANIAN	POSITION
G C Deane	Project Director	E F Haule	Forestry
D W Smith	Project Manager	S Mwansasu	Forestry
P B Smyth	Interpreter	L Okello	Interpreter
C Smyth	Interpreter	A A Mttoi	Interpreter
S Henderson	Senior Cartographer	A Majimbe	Cartographer
M Whitelegge	GIS Specialist	J M Nzengula	Cartographer
J W Trevett	Printing Advisor	E Ntibansubile	Cartographer
D Eadie	Printing Engineer	L V Mtaroni	Carto-Digitiser
		T B Yamsebo	Cartographer
		G Sampa	FBD Authoriser
		R Penza	SMD Authoriser *

Note : * Mr Penza's input under separate FRMP contract.

The original contract was due for completion mid-September 1996. Following the identification and acceptance of logistical constraints, this contract duration was extended to 31 January 1997 by Addendum to Contract issued 20 June 1996.

The finally approved Work Programme and Staffing Schedules are presented with the Terms of Reference for the Project, at Appendix A.

The division of staff-month allocation amongst the Project team is approximately 40 per cent expatriate, 60 per cent Tanzanian.

1.2 OBJECTIVES

The objectives of the Project are directed by the Terms of Reference (Appendix A) and have been to :

- Provide country-wide baseline forest resource information regarding forest areas and forest types.
- Provide baseline information about other land uses, particularly agriculture.
- Facilitate an assessment of natural resource and land use change over time, relating the changes to possible causes, and,
- Develop the framework for regular national resource monitoring

1.3 OUTPUTS

The above objectives are met by the following Project outputs :

- Digital products for each satellite image scene.
- Digital and hard copy products for each scale-controlled image map.
- Film positives of the completed 1:250,000 topographic bases
- Interim products including
    - Land cover interpretation overlays to each map sheet.
    - Drainage cover interpretation overlays to each map sheet.
    - Authorised Forest Reserve and other Designated Area boundary overlays to each map sheet.
    - Authorised Regional and District boundaries (on paper copies) for each map sheet
    - Flight indices for all aerial photographic surveys accessed in the course of interpretation, for each map sheet.
    - All (interim) digital cartographic data on hard disk.
- 500 approved copies for each of the 64 map sheets within the 1:250,000 scale thematic map series.
- Finalised (corrected) digital cartographic data (on CD ROM).
- Colour separations (repromats) to accompany each map sheet.
- Baseline statements of land cover distribution, according to the approved classification, and by map sheet, District, Region, and for the Nation as a whole.
- A Data Dictionary describing each of the mapping units.
- Quarterly Progress, and Final Reports.
- A consolidated and operational facility, with trained and experienced Tanzanian expertise, that may be utilised to facilitate the future monitoring of land use change, within a framework developed by the Project's sister component, TANRIC.

2. APPROACH AND METHODOLOGY

2. APPROACH AND METHODOLOGY

Abstract

Amongst the many outputs of the Project, the thematic maps themselves are arguably the most important, and should maximise (within the constraints of presentation scale) the relevant information available to the end-user. Initially, the optional forms of presentation are discussed and recommendations, based upon the consultants' previous experience, are arrived at. Optional satellite systems for resource data capture are investigated, and the alternative approaches to interpretation (manual or automatic) are debated. The classification and map legend results from striking a balance between end-user aspirations and the intrinsic data content of the interpretation medium at the presentation scale. The procedures used to field-verify initial interpretation through the systematic collection of ground truth data are then related. The approach to cartography is questioned in terms of whether it would be technologically more suitable to adhere to traditional manual techniques, well established within Tanzania, or whether the future may be better served by establishing a wholely digital data base. Finally, the approach to the printing of the final map series is considered and the quality control systems imposed are described.

2.1 PREVIOUS EXPERIENCE

In recent years, the opportunities to participate in the mapping of land cover over a land area the size of Tanzania have been relatively rare. The success of such an exercise will be judged by the end-user, in terms of the accuracy of the thematic and cartographic data presented, and in terms of the usability - basically, the readability - of the maps when published.

A number of optional formats for map presentation were considered at the negotiation stage of the Project. These options were reduced to two candidates :

1) A line presentation overlaying a half-tone reproduction of the corresponding satellite image, with mapping units identified by alpha-numeric coding, or,

2) A full colour and symbolised presentation, but without the underlying imagery.

The consultants had previously been involved with nation-wide mapping projects, at the same presentation scale of 1:250,000, and involving both of these approaches. Land Systems and Soils maps prepared by the consultants for the Government of Sudan, for example, were based upon the first approach. Vegetation and Land Use maps prepared for the Government of Nigeria, on the other hand, utilised the second. It was possible, therefore, to provide examples of finished products in each case.

There are arguments in favour of each approach, but the deciding factor concerned the relative ease of use of the final product. The presentation scale of 1:250,000 is essentially synoptic - it represents an overview. It is important, therefore, that the end user gains a ready perception of the distribution of the thematic data across the map sheet (Is it mostly woodland or cultivation ? Where is the cultivation concentrated ? Where are the next changes likely to occur?). These questions are readily answered by a full colour presentation, but it is not easy for the mind to carry the distribution and/or relative dominance of land cover units that are merely represented by an alpha-numeric code against a monochrome background.

The consultants recommended the second approach and this was accepted. All subsequent technical decisions, therefore, have been based upon the need to adhere to this fundamental prescription.

2.2 THE SELECTION OF IMAGING SYSTEM AND IMAGERY

The choice of imaging system to provide the main interpretation medium was driven by two principal criteria :

- The need to utilise the most up-to-date imagery within as narrow a time-frame as possible (essentially, all imagery was to be acquired within the anticipated two-year duration of the contract), and,

- the desirability that all acceptable coverage for the entire country be sourced from one system.

Original proposals had been based upon the utilisation of Landsat 6 -TM. Unfortunately, this satellite (launched in late 1993) failed to achieve orbit, thereby reducing the options available. During contract negotiations the relative merits of accessing a range of currently operative systems were discussed. These systems included :

- Landsat 5 - TM
- SPOT
- JERS-1
- Indian and Russian systems.

Subsequent discussions reduced the short-list to two, on the basis of both known coverage (over Tanzania) and cost. The two remaining candidates were Landsat 5 - TM and JERS-1. The advantages and disadvantages of either system are given below :

Landsat TM
Advantages :
- 30m ground resolution suitable for mapping at 1:250,000 scale.
- Spectral range suitable for vegetation mapping.
- 16-day repeat cycle (about 8 tries per dry season).
- Proven reliability of the imaging system.
- Proven reliability of the ground receiving station data processing.

Disadvantages :
- On-board recorders have failed, so data must be captured within the footprint of a receiving station.

JERS-1
Advantages :
- Approx. 20m ground resolution suitable for mapping at 1:250,000 scale.
- Spectral range suitable for vegetation mapping.

Disadvantages :
- A prototype experimental system.
- The future programming operation not decided (in early 1994).
- 44 day repeat cycle (so possibly only 3 tries per season).
- Two year design life (so satellite may fail within the life of the Project).
- Radar data acquisition takes precedence over optical data acquisition.

Other considerations were taken into account. The cost of nation-wide coverage by JERS-1 was estimated to be considerably more expensive than that available from Landsat 5. The latter, however, was (at one stage) able to acquire imagery of only the southern two-thirds of the country (because of the failure of the on-board recorders). Initially, it was proposed to compromise by using a combination of imagery from the two systems - Landsat to save potential cost, but with JERS to complete the required coverage. This proposal, however, failed to satisfy the second of the governing criteria.

This apparent impasse was overcome by the obtaining of a commitment from TELEOS of its intention to install a mobile receiving station within Kenya during the life of the Project. This raised the prospect of obtaining nationwide coverage from the cheaper and proven system - Landsat 5 - TM. This system was therefore chosen to acquire imagery for the Project.

For the purpose of optimal discrimination of vegetation, the Landsat TM bands 4, 3 and 5 were chosen to create the false colour composite image maps. Band 3 is in the visible spectrum; bands 4 and 5 register within reflected infra-red.

2.3 MANUAL INTERPRETATION VERSUS AUTOMATIC CLASSIFICATION

The computerised classification of digital satellite data has been used for many applications. The principal advantage is time saving. The application, however, is only reliable where image signatures are consistent.

The Terms of Reference require that imagery used upon the Project be acquired within as narrow a time-frame as possible (in order to create one-time baseline statements). Of necessity, this has meant that imagery has had to be acquired during the two main cloudless seasons (ie pre-main rains, and post-main rains, and avoiding the unpredictable short rains around November).

The characteristics of imagery acquired pre-main rains are different to that acquired post-main rains. Before the rains, for example, many woodland areas are leafless and may have been burned beneath to encourage grass regrowth for occasional grazing. Leafless woodland appears grey upon the image, but if burned beneath it may register in very dark tones. The same area after the main rains would be in full leaf and would register in healthy red tones. Under these circumstances, a system of automatic classification based upon reflected frequencies could seriously mislead the image interpreter.

The answer to this problem is the use of local knowledge. This means manual interpretation by local specialists who know the country well, the close targetting of field-verification exercises, and the assiduous use of complementary data, particularly archival aerial photography. Manual interpretation was the only feasible approach.

Manual interpretation was carried out in two stages. Scale-controlled image maps were subjected to a preliminary interpretation which served to identify areas of doubt or question, and also those areas where interpretation could be completed with a high degree of confidence. This enabled the direction of field verification exercises to collect ground truth data that would either answer the questions or confirm the confidences. The procedures for field verification are described further in Section 5. With the benefit of field information and secondary data, including archival aerial photography, a finalised interpretation was then completed by delineating mapping units according to the classification by hand drawing with permanent inks onto clear acetate overlays to each of the scale-controlled image maps.

2.4 MAP LEGEND : END-USER ASPIRATIONS IN RELATION TO INFORMATION CONSTRAINTS

The derivation of the agreed land cover classification and its final form are related in Section 4 of this Volume. The mapping units comprising the map legend are described in more detail in the Data Dictionary, Volume 2. An important consideration in the approach to classification and legend, however, concerned the debate between what end-users would wish to see presented upon the thematic maps and the constraints imposed by the intrinsic data content of the prime and secondary data sources available to the Project team, at the intended presentation scale of 1:250,000.

Potential end-users were canvassed for their views. These potential end-users included Ministry of Natural Resources, Department of Forestry, Department of Agriculture, Ministry of Lands, the Institute of Resource Assessment, and the National Environmental Management Commission. Representatives of many other organisations, including NGOs, have contributed to the discussion on a less formal basis.

The main issues discussed, and the outcomes that have directed the presentation of the thematic map series, are as follows :

2.4.1 Detail

The presentation scale of 1:250,000 intrinsically limits the detail of information that may be shown. The smallest area (Minimum Mapping Unit) that may be delineated and annotated is approximately 0.4cm square. At the presentation scale, this equates to a land area of 1 sq km (or 100 ha). This means that medium sized farms, settlements or water bodies, for example, with areas below 100 ha are unlikely to register as individual units upon the maps.

2.4.2 Updated Topographic Detail

The desire for the updating of topographic information to be presented as a base to the thematic series was expressed by a number of potential end-users.

The Project had only two reasonable alternatives to this issue :

1) Utilise the available topographic base from the exisiting (but rather outdated) 1:250,000 series, or,

2) Create a generalised topographic base from image interpretation.

The satellite-recorded frequencies used to compile the image maps were chosen for the optimal discrimination of vegetation types. The resolving capabilities of the system, however, limit the degree to which narrow infrastructure features register upon the imagery (particlularly in the case of, say, murram roads which are made from materials similar to the surrounding ground surfaces). Major urban conurbations register well, as do air strips. Road, railway and power line alignments may be evident where they cut through a major vegetation formation (such as woodland), but may be much less evident as they pass through minor formations (such as open grassland). In some cases, therefore, the identification of a feature (a new road or railway alignment, for example) may be discontinuous. The identification of only part of a new road would not be of much use to the map user.

Minor villages do not register on the imagery at all well, as many are comprised of dwellings constructed from natural materials (ie thatched mud huts) which reflect a signature similar to some of the vegetation units. Their location, however, is implied by the cultivated lands that generally surround them.

It was agreed, therefore, that a comprehensive update of topographic detail from image interpretation alone was not feasible, and that the most sensible recourse would be to incorporate a selected topographic base from the existing series into the thematic maps, but to be modified where justified by clear evidence.

On this basis, the approach has been to prepare combinations of the Black and Brown plates from the topographic series as a base for the thematic series. These combinations have been produced by SMD as clear positives. When these are overlaid to the scale-controlled image maps it becomes possible to identify those areas where a reliable up-date is justifiable. In this way it has been possible to add certain features (missing railway lines or new road alignments) to the topographic base. This work has been carried out by erasure and fine-drawn additions to the individual topo-base positives.

Throughout this exercise, the governing rule has been that updates are only incorporated or added to the topographic base where clear and total evidence is available. On occasion this evidence is clear from the imagery itself. On other occasions, it has been necessary to refer to more detailed, or recent, topographic cartography (eg the 1:50,000 scale map series), or other secondary data.

2.4.3 The Inclusion of Further Topographic Information

Many of the potential end-users were interested in the presentation of land form and edaphic characteristics. This is very understandable, as it is the relationships between land slope, aspect, climate, hydrology, pedology, soil type, existing land cover, occupancy and present land use that determine land capability and the economic potential for the future.

To this end, a number of interested parties wished to see contour lines and major soil types expressed upon the thematic series.

In the case of contour lines, it was agreed that their inclusion would serve only to confuse the already agreed format for full colour and symbolised map presentation. Much of Tanzania is flat, and contours at 1:250,000 scale provide little useful information. The steep parts (Southern Highlands, Meru, Kilimanjaro) are very steep and, in these cases, the inclusion of contour lines would risk obscuring thematic and other topographic detail. Given that the Black plate selected as part of the topographic base includes spot heights and trigonometric detail, the decision was taken to leave out contour information (usually expressed on the Magenta plate to the topographic series).

So far as the mapping of soil types is concerned, this is outside the Terms of Reference and the resources of the Project. Also, the soil survey record for the country is fragmented. However, the outputs of this Project will make an input into the TANRIC data base. TANRIC has already captured a considerable amount of soil survey data. It is within a GIS such as TANRIC that the analysis of the relationships expressed above should take place.

2.4.4. The Representation of Current Land Use

The interpretation of the scale-controlled image maps has been driven by the need to establish a current baseline for land cover distribution according to the agreed classification and legend (described in Section 4). Associated with this prime directive, however, is the desire to express the distribution of current land use.

The ability to express reliably current land use upon the thematic maps has been the subject of considerable debate. There are a number of aspects to the issue :

- In certain areas, land use is **clearly linked** to land cover. In areas mapped as Cultivated Lands, for example, the land use is Agriculture - it may be for tree crops, or annual crops, or a mixture, and grazing may be included - but the use is Agriculture.
- In other areas, land use is **implied** by the distribution of land cover. It may be assumed, for example that land use within Forest Reserves is for timber production, watershed protection or economic reservation. Within Game Reserves, conservation and licenced hunting are the implied land uses. Within National Parks, current regulations prohibit land use beyond conservation, research and organised tourism.
- External to these areas, however, - in the Public Lands that constitute a large part of Tanzania - **land use may be very varied.** Areas of open woodland, for example, are widely used for hunting, gathering, pit-sawing, fuelwood harvesting, the collection of minor forest products and traditional medicines, bee-keeping, rope-making, etc. These unreserved areas also attract occasional tourism and dedicated research activities.
- The territorial area of Tanzania includes very large areas of both freshwater and ocean. Here, the implied "land" use is for fisheries and, in certain areas, for tourism, research and conservation.

The dilemma for the mapper lies in where to place the boundaries to these activities. In most cases this is not possible. Agriculture and Forestry may be closely associated with land cover types, but not exclusively. Activities such as hunting, tourism, livestock grazing and research, have no recognisable boundaries. Neither do activities such as fishing or aquaculture - they are likely to take place wherever the resource is present, but whether they actually do or not requires dedicated research beyond the resources of this Project.

The resolved approach has been to record observed land use at sample sites during the field verification exercises and to extrapolate these observations to identify linkages with land cover types. This linkage is tabulated within the Data Dictionary.

2.5 THE COLLECTION OF GROUND TRUTH DATA

The Terms of Reference require the mapping of land cover / land use from the interpretation of a suitable remotely sensed medium, in this case, Landsat 5-TM. The accuracy of interpretation is markedly enhanced by the collection of ground truth data. The approach to the collection of ground truth data was based upon two activities :

Field Traverses : These were conducted throughout the road network of Tanzania. Starting from a known point, entry and exit from land cover units were recorded (on dictaphone cassette) and logged against vehicle speedometer readings. The geo-reference of each start point, interim way-points and end-point of each traverse were recorded using Magellan GPS.

All recorded traverses were written up in hard copy to aid final interpretation and for future reference.

Sample Site Descriptions : Along vehicle traverses (and on many occasions, traverses by foot) sample sites were selected for more detailed description. Sample sites were selected on the basis of preliminary image interpretation either because they were thought to be core examples of a particular land cover unit, or because their identification from image interpretation alone was questionable. At each (geo-referenced) site, the profile of the land cover formation was sketched, dominant species from the tree, bush and herb layers recorded, together with notes on the site characteristics and observed land use.

These activities are detailed further in Section 5. Their purpose was not only to compile a record of observations to assist final interpretation, but also to build a searching image for each land cover type (and its possible variations) in the recognition of each interpreter. Much time was spent in the early stages of the Project to ensure that all members of the interpretation and field-verification team came to identify land cover types with a high degree of consistency.

The above activities were the main components of the validation exercise, but a large volume of secondary data was also used to assist final interpretation. This included a wide range of technical references and earlier thematic cartography, but especially the national aerial photographic archive. Principal references are listed at Appendix E.

2.6 TO SCRIBE OR DIGITISE ?

The approach to cartography, intially proposed, focussed upon the utilisation of traditional (manual) techniques that were well established in Tanzania, and with which the nominated specialists were very familiar. This process began on schedule in April 1995. Progress was reviewed during subsequent months, however, and was reported upon in Progress Report No.3, of 15 September 1995.

The rate of achievement had fallen behind schedule and the value of an alternative, fully digital, approach was considered. The alternative rationals are detailed below :

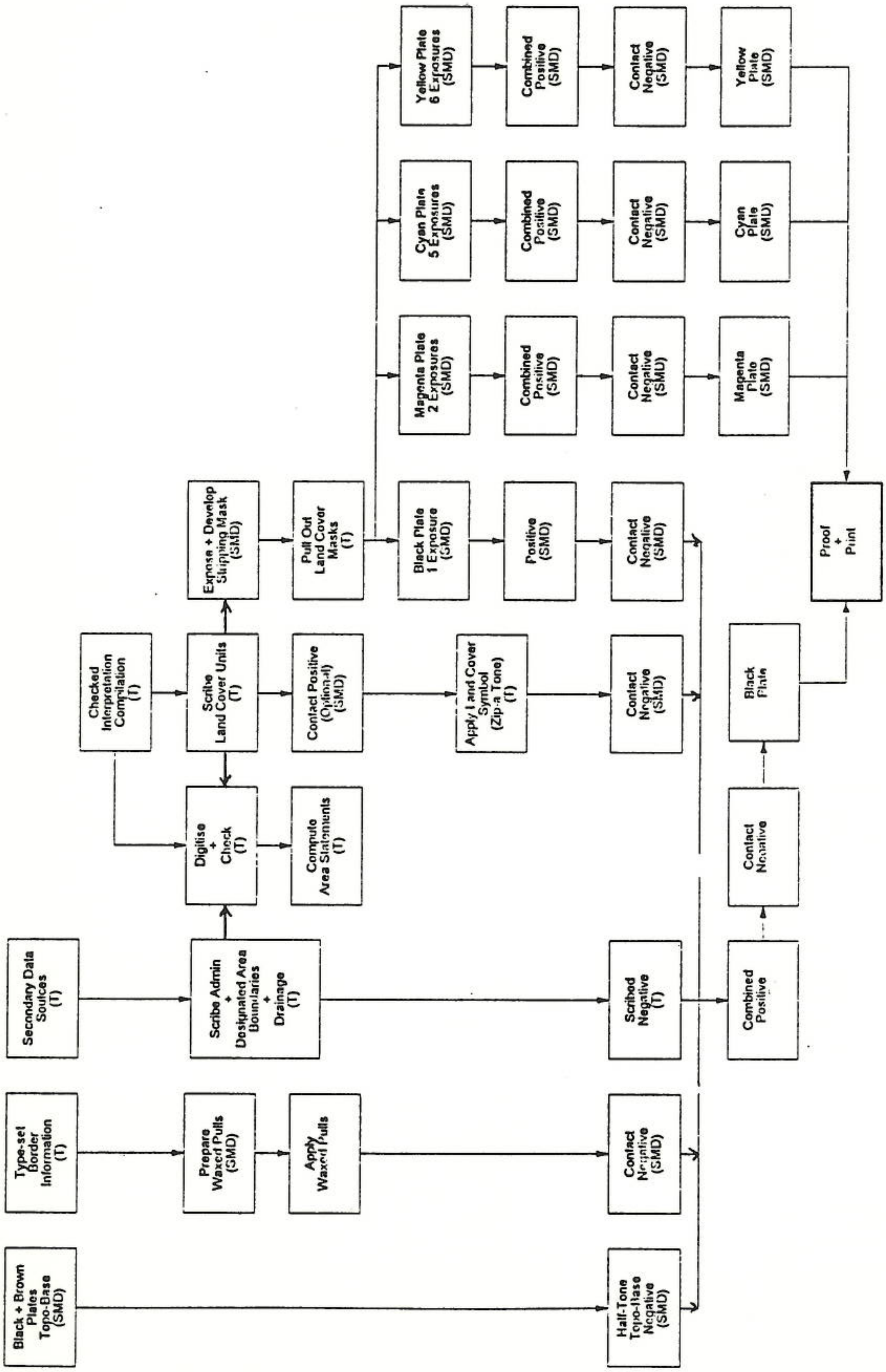
2.6.1 The Traditional Approach to Cartography

The traditional approach to cartography, and as originally proposed, is represented schematically in Figure 2.1.

The approach leads to the production of five negatives from which are produced printing plates for each of the four ink colours (Black, Magenta, Yellow and Cyan) and for the topographic base map. The Magenta, Yellow and Cyan plates comprise percentage screens that allow the reproduction of the range of colours chosen for the final maps. The Black plate also contains border information, administrative and designated area boundaries, the boundaries to the map units, and the symbols intended to discriminate between land cover sub-types.

Colours are reproduced via the masking of mapping units. These masks are then used to expose photographic film to the number of percentage screens needed to provide the contribution of any given ink to the range of colours appreating on that particular map sheet.

FIGURE 2.1 THE TRADITIONAL APPROACH TO CARTOGRAPHY



In order to make the masking process as simple as possible, the scribed boundaries of the mapping units are used to expose sensitised masking film, thereby effectively cutting out the masks which may be peeled off and applied as required.

Symbols used to discriminate between land cover sub-types are applied manually after cutting from pre-printed waxed sheets.

The relative complexity of each map sheet affects these operations in a number of ways. The greater the number of Land Cover Types represented on a given map-sheet, the greater the number of percentage screens needed to reproduce them from the four inks available. The greater the range of sub-types, the greater the number of wax-pull symbol screens that must be cut and applied. The smaller the mean size of the mapping units, the more intricate and time-consuming becomes this work.

A review of the mean complexity of interpretations was carried out, together with the ratification of the colour shades to represent the land cover types, allowing the re-estimation of the labour and materials needed. The following resulted :

- Each map sheet would require on-average 14 exposure operations to produce the plate negatives. For the 64 map-sheet series, the total number of reprographic operations would approach 900.
- These tasks, together with the production of other black plate data (topographic base, symbols, etc) would consume an estimated 800 sheets of lithographic film.
- The time estimated for cartography and digitising (for area measurement) was revised to over 400 staff days, but only about 250 were available within the approved staffing schedule.

The implications of the review were that :

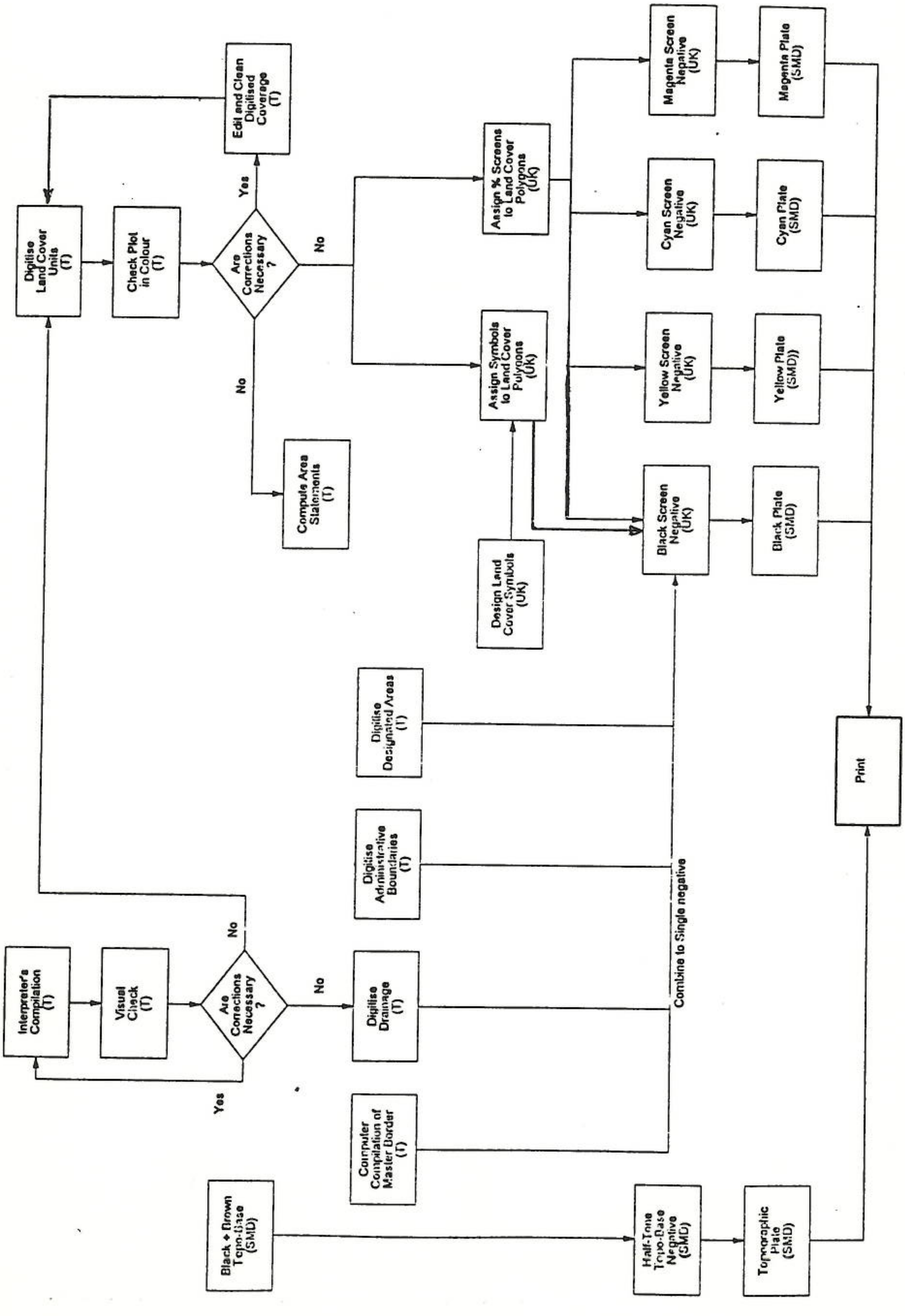
- The amount of reprographic work to be carried out would heavily strain SMD's staff resources and would require far more lithographic film than budgeted for.
- The need to punch-register un-exposed photographic film would require the construction of a dark room around the Protocol punch at SMD (as this was too large to be moved to existing dark rooms).
- The amount of work involved in peeling and applying masks would necessitate the use of sensitised masking film, which would be much more expensive than the ordinary masking film originally estimated for.

The consultants, therefore, explored an alternative approach which utilised, more heavily, computer hardware and software that had recently become commercially accessible.

2.6.2 The Alternative Digital Approach

The digital approach to arriving at negatives for plate making is shown schematically in Figure 2.2

FIGURE 2.2 THE ALTERNATIVE DIGITAL APPROACH



The thematic interpretations would be digitised for area statement computation as already proposed (this process, together with the topographic base map production, is common to both approaches). Having digitised the map unit boundaries, however, these data may be used to plot the line work (thereby removing the need for scribing) and as polygons to which both colours and symbols may be ascribed. Percentage screens and symbols to discriminate between land cover sub-types may be computer generated using dedicated software available at the consultants' head office.

Border information for each sheet would be designed and generated using Coreldraw software, and designated area boundaries would be digitised for later addition. These operations would be carried out by the team in Tanzania.

These techniques were explored, fine-tuned and tested using the pilot Tabora sheet as the test bed. Examples of the product were prepared by the consultants for review and discussion with the Technical Committee.

The following points were significant :

- The methodology proved reliable and resulted in a high quality product to specification.
- The methodology proved cost-effective.

The alternative, digital, approach was recommended to the Client and this recommendation was accepted.

2.7 PRINTING AND THE ART OF MAP MAKING

From the outset, the philosophy of the Project has been driven by two fundamental criteria :

- That the final product - the maps themselves - should be as useful and as usable as possible.
- That the Project should be as Tanzanian as possible, resulting in a legacy of facility and expertise, as opposed to the vacuum that so often results when external assistance is removed.

The attainment of the second criterion has been substantiated in the structure of the consultancy team. The objective also extended to map printing, but this is discussed more fully in Section 9.

The approach to map printing began at the very start of the project, when a full colour format for presentation was decided upon. This format requires that land cover formations be shown in colour, and that sub-formations within them be defined by an overlaying symbol.

Although science determines the input and, to some extent, the production of the maps, there exists an artistry in cartography. Much thought and effort, therefore, has been given to the selection of colours to represent the vegetation formations so that the maps reflect the real appearance. Forests register in verdant green, the drier bushlands in dusky brown, and cultivated lands in the reddish browns that characterise so many of Tanzania's soils.

Symbolisation is consistent throughout the legend - eg the overlying symbol for Open Woodland is the same as that for Open Bushland, although their underlying colours differ.

The approach has been to maximise the end-user's immediate impression of the land cover distribution across each of the 64-sheet series.

3. IMAGE ACQUISITION AND IMAGE MAP PRODUCTION

3. IMAGE ACQUISITION AND IMAGE MAP PRODUCTION

Abstract

The territorial area of Tanzania is covered by a total of 48 Landsat TM scenes.The contract required that all imagery used upon the Project be acquired during the life of the Project. This requirement was subject to constraints related to (a) the seasons of the year during which acceptably cloud-free imagery could be obtained and (b) the ability to down-load from a satellite system with currently non-functional on-board recorders. These constraints are explored and the means to overcome them are explained. These included the eventual acquisition of SPOT imagery covering the main offshore islands, for which no cloud-free Landsat TM imagery proved available. The acquired scene data are tabulated. The procedures used to convert raw scene data to enhanced and geometrically corrected image maps (64 for the whole country) are explained, and the image maps accepted onto the Project in Tanzania are listed.

3.1 AVAILABILITY AND QUALITY OF LANDSAT TM SCENE DATA

Mainland Tanzania and the islands of Pemba, Zanzibar and Mafia fall within the coverage of a total of 48 Landsat TM scenes, as illustrated in Figure 3.1. The coverage is defined by satellite paths 165 to 172, and rows 61 to 68. Each scene is referenced in terms of these coordinates.

One condition of the contract was that all imagery to be used upon the Project should be acquired during the life of the Project, with the intention of creating as narrow a baseline as possible for land cover distribution in order to reduce possible time-frame errors in future land cover change monitoring exercises. Effectively, this meant that all imagery should be acquired post - May 1994, and as soon as feasible thereafter. The dates at which satisfactory scene data were acquired are listed by scene in Table 3.1.

The Terms of Reference for the Project are vague with regard to specified image data quality. However, the fundamental specifications (resolution and available frequencies) of proven Landsat TM image data capture were accepted at the time of negotiation. The remaining variables concerned the quality of the digital data and the degree to which cloud cover or shadow obscured the interpretable image.

Data quality is largely related to recording errors, or further errors introduced during the down-loading of data from the satellite to the receiving station. These errors may be manifest in falsely recorded pixel values, or lines missed during the scanning process, for example.

So far as cloud-cover is concerned, the consultants relied upon their own experience and imposed a limit of no more than 10 per cent cloud coverage on any one scene, and certainly no more than 10 per cent cloud coverage in any one quadrant (one quarter of each scene). Wherever possible (and within the acquisition time constraints imposed as above) the search was for totally cloud-free imagery. In some cases, one quadrant of a scene was unacceptably effected by cloud cover. In such cases (the south-east quadrant of the Masasi sheet for example) later, improved, coverage was looked for and then inserted into the processing to image map (Section 3.2).

Landsat TM is a continuous imaging system. It does not need to be programmed to acquire over a particular area, but the receiving stations monitor the quality of image acquisition and only record those acquisitions deemed to be acceptable (ie, if an area is persistently cloud

FIGURE 3.1 LANDSAT TM COVERAGE OF TANZANIA

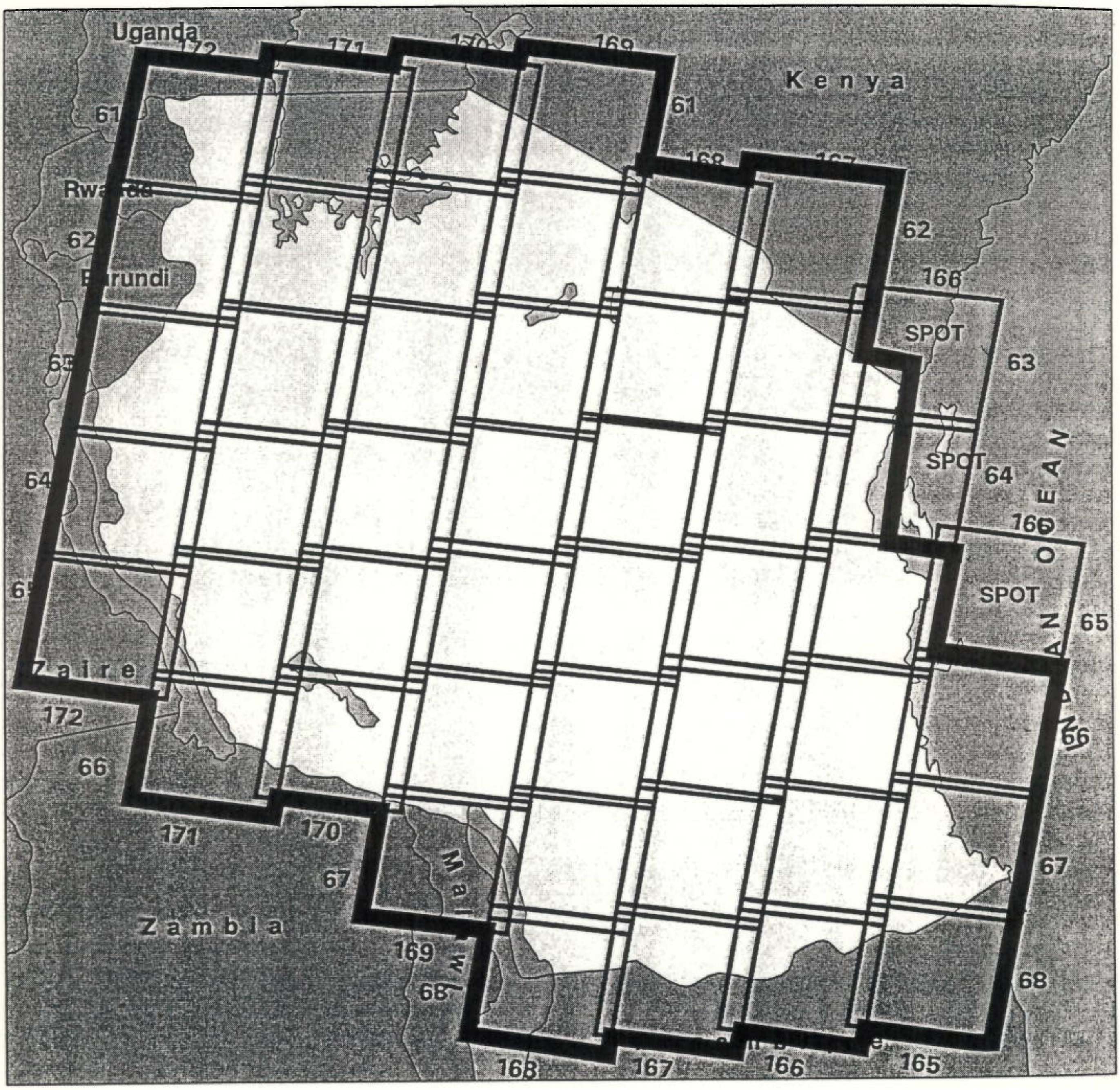


TABLE 3.1 LANDSAT TM SCENE ACQUISITION DATES

PATH	Row 61	Row 62	Row 63	Row 64	Row 65	Row 66	Row 67	Row 68
165	-	-	-	-	SPOT	30-5-94	30-5-94	30-5-94
166	-	-	5-1-96	5-1-96	9-6-95	9-6-95	9-8-95	25-8-94
167	-	26-2-96	1-7-95	2-7-95	15-7-95	15-7-95	16-6-95	17-9-94
168	-	30-1-95	27-9-95	27-9-95	27-9-95	23-6-95	27-9-95	10-10-94
169	21-1-95	6-2-95	14-8-94	14-8-94	14-8-94	14-8-94	14-8-94	14-8-94
170	17-3-95	17-3-95	8-10-94	8-10-94	8-10-94	8-10-94	-	-
171	8-3-95	8-3-95	13-9-94	13-9-94	13-9-94	13-9-94	-	-
172	23-9-95	3-8-94	3-8-94	3-8-94	3-8-94	-	-	-

Notes : An additional quadrant was obtained to replace clouded areas on 167/067, 9-6-95. SPOT imagery of the islands (supplements to 166/063, 166/064 and 165/065) was obtained 2-4-96 and 30-6-96.

covered during a particular time of year, few images may be recorded, even though the satellite may have passed over many more times).

The search for the best possible scene data, therefore, required the constant monitoring of contemporary acquisitions and their assessment in terms of data quality and cloud-freeness. The Landsat 5-TM data for Tanzania are received by a station located in South Africa, operated by the Satellite Application Centre (SAC) of the Council for Scientific and Industrial Research. SAC produces a catalogue of recorded acquisitions which details both data quality (indexed) and cloud cover by quadrant (in per cent). These catalogues were constantly accessed by the consultants through the National Remote Sensing Centre (NRSC), Farnborough, UK, from whom the selected scene data were ultimately purchased. Only the highest data quality and the lowest cloud effect for each scene were accepted by the consultants prior to ordering the Comupter Compatible Tapes (CCTs) for each scene. For the northern area, where scenes were collected by the briefly operational Teleos system, the central Landsat archive operated by EOSAT was regularly consulted in order to identify the most useful scenes. As a result, the Project has been provided with the very best possible Landsat TM coverage of Tanzania acquired within the duration of the Project. A number of issues have constrained the acquisition and acceptance of raw scene data, however, as follows.

3.1.1 Acquisition Date Constraints

Landsat TM is an optical system. This means that cloud cover will register upon any given image scene, and will obscure ground information required for the interpretation of the distribution of land cover. In the attempt to obtain imagery with as little cloud cover as possible, therefore, acquisition must take place during the dry seasons of the year.

Most of Tanzania experiences two rainy seasons as the Inter-Tropical Convergence Zone (ITCZ) moves across the country. Short rains occur around November / December throughout much of the country, but may be very sparse in northern and coastal regions. The main rains occur during the period March to May, but the timing varies across the country. Rainfall is notoriously unpredictable, but these periods are characterised by heavy cloud formation and are avoided for the purposes of image acquisition. As Table 3.1 illustrates, almost all satisfactory imagery was obtained during the period June to October, and mostly from the years 1994 and 1995.

During this dry period of approximately June to October, the vegetation communites undergo seasonal changes, and land use (particularly for agriculture) passes through its seasonal cycle. These changes may be illustrated by considering the cloud-free period immediately post-main rains and that immediately pre-main rains, as follows :

- Immediately post rains, most arboreal vegetation communities are still in full leaf. Most crops are coming to ripening and are ready for harvest. The landscape is very green and, by virtue of the false colour presentation, the imagery is dominated by red tones. The ability to discriminate between land cover types from image interpretation alone is thereby reduced.

- Prior to the main rains, many woodland areas are leafless but evergreen Forest and wetlands vegetation (such as Papyrus swamp and Mangrove) remain in full leaf. Crops are almost entirely off, and the land is in preparation for the next planting. The information content of imagery acquired at this time is greater. The distinction between Forest and Woodland is more clear, and there is less potential to confuse annually Cultivated Lands with Grassland or Bushland, for example. However, the practise of burning to promote graze regrowth (or for hunting purposes) serves to reduce image information content at this time of year. Recently burned grass areas, for example, may register in the same very dark tones as leafless woodland that has been burned beneath.

In order to comply with the need to create as narrow a data base as possible, it has been necessary to utilise imagery from both these periods, although the majority has been acquired during the period just after the main rains.

3.1.2 Receiving Station Constraints

As related in Section 2.2, the on-board recorders of the Landsat 5 satellite are no longer functional. This means that the image data recorded by the satellite may only be accessed by a receiving station possessing line-of-sight to the satellite. Once the satellite has passed over the horizon, data may not be down loaded.

Approximately the southern two-thirds of Tanzania may be accessed from the EOSAT receiving station in South Africa, and it is from here that the majority of image data have been obtained. The northern part of the country (Rows 061, 062 and parts of 063 and 064) were imaged via the TELEOS mobile station in Kenya. Some delays were experienced due to data reading difficulties suffered by EOSAT when the TELEOS - acquired data were passed to them. The end result, however, was that imagery of acceptable quality was obtained for the whole of the Tanzanian mainland from the Landsat TM system during the life of the Project.

Some difficulty was experienced, however, in obtaining imagery of acceptable quality for the main offshore islands of Pemba, Zanzibar and Mafia, as related in the following section.

3.1.3 Acquisition of Imagery for Areas not covered by Landsat TM

The islands are not covered well by Landsat TM, for two reasons.

- Pemba and the northern part of Zanzibar lie north of the footprint that may be accessed by the EOSAT receiving station in South Africa.

- The islands are subject to a greater degree of cloudcover than the majority of the mainland.

By late 1995 no acceptable TM imagery had been acquired for these islands. As the rainy season was approaching, the prospects for successful acquisition were not good. The decision was taken (after consultation with the Technical Committee) to place a programming request with the SPOT system for cover of the islands. This was intiated in September 1995. Acceptable cloud free imagery was not obtained until April and June 1996, however. At this time, the Spot imagery was mosaiced with the mainland TM coverage for the coastal sheets of Mombasa, Pemba, Dar es Salaam, Mafia and Kilwa, and the revised image maps reproduced. National coverage was complete.

3.1.4 Catalogue of Accepted Scene Data

This is expressed in Table 3.1

3.2 PROCESSING SCENE DATA TO IMAGE MAPS

The objective of the image processing activities within the project has been to produce accurately geo-referenced satellite image maps that correspond precisely to the existing 1 : 250,000 scale topographic map series, the layout of which is shown in Figure 3.2. These image maps formed the base material of the visual interpretation exercise.

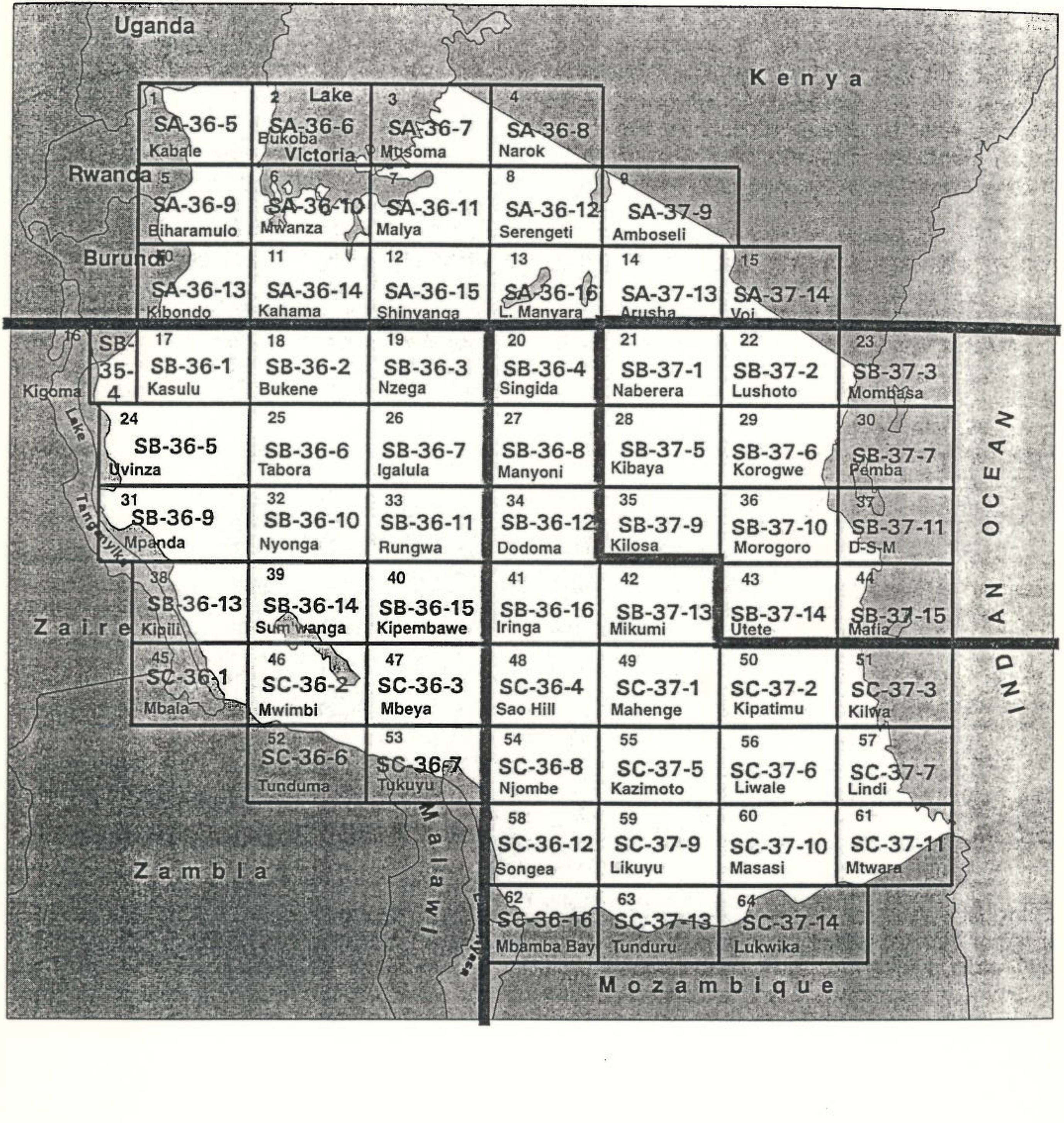
The image maps have been prepared from the digital satellite data acquired for the Project. The preparation involved re-sampling the data to fit known control points, contrast enhancement to improve the colour balance between images, mosaicing of adjacent images and extracting from the mosaic the data that corresponds to each mapsheet at 1:250,000 scale. This has been achieved by using the ERDAS Imagine image processing system at the consultants UK offices. The enhanced digital data have been written to film using a ColorFire 240 precision film-writer; these form the master negatives of the image maps and the final image maps were produced as accurately scaled photographic prints produced from these negatives.

The production of satellite image maps involved the following activities :

- **Geometric correction**
  This involved a two stage process. The first stage was to ensure that adjacent images match each other exactly and the second stage used control points selected from the 1 : 50,000 scale map series to fit the images to the maps. This procedure ensures the best fit between individual images and also between the imagery as a whole and the maps used for the control.

  Images used for the project were read into the image processing system and tie points were identified on overlapping portions of images so that the best fit between adjacent images could be achieved. Ground control points selected from the topographic maps were then used to fit the images to the map base.

FIGURE 3.2 IMAGE MAP COVERAGE OF TANZANIA



This approach takes advantage of the inherently good internal geometry of space imagery while at the same time allowing for the fact that individual scenes are not located very accurately on the ground. It is also flexible, allowing extra weight to be given to some control points. For example, it is often the case where a large mosaic is being prepared, that all the scenes are not delivered by the suppliers at the same time. Under these circumstances, it is possible to carry out an independent block adjustment for part of the area in advance of receipt of all the data, by ensuring a perfect match of the imagery with the control points along the border with the images which may still have to be delivered. In the same way, the difficulties which are encountered at the joins between different projections (such as between different zones of the UTM projection system) can be handled easily and effectively.

As the data for this project were delivered at different times and covered different UTM zones, this approach ensured the highest overall geometric accuracy of the final image map products.

- **Contrast enhancement**
  In order to facilitate the best possible interpretation of the land cover it has been necessary both to enhance the contrast within an image in order to avoid areas that are overall too dark or too light and to match, as far as possible, the variations between images so that consistency in the interpretation of features is maintained. This has been overcome by applying a space-variant contrast stretch to scenes which are to be mosaiced together.

  In this procedure a window is passed over the image beneath which the image brightness mean and standard deviation are constrained to user-defined values by changing the intensity number of the pixel which falls in the centre of the window. In this way images are produced which have rather uniform brightness and contrast when averaged over the area that lies under the window. The window size is chosen so that it corresponds to the image areas which show large-scale changes in the average brightness. By this procedure the average brightness of features on the enhanced imagery is optimised for visual interpretation.

  Use of the space-variant contrast stretch for the project ensured that the images are most suitable for the interpretation of land cover features.

- **Mosaicing**
  Adjacent geometrically corrected and radiometrically matched scenes were set out on the image processing equipment in their correct relative positions. A corridor was defined by the operator within the area of overlap across which the scenes were to be merged together. The corridor, generally speaking, was designed to avoid features of contrasting appearance on each scene, for example differences in the distribution of vegetation caused by different seasons of acquisition. A mask was then applied to each scene within the corridor and the scenes added together. The result is a seamless join between the images.

  In some cases where there is a significant difference between images, it may be desirable for the interpreter to be able to see where adjacent images have been joined together. In these circumstances a single butt-join, usually following some prominent ground feature (like a river), was used.

- **Map sheet preparation**
  The mosaiced blocks of imagery were subdivided into mapsheets that correspond to the 1:250,000 scale topographic map series (Figure 3.2).

- **Film writing**
  Once all the stages of image processing had been completed, the enhanced digital data were written to film using the ColorFire 240 precision film-writer. This produced a master negative from which the final image maps were produced as colour photographic prints at the final working scale.

  The procedures involved in the production of the image maps are shown in the flow chart, Figure 3.3.

- **Quality control**
  At each stage in the image processing activity, a comprehensive sequence of quality control procedures was implemented. These ensured that the geometric correction was carried out to a uniform accuracy and ensured that the colour balance, sharpness and scale accuracy of the final image maps met all the consultants quality standards.

- **Image Map Sheet Layout**
  The layout of image maps corresponds to the 1 : 250,000 scale map series produced by the Surveys and Mapping Division. As a result there are 64 image maps to cover the whole country. Each image map has been supplied with the following border information :

- sheet number and name corresponding to the SMD 1 : 250,000 scale map series.
- a compilation note concerning the source of ground control from topographic maps.
- a map sheet index.
- a satellite scene index.
- details of the UTM grid and projection.
- scale bar.
- grid tics and sheet corner latitude and longitude.

The image maps delivered to the Project in Tanzania are listed in Table 3.2

FIGURE 3.3 IMAGE PROCESSING FLOWCHART

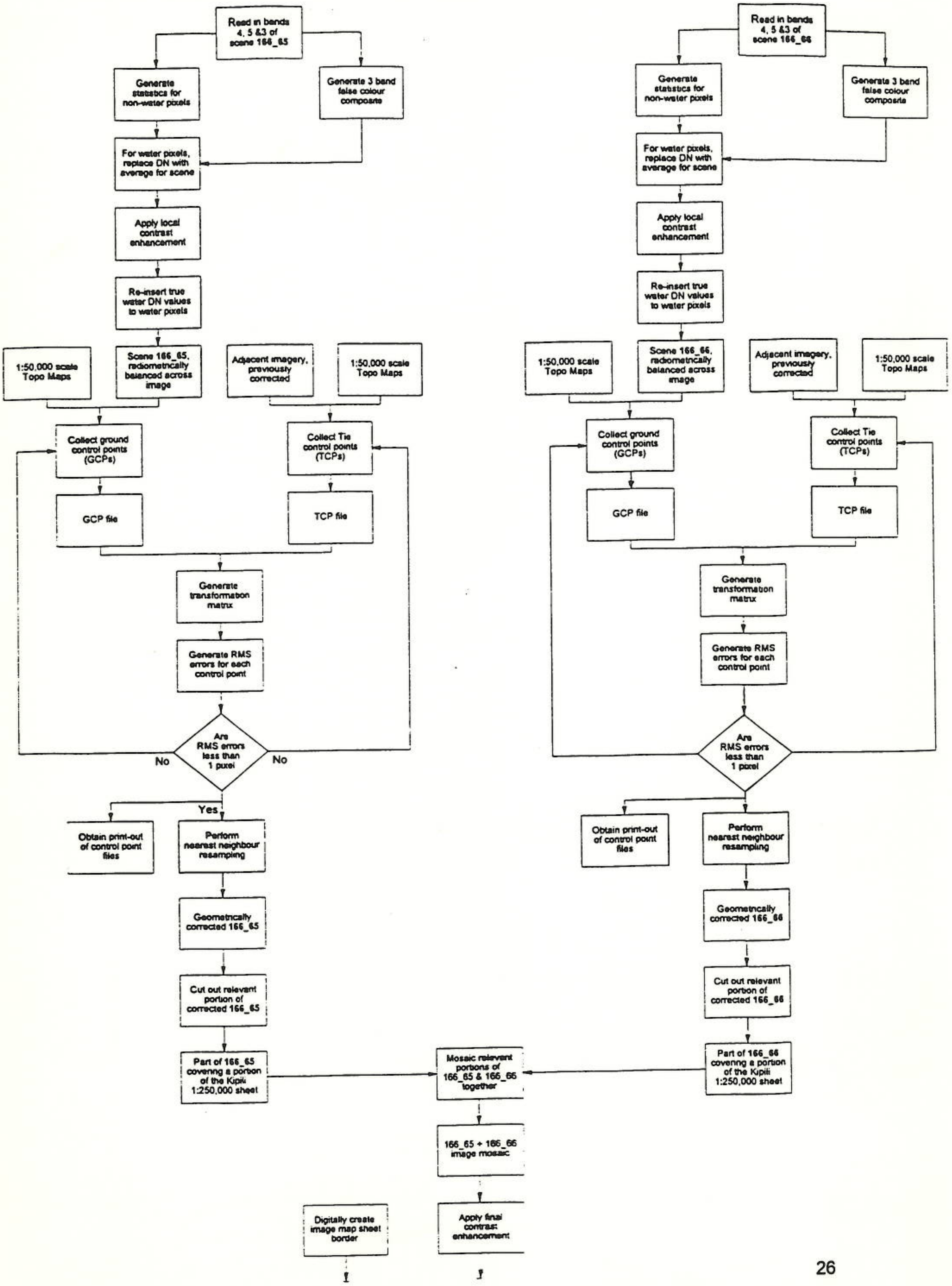


FIGURE 3.3 (Continued)

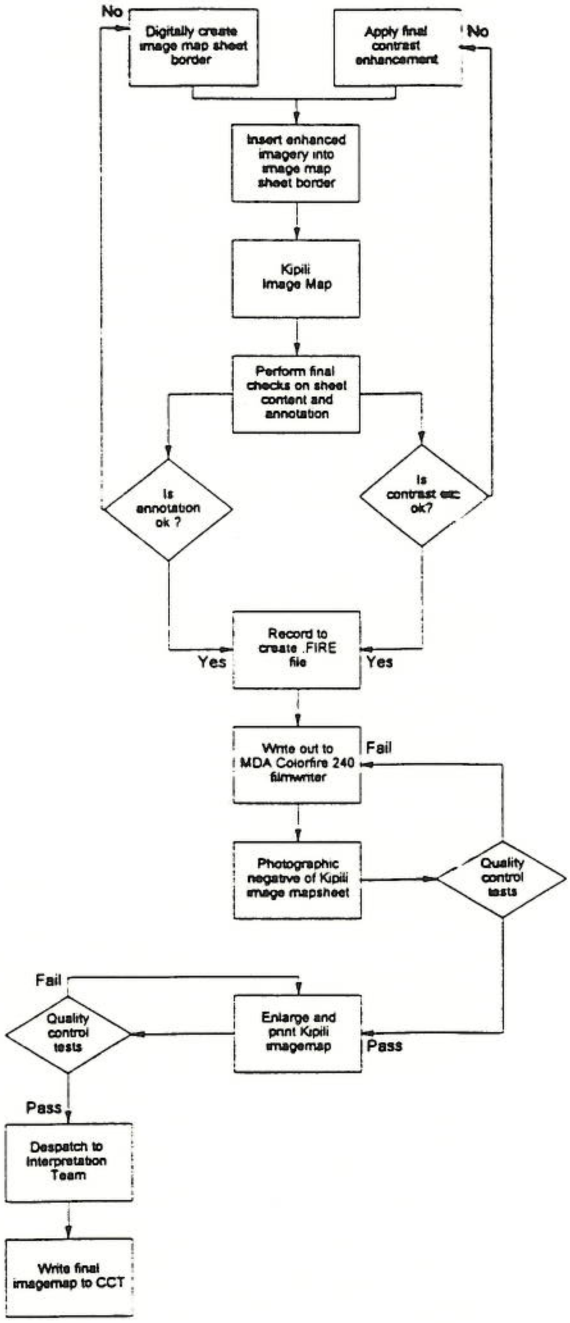


TABLE 3.2 LIST OF IMAGE MAPS

IMAGE MAPS

HTS No.	Ref. Code	Title of Map	Map Scale	Pub. Date	Map Projection	No.of copies	Medium	Comment
1	SA-36-5	KABALE	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
2	SA-36-6	BUKOBA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
3	SA-36-7	MUSOMA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
4	SA-36-8	NAROK	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
5	SA-36-9	BIHARAMULO	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
6	SA-36-10	MWANZA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
7	SA-36-11	MALYA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
8	SA-36-12	SERENGETI	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
9	SA-37-9	AMBOSELI	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
10	SA-36-13	KIBONDO	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
11	SA-36-14	KAHAMA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
12	SA-36-15	SHINYANGA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
13	SA-36-16	LAKE MANYARA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
14	SA-37-13	ARUSHA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
15	SA-37-14	VOI	1:250 000	1996	UTM	1	PHOTO PAPER	FULL COLOUR
16	SB-35-4	KIGOMA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
17	SB-36-1	KASULU	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
18	SB-36-2	BUKENE	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
19	SB-36-3	NZEGA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
20	SB-36-4	SINGIDA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
21	SB-37-1	NABERERA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
22	SB-37-2	LUSHOTO	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR

TABLE 3.2 (Continued)

23	SB-37-3	MOMBASA	1:250 000	1996	UTM	1	PHOTO PAPER	FULL COLOUR
24	SB-36-5	UVINZA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
25	SB-36-6	TABORA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
26	SB-36-7	IGALULA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
27	SB-36-8	MANYONI	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
28	SB-37-5	KIBAYA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
29	SB-37-6	KOROGWE	1:250 000	1995-96	UTM	1	PHOTO PAPER	FULL COLOUR
30	SB-37-7	PEMBA	1:250 000	1996	UTM	1	PHOTO PAPER	FULL COLOUR
31	SB-36-9	MPANDA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
32	SB-36-10	NYONGA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
33	SB-36-11	RUNGWA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
34	SB-36-12	DODOMA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
35	SB-37-9	KILOSA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
36	SB-37-10	MOROGORO	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
37	SB-37-11	DAR ES SALAAM	1:250 000	1995-96	UTM	1	PHOTO PAPER	FULL COLOUR
38	38-36-13	KIPILI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
39	SB-36-14	SUMBAWANGA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
40	SB-36-15	KIPEMBAWE	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
41	SB-36-16	IRINGA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
42	SB-37-13	MIKUMI	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
43	SB-37-14	UTETE	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
44	SB-37-15	MAFIA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
45	SC-36-1	MBALA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
46	SC-36-2	MWIMBI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
47	SC-36-3	MBEYA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR

TABLE 3.2 (Continued)

48	SC-36-4	SAO HILL	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
49	SC-37-1	MAHENGE	1:250 000	1994-95	UTM	2	PHOTO PAPER	FULL COLOUR
50	SC-37-2	KIPATIMU	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
51	SC-37-3	KILWA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
52	SC-36-6	TUNDUMA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
53	SC-36-7	TUKUYU	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
54	SC-36-8	NJOMBE	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
55	SC-37-5	KAZIMOTO	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
56	SC-37-6	LIWALE	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
57	SC-37-7	LINDI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
58	SC-36-12	SONGEA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
59	SC-37-9	LIKUYU	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
60	SC-37-10	MASASI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
60	SC-37-10	MASASI	1:250 000	1994-95	UTM	2	PHOTO PAPER	FULL COLOUR
61	SC-37-11	MTWARA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
62	SC-36-16	MBAMBA BAY	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
63	SC-37-13	TUNDURU	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
64	SC-37-14	LUKWIKA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR

4. CLASSIFICATION AND LEGEND

4. CLASSIFICATION AND LEGEND

Abstract

In this Section, the initial approach to land cover and land use classification is described and the historical research carried out is related in terms of previous approaches in the East African Region. These include hierarchical, physiognomic and ecological approaches. A framework for classification construction is substantiated, and the finally agreed classification and map legend is expressed and the implications for land use are tabulated. The maps have limited border space for the inclusion of descriptive information, so a Data Dictionary has been compiled to more fully describe the mapping units and their variables. The contents of the Data Dictionary are outlined.

4.1 DERIVATION OF THE PREFERRED CLASSIFICATION AND LEGEND

The production of the Land Cover and Land Use thematic map series has targetted the discrimination of the principal land cover types of Tanzania and the land uses that are either specifically or generally associated with these types. Such an exercise requires the division and sub-division of the overall environment into recognisably homogeneous units to which boundaries and names may be applied in order that they may be mapped with reliability and understanding. Classification, therefore, requires an agreed approach; a set of criteria that may be used to consistently discriminate one class from another; and a system of nomenclature that is unambiguous to the end-user.

It is these decisions that guide the interpretation of the base data sources (in this case satellite imagery and supporting aerial photography) and - arguably even more importantly - the confirmation of classification during the process of field verification, when sample ground-truth information is collected.

Classifications, in any context, set limits. In the case of land cover mapping, however, nature does not oblige with the provision of such clear limits, or finite boundaries. The vast majority of natural vegetation communities (with a few notable exceptions - such as the Itigi Thickets) intergrade, and boundary decisions need to be made during the interpretation and mapping process. Thus, for a classification system to be as useful and reliable as possible it should be targetted at minimising the decision-making required at the margin of adjoining classes. The process and debate used to acheive this are descibed below.

The Legend (map legend) is a reflection of the agreed classification. It identifies the mapping units and topographic features appearing upon the map sheets, but the ability to provide comprehensive information is naturally limited by space available within the map border and herein lies the main reason for the Data Dictionary.

General Considerations in Establishing the Classification and Legend

The Classification, and thereby the information presented upon the thematic maps, is driven by a number of considerations, most of which are inter-related to various degrees. These are :

- The expectation of potential end-users for certain types of information to be presented on the finished maps.
- The information content of satellite imagery at the presentation scale.

- Constraints to the above brought about by the need to acquire multi-seasonal imagery in order to minimise the time frame over which data are collected.
- The selection of the approach to classification, the discriminative criteria to be applied, and the system of nomenclature to be used.

The information to be presented upon the thematic map series is clearly stated in the Project's Terms of Reference but the aspirations of potential end-users (IRA, SMD, Forestry, Agriculture, Water Resources, NEMC, etc.,) were canvassed at an early stage in order to maximise the final value of the map series. The nature of the imagery is such that infrastructural up-dates are only possible where visible on the imagery and this is not entirely consistent. It has, however, been possible to add missing topographic information or to update alignments of, particularly, some new roads or railway lines. Surface hydrology has been mapped, but only where chanels are reliably tracable from the imagery. Disruptions in the drainage network, however, are completed by riparian-associated land cover units.

The required presentation scale of 1:250,000 intrinsically limits the detail of information presentable. The ground area equivalent of the Minimum Mapping Unit at this scale is between 50 and 100ha. This means that small farms are not shown individually, but will be acknowledged within one of the "mosaic" units (eg Woodland with Scattered Cultivation).

The need to acquire imagery from different seasons in order to reduce the time-frame of the baseline survey to a reasonable minimum (two years) also caused some problems for interpretation and unit identification. The practice of broad-scale burning of traditional grazing areas prior to the on-set of the main rains, for example, serves to confuse land cover discrimination because the dark signatures from recently burned land tend to dominate the reflectance from a leafless bushland or woodland. This problem is only overcome through assiduous use of local knowledge, field verification, interpreter experience, and reference to archival aerial photography.

The above considerations suggested a "user friendly" approach to classification and legend. This conclusion was supported by an earlier decision, taken at a very early stage in the work, that the thematic maps should be prepared in full colour. Each Land Cover Type (Formation) would be represented in a particular colour and Sub-Types (Sub-Formations) would be discriminated by overlain symbols, thereby avoiding the need for potentially confusing alpha-numeric annotations.

The remaining decision concerned the general approach to the classification and the nomenclature to be applied. This debate is related below.

4.1.1 Research into existing Regional Classifications

The approach adopted for the classification of the vegetation of Tanzania was based upon a thorough review of relevant botanical, ecological and geographic literature held principally in four major libraries: the Herbarium and Library of the Royal Botanical Society at Kew, the School of Oriental and African Studies and University College - both at the University of London and the University Library in Dar es Salaam. The library at the headquarters of Hunting Technical Services also proved to be a useful source of relevant reference material.

Three fundamentally different approaches to the classification of vegetation have previously been used in the East African context.

The Hierarchical Approach

Grunblatt *et al.*, (1989) have attempted to apply a hierarchical system to the classification of vegetation in Kenya. They proposed four nested levels of vegetation description in their classification system which is summarised below.

Level 1 names were designed to be descriptive of the primary vegetation lifeform found at the site, with a modifying statement relating to the observed canopy cover. Hence use of the terms 'forest', 'woodland', 'shrubland' or 'grassland' with the modifiers 'closed', 'dense', 'open' and 'sparse' for varying degrees of canopy cover. Thus the term 'open woodland' would constitute a Level 1 description under the proposed system. Level 1 descriptions represent general information available from reconnaissance level satellite image interpretation.

Level 2 names provide a description of lifeforms of secondary importance, leading to the use of terms like 'open shrubbed woodland' for those sites of open woodland in which there is also a significant shrub cover. Level 2 names were designed to be descriptive of information that could be obtained from more detailed satellite image or aerial photo interpretation.

The third level of classification, **Level 3**, incorporated a modifier descriptive of vegetation height, for instance, 'tall open shrubbed woodland' where tree height is 10 metres or more. The use of Level 3 names would be appropriate for detailed aerial photo-interpretation or general ground survey.

The most detailed level of classification, **Level 4**, identifies the dominant species within the lifeforms being described, for instance; *Acacia tortillis* tall open shrubbed woodland'. Level 4 names would be appropriate for very detailed aerial photo interpretation or ground survey.

The primary objective of the hierarchical approach was to enable the determination of vegetation type from a variety of data sources, including satellite information, aerial photographs and ground survey. While this objective is worthy of praise, the actual classification system described relates only to 'natural' vegetation, with no concession to induced vegetation types like forest plantations or cultivation. This approach could be modified to encompass all of the vegetation types to be found in Tanzania, but the Level 1 and Level 2 descriptions recommended for reconnaissance mapping are only just detailed enough to be useful, and the intrinsic scheme is insufficiently flexible. If Level 3 and Level 4 descriptions were adopted, the resulting classification scheme would be too complicated to be practically achievable, especially given the probable necessity to include 'mosaic' classes where there may be an intimate mix of different vegetation types occurring in units which are too small to be mapped as individual polygons.

The Physiognomic Approach

One alternative to the hierarchical system of classification of East African vegetation is the physiognomic approach adopted by several researchers since the early 1940s. This approach involves the categorisation of vegetation into a series of physiognomic types according to visible (or physical) attributes, notably the height and canopy cover (or density) of the dominant life forms of those plant associations which actually occur. Special consideration is given to the relative contributions of woody plants and grass, with sub-types being defined by species composition of the dominant life form, and grassland type.

In 1956, the Scientific Council for Africa South of the Sahara held a Specialist Meeting on Phytogeography at Yangambi, Zaire, with a view to developing an internationally acceptable, physiognomical system for the classification of African vegetation. Following the conference, a detailed classification scheme was published. However, both the East African and Southern African regions were under-represented at the conference, with the result that the vegetation of these regions was not given adequate consideration. Therefore, the Yangambi scheme has been considered by many to by inappropriate for application in the context of East Africa, referring as it does to such terms as 'steppe' and 'savannah' which are rarely considered to be correctly applied to East Africa and too much abused to be any longer of service for exact purposes, (Pratt *et al.*, 1966).

Several authors, led (in 1943), by Greenway, have applied a strictly physiognomic approach to the classification and mapping of the vegetation of East Africa. The scheme proposed by Greenway was stimulated by the Inter-territorial Pasture Research Conference at Nairobi in 1940 which appointed a committee to draw up a classification of East African vegetation types. Greenway's scheme, as outlined in his 1943 publication, constitutes the Second Draft Report of the Vegetation Classification Committee.

The proposed approach was itself an evolution of an earlier scheme devised by Burtt-Davy, (1938), and was based upon seven 'Main Types', with an additional consideration being given to Induced vegetation types. Each Main Type or 'Formation' can be further described at the Type level, Sub-type level and Association level as the example below illustrates :

Main Type:	for example - Forests,
Type:	for example - Groundwater Forests,
Sub-type:	for example - Riverine Forest,
Association:	for example - *Acacia xanthophylla* Forest.

The seven Main Types as proposed by Greenway (1943), are given below :

I. Forest
II. Woodland
III. Wooded Grassland
IV. Grassland
V. Permanent Swamp Vegetation
VI. Bushland, Thicket and Scrub
VII. Semi-desert Vegetation

Greenway concedes that different types, often belonging to different Main Types, frequently occur in close conjunction, sometimes in a manner predictable according to topography and ground water conditions. This fact raises difficulties in description when the description has to take a generalised form, as in the case of reconnaissance level mapping. There are several kinds of vegetation 'complex' that may call for recognition in this way. In Tanzania, a simple example of such a complex might be a two-member catena where Woodland and Grassland occur in conjunction, the vegetation being influenced by edaphic factors which are, in turn controlled by topography. The simplest description of such a complex might take the form; '*Brachystegia* Deciduous Woodland - Valley Grassland, Catena', with the indication that the grassland occupied the smaller area.

The classification scheme proposed by Greenway has been used as the basis for Gillman's classic vegetation map of Tanganyika, (Gillman, 1949) which is still regarded as being superior to many more recent maps, (Lovett, 1992). The importance of Greenway's scheme is further reinforced by the fact that this classification is the one used by the workers on the Flora of Tropical East Africa at Kew, (Turrill & Milne-Redhead eds., 1952) as their source of habitat terminology, as well as providing the basis for the classification of East African rangelands adopted by the East African Agriculture and Forestry Research Organisation (E.A.A.F.R.O.), (Pratt *et al.*, 1966). Additionally, it is the scheme used by Lind and Morrison, (1974) in their book on, 'East African Vegetation'.

The Ecological Approach

As well as a purely physiognomic scheme, Pratt *et al.* (1966) propose a complementary ecological approach to the classification of vegetation in particular to define the production potential of rangelands. The recognition of ecological land-units, in which the major combinations of climate, soil and topography are isolated and equated with their basic vegetation types, is considered to be the best approach to the classification of land potential. This approach recognises six broad ecological zones throughout the East African region, defined primarily by climate but incorporating vegetation and land-use descriptions. Each of the six ecological zones could be further subdivided according to soils and topography as new survey data becomes available.

In Tanzania, the relationships between climate, vegetation and land-use were not as clearly defined as in other parts of East Africa, so the boundaries which define the ecological zones were derived principally from direct climatic data. Since there were relatively few metereological recording stations in Tanzania at the time Pratt *et al.* were defining their ecological zones, much subjective extrapolation was necessary in drawing up the climatic boundaries.

In a later work, (Pratt & Gwynne, 1977), it is recommended that for the purposes of mapping with a view to development planning, there is an advantage in separating the description of land potential, as indicated by the ecological approach, from the physiognomic description of the present vegetation. The former is permanent, but may have to be inferred, while the latter, although it can be observed directly, may be changeable - as when fire converts bushland to grassland, or when bush encroachment occurs.

4.1.2 Consultation with Potential End-Users

Consultation with the potential end-users of the thematic map series has been a continuous and on-going process. Occasionally the process has been formalised in meetings attended by representatives of the mainly concerned Government line agencies. Less formal inputs to classification have been made from other donor-assisted programmes, from international agencies, from NGOs, and from conservation groups. In the main, however, the classification and legend has been driven by close discussion with specialists at the Institute of Resource Assessment, University of Dar es Salaam. This resulted in an agreed approach that concentrated on the Physiognomy of land cover, as follows.

4.1.3 The Pysiognomic Approach to Land Cover Classification.

The derivation of the broadly physiognomic approach to the classification and mapping of vegetation under the current Forest Resources Management Project is discussed below.

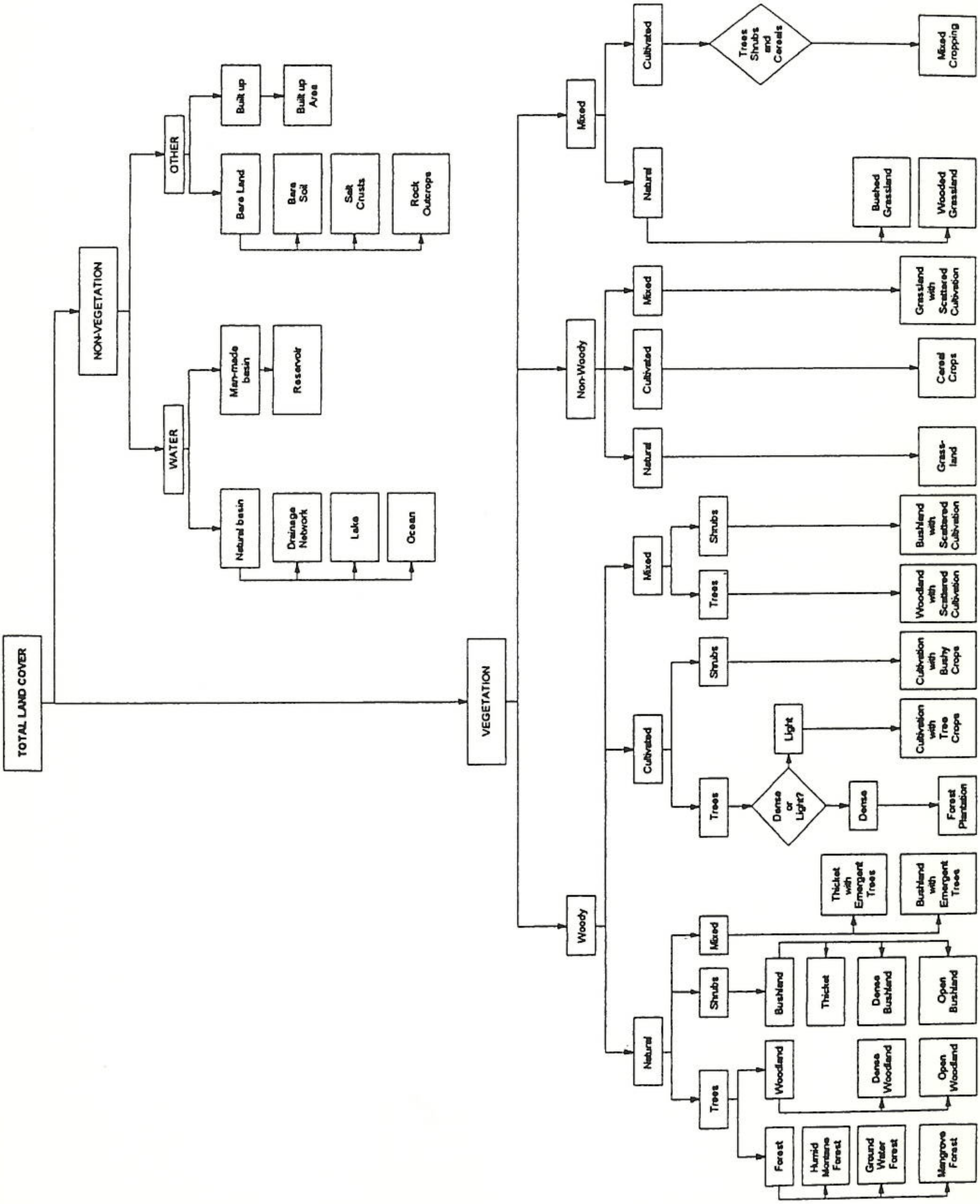
The above analysis of historical attempts to rationalise the classification of East African vegetation leads one to prefer a physiognomic approach, particularly as a main purpose of the Project is to provide a baseline statement of land cover and land use, nationwide, for the purpose of future monitoring. It is important, therefore, that the map legend (and the classification upon which it is based) is unambiguously a statement of the present nature of land cover and use units, and is not confused in any way by considerations of ecological succession, or possible future development.

It was recognised at an early stage during discussions with specialists from the Institute of Resource Assessment (IRA) that the classification for land cover should be intially considered to be provisional, in the sense that the classification should possess an intrinsic flexibility that would allow it to evolve. Whilst the volume of vegetation and land use survey documentation is certainly sufficient to confidently predict the majority of vegetation / land cover types to be encountered across Tanzania, the relationship of these to the satellite imagery would only be fully explored as the work progressed.

It has certainly proved easier, during image interpretation, to descriminate between some units than between others, and limitations imposed by a minimum mapping unit size at 1 : 250,000 scale have, on occasion, introduced the necessity to map "mosaic units". Further, there occurs variation in floristic composition within the same physiognomic unit. For example, Wooded Grassland will possess a consistent shape (physiognomy) across the country. This consistency is implicit for any unit within the classification. It is to be known, however, that species composition does vary from place to place across the country as a consequence of variations in climate. The map legend is not structured to accommodate this, and such variations, where recorded, are referred to in the Data Dictionary.

A framework for the land cover classification was developed by the IRA in consultation with the consultants; the essential objective being to establish a framework which allows such future fine-tuning and also demonstrates the potential to provide the information required by end-users of the map series. This framework is shown at Figure 4.1.

FIGURE 4.1 A FRAMEWORK FOR THE CLASSIFICATION OF LAND COVER



The framework for the classification was developed logically via a progressive sub-division of Total Land Cover under the influences of moisture regime, altitude and pressure from Man's activities. An example of this sub-division train might be as follows :

- Total Land Cover may be divided into Vegetation, Water and Others,
- If Vegetation, this may be Woody, Non-woody or a Mixture of the two
- If Woody, this may be Natural, Cultivated or Mixed
- Natural Woody Vegetation may comprise Trees, Shrubs or a combination
- Communities dominated by Trees, are Forests and Woodland
- Forests may be classified according to the influence of moisture and altitude. Montane Forest; Groundwater Forest and Mangrove are examples.

This logic train lead to the identification of the basic range of land cover types to be encountered, and thereby the provisional classification, as shown below :

LAND COVER TYPE	SUB-TYPE	DISTINCTION
FOREST	Humid Montane Forest	Closed / Open
	Groundwater Forest	
	Mangrove	
	Forest Plantation	Species
WOODLAND	Dense Woodland	
	Open Woodland	
	Woodland with Scattered Cultivation	
BUSHLAND	Thicket	Species
	Dense Bushland	
	Open Bushland	
	Bushland with Scattered Cultivation	
MIXED TREES AND BUSHLAND	Thicket with Emergent Trees	Species
	Bushland with Emergent Trees	
GRASSLAND	Wooded Grassland	Species
	Bushed Grassland	
	Open Grassland	
	Grassland with Scattered Cultivation	
CULTIVATED LAND	Cultivation with Tree Crops	Species
	Cultivation with Bushy Crops	
	Cultivation with Herbaceous Crops	
	Mixed Cropping	
WATER	Ocean	
	Lake	
	Reservoir	
BARE LAND	Bare Soil	
	Salt Crusts	
	Rock Outcrops	
OTHERS	Urban / Industrial Built-up Area	

The above classification was the result of considerable debate. Throughout the interpretation and field work of the Project it has stood-up very well to interrogation and has been subjected to only minor adjustment before acquiring its final form. These adjustments have been confined very largely to a reduction in discrimination of Forest Sub-Types (because of unreliable image discrimination) and an occasional change of nomenclature.

Classification for Land Use

This issue was the subject of protracted debate, especially as the discrimination of land use and its presentation within a cartographic medium is far more problematic than is the case for land cover.

First, there is the consideration of present land use or potential land use. Whilst it is useful to know how land is used at present, the planner is perhaps more interested in information that will allow the optimisation of future land use. This potential - or land capability - is a quality that can be mapped given the required data. A boundary may be drawn to land areas evaluated according to a pre-determined set of criteria. This Project, however, has been more concerned with a statement of how land is used at present. This is much more difficult to map because, whilst certain land uses (such as estate farming or plantation forestry) may have recognisable and mappable boundaries, many land uses (such as grazing, hunting and recreation) do not.

The second point concerns the presentation of land use information, even in those cases where a boundary to such use may be recognised and defined. Land use boundaries in many instances will not coincide with the land cover boundaries to be mapped. Land use for grazing, for example, is likely to embrace grassland, bushland and woodland land cover units. Any attempt to present both land cover and present land use boundaries upon one map would be bound to lead to confusion.

This nothwithstanding, clear associations may be drawn between mapped land cover and implied land use based upon observation, for example :

- Areas mapped as Natural Forest may be open to concessionary exploitation
- Areas mapped as Forest Reserve are largely managed as a protected strategic reserve, but may be exploited under licence.
- Areas mapped as Forest Plantation may be expected to be managed legitimately for production forestry.
- Areas mapped as Game Reserve may attract both tourist and hunting trade.
- Areas mapped as National Parks should ostensibly be used only for conservation, game management and the tourist trade.
- All areas mapped as Cultivated Lands are almost exclusively devoted to agricultue (although irrigated lands are not discriminated within the map legend)
- Other Grassland, Bushland and Woodland areas may be subjected to varying degrees of grazing, minor forest product collection, beekeeping, hunting and recreation.
- All Inland Water areas and Ocean, together with portions of Permanent Swamp, may attract fisheries, aquaculture and recreational activities.

The above associations are obvious. At the presentation scale of 1:250,000, however, the delineation of boundaries to the majority of these activities is neither feasible nor of any real value.

4.1.4 The Agreed Classification

The agreed classification is tabulated in Table 4.1.

TABLE 4.1 CLASSIFICATION FOR LAND COVER AND IMPLIED LAND USE

LAND COVER TYPE	SUB-TYPE	Code	IMPLIED LAND USE
FOREST	Natural Forest	Fn	Conservation, Logging
	Mangrove	Fm	MFPs, Fish Farming
	Plantation	Fp	Commercial Forestry
WOODLAND	Woodland (unspecified Density)	Wu	Wood Gathering &
	Closed Woodland	Wc	Bee-Keeping &
	Open Woodland	Wo	Hunting / Recreation
	Woodland with Scattered Cropland	WSc	Above & Shifting Farming
BUSHLAND	Bushland(unspecified Density)	Bu	Hunting / Recreation
	Dense Bushland	Bd	and Grazing, otherwise
	Open Bushland	Bo	All as for Woodland
	Bushland with Scattered Cultivation	BSc	Above & Shifting Farming
	Bushland with Emergent Trees	B(et)	
	Thicket	Bt	None observed
	Thicket with Emergent Trees	Bt(et)	None Observed
GRASSLAND	Wooded Grassland	Gw	
	Bushed Grassland	Gb	For all these sub-types,
	Open Grassland	Go	Land use mostly confined to
	Grassland with Scattered Cropland	GSc	grazing (in Tse-tse free areas)
	Wooded Grassland(Seasonally Inundated)	Gws	plus wood gathering
	Bushed Grassland(Seasonally Inundated)	Gbs	
	Open Grassland(Seasonally Inundated)	Gos	Cropping on residual waters
CULTIVATED LAND	Mixed Cropping	Cm	Grain, vegetables, Fruit
	Cultivation with Tree Crops	Ctc	Coconut, Mango, Cashew
	Cultivation with Tree Crops(& Shade Trees)	Ctc(st)	Coffee
	Cultivation with Bushy Crops	Cbc	Tea, Cotton, Cloves
	Cultivation with Herbaceous Crops	Chc	Maize, Wheat, Rice, Bananas
OPEN LAND	Bare Soil	BSL	Residual grazing ?
	Salt Crusts	SC	Mining for salt
	Rock Outcrops	RO	Recreation
	Ice-Cap / Snow	ICE	Recreation
WATER FEATURES	Ocean	Ocean	Fishing & Recreation
	Inland Water	IW	Fishing & Recreation
	Swamp / Marsh (Permanent)	S/M	Aquaculture
OTHERS	Urban Area / Airfields	▨	Residence / Industrial

The table indicates nomenclature used for Land Cover Type (Formation) and Land Cover Sub-Type (Sub-formation), together with the codes used during the compilation of master overlays to the scale-controlled image maps. The table also indicates the principal land use normally associated with each class.

4.2 THE MAP LEGEND

4.2.1 Legend for Land Cover

Figure 4.2, gives an abbreviated illustration of the Land Cover and Land Use Legend as it appears upon each of the map sheets in the thematic series, indicating the colours chosen to represent each Land Cover Type and the symbolisation chosen to discriminate between Sub-Types. (Note : for the purpose of this draft, these are photocopies and do not reflect the colours appearing on the maps).

4.2.2 Implied Land Use

The relationships between mapped land cover and implied land use are expressed in Table 4.1.

4.3 THE DATA DICTIONARY

4.3.1 Summary of Contents

A Data Dictionary (Volume 2 of this report) has been compiled to accompany the thematic map series, in order to more fully describe the mapping units presented upon the maps themselves. Its contents are as follows :

- User Guide.
- The Derivation of Classification and Legend.
- Classification for Land Cover and Land Use
- Criteria, and Definition of the Map Units
- The Mapping Units, Illustrations and Variety.
- The Distribution of Land Cover by Map Sheet
- The Distribution of Land Cover by Administrative Area
- Technical References

FIGURE 4.2 THE LAND COVER LEGEND

LEGEND

FOREST

- ▨ Natural Forest
- ▨ Mangrove
- ▨ Plantation

WOODLAND

- ▨ Woodland (unspecified density)
- ▨ Closed Woodland
- ▨ Open Woodland
- ▨ Woodland with Scattered Cropland

BUSHLAND

- ▨ Bushland (unspecified density)
- ▨ Dense Bushland
- ▨ Open Bushland
- ▨ Bushland with Scattered Cropland
- ▨ Bushland with Emergent Trees
- ▨ Thicket
- ▨ Thicket with Emergent Trees

GRASSLAND

- ▨ Wooded Grassland
- ▨ Bushed Grassland
- ☐ Open Grassland
- ▨ Grassland with Scattered Cropland
- ▨ Wooded Grassland (seasonally inundated)
- ▨ Bushed Grassland (seasonally inundated)
- ▨ Open Grassland (seasonally inundated)

CULTIVATED LAND

- ▨ Mixed Croppping
- ▨ Cultivation with Tree Crops
- ▨ Cultivation with Tree Crops (with shade trees)
- ▨ Cultivation with Bushy Crops
- ▨ Cultivation with Herbaceous Crops

OPEN LAND

- ☐ Bare Soil
- ▨ Salt Crusts
- ☐ Rock Outcrops
- ☐ Ice-cap, Snow

WATER FEATURES

- ☐ Ocean
- ▨ Inland Water
- ▨ Swamp/Marsh (permanent)

OTHERS

- ▨ Urban Areas/Airfields

5. INTERPRETATION AND FIELD VERIFICATION

5. INTERPRETATION AND FIELD VERIFICATION

Abstract

The procedures employed throughout the manual intepretation of the scale-controlled imagery are described, together with the systems utilised for the field-verification of these interpretations. The availability of secondary data to support the finalisation of interpretations is discussed, and the creation of separate overlays for interpreted surface water drainage is explained. Finally, the important exercise of the edge- and corner-matching of each sheet to its neighbours is mentioned.

5.1 PRELIMINARY INTERPRETATION FOR LAND COVER AND PROBLEM IDENTIFICATION

The manner in which processed image maps were delivered to the Project in Tanzania was very much dictated by the timing of scene image (raw data) availability, as indicated in Table 3.1. Figure 3.2 shows the spatial distribution of image maps prepared from these raw data. This distribution is divided into four Blocks :

Block 1 is in the west -southwest
Block 2 is in the southeast
Block 3 is in the north, and
Block 4 is in the centre east.

This Blockwise approach was deemed sensible in that :

1) Raw scene data for up to four scenes may be required to compile any one image map, owing to the relative spatial distribution of the two layouts.

2) Similarly, the interpretation of any given image map sheet may not be finalised until it has been edge-matched and corner-matched against its neighbours. In the centre of the country, this may mean that nine sheets have to be completed before the one in the middle may be finalised.

3) The organisation of field-verification exercises is made logistically more efficient by targetting large parts of the country at a time.

4) Raw image data are acquired more readily in the drier parts of the country - the west and south-west. Parts of the south and coastal areas are more persistently cloud-covered and acceptable scene data are less frequently acquired. The logical approach, therefore, was to work from the southwest to the northeast, following the acquisition of scene imagery.

Raw scene data were acquired as per Table 3.1 and then processed to image maps at the consultants' head offices prior to delivery to Tanzania, as detailed in Section 3. Processed image maps were delivered to the Project in Tanzania according to, approximately, the Blockwise schedule indicated above. Upon arrival in Tanzania, each image map was inspected by both the resident consultants and specialists from the IRA, UDSM, for correctness and acceptable cloud-freeness. Rejects were re-processed. Happily these were few, but incurred the need to purchase an extra, less cloud-effected quadrant for the Masasi sheet, for example.

Interpretation began in mid-November 1994, with the mobilisation of the two expatriate interpreters. They were joined in mid-December 1994 by the two (long-term) Tanzanian interpreters and two Forestry Specialists (short-term) whose principal responsibility was to aid in the establishment of an acceptable and workable classification (and map legend) for land cover and land use.

The initial requirement was for familiarisation. Prior to mobilisation, the expatriate consultants carried out a literature review of East African vegetation classifications from sources available in the UK, including the library of the National Herbarium at Kew Gardens. This was continued upon arrival in Tanzania from library sources available at the University of Dar es Salaam and elswhere (Appendix E).

In December 1994 the Project Director joined the Project for a short visit, the purpose of which was to establish the image criteria for the discrimination of land cover types and begin the process whereby individual team members began to correlate image signature with ground truth with consistency of agreement. This intitial exercise concentrated upon the area around Tabora, for which footprint imagery was available at an early stage in the life of the Project.

This early familiarisation work was followed-up with a major field-verification exercise during January and February 1995, involving the consultant Foresters, and both the expatriate and Tanzanian Interpreters. The purpose, again, was to create within the team a consistency of recognition of land cover types whilst at the same time collecting as much ground truth data as possible. This work was carried out in the centre south, west and north west of the country.

At the same time, the fundamental approach to land cover classification was being debated. There was, therefore, an exchange of information between the feed-back from early fieldwork and the representatives of potential end-users who would determine the final classification and map legend.

Early work was carried out using a combination of raw image scenes and scale-controlled image maps. The scale-controlled image maps began to arrive on-Project, in bulk, in early 1995. At this point the Project interpretation team had arrived at consistent image recognition and were ready for the systemisation of image map interpretation. This began with preliminary interpretation of the scale controlled image maps.

Preliminary interpretation concerned the initial identification of major topographic features (urban, roads, rivers) and of the distribution of recognisable land cover types. The former, in combination with information from preliminary topographic base data from SMD, allowed the detailed planning of field verification work, including the logisitics of staff time required, vehicle use, accommodation, etc. Of greater importance, however, was the identification of areas of relative certainty. From the training experience mentioned above, the Project interpreters were able to recognise certain land areas as falling within a given land cover class with a high degree of reliability. The classification of some other areas, however, (particularly if they had been subjected to dry season burning) was more questionable.

The preliminary interpretation exercise served to direct field-verification. It was important both to substantiate areas of confidence and also to research ground truth in areas where interpretation from image signature alone was questionable. The processes whereby this information was gathered are outlined in the following section.

5.2 FIELD VERIFICATION

There were two aspects to field verification of preliminary interpretation :

5.2.1 Field Traverses

The principal ground truth data collection strategy involved the conduct of field traverses by FWD vehicle. These were conducted throughout the majority of the Tanzanian national road network, involving as much minor road use as necessary or feasible (some parts of the country proved to be almost inaccessible).

Following the identification of areas of certainty and uncertainty during preliminary interpretation, the logistics of each field-verification exercise were planned. Generally, field teams were organised in teams of two - one expatriate and one Tanzanian consultant - in order to maximise the combination of technical experience and local knowledge.

Each field traverse (which would normally be expected to be about 100 km per working day, depending upon road conditions) began from a known point, geo-referenced using Magellan GPS. From this known point, the passage into and out of land cover units recognised in accordance with the established classification were recorded against the vehicle kilometer reading by voice onto microcassette, for variations on both sides of the traverse and with additional notes for vegetation communities recognisable within line of sight. Navigation along traverses was checked using the Magellan GPS at mappable way-points and at Sample Sites (see Section 5.2.2). The traverse routes for which detailed records have been archived are illustrated in Figure 5.1.

During the field-verification exercises, the recorded notes were written into hard copy using pre-printed pro-formae to be kept on-Project and used during the finalisation of interpretations. An example of such pro-formae is given at Figure 5.2.

The advantage of the field-traverse approach to ground-truth data collection is that it is very efficient in terms of the volume of data collected over time, and in terms of the learning experience conferred upon the interpretation teams. Over 20,000 km of detailed notes have been collected in this manner. Mean unit width is about 500m, so more than 40,000 units have been sampled during the course of the Project.

The principal disadvantage of the traverse approach to ground truth sampling is that it is intrinsically biased by being directed by the road and track network. Settlement and development for agriculture tends to be encouraged by the provision of access. Therefore, wherever roads are opened, people may settle, clear land and grow crops. This biases the sampling of land cover units towards the Cultivated Land end of the classification and legend. On the other hand, an advantage is created by concentrating on those areas where land use change is more likely to occur in the future, and this is important when creating a baseline for the future monitoring of land use change (the prospects for land use change are much less in the conserved and protected areas which have less, or restricted, accessibility).

Nevertheless, this potential bias was recognised, as was the importance of getting off-road regularly in order to sample less disturbed vegetation. This introduces the second level of ground truth sampling carried out.

FIGURE 5.1 FIELD TRAVERSES FOR WHICH DETAILED NOTES HAVE BEEN RECORDED

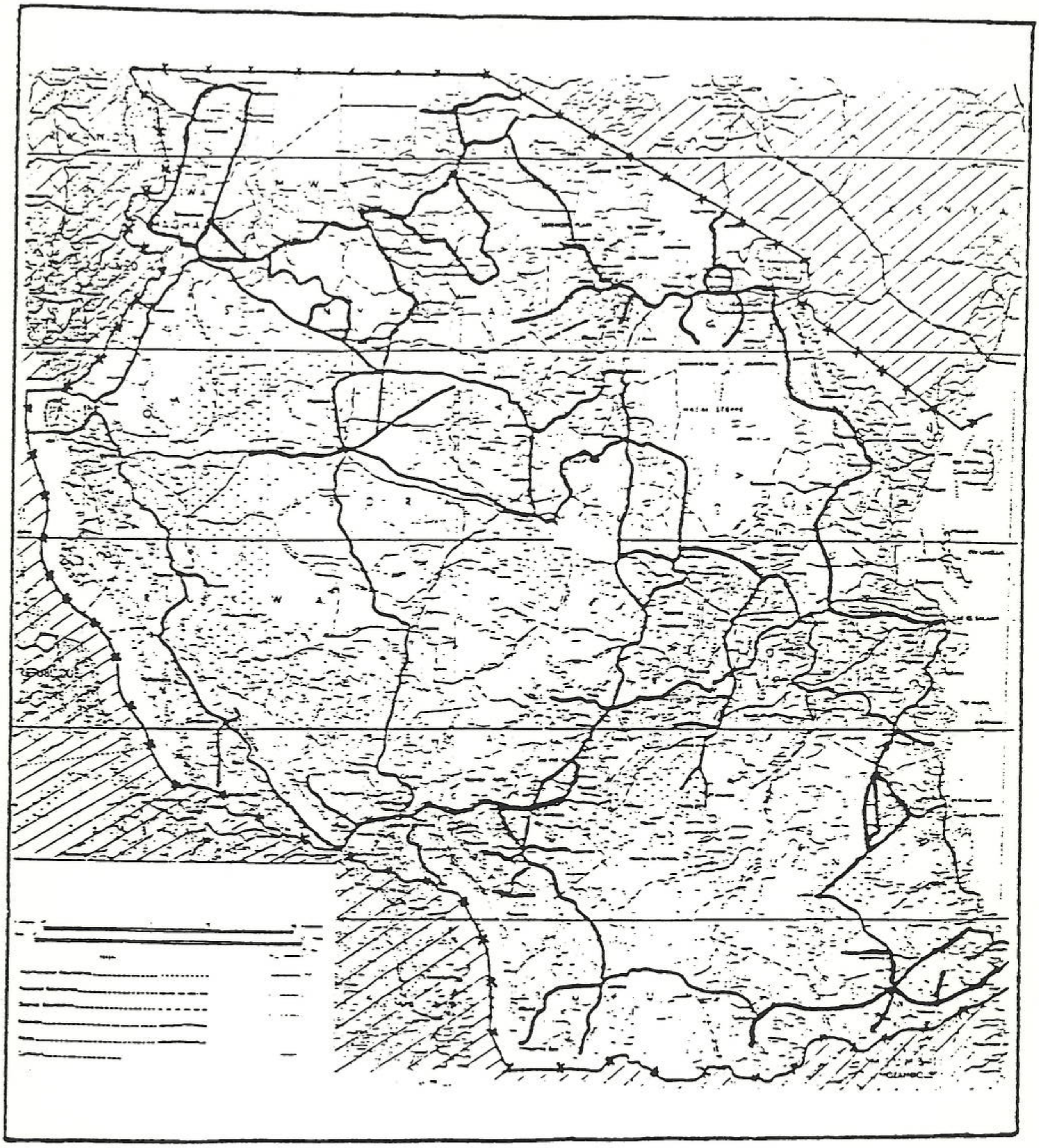


FIGURE 5.2 FIELD TRAVERSE NOTES - EXAMPLE PRO-FORMA

NATIONAL RECONNAISSANCE LEVEL LAND USE AND NATURAL RESOURCES MAPPING PROJECT

TRAVERSE DATA COLLECTION (Interpretation Field Verification)

Observers:

Date:

Start Location:

End Location:

Map Sheets Covered:

Tape No.

Side No.

Km	VEGETATION UNIT		Km	VEGETATION UNIT	
	Left-Hand-Side	Right-Hand-Side		Left-Hand-Side	Right-Hand-Side

5.2.2 Sample Sites

During the conduct of field traverses, more detailed descriptions were recorded at selected sample sites.

The choice (location) of sample sites was made according to two criteria :

1) Where they were thought (via preliminary interpretation and ground recognition) to be fully representative of mapping units within the classification.

2) Where they were thought (via the same process) to be marginal to the main mapping units, or where their identification and description from image interpretation alone was in some question, or doubt.

It was through the recording of sample site information, which often required walking some distance of-road, that these questions were progressively answered, and that the ability of the interpreters to extrapolate interpreted image signature with a high degree of reliability was established.

At each sample site, the following data were recorded upon pro-formae sheets, exemplified in Figure 5.3.

- Sample Site identification.
- A sketched profile of the vegetation cover.
- Identification of the species dominants in Tree, Bush and Grass layers.
- UTM (or Long./Lat.) coordinates of the site.
- Site elevation.
- Site Aspect.
- 1:250,000 scale series map sheet reference.
- Land form at the site.
- Unit identification and code.
- (Arboreal) cover density.
- Observed land use(s).
- Observers and date of observation.

In addition, other site parameters were recorded, sometimes after reference to secondary data. These included :

Soil type; rainfall; geology; Gillman vegetation unit; Land Status (whether reserved or not); Region and District of location; plus general comments on road quality, useful geo-references, etc.

An example of a completed Sample Site Description form is given at Figure 5.3.

5.3 FINALISATION OF INTERPRETATION FOR LAND COVER

The finalisation of interpretation for land cover upon each map sheet resulted from a combination of the information collected during the above two exercises, together with reference to existing secondary data, including the following :

FIGURE 5.3 SAMPLE SITE DATA COLLECTION - AN EXAMPLE

NATIONAL RECONNAISSANCE LEVEL LAND USE AND NATURAL RESOURCES MAPPING PROJECT

TRAVERSE DATA COLLECTION (Sample Site Information)

Sample Site No.

Sketched Profile (all measurements are approximate)

DOMINANT SPECIES		
TREES	BUSHES	GRASSES

UTM Coords E: N:

Elevation(m) GPS: Map:

Slope/Aspect :

Map Sheets Covered:

Soil Description:

Landform:

LAND COVER UNIT:

LAND COVER CODE:

COVER DENSITY CLASS

DENSE ☐ MODERATE ☐ OPEN ☐

OBSERVED LAND USE - CHECKLIST			
Agriculture		Tourism	
Grazing/Browsing		Hunting	
Timber Production		Fishing	
Firewood Production		Brewing	
Charcoal Production		Tree Tapping	
Bee-Keeping		Mineral Extraction	
Tobacco Production		Medicinal	
Conservation		Other(state which).....	

Observers:

Date:

Supplementary Information

Published Material

- **Soil Type:**
- **Rainfall:**
- **Geology:**
- **Gillmans Vegetation Map Unit:**
- **Land Status:**

  Forest Reserve

  National Park

  Game Reserve

- **Administrative Unit:**

  Region....

  District....

Field Notes

- **Quality of Road:**
- **Useful Route-Markers:**
- **General Observations:**

5.3.1 Archival Aerial Photography

Access to the national aerial photographic archive was very kindly granted by SMD. The dates of acquisition for this archive vary from 1972 (for Serengeti) to 1993 (for Shinyanga). Accordingly, some photographic cover is up to 25 years out of date, and boundary information cannot be relied upon. Even old photography, however, if used in combination with field knowledge and with some caution, may assist in the identification of certain land cover units. The entire archive was accessed during the course of the Project.

5.3.2 Other Supporting Data

These include reference to previous studies, reports and cartography. The sources are listed at Appendix E.

5.4 INTERPRETATION FOR SURFACE DRAINAGE

Initially it was assumed that the national surface water drainage system as scribed for the national 1:250,000 scale topographic map series would form a suitable base for the thematic series. At an early stage in the Project, however, it was recognised that the rivers shown on the Blue Plate to the topographic series (mapped from aerial photography from different periods and then transferred from 1:50,000 scale) did not always exactly match riverine-associated land cover units derived from (current) image map interpretation. Mostly, the variation in registration was minimal, but enough to cause concern.

The decision was taken to attempt the plotting of surface drainage from image interpretation. The advantage was that the coverage for drainage would then exactly match that for land cover. The disadvantage was that not all river chanels were interpretable from the image data. River channels tend to disappear in the seasonally inundated, "Mbuga" units, and may disappear altogether in areas of permanent swamp.

A compromise was decided upon that required the mapping of river and stream channels to link with "seasonally inundated" and "permanent swamp" land cover units. Thereby, when the two data sets are presented together, the whole becomes sensible as a drainage network.

5.5 EDGE-MATCHING AND FINAL CORRECTIONS

The Project has been charged with the responsibility of producing a national map series, comprising 64 map sheets. It is most important that the information presented upon each map sheet is seen to be continuous when laid against its neighbours (and this applies to all data sets, whether Land Cover, Drainage, Designated Area boundaries or Administrative Area boundaries). A great deal of effort has been expended by Project staff to this end, beginning with the edge and corner-matching of the manual interpretations. The furtherance of this process after digitisation is related in subsequent Sections.

6. THEMATIC CARTOGRAPHY

6. THEMATIC CARTOGRAPHY

Abstract

Here, the approach to thematic cartography is described, together with the methods employed. Originally, traditional methods of cartography were considered to be the most appropriate but were soon found to be too time-consuming and onerous. An alternative, digital, approach to cartography was agreed upon which required the conversion to digital form of all data sets comprising the final maps, with the exception of the topographic data which would remain in hard copy form. The methods employed are described here.

6.1 THE APPROACH TO CARTOGRAPHY

The initial proposal was to utilise traditional cartographic techniques for map production. This proposal was based upon the recognition that the installed facilities at Surveys and Mapping Division and the skills and experience of Tanzanian cartographic specialists were much more related to this technological level and that this lent a robustness to the approach.

The traditional approach, however, relies upon labour intensive tasks (such as scribing, and the cutting and application of masks and screens) for which the time required is directly related to the complexity of the maps.

When a reasonable number of satellite image maps had been received on-Project and subjected to interpretation and checking it became possible to more accurately judge the complexity of land cover distribution on the final compilations. It was clear that the cartographic workload could not be met by the committed Project resources adopting the traditional approach. An alternative approach making greater use of digital technology and computer-assisted processing was proposed and agreed to.

The debate regarding the final approach to cartography is related in more detail in Section 2.6.

6.2 METHODOLOGIES

6.2.1 General

All digitising, data storage, data manipulation (editing), and data retreival was carried out using the ARC/INFO system. Three copies of licenced PC software were purchased for the Project, including manuals and dedicated licence keys (dongles). Hardware comprised three digitising set-ups - three Calcomp A1 digitising tablets each connected to a PC protected by an Uninterrupted Power Supply (UPS) in line with a voltage regulator. Peripherals included a tape drive for data back-up and two further lap-top computers on loan from the consultants to provide greater editing capacity. Microsoft Office was installed for word processing and Corel 5 for graphics. Printing was carried out using a Hewlett-Packard Laser Jet IV with enhanced memory (+ 8MB) to accommodate a wider range of fonts for map annotation. An 8-pen colour plotter was installed to allow the draft printing in hard copy of digitised coverages for checking and edge-matching purposes.

In order to create all the digital data sets (coverages) necessary to compile the maps, digitising had to be completed for four themes - land cover, surface water drainage, Forest Reserve and other Designated Area boundaries, and Administrative Area boundaries. These data sets were prepared initially as hand-drawn hard copy compilations on stable transparent or translucent film. All compilations were effectively tracings of the relevant thematic information for each of the 64 sheets comprising the 1:250,000 scale topographic series. The thematic compilations for any given map sheet in the series, therefore, were defined by the same geographical coordinates and could be overlaid to one another.

The process of digitising is based upon the premise that the position of any point in a plane may be defined by x and y coordinates. A sequence of points may be joined to form a line, or arc, and a closed arc forms a shape, or polygon. Arcs and polygons may be assigned attributes, such as names or codes, and their dimensions (length or enclosed area) may be computed. This principle is common to the digitising of any theme.

Before any digitising may commence the tablet must be configured for ARC/INFO and preferred tolerances set (see Appendix B).

When commencing the digitising of any theme the relevant compilation is first firmly fixed to the digitising tablet, ensuring that all work lies within the active area of the tablet. It is useful to cover the work with a clean sheet of tracing paper in order to record the progress of digitising. This becomes essential when the work to be digitised is complex, in order to avoid missing any polygons. Using the cursor, the Latitude/Longitude corner coordinates are recorded. This defines the first polygon - the space covered by the work. After this, the coordinates of the cursor when tracing points or lines from within the work are recorded at the push of a button.

Each coverage was processed as follows :

- Creation of raw digitised coverage (= digitiser inches)
- Cleaning of the coverage (identifying errors)
- Editing of the coverage (correcting errors)
- Transformation of the coverage to the Universal Transverse Mercator (UTM) projection (this makes the coverage the same as the corresponding topographic map sheet)
- Checking for sliver polygons and editing out
- Coding of polygons
- Clipping of the coverage back to the edges of the 1:250,000 sheet (to allow edgematching to adjacent sheets)
- Edge match editing
- Production of a draft colour plot and checking
- Generation of final coverage and copying

In addition, the UTM grid and master border for each final map sheet were created. This information included the following :

- Sheet name and serial number (corresponding to the topographic series and individual for each sheet)
- Legend for land cover and land use (common to all sheets)
- Compilation Note (individual to each sheet)
- Map Sheet Index (individual to each sheet)
- Scene Index (individual to each sheet)
- Grid Data (individual to each (of 3) UTM Zone)
- Magnetic Declination Data (individual to each sheet)
- Scale Bar (common to all sheets)
- Topographic Legend (common to all sheets)
- Administrative Boundary Inset (individual to each sheet)

- Acreditation and copyright notes (common to all sheets)
- Longitude / Latitude and UTM coordinates and tics (individual to each sheet).

The procedures required to generate, edit and finalise these coverages were complex, and the routines used are too bulky to reproduce in this main section. They are contained in Appendix B and provide the basic instructions for reproducing the digital cartography carried out by the Project team. Appendix B includes user notes on the following :

- Configuration for ARC/INFO
- File Naming Conventions
- Map Digitising (including cleaning, editing, transformation, coding, plotting, etc.,)
- The construction of Drainage Datasets
- The generation of Forest Reserve boundary datasets (including annotation)
- UTM Projections and edge-matching routines
- The generation of UTM tic marks
- The computation of Area Statements
- Handy hints and tips

The generation of each of the main data sets is described below :

6.2.2 Land Cover

The land cover data set was prepared for the cartographers in the form of hand-drawn and coded compilations on clear inktake film as described in Section 5. Each compilation was drawn so as to slightly exceed the limits defined by the Longitude / Latitude corner coordinates of each sheet in order to avoid any information gaps when edge-matching to adjacent sheets. The original compilations are stored currently in the Project offices.

The digitising of land cover was arguably the most time consuming cartographic exercise and required considerable skill and concentration on the part of the team. Once the land cover units for a given map sheet had been digitised, they were then coded according to their class within the map legend. Each map sheet is comprised of an average of some 700 mapping units (polygons). In the course of digitising, each polygon was given a number in sequence. Each numbered polygon was then allocated the appropriate code, from the legend range of 35 land cover classes. These codes were then utilised to drive the operation of the draft plotter and, later (Section 8) to generate the colours and symbols that form the basis of the thematic map.

6.2.3 Drainage

The mapping of surface water drainage (rivers, streams and lakes) provided a particular problem. Intially, it had been intended to incorporate these data from the blue plate of the existing topographic base. It was discovered, however, that this information - derived from the interpretation of aerial photography (of various earlier dates) and subsequent transfer from 1:50,000 scale compilations to the 1:250,000 scale of the topographic series - did not always register **exactly** with corresponding information derived from the interpretation of Landsat TM imagery conducted by the Project. In general, the deviations were not great but were sufficient to give concern, for example, in cases where narrow riparian-associated land cover units (such as seasonally inundated bushed grassland) should match exactly the mapped drainage course. In too many instances, the topographic base-derived drainage lines wandered outside the boundaries of these narrow interpreted units when the two data sets were combined. Additionally, some significant water bodies were found to have altered in dimension since the publication of the topographic series. Lake Rukwa is a notable case in point, the lake today being much larger than when surveyed for the topographic base. These observations were debated and led to the abandoning of the blue plate from the topographic base, in favour of an approach which required the interpretation of drainage channels and water bodies from the satellite image maps, thereby improving the spatial agreement with the interpreted land cover information.

It was recognised that the digitised data for surface drainage would need to be a separate coverage from that for land cover as there would be many instances where drainage channels would be coincident with other thematic boundaries - particularly parts of Designated Area boundaries and / or parts of Administrative Area boundaries. The matching of these coincidences requires the copying of the one data set (drainage) in order to create the second (say, part of a Forest Reserve boundary). This exercise would have been problematic if the land cover and drainage data sets had been combined as one coverage. The two themes were therefore both compiled and digitised separately.

The drainage coverages were annotated with the names of major rivers and water bodies. These were drawn in the main from paper copies of the 1:250,000 scale topographic series. For some sheets in this series, however, only unfinished compilations were available to the Project team and these often did not include river names. In these cases, alternative sources were consulted including part of the 1:50,000 scale topographic series.

6.2.4 Designated Areas

Designated Areas, for the purpose of this thematic series, include Forest Reserves, National Parks, Game Reserves and Conservation Areas. These boundaries are only partially represented upon the 1:250,000 scale topographic series and, for many of the map sheets, the information is significantly out of date. In the case of Forest Reserves for example, the situation is particularly dynamic, with new reserves being created and old ones being de-gazetted every year.

In the search for a complete and authoritative set of these boundaries, the only sensible recourse was to consult the national archive of gazetted areas. Most of these original data are held by Ministry of Natural Resources at the offices of the Forestry and Beekeeping Division, Ivory Room; with the Department of Wildlife; and with the Tanzania National Parks Authority. The archive is elderly. Although the bulk of reservation took place during the 1950's some forest reserves date from the very early 1900's. The archive is also large, comprising in excess of 500 forest reserve and other designated areas. Not surprisingly, therefore, the archive is inconsistent in the scale and the manner of recording of boundary data. The scale of original maps may vary from 1:5,000 to 1:500,000. Some maps are supported by survey data in terms of longitude and latitude coordinates tied to known features or benchmarks. Others may be supported only by surveyor's notes or, occasionally, with no locational information at all. Some of the older cartography was annotated in German.

The methodology adopted was to transfer by scale-drawing all relevant designated area boundaries to translucent drafting film overlays to the 64 map sheets comprising the 1:250,000 scale series. This would ultimately provide draft hard copy for digitising in exactly the same sheet layout as the other data sets.

At the outset it was recognised that, during the time it would take to complete the transfer of all designated area boundaries to the map scale, it was very likely that some new areas would be added and some previously reserved areas would be de-gazetted, and that this process would continue into the future. The decision was taken, therefore, to create a temporal baseline and to map only those areas gazetted at the time of the then most-recent review prepared by the Department of Forestry - ie January, 1995.

The transfer process involved the following :

- Identification of all qualifying designated areas featuring on each map sheet
- Preparation of overlays
- Location of official sources for the boundaries of each designated area (these were mostly archived original cartography and notes published in the Government Gazette)
- Location of supplementary sources (mostly 1:250,000 and 1:50,000 cartography)
- Recording of source details (eg Job No, location, date, scale, correct spelling of names, etc.)
- Reference to other Project-generated data sets (land cover, drainage and administrative area boundaries) in order to identify any boundary coincidences
- Scale transfer to overlays (by scale drawing and / or pantograph)
- Edge- and corner-matching to adjacent sheet overlays
- Final checking and authorisation by Department of Forestry.

Boundary coincidences with other data sets were colour-coded on the overlays. This allowed the cartographic team to import alignments from the other relevant data sets at the time of digitising the designated area boundaries, thereby ensuring an exact match when printed. Finally, the names of designated areas were added to an annotation file for each map sheet. Different fonts and type sizes were selecetd to discriminate between Forest Reserves, Game Reserves and National Parks.

6.2.5 Administrative Areas

Administrative Area boundaries in the context of Project work were confined to International, Regional and District boundaries. Other administrative and political subdivisions exist, but these were not required to be mapped at the thematic scale of 1:250,000. Considerable effort was required to arrive at a complete and authoritative set of these boundaries. Initially, the boundaries appearing on the existing 1:250,000 topographic base were checked against corroborative sources - particularly the 1:2,000,000 scale map of administrative areas produced by SMD. This exercise revealed that, for the majority of the 64 sheets in the 1:250,000 series, some boundaries were omitted, misaligned or wrongly classified. This was primarily a function of the age of the topographic series. Many boundary changes had taken place but had not been reflected in updates to the series.

Again, the only sensible recourse was to consult the primary source of information - the archives of the Surveys and Mapping Division. A collaborative arrangement was set up whereby the consultants identified and listed the apparent boundary anomolies and then provided plan photo-copies of the 1:250,000 topographic map sheets to the Boundary Section at SMD for authorised correction. The output was a complete national coverage at 1:250,000 scale of the required boundaries on paper copy. Paper, however, is not a stable medium (particularly in the humidity of Dar es Salaam) and so the authorised boundaries were transferred by the Project Cartographers to the clear film positive topographic bases (see section 6.2.7). These alignments were then digitised and encoded according to their boundary status (National, Regional or District). Finally, all transfer lines and original administrative boundaries (whether erroneous or not) were erased from the topographic base film.

Two minor irresolvable issues remained, relating to the international boundary and to area statement computation (Section 7). In part of the the west of the country (Kigoma, Uvinza and Mpanda) the topographic base coverage does not extend to wholely include the international boundary. This portion of the boundary is therefore also not represented upon the thematic series but, as it is located along the centre-line of Lake Tanganyika and no land areas are affected, this is of little significance. For the purpose of computing area statements by administrative area, this missing bit of boundary was digitised from 1:2,000,000 scale cartography and added to the relevant coverages.

In the east of the country there appears to be no officially recognised international boundary. All existing cartography researched by the Project shows the northern and southern international boundaries terminating at the coast, with no connection surrounding the islands of the Republic or delimiting territorial waters extending into the Indian Ocean. We are given to understand that such limits are the subject of debate by Government but have yet to be agreed. In the absence of such agreement, there was no alternative but to take the coast of the mainland and the main offshore islands as being the eastern limits of Tanzanian territory for the purpose of area statement computation. In convention with all other existing maps, this eastern international boundary is not shown on the thematic maps.

6.2.6 The Topographic Base

The Terms of Reference (Appendix A) required that the land cover and land use thematic map series should coincide with the layout of the existing 1:250,000 scale topographic map series. This was achieved through the production of scale-controlled image maps matching the 64-sheet layout of the topographic series (Section 3.2).

Further requirements were to show "infrastructure (roads, railroads, urban centres, villages, towns, cities)" and relate the map content to "a geographic referencing system similar to that used in the standard National series". The latter requirement was satisfied through the creation of both Latitude / Longitude and UTM reference grids, located by margin tic marks, to be included in the master border for the thematic series. There remained two principal options for the mapping of current infrastructure :

- To use part or all of the data used to produce the existing series of 1:250,000 topographic maps, or

- Create a new topographic base from the interpretation of the Project-acquired satellite imagery.

The relative merits of these options have been discussed in Section 2 and, for the reasons given, the decision was taken to utilise the existing topographic data, but as a selection of (initially) the Black, Brown and Blue separations from the full complement of separations needed to produce the full-colour topographic series. It was considered that this selection would provide all the salient topographic and border information needed, but would avoid potentially confusing information such as generalised vegetation symbols (Green separation) or contour lines (Magenta separation). Ultimately the Blue separation was also excluded from this selection, for the reasons given in Section 6.2.3, above.

One early problem concerned the completeness of the 1:250,000 scale topographic series. The situation at Project commencement was that, of the 64-sheet series, 44 sheets had been published and, of these, 17 remained in stock as printed paper copies available for purchase.

The consultants borrowed copies of published maps from various sources and plan-photocopied them for Project use. Of the remaining 20 unpublished (ie never printed) map sheets, most were available only as hand-drawn compilations or, in a few cases, separations ready for plate making and printing. Most of these were available to be plan-photocopied also, thus providing the Project with an almost complete set of the 1:250,000 scale topographic series.

In the meantime a programme was put in place for the Surveys and Mapping Division to finalise the topographic series to a specification that would allow the satisfactory production of the thematic series. This specification called for the production of a clear film positive for each sheet in the series showing the information contained upon the Black, Brown and (initially) Blue separations, namely :

- All border information and reference coordinates,
- Roads, tracks and railways,
- Cities, towns and villages,
- Spot heights and Trigonometrical points,
- Special features such as boundary pillars, churches, lighthouses, mines, archaeological sites, etc.,
- Administrative boundaries,
- Place names (and some designated area names)
- (Initially) rivers, water bodies and their names.

The required materials were provided to SMD by the Project and an honoraria to compensate SMD cartographic staff for working longer hours was also made available from Project funds.

For those sheets (about two-thirds of the series) for which satisfactory master separations were available, the meeting of this specification was fairly straightforward, requiring only the exposure of the separations in combination to a negative, from which the desired positive was produced. For the remaining sheets, however, which required the preparation of new, or replacement compilations, the following tasks had to be carried out :

- Generalised tracing of features from the corresponding 1:50,000 scale maps (24 per sheet)
- Photographic reduction of compilations to 1:250,000 scale
- Scribing of separations at 1:250,000 scale
- Combination to negative, followed by conversion to positive.

This work commenced in December 1994 and was expected to take about three months to complete. Owing to a number of set-backs, however, including frequent interruptions of power and water supplies at SMD and the need to return a number of the positives for correction, the work took somewhat longer. The final topographic base was received by the Project team in June 1996.

The decision to complete a selected portion of the existing 1:250,000 topographic series and then adopt this selection as the base for the thematic series was taken when the Project was still committed to a traditional approach to cartography. By the time that arguments were established in favour of changing to a digital approach, too much effort and materials had been sunk into the preparation of the topo-bases to consider digital production. In any case, digitising of the topographic data would be a major project in its own right. As a result, the topographic base remains the only non-digitised data set of those needed to produce the final maps. This has meant that further work had to be carried out by the Project cartographers to ensure that the hard copy information fully complimented the digitised information and that clashes or duplication of information were avoided. This work included the following, on a sheet-by-sheet basis :

- The removal of all border information from the topobase film (replaced by the computer-generated master border).
- The removal of Latitude / Longitude corner annotations from the topobase film (replaced in the master border), but not the corner marks or tics.
- The addition / replacement of Latitude / Longitude minute annotations on the topobase film (these were ommitted from the new compilations prepared at SMD).
- The removal of UTM grid annotations from the topobase film (replaced by standarised annotations in the master border).
- The eventual removal of all administrative area boundaries from the topobase film (replaced by the digitised coverage).
- The removal of any Forest Reserve, Game Reserve or National Parks names from the topobase film (replaced by new and standardised fonts within the annotations coverage for each sheet).
- The addition and/or correction of infrastructure features on the topobase film, but only where supported by clear evidence from the satellite imagery.
- The addition of main road destinations along the edges of each map box.

Finally, one piece of "cartographic surgery" was deemed desirable. In the 1:250,000 topographic series the MTWARA sheet (SC-37-11) is oversize, being deeper than the standard map sheet size in the north-south direction to accommodate a small portion of Tanzania bordering Mozambique. In order to maintain a standard paper size for printing and for convenience of storage and handling, this portion is now shown as an inset on the bordering sheet LUKWIKA (SC-37-10). It was necessary to edit both topobase films to acheive this.

6.3 MAP DESIGN

At the proposal and negotiation stage of the Project two options for map presentation remained on the table :

- A line presentation superimposed upon a corresponding half-tone monochrome image, with thematic units identified via a suitable alpha-numeric coding, or

- A full colour presentation (without an underlying image). Major thematic units would be represented in different colours. Subdivisions of these units would be discriminated by overprinted symbols.

The latter was considered to be the more user-friendly and, as full sets of imagery were to be provided as products anyway, it was chosen as the preferred option.

The basic character of the maps was determined at an early stage in the Project, therefore, but it evolved in detail throughout the duration of the Project in order to accommodate the change in approach from traditional to digital cartography, and to fine tune cartographic presentation and legibility. The evolution and final appearance of the principal characteristics of the maps are described below :

Representation of the mapping units : The agreed classification recognises 8 Formations divided into a total of 35 Sub-formations (Section 4 and Figure 4.2). The principal land cover

Formations (Forest, Woodland, Bushland, Grassland and Cultivated Land) were each allocated a consistent colour, chosen from a Pantone shade set catalogue. The shades were chosen to reflect as far as possible Formation appearance in reality. Care was taken to ensure that the colours would be sufficiently subtle to be "easy on the eye", and yet be sufficiently distinct to facilitate discrimination. Ease of reprography and printing were also taken into account when selecting the shades - nearly all require no more than two inks (from the four used in full colour printing) for their reproduction.

Similarly the symbols used to discriminate between Sub-formations were chosen to reflect the real differences in physiognomy. Thus, the symbol identifying "Closed Woodland" has the appearance of a dense tree canopy; permanent or seasonally wet Sub-formations carry the conventional horizontal dashes; Cultivated Land Sub-formations are allocated geometrically aligned symbols reflecting the organisation implicit in agriculture, etc. Further the symbolisation is deliberately consistent with nomenclature - ie the overprinted symbol for "Woodland with Scattered Cropland", for example, is the same as that for "Bushland with Scattered Cropland". Discrimination is according to the different base colours of the two Formations.

The symbols used were intially selected from published catalogues and then recreated in ARC at the consultants headoffices, as was the allocation of percentage dot screens to allow the creation of the desired colours at printing. The processes whereby these were acheived are discussed further in Section 8.

Designated Area Boundaries : A dark green line was chosen to represent Forest Reserve boundaries; a purple line to represent the boundaries of other designated areas - Game Reserves and National Parks. Various line widths were experimented with before settling on the final weight.

In many instances these boundaries are shared and the following convention was developed to indicate the nature of such sharing :

- The boundary between adjacent Forest Reserves is shown as a double green line.
- The boundary between adjacent Game Reserves / National Parks is shown as a double purple line.
- The boundary between a Forest Reserve and an adjacent Game Reserve / National Park is shown as a green line next to a purple line.
- The boundary shared by coincident Forest and Game Reserves - ie where the two occupy the same area of land - is shown as a green and purple hatched line.

Designated Area Annotations : In order to standardise throughout the map series, these were completely re-done (ie any appearing on the topobase films were removed). Various fonts were experimented with before deciding upon Times New Roman. The following conventions were adopted.

- Forest Reserve names in Italic Bold lower case with upper case initials.
- Other Designated Area names in non-Italic Bold Capitals.

Type size and letter spacing were selected on a case-by-case basis according to the size of the Area in question. The Annotations were positioned so as to avoid clashes with other information appearing on the maps and, in many cases, this required more than one adjustment as the component data sets (coverages) came together. The main potential for annotation clashes was with the topographic base.

Administrative Area Boundaries : Standard conventions were adopted for the representation of the three categories of Administrative Areas, ie :

- The International boundary is shown by bold dash and two dots with a red overhatch.
- Regional boundaries are shown by bold dash and one dot.
- District boundaries are shown by a dash and two dots in a lighter line weight.

Within the series, many map sheets fall across two or three Regions and five or six Districts. This posed problems for the presentation of boundaries and annotations on the main map, because of all the other annotations already in place. The decision was taken to indicate boundaries upon the main map but to summarise and name these within an inset box to be included in the master border to each sheet.

This approach allowed another problem to be overcome. Administrative boundaries are occasionally aligned in part along major rivers. The digital processing allocates both attributes **exactly** the same line. As a result, neither are clear when printed. As all alignments and names are shown in the inset box, it became possible to not show these coincidences on the main map, leaving the river clearly shown but still obviously the boundary.

Presentation of the Map Legend : Conventional positioning is to the right of the main map, so the remaining options here were whether to present the entire legend of 35 classes as headings alone on all map sheets (which would occupy all of the space available) or, to present only those classes appearing on any given map sheet (which would leave various amounts of space for further explanation, floristic information, etc.). An analysis of a sample of draft colour plots indicated that most map sheets included land cover units amounting to at least 70 per cent of the legend. The benefits of presenting only a sheet-specific legend were clearly minimal and the decision was taken to include the full legend on all sheets in the series.

The Remainder of the Master Border : The titling of each sheet follows the layout, nomenclature and numbering of the national series. The compilation, accreditation and copyright notes are self-explanatory. The compilation note, together with the scene index and map sheet index identify the satellite scenes and the season(s) of acquisition from which the interpreted medium (image map sheet) was derived.

The topographic legend provides a key for both the information represented upon the selected topographic base (Black and Brown plates from the National (1:250,000 scale topographic) series) and for the Project-generated boundary codings. It was derived by reference to the border information presented on the National series (although there were some variations between editions), initially created in Coreldraw and later imported into ARC.

Tanzania lies across three UTM Zones (35, 36 and 37). This has implications for the information given under Grid Data.

Finally, Magnetic Declination data (which is different for every sheet) had to be computed afresh, as the information was only available for the published portion of the topographic series. The declination values were gathered at the consultants head office by reference to ONC data.

6.4 DATA MANAGEMENT AND QUALITY CONTROL

The above sections summarise the procedures employed in the process of moving from hand-drawn compilations of the required data sets to the point where digitised coverages are ready for combination, final editing and processing to colour separations and printing plates. This summary, however, gives little indication of the volume of the work and the consequent requirements upon production control and data management to avoid errors being incurred or processes omitted.

By way of illustration, there are 64 map sheets in the series. Each thematic map is comprised of 8 coverages. 6 of these coverages require 10 steps to process, a dedicated computer file being created at each stage. Without allowing for last minute changes or additions, this amounts to over 4,000 files to be managed.

The Project's Senior Cartographer devised and maintained a production control system that documented the timing of the completion of all processes by map sheet by means of pro-formae record sheets. Materials in process were often moved to other offices to assist in or verify the compilation of other data sets. These loans and returns were similarly documented and controlled. Data and materials moving between the Project offices in Tanzania and the consultants' head offices in the UK were documented via despatch notes. Examples of these control forms are given in Appendix C.

All digital cartographic data files were regularly copied to floppy diskette and backed up again onto micro tape weekly. Tape copies were rotated, with one copy being kept away from the Project offices as security against fire or some other catastrophy. Hard copy materials were labelled and stored in map cabinets and chests within the Project Offices.

7. COMPUTATION OF CURRENT LAND COVER DISTRIBUTION AS A BASIS FOR MONITORING CHANGE

7. COMPUTATION OF CURRENT LAND COVER DISTRIBUTION AS A BASIS FOR MONITORING CHANGE

Abstract

A principal purpose of the Project was to establish a current baseline of the nationwide distribution of land cover and land use in order that future changes may be monitored and evaluated. Implicit in this requirement was the establishment of a procedure that could be replicated. In this section the need for land use change monitoring is stated and the nature of land use change is explored. The methods employed to arrive at the required statements of land cover distribution are given, and the results of the baselining exercise are illustrated.

7.1 INTRODUCTION

Amongst the various outputs of the Project, two are of paramount significance :

- The 1:250,000 scale thematic series of maps that provide a statement of the spatial distribution of land cover and land use types across the nation in relation to the known geography of the country.

- Area statements by category that provide a statement of the statistical distribution of these classes.

Both of these constitute useful tools for the planner and decision-maker. Up to this point, this report has concentrated upon describing the ways in which the first of these products, the maps, were created. In this section attention is paid to the derivation of the statistical information.

7.1.1 The Need for the Monitoring of Change

One of the prime functions of government is the allocation of resources. This requires careful budget anaylisis and planning; the setting of clear priorities in the face of conflicting arguments from competing sectors such as development, defence and social welfare; the allocation of available resources (men, money and materials) on the basis of these priorities; and the monitoring of the effectiveness of these allocations.

For these things to happen, much information and analysis is required but, in the context of the work of this Project, the key words are "available resources". It is not possible to make credible and sustainable resource allocations in the absence of a reliable inventory of such resources (irrespective of their nature), or without an understanding of trends in their status.

Inventories are straight forward and may be completed quite quickly, but the establishment of trends requires time - particularly in the case of natural resources.

The majority of perceived pressure upon natural resources is, arguably, the result of human activity. Even where the apparent blame may be laid at the door of other populations or natural catastrophe there exists all too often an indirect link to short-sighted planning or negligence on the part of Man. Experience clearly demonstrates that there is a clear relationship between natural resource degradation and the concentration of human population (and the activities that such concentrations indulge in). If this premise remains true, then the management of the human population becomes a major key to the management of the natural resources in its husbandry.

Tanzania is blessed with an abundance of natural resources of present or potential economic value. Agriculture is a traditional mainstay of the economy and, although global prices for the more customary export commodity crops have been low, this sector shows some signs of recovery. The minerals sector is attracting considerable investment with requirements for employment and labour relocation. Wildlife, sealife and landscape resources are internationally renowned and the tourism sector is burgeoning. The movement and/or concentration of people is an explicit consequence of the encouraged development of these growth areas, possessing an attendant risk to the integrity of local natural resources.

Tanzania, however, is also unfortunate in being bordered by countries that, in the recent past, have suffered major internal socio-political conflict - Uganda, Mozambique, Rwanda, Burundi, Zaire. With great generosity, Tanzania has accommodated many of the refugee populations fleeing these disturbances, but with significant consequence for the Treasury and for previously conceived land use development plans.

The current situation in Tanzania, therefore, is dynamic. Increasing economic growth, on the one hand, and the need to react humanely to the consequences of external crises on the other, both precipitate change. For effective planning, the location, extent and rates at which such change takes place need to be known.

7.1.2 The Natures of Change

The principal outputs of the Project provide a baseline statement, changes from which may be monitored, evaluated and perhaps extrapolated in the future. In order for such monitoring to be directed effectively, it may be beneficial to consider briefly the various ways in which change may occur.

Planned or Unplanned ? : From the resources management standpoint this is an important distinction. If, for example, smallholder agriculture is to be encouraged as deliberate policy then this implies that a decision has been taken to, say, sacrifice the habitat provided by an area of otherwise unproductive bushland in favour of the benefits of employment and food security afforded by the replacement land use (agriculture) and that the proposal has an adjudged net benefit. Unplanned events may take place to the detriment of land resources or areas which policy has declared to protect - such as reserved or conserved areas. A simple statement of change having taken place is therefore insufficient. A further analysis is required to determine whether such change was desired or not.

Long Term or Short Term ? : Long term changes are normally associated with the need to accommodate natural population growth, or are associated with long term economic development plans. They need to be planned for carefully as their consequences may be more or less permanent. Arguably, the consequences of short term changes precipitated by, say, the unexpected need to support a temporary refugee population, or the issue of a closely supervised mining licence with a fixed lifetime, may be less serious. The ability of natural communities to regenerate when left alone is often underestimated.

Quantity or Quality ? : Quantifiable changes are relatively easy to monitor, particularly where areal changes are concerned. A retreating forest boundary under pressure from subsistence farming is readily noticeable and may be reliably measured using procedures such as employed in this Project. Qualitative changes, however, are more insidious. The progress of tree ring-barking to provide dead firewood supplies, for example, is very difficult to monitor. The end result may be deforestation and conversion to subsistence agriculture, but in the early stages of the process the woodland in question may maintain the same area and maintain much the same outward appearance, even though the stand volume is gradually depleting.

This Project has gone some way to answering this last question by recognising different density classes within the Woodland and Bushland classes, thereby introducing some qualitative assessment into the otherwise largely quantitatively oriented area statements. The output exemplified here (and fully tabulated in Volume 2), however, should be seen as the first major input into a continous analytical process that requires more information (outside this Project's ToR) before all the planning-related questions may be answered. Herein lies a role for TANRIC which, as an institutionalised project, has both the brief and the committed resources to accumulate land cover / land use change data over time and to compare intention with realisation.

7.2 AREA STATEMENTS OF THE PRESENT DISTRIBUTION OF LAND COVER CLASSES

7.2.1 Requirements

The Terms of Reference require the computation of the distribution of the mapped land cover classes across each of the 64 sheets comprising the series, and also by administrative area. The output is organised as follows :

- Area statements of land cover class distribution for each of the 64 map sheets.
- Area statements of land cover class distribution for the nation as a whole (including the islands of Pemba, Zanzibar and Mafia).
- Area statements of land cover class distribution for each of the 26 Regions comprising the United Republic of Tanzania.
- Area statements of land cover class distribution for each of the 99 Districts comprising these Regions.

In each case, the areas of the land cover units represented are tabulated in hectares, together with their percentage contribution to the total.

7.2.2 Outline Methodology

The traditional approach to area statement computation from prepared cartography is planimetry. This may be accomplished by using dot / square grid transparencies or by using any of a range of mechanical devices to measure enclosed areas. The employment of ARC/INFO software, however, provides the facility to compute areas from digitised data, and this has been the proposed approach from the outset (ie it has remained independent of any changes to the overall approach to cartography - section 2.6).

The routines used to derive the area statements (along with the other basic digitising routines) are given in Appendix B They appear *prima facie* straightforward but, in practice, they proved to be time-consuming when employed on PCs, and this was exacerbated by the sheer bulk of processing to be completed - in all, 190 tabulations.

Area statements by map sheet were generated by employing these routines. In the case of area statements by administrative area, however, additional steps were required.

For any given Region, for example, the first requisite was to map-join the land cover data sets for all of the map sheets embracing that Region (often 6, or more). The digitised boundary for that Region then had to be imported from its corresponding data file(s) and superimposed upon the joined land cover display. Only at this point was it possible to instruct the computer to isolate ("cookie-cut") the land cover data enclosed within the Regional boundary. From this, the required distribution was computed. This process had to be repeated for all Regions and all Districts wherever their boundaries extend beyond the confines of a single map sheet. The Project-installed PCs, whilst ideal for map digitising and editing, work slowly for this particular exercise and so much of the data processing was carried out on the more powerful TANRIC computer, exemplifying the excellent inter-component cooperation evolved within FRMP.

7.2.3 Example Tabulation of Computed Area Statements

The full output of area statements as required by the ToR is presented in Volume 2, the Data Dictionary. For the purpose of this main report, however, examples are included here as Table 7.1. This table includes specimen statements as follows :

- Distribution of land cover for Tanzania as a whole.
- Distribution of land cover throughout the Dodoma map sheet (SB-36-12).
- Distribution of land cover throughout Dodoma Region.
- Distribution of land cover throughout each of the three Districts comprising Dodoma Region - Dodoma, Kondoa and Mpwapwa Districts.

TABLE 7.1 EXAMPLE TABULATED AREA STATEMENTS

TOTAL AREAS WITHIN TANZANIA
Distribution of land cover

Classification code	Hectares	Percentage cover
Airport	114.28	0.00
Airstrip	30.98	0.00
B(et)	5355976.82	5.67
Bd	597581.21	0.63
Bo	944082.37	1.00
BSc	9234804.62	9.77
BSL	126177.75	0.13
Bt	524826.98	0.56
Bt(et)	659000.70	0.70
Cbc	89234.34	0.09
Chc	2187336.74	2.31
Cm	6322958.37	6.69
Ctc	1433223.84	1.52
Ctc(st)	110754.72	0.12
Fm	156877.51	0.17
Fn	2431315.28	2.57
Fp	134914.34	0.14
Gb	1962818.30	2.08
Gbs	2923033.25	3.09
Go	1859896.56	1.97
Gos	1782196.44	1.89
GSc	4703633.86	4.98
Gw	4072640.07	4.31
Gws	2056165.74	2.18
Ice	1551.85	0.00
IW	6344789.31	6.71
Ocean	26068.36	0.03
RO	9280.82	0.01
S/M	981260.37	1.04
SC	1986.95	0.00
Urban	64584.84	0.07
Wc	5719223.33	6.05
Wo	24721669.90	26.15
WSc	6994674.29	7.40
Total	**94534685.10**	**100.00**

Note : Ocean totals fall within Tanga and Dar - es - Salaam regions only.

TABLE 7.1 (Continued)

34. DISTRIBUTION OF LAND COVER FOR SHEET NUMBER SB-36-12 (DODOMA)

Classification code	Hectares	Percentage cover
B(et)	290814.01	15.64
Bd	61757.39	3.32
Bo	127851.35	6.88
BSc	524267.68	28.20
BSL	4.42	0.00
Bt	41092.24	2.21
Bt(et)	2044.91	0.11
Chc	106.62	0.01
Cm	47212.05	2.54
Gb	340.41	0.02
Gbs	94083.71	5.06
Go	267.50	0.01
Gos	78598.20	4.23
GSc	86920.94	4.68
Gw	16010.33	0.86
Gws	17743.89	0.95
IW	17981.73	0.97
S/M	20117.78	1.08
Urban	2304.79	0.12
Wo	328764.11	17.69
WSc	100577.29	5.41
Sheet Total	1858861.34	100.00

TABLE 7.1 (Continued)

DODOMA REGION
Distribution of land cover

Classification code	Hectares	Percentage cover
B(et)	160942.90	3.82
Bd	58613.91	1.39
Bo	122845.24	2.91
BSc	1360143.18	32.27
BSL	3199.72	0.08
Bt	44532.46	1.06
Bt(et)	22390.41	0.53
Chc	23525.14	0.56
Cm	210801.96	5.00
Fn	19689.97	0.47
Fp	293.20	0.01
Gb	21087.41	0.50
Gbs	131653.49	3.12
Go	10675.73	0.25
Gos	124296.05	2.95
GSc	508731.15	12.07
Gw	89475.13	2.12
Gws	25938.17	0.62
IW	26817.85	0.64
RO	72.54	0.00
S/M	14294.74	0.34
Urban	3769.80	0.09
Wc	111988.36	2.66
Wo	631463.04	14.98
WSc	487652.40	11.57
Total -Dodoma region	4214893.94	100.00

TABLE 7.1 (Continued)

DODOMA DISTRICT
Distribution of land cover

Classification code	Hectares	Percentage cover
B(et)	58428.64	3.42
Bd	42347.15	2.48
Bo	104362.94	6.11
BSc	674897.76	39.51
BSL	0.23	0.00
Bt	21499.52	1.26
Bt(et)	670.47	0.04
Chc	1276.96	0.07
Cm	81586.46	4.78
Fn	1016.66	0.06
Gb	2211.88	0.13
Gbs	91918.66	5.38
Go	5024.01	0.29
Gos	57434.95	3.36
GSc	142956.34	8.37
Gw	19492.22	1.14
Gws	17401.74	1.02
IW	24479.33	1.43
RO	72.54	0.00
S/M	5962.03	0.35
Urban	2304.79	0.13
Wc	53596.47	3.14
Wo	141134.31	8.26
WSc	158073.18	9.25
Total - Dodoma District	1708149.24	100.00

TABLE 7.1 (Continued)

KONDOA DISTRICT
Distribution of land cover

Classification code	Hectares	Percentage cover
B(et)	56894.66	4.17
Bd	10867.43	0.80
Bo	18236.88	1.34
BSc	466826.31	34.22
BSL	3136.73	0.23
Bt	22466.47	1.65
Bt(et)	10989.52	0.81
Chc	17400.44	1.28
Cm	97139.43	7.12
Fn	1267.35	0.09
Fp	134.24	0.01
Gb	4684.47	0.34
Gbs	30445.69	2.23
Go	2226.96	0.16
Gos	54293.52	3.98
GSc	75330.32	5.52
Gw	40707.85	2.98
Gws	4740.59	0.35
IW	348.66	0.03
S/M	8267.56	0.61
Urban	486.92	0.04
Wc	33771.37	2.48
Wo	265907.13	19.49
WSc	137665.15	10.09
Total - Kondoa District	1364235.64	100.00

TABLE 7.1 (Continued)

MPWAPWA DISTRICT
Distribution of land cover

Classification code	Hectares	Percentage cover
B(et)	45619.60	3.99
Bd	5399.33	0.47
Bo	245.43	0.02
BSc	218419.11	19.12
BSL	62.76	0.01
Bt	566.48	0.05
Bt(et)	10730.42	0.94
Chc	4847.73	0.42
Cm	32076.07	2.81
Fn	17405.96	1.52
Fp	158.96	0.01
Gb	14191.05	1.24
Gbs	9289.15	0.81
Go	3424.76	0.30
Gos	12567.58	1.10
GSc	290444.49	25.42
Gw	29275.05	2.56
Gws	3795.83	0.33
IW	1989.86	0.17
S/M	65.16	0.01
Urban	978.09	0.09
Wc	24620.53	2.15
Wo	224421.59	19.64
WSc	191914.07	16.80
Total - Mpwapwa District	1142509.06	100.00

8. FINAL PROCESSING

8. FINAL PROCESSING

Abstract

Final processing began with the transfer of first-level corrected data sets from Tanzania to the UK where more powerful computers were available. Final corrections and adjustments were made, including the ensured adherence to accepted cartographic conventions as directed and authorised by an independent consultant. The finally approved data sets were converted to formats compatible with the filmwriters utilised in the subsequent stages of plate-making and printing (Section 9). These processing procedures are described, together with the main problems encountered and the procedures adopted for their solution.

8.1 INTRODUCTION

This section relates the processes involved in the final editing of the digital data sets comprising the maps, upto the point of production of corrected data files in a format suitable for filmwriting and subsequent plate-making and printing. These processes are summarised in seven stages.The early stages were carried out partly by the team in Tanzania and partly by computer personnel in the consultants' head offices in the UK, with a constant dialogue between the two throughout. The latter stages were carried out wholely in the UK.

8.2 EQUIPMENT

As related in Section 6, the Project facility established in Tanzania was based upon PC digitising computers driven by PC ARC/INFO software. More powerful Workstation computers and dedicated software were used in the UK for processing and final editing. The main piece of equipment used for this project was a SUN SPARCstation 10. The Workstation was loaded with ARC/INFO version 7.1.1. Additional equipment included an HP 650c colour plotter and a number of 486 / pentium Personal Computers installed with PC ARC/INFO 3.4.1.

8.3 SUMMARY OF THE PROCESSING STAGES

Stage 1
Data Capture through visual interpretation of Landsat TM and SPOT imagery, then digitized into Personal Computers using PC ARC/INFO, carried out in Tanzania (Section 6).

Stage 2
The coverages where then put through a number of intermediate stages before despatch to The consultants' head offices. These stages included map projection, map attribute editing, map joining and the building of topology. This was also carried out in Tanzania.

The following stages were carried out at the consultants' head offices in the UK :

Stage 3
Coverages received from Tanzania were exported and converted from MS-DOS file format to SUN UNIX file format. These files were then imported into various directories corresponding to each of the 64 map identities. Each map attribute, such as a river, a forest reserve or a land unit was kept in a separate ' coverage '.

Stage 4
Further editing was carried out which included map joining, editing text fonts, text size and annotation placement. Last minute editing was also carried out on certain coverages which reflected new data or errors in the original data sets.

Stage 5
A draft inkjet of the final map was produced on the plotter and sent back to Tanzania for checking and further advice on editing.

Stage 6
The inkjets were returned with comments and new datasets if required. Final editing was carried out A final inkjet incorporating all the required edits was produced for final checking before conversion of the map composition to a placeable postscript format, from which colour separations and then printing plates were produced.

Stage 7
Plate production and map printing, described in Section 9.

8.4 OUTLINE METHODOLOGY

This section is confined to explaining the procedures involved from Stage 3 onwards. Stages 1 and 2 were referred to in Section 6.

8.4.1 Stage 3 : Importing of the Data.

The file formats utilised by a PC and a Workstation are not compatible. The initial work in Tanzania was carried out on Personal Computers. They are cost-effective, robust and well suited to routine digitising work. However, they possess neither the memory nor the speed for efficient data processing. The raw digital data received in the UK from the Project in Tanzania were in a compressed format. The compressed files are known as 'export' files and had to be converted into a file format readable by Sun Workstations. The UNIX command environment allows the conversion of such PC file formats easily. Once converted, the coverages were then 'imported', ready for the next stages.

The raw data for each eventual map sheet comprised between eight and twelve coverages representing the different types of land cover, drainage, designated area, and administrative area boundaries present. All the work was carried out in each specific directory. In addition, postscript files were produced from Corel Draw version 5.0 and also imported into each map sheet directory. These latter files contained all the map sheet-specific border information, such as Magnetic Declination data and satellite image band numbers.

The remaining portions of the map design, which are common to all the map sheets, were kept in a separate 'template' directory that could be called up as each map sheet was processed. Such template information included the legend text, legend key, topographic legend, map production acknowledgments and logos.

Additional non-graphic data such as each map coordinates in latitude and longitude, map title and satellite scene index were kept in another data file. This file was used to 'feed' information into the map production program as and when it was required, without user input.

8.4.2 Stage 4: Initial Map Editing.

Due to the greater power of the Workstation, more CPU intensive work may be carried out simultaneously; much more than a single PC could accomplish. The main process carried out at this stage was 'edgematching'. This was the matching up of neighbouring map sheets and, checking visually, whether the land units, rivers and administrative areas, etc., that crossed into another sheet actually matched up with the correct feature on its neighbour's sheet. Any anomalies were corrected using the powerful GIS editing functions of ARC/INFO. Frequent errors included rivers that were visibly extending into a water body, land units with a different land cover type on a neighbouring sheet and mis-matched land cover boundaries. Each sheet was rigorously checked for such initial oversights and notified to the Project in Tanzania so that raw coverages may be updated .

8.4.3 Stage 5: Draft Inkjet Production and more Editing.

Once the initial editing was completed, a draft copy of each map compilation (inkjet plot) was sent back to Tanzania for visual checking. Early, global (ie required on all the maps) adjustments notified from the team in Tanzania included a reduction in the intensity of the land units' shade, increasing the clarity of annotations and the altering of some border information such as the administrative inset map and the topographic legend.

The inkjet plots received in Tanzania were subjected to systematic scrutiny directed by a pro-forma checklist, a blank of which is shown at Figure 8.1. The checked inkjets (bearing annotated corrections, as necessary) together with the completed checklist and the corresponding topographic base film positive in each case, were then returned to the UK for further editing corrections. Where this required changes to the raw digital coverages, these were accomplished in Tanzania and revised files on floppy diskette were also sent to the UK.

It was at this stage that a "skewing problem" was discovered. For many of the map sheets, when checked, the corners of the inkjet plots did not exactly match the corners of the topographic base films. Also, in some cases, the body of the map was slightly off-centre within its master border. The skewing was initially attributed to expansion of the non-stable paper inkjets in the humidity of Dar es Salaam but it was actually due to a printer command being omitted, which caused the inkjet plotter to print the maps with the UTM grid parallel to the map border. The distortion was greatest towards UTM zone boundaries. The solution actually proved to be very simple. The skewness was altered by interactively reshaping each map sheet so that the southern border of the map sheet was parallel with the whole map. After the introduction of this correction, the fit between the printed digital data and the topographic film positive was exact in each case.

8.4.4 Stage 6 : Final Inkjet Proof and Conversion to Postscript Format.

The management of this stage of final processing was influenced by the eventual decision on the part of the Client to print the thematic map series in the UK. Given the greater computer power available at the consultants' head office, it made sense to transfer all salient data to the UK and finish processing there. This initiative integrated very well with the wish of the Client to exert independent supervision of the adherence of the final product to the standards of cartographic presentation and convention required of a national series of maps.

To this end, the Client engaged an independent advisor (Mr R Penza, a retired Head of Cartography from the Surveys and Mapping Division) to examine the thematically corrected inkjets, in combination with the corresponding topographic base film positive, and to identify final adjustments needed to bring the final product to standard. These final adjustments concentrated upon the following :

- Further checking of thematic data edge-matching.
- The need to add main road destination data within all sheet borders.
- The style and positioning of all computer-generated annotations (principally Forest Reserve and river names).
- The identification of annotation clashes with topographic base information, and their resolution.
- Critical review of the border information to each map sheet, with particular attention to the Administrative Area border inset map.

FIGURE 8.1 FIRST LEVEL CHECKLIST PRO-FORMA

SHEET NAME:	**SHEET NO:**	**HTS NO:**

Inkjet proof received:	
Cromalin proof received:	

	MASTER BORDER	comments	OK ?	CORRECTED
1	position of title, spelling			
2	lat/long value, position			
3	UTM value, position			
4	topo date			
5	grid data			
6	mag. dec. data			
7	compilation note			
8	map centred within MB			
	ADMIN. INSET MAP			
9	- position - region names			
10	- spelling			
11	- position - district names			
12	- spelling			
	MAP SHEET INDEX			
13	- numbers correct			
14	- shading			
	SCENE INDEX			
15	- numbers correct			
16	- shading			
	DESIGNATED AREAS			
	FOREST RESERVES			
17	- position			
18	- spellings			
19	- clash with detail on topo film			
	GAME RESERVES			
20	- position			
21	- spellings			
22	- clash with detail on topo film			
	NAT. PARKS + CONS. AREAS			
23	- position			
24	- spellings			
25	- clash with detail on topo film			
	TOPO FILM			
26	check position			
27	clash of annotations			
28	fitting marks			
29	lat/long values - remove			
30	add minutes			
31	clean			
32	neg made			
33	despotted			

comments:

Approved by : ....Date :.................................

This work was carried out systematically and in full collaboration with the Project team now returned to the UK. The aim was to fine-tune the final map product and maximise the legibility and usability of the maps.

Desired corrections were noted upon transluscent overlays to each combined inkjet and topobase. Corrections were entered upon the Workstation, checked off upon the overlay, and a revised inkjet produced. The revisions were then finally checked against the correction overlay to ensure that all had been incorporated correctly. The quality control on each map sheet was rigorous, and only once all visible errors were corrected, and all required annotation added, or annotation clashes resolved, was it then safe to proceed to the final stages.

The inkjet proofs were produced from what is known as a map composition, made up of graphical files representing individual graphical elements. This map composition was then converted into a placeable postscript format (.eps). This format allowed the map to be separated into four layers (cyan, yellow, magenta and black) and processed as such. ARC/INFO can produce many different graphical formats, of which .eps files is one. A simple command converted the map composition into a postscript file, it was then transferred to either a CD-ROM or a ZIP disk and despatched for further processing to film separations.

Problems occured even at this late stage. The conversion to postscript requires substantial disk space, but the computer provides no indication if this space is used-up. If the available disk space is exhausted before all the input data is down-loaded, the information passed for filmwriting is *de facto* incomplete, and may result in colour changes or missing bits of information upon the maps. Unfortunately, it is only possible to identify this after filmwriting and the production of separations and this alone justified the decision to have sample Cromalin proofs prepared for interim checking. The difficulty was recognised before much time and effort had been wasted and appropriate procedures were put in place to ensure that the available hard disk space on the Workstation was maximised prior to the postscripting of map files onto ZIP disk.

8.4.5 Stage 7 : Plate Production and Map Printing

The production of negative colour separations, negative plates, and the full colour wet printing of the map series in the required 500 copies were subcontracted. The processes involved are outlined in the Section 9.

9. REPROGRAPHICS AND PRINTING

9. REPROGRAPHICS AND PRINTING

Abstract

Reprographics and plate-making, and full colour printing were subcontracted, with constant supervision and quality control exercised from the consultants' head offices.The process chain involved is outlined and the quality control procedures imposed are described.

Throughout the life of the Project it had been intended to print the maps in Tanzania. In the final event, this was not to be. The debating of this issue is summarised in the introduction to this Section.

9.1 INTRODUCTION

The Contract required the production of the thematic series (of 64 map sheets) in 500 copies. Although this is not a large production run in the context of the usual demands upon wet printing, this process remained the only option (available computer printers can do the job, but are still too slow and expensive). Wet printing in full colour is effected using four process inks - Black, Cyan, Magenta and Yellow. Each is applied to the work in the proportions (percentages) required to produce the desired finally printed colours when in combination. The inks are applied via dedicated plates, accurately registered to each other. The plates are etched photographically by exposure to corresponding celluloid films (in this case, both negative films and negative plates were used). The celluloid films are prepared either from hard copy compilations (traditional method) or from computer files (digital method) - see Section 2.

Original Project proposals were oriented towards the traditional approach to cartography, which would result in the production of all of the needed compilations on-Project in Tanzania. The logical continuation of this approach was to finish the job by printing the maps in Tanzania, with the government printer (Surveys and Mapping Division) being the favoured subcontractor. The mid-Project change to a digital approach to cartography in no way altered this aspiration, as digital cartographic output could be accommodated equally as well as hard copy compilations.

The final commitment to the printing sub-contract was influenced by the condition of the facilities at SMD and the perceived reliability of externally-supplied services (principally water and electricity) at the time scheduled for printing. The debate surrounding the intended commitment to subcontract with SMD is fully detailed in the Progress Reports of the Project and it is not necessary to repeat this in detail here. The following milestones, however, serve to provide a summary :

- The consultants' Printing Advisor completed a short input during November, 1994. Part of his time was dedicated to negotiating the completion of the topographic series, but he also carried out a quick inspection of the printing facilities at SMD and prepared an internal paper laying out preferred procedures and technical specifications for map printing.

- The basis for subcontract with SMD was discussed during December, 1994, including the quantities and costs of reprographics works (for traditional cartography) and the SMD-adjudged maintenance requirements of the main presses at SMD. Broad technical specifications were discussed and the likely materials requirements were estimated for.

The need for additional darkroom facilities was also identified and quotations were obtained by SMD for this extra item.

- Completion of the draft subcontract required estimation for a range of printing press spare parts and printing consumables. Due to the age of the presses involved, suppliers of some of the spare parts needed were hard to find. This work was conducted from the consultants' head offices. At the same time, the wording of the subcontract document and its attached schedules for materials, work programme and technical specification were completed.

- The finalised draft subcontract was presented in July 1995 and in discussion with SMD it obtained broad agreement. Further progress was influenced by two key issues, however.

  a) The consultants were in the process of proposing the alternative digital approach to cartography, which would markedly reducing the reprographics workload upon SMD, and thereby alter the cost of the subcontract, and

  b) The estimated cost of spare parts for the presses at SMD and the cost of consumables to be imported to Tanzania (researched from the UK) when added to SMD's estimate for labour brought the subcontract estimate to almost 150 per cent of budget.

  A complete reconsideration was required.

- The subsequent approval of the digital approach to cartography meant that the separations to allow plate-making would be film-written from digital data, and not prepared photographically from hard-copy compilations. It was proposed (in September 1995) to test this procedure. The consultants would arrange for the preparation, in the UK, of the required colour separations for one sample sheet (in this case the Tabora sheet SB-36-6) together with a Cromalin proof prepared from these separations to provide a target standard. These would be delivered to SMD for plate-making and test printing. Also at this time, the need was identified for an independent inspection of the main presses at SMD to ensure that all maintenance requirements had been estimated for fully.

- The proofs for the Tabora sheet were printed by SMD in January 1996 on the Duffa flatbed press. Apart from some minor colour imbalances and slight mis-registration (comparison was made to the Cromalin proof provided by the consultants), the results were quite encouraging. The Duffa, however, is not suited to large print runs and inspection of the main presses was still required.

- In February 1996, the Press Engineer (Mr D Eadie, of DENTEC) arrived to inspect the presses installed at SMD. The inspection report of the Engineer was circulated in March 1996 and was summarised in Progress Report No 5. Interruption of the power supply to SMD prevented full test printing, but the Engineer was able to inspect all machines, identify the Roland Rekord press as being the most suitable for the purposes of the Project, and to quantify the requirements for its repair.

- Competitive tenders (five) for the required repairs were invited by FRMP and the bid of the inspecting engineer (DENTEC) was selected. Authority to carry out the repairs under separate FRMP funding was authorised during the IBRD mid-term review (at which time also the Government's clear desire that the maps be printed in Tanzania was stressed), and a deadline for the completion of repairs to the press and the proofing of printing from it was set for the end of August, 1996. Implicit in this decision was the conferred option for the consultants to explore alternative subcontractual arrangements should this deadline not be met. The mobilisation of the press repair contract by FRMP was conducted as quickly as possible, and with considerable help from the consultants. Some of the spare parts required proved difficult to obtain, however, (the machine concerned had been out of production for many years and the original manufacturers in Germany had to be contacted), and this delayed the initiation of repair work until the end of November 1996. Nevertheless, given the universally held desire to print the maps at SMD, the consultants waived the option to place the subcontract elsewhere, pending the result of the repair work and proof printing.

- The repair contractor arrived in Tanzania with all required spare parts, a supply of printing materials and the separations for two further map sheets (Bukene and Rungwa) with which to proof the press following repair. At this point it was discovered that the Roland Rekord press would not run without further attention to the electricity supply control board (the potential for this fault had been identified at inspection but was specifically excluded from the tender documents for repair). The consultants funded the repair of the control board, allowing all other planned repairs to proceed.

- Scheduled repairs to the Roland Rekord were completed in the first week of December 1996 and test printing began. The Tabora sheet was printed first, using the plates used for proofing of the Duffa flatbed earlier. This was not very successful as the plates had become damaged in storage and many unwanted black marks appeared on the prints. The Bukene and Rungwa sheets were printed using plates purchased locally by the consultants and developed from the corresponding separations at SMD. The Bukene proofs exhibited pronounced fading of the black detail, particularly towards the corners of the sheet. This was attributed to uneven exposure of the black plate during plate-making. Greater attention was paid to this part of the process when proofing the Rungwa sheet and the results were very much improved.

- The outcome of the test printing was discussed at length with the Director and senior technical staff of SMD. It was judged that shortcomings in the test prints were due mostly to poor plate-making resulting from the use of inappropriate equipment (the lights used to expose the photo-sensitive plates). The option of renewing the plate-making equipment at SMD was rejected on the grounds of cost and time. It was eventually decided that plate-making should be carried out in the UK and that the printing would be carried out at SMD as planned.

- The consultants began to prepare another revised draft of the subcontract documents incorporating this change whilst at the same time mobilising plate-making and the supply of materials. By mid-January 1997, the following had been accomplished.

- 120 reams (60,000 sheets) of SRA1 x 100gsm paper had been purchased, 48 reams of which had been air-freighted to Tanzania together with 250 sheets of kraft wrapping paper.
- 260 unexposed printing plates had been purchased and trimmed to the exact size suited to the Roland Rekord press at SMD.
- Colour separations for a total of 16 map sheets (25 per cent of the series) had been prepared, together with two Cromalin proofs.
- Printing plates for 8 of these 16 map sheets had been prepared and packaged ready for air-freighting to SMD in Tanzania.

- It was clear at this stage, however, that the target completion date of 31 January 1997 was looking increasingly unacheivable. The Technical Committee met on 15-01-97 to agree a strategy for completion. This resulted in the formation of a small working group charged with the identification of options and returning recommendations to the Technical Committee. These options were to include the inspection of proofs (prior to platemaking) for cartographic convention and correctness by an independent consultant (this, at the request of SMD and approved by the Technical Committee). The options identified were as follows :

  1) For the selected cartography consultant to join the Project team throughout the final checking of remaining ink-jet proofs.
  2) For the Project to demobilise and complete all final edits in the UK, leaving the final acceptance of the printed maps in the hands of the Government Printer, SMD.
  3) To extend the Project in Tanzania to allow both final editing by the cartography consultant and acceptance of the finally printed maps by the consultant team, or,
  4) To finally edit and print the maps in the UK under the supervision of the consultant cartographer.

- The Technical Committee re-convened 22-01-97. Option (4) was selected and the consultants were formally notified of this decision by letter dated 05-02-97.

- At this point, the shipment of all printing materials ex-UK was stopped and procedures were put in place to finalise an agreement with an alternative printer in the UK. Concurrently, an independent cartography consultant (Mr R Penza) was selected by SMD with FRMP and IBRD approval. Arrangements were made for his mobilisation to the UK under separate funding provided by FRMP. Mr Penza departed for the UK 21-02-97. The Project then demobilised rapidly from Tanzania, the Senior Cartographer leaving 25-02-97 and the Project Manager 28-02-97.

- One consequence of the decision to print in the UK was the creation of considerable sunk costs comprised of the paper consigned to Tanzania, the separations produced and the plates cut. The paper could be taken into SMD stock, but the separations had to be scrapped as they bore accreditation for printing by SMD, which would no longer be correct. An intensive search amongst UK printers failed to identify any using a Roland Rekord or any other machine that could use the plates already cut to size for the Rekord. The prepared plates, therefore, became redundant also.

Mr Penza's valuable contribution to the cartographic standard of the final maps is described in section 8.4.4. The reprographic and printing arrangements are outlined below.

9.2 REPROGRAPHICS

Reprographics covers the making of film separations (one for each of the four process colours) and the making of the printing plates from these.

The final output from the consultants head offices was the postscript .eps files containing the digital information needed to produce the colour separations for each map sheet. Separations production and plate-making were conducted ex-house because of the specialised equipment and software used. The first stage in the process required the conversion of the postscripted data to a language that is compatible with the current generation of film writers. The image setter language used in this case was TYPAN RIP.

Once in TYPAN, the data for each map sheet were imported to an Agfa Advantra 44 film writer. This is one of the larger film writers with a 44" x 36" format. The majority of printing in the UK today is carried out from positive separations. In this case, however, the Client was quite specific that negative separations and plates should be produced. To this end, the following stages were gone through for each of the 64 map sheets in the series.

- A family of four negatives (Black, Cyan, Magenta and Yellow) were produced from the Advantra.
- One positive was produced for the Black plate from its negative.
- This positive was then combined with the topgraphic base positive and exposed together to form a combined negative (a "new" fourth negative).
- From these four negatives, the plates for printing each sheet were prepared.

In addition, four positive separations were prepared for each of eight sheets selected for sample checking by Cromalin proofing (see Section 9.4).

9.3 PRINTING

As mentioned above, the search to find a printer with a press capable of using the plates already cut to fit SMD's Roland Rekord failed. The next best option was to find a printer using a press taking plates that were just slightly larger than those used by the Rekord, thereby retaining the possibility of further future use on the Rekord after minor trimming. The earlier-favoured alternative printers, Victoria Litho, do not possess such a machine but nearby Moorland Printers do - two Roland 6000s, a more modern version of the Rekord. Following an inspection of their facilities (accompanied by the cartography consultant) and an examination of similar work carried out previously, an order for the printing of the maps was placed with them.

Sets of printing plates were provided in batches of between 10 and 20. This facilitated the setting up of fairly large runs at one time, on one machine, with one operator and thereby reducing some of the variables that might be introduced - such as different ambient temperatures, or different colour perception on the part of the operator(s).

Generally, 400 - 500 prints were run off during the setting-up for each sheet. This allowed optimum colour matching and registration to be acheived before printing the required 500 final copies.

Production control at this stage was largely the responsibility of the printer with periodic supervision from the consultants. As batches were printed, however, specimen maps were delivered to the consultants for final checking.

Examples of the maps as they were being printed were sent to FRMP Tanzania for review and comment (the first batch of 3 sheets at the end of March 1997 and a further batch of 10 sheets in early May). Received comments were satisfactory and complimented the high standard of the printing.

After printing and trimming, each map sheet in 500 copies was wrapped in protective kraft paper ready for freighting to Tanzania.

9.4 QUALITY CONTROL PROCEDURES

The digital map data (postscript .eps files) output from the consultants head offices was authorised via the checking of inkjet plots produced from the data, in combination with the topographic base film positives (Section 8).

There are three main process stages between that point and sight of the finally printed maps, however :

- Separations production
- Plate-making, and
- Printing.

The technologies and methodologies employed at each of these stages were well-tried and robust, but the potential for something to go wrong always exists and it was important to monitor each stage and be able to react quickly to solve any identified problems before they continued further into the production run.

The production of separations was monitored by checking Cromalin proofs produced from positives of the separations. Cromalins are one-off prints and are expensive to produce, so a sample of eight map sheets (12.5 per cent of the series) was selected to represent as much variation in land cover as possible (and therefore in colour and symbols). Cromalins prepared for these eight map sheets (Kabale, Kahama, Arusha, Uvinza, Tabora, Sumbawanga, Kazimoto and Liwale) were checked by the consultants for completeness of information content, accuracy of registration, correctness and consistency of colours, clarity of symbolisation, and legibility of annotations.

Plate-making was monitored by checking Ozalid prints prepared from the Black and Cyan plates of each map sheet (most of the information making up the maps is contained on these two plates). An Ozalid was prepared for each of the 64 map sheets prior to printing. The black and white presentation allowed further checking of registration, symbolisation and annotations. It also allowed examination of the percentage dot screens transferred from separation to plate, and thereby producing some assurance that the desired colours would be created at printing.

10. PROJECT OUTPUTS AND HANDOVER

10. PROJECT OUTPUTS AND HANDOVER

Abstract

The various outputs of the Project are listed and the custodial institutions in Tanzania are identified.

10.1 INTRODUCTION

This final Section lists the outputs of the Project, the formats in which they have been prepared, the arrangements for their hand-over and their intended destination in Tanzania (ie the institutions intended to receive and take responsibility for the Project outputs, and from where the data may be accessed in the future).

10.2 SATELLITE SCENE DATA

All satellite scene raw data (including full Landsat TM scenes, quadrants and replacement quadrants covering mainland Tanzania, and SPOT acquisitions covering the islands of Pemba, Zanzibar and Mafia) were obtained as Computer Compatible Tapes (CCTs). Hard copy imagery was produced for a total of 19 scenes (Appendix D) in order to allow field reconnaissance and familiarisation during the first Dry Season of the Project (November / December 1994) and before sufficient scene data had been delivered to allow the production of the first batch of scale-controlled image maps.

All raw data has remained on CCT throughout the duration of the Project, for two reasons:

- Conversion of the data to the interpretation medium (scale-controlled image maps) did not require the interim production of hard copy imagery for each scene, and (less importantly)

- All raw image data remain subject to copyright until irreversiby processed (ie converted to scale-controlled image maps).

The full complement of CCTs is bulky (weighing around 250 kg), they may only be read via a dedicated tape drive, and they contain first generation (unprocessed) data only. It is the enhanced (rectified, mosaiced and edited) data that are of greatest value for future use.

With Client agreement (April 1997), hard copy raw imagery has not been produced. Instead, the CCT data were down-loaded onto CD-Rom, thereby providing a lighweight and easily handled data-storage medium that may be accessed by computer hardware and software already in the Client's possession. These data have been produced in two forms :

- All channel raw scene data, and
- Rectified scene data in the three channels (4, 5 and 3) used to compile the scale controlled image maps.

These data on CD-Rom were delivered to TANRIC, via FRMP.

10.3 IMAGE MAP DATA

10.3.1 Digital Data

The digital data comprising each of the 64 scale-controlled image maps were similarly ouput to CD-Rom. At the request of TANRIC each image map is represented by separate files for each of the spectral channels (4,5,and 3) used to compile the final false-colour image. These files were written as ERDAS.LAN in DOS for ease of access by the IDRISI programme installed at TANRIC.

10.3.2 Hard Copy Data

Two copies of the 64 sheet set of image maps were prepared by the consultants. The first set was used for interpretation and field verification work by the Project team in Tanzania. This set remains in good condition and was stored along with other interim products in the Project facility at IRA (Section 10.5). A pristine archive copy was delivered to IRA via FRMP at the conclusion of the Project.

10.4 TOPOGRAPHIC DATA

Base topographic data (roads, railways, towns, villages, spot heights, etc.,) exist in non-digital form as clear film positives corresponding to each of the 64 map sheets. These were produced by SMD with Project assistance (Section 6.2.6) and were combined photographically with the black separation during reprographics (Section 9.2). For this purpose they were taken to the UK and were then returned to SMD through FRMP following acceptance of the final printed maps.

Of the 64 topobase films, 20 were re-photographed and cleaned in order to improve the quality of the respective combined black separations, and thereby the black plate at printing. In total, therefore, 84 topobase films were returned to SMD.

10.5 THEMATIC CARTOGRAPHIC DATA

Thematic cartographic data exists as both interim and final products. It will be **important** to recognise this distinction when accessing for future use - some interim products do not exactly represent the corresponding final, corrected, product.

10.5.1 Interim Cartographic Products

Interim products include the hard-copy cartography and thematic compilations used to create the digitised data **and also** the interim digital data themselves (ie all the digital data generated by the Project in Tanzania but then subjected to final editing, correction and adjustment during the latter stages of the Project in the UK).

a) Hard Copy Interim Products

These include the following, corresponding to each of the 64 map sheets in the 1:250,000 series :

- One working set of scale-controlled image maps (plus one archive set delivered at Project-end)
- Topographic sheets (paper originals and plan photo-copies)

- Land cover interpretation compilations (intake overlays)
- Flight indices of archival aerial photography (transluscent films)
- Unrectified Landsat TM scenes (19 No)
- Designated Area overlays (transluscent films)
- Surface drainage compilations (inktake overlays).
- Administrative area boundaries (plan photo-copies)

All hard copy interim products were labelled and stored in the Project facility at IRA, UDSM. They are catalogued and referenced in Appendix D to this volume.

b) Digital Interim Products

These products represent the total digital work carried out by the Project team in Tanzania prior to final editing and correction in the UK. They include, for each map sheet and in cleaned, clipped, transformed and final versions, the following coverages :

- Land cover
- Surface drainage
- Forest Reserves
- Game Reserves
- National Parks
- Administrative areas
- UTM grid
- Annotations
- Master border information

These data are stored on the hard disks of the three digitising PCs located within the Project facility at IRA, UDSM. They were also copied onto floppy diskette and (partially) onto mini-tape. All these data were handed over to IRA, through FRMP.

10.5.2 Final Cartographic Products

The final digital cartographic products include all relevant and finally edited / corrected versions of the above coverages (GIS files), plus copies of the postscript files in export format which were used to produce the final maps (Map files). These were downloaded onto CD-Rom at the end of the Project and delivered to FRMP for custody with either SMD or IRA.

10.6 FIELD NOTES AND OTHER PRIMARY DATA

Field traverse notes and sample site descriptions used to finalise land cover interpretation were filed and remain within the Project facility at the IRA, UDSM.

10.7 REPROGRAPHICS AND PRINTING PRODUCTS

10.7.1 Reprographics

Reprographic products are the colour separation negatives used in plate making. They constitute a very valuable product as they will allow the re-printing of the thematic series (in whole or part) as and when the future need arises. The following were produced for each of the 64 map sheets and were delivered to SMD, through FRMP :

- Four negative separations (Black, Cyan, Magenta and Yellow)
- One Black positive
- One combined Black positive (Black detail combined with topographic detail)
- One combined Black negative.

10.7.2 Printing Products

These included :

All plates used for the printing of the thematic map series.
The thematic map series of 64 map sheets in 500 copies each.

These were delivered to SMD through FRMP at the completion of the Project.

10.8 REPORTS

The following reports were submitted throughout the course of the Project :

15-12-94	Inception Report
15-03-95	Progress Report No1
15-06-95	Progress Report No2
15-09-95	Progress Report No3
15-12-95	Progress Report No4
15-03-96	Progress Report No5
15-06-96	Progress Report No6
15-09-96	Progress Report No7
15-01-97	1st Draft Data Dictionary
31-05-97	Draft Final Report, Volume 1 : Main Report
	Draft Final Report, Volume 2 : Data Dictionary*.

* **Note** : The Data Dictionary contains another important product of the Project - area statements for the distribution of land cover classes by map sheet and by Administrative area (Nation, Region and District).

APPENDICES

APPENDIX A

TERMS OF REFERENCE, WORK PROGRAMME AND STAFFING SCHEDULE

APPENDIX A

NATIONAL RECONNAISSANCE - LEVEL LAND USE AND NATURAL RESOURCE MAPPING

Term of Reference for the Mapping Contractor

1. BACKGROUND

Increasing population and expanding agricultural practices are subjecting forest resources in Tanzania to stress and causing rapid deforestation in many regions of the country. Large areas of forest lands are being converted to agricultural land uses, and forest products are being extracted to meet the increasing energy demands for fuelwood. The extent of remaining forest and the rate at which forest lands are being converted are not known with any degree of certainty. Within the TFAP, the government is attempting to address issues of sustainable development and resource management and to prepare strategies combat problems of environmental degradation. To accomplish these objectives, there is a need for reliable information about the current extent and condition of the forest resources and for an assessment of recent land use changes. The information requirement should be within the framework of a national program for resource and environmental information. the Government of Tanzania has requested support from the World Bank under the Forest Resource Management project to develop an information base for forest resources and other land uses.

2. OBJECTIVES

The pupose of the reconnaissance level resource and land use mapping will be:

(i) to provide country-wide baseline forest resource information regarding forest areas and forest types;

(ii) to provide baseline information about other land uses, particularly agriculture;

(iii) to facilitate an assessment of natural resource and land use changes over time, relating the changes to possible causes, and

(iv) to develop the framework for regular national forest resource monitoring;

3. METHODOLOGY AND OUTPUTS

Maps showing a reconnaissance level inventory of forest cover and other land uses will be prepared, addressing the immediate needs at a national and regional level for information defining how much forest cover still exists, where the forest resources occur, where agricultural activities are encroaching on forest reserves, and what the relationship is between population distribution and resource supplies. The mapping and inventory will be based on satellite image interpretation, appropriate to produce 1:250,000 scale maps. The image interpretation must be corroborated with sufficient field sampling and ground "truthing" to enable reliable classification of forest cover and agricultural land use. Specifically the activity will include:

(i) The mapping exercise will cover the entire country and will coincide with the existing 1:250,000 series topographic maps of the country.

(ii) The 1:250,000 National Series of maps in Tanzania covers the country is 64 sheets, nearly one quarter of which are less than full sheets with areas over water and neighbouring country land masses.

(iii) The maps should show the distribution of forest and agricultural land use according to a classification system agreed upon with the Government of Tanzania and the World bank. The IRA will be responsible for development and drafting of the classification system in conjunction with the FBD, SMD, MALD and NEMC. The information should be obtained from recent satellite data augmented with sufficient ground information to validate the image interpretation. For some areas of the country, resent, high resolution satellite imagery and aerial analysis of portions of the country. This may be useful to assist with the interpretation work. As a minimum, the maps should include information on:

  - Natural and induced vegetation cover types according to the recommended classification (see 3 (ii) above); and including identification of dominant species.
  - Vegetation cover densities based on ~~g~~crown cover (e.g. dense medium, and open).
  - Designated areas (including forest reserves, national parks, game reserves, conservation areas, and public forest lands).
  - Land use (distinguishing major agricultural activities etc.)
  - Infrastructure (roads, railroads, urban centres, villages towns, cities).
  - Administrative boundaries (national, regional, and district).
  - Surface hydrology according to the recommended classification.

(iv) The maps should be printed with the thematic information in colour on a mosaiced, monochrome sateline image background. Each map sheet should include a legend describing the classification system, a geographic referencing system similar to that used in the standard National series, and other reference data (scale, map showing location of each sheet relative to the entire country, and identification of satellite images used in the mosaic). Five hundred (500) copies of each map sheet should be produced and delivered to IRA (or another agency which may be defined at the time).

(v) A data dictionary should be prepared which describes in detail what is included in each of the map classes. This should be graphically illustrated as appropriate.

Area statistics should be provided for each of the land cover/land use categories used in the 1:250,000 scale classification system. These statistics should be summarized by administrative areas (nation, regions, and districts) and presented in report form (minimum 50 copies).

(vi) Local staff from relevant agencies should be used to the extent possible for field work, data analysis, and image interpretation.

(vii) A copy of the digital imagery (ie. CCTs or other suitable media) and imageries used in the analysis of land cover should be delivered to the IRA.

4. INPUTS

The contractor will be responsible for identifying and procuring all required imagery, making logistical arrangements for in-country field work, and organizing the work flow from data collection to map production. It is estimated that the exercise can be completed within two years, allowing for the acquisition of cloud free satellite imagery and field work during the non-rainy seasons of the year.

5. ORGANIZATION

The land-use and resource mapping activity will include information about parameters in addition to the forest resources; therefore, it will be directed on behalf of the Government of Tanzania by the Institute of Resource Assessment (IRA). The Inventory Section of Forestry and Beekeeping Division (FBD), the survey and Mapping Division (SMD), the Ministry of Agriculture and Livestock Development (MALD), and the National Environmental Management Council (NEMC) will be directly involved with the development of a classification system for the baseline mapping. the IRA will be responsible for coordinating the relevant agencies, together with the contractor, to finalize the classification system and to test its feasibility.

6. REPORTING REQUIREMENTS

Inception Report:

To be delivered after three months in-country. This report would lay out the activities to be undertaken, together with inputs of materials, equipment and personnel, and the expected outputs, together with the timing thereof. An updated version of the work schedule presented in Section 4 of the consultant's Technical Proposal would be presented. The report would be reviewed by the Project's Technical Coordination Committee and the World Bank. Amendments would then be made as recommended and as agreed between the Client and the Consultant.

Progress Reports:

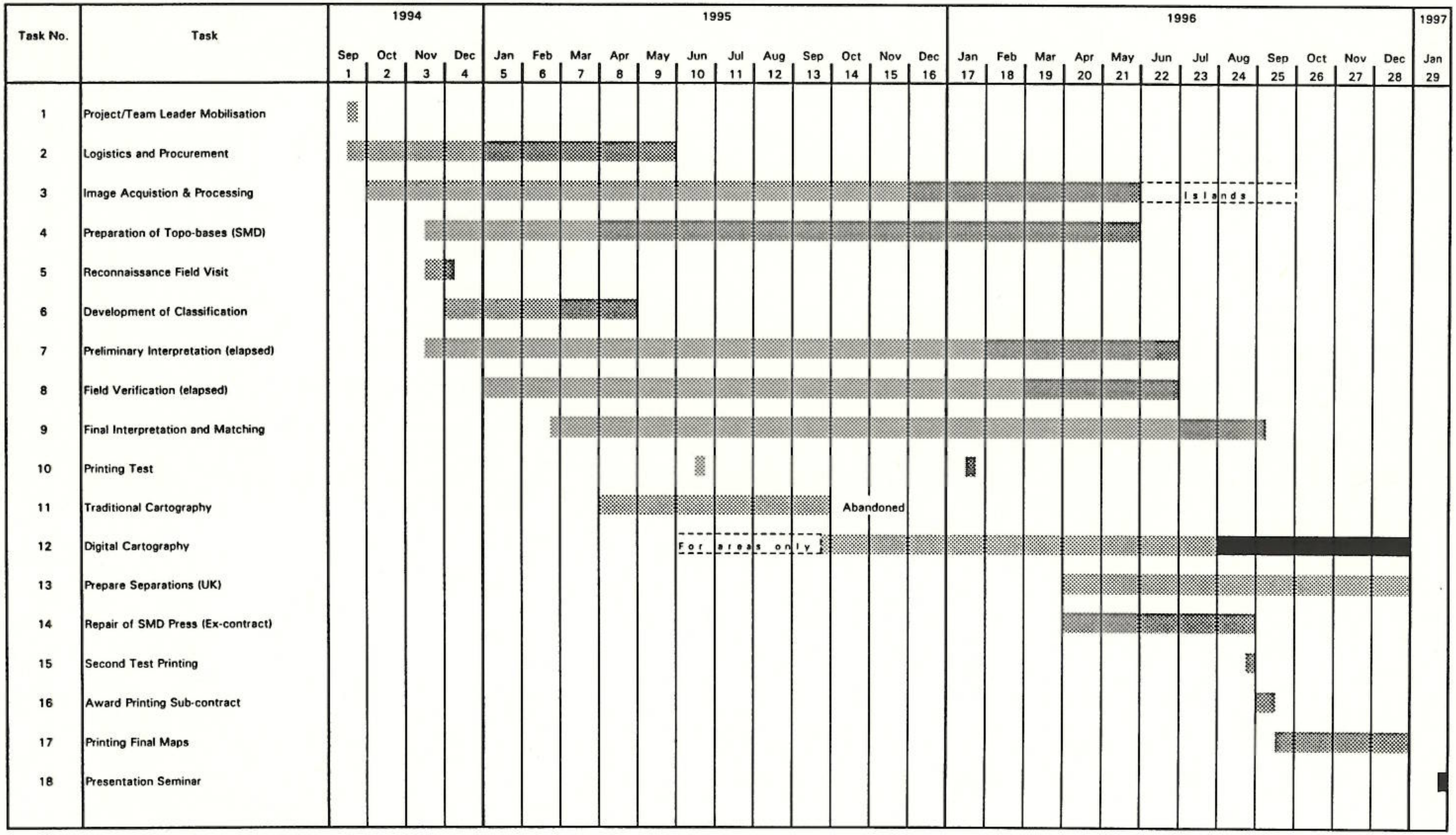
To be delivered to the Client every three months following the acceptance of the Inception Report. These reports would set out in a clear, but succinct, manner, achievements and outputs to date, with reference to the targets agreed upon in the Inception Report and the Work Schedule. Impediments to efficient operation should be mentioned. Expected progress in the succeeding quarter should be stated with any variation to the agreed to Work Schedule justified and agreed to with the Client. The reports would serve to assist in ascertaining that the payments being made to the Consultant are commensurate with the agreed upon schedule of outputs.

Final Report:

To be issued first as a draft at the conclusion of the cartographic and digitising activities. It would present in detail the methodologies employed in all aspects of producing the maps, including the rationale for methodologies where various options were available. It would present statistical data as required under the terms of reference, including a data dictionary and area statistics for each of the land cover/land use categories, summarized by administrative areas. Upon review by the Client and the World Bank the report would be finalized, incorporating agreed to amendments".

7. WORK SCHEDULE (see overleaf Appendix A(i))

FIGURE A.1 REVISED WORK PROGRAMME AT APRIL 30 1996



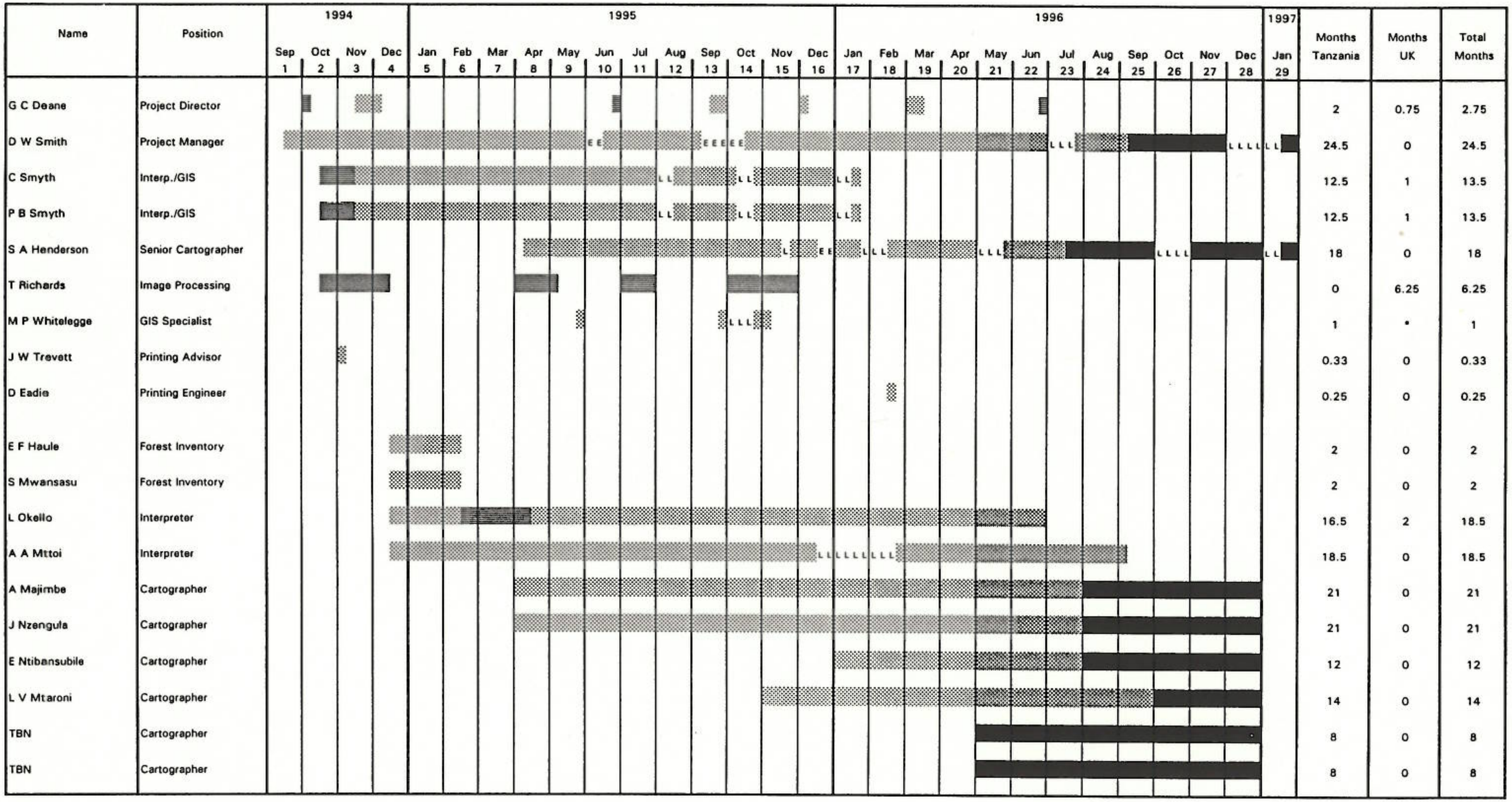
Notes :

▒ Task duration originally proposed

▓ Actual Task duration to 30 April, OR, anticipated duration achievable within resources of present contract

■ Tasks for which additional resources required (see Staff Schedule and Text) and subject to Addendum

FIGURE A.2 REVISED STAFFING SCHEDULE AT APRIL 30 1996



Name	Position	Months Tanzania	Months UK	Total Months
G C Deane	Project Director	2	0.75	2.75
D W Smith	Project Manager	24.5	0	24.5
C Smyth	Interp./GIS	12.5	1	13.5
P B Smyth	Interp./GIS	12.5	1	13.5
S A Henderson	Senior Cartographer	18	0	18
T Richards	Image Processing	0	6.25	6.25
M P Whitelegge	GIS Specialist	1	*	1
J W Trevett	Printing Advisor	0.33	0	0.33
D Eadie	Printing Engineer	0.25	0	0.25
E F Haule	Forest Inventory	2	0	2
S Mwansasu	Forest Inventory	2	0	2
L Okello	Interpreter	16.5	2	18.5
A A Mttoi	Interpreter	18.5	0	18.5
A Majimbe	Cartographer	21	0	21
J Nzengula	Cartographer	21	0	21
E Ntibansubile	Cartographer	12	0	12
L V Mtaroni	Cartographer	14	0	14
TBN	Cartographer	8	0	8
TBN	Cartographer	8	0	8

Notes :

*	GIS Specialist time required in UK, but charged to approved budget for Digital Processing
▤	Staff time in UK
░	Actual Staff time expended to April 30, 1996
▒	Balance of contracted Staff time
█	Staff time required to complete, and subject to Addendum

E External Leave

L Local Leave

APPENDIX B

DIGITAL CARTOGRAPHY ROUTINES

User Note 1: File Naming Conventions

ZZ = HTS Map Sheet Number
XX and YY are SMD sheet numbers

Vegetation Coverages

1. Raw digitised data SB_XX_YY
2. Cleaned CSB_XX_YY
3. Transformed TSB_XX_YY
4. Clipped from SHEETZZ, CLIPZZ
5. Final after all 8 surrounding coverages edgematch FINALZZ

Associated ASCII files

1. Ascii file for lat/long values TSB_XX_YY.LAT
2. Ascii file for UTM values TSB_XX_YY.UTM
3. Map composition SHEET_NAME.MAP
4. Plot file SHEET_NAME.PLT

Drainage Coverages

1. Raw digitised data RIV_ZZ
2. Cleaned and Built for lines CRIV_ZZ
3. Transformed TRIV_ZZ
4. Final after all 8 surrounding coverages edgematch RIVERZZ

Forest Coverages

1. Copy of drainage coverage FORESTZZ
2. Appended with SHEETZZ, FINFORZZ
3. Final after all 8 surrounding coverages edgematch FORRESXX

Administrative Coverages

1. REGIONPP, where PP is a number from 1 - 20 based on the attached list
2. REGBNDPP, Boundary polygon for each region
3. REGVEGPP, clipped mosaiced vegetation coverage for each region
4. NATBND, Tanzania's international boundary (Composite from all maps)

Game Reserves.

1. GR_XX, copy of forest reserve boundary (assuming coincident lines)
2. APPGR_XX, appended with SHEETZZ
3. GAME_XX, final after all 8 surrounding coverages edgematch

National Parks.

1. NATPXX, copy of Game reserve boundaries (assuming coincident lines)
2. APPNPXX, appended with SHEETZZ
3. NATPAKXX, final after all 8 surrounding coverages edgematch

Conservation Areas.

1. CONXX, copy of NATPXX (assuming coincident boundaries)
2. APPCAXX, appended with SHEETZZ
3. FINCONXX, final after all 8 surrounding coverages edgematch

The use of previously digitised coverages for the creation of subsequent designated areas is important as many of the boundaries will be coincident. The most efficient method is to copy the coverage which contains the most coincident lines, and then to select and PUT from the other coverages as necessary. This is outlined in point 4 of the hints and tips user note.

List of Regions and associated HTS numbers (PP)

1.	Arusha
2.	Pwani
3.	Dodoma
4.	Singida
5.	Iringa
6.	Kagera
7.	Mara
8.	Kigoma
9.	Mwanza
10.	Tabora
11.	Kilomanjaro
12.	Lindi
13.	Mbeya
14.	Morogoro
15.	Mtwara
16.	Ruvuma
17.	Rukwa
18.	Shinyanga
19.	Tanga
20.	Dar Es Salaam

User Note 2: Construction of Drainage datasets

Mike Whitelegge 23/10/1995

1. Digitise from supplied overlay in the usual manner, (**NB** Make sure you use the same tic locations as for the vegetation coverage!). DO NOT digitise the bounding box. It is not needed within this dataset. You should digitise a slight overlap where the river enters an mbuga, or a lake, or ends at the coast.

2. Clean the coverage.

3. Build the coverage for lines. ie **BUILD <cov> LINES**. This will generate an .AAT which is the equivalent to a .PAT but for line coverages.

4. Make an empty coverage ready for transformation. You can easily do this by creating from the already transformed vegetation coverage, as the tic locations and values will be the same for both datasets **(NB Check item 1!)**
   ie: **CREATE** *<name for trans rivers> <name of transformed veg cover>*
   example **CREATE TKIPRIV TSC_36_3**

5. Transform the river coverage by:
   ie: **TRANSFORM** *<river coverage> <name for trans rivers>*
   example: **TRANSFORM CKIPRIV TKIPRIV**

6. Check for any unwanted dangles in Arcedit. This will be a difficult task as many of the dangles are not really errors, but simply the end of a river. You may find it better to produce a paper plot and do a visual check using your cartographic judgement. The lines to not have to be topologically joined as we are not concerned about closed polygons for this dataset.

7. Make any edits you feel necessary.

8. Using the SHEET coverage which you RESELECTED from ZONEXXUT whilst doing the vegetation coverage, CLIP the river coverage the create a new river coverage. Remember that you are clipping a line coverage, not a polygon coverage.
   ie: **CLIP** *<river cov> <sheet cov> <clip river cov>* **LINE**
   example **CLIP TKIPRIV SHEET40 KKIPRIV LINE**

9. This will now have produced a coverage for the drainage which matches the sheet boundary exactly. The next step is to digitally edgematch with all of the adjacent sheets.

10. Assuming that you have gone through the above steps for two adjacent sheets, and have two clipped line coverages, you now have to join these together. The command used previously for the vegetation coverages was MAPJOIN. However, MAPJOIN will not work for line coverages. The command which we will be using is called APPEND. The syntax is as follows:
    APPEND *<out cover>* **LINE ALL**
    The LINE and the ALL commands are keywords which indicate to ARC that we want to append lines together and make the new coverage have unique ids. This will help when we come the cartographic drawing of the rivers on the final maps. If we assume that we have two coverages : KKIPRIV and KMBEYARI, then the append instruction will be :
    ```
    APPEND RIV40_47 LINE ALL
    KKIPRIV
    KMBEYARI
    END
    ```
    This will create a new coverage called RIV40_47 containing all of the arcs from both input coverages.

11. The next step is to edit the edges so that the lines join. Do this in ARCEDIT.

12. Now you should have a correct coverage with no edge match problems. Finally, we need to CLIP out the coverage again. The command for this is the same as in point 8. Make certain that you call the coverage RIVER_xx, where xx is the HTS sheet number, and make a backup copy of it. Remember that all four edges will have to be matched before the coverage is final. I suggest that you build together a block of 9 sheets and clip the centre one each time.

13. **Additional notes for cartographic representation of the rivers on the map**
This may seem slightly complicated at first !!!. As you already know, the rivers are being digitised because of inaccuracies in the supplied topo maps and there will be a mis-match with the interpreted riverine vegetation polygons. The rivers which are shown on the interp are only those which can be seen from the imagery and in many cases will only be present to link up areas of riverine vegetation lakes etc. In order to produce a nice looking product, it is important that the rivers stop at certain polygon boundaries. The way to do this is to delete all the bits of rivers which fall in the riverine polygons. This is done via the following steps:

    i) Using RESELECT create a polygon coverage from the vegetation coverage which only contains potentially riverine polygons and water. These have been identified as the following codes :Gws, Gbs, Gos, IW, OCEAN, Fn, BSL, Wc, S/M. This is done as follows:

    ```
    RESELECT <veg cover> <water xx> POLY
    RES VEGCODE IN
    {'Gws','Gbs','Gos','IW','OCEAN','Fn','BSL','Wc','S/M'}
    return
    N
    N
    ```

    Hopefully, you should now have a coverage containing a few disparate polygons. You now have to go into Arcedit and delete any polygons which are not linear and therefore not riverine. This will take a bit of practice to be able identify the polygons in question. You should delete both the polygon labels and any bits of boundary. Be careful not to delete shared boundaries where the adjacent polygon is still required. The resulting coverage should only contain polygons where you **DO NOT** want rivers to show.

    ii) The next step is to use an overlay command to delete any bits of river which happen to fall within any one of the polygons in the coverage from step i. The command to use is ERASECOV. This is done as follows:

    ```
    ERASECOV <river coverage> <erase_cover> < new cover> LINE
    ```

    The river coverage is your RIVER_xx
    The erase cover is from step i
    The new cover will be a line coverage where the rivers stop at the riverine polygons.

    iii) The best thing to do now is to make a plot showing mbuga's etc and the clipped rivers to ensure nothing untoward has gone on. If when you check the plot and see mistakes, then I suggest going back to Arcedit and editing the new river coverage whilst using the riverine vegetation polygon coverage as a BACKCOVER.

14. Now you should have a final river coverage which has NO errors. The next step is to add annotation for the river names. This is done in Arcedit by setting the editfeature to anno, setting the annotype to line and adding away! You will have to check for

name clashes with the topo sheet information. I suggest using an annosymbol of 85 perhaps so the dimensions don't change much when I come to change them to arial on the workstation.

User Note 3: Generation of Area Statements

Mike Whitelegge 23/10/1995

1. Assuming you have a final coverage with no errors which is 100% checked and correct!

2. As you already know, the .PAT contains all of the necessary information relating to vegetation types and the associated polygon areas. The task in hand is merely to aggregate these areas for each vegetation type.

3. The first level of statistics is probably the easiest to produce and relates to map sheets. This is the easiest as the data is already in this spatial unit.

4. At the [ARC] prompt, use the FREQUENCY command. This will produce a new tables file which will contain all unique occurrences of the specified item (VEGCODE) which has summary information for AREAs.

   eg

   ```
   FREQUENCY FINAL_21.PAT FINAL_21.FRE
   Enter Frequency item names (type END or a blank line when done) :
   ============================================================
   Enter the 1st item: VEGCODE
   Enter the 2nd item : END
   Do you wish to use the above items (Y/N)? Y

   Enter Summary item names ( type END or a blank line when done ):
   ===========================================================
   Enter the 1st item : AREA
   Enter the 2nd item: END
   Do you wish to use the above items (Y/N) ? Y
   ```

   The new tables file which has been created will be FINAL_21.FRE which can be selected and viewed in tables in the normal way.

5. This method will be used for extraction of all of the required statistical information. The only extra work required is to be able to identify areas which do not conform to map sheet boundaries, such as administrative areas, or perhaps forest reserves. There are a number of different methods to do this, each with advantages and disadvantages. I suggest the following procedure is employed.

6. From the topo base, create a coverage per region (of which there are 20), each containing district polygons. You will have to do this on a sheet by sheet basis and then APPEND or MAPJOIN. Put the names of the districts into a suitable item added to the .PAT

7. Using MAPJOIN, create a seamless dataset of vegetation to cover one region. Remember that you can only join maps which all fall into the same UTM zone. If you have to produce statistics for areas which cross zones, then see the extra section in the UTM zones user note.

8. Dissolve all map sheet boundaries on the basis of VEGCODE

9. Pick out the boundary of each region by **building for lines** and then reselecting arcs where LPOLY# = 1 OR RPOLY# = 1. This makes advantage of the fact that the universal polygon is always internal number 1 and that for an arc to be on the boundary, it must have the universal polygon either to it's left or right. The actual command is:

```
RESELECT <region cover> < region boundary> LINE
RES LPOLY# = 1 OR RPOLY# = 1
return
N
N
```

This will create a new coverage called whatever you substitute region boundary for which only contains the boundary arcs.

10. In Arcedit add a label and check for any dangles. Edit as necessary.

11. **CLEAN**.

    You should now have 3 coverages.

    1. A big coverage of vegetation (product of MAPJOIN)
    2. A region coverage with only the region boundary
    3. A region coverage containing district polygons

12. **CLIP** the vegetation coverage with the region boundary. This will create a coverage showing vegetation for that region only. Use the **FREQUENCY** command on that coverage in the same way as done in point 4. This will show areas for each region.

13. In order to get statistics out for districts, you will need to overlay the coverage containing district polygons with the clipped regional vegetation. The overlay command to use is **UNION**

    UNION *<reg veg> <reg district>* < *vegadmin* > (or something like that!)

14. This will now produce a coverage (vegadmin) which contains polygons made up of both vegetation boundaries and admin boundaries.

15. Perform a **FREQUENCY** command on the unioned coverage but this time, specify a 2nd frequency item name of the district name. This will then produce area summaries for all unique combinations of district and vegetation. The sum of any one particular vegetation type for all districts will hopefully match the total shown for the region as from point 12.

16. I would simply add up all of the regions to produce a national figure.

17. Forest reserve statistics are a little bit different (surprise surprise!!). There are numerous ways to do these each equally good or bad. You could do a sheet by sheet total by **UNIONING** the reserve boundaries with the corresponding vegetation coverage, and doing a **FREQUENCY** on both VEGCODE and RESERVE_UNIT. This will give stats per reserve per sheet, so you would have to add up all of the bits of each sheet covered by any one reserve.

    Alternatively, you could mapjoin some maps together until you had an entire reserve in one coverage, dissolve away unnecessary boundaries, reselect the polygon of the reserve in question and use this polygon to clip out vegetation from a series of mapjoined vegetation coverages which correspond to the extent of the reserve. Stats are then simple as you are left with one coverage showing vegetation for one reserve.

    Look at the results carefully to make sure they make sense and that nothing has gone wrong along the way. Remember the GIGO rule!!

User Note 4: Generation of Forest Reserve Boundaries dataset.
Mike Whitelegge 24/10/1995

1. The forest reserve boundaries are not going to be straightforward to collect. The only definitive source of boundaries is the blue print plans which are stored at the Ministry of Forestry at the Ivory Rooms. Unfortunately, some of these plans are without co-ordinates or have inaccurate coordinates which makes it difficult to input them to a GIS. Another problem is that many of the reserve boundaries are coincident to rivers and the rivers shown on the plans do not match the rivers as seen from the imagery.

2. A definitive list of all of the reserves has been supplied by the Ministry. The majority of reserves on this list have cross-references to maps which show the boundaries of the reserves. The lists are split by region.

3. It is necessary to manually transpose the reserve boundaries from the supplied blue prints to a base map showing interpreted drainage and with reference to the topo base, prior to digitising. In order to make this task easier, a reference grid can be drawn onto the base map.

4. This will ensure that the boundaries look correct, as they will fit the drainage exactly. The only problem is that the areas of the reserves in the GIS may not match the known area of the reserve.

5. It is anticipated that staff from the Forestry Department will be responsible for transposing the reserve boundaries onto a supplied base map showing drainage and a reference grid (plus tic points). This will hopefully reduce some errors as these staff are very familiar with the reserve boundaries anyway.

6. The Forestry Department will therefore supply the reserve boundaries to HTS ready for digitising.

7. In order to digitise, you should first make a copy of the drainage coverage and call it FORESTxx or something similar. In ARCEDIT set the FORESTxx to be the editcoverage and a suitable drawenvironment. Use the **COO DIG** command to indicate that you wish to input coordinates from the table. Add arcs from the reserve map using the rivers as boundaries if they are there already. This is important as any coincident drainage/reserve boundary line has to be the exact same line - It is impossible to digitise the same line twice and get the same result !! Join up any gaps in the rivers with straight lines simply to close off the polygons. Before quitting from Arcedit, set your EF to ARC, SEL ALL, CALC $ID = 1 and UNSPLIT. This will remove as many pseudo nodes as possible and make the coverage easier to work with. It will also set the user-ids of all of these lines to be 1, which means that we can select them all at the cartographic stage to draw.

8. Build your SHEETxx coverage (you will have reselected this from one of the ZONEnnUT coverages [UMASTER] ages ago) for lines. This will create a .AAT file. Go into Arcedit and select all of the arcs and calc $id = 2. This will indicate that we do not wish to show the lines on the final map. Append your FORESTxx with the SHEETxx coverage. This is simply a way to put the sheet boundary into the forest coverage without digitising it again.

9. **CLEAN** and edit the appended coverage (You will have called it FINFORxx or something). You should delete all arcs which don't form part of any forest reserve boundary, including any bits of sheet edges. Remember, if you add any arcs, make sure they have user-ids of either 1 (visible) or 2 (boundary). Clean again after editing.

10. By this time you should have a topologically correct polygon coverage, where the arcs are either coded as 1 or 2, but no labels yet. In order to put in the reserve names you can either do a **CREATELABELS**, make a plot, use **CODING.SML, DEFINE, ADD FROM, JOINITEM** and all that malarkey or, considering that there will only be few

polygons you can add them interactively. To do this, simply go into ARCEDIT, do all the drawe business etc and then set **EF** to label. You can then add labels and their user_id will increment by one each time. As you add, make a note on the paper plot which polygon number you are giving each reserve. Save, quit and **BUILD**.

Check for NODE and LABEL errors.

11. In tables, select the FINFORXX.PAT file and **ADDITEM** the following item:
RES_NAME 25 C

    This means that the column will be called RES_UNIT and it will be a character item of 25 characters wide.

12. Use FORMS UPDATE to put the reserve info into the .PAT. Start at record 2, (record 1 will be the universal polygon!). Remember that you are dealing with the USER_ID, NOT the internal ID !!!

13. Hopefully you should now have a correct, clean and all round lovely polygon coverage showing forest reserve boundaries. If you need to put forest reserve names then do them as annotation as described in Step 14 of the River Notes.

User Note 5: UTM Projections and edgematching routines
Mike Whitelegge 30 October 1995

1. Tanzania falls into three UTM zones, 35,36 and 37.

2. When performing file projections, be sure to use the correct SML file for the parameters. This will be either ZONE35.SML, ZONE36.SML or ZONE37.SML.

3. When RESELECTing the SHEETxx neatline polygon which used to be reselected from UMASTER, use either ZONE35UT, ZONE36UT or ZONE37UT. The sheet numbers are the same as they were for UMASTER. UMASTER is still on the hard disk as sheets will have to be extracted from it still when we clip the 'false zone' coverage. **MAKE SURE YOU GET THE SHEET BOUNDARY FROM THE CORRECT COVERAGE!!!!**

4. The clipping and editing will be the same as before.

5. Edgematching two sheets from the same zone will also be as before.

6. Adjacent UTM zones do not butt-join. This is due to central meridians being parallel and edges of UTM zones narrowing at the top and bottom. This is therefore going to cause problems when edgematching two sheets from two different zones. The co-ordinates also will not be continuous, as each UTM zone has it's own local origin.

7. The answer to this is to digitise as usual, clip and edgematch within a zone, and then project from one zone to another, edgematch the join, and project back to the correct zone. This is taking advantage of the ability to 'extend' a UTM zone slightly without encountering too much distortion. The details of this multiple projection are shown below:

8. Assuming we are dealing with the sheets SAO HILL and MAHENGE, Sao Hill is in Zone 36 and Mahenge is in Zone 37. They have a common boundary at 36° East. You should first perform all of the edgematches within each zone. This would mean edgematching Sao Hill with Iringa, Kipembawe, Mbeya, Tukyu and Njombe. The Mahenge sheet would be edgematched with Kazimoto, Liwale, Kipatimu, Utete and Mikumi. You should then project the Mahenge sheet from zone 37 to zone 36. This is done as follows:

```
PROJECT COVER TSB_37_1 Z36_37_1
          :INPUT
          :PROJECTION UTM
          :UNITS METERS
          :ZONE 37
          :SPHEROID CLARKE1880
          :YSHIFT -10000000
          :PARAMETERS
          :OUTPUT
          :PROJECTION UTM
          :UNITS METERS
          :ZONE 36
          :SPHEROID CLARKE1880
          :YSHIFT 10000000
          :PARAMETERS
          :END
```

This will create a new coverage called Z36_37_1 which can be MAPJOINed to Sao Hill in the normal way. When you have edited the join clip it back with the sheet polygon from UMASTER, **NOT** ZONEXX_UT. You then need to project the coverage back to it's correct zone. This is done as follows:

```
PROJECT COVER Z36_37_1 FINALxx
        :INPUT
        :PROJECTION UTM
        :UNITS METERS
        :ZONE 36
        :SPHEROID CLARKE1880
        :YSHIFT -10000000
        :PARAMETERS
        :OUTPUT
        :PROJECTION UTM
        :UNITS METERS
        :ZONE 37
        :SPHEROID CLARKE1880
        :YSHIFT 10000000
        :PARAMETERS
        :END
```

You will need to do this for all of the edge sheets between the zones. I suggest that as Zone 36 is the middle zone, we should use this as the 'static' one and project data from 35 and 37 as necessary.

9. When you come to generate area statements for areas which cross zones, then it is probably easiest to calculate areas for each zone and simply add them together. This should give the most accurate results as zonal distortion is minimised. If however, you have a small area from one zone, or you need to produce a map of a forest reserve which is slightly in the next zone, then project the coverage which contains the samller of the two zone areas into the other zone and join as in step 8. You obviously will also have to do this for the coverages containing the forest reserve or other designated area boundariy information. The actual processing used in this operation is very straightforward. If you keep track of where you are and what your coverages are called then mistakes are unlikely. Use the sheet layout and check your data regularly in Arcplot at each stage!

User Note 6: Generation of UTM tic marks

Mike Whitelegge 1/11/1995

1. The decision has been made to show UTM tic marks on the map borders.

2. I have created a coverage containing a grid of UTM lines at an interval of 10000. This is called UTMGRID and is on Mildred. This coverage has line topology.

3. CLIP the UTMGRID with the SHEET boundary (from ZONEXXUT) to create a coverage called GRIDXX.

```
CLIP UTMGRID SHEETxx GRIDxx LINE
```

4. This will give us the UTM grid for just the sheet in question.

5. Create a polygon which is 1250 metres smaller in each dimension than the sheet boundary. This is done by buffering with a negative value.

```
BUFFER SHEETxx INNERxx # # -1250 # POLY
```

   The resulting coverage will be INNERxx.

6. Perform an ERASECOV on the GRIDxx coverage with the INNERxx polygon. This will effectively delete the meshwork of lines and just leave tics around the edge of length 1250 metres (5mm at 1:250000 scale).

```
ERASECOV GRIDxx INNERxx TICSxx LINE
```

   The resulting coverage will be TICSxx.

7. The only potential problem is if a UTM grid line happened to fall within 1250 metres of the edge of the map. To get around this problem, you need to go into Arcedit and do a bit of manual editing. A quick way to do this is to SEL FOR LENGTH > 1500 and DELETE. This should not select any of the tics which by their definition are only 1250m long. SAVE, QUIT and reBUILD the coverage for LINE topology. The final coverage with all the correct tics in will be TICSxx. You should add annotation as required for every 50000m tic interval. Make sure that the UTM values do not clash with the lat/long corner values.

User Note 7: Handy Hints and Tips

Mike Whitelegge 25/10/1995

The following notes contain some useful pointers and shortcuts to help you on your way. They are not exhaustive and merely point you in the right direction. It will probably be necessary to consult the manuals along with these notes.

1. Finding a polygon which you cannot see on the plot.

This can be done in either Arcplot or Arcedit. Your coverage must be clean before doing this so if you are in Arcedit, save, quit and clean before trying or you will probably see the message *'IDS do not agree between LAB and PAT'*. This message will also be shown if you have used the same id for more than one polygon, or have two labels in one polygon. Make it a habit to use **DESCRIBE** and **CLEAN** along with **NODEERRORS** and **LABELERRORS**. Most of the problems you are encountering are due to coverages not being clean and free of node and label errors.

Arcplot

```
1.      mape <coverage>
2.      arcs <coverage>
3.      reselect <coverage> polys <coverage_id> = <number>
4.      polygonshades <coverage> 2
or      polygontext <coverage> area
```

if you need to repeat the exercise, be sure to do a **CLEARSEL** before reselecting another polygon. If you do not do this, you will be trying to reselect from the previous reselection and will probably get the message *'0 records selected'*.
When you find the polygon, you should be able to locate yourself on the paper plot.

Arcedit

```
1.      edit <coverage>
2.      drawe arc lab
3.      ef lab
4.      sel for <coverage_id> = number
5.      clear
6.      draws
```

this will draw a small box in the 'lost' polygon. You should zoom in and then do a draw, followed by a draws. This will enable you to find the polygon.

2. Code Integrity

It is important that all of the codes which you put into the vegcode item are valid. In order to make data entry easier, you can now type all of the information in lower case (When you run @CODING). When you have done your joinitem and removed all of the sliver polygons in Arcedit (XX's). You should run the macro **@CHECK**. This will change all of the lower case codes into the correct case and will also show you a list of invalid codes, missing codes and XX codes which need to be corrected. Remember to **CLEAN**. If you have XX codes, then it means you have not removed all of the slivers as identified on your paper plot.

3. Adding lines into the coverage.

You may need to add in a line due to mistakes when digitising or mistakes from the edgematch operation. This is done in Arcedit. You should first set your editcoverage and drawe etc. Use the **COO DIG** command to tell Arcedit that you intend to input coordinate information from the table not the mouse. When you issue the COO DIG command, you will be prompted to input the tic locations (the same as in ADS). Assuming your RMS error is acceptable, set the EF to ARC, and add using 2's and 1's in the normal way. If you want to return to inputting and selecting from the mouse, use the command **COO CURSOR**.

4. Copying lines to other coverages

It may be necessary to copy a line from one coverage to another in order to use the exact same line for a number of different purposes. This is going to be the case for the designated area boundaries. To do this, go into Arcedit, edit the coverage which contains the required line, ef arc, select the line(s) in question and use the command **PUT** *<coverage>*, where coverage is the name of the coverage where you want to put the lines. One word of caution is that if you are PUTting lines into a coverage where the $id of the line is important (such as forest reserve boundaries where lines are 1 - show on maps, 2- don't show on maps) then you will most probably have to check the ids of the copied lines.

5. Editing lines during edgematching

When you have **MAPJOIN**ed two coverages together, and performed a **DISSOLVE** (in the case of the vegetation coverage), you will undoubtedly need to do a little tweaking. Often you simply need to 'reshape' a line to make it more appealing in a cartographic sense! In Arcedit, you can sel the line, and use the **RESHAPE** command. Take care and do lots of saves, if you reshape wrongly then you cannot get your original line back without quitting and not saving. When you add in the shape of the new line, you need to ensure that it intersects the line you are reshaping. Try a few reshapes to get the hang of it.

Another method, which is especially useful for removing spikes in lines is **VERTEX DELETE**. You must first ef arc, select one arc and issue the command VERTEX DELETE. This allows you to select a vertice and delete it, straightening out the line in the process, without breaking the arc.

6. Changing Attribute information from within Arcedit

There may be situations where you need to change the vegcode information due to mistakes or during edgematching. You already know how to do this in tables, but this would mean exiting from Arcedit, cleaning, going into tables, updating, quitting, going back into Arcedit to continue editing - What a palaver!!! Well don't worry, there is a better way and you can do all the necessary whilst still being in Arcedit. Set your ef to label, select the label(s) which you want to update, and issue the command **MOVEITEM** *<code>* **TO VEGCODE**. This will work for any of the character items in the .PAT. For numeric items, use the command **CALC** *<item>* = *<value>*. If you have done lots of edits to the labels in a coverage, this command may give you an error message saying that *'IDs between lab and pat do not agree, exit and clean'*. If this is the case, then do as you're told!

7. Confusion over coverages, map compositions and plot files.

Coverages contain the basic arcs, labels, attributes and topology which represent real world datasets. When we want to produce a map from Arc/Info, we must put this coverage information into a map composition, which simply holds graphical information about a coverage. We are able to manipulate a map composition by moving elements and adding text etc. Once we are happy with the layout and content of the map composition, we can make the map composition into a plot file, in order to make the plotter quicker, we then sort the plot file and make a second plot file. Coverages and map compositions are held in DOS as sub-directories. Plot files are flat ascii files with .plt extensions. Coverages and Compositions cannot have the same name due to DOS limitations and storage protocols. When you run any of the macros which produce paper plots, you are first prompted for the name of the map composition to create. This is the same as issuing the command **MAP** *<comp-name>* in Arcplot, and simply means that anything you send to the screen will also be written to that map composition. The command **MAP END** closes the composition. When you issue the command **DISP 1039**, you are prompted for the name of a plot file to create. It is good practice to use the same name as the map composition. You then issue the command **PLOT** < *map comp*>. This simply transfers the information from the composition into the plot file.

8. Creating hard-copy from TABLES files.

Often when you are in tables, you need to be able to print out some or all of the information held in the tables files. To do this, use the command **&OPENW** *<filename>*. This means that any subsequent command which would put information on the screen (ITEMS, or LIST etc) will send that information to the file. This continues until you issue the command **&CLOSEW**. When you quit from tables, you will see that you have a DOS ascii file called filename.ext, which you can edit and print in the usual way.

9. Putting more than one layer of information onto a map.

You may need to display more than one layer of information on a map, for example when producing maps of drainage and a reference grid. This is very simple. Initiate a map composition and set the mapextent and scale. Using different LINECOLORS, simply draw the arcs of any number of coverages over the top of one another. Make the plot file in the usual way.

10. Creating Reference Grids.

The easiest way to create Lat/Long reference grids is to use the GENERATE command. This has the following syntax:

GENERATE *<cover>*

You will then enter the generate module. You should generate a GRID. You will then be prompted for the coordinates of the origin. Get this off the image or topo base, it will be in the form 30^{o},0',5^{o},0' or something, the Y axis value will be the same x value and 9999. The cell size will be 0.25 by 0.25 to indicate 1/4 of a degree and the numbers of rows and columns should be fairly easy to calculate. When you next see the Generate > prompt, quit to return to the [ARC] prompt.

You will need to PROJECT this coverage from Lat/Long into UTM using one of the projection sml files as described in the UTM user note.

The command would be:

PROJECT COVER *<in cover> <out cover>* **zoneXX.sml**

XX will be either 35, 36 or 37.

11. Coverage History

To obtain a list of all of the commands to which a coverage has been subjected, use the LOG command. This is done as follows:

LOG <cover>

This assumes that NOLOG has been suitable set in the AUTOEXEC.BAT.

User Note 8: Construction of Designated Area datasets
Steph Henderson 4/03/1996

1. **Copycov** (the first version eg cmbeyari, before clipping) the drainage coverage and call it REGXX.

2. Then go into Arcedit, disp 4. Use **COO DIG** command to telll Arcedit that you intend to

   input coordinate informatiion from the table not the mouse.. Whe you issur the COO DIG command, you wil be prompted to input the tic locations (the same as ADS). Assuming your RMS error is acceptable, set the EF to ARC add using 2's and 1's in the normal way.

   Digitise from Topograhphic film base as supplied from SMD, (**NB** Make sure you use the same tic locations as for the vegetation coverage!). DO NOT digitise the bounding box. It is not needed within this dataset.

3. Delete any linework you have copied, but is not required for this dataset.

4. Clean the coverage. **Clean region43 CREG47 0.05 0**

5. Build the coverage for lines. ie **BUILD <cov> LINES**. This will generate an .AAT which is the equivalent to a .PAT but for line coverages.

6. Make an empty coverage ready for transformation. You can easily do this by creating from the already transformed vegetation coverage, as the tic locations and values will be the same for both datasets (**NB Check item 1!**)

   ie: **CREATE** *<name for trans region> <name of transformed veg cover>*
   example **CREATE TREG45 TSC_36_3**

5. Transform the region coverage by:

   ie: **TRANSFORM** *<region coverage><name for trans region>*
   example: **TRANSFORM CREG45 TREG45**

6. Check for any unwanted dangles in Arcedit.

7. Make any edits you feel necessary.

8. Using the SHEET coverage which you RESELECTED from ZONEXXUT whilst doing the vegetation coverage, CLIP the region coverage to create a new region coverage. Remember that you are clipping a line coverage not a polygon coverage.

   ie: **CLIP** *<region cov> <sheet cov> < clip region cov>* **LINE**
   example **CLIP TREG45 SHEET45 REG45 LINE**

9. This will now have produced a coverage for the regions which matches the sheet boundary exactly. The next step is to digitally edgematch with all the adjacent sheets.

10. Assuming that you have gone through the above steps for two adjacent sheets, and have two clipped line coverages, you now have to join these together. The command used previously for the vegetation coverages was MAPJOIN. However, MAPJOIN will not work for line coverages. The command which we will be using is called APPEND. The syntax is as follows:

    APPEND *<out cover>* **LINE ALL**

    The LINE and the ALL commands are keywords which indicate to ARC that we want to append lines together and make the new coverage have unique ids. This will help when we come the cartographic drawing of the regios on the final maps. If we assume that we have two coverages : REG45 and REG46, then the append instruction will be :

```
APPEND REG45_46 LINE ALL
REG45
REG46
END
```

This will create a new coverage called REG44_46 containing all of the arcs from both input coverages.

11. The next step is to edit the edges so that the lines join. Do this in ARCEDIT.

12. Now you should have a correct coverage with no edge match problems. Finally, we need to CLIP out the coverage again. The command for this is the same as in point 8. Make certain that you call the coverage REG _xx, where xx is the HTS sheet number, and make a backup copy of it. Remember that all four edges will have to be matched before the coverage is final. I suggest that you build together a block of 9 sheets and clip the centre one each time.

APPENDIX C

PRODUCTION CONTROL PRO-FORMAE

SHEET NO:	SHEET NAME:	HTS no:

Tic points	UTM value **X**	UTM value **Y**	Lats.	Longs.
1				
2				
3				
4				

ACTION INTERP.

	Start date. cov. name	new coverage name	Supervisor check	Date
Digitise Interp.				
1st Clean				
1st Build				
Make back-up disc				
1st Edit				
Produce 1st check plot				
Coding				
Edit sliver polygons				
2nd Clean				
2nd Build				
Transform sheet				
Produce 1st colour plot				
2nd colour plot				
Clip using Zone*xx* ut				
Make back-up disc				

Edge - matching				
N	S	E	W	
	mapjoin	Dis	Final	
Make back-up disc				

ACTION DRAINAGE

Digitise Drainage				
1st Clean				
1st Build				
Make back-up disc				
1st Edit				
Transform				
Produce 1st check plot				
Clip using Zone xxut				
Make back-up disc				

N	S	E	W	
	Mapjoin	Dis	Final	
Make back-up disc				

COMMENTS:

Map Ref No.	HTS No.	Mapsheet Name:	Priority Zone:	cleaned version	transformed version	clipped version	edge matched	comments
SA-36-5	1	KABALE	3					
SA-36-6	2	BUKOBA	3					
SA-36-7	3	MUSOMA	3					
SA-36-8	4	NAROK	3					
SA-36-9	5	BIHARAMULO	3					
SA-36-10	6	MWANZA	3					
SA-36-11	7	MALYA	3					
SA-36-12	8	SERENGETI	3					
SA-37-9	9	AMBOSELI	3					
SA-36-13	10	KIBONDO	3					
SA-36-14	11	KAHAMA	3					
SA-36-15	12	SHINYANGA	3					
SA-36-16	13	LAKE MANYARA	3					
SA-37-13	14	ARUSHA	3					
SA-37-14	15	VOI	3					
SB-35-4	16	KIGOMA	1					
SB-36-1	17	KASULU	1					
SB-36-2	18	BUKENE	1					
SB-36-3	19	NZEGA	1					
SB-36-4	20	SINGIDA	2					
SB-37-1	21	NABERERA	4					
SB-37-2	22	LUSHOTO	4					
SB-37-3	23	MOMBASA	4					
SB-36-5 (&35-8)	24	UVINZA	1					
SB-36-6	25	TABORA	1					
SB-36-7	26	IGALULA	1					
SB-36-8	27	MANYONI	2					
SB-37-5	28	KIBAYA	4					
SB-37-6	29	KOROGWE	4					
SB-37-7	30	PEMBA	4					
SB-36-9 (&35-12)	31	MPANDA	1					
SB-36-10	32	NYONGA	1					
SB-36-11	33	RUNGWA	1					
SB-36-12	34	DODOMA	2					
SB-37-9	35	KILOSA	4					
SB-37-10	36	MOROGORO	4					
SB-37-11	37	DAR-ES-SALAA	4					
SB-36-13	38	KIPILI	1					
SB-36-14	39	SUMBAWANGA	1					
SB-36-15	40	KIPEMBAWE	1					
SB-36-16	41	IRINGA	2					
SB-37-13	42	MIKUMI	2					
SB-37-14	43	UTETE	4					
SB-37-15	44	MAFIA	4					
SC-36-1	45	MBALA	1					
SC-36-2	46	MWIMBI	1					
SC-36-3	47	MBEYA	1					
SC-36-4	48	SAO HILL	2					
SC-37-1	49	MAHENGE	2					
SC-37-2	50	KIPATIMU	2					
SC-37-3	51	KILWA	2					
SC-36-6	52	TUNDUMA	1					
SC-36-7	53	TUKUYU	1					
SC-36-8	54	NJOMBE	2					
SC-37-5	55	KAZIMOTO	2					
SC-37-6	56	LIWALE	2					
SC-37-7	57	LINDI	2					
SC-36-12	58	SONGEA	2					
SC-37-9	59	LIKUYU	2					
SC-37-10	60	MASASI	2					
SC-37-11	61	MTWARA	2					
SC-36-16	62	MBAMBA BAY	2					
SC-37-13	63	TUNDURU	2					
SC-37-14	64	LUKWIKA	2					

EQUIPMENT AND MATERIALS TAKEN TO THE IVORY ROOM BY VINCENT AND ELIAS FOR FOREST RESERVES, GAME RESERVES AND NATIONAL PARKS

															EQUIPMENT			
Map Ref No.	HTS No.	Mapsheet Name:	Priority Zone:	Topo film from SMD	UTM grid + mns.	colour plot	Drainage interp.	Photocopy of Topo base	Topo. map (colour)		Drafting film			Date taked to Ivory Room	Proportional dividers	Scale	Compasses	
SA-36-5	1	KABALE	3															
SA-36-6	2	BUKOBA	3															
SA-36-7	3	MUSOMA	3															
SA-36-8	4	NAROK	3															
SA-36-9	5	BIHARAMULO	3															
SA-36-10	6	MWANZA	3															
SA-36-11	7	MALYA	3															
SA-36-12	8	SERENGETI	3															
SA-37-9	9	AMBOSELI	3															
SA-36-13	10	KIBONDO	3															
SA-36-14	11	KAHAMA	3															
SA-36-15	12	SHINYANGA	3															
SA-36-16	13	LAKE MANYARA	3															
SA-37-13	14	ARUSHA	3															
SA-37-14	15	VOI	3															
SB-35-4	16	KIGOMA	1															
SB-36-1	17	KASULU	1															
SB-36-2	18	BUKENE	1															
SB-36-3	19	NZEGA	1															
SB-36-4	20	SINGIDA	2															
SB-37-1	21	NABERERA	4															
SB-37-2	22	LUSHOTO	4															
SB-37-3	23	MOMBASA	4															
SB-36-5 (&35-8)	24	UVINZA	1															
SB-36-6	25	TABORA	1															
SB-36-7	26	IGALULA	1															
SB-36-8	27	MANYONI	2															
SB-37-5	28	KIBAYA	4															
SB-37-6	29	KOROGWE	4															
SB-37-7	30	PEMBA	4															
SB-36-9 (&35-12)	31	MPANDA	1															
SB-36-10	32	NYONGA	1															
SB-36-11	33	RUNGWA	1															
SB-36-12	34	DODOMA	2															
SB-37-9	35	KILOSA	4															
SB-37-10	36	MOROGORO	4															
SB-37-11	37	DAR-ES-SALAAM	4															
SB-36-13	38	KIPILI	1															
SB-36-14	39	SUMBAWANGA	1															
SB-36-15	40	KIPEMBAWE	1															
SB-36-16	41	IRINGA	2															
SB-37-13	42	MIKUMI	2															
SB-37-14	43	UTETE	4															
SB-37-15	44	MAFIA	4															
SC-36-1	45	MBALA	1															
SC-36-2	46	MWIMBI	1															
SC-36-3	47	MBEYA	1															
SC-36-4	48	SAO HILL	2															
SC-37-1	49	MAHENGE	2															
SC-37-2	50	KIPATIMU	2															
SC-37-3	51	KILWA	2															
SC-36-6	52	TUNDUMA	1															
SC-36-7	53	TUKUYU	1															
SC-36-8	54	NJOMBE	2															
SC-37-5	55	KAZIMOTO	2															
SC-37-6	56	LIWALE	2															
SC-37-7	57	LINDI	2															
SC-36-12	58	SONGEA	2															
SC-37-9	59	LIKUYU	2															
SC-37-10	60	MASASI	2															
SC-37-11	61	MTWARA	2															
SC-36-16	62	MBAMBA BAY	2															
SC-37-13	63	TUNDURU	2															
SC-37-14	64	LUKWIKA	2															

EQUIPMENT AND MATERIALS RETURNED TO HTS FROM THE IVORY ROOM

															EQUIPMENT			
Map Ref No.	HTS No.	Mapsheet Name:	Priority Zone:	Topo film from SMD	UTM grid + anno.	colour plot	Drainage interp.	Photocopy of Topo base	Topo. map (colour)		Drafting film (sheets)			Date returned to HTS/IRA	Proportional dividers	Scale	Compasses	
SA-36-5	1	KABALE	3															
SA-36-6	2	BUKOBA	3															
SA-36-7	3	MUSOMA	3															
SA-36-8	4	NAROK	3															
SA-36-9	5	BIHARAMULO	3															
SA-36-10	6	MWANZA	3															
SA-36-11	7	MALYA	3															
SA-36-12	8	SERENGETI	3															
SA-37-9	9	AMBOSELI	3															
SA-36-13	10	KIBONDO	3															
SA-36-14	11	KAHAMA	3															
SA-36-15	12	SHINYANGA	3															
SA-36-16	13	LAKE MANYARA	3															
SA-37-13	14	ARUSHA	3															
SA-37-14	15	VOI	3															
SB-35-4	16	KIGOMA	1															
SB-36-1	17	KASULU	1															
SB-36-2	18	BUKENE	1															
SB-36-3	19	NZEGA	1															
SB-36-4	20	SINGIDA	2															
SB-37-1	21	NABERERA	4															
SB-37-2	22	LUSHOTO	4															
SB-37-3	23	MOMBASA	4															
SB-36-5 (&35-8)	24	UVINZA	1															
SB-36-6	25	TABORA	1															
SB-36-7	26	IGALULA	1															
SB-36-8	27	MANYONI	2															
SB-37-5	28	KIBAYA	4															
SB-37-6	29	KOROGWE	4															
SB-37-7	30	PEMBA	4															
SB-36-9 (&35-12)	31	MPANDA	1															
SB-36-10	32	NYONGA	1															
SB-36-11	33	RUNGWA	1															
SB-36-12	34	DODOMA	2															
SB-37-9	35	KILOSA	4															
SB-37-10	36	MOROGORO	4															
SB-37-11	37	DAR-ES-SALAAM	4															
SB-36-13	38	KIPILI	1															
SB-36-14	39	SUMBAWANGA	1															
SB-36-15	40	KIPEMBAWE	1															
SB-36-16	41	IRINGA	2															
SB-37-13	42	MIKUMI	2															
SB-37-14	43	UTETE	4															
SB-37-15	44	MAFIA	4															
SC-36-1	45	MBALA	1															
SC-36-2	46	MWIMBI	1															
SC-36-3	47	MBEYA	1															
SC-36-4	48	SAO HILL	2															
SC-37-1	49	MAHENGE	2															
SC-37-2	50	KIPATIMU	2															
SC-37-3	51	KILWA	2															
SC-36-6	52	TUNDUMA	1															
SC-36-7	53	TUKUYU	1															
SC-36-8	54	NJOMBE	2															
SC-37-5	55	KAZIMOTO	2															
SC-37-6	56	LIWALE	2															
SC-37-7	57	LINDI	2															
SC-36-12	58	SONGEA	2															
SC-37-9	59	LIKUYU	2															
SC-37-10	60	MASASI	2															
SC-37-11	61	MTWARA	2															
SC-36-16	62	MBAMBA BAY	2															
SC-37-13	63	TUNDURU	2															
SC-37-14	64	LUKWIKA	2															

CHECK SHEET FOR DESIGNATED AREAS

SHEET NO:	**SHEET NAME:**	**HTS NO:**

	YES	NO	N/A	Name of coverage	New name of coverage
Digitised from scratch					
Clean					
transform (using which coverage?)					
drainage cover used					
append with sheet					
linework taken from other coverages					
vegcover					
drainage					
administrative					
separate coverages made for					
game reserves					
national parks					
cons. areas					

work carried out by:	
checked by:	

annotations added					

comments:

COMPLETELY FINISHED eg:- all linework, annotations, edgematched	

c:\steph\forms\desareas.xls

CHECK LIST FOR MIKE (to accompany disc/tape when sending to HH)

SHEET NO:	**HTS SHEET NO:**	**DATE:**
SHEET NAME:		

A CONTENTS OF DISC/TAPE

			File name	Tick if included	Comments
1	Vegetation boundaries	=	**FINAL**		
2	Rivers	=	**RIVER**		
	Annotation				
3	Forest Reserves	=	**FORRES**		
	Annotation				
4	National Parks	=	**NATPAK**		
	Annotation				
5	Conservation Areas	=	**FINCON**		
	Annotation				
6	Game Reserves	=	**GAME**		
	Annotation				
7	Lat+Long values				b.left
8	UTM Grid	=	**TICS**		
	Annotation				
9	Master Border Info.				
	a. Magnetic Declination				.txt file
	b. Int. boundary symbol				
	c. Image cover eg:path, row, date				
	d. Grid data				
	e. Date of base map				

B ADDITIONAL BITS AND PIECES

1	A4 sheet indicating Image Cover for Master Border		
2	A4 sheet indication map sheet index for Master Border		
3			

CHECK FORM FOR FINAL INKJET PROOFS

SHEET NAME: **SHEET NO:** **HTS NO:**

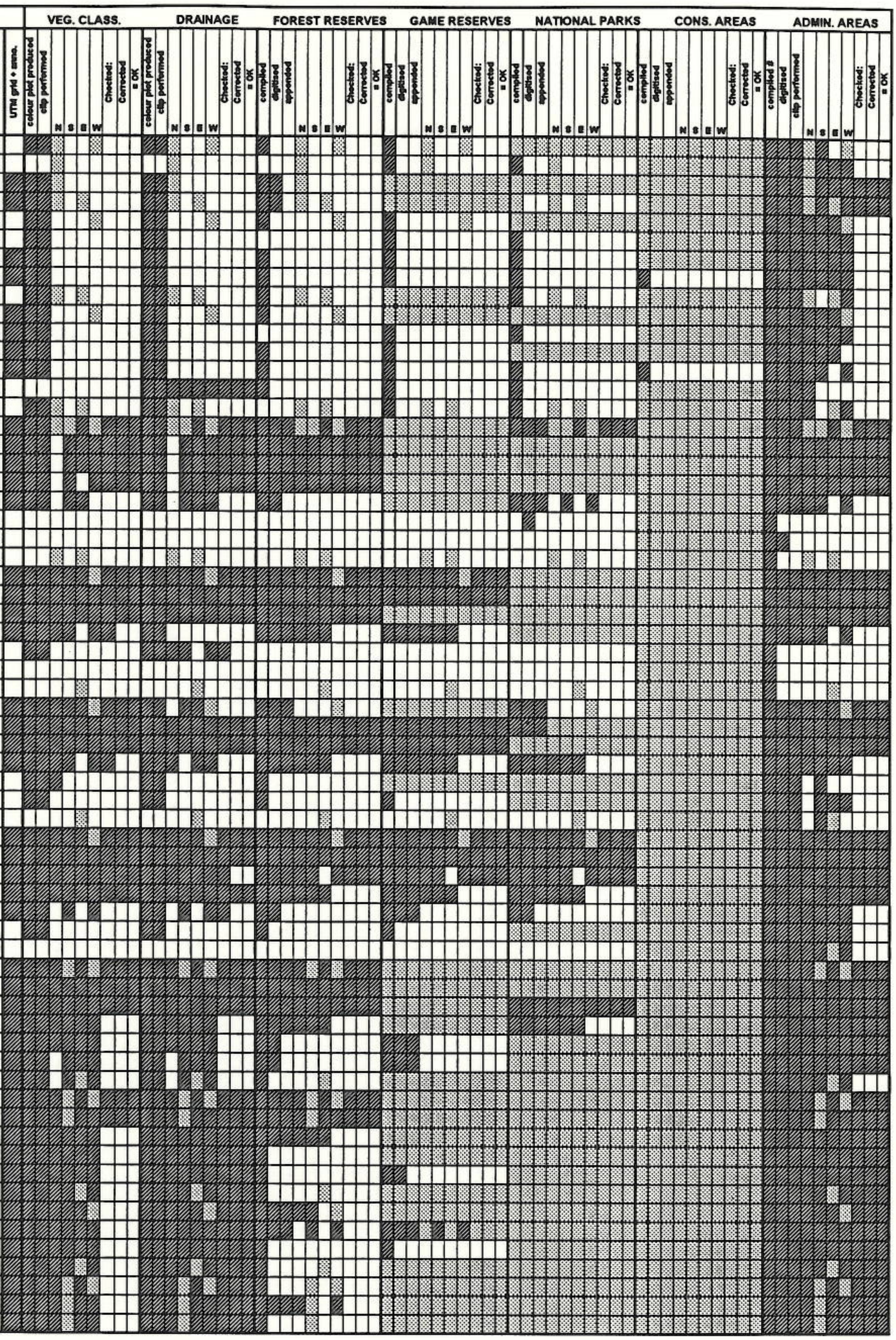
Inkjet proof received:	
Cromalin proof received:	

	MASTER BORDER	comments	OK ?	CORRECTED
1	position of title, spelling			
2	lat/long value, position			
3	UTM value, position			
4	topo date			
5	grid data			
6	mag. dec. data			
7	compilation note			
8	map centred within MB			
	ADMIN. INSET MAP			
9	- position - region names			
10	- spelling			
11	- position - district names			
12	- spelling			
	MAP SHEET INDEX			
13	- numbers correct			
14	- shading			
	SCENE INDEX			
15	- numbers correct			
16	- shading			
	DESIGNATED AREAS			
	FOREST RESERVES			
17	- position			
18	- spellings			
19	- clash with detail on topo film			
	GAME RESERVES			
20	- position			
21	- spellings			
22	- clash with detail on topo film			
	NAT. PARKS + CONS. AREAS			
23	- position			
24	- spellings			
25	- clash with detail on topo film			
	TOPO FILM			
26	check position			
27	clash of annotations			
28	fitting marks			
29	lat/long values - remove			
30	add minutes			
31	clean			
32	neg made			
33	despotted			

comments:

Approved by : ....Date :.................................

TABLE 9.1 DIGITAL CARTOGRAPHY PROGRESS AT 08-10-96



Map Ref No.	HTS No.	Mapsheet Name:	Priority Zone:
SA-36-5	1	KABALE	3
SA-36-6	2	BUKOBA	3
SA-36-7	3	MUSOMA	3
SA-36-8	4	NAROK	3
SA-36-9	5	BIHARAMULO	3
SA-36-10	6	MWANZA	3
SA-36-11	7	MALYA	3
SA-36-12	8	SERENGETI	3
SA-37-9	9	AMBOSELI	3
SA-36-13	10	KIBONDO	3
SA-36-14	11	KAHAMA	3
SA-36-15	12	SHINYANGA	3
SA-36-16	13	LAKE MANYARA	3
SA-37-13	14	ARUSHA	3
SA-37-14	15	VOI	3
SB-35-4	16	KIGOMA	1
SB-36-1	17	KASULU	1
SB-36-2	18	BUKENE	1
SB-36-3	19	NZEGA	1
SB-36-4	20	SINGIDA	2
SB-37-1	21	NABERERA	4
SB-37-2	22	LUSHOTO	4
SB-37-3	23	MOMBASA	4
SB-36-5 (&35-8)	24	UVINZA	1
SB-36-6	25	TABORA	1
SB-36-7	26	IGALULA	1
SB-36-8	27	MANYONI	2
SB-37-5	28	KIBAYA	4
SB-37-6	29	KOROGWE	4
SB-37-7	30	PEMBA	4
SB-36-9 (&35-12)	31	MPANDA	1
SB-36-10	32	NYONGA	1
SB-36-11	33	RUNGWA	1
SB-36-12	34	DODOMA	2
SB-37-9	35	KILOSA	4
SB-37-10	36	MOROGORO	4
SB-37-11	37	DAR-ES-SALAA	4
SB-36-13	38	KIPILI	1
SB-36-14	39	SUMBAWANGA	1
SB-36-15	40	KIPEMBAWE	1
SB-36-16	41	IRINGA	2
SB-37-13	42	MIKUMI	2
SB-37-14	43	UTETE	4
SB-37-15	44	MAFIA	4
SC-36-1	45	MBALA	1
SC-36-2	46	MWIMBI	1
SC-36-3	47	MBEYA	1
SC-36-4	48	SAO HILL	2
SC-37-1	49	MAHENGE	2
SC-37-2	50	KIPATIMU	2
SC-37-3	51	KILWA	2
SC-36-6	52	TUNDUMA	1
SC-36-7	53	TUKUYU	1
SC-36-8	54	NJOMBE	2
SC-37-5	55	KAZIMOTO	2
SC-37-6	56	LIWALE	2
SC-37-7	57	LINDI	2
SC-36-12	58	SONGEA	2
SC-37-9	59	LIKUYU	2
SC-37-10	60	MASASI	2
SC-37-11	61	MTWARA	2
SC-36-16	62	MBAMBA BAY	2
SC-37-13	63	TUNDURU	2
SC-37-14	64	LUKWIKA	2

▨ process completed

░ not applicable

Compiled = All boundary information researched, compiled and drawn up ready for digitising
Compiled # = compiled by SMD and transferred to film base

APPENDIX D

CATALOGUE OF HARD COPY INTERIM PRODUCTS

IMAGE MAPS

HTS No.	Ref. Code	Title of Map	Map Scale	Pub. Date	Map Projection	No.of copies	Medium	Comment
1	SA-36-5	KABALE	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
2	SA-36-6	BUKOBA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
3	SA-36-7	MUSOMA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
4	SA-36-8	NAROK	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
5	SA-36-9	BIHARAMULO	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
6	SA-36-10	MWANZA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
7	SA-36-11	MALYA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
8	SA-36-12	SERENGETI	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
9	SA-37-9	AMBOSELI	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
10	SA-36-13	KIBONDO	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
11	SA-36-14	KAHAMA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
12	SA-36-15	SHINYANGA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
13	SA-36-16	LAKE MANYARA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
14	SA-37-13	ARUSHA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
15	SA-37-14	VOI	1:250 000	1996	UTM	1	PHOTO PAPER	FULL COLOUR
16	SB-35-4	KIGOMA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
17	SB-36-1	KASULU	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
18	SB-36-2	BUKENE	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
19	SB-36-3	NZEGA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
20	SB-36-4	SINGIDA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
21	SB-37-1	NABERERA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
22	SB-37-2	LUSHOTO	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
23	SB-37-3	MOMBASA	1:250 000	1996	UTM	1	PHOTO PAPER	FULL COLOUR

24	SB-36-5	UVINZA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
25	SB-36-6	TABORA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
26	SB-36-7	IGALULA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
27	SB-36-8	MANYONI	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
28	SB-37-5	KIBAYA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
29	SB-37-6	KOROGWE	1:250 000	1995-96	UTM	1	PHOTO PAPER	FULL COLOUR
30	SB-37-7	PEMBA	1:250 000	1996	UTM	1	PHOTO PAPER	FULL COLOUR
31	SB-36-9	MPANDA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
32	SB-36-10	NYONGA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
33	SB-36-11	RUNGWA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
34	SB-36-12	DODOMA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
35	SB-37-9	KILOSA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
36	SB-37-10	MOROGORO	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
37	SB-37-11	DAR ES SALAAM	1:250 000	1995-96	UTM	1	PHOTO PAPER	FULL COLOUR
38	38-36-13	KIPILI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
39	SB-36-14	SUMBAWANGA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
40	SB-36-15	KIPEMBAWE	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
41	SB-36-16	IRINGA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
42	SB-37-13	MIKUMI	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
43	SB-37-14	UTETE	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
44	SB-37-15	MAFIA	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
45	SC-36-1	MBALA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
46	SC-36-2	MWIMBI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
47	SC-36-3	MBEYA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
48	SC-36-4	SAO HILL	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
49	SC-37-1	MAHENGE	1:250 000	1994-95	UTM	2	PHOTO PAPER	FULL COLOUR

50	SC-37-2	KIPATIMU	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
51	SC-37-3	KILWA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
52	SC-36-6	TUNDUMA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
53	SC-36-7	TUKUYU	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
54	SC-36-8	NJOMBE	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
55	SC-37-5	KAZIMOTO	1:250 000	1995	UTM	1	PHOTO PAPER	FULL COLOUR
56	SC-37-6	LIWALE	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
57	SC-37-7	LINDI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
58	SC-36-12	SONGEA	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
59	SC-37-9	LIKUYU	1:250 000	1994-95	UTM	1	PHOTO PAPER	FULL COLOUR
60	SC-37-10	MASASI	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
60	SC-37-10	MASASI	1:250 000	1994-95	UTM	2	PHOTO PAPER	FULL COLOUR
61	SC-37-11	MTWARA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
62	SC-36-16	MBAMBA BAY	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
63	SC-37-13	TUNDURU	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR
64	SC-37-14	LUKWIKA	1:250 000	1994	UTM	1	PHOTO PAPER	FULL COLOUR

1 : 250 000 TOPOGRAPHIC SHEETS

HTS No	Ref. Code	Tittle of Map	Map Scale	Pub. Date	Map Projection	No. of Copies	Medium	Comments
1	SA-36-5	KABALE	1:250 000	1996	UTM-GRID	1	PAPER	FULL COLOUR
1	SA-36-5	KABALE	1:250 000	1966	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
2	SA-36-6	BUKOBA	1:250 000	1966	UTM-GRID	1	PAPER	FULL COLOUR
3	SA-36-7	MUSOMA	1:250 000	1965	UTM-GRID	1	PAPER	FULL COLOUR
4	SA-36-8	NAROK	1:250 000	1965	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
5	SA-36-9	BIHARAMULO	1:250 000	1966	UTM-GRID	1	PAPER	FULL COLOUR
6	SA-36-10	MWANZA	1:250 000	1981	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
7	SA-36-11	MALYA	1:250 000	1982	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
8	SA-36-12	SERENGETI	1:250 000	1976	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
9	SA-37-9	AMBOSELI	1:250 000	1965	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
10	SA-36-13	KIBONDO	1:250 000	1985	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
11	SA-36-14	KAHAMA	1:250 000	1981	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
12	SA-36-15	SHINYANGA	1:250 000	1975	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
13	SA-36-16	LAKE MANYARA	1:250 000	1976	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
14	SA-37-13	ARUSHA	1:250 000	1967	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
15	SA-37-14	VOI	1:250 000	1971	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
16	SB-35-4	KIGOMA	1:250 000	NILL	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
17	SB-36-1	KASULU	1:250 000	1980	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
18	SB-36-2	BUKENE	1:250 000	1983	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
19	SB-36-3	NZEGA	1:250 000	1982	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
20	SB-36-4	SINGIDA	1:250 000	1966	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
21	SB-37-1	NABERERA	1:250 000	1970	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
22	SB-37-2	LUSHOTO	1:250 000	1960	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
23	SB-37-3	MOMBASA	1:250 000	1963	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE

24	SB-36-5	UVINZA	1:250 000	1975	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
24	SB-36-5	UVINZA	1:250 000	1975	UTM-GRID	1	PAPER	FULL COLOUR
25	SB-36-6	TABORA	1:250 000	1980	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
25	SB-36-6	TABORA	1:250 000	1981	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
26	SB-36-7	IGALULA	1:250 000	1987	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
27	SB-36-8	MANYONI	1:250 000	1963	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
28	SB-37-5	KIBAYA COMPILATION	1:250 000	1971	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
29	SB-37-6	KOROGWE COMPILATON	1:250 000	1971	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
30	SB-37-7	PEMBA	1:250 000	1973	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
31	SB-36-9	MPANDA	1:250 000	1965	UTM-GRID	1	PAPER	FULL COLOUR
32	SB-36-10	NYONGA	1:250 000		UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
33	SB-36-11	RUNGWA	1:250 000		UTM-GRID	1	PHOTOCOPY	BLACK &WHITE
34	SB-36-12	DODOMA	1:250 000	1996	UTM-GRID	1	PHOTOCOPY	BLACK &WHITE
35	SB-37-9	KILOSA	1:250 000	1964	UTM-GRID	1	PHOTOCOPY	BLACK &WHITE
36	SB-37-10	MOROGORO	1:250 000	1964	UTM-GRID	1	PHOTOCOPY	BLACK &WHITE
37	SB-37-11	DAR ES SALAAM	1:250 000	1968	UTM-GRID	1	PHOTOCOPY	BLACK &WHITE
38	SB-36-13	KIPILI	1:250 000	1965	UTM-GRID	1	PAPER	FULL COLOUR
38	SB-36-13	KIPILI	1:250 000	1965	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
39	SB-36-14	SUMBAWANGA	1:250 000	1968	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
40	SB-36-15	KIPEMBAWE	1:250 000	NILL	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
41	SB-36-16	IRINGA	1:250 000	1986	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
42	SB-37-13	MIKUMI	1:250 000	1963	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
43	SB-37-14	UTETE	1:250 000	1973	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
44	SB-37-15	MAFIA	1:250 000	1970	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
45	SC-36-1	MBALA	1:250 000	1969	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
46	SC-36-2	MWIMBI	1:250 000	1968	UTM-GRID	2	PHOTOCOPY	BLACK & WHITE

47	SC-36-3	MBEYA	1:250 000	1963	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
48	SC-36-4	SAO HILL	1:250 000	1963	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
49	SC-37-1	MAHENGE	1:250 000	1962	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
50	SC-37-2	KIPATIMU	1:250 000	1963	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
51	SC-37-3	KILWA COMPILATION	1:250 000	1969	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
52	SC-36-6	TUNDUMA	1:250 000	1970	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
53	SC-36-7	TUKUYU	1:250 000	1968	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
54	SC-36-8	NJOMBE	1:250 000	1979	UTM-GRID	1	PAPER	FULL COLOUR
55	SC-37-5	KAZIMOTO	1:250 000	1996	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
56	SC-37-6	LIWALE	1:250 000	1975	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
57	SC-37-7	LINDI	1:250 000	1970	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
58	SC-36-12	SONGEA	1:250 000	1975	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
59	SC-37-9	LIKUYU	1:250 000	1975	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
60	SC-37-10	MASASI	1:250 000	1973	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
61	SC-37-11	MTWARA	1:250 000	1971	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
62	SC-36-16	MBAMBA BAY	1:250 000	1977	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
63	SC-37-13	TUNDURU	1:250 000	1976	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE
64	SC-37-14	LUKWIKA	1:250 000	1974	UTM-GRID	1	PHOTOCOPY	BLACK & WHITE

LAND COVER OVERLAYS

HTS No.	Ref. Code	Tittle of Map	Map Scale	Pub. Date	Map Projection	No. of Copies	Medium
1	SA-36-5	KABALE	1:250 000	1995-96	UTM	1	INK-TAKE FILM
2	SA-36-6	BUKOBA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
3	SA-36-7	MUSOMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
4	SA-36-8	NAROK	1:250 000	1995-96	UTM	1	INK-TAKE FILM
5	SA-36-9	BIHARAMULO	1:250 000	1995-96	UTM	1	INK-TAKE FILM
6	SA-36-10	MWANZA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
7	SA-36-11	MALYA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
8	SA-36-12	SERENGETI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
9	SA-37-9	AMBOSELI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
10	SA-36-13	KIBONDO	1:250 000	1995-96	UTM	1	INK-TAKE FILM
11	SA-36-14	KAHAMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
12	SA-36-15	SHINYANGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
13	SA-36-16	LAKE MANYARA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
14	SA-37-13	ARUSHA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
15	SA-37-14	VOI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
16	SB-35-4	KIGOMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
17	SB-36-1	KASULU	1:250 000	1995-96	UTM	1	INK-TAKE FILM
18	SB-36-2	BUKENE	1:250 000	1995-96	UTM	1	INK-TAKE FILM
19	SB-36-3	NZEGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
20	SB-36-4	SINGIDA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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23	SB-37-3	MOMBASA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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25	SB-36-6	TABORA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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27	SB-36-8	MANYONI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
28	SB-37-5	KIBAYA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
29	SB-37-6	KOROGWE	1:250 000	1995-96	UTM	1	INK-TAKE FILM
30	SB-37-7	PEMBA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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33	SB-36-11	RUNGWA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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35	SB-37-9	KILOSA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
36	SB-37-10	MOROGORO	1:250 000	1995-96	UTM	1	INK-TAKE FILM
37	SB-37-11	DAR ES SALAAM	1:250 000	1995-96	UTM	1	INK-TAKE FILM
38	SB-36-13	KIPILI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
39	SB-36-14	SUMBAWANGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
40	SB-36-15	KIPEMBAWE	1:250 000	1995-96	UTM	1	INK-TAKE FILM
41	SB-36-16	IRINGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
42	SB-37-13	MIKUMI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
43	SB-37-14	UTETE	7	1995-96	UTM	1	INK-TAKE FILM
44	SB-37-15	MAFIA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
45	SC-36-1	MBALA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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47	SC-36-3	MBEYA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
48	SC-36-4	SAO HILL	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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56	SC-37-6	LIWALE	1:250 000	1995-96	UTM	1	INK-TAKE FILM
57	SC-37-7	LINDI	1:250 000	1995-96	UTM	1	INK-TAKE FILM
58	SC-36-12	SONGEA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
59	SC-37-9	LIKUYU	1:250 000	1995-96	UTM	1	INK-TAKE FILM
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61	SC-37-11	MTWARA	1:250 000	1995-96	UTM	1	INK-TAKE FILM
62	SC-36-16	MBAMBA BAY	1:250 000	1995-96	UTM	1	INK-TAKE FILM
63	SC-37-13	TUNDURU	1:250 000	1995-96	UTM	1	INK-TAKE FILM
64	SC-37-14	LUKWIKA	1:250 000	1995-96	UTM	1	INK-TAKE FILM

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13	SA-36-16	LAKE MANYARA	1:250 000	1980-84	UTM	1	TRACING-PAPER
14	SA-37-13	ARUSHA	1:250 000	/	UTM	1	TRACING-PAPER
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20	SB-36-4	SINGIDA	1:250 000	1990-95	UTM	1	TRACING-PAPER
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27	SB-36-8	MANYONI	1:250 000	1990-95	UTM	1	TRACING-PAPER
28	SB-37-5	KIBAYA	1:250 000	/	UTM	1	TRACING-PAPER
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41	SB-36-16	IRINGA	1:250 000	1975-79	UTM	1	TRACING-PAPER
42	SB-37-13	MIKUMI	1:250 000	/	UTM	1	TRACING-PAPER
43	SB-37-14	UTETE	1:250 000	1980-84	UTM	1	TRACING-PAPER
44	SB-37-15	MAFIA	1:250 000	1975-79	UTM	1	TRACING-PAPER
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45B	SC-36-1	MBALA	1:250 000	1975-79	UTM	1	TRACING-PAPER
46	SC-36-2	MWIMBI	1:250 000	/	UTM	1	TRACING-PAPER
47	SC-36-3	MBEYA	1:250 000	1975-79	UTM	1	TRACING-PAPER
48	SC-36-4	SAO HILL	1:250 000	1975-79	UTM	1	TRACING-PAPER
49	SC-37-1	MAHENGE	1:250 000	/	UTM	2	TRACING-PAPER

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51	SC-37-3	KILWA	1:250 000	1980-84	UTM	1	TRACING-PAPER
52	SC-36-6	TUNDUMA	1:250 000	/	UTM	1	TRACING-PAPER
53	SC-36-7	TUKUYU	1:250 000	1975-79	UTM	1	TRACING-PAPER
54	SC-36-8	NJOMBE	1:250 000	/	UTM	1	TRACING-PAPER
55	SC-37-5	KAZIMOTO	1:250 000	/	UTM	1	TRACING-PAPER
56	SC-37-6	LIWALE	1:250 000	1975-79	UTM	1	TRACING-PAPER
57	SC-37-7	LINDI	1:250 000	/	UTM	1	TRACING-PAPER
58	SC-36-12	SONGEA	1:250 000	/	UTM	1	TRACING-PAPER
59	SC-37-9	LIKUYU	1:250 000	1991	UTM	1	TRACING-PAPER
60	SC-37-10	MASASI	1:250 000	1980-84	UTM	1	TRACING-PAPER
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61	SC-37-11	MTWARA	1:250 000	/	UTM	1	TRACING-PAPER
62	SC-36-16	MBAMBA BAY	1:250 000	/	UTM	1	TRACING-PAPER
63	SC-37-13	TUNDURU	1:250 000	/	UTM	1	TRACING-PAPER
64	SC-37-14	LUKWIKA	1:250 000	1990-91	UTM	1	TRACING-PAPER

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5	SA-36-9	BIHARAMULO	1:250 000	1996	UTM	1	DRAFTING FILM	BLACK PENCIL
6	SA-36-10	MWANZA	1:250 000	1996	UTM	1	DRAFTING FILM	BLACK PENCIL
7	SA-36-11	MALYA	1:250 000	1996	UTM	1	DRAFTING FILM	BLACK PENCIL
8	SA-36-12	SERENGETI	1:250 000	1996	UTM	1	DRAFTING FILM	BLACK PENCIL
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13	SA-36-16	LAKE MANYARA	1:250 000	1996	UTM	1	DRAFTING FILM	BLACK PENCIL
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9	SA-37-9	AMBOSELI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
10	SA-36-13	KIBONDO	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
11	SA-36-14	KAHAMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
12	SA-36-15	SHINYANGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
13	SA-37-13	LAKE MANYARA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
14	SA-37-13	ARUSHA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
15	SA-37-14	VOI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
16	SB-35-4	KIGOMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
17	SB-36-1	KASULU	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
18	SB-36-2	BUKENE	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
19	SB-36-3	NZEGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
20	SB-36-4	SINGIDA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
21	SB-37-1	NABERERA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
22	SB-37-2	LUSHOTO	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
23	SB-37-3	MOMBASA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	

24	SB-36-5	UVINZA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
25	SB-36-6	TABORA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
26	SB-36-7	IGALULA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
27	SB-36-8	MANYONI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
28	SB-37-5	KIBAYA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
29	SB-37-6	KOROGWE	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
30	SB-37-7	PEMBA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
31	SB-36-9	MPANDA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
32	SB-36-10	NYONGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
33	SB-36-11	RUNGWA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
34	SB-36-12	DODOMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
35	SB-37-9	KILOSA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
36	SB-37-10	MOROGORO	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
37	SB-37-11	DAR ES SALAAM	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
38	38-36-13	KIPILI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
39	SB-36-14	SUMBAWANGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
40	SB-36-15	KIPEMBAWE	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
41	SB-36-16	IRINGA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
42	SB-37-13	MIKUMI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
44	SB-37-15	MAFIA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
45	SC-36-1	MBALA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
46	SC-36-2	MWIMBI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
47	SC-36-3	MBEYA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
48	SC-36-4	SAO HILL	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
49	SC-37-1	MAHENGE	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
50	SC-37-2	KIPATIMU	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
51	SC-37-3	KILWA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	

52	SC-36-6	TUNDUMA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
53	SC-36-7	TUKUYU	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
54	SC-36-8	NJOMBE	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
56	SC-37-6	LIWALE	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
57	SC-37-7	LINDI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
58	SC-36-12	SONGEA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
59	SC-37-9	LIKUYU	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
60	SC-37-10	MASASI	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
61	SC-37-11	MTWARA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
62	SC-36-16	MBAMBA BAY	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
63	SC-37-13	TUNDURU	1:250 000	1995-96	UTM	1	INK-TAKE FILM	
64	SC-37-14	LUKWIKA	1:250 000	1995-96	UTM	1	INK-TAKE FILM	

APPENDIX E

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