SDSU-RSI-83-10

Land Classification/Soil Survey Project of the

SYRIAN ARAB REPUBLIC

VOLUME 9

A Geographic Information System for Syria

October 1982

Prepared for

United States Agency for International Development
and the
Syrian Arab Republic

Prepared by

Louis Berger International, Inc.
East Orange, New Jersey, U.S.A.

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota , U.S.A.

and the
Ministry of Agriculture and Agrarian Reform
Directorate of Soils

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A Geographic Information System for Syria

List of Volumes

1. Introduction, Summary and Recommendations
2. Reconnaissance Soil Survey, 1:500,00 scale
3. Soil Survey of the First Settlement Zone, 1:100,00 scale
4. Detailed Soil Survey of the Tartous Area, 1:25,000 scale
5. Reconnaissance Land Use Survey of Syria, 1:500,000 scale and Land Use Survey of the First Settlement Zone, 1:100,000 scale
6. An Evaluation of Syrian Rangeland Problems
7. Irrigation in Syria
8. Land Classification and Soil Survey Training Program
9. A Geographic Information System for Syria
10. Analytical Soil Data in Support of the 1:500,000, 1:100,000, and the 1:25,000 scale Soil Surveys of Syria

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FOREWORD

The various volumes of the contract final report on Technical Assistance to Syria's Land Classification and Soils Survey Project deal with major components of the overall development of a technical capability to acquire, manage, and manipulate natural resource data. The contract activities were designed to establish technical capability and an appreciation for the methods and materials for resource mapping. This volume deals with the utilization of a minicomputer and geographic information system software to provide resource management assistance. The acquisition of the information system (hardware and software), the training of a Syrian operator, and the development of the deliverable project data base will be discussed. Recommendations are made for continuation of activites and technological developments.

volume 9

A Geographic Information System for Syria

1 INTRODUCTION*

The Land Use and Soils Classification Project was designed to improve the capability of the Ministry of Agriculture within the Syrian Arab Republic. The soil and vegetative resources of Syria were to be mapped at reconnaissance scale. The laboratory and manpower resources of the Ministry were to be upgraded by addition of laboratory equipment and training in laboratory and field procedures required to effectively map natural resources. In addition, the project design included provision of computer capability to store, manage, retrieve, process and display geographical resource data.

This volume discusses the project activities related to the establishment of a Geographic Information System (GIS) for Syria. The objectives of this phase of the overall project were (1) to specify and acquire a minicomputer, (2) install geographic information system software, (3) prepare a soils and landuse data base, (4) train an operator/administrator and (5) install the system in Damascus.

1.1 SPECIFY AND ACQUIRE A MINICOMPUTER

A survey and comparison of technical capabilities and costs of various minicomputers were necessary in order to make an acquisition recommendation to United States Agency for International Development (USAID) and Syrian Arab Republic Government (SARG) officials. Major vendors were considered; one was recommended and the hardware acquired.

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*Prepared by Mike Wehde, Darrell Hause and Steve Kappel. Mike Wehde is Manager of Auxiliary Services; Darrell Hause is Systems Development Engineer; Steve Kappel is Research Systems Scientist; all at the Remote Sensing Institute, South Dakota State University, Brookings, SD, USA.

1.2 INSTALL GEOGRAPHIC INFORMATION SOFTWARE

The AREAS, Area REsource Analysis System, which was developed and operated by the Remote Sensing Institute, was to be adapted to the minicomputer. This required consideration of the similarities and differences between the IBM operating system and that of the minicomputer during hardware survey as well as adaptation of software after hardware acquisition.

1.3 PREPARE A SOILS/LANDUSE DATA BASE

The natural resource data being mapped by other phases of project activity (soils at 1.500,000, landuse at 1:500,000 and selected areas of soils and landuse at 1:100,000) were considered logical entries into the computer data base. The conversion of these to computer compatible format was included in the information system objectives of the project.

1.4 TRAIN AN OPERATOR/ADMINISTRATOR

The continued successful utilization of the information system when installed in the Ministry of Agriculture would require a Syrian staff scientist with detailed knowledge of the computer, the software and the data base. An objective of resident U.S. training for a Syrian scientist was included.

1.5 INSTALL THE SYSTEM IN DAMASCUS

An objective of U.S. computer scientist residency in Syria in the final phase of the project activity was included to provide assurance of the data base and information system integrity at the time of final transfer to the Ministry. The assistance of minicomputer maintenance personnel under an established maintenance contract was planned to provide hardware transition from the U.S. to Damascus without interruption in maintenance certification.

2 THE PRIME 250 MINICOMPUTER

The acquisition of a minicomputer system began with a technical survey, followed by a written recommendation to USAID and SARG. Upon approval the system was ordered for delivery to the Remote Sensing Institute for adaptation of the information system

2.1 THE COMPUTER SURVEY

A survey of alternative minicomputer systems was carried out and a written recommendation for selection was provided to USAID and SARG for approval. Only the essential highlights of that recommendation paper will be repeated here.

The vendors considered were International Business Machines, Hewlett Packard, PRIME Computer, Digital Equipment Corporation, Data General, Texas Instruments, and Wang. Data General, Texas Instruments and Wang were dropped from the survey because of (1) an Original Equipment Manufacturer (OEM) rather than end user orientation in the market, (2) inadequate real memory, and/or (3) the overseas marketing and service availability.

The remaining four vendors were contacted regarding the project objectives and approximate budget dollars, and representatives made initial model recommendations as follows:

IBM	Series Model 4955/E
H.P.	Series 1000 Model 45F
D.E.C.	PDP 11 Model 44
PRIME	Model 250

2.1.1 GENERAL CONSIDERATIONS

The technical evaluations of the hardware and software alternatives were made by consideration of (1) the specific Syrian application requirements, (2) the transferability/adaptability of the geographic information system, AREAS, the Area REsource Analysis System, (3) the expansion potential, and (4) cost.

The Syrian application was reviewed with respect to plotter capacity, disk file requirements, processor performance and file management/security. These are product, data base, processing, and overall operations concerns, respectively.

The adaptability of AREAS to the minicomputer selected was evaluated in relation to the languages used in the IBM 370 version, and the IBM-Calcomp plotter software. FORTRAN and ASSEMBLY were considered the minimum language configuration. Plotter software was sought with Calcomp-equivalent support subroutines to ease the conversion of plot related software.

The market was considered from the price/performance standpoint among the qualified offerers of systems with differing capability.

A growth in interest in geographic information systems was anticipated as was the likelihood of adding image processing at some future date. Therefore, consideration was given to the expansion potential for the computer hardware and the available software features of the vendor (time sharing, networking, alternate languages, data base packages, word processing, etc).

In the early discussions with vendor representatives, IBM appeared weak in capacity to meet the project requirements. In fact, the representatives themselves withdrew from active competition. PRIME, HP and DEC all received formal requests for quotations and a technical questionnaire on the CPU, operating system, and file management features of their proposed configuration(s). DEC did not file a completed questionnaire and responded with a model and cost offer which was non-competitive. Prime and HP were comparatively evaluated for project effectiveness.

2.1.2 HARDWARE FACTORS

The hardware factors which were reviewed in comparing the offers of PRIME and Hewlett Packard included main memory, disk storage (both quantity and fixed/removable ratio), and magnetic tape speed and recording density. The availability of service in the U.S. and in Syria and delivery terms were also important to the project.

2.1.3 SOFTWARE FACTORS

The software factors which were reviewed in comparing the offers included the FORTRAN and ASSEMBLY languages required for AREAS, file naming and protection features, input/output spooling, ability to account for connect time, processor time, I/O time and disk storage, the availability of sort, dump, copy and debug utility programs, and file management capabilities such as the directory structure , file naming, direct access methods, and variable length records. Many of these factors are features designed into the operating system and are not separately implementable by a user.

2.2 PRIME 250 FEATURES

The features which were considered in the survey of minicomputers are summarized for the PRIME 250 under categories of hardware and software.

2.2.1 HARDWARE

The PRIME 250 hardware together with the Houston Instruments drum plotter is shown in Figure 9-1 . It is convenient in the discussion of the computer hardware to separate the central processor characteristics from those of the peripheral units. Several of the features will be reported in terms of the capacity acquired for the project and in terms of the expansion potential to maximum capacity of the hardware.

2.2.1.1 PROCESSOR

The processor has an internal architecture based on 32 bits, including the arithmetic unit and 128 registers--64 of which are programmer accessable. The error-correcting MOS memory was provided at the .5 Megabyte level although the system can accommodate up to 2 Megabytes. The memory is segmented and managed in 2 Kilobyte pages giving the appearance of up to 32 Megabytes of available memory per user. An 80 nanosecond access, look-ahead cache memory page is provided with a look-ahead algorithm typically providing an 85% success in anticipating the next required memory element.

Up to sixteen users may share the system. Each one will have the operating system available in his/her address space although the code exists in memory as one copy only. Hardware implemented rings of security protect the operating system from user damage and protect users from each other.

2.2.1.2 PERIPHERALS

Peripheral devices are interfaced through controllers which form sub-systems supporting several devices of a given type. The controllers are "channel coded", that is, intelligent to the point of alleviating the processor from some of the tasks of data manipulation before and after transfer. Controller types are disk, tape, unit record, and asynchronous multi-line.

The PRIME system can support 2 disk subsystems with up to 4 disk devices each for a total of 8 drives or a maximum storage capacity of 2.4 billion bytes. The data transfer rate is 1.2 Megabytes per second, and the average seek time is 30 milliseconds. The 250 was acquired with one 64 Megabytes cartridge module

drive (CMD) having 45.6 Megabytes fixed on the drive and 16 Megabytes removable in cartridge form. Although these last storage capacities do not total 64 Megabytes, they do reflect the user accessible file space available.

The PRIME system can support 2 tape subsystems of up to 4 drives each for a maximum of 8 tape drives. Although various speeds and densities are available, one Pertec 4180 9-track, 800/1600 BPI drive at 45 IPS was selected for data exchange with other computer systems in industry standard codes (EBCDIC, ASCII, Binary).

A maximum of 6 unit record devices can be supported by the 2 subsystems allowed for card readers, punches, printers,etc. In the configuration acquired the only unit record device is the line printer. A Printronix P300 printer with 132 positions and a 300 LPM (line per minute) rate at 10 characters per inch and matrix print or plot capability was specified.

The AMLC (asynchronous multi-life) provides the interface for the multi-user terminals via EIA RS232 communications at baud rates from 75 to 19200 baud. One controller for up to 4 devices was acquired although the configuration for the project only required single user capability

2.2.2 SOFTWARE

The system software provided with the computer hardware can best be reviewed in two sub-categories: operating system and utilities.

2.2.2.1 OPERATING SYSTEM

The operating system must make the hardware resources of the computer available to the user by providing resource, task and file management functions. PRIME was innovative in designing the operating system and then designing the hardware to optimize the performance features in the operating system design. The PRIME operating system is known as PRIMOS.

PRIMOS supports many computer languages, thereby broadening the usefulness of the computer in many disciplines. Languages supported are ANSI 74 COBOL, ANSI 77 FORTRAN, BASIC, BASIC/VM, RPGII, PL/1, PASCAL, and PRIME Macro-Assembler. A Data Base Management System, DBMS, a Multiple-Index Data Access System, MIDAS, a data format manager, FORMS, and a source-level debugger are all supported for applications development.

PRIMOS manages virtual memory in 2 Kilobyte pages for real memory in quantities from 256 Kilobytes to 8 Megabytes depending on the hardware model. It supports multiple users in interactive mode together with batch mode and real-time supervisory services. A LOGIN system controls access, and assists in the monitoring of each users resource consumption (time, disk space, etc.). Password protection of the directories control user status and protection attributes on each data file and controls the rights to that file based on the user status.

PRIMOS provides rapid user response by residing in each users address space in a re-entrant code form. Hardware protection keeps users from modifying or destroying PRIMOS while all users share in utilization of the features. This

technique allows one copy of the code to be in memory regardless of the number of active users.

2.2.2.2 UTILITIES

The utility functions provided with the PRIME computer system are described together with the PRIMOS command which invokes the function as follows: (1)CMPF - compare two source files and report the differences between them, (2) FUTIL - a file utility for copying, deleting, creating, protecting, checking status, etc. on files and directories, (3) SLIST - to print source files at the user terminal, (4) SORT - to rearrange data files according to specified order in various data fields of the records, (5) UPCASE - to convert lower case source files to upper case, (6) MAGNET - to provide magnetic tape read/write with code conversions compatible with other computer systems, (7) MAGSAV - to archive PRIME format disk files directly to tape, (8) MAGRST - to restore MAGSAV'd PRIME files directly to disk, (9) RUNOFF - to process text files prepared by the EDITOR into report format, (10) SPOOL - to transfer files to the printer queue, (11) ED - the EDITOR for entry of source text and subsequent correction or modification, (12) SEG - the object program linker, (13) VSPD - the symbolic program debugger and (14) DBG the source level debugger for interactive control and monitoring of an executing program.

3 THE AREAS GEOGRAPHIC INFORMATION SYSTEM

The need for computer processing of natural resource information goes beyond the need for simplification of maps for display and includes the functions of map merger, composite and customized mapping. Potential users of such information include conservationists, resource managers, land use planners, and zoning officials as well as research scientists and mappers.

The Area REsource Analysis System (AREAS), developed at the South Dakota State University Remote Sensing Institute, is a computerized data processing package that evolved out of the growing information and processing requirements of natural resource scientists. The functions, capabilities and application techniques were developed by the interaction of resource scientists with computer specialists.

3.1 DESIGN CONCEPTS

The AREAS design minimizes storage requirements by using the implicit north to south row sequence, recording only the column positions where the class or theme changes within the row (a compact sequential encoding), using variable length records only as long as the complexity of the map requires, and using minimum memory units (bits) to represent the column and class entries in the data set.

The compact sequential geocoding technique is widely recognized as a compression method for saving storage space. The AREAS design also promotes the concept of increasing processing efficiency by carrying out analyses in compact, sequential logic rather than raster expansion of the data records. This approach to algorithm development increases somewhat the complexity of the algorithms, but

it dramatically reduces the computational time and cost.

A resource management project utilizing AREAS will often generate many intermediate files of data related to the solution of a problem. Usually a problem solution will also require the use of several AREAS processing functions. The keeping of project notes on relationships of data files and the actual processes applied can be burdensome. AREAS processing functions were also designed to assist the user in overcoming the task of good record keeping. The AREAS system keeps identification data in each map data set. Processing functions can then obtain these descriptions for reporting at each step of a problem solution. Furthermore, each function writes a report in a standard 8 1/2 by 11 inch format containing data file descriptions, processing parameters, file size information and a place for noting the data set names on the disk directory. Any user who conscientiously keeps and binds these reports can easily keep a project log with an auditable trail through the data sets used to answer a question or solve a mapping problem.

The initial conceptual design for AREAS was adapted to the multi-user, university IBM environment. The advantages of disk files over tape records were obvious. One could access files without relying on operator intervention (and sometimes mistakes). The data dictionary (disk VTOC) could automatically provide information to the operating system concerning the data set characteristics such as formatting, record length, blocking, etc. Magnetic tapes could be used to archive the less frequently used data for future reference. Most of the functions could be adapted to a magnetic tape operation through judicious use of job control language(JCL) provided there were enough tape drives to accommodate the number of data sets to be processed in one job step.

Many parameters of a job to execute an AREAS function would be essentially constant for most users. It was also convenient to store standard sets of JCL in a procedure library. This made it possible to execute any function with a minimum of JCL preparation while still providing for flexibility via JCL over-ride in the job stream.

The concepts discussed reflect the desire to simplify the use of AREAS, to maximize the speed of the functions, to minimize the cost and storage requirements, and to assist the user in the record keeping tasks.

3.2 CAPABILITIES

The functional capabilities of AREAS might be grouped into the categories of data entry, data management, map and image analyses, and product generation.

3.2.1 DATA ENTRY

The primary purpose of the AREAS system is to analyze and manipulate thematic map data. There is one AREAS function which combines a map with a digital image. Input processes are therefore provided for both map data and digital image data.

3.2.1.1 MAP DATA

The single data type, which most heavily motivated the development of storage, processing and display features within AREAS, is resource maps. Thematic maps of classes of resource categories are indispensible in the management of those resources. The data base design and the early concepts of compact sequential process logic were outgrowths of the map processing motive.

In the first few years of AREAS operation, a manual encoding technique was utilized. In the last year of development, a computer-interface coordinate digitizer was incorporated to increase the digitization accuracy by orders of magnitude and reduce digitizing time as well. The manual technique remains useful for low-resolution, relatively inexpensive and comparatively quick analyses.

The system proposed for delivery to Syria was limited to the manual digitization technique in order to acquire the necessary computer and plotter capability within budget limitations. Early project plans for the data base were also for the manual data encoding technique. With the development of the coordinate digitizer technique and the delays in the acquiring the resource maps for digitization, it became necessary to use the coordinate digitizer to accomplish the project data base objective. For this reason only, both techniques are described. The software for the table digitizer was not delivered to Syria since no hardware digitizer was provided. This software is available should the SARG choose to upgrade the hardware.

3.2.1.1.1 MANUAL TECHNIQUE

The manual encoding process begins with the manufacture of a cellular grid. A drum plotter program, which employs a fine-tip ball-point pen, is used to draw, to the desired scale and cell size, a grid of cells on transparent acetate. The resulting overlay, when placed over the input map, determines the assignment of rows and columns and also assists in the definition of the spatially dominant theme within the cell.

AREAS does not require entries for each cell. To speed encoding, reduce errors and reduce the volume of data, only the first cell of any class or theme within a row is recorded. As a carryover from earlier IBM operations, the data is encoded into 80-column "card images" which are compatible with newer video terminal technology. The coding of each new row begins on a new card-image, continues indefinitely, card-image after card-image until ending with an asterisk. Commas separate the variable-length data fields eliminating many of the potential coding and keypunch placement errors that occur when a rigid format is required. An edit program helps correct format and content discrepancies.

Once the detectable syntax errors are removed, the data are correct in form and format. Unintentional misplacement of boundaries cannot be detected by the edit program. A line plotting program is used to reproduce the data set on acetate or translucent paper at the same scale as the original map. This overlay is placed over the input map for easy recognition of boundary placement errors.

3.2.1.1.2 COORDINATE DIGITIZER

The Remote Sensing Institute staff have developed the necessary software for supporting a Summagraphics coordinate digitizer and a standard video terminal as

a user station conversing with a Prime computer. The package of software contains programs for the interactive digitization of map lines,nodes and codes, the plotting of the digitized lines, the editing of line,node and code errors, and the conversion of the data files into a standard AREAS cellular data set.

The advantages of this data entry approach are the more rapid conversion of map graphics into computer format and the much higher resolution capability of the equipment. The table digitizer, for example, is capable of resolving line coordinates to the thousandth of an inch while manual grid encoding cannot surpass approximately one tenth inch.

3.2.1.2 IMAGE DATA

Digital image data can be incorporated into AREAS analyses in one of two ways. A standard digital image, single band, 8-bit pixels, with record length equal to the pixel width of the image, can be stored in a Sequential Access Method (SAM) type disk data file. This form is only used by AREAS as one of the data forms for the IMAGSTAT function.

A second form of image entry involves the conversion of the image to a thematic form by some classification or level slicing technique prior to the IMAGEIN function. This process will convert the image data into the compact sequential coding of AREAS and any AREAS functions can be applied as desired.

3.2.2 DATA MANAGEMENT

The data management functions (MAGSAV and MAGRST) enable the user to archive or restore AREAS data sets to tape and to disk, respectively. SUMMARY makes header information available to the user in printer format.

3.2.3 ANALYSES OF MAPS AND IMAGES

The AREAS system is primarily a map processing system, but there are functions which manipulate digital images.

3.2.3.1 MAP PROCESSING

Map processing functions can be grouped into categories of spatial manipulations (resolution and coverage) of the data set and map analyses (interpretations, overlays, inventories).

3.2.3.1.1 SPATIAL ATTRIBUTES

The spatial attributes of interest are the resolution of the cell in ground units and the region of coverage of the map. The resolution of the cell can be changed by the AREAS functions EXPAND and SHRINK with some judgement assistance from the BOUNDARY function in selecting the factor to be used. Maps can be joined by the MERGER function or smaller coverage regions carved out by the WINDOW function. A FILLER function is useful in using MERGER to assemble several map segments into one larger map when the total region is irregularly shaped.

3.2,3.1.2 ANALYSES

Once maps have been entered into AREAS and properly prepared in coverage/resolution, most resource management decisions can be improved through the use of one or more of the analysis functions. Inventory tables of the areal extent of resources can be generated by the TABULATE function. Maps can be generalized or simplified by the INTERPRT function. SUBSET is a quick INTERPRT function for the selection of a few specific themes from those present in an AREAS map data set.

The overlay of two or more maps is one of the most powerful functions (in comparison to the human capability to produce similar results). COMPOSIT provides this capability for two to four map overlay per execution. DIFFER is a special INTERPRT for use on the result of a COMPOSIT of two maps with like themes, such as two different years of land use categories. DIFFER reduces the composite output to matching and non-matching categories as would be done in a change analysis.

3.2.3.2 IMAGE PROCESSING

The first of the image related functions to be provided was the conversion of a standard 8-bit image form (raster data) into an AREAS compatible data set. This is useful only if the image has been reduced in some way to a set of homogeneous thematic polygons. IMAGEIN provides this capability.

GRAPHICS allows the user to build annotation and graphical data such as a legend in an image form. This must then be followed by the IMAGEIN function to allow further AREAS manipulation.

The only AREAS function which actually uses a digital image as one of the inputs is IMAGESTAT. This function uses the polygons outlined in an AREAS data set as the control for the calculation of means and variances in the corresponding spatial regions of a registered image data file.

3.2.4 PRODUCTS

An AREAS function applied to a map/image data set(s) can generate one or more of several forms of output products. These products differ in form, material, and purpose in relation to the device which produces the product. AREAS functions are present for accessing the following devices: line printer, drum plotter, film recorder, and video terminal.

A line printer always plays an important role in the operation of any software package. All AREAS functions which create or alter disk data sets also generate a report on the process for purposes of project record keeping. Furthermore, in AREAS there are also two functions which specifically generate analysis output for line printer display. These functions are the TABULATE and PRINTMAP functions. The output products are area tabulations with percentage breakdowns for a map data set and mapping using symbols to encode the polygon themes.

An information system for map analyses must have access to a pen plotter to provide the scale and aspect flexibility necessary for mapping results to the users specifications. In addition to the scale flexibility, the pen plotter usually offers the additional advantage of material alternatives, for example -

paper, mylar, ball point pens, felt tip pens, multicolor pens etc.

The Remote Sensing Institute is fortunate to have available an outside agency offering film recording services (the conversion of raster image matrices into color or black and white film transparencies). The AREAS IMAGEOUT program provides for conversion of map data less than 4096 rows by 4096 cells into a raster image compatible with most film recorders. This alternative is useful for producing report figures and slide materials, but is not a viable mapping technique due to scale and size limitations.

The users video terminal is of course necessary for operation of the AREAS system. It also can serve as an output display for processing reports and tabulation files prior to spooling (printing in hardcopy) at a more convenient time.

3.3 FUNCTIONS SUMMARY

The AREAS functions which were in place on the South Dakota State University, Brookings, South Dakota, campus IBM 370/148 at the start of the Land Classification and Soil Survey Project are summarized in Table 9-1.

4 ADAPTING AREAS TO THE PRIME 250

The task of converting the IBM AREAS package to the PRIME 250 will be reported by first reviewing some of the IBM implementation details. In a subsequent section the PRIME adaptation will be discussed in terms of the modified data base design, the adaptation of IBM programs, the improvement of functions and the addition of functions.

4.1 IBM IMPLEMENTATION

The initial concepts of AREAS were first tested and developed on an IBM computer. The design of the AREAS package and the operation of AREAS in the IBM environment will be reviewed.

4.1.1 DESIGN

The data base design and the approach to algorithm logic were considered the unique features which would make AREAS an improved cellular geoinformation processor. The primary goals for construction of a new package of software were to compress the data base and to make the operations more economical.

4.1.1.1 DATA BASE

The design of the data base required selection of the encoding technique for cellular data, decision on the storage method and design of record formatting.

Several encoding schemes for cell oriented data were well known at the time of the AREAS design. Complete encoding, sequential encoding and compact sequential encoding techniques are easily understood and the comparative

advantages readily recognized. Figure 9-2 shows a small, cellular map and the comparison of the three encoding techniques. Clearly the most conservative of storage is the compact sequential coding technique. This was chosen for the AREAS system.

The assignment of computer memory and storage to accommodate the compact sequential data encoding in Version 1 of the AREAS system was made on the basis of the availability of one, two, and four byte variables in the FORTRAN compiler on the IBM. Limiting the designation of row numbers and column numbers to half-words (2 bytes) allowed spatial grids of 65,536 elements square and saved 50% of the full-word (4 byte) standard FORTRAN integer variable.

Map themes which must be indicated at each column change point in a compact sequential encoding record, are usually alphanumeric rather than pure numeric. Arbitrarily defining a 4-character limit on these alphanumeric codes and placing them in a code table apart from the map records allowed a 256-code limit to define the map data entries in one byte. This clearly provides a 75% savings in the storage of the data themes within the map records.

Since the map complexity alone determines the length of a record and that complexity will vary from map region to map region, the records were made variable length on a record-by-record basis to meet the map requirements.

4.1.1.2 FUNCTIONS

The algorithms for various map processing functions were developed in the sequence of need during on-going resource management projects within the institute. For this reason the functions received applications testing immediately after development and were performance adjusted to the real needs of a resource scientist.

The logic of the functions was implemented in such a manner to utilize the compact sequential form of the data base. That is, there is no full-raster expansion of data records to simplify the coding of functions at the expense of I/O overhead in the function itself. This "compact-sequential logic" improves the function computations in a manner parallel to the improvement in storage requirements from compact-sequential coding. Both the computational improvements and the storage improvements are then a function of the map complexity.

4.1.2 AREAS OPERATION

The installation of the AREAS software in the IBM environment consisted of building a program library of compiled, executable modules which makes functions available for immediate execution, the building of a procedure library for the minimization of the preparation of JCL, and the preparation of a users guide to the parameter data formats and JCL necessary for operation of AREAS.

The operation of a project was assisted by the design of formatted data processing reports for each function which generates new data files. The reports had sections which were formatted for the hand record keeping of file names and tape numbers. The reports, if properly maintained, were a quick method to provide an audit trail for the data files generated in the course of a project.

These provisions for convenient operations and simple record keeping were considered important to the successful application of AREAS to a resource project.

4.2 PRIME INSTALLATION

The adaptation of AREAS to the PRIME 250 minicomputer required the following efforts (a) data base design changes, (b) adaptation of the FORTRAN programs to the operating system PRIMOS, and (c)changes in the AREAS functions which in some cases represented improvements of IBM functions and in other cases represented addition of capability.

4.2.1 DATA BASE DESIGN CHANGES

Changes in the data base design were made in (a) the contents of the header section and (b) the compression of the data records. The header section was expanded to include information about (1) the latitude and longitude of the map corners and map center, (2) a 10 level history table and (3) the units and calibration for the map cell. The space for the latitude and longitude was only allocated in the header but has not yet been incorporated into any of the processes other than DISPLAY and MODIFY.

The records of the actual map data lines were compressed into the minimum number of bits necessary to represent the number of rows, columns, and data codes actually present in the map being stored. The header information contains these extent parameters which makes subsequent programs aware of the decompression necessary for processing the map data records.

4.2.2 ADAPTATION OF IBM AREAS FUNCTIONS

One of the most significant changes in the AREAS functions during conversion from IBM to PRIME was the elimination of assembly language coding for the CARDSIN function and for the input-output subroutines which manipulate the map data records. The PRIME FORTRAN library contains functions for the manipulation of bits within data bytes. These functions were used to rebuild the CARDSIN function in FORTRAN and to create the PUTREC and GETREC subroutines in FORTRAN. Also to better facilitate operation in the PRIMOS segmented virtual memory processing, the larger data arrays were separated into common blocks apart from the executable code since these are stored and managed in different segments during virtual execution. Lastly, the IBM procedure library is most closely resembled by the establishment of PRIMOS level commands for each of the AREAS functions.

4.2.3 IMPROVEMENTS IN AREAS FUNCTIONS

Additional modifications in the AREAS functions might be viewed as improvements although in most cases the changes were necessitated by the PRIMOS environment.

Data definition for processing which is handled by the IBM method of Job Control Language (JCL) is facilitated by subroutine calls within the functions themselves on PRIME. Without JCL, the functions run by preparation of required parameter files and provision of the input file(s). The function will generate

the output file, if any, and a report file. At program execution time the user supplies the file names for required files (parameters, input, output, and report). Since all file names are known within the executing module, the data processing reports are automatically completed. This reduces the project record keeping to the task of binding the reports in proper sequence.

The longer running programs were separated into a batch category and an interactive program provided to assist the user in the preparation of the parameter data for the batch run. The shorter execution programs were simply modified to run interactively. All programs are, therefore, interactive, prompt driven which eliminates the need for a users guide book to define formats for parameters.

During the conversion of the functions the source language was inspected for the nesting order of DO loops which might result in excessive paging of data segments. In several cases speed of execution on the PRIME could be assured by reversing the sequence of manipulation of the double subscripted arrays.

Several AREAS functions were modified. TABULATE was improved to make use of the calibration information in the map data header records to determine the extent of a map cell and allow the user several choices of units for the output report tabulation. The SHRINK function was modified to be the equivalent of the IBM version functions AGGREGATE and SHRINK together.

PRINTMAP was heavily modified to make use of the plotting capability of the Printronix printer. Overstrike greytones from the IBM line printer were replaced with graphic symbols which would in most cases provide continuous patterns over adjacent, homogeneous cells. In the course of this development, the graphics cell aspect was corrected to a square of 6 plot dots in each dimension rather than the character density of most line printers which is 6 to 10 or 8 to 10 typically.

4.2.4 ADDITION OF AREAS FUNCTIONS

Several AREAS functions were outgrowths of the operation of AREAS in the PRIMOS environment. An AREAS command was added to provide the user with the overall menu of AREAS functions available. This improved the interactivity of AREAS in the PRIMOS environment and helped eliminate the need for a user guide book.

A DIFFER command was added to simplify the INTERPRT process in the case of a 2-layer composite of two maps having essentially the same data themes or codes. For example two successive years landuse might be overlaid for a change analysis and an INTERPRT to identify the matching and non-matching categories from the composite table would be a necessary step. DIFFER will take the 2-layer code table from a composite data set and automatically reduce the data set to two categories SAME and DIFF, respectively.

DISPLAY was added to provide a display formatted to the user terminal and containing the data set header information from an AREAS data set. This is essentially the same as the SUMMARY function except the user wants the result at the terminal for quick inspection and probably not for a printed final record.

With the expansion of the definition of the data base header record contents, came the necessity for the user to be able to modify certain of the entries which are not crucial to the ability of other functions to access the map data records. MODIFY allows the user to change the data set label, lat-long values, cell calibration, but not extent entries such as number of rows, columns, codes, or the code table itself.

A GRAPHICS command allows the user to process a pre-prepared graphics command file for the generation of a digital image containing titling, legend, or cosmetic lines. Such an image can be converted to AREAS format by the IMAGEIN function and subsequently merged or overlaid as desired with other AREAS map data sets.

A PLOT command was also provided to move the output file from the PLOTTER function to the plot spooler for transfer to the drum plotter. PLOT interactively requests information about the plot size and materials. This information is coded into the job name to enable the system operator to manage the plotter resources more effectively.

4.3 FUNCTIONS SUMMARY FOR PRIME/AREAS

The AREAS functions resulting from the PRIME adaptation of the IBM version plus the additions which were possible within the PRIMOS environment are listed in Table 9-2.

4.4 THE SOILS EVALUATION PROGRAM

In the 1:500,000 soils data base, the mapping units are comprised of differing proportions of unique soils with characteristic physical properties. The mapping of regions with distinct physical characteristics would be possible using the INTERPRT function of AREAS if the resource scientist would take the time to generate the interpretation recipe from the table of soil composition for each mapping unit and the table of physical properties of each soil.

Much of the work to prepare such an interpretation could be quickly and effectively done by computer. For this reason a special evaluation algorithm was written for the PRIME computer. The soils composition of each mapping unit was encoded into a table and stored in the computer as was a table of characteristics of each of the unique soils. The evaluation program was not installed in AREAS as a function since it is not general purpose to all AREAS data sets. It is specific to the soils data base for Syria and the mapping unit compositions in the 1:500,000 survey.

The EVALUATION program is an interactive program for selection of the desired properties of the soils in this particular data base. The properties tabled in the computer for reference in the EVALUATION process are listed in Table 9-3. Once a user selects a property, he is shown the number of distinct levels or divisions of the property which exist within the data base and the meaning of each. He may then also select a division or divisions of the property for mapping.

The algorithm scans the data base for soils which meet the criteria specified. Mapping units are also scanned to determine the percentage

composition within each unit which meets the criteria. The user is advised as to the number of different compositional percentages present and is asked how he would like to encode these as categories for mapping. He may elect to evenly subdivide the percentages 0-100 or he may specify the assignment of break points, especially if the compositional percentages do not distribute over the entire range 0-100.

A simplified, hypothetical example may clarify the process which is implemented in the EVALUATION program. Suppose that the AREAS map data base contains 5 mapping units labeled V, W, X, Y, and Z. Suppose further that among the discriminating factors which distinguish these mapping units from one another are the relative amounts of the 5 distinct soils aa, bb, cc, dd, and ee. The first compositional table describing the mapping units which is stored in support of the EVALUATION program would appear as follows:

	soil				
map unit	aa	bb	cc	dd	ee
V	.05	.05	.15	.25	.50
W	.20	.20	.20	.20	.20
X	.33	0	0	.33	.33
Y	.60	.10	.10	.10	.10
Z	0	.50	.40	.10	0

The second compositional table describing the physical properties of each of the distinct soils would appear as follows:

	property		
soil	salinity	permeability	alkalinity
aa	1	7	3
bb	1	3	1
cc	4	5	5
dd	2	2	2
ee	3	1	4

The code numbers in the property table are defined within the EVALUATION program. These numbers represent ranges or increments of values of the variable involved. For the above example, the definitions contained within the EVALUATION program are as follows:

	property		
code	salinity	permeability	alkalinity
1	0-4	2.00 - 6.25	0- 5
2	4-8	0.50 - 2.00	5-15
3	8-16	6.25 -12.50	15-30
4	over 16	0.125- 0.50	30-50
5	-	12.50 -25.50	over 50
6	-	below - 0.125	-
7	-	above -25.00	-

With these example tables defined, an example execution of the EVALUATION process can be described. The resource analyst enters the command SEG EVAL.SEG or whatever user abbreviation is defined to activate the compiled program EVAL.SEG. The process will set up an INTERPRT table for the standard AREAS process INTERPRT to run in batch mode. The EVALUATION program asks for a name for this batch job. It requests the name of the input data set (and immediately verifies that such a data set does exist). EVALUATION asks for the data set label to be installed in the output AREAS data set. It also requests the type of analysis. SOILS is the only correct answer at present although the program was designed to have alternate tables and characteristics eventually.

EVALUATION then lists the physical properties available in the data base tables,i.e. permeability, salinity, and alkalinity, and request that the user select one. If the user selects Salinity for example, the code levels for salinity and the corresponding ranges of conductivity are displayed to the user as follows:

Salinity

Code	E. C. (mmhos/cm)
1	0-4
2	4-8
3	8-16
4	16-

The user is then allowed to select a code or codes to be grouped to represent the characteristic desired. For example, if salinity less than 8 mmhos/cm is desired, then the codes 1 and 2 would be selected. When this selection is completed the EVALUATION process begins the systematic cross comparison of the composition table, soil characteristic table, and input AREAS soil data set.

The program process would begin by scanning the soil characteristics table for selected codes 1 and 2. This would indicate that soils 'bb' and 'dd' meet the desired criteria. Next the mapping unit compositional table would be scanned for mapping units with some portion of 'bb' and/or 'dd' present.

The program reports to the user the various unique percentages of mapping units which have the requested characteristic. In the above case this would be a report of percentages represented 20, 30, 33, 40, and 60 (units Y,V,X,W,Z respectively). The specification of the interpretation of the input AREAS soils data base is still not complete, however, since there are several different percentages of the desired property (salinity §8). Next, the program asks the user how many distinct groups he wants to preserve. The user is now faced with the decision of mapping one or several levels representing differing degrees of success in his search for the desired property. He might, for example, want to map those units where greater than 50% of the composition matches the selected range 0-8 mmhos/cm. Alternatively, he might wish to map all mapping units with differing codes showing the differing percentages of success in his search.

Let us suppose the latter is the case. He would then specify let us say 5 groups. The process will ask if he wants the groups evenly spaced throughout the maximum range 0-100%. If he allows this assignment, the process will break the range up 1-20, 20-40, 40-60, 60-80, 80-100 and the mapping units Y,V, and X will be output code 2, the unit W will be output code 3, and the unit Z will become output code 4. Note that this alternative grouped Y, V, and X together in the code group for percentages 20-40.

If the user does not allow even spacing of the percentage assignment to groups, he is asked to supply the breakpoints for assigning the codes. This alternative enables the judicious user to maintain the identity of every different percentage level of success in his quest for a particular characteristic. If he again requests 5 groups, he will be allowed specification for four breakpoints. These could be selected as 21, 31, 34, and 41 to make the ranges 0-21, 21-31, 31-34, 34-41, 41-100. Clearly the mapping units would each then fall in a separate output code which would be exactly known to the user.

Once the grouping is specified for the percentages, the INTERPRT table is generated. The user is asked to specify an output file name and the batch INTERPRT process is triggered to generate the AREAS data set with the requested property. A PRINTMAP or IMAGEOUT process could then be used to spatially display the location of the mapping units having 20%, 30%, 33%, 40%, and 60% of their soils with less than 8 mmhos/cm salinity.

If this example of EVALUATION processing is carefully studied, the user will recognize that the final mapping data set in AREAS compatible format contains some subset of the original data base soil mapping unit boundaries together with a code that indicates a likelihood of locating the desired property. Since compositional characteristics cannot subdivide the polygons stored for the mapping units, this is the best that can be accomplished from a knowledge of the properties of the soils comprising each mapping unit.

5 THE SYRIA PROJECT DATA BASE

In order to stimulate the use of the computerized information system capabilities and simultaneously make the resource data gathered in other project phases more useful to the Ministry, a project data base was created for delivery with the system.

5.1 SYRIA DATA BASE CONTENTS

The resource project maps of land use and soils were entered into an AREAS-compatible data base. Both were incorporated at a scale of 1:500,000 throughout the country and at 1:100,000 in selected settlement zones. The 1:100,000 maps were subdivided into sections for purposes of project atlas production. This resulted in 37 map sections for the three settlement zones. The zones were labeled A, B, and C with numbers designating the subsections of each for the atlas.

5.1.1 CELL SIZE SELECTION

The selection of cell size for the Syria data base was made based on consideration of the limitation of manual digitization and on the minimum mapping units which are to be represented in various scales of resource maps.

Experience with manual digitizing for AREAS had demonstrated that the maximum resolution which is reasonable to attempt with overlay gridding is one millimeter by estimating the sub-divisions of a 2 millimeter overlay grid. For the 1:500,000 scale maps this corresponds to 0.5 kilometers on the ground. Similarly the 1:100,000 scale was resolved to 0.1 kilometers on the ground.

Minimum size mapping units to be retained in resource surveys at various scales are established as mapping standards. For a 1:500,000 scale, the unit is 1000 hectares(2471 acres). For the 1:100,000 and 1:25,000 scales, the units are 40.5 ha (100 acres) and 4 ha (9.88 acres), respectively. If the unit were a square, the actual dimension on the map to be digitized would be 0.249, 0.254, and 0.315 for the three scales. To preserve the existence of such a mapping unit during digitization with a square cell, the cell must be smaller than 1/2 of this dimension. To preserve the ground location of a mapping unit is more demanding, and the errors introduced are on the order of 1/2 of the cell dimension. The 1 mm cell is 0.039 inches which is from 1/8 to 1/10 th the size of the minimum mapping unit according to mapping standards.

One half of this cell size results in placement errors of 812, 162.5, and 40.625 feet for the three map scales. In each case, the error is a map boundary shift on the map of approximately 2 hundredths of an inch.

Although a high resolution coordinate digitizer was employed to prepare the map data in AREAS format, a lower resolution cell was selected to simulate the cell size of the original project plan for manual digitization. This also assured that future map data to be entered in Syria by the manual technique could be directly compatible with the delivered data base.

5.1.2 THE 1:500,000 MAPS

The first resource map from the project activities available for digitization was the 1:500,000 soil survey of the entire country of Syria. Although the scale was small, the coverage of the map was broad and the document size large. Since the Summagrid table digitizer was not quite large enough for the entire map, the map was divided into halves for digitization. The two parts were digitized and editted separately and joined within AREAS. The experience with this approach revealed that it is better to divide large maps into smaller

segments to improve the turn-around time in computer edits and manipulations prior to the final merger into one map for the data base.

The 1:500,000 landuse map was received much later in the project and the digitization of this map was done on a basis of four pieces. This proved more manageable in the digitization and edit phases, especially with more than one operator handling the data.

Since the maps were digitized separately, the registry of common lines had to be done within AREAS. The country border was selected from each of the soils and landuse maps and the map overlay (COMPOSIT) and map generalization (INTERPRT) functions used to prepare a single national outline map representing the common area in the two input maps. The resulting outline map was used to adjust the outline in both the soils and landuse maps by again using overlay and generalization. The high resolution of the digitizer and ability of the operations staff were demonstrated by the error in the outlines of the two original digitizations (before correction) being a fraction of one percent.

Water bodies, lakes and reservoirs, could have also been adjusted into boundary agreement by overlay and the interpretation of the maximum combined areas. This was not done because the boundary disagreement was quite large, probably due to seasonal variation in the original data sources used in the project map preparation. With AREAS functions, these detailed adjustments can be carried out in Syria by complete replacement of data segments in the vicinity of lakes as deemed most appropriate by the scientists who will eventually utilize the data base. These techniques for update and correction are also useful in the continual process of urban change in the landuse data set.

The characteristics of the 1:500,000 scale soils and landuse maps after entry into AREAS are summarized in Table 9-4. The soils and landuse maps compressed into AREAS data sets require 147,120 bytes of storage to represent the 2,855,082 cells of land surface plus the auxiliary information. For this example, the AREAS data is compressed to 5% of the storage which would be required for the same data in a raster image form with one byte per cell.

The line drawings for these maps are presented in Figures 9-3 and 9-4, respectively.

5.1.3 THE 1:100,000 MAPS

The 1:100,000 maps arrived at RSI in composite form for digitization. After sectioning the three settlement zones into atlas-sized regions, the maps were prepared for digitization by assigning temporary categories to those polygons having complex soil/landuse combinations.

One digitization and edit cycle was then employed to get each composite map into AREAS format. The maps were digitized without adjacent map comparisons, scaling or line matching between maps to assure edge compatibility. There was no intention for the 1:100,000 maps to be joined into larger coverage blocks. If

this is attempted with the AREAS processing functions, one should expect discontinuities in polygons at the junctures of the map sections.

The AREAS function INTERPRT was then used to separate the two map types and restore the proper category labels to each. This technique assured complete agreement in the common boundary lines,ie. national boundary, cities, lakes, etc.

The 74 1:100,000 maps (37 of each type) may be identified by location relating to the Syria national border as shown in Figure 9-5. The 74 maps in AREAS format require 539,640 bytes of storage to represent the 9,887,122 cells of land surface. Again AREAS compression requires about 5% of the storage which would have been necessary to represent the same data in a raster image form with one byte per cell. The characteristics of the AREAS data sets for the 1:100,000 scale maps are summarized for reference in Table 9-5.

Examples of the detail in the maps at this scale are shown in Figures 9-6 and 9-7 for soils and landuse in the settlement zone labeled B-10.

6 THE INFORMATION SYSTEM/COMPUTER TRAINING

The necessity of training a Syrian scientist in the operations of the computer system and the geographic information software was recognized early in the formulation of the project concepts. Although a brief period of residency in Syria by a U.S. scientist for the purpose of installation and verification was provided in the project plan, there was no intent to burden the specialist with the extensive tasks of training Syrian scientist(s) in computer systems operation and information system techniques. A six month period of U.S. residence for the designated Syrian operator was proposed to accomplish these tasks prior to the delivery of the system and the arrival of the U.S. specialist.

The qualifications proposed for the selection of the Syrian candidate for training included English language capability and previous computer experience as an operator or programmer or preferrably both. Some difficulty was experienced in locating such a candidate, and RSI offered, at USAID request, a proposal to extend the U.S. residency by three months to allow for preparatory training in computers for a scientist with limited computer exposure.

The training phase of the project developed into a 7 month period. The intention was to utilize the additional month to sharpen the skills of a scientist who did not meet all of the qualifications outlined for the computer training.

The scientist selected for training unfortunately had no computer background. A general knowledge questionnaire was given to Said Sheikh Al Shabab on arrival for US training. He was asked to indicate knowledge or experience in the following areas: computer architecture, computer operation, computer programming, minicomputers, microprocessors, operating systems, algebra, differential equations, calculus, trigonometry, geometry or graphics and drafting. He indicated no experience in any of these areas. Additional questions about hardware, software, specific computer languages, mathematics and general computer terminology also elicited a response of no familiarity.

The extremely limited background of the trainee dictated that topics had to be added to the curriculum. An introduction of about two weeks duration was devoted to general computer systems. Two weeks of FORTRAN programming and two weeks of programming experience was added. This represented a reduction in the time spent on the geographic information system and computer system administration and should not be considered a remedy for inexperience in the remainder of the training. The training in all topics will be reviewed in the sections which follow.

6.1 GENERAL COMPUTER SYSTEMS OVERVIEW

Approximately the first two weeks were spent indoctrinating the trainee to computers. A combination of lectures, reading assignments, and written exercises was used to present the concepts of hardware, software, number systems, and computer access. Terminology was considered important because of the newness of the discipline to the trainee.

Hardware was discussed in terms of the major system components, the central processor (CPU), the arithmetic/logic unit (ALU), memory, and input/output (peripheral) devices. No details of the system architecture (busses, registers, channels, etc.) were presented since these would be too detailed for anyone other than a computer engineer, and these topics would not add to the ability of the trainee to be an effective user of the system. The overall intent was to stimulate an interest in the complex and powerful machinery contained within the computer cabinet.

Software was categorized into operating system, system utilities, and user or applications software. User languages were reviewed by names and typical applications purpose. The overall intent was to provide insight into the usefulness of software as the interface between the user with an application and the actual machinery.

Binary, Octal and Hexadecimal number systems were reviewed in reference to the decimal number system. Simple mathematics such as addition in each system were reviewed. The intent was to instill an appreciation for the means by which an "on-off" states machine could be designed to handle mathematics.

Exercises were provided for introduction to the technique for computer access. Logging in and logging out were explained. This served to remove some of the apprehension about touching the equipment. In addition, the EDITOR subsystem was taught to provide insight into the methods for entering user programs or data into the machine. Exercises with the editor rapidly reduced the difficulty of learning to communicate with a computer and the frustration of learning a keyboard layout and operation for the first time.

6.2 FORTRAN PROGRAMMING

FORTRAN language programming was taught over a one month period beginning with approximately two weeks of lectures and exercises in the purpose and performance of the various commands in the language. Several simple programs were provided to illustrate typical command useage and to provide familiarity with the entry of source language with the EDITOR and the compilation and execution of the programs. The latter two weeks were spent with program

assignments and actual programming, debugging, and program execution.

At the conclusion of the FORTRAN session, the trainee should have acquired an appreciation for the methods of using software to control the hardware and generate useful results. This training also served to clarify concepts such as source program files, executable files, data files, file directories, and interactive program execution---all of which would be contributary to the better understanding of the operation of the AREAS geographic information system software.

6.3 THE PRIMOS COMMANDS

Throughout the training various PRIMOS operating system commands were introduced as they were needed. From time to time commands which were felt to be potentially useful but not necessarily an integral part of the training topics were presented as a lecture and exercise to simply provide awareness and perhaps enough understanding to stimulate future use. Not all PRIMOS commands were taught as some relate to features which were not available on the Model 250. Those PRIMOS commands which were used or taught during the entire training period are collected in this section in Table 9-6 for ready reference rather than distributing them throughout discussions of the various topics.

6.4 AREAS OPERATIONS

Training in the features, applications, and operation of AREAS was a major objective of U.S. resident training in the total project plan. This training began in about mid-May. The two prior months spent on indoctrination to computers would have been easily handled in a week if the original trainee qualifications had been met. The last two weeks of May were spent in gaining a familiarity with the various AREAS functions and how to operate them. AREAS training was deliberately interrupted for the month of June to allow training in computer system administration and operation before resuming AREAS training in July. Approximately three weeks of July were then devoted to carrying out typical resource management projects using AREAS functions.

During the course of the four projects, the usefulness and hopefully the necessity of a project record book containing the processing plan in flow chart form and listings of file names was demonstrated. The intent of the projects was to provide experience in the analysis, manipulation, or editing of AREAS resource map data to obtain specific information for a resource management problem.

The organization and identification of files to allow a retrace of processing steps when unexpected results occur is necessary. This was the single lesson common to all four projects. The record keeping necessary for project organization was impressed and the usefulness of AREAS processing reports demonstrated. The magnitude of the file management task was observed through experience with the projects.

The projects were selected to demonstrate techniques for applying AREAS to achieve specific results. The first three were intended to show methods for the manipulating, editing, or registering of map data sets. The last was designed as a typical resource problem questionnaire to be answered by one or more AREAS

analyses.

6.5 COMPUTER SYSTEM ADMINISTRATION

Computer system operation and administrative tasks were reviewed. Discussion topics are summarized in the following paragraphs.

Line printer operations are controlled by a portion of the operating system called the SPOOLER. Commands for setting printer characteristics, controlling print tasks and observing the contents of the queue awaiting printing were demonstrated. Common actions for the operator are taking the printer offline, restoring online, dropping an active printout, and cancelling a waiting printout.

The BATCH processing system was studied. Topics included the definition and purpose of queues, the meaning of batch process, the setting of batch queue characteristics, monitoring job flow, holding and releasing jobs, aborting jobs, and cancelling waiting jobs. Commands for the user to observe job status were taught.

In the course of computer operations, two matters require regular, periodic attention. The first is backing up the system to magnetic tape to provide a reference for rebuilding the system in the event of a disk system failure or inadvertant file loss during processing. The second is the printing and purging of the system LOGREC for maintenance and performance reference. The former action protects system users from costly, time consuming loss of files. The latter keeps the system from consuming the disk space by converting the system log to hardcopy.

General operations tasks such as changing the ribbon or loading paper in the printer, removing plots or loading plotter paper or mylar, the location and replacement of hardware fuses, and the cleaning of the heads and drive rollers on the tape unit were demonstrated as the events occured in the normal course of operating the "250" for training.

6.6 TRAINING EVALUATION

The selection of a trainee without any prior computer exposure altered the content of the course and reduced the rate of progress through the material. A qualified trainee might have been expected to learn enough of the data base design and implementation technique of AREAS to be able to modify or add to the functions in the package. Likewise, an experienced trainee might have been able to more thoroughly understand the techniques and motivations for management of the system.

With the time and background available, Said Sheikh Al Shabab is to be commended on his enthusiasm and effort in absorbing a significant amount of material in a new discipline. He has achieved a reasonable knowledge of the capabilities of the AREAS system; he knows how to operate the functions; he knows some of the procedures for startup, operation, and shutdown of the computer.

Although he completed training in FORTRAN programming, that training was academic and superficial compared to the intricacies and details built into the

AREAS system. He should not be expected to change the software or add capabilities to AREAS. He can operate and advise on application of AREAS.

Although exercises, reading, and demonstrations covered many topics of system management and operations, most of these topics will fade quickly from his understanding without the background to form a frame of reference or the continual day-to-day experience with actual use. The training period was too short to use the latter approach to install systems administration knowledge. Most PRIMOS commands which assist in system administration were only demonstrated a few times and covered in one or two exercises. There were no exercises which he did not complete, but there is much question about retention of knowledge or sufficient understanding to enable recall of the appropriate steps in a given situation. In the latter days of residency, there were several occasions of non-recall of material which had been covered some weeks earlier. This again is not a lack of effort during training, but mostly a lack of background to enable perspective and retention.

The background of the trainee warranted a much more extended training period to build a complete framework including understanding of computers. It is hoped that sufficient knowledge is retained through the time lapse from the end of training until the actual computer installation to enable Said to effectively demonstrate the geographic information system concept and produce products from the data base.

7 RECOMMENDATIONS

This section is primarily devoted to recommendations to the Syrian Ministry of Agriculture on the geographic information system. The data base, the training and staffing of the computer lab, the relationship with the National Remote Sensing Center, and the anticipated system upgrades are discussed.

7.1 DATA BASE

No matter how sophisticated the processing capability may be, the quality and usefulness of the products it provides to the resource managers will depend on the quality of the data base which is being processed. The data base delivered with the project is limited and serves to assist the Ministry in evaluation of the processing capabilities of the system. Data base maintenance and upgrades will be necessary to keep the entire system useful to the Ministry.

7.1.1 MAINTENANCE

Natural resource management data may be relatively static or fixed with time such as soils or topography. It also may be dynamic or changing with time such as land use. Clearly the dynamic data in a data base will require constant update by either complete re-entry at regular intervals (land use each year or 5 years) or by update of the existing data in regions of significant change (editing urban boundaries). Even the data which was considered static at the time of entry into the data base may require changes as the accuracy is improved through better survey techniques. For these reasons the data delivered with the system cannot be considered complete. A maintenance effort must be recognized and established to keep the data useful.

7.1.2 UPGRADES

Experience with the system and the resource managers information requirements will direct the course of development of other data layers in the information system. Natural and artificial region boundaries such as drainage watersheds and political management zones, respectively, may be examples of added information necessary to address the management questions of interest.

Other forms of data such as point, line and network data may eventually become important as the information system itself is expanded (see sec. 7.4). Improvements in future releases of AREAS or the acquisition of alternative information system capabilities will determine the choices in expanding the data base contents.

7.2 TRAINING AND STAFFING

Although a trainee has been exposed to systems administration and computer programming as well as the operations of the geographic information system, because of his limited background the training should not be considered adequate to expect continued development of AREAS software nor any hardware maintenance. The matters of lab operations, systems development, and systems maintenance are discussed further.

7.2.1 OPERATIONS

The PRIME 250 computer was selected to meet a single user information processing requirement. Although the PRIMOS operating system is multi-user, the installation should not require a particular individual to be a full time operator. As the number of users attached to the system grows, it will become more important that one individual either work at the console or at a terminal in close proximity to the system to handle mounting tapes and preparing plotter pens and paper for remote users. With an increase in users, there will also be a more rapid consumption of printer paper. One operator removing printouts will reduce the number of printer check errors and avoid congestion around the printer during operating hours.

7.2.2 DEVELOPMENT

To accomplish any other tasks than those installed on the system at delivery, will require personnel with computer training. The number of programmers and system analysts will be dependent on the variety of new developments desired and the availability of those needed improvements in the software market. The geographic information system as installed does not include all analysis capabilities of the current state-of-the-art, large scale geographic information systems. There will certainly be ideas for integrating new data types and adding new analyses to the system. The AREAS package is delivered in source form as well as executable form and personnel with some experience in programming the PRIME may be capable of modifying existing software. With some training in the data base design, these people would also be in a position to attempt development of added features.

If these types of activity are desirable to the Ministry, it will be necessary to hire at least one full time systems programmer to be devoted to

development. Developmental work does not interleave well with being the single operator of the geoinformation system. Development and operations duties could be shared if the operations duties are only of a console overseer nature (outside users running the day to day processing). This approach, however, would place an over-qualified individual in the operators position.

7.2.3 MAINTENANCE

The capability to maintain the hardware will require a totally different background. A technical knowledge of the architecture of computer systems and the procedures for troubleshooting and servicing electronic equipment is absolutely necessary. The decision to place an individual within the Ministry for maintenance must be carefully made. Although maintenance contracts are expensive, they do assure the availability of people with proper experience on the particular equipment involved. They are also in the field from day to day keeping informed of the idiosyncrasies of the equipment. Furthermore, under a contract there is an implicit priority on access to the available spare parts.

A maintenance person on staff will not be kept very busy with one system. Preventive maintenance (cleaning and filter changes) will probably be done no more frequently than once a month if the lab is properly environmentally controlled. System failures will likely be months apart, and it may be years before the exact same malfunction occurs, allowing the benefits of previous exposure to the problem.

7.3 NRSC INTERFACE

A USAID/SYRIA grant (no.276-0041) was made to assist the development of a National Remote Sensing Center, NRSC. SARG has established a National Remote Sensing Committee and the facility will be in Damascus. The similarities of interests in technical capability and data should be recognized and exploited by establishing some working relationship.

7.3.1 SOFT

A soft interface refers to the exchange of information in printed or magnetic tape form via mail or courier service. This is the least expensive approach and is adequate for the sharing of data files and comparison of similar or complimentary analyses at each agency. The Prime MAGNET utility will generate magnetic tapes in an industry standard compatible with essentially all computer systems. This makes the soft interface technically possible immediately upon installation assuming the relationship between agencies has been established.

7.3.2 HARD

A hard interface refers to connection of the agency computer systems by some direct communications method such as a private cable or through telecommunications. This is more difficult to establish and more expensive to operate. This does offer the potential for each system to access the other for complimentary processing capabilities. Unless the computer systems are manufactured by the same company, the communications directly via networking will require special software which may already exist within either of the vendor companies or it may require development on one of the systems to become

subordinate to the other. Such a technique may also involve more complex and formal agreements between the agencies to control the use of system resources at each facility.

7.4 SYSTEM UPGRADES

The continued viability of the geographic information system will depend also on the efforts to upgrade the hardware and software to improve the capabilities of the system.

7.4.1 HARDWARE

The Ministry will need to add an additional .5 Megabytes of main memory to the P250 to support the batch operations of AREAS simultaneously with data entry/edit. Certainly this memory will become a necessity in the event additional users are given terminal access to the system. This acquisition will be the most critical to the proper performance of the minicomputer under a growing work load. This includes load due to batch and phantom jobs running concurrently with the interactive user. The anticipated delays in processing paperwork to accomplish this acquisition should be taken into account and allowed for in the timing of the request.

The next most likely addition to be anticipated would be disk space. This will become necessary with the growth of the data base, the addition of users, and particularly the addition of processing capability such as digital image processing.

Another significant improvement in the operational performance of the system as a geographic information processor would be the addition of a coordinate digitizer for high resolution graphics and map data entry. RSI personnel have developed the software for such a data entry technique, and the acquisition would be rapid and inexpensive if the proper hardware were acquired.

7.4.2 SOFTWARE

The Ministry of Agriculture is advised to maintain contact with the Remote Sensing Institute in order to obtain future releases and upgrades of the AREAS system. These releases would be provided at transfer cost (media and shipping). RSI can also provide training in programming or systems analysis and development to properly qualified scientists.

The Ministry is also advised to evaluate other commercial software capabilities in conjunction with anticipated resource management information requirements. There is, for example, available software for both polygon and grid cell processing of resource data from Environmental Systems Research Institute in Redlands, California,USA. Said Sheikh Al Shabab was exposed to the capabilities of the ARC, GRIDS and TOPO software packages during a training inspection trip. This system is available for license and is supported for installation on PRIME hardware.

Table 9-1 IBM AREAS Functions at Project Startup

ADJACENT	- reports which codes adjoin spatially
AGREGATE	- adjust boundaries to simulate fewer (larger) cells
BOUNDARY	- inter-boundary distance analysis
CARDSIN	- create an AREAS data set from manually encoded card images
COMPOSIT	- Overlay 2 - 4 maps into one map
DELETE	- discard an AREAS data set
DISTAP	- Disk-to-tape archive operation
EXPAND	- adjust boundaries to simulate more (smaller) cells
FILLER	- generate a dummy, single-code data set for use with merger
GRID	- generate rectangular cell grids on mylar for input overlay
IMAGEIN	- convert a thematic digital image to an AREAS data set
IMAGEOUT	- generate a digital image from an AREAS data set
IMAGSTAT	- statistics for image regions are calculatred based on an AREAS map defining the regions
INTERPRT	- tabulate map areas or redefine themes
LISTING	- line printer list of the map data lines
MERGER	- join up to 5 maps at ends or edges
PLOTTER	- generate a Calcomp drum plotter data set
PRINTMAP	- line printer overstrike mapping to shade polygons
SHRINK	- companion to AGREGATE to reduce the rows and columns
SUBSET	- to select a subset of map themes and combine all others
SUMMARY	- to report map indentification data from an AREAS data set
TABULATE	- generate area tables (inventory)
TAPDIS	- tape-to-disk data set restoration
WINDOW	- extracts a smaller rectangular data subset

Table 9-2 AREAS Functions Implemented on PRIME

A	list the AREAS history table definitions
ALISTING	list the change point information for an AREAS data set
AREAS	display AREAS commands/descriptions
BOUNDARY	interboundary distance analysis
CARDSIN	create map data set from a cardimage file
COMPOSIT	overlay 2 to 4 maps into one data set
DIFFER	automatic INTERPRT of 2 level composite map with matching code tables/different boundaries
DISPLAY	display map data information at the terminal
DISTAP	disk to tape copy replace by MAGSAV
EXPAND	cell size change, more, smaller
FILLER	generate a dummy, singlecode map for use with merger
GRAPHICS	generate a character image for IMAGEIN
GRID	generate a plot file for a cellular grid
IMAGEIN	convert a thematic image to AREAS format
IMAGEOUT	convert an AREAS data set to image format
IMAGESTAT	means and vars. of image regions based on the AREAS data set polygons
INTERPRT	reassign or group data codes in a map data set
MERGER	join up to 5 data sets spatially at the ends or edges
MODIFY	change certain entries in the map data set headers for an AREAS data set
PLOT	spool plotfiles to the plotter
PLOTTER	convert an AREAS data set to plotter instructions
PRINTMAP	line printer mapping via dot matrix patterns within polygons
SHRINK	cell size change, fewer, larger
SUBSET	select a subset of map codes for continued analysis
SUMMARY	generate a summary of data set header information
TABULATE	generate area tables, an inventory of resources
TAPDIS	tape to disk replaced by MAGRST
WINDOW	select a spatial subset from a map

TABLE 9-3 THE PROPERTY CHOICES FOR SOILS EVALUATION.

TOPOGRAPHY	SOIL DEPTH
SURFACE TEXTURE	SUBSOIL TEXTURE
SOIL DRAINAGE	WATER TABLE
FLOODINGS	SALINITY
ALKALINITY	SURFACE GRAVEL
SUBSURFACE COARSE FRAGMENTS	SURFACE STONINESS
ROCKINESS	WATER EROSION
WIND EROSION	PERMEABILITY
SOIL REACTION	

Table 9-4 The 1:500,000 Data Base.

Map Type	rows	columns	codes	area (SQKM)	file size (bytes)
Land Use	1173	1217	8	356,885	82,640
Soils	1173	1217	109	356,885	64,480

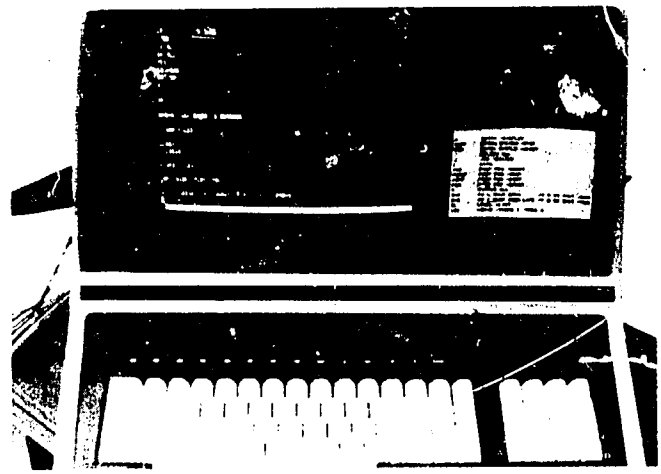
Table 9-5 The 1:100,000 Data Base.

Map ID	Map Extents			Land Use		Soils	
	rows	cols	area (SQKM)	codes	file size	codes	file size
A01	320	419	1340.80	10	8072	10	7870
A02	320	419	1340.80	9	7368	7	6792
A03	319	419	1336.61	6	7222	7	6348
A04	320	419	1340.80	8	8488	8	6974
A05	319	419	1336.61	5	4914	4	4428
A06	319	419	1336.61	8	9430	8	7718
A07	319	419	1336.61	6	4474	5	4090
A08	320	419	1340.80	7	6770	9	7052
A09	319	419	1336.61	7	7454	6	7210
B01	320	419	1340.80	6	8484	5	5742
B02	320	418	1337.60	7	5944	7	5220
B03	319	420	1339.80	8	9228	8	7336
B04	320	419	1340.80	7	10518	9	9304
B05	319	419	1336.61	8	8544	11	7796
B06	320	419	1340.80	6	11704	7	11324
B07	319	419	1336.61	10	11696	8	7542
B08	319	419	1336.61	7	10480	10	9292
B09	319	419	1336.61	7	6792	9	7708
B10	319	419	1336.61	10	13748	13	9470
B11	319	420	1339.80	7	8886	9	7464
B12	319	420	1339.80	4	10148	9	9448
B13	319	419	1336.61	9	10152	7	4828
B14	320	419	1340.80	6	7672	12	9226
B15	319	419	1336.61	9	12852	6	5120
B16	319	419	1336.61	8	9828	12	8824
B17	319	420	1339.80	10	9318	10	7624
B18	319	419	1336.61	7	6838	11	6320
B19	319	419	1336.61	8	10286	8	8876
C01	319	420	1339.80	2	3776	3	3792
C02	319	419	1336.61	4	3708	4	3708
C03	319	419	1336.61	6	5692	6	5124
C04	319	420	1339.80	5	5762	4	5472
C05	319	419	1336.61	6	6118	7	6388
C06	319	419	1336.61	6	5462	8	5872
C07	319	419	1336.61	4	3614	7	3552
C08	320	420	1344.00	4	3864	5	3752
C09	319	419	1336.61	5	4820	6	5008

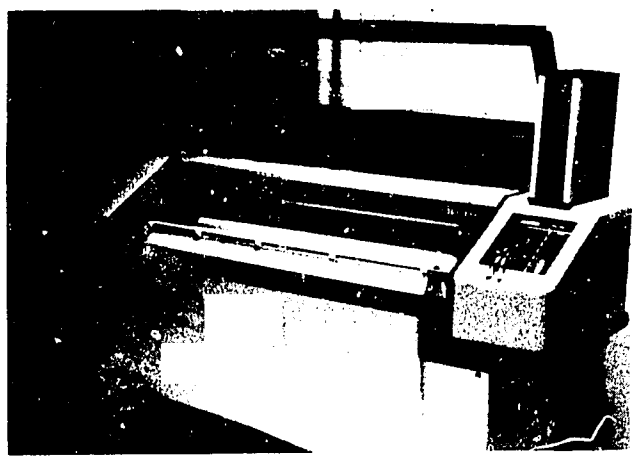
Table 9-6 PRIMOS User Commands Listing.

AB	to create and use abbreviations for PRIMOS commands
AS	to assign a device such as a tape drive for personal use
A	to attach, to make another ufd the working directory
AVAIL	to display the disk usage statistics
BASIC	to execute a BASIC language interpreter
BATCH -DISPLAY	to check the status of the batch queues and jobs in the batch subsystem
C	to close files or file units left open from a previous job
CN	to change the name of a file or directory
CO	to read command input from a file instead of the terminal
COMO	to keep a session history in a named disk file
CREATE	to build a new ufd or sub-ufd directory
DATE	to display the current date and time
DELETE	to discard a file or empty directory
ED	to invoke the EDITOR for creating or editing files
FTN	to invoke the FORTRAN compiler
FUTIL	to invoke the file utility program for manipulating, moving and/or, protecting files
JOB	to submit a job to the batch processor or monitor status
L	display the directory, file names, owner/nonowner status and sub-ufds
LOGIN	initiates a user session by attaching a user to a specified ufdname
LO	terminates a user session
MAGNET	initiates the interactive magnetic tape utility for non PRIME format transfer of files to/from disk
MAGRST	restores files, directory-trees or partitions from a magnetic tape created with MAGSAV
MAGSAV	writes a PRIMOS disk file, directory-tree or partition to magnetic tape
PASSWD	changes the owner and non-owner passwords of the current directory
PROP	tells the user which printers and plotters are running and describes the environment for each
PROTECT	sets the protection rights for owners and non-owners for the specified file
R	resumes execution of an r-mode program
RUNOFF	invokes the text processor
SEG	executes a v-mode program
SIZE	displays the size of a specified file in normalized words
SLIST	print the file contents at the user terminal
SPOOL	transfers disk file/s to the printer queue for scheduling
STAT	displays information about devices, file units and users
TIME	displays connect time and compute and disk IO times
UN	unassigns a device from user access

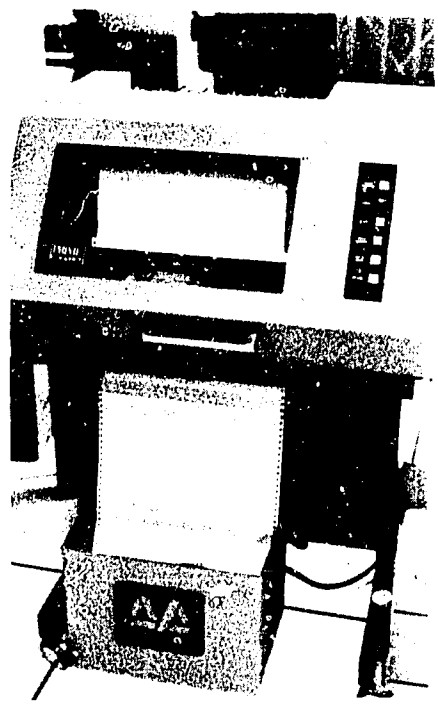
(a)



(b)



(c)



(d)

Figure 9-1 The PRIME 250 Hardware and the Houston Instruments Plotter. (a) the CPU,Disk and Tape units, (b) the Control Console, (c) the Plotter and (d) the Printronix Printer.

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] :B: ] : : : : : : : : : : :
-------.....................---
]A: ] : : : :C: : : : : : ] ]
.............................
] : ] : : : : : : : : : : ] ]
-----.............--------...
] : : : : : : : : ] : : : : ]
.............................
] : : : : : : : : ] : :D: : ]
-----------------------------
```

(a) gridded cellular map

1,1,B,1,2,B,1,3,B,1,4,C,1,5,C,1,6,C,1,7,C,1,8,C,1,9,C
1,10,C,1,11,C,1,12,C,1,13,C,1,14,C,2,1,A,2,2,A,2,3,C,
2,4,C,2,5,C,2,6,C,2,7,C,2,8,C,2,9,C,2,10,C,21,11,C,2,
12,C,2,13,C,2,14,D,3,1,A,3,2,A,3,3,C,3,4,C,3,5,C,3,6,C
,3,7,C,3,8,C,3,9,C,3,10,C,3,11,C,3,12,C,3,13,C,3,14,C,
4,1,C,4,2,C,4,3,C,4,4,C,4,5,C,4,6,C,4,7,C,4,8,C,4,9,C,
10,D,4,11,D,4,12,D,4,13,D,4,14,D,5,1,C,5,2,C,5,3,C,5,4
,C,5,5,C,5,6,C,5,7,C,5,8,C,5,9,C,5,10,D,5,11,D,5,12,D,5,
13,D,5,14,D

(b) complete coding

B,B,B,C,C,C,C,C,C,C,C,C,C,C
A,A,C,C,C,C,C,C,C,C,C,C,C,D
A,A,C,C,C,C,C,C,C,C,C,C,C,D
C,C,C,C,C,C,C,C,C,D,D,D,D,D
C,C,C,C,C,C,C,C,C,D,D,D,D,D

(c)sequential coding

1,1,B,4,C
2,1,A,3,C,14,D
3,1,A,3,C,14,D
4,1,C,10,D
5,1,C,10,D

(d)compact sequential coding

Figure 9-2 Coding Options for Cell Oriented Map Storage.

Fig. 9-3 Line Drawing of the 1:500,000 Soils Map Data

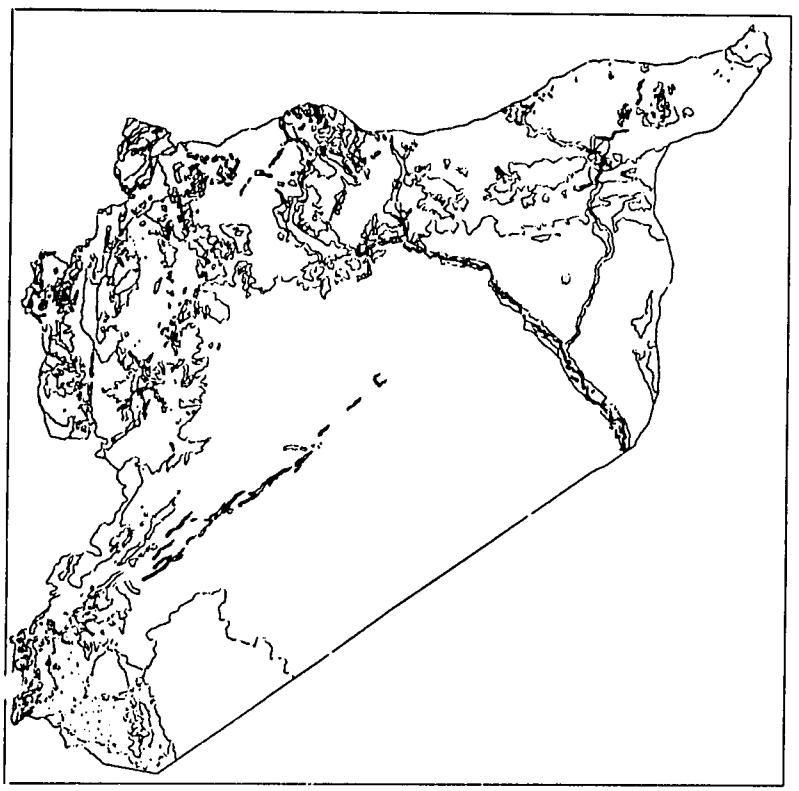

Fig. 9-4 Line Drawing of the 1:500,000 Landuse Map Data.

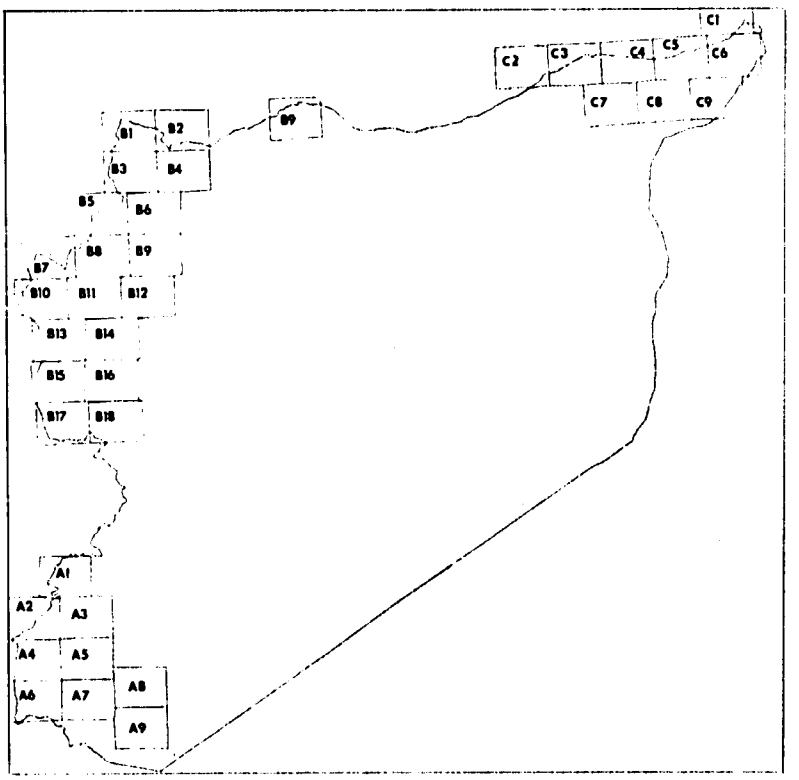

Fig. 9-5 Location Map for the 1:100,000 Map Data Sets.

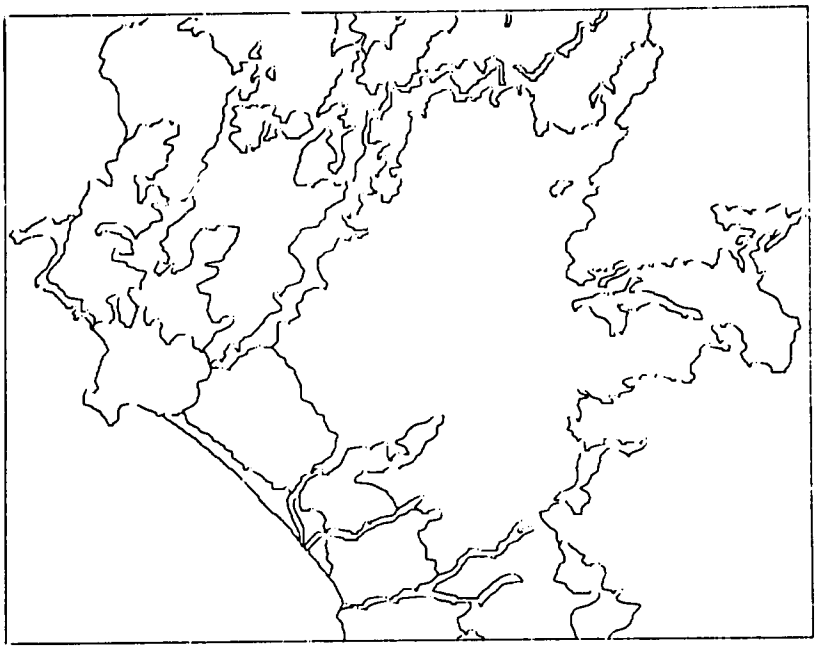

Fig. 9-6 Line Drawing of the 1:100,000 Soils Map in Settlement Zone B-10.

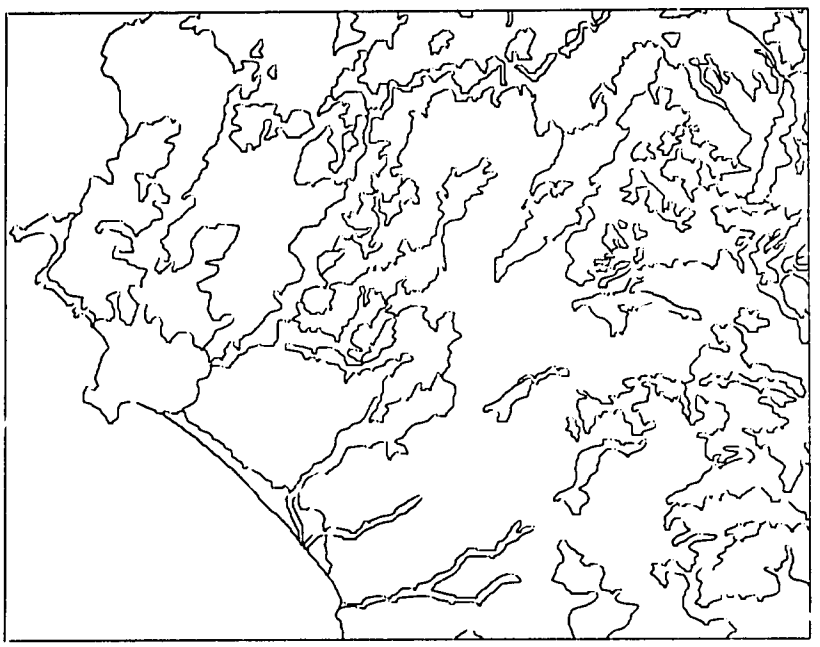

Fig. 9-7 Line Drawing of the 1:100,000 Landuse Map in Settlement Zone B-10.