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Final Report

ECUADOR LAND TITLING PROJECT

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PART I. PREPARATION OF RURAL CADASTRAL MAPS

A. INTRODUCTION

The basic topographic maps covering Ecuador at scales of 1:250,000 and 1:100,000 provide the framework for compiling and indexing basic rural cadastral maps of the entire country at 1:10,000 scale. These in turn provide the framework for compiling and indexing special larger scale cadastral plans of selected areas.

1. FORMATS

The 1:250,000 scale topographic map sheet encompasses an area of 1° of latitude by 1° of longitude, which is divided into six 1:100,000 scale map sheets, each covering 20' of latitude by 30' of longitude. The 1:100,000 scale map sheets are then divided into one hundred cadastral maps at 1:10,000 scale, each covering 2' of latitude by 3' of longitude.

2. INDEXING

a. The basic index number comes from the 1:250,000 scale map sheets, which in Ecuador are identified from West to East starting with the letter "M" and from North to South starting with the roman numeral I. Thus, a typical index number would be NIV.

b. The six 1:100,000 scale topographic map sheets within each 1:250,000 scale map sheet are numbered from A to F as follows:

A - B
C - D
E - F

Thus, a typical index number of a 1:100,000 scale map would be NIV-B.

c. The cadastral maps at 1:10,000 scale are numbered from 1 to 100 within each 1:100,000 map sheet, from left to right (West to East) and from the top to bottom (North to South). Thus, a typical 1:10,000 scale map index number would be NIV-B-23.

d. In order to provide uniformity in the numbering of the 1:10,000 scale rural cadastral maps, the roman numerals are converted to arabic numbers and the 1:250,000 and 1:100,000 scale indexes are grouped together. Thus, NIV-B becomes

N4B. Two digits are used to number the 1:10,000 scale maps, starting with 01 and ending with 00, which represents 100. Thus, the rural cadastral map index number has five digits, such as N4B-23.

3. CALCULATING COORDINATES

a. General Description

By knowing the NW coordinate of the 1:250,000 scale topographic map sheet number MI, or of any other 1:250,000 scale map sheet, it is possible to calculate the coordinates of any 1:10,000 scale cadastral map simply by following the subdivisions of 20' x 30' and 2' x 3'.

b. 1:100,000 Map Coverage

The 1:100,000 scale topographic maps are (for the most part) available. The easiest and most practical method for numbering the 1:10,000 scale rural cadastral maps, and for calculating the coordinates that correspond to each one, is to construct a transparent overlay of a 1:100,000 scale topographic mapsheet which is divided into 3' intervals (10 units) from West to East and into 2' intervals (10 units) from North to South, and to number the resulting square from 01 to 00 (is 1 to 100) as explained above. Since the geographic coordinates are shown on the four corners of each 1:100,000 scale topographic sheet, it is a simple matter to determine the coordinates of any of the 1:10,000 scale maps units within that sheet.

B. PROPOSED MAPPING SYSTEM

1. GENERAL

As explained in Part III, the rural land parcels will be identified and delineated on actual photographs at 1:20,000 scale, with special areas of "minifundios" being delineated on photo enlargements of varying scales. It is proposed to use a computer automated photogrammetric mapping system to transfer the field data from the annotated photographs and enlargements to the cadastral map sheets. The proposed system will digitize the land parcels and pertinent land features and produce hard copy or immediate use for land titling purposes.

2. DIGITIZED DATA

The digitized data will provide the framework for a multi-use geographic information system and for future cadastral maintenance.

3. MAPPING OPERATION

The mapping operation will be carried out in two phases: the first phase involves all activities related to aerial triangulation and adjustment, and the preparation of "plot sheets"; the second phase involves the actual stereo digitization of the annotated photographs as they are received from the field.

4. STYLE SHEET AND MARGINAL INFORMATION

A special style sheet and marginal information has been designed for this project.

The preparation of the map sheets will be done by the project mapping sections independently of the photogrammetric phase. This section will be responsible for assigning the overall parcel cadastral numbers.

C. SUPPLEMENTAL MAP CONTROL (SMC)

1. GENERAL

Ecuador has an extensive First Order Triangulation Net and second and third order Supplemental Map Control Net which has been developed over the past thirty years by bilateral mapping agreements between the United States Government (Defense Mapping Agency - Inter American Geodetic Survey) and Ecuador.

2. AVAILABLE SUPPLEMENTAL MAP CONTROL

The area to be mapped by IERAC is well covered by this SMC net and any additional control that is needed can readily be obtained.

The symbols used in SMC are universally used and are repeated here for project personnel who are not familiar with them.

3. SMC SYMBOLS

HVPP	$\boxed{0}$	Horizontal/vertical picture point, identifiable on an aerial photo.
VPP	0	Vertical picture point, identifiable on an aerial photograph.
BM	X	Benchmark vertical elevation established on a level line survey, not necessarily photo identifiable.
	△	First order control point, initial ground survey point used to establish primary control net. Not necessarily photo identifiable.

4. ACCURACY REQUIREMENTS

Accuracy requirements call for second (2nd) order (see Table 1).

Standard SMC methods will be used to acquire any additional control that may be required.

D. AERIAL TRIANGULATION AND BLOCK ADJUSTMENT

1. GENERAL

Present Aerial Triangulation capabilities within Ecuador preclude the use of a purely analytical system of aerial triangulation; however, a semi-analytical system using "INDEPENDENT MODELS" and appropriate computer software programs can achieve the desired accuracy required for the compilation or the rural cadastral maps. The area to be mapped will be divided into blocks so that the best mathematical solution and most economical use of ground control can be attained. Block sizes will vary from 200 to 400 models (or larger) within the project area.

2. SIZE OF PROJECT AREA

The project aera is estimated to be about 40,000 km^2.

3. AVAILABLE 1:10,000 MAPS

The Instituto Geografico Militar (IGM) recently has completed 190 sheets at 1:10,000 scale covering approximately 10,000 km^2, which are available to IERAC for its initial phase of field work in an area north of Guayaquil. (See Attachment A for this coverage.)

TABLE 1

MAXIMUM ERROR OF CLOSURE IN PROJECT CONTROL SURVEYS

Order of Accuracy	Unadjusted Horizontal Distances	Unadjusted Horizontal Angle's			Unadjusted Vertical Distances (ft. or mm)
		Travelers	Triangle Closure		
			Average	Maximum	
Second	1:10,000	(10sec.) $\sqrt{N}$	3 seconds	5 seconds	(0.035 ft.) $\sqrt{M}$ (miles) (8A mm) $\sqrt{K}$ (Km)

4. SIZE OF AREA REQUIRING AERIAL TRIANGULATION

It is estimated that it will take 5,500 models to cover the remaining 30,000 km^2 within the project area, which will require a minimum of 28 blocks of 200 models (ideal situation) to complete the project. The control plan will be developed from the available Supplemental Mapping Control (SMC) and first order triangulation net. Since the present control was not designed for computer block adjustments, it is believed that the majority of this control will not be used for the block adjustments. The existing SMC information has been requested from the IGM but to date has not been received. Therefore, it is estimated that at least 450 new control points will have to be established in order to control the aerial triangulation blocks.

5. LOCAL PRIVATE PHOTOGRAMMETRIC COMPANY

The Project proposes to contract a local photogrammetry mapping firm to do the SMC, the aerial triangulation and adjustment, and the stereo-digitizing/compilation of the rural cadastral maps. The system has been designed to accomplish the aerial triangulation simultaneously with the SMC field work, as this type of aerial triangulation (independent models) allows for a resetting of the triangulated models at a latter date when field control becomes available. Preparation of the aerial triangulation process will be conducted in the classic method of selecting pass points and locating all available control, which will then be pugged (pricked) onto the aerial photo film diapositives, using an instrument called a "pug point transfer device". The company doing the triangulation will have the option to use either the 40 or 60 micron drill size, as either will give the required accuracy desired. The use of the "pug" instrument is mandatory.

The contact photos will have the location of the pug point located within the square that is drafted onto the contact photo but will not have a pugged (pricked) mark on the contact photo, this drilled pug mark will only appear on the film negative.

Upon completion of the aerial triangulation phase, a computer program will adjust the block. The final computer values will be furnished as a printed listing of coordinates and elevations, and at the same time they will be plotted on a stable mylar (004") base material. The corresponding 2' x 3' format corners will be indicated on this "plot sheet" or "compilation manuscript".

6. COMPARISON OF FULLY ANALYTICAL AND SEMI-ANALYTICAL METHODS

A comparison or accuracies using fully analytic verses semi-analytic methods are shown in Table 1.

7. PREPARATION OF SEMI-ANALYTICAL SMC PLAN

The preparation of a semi-analytical control plan is illustrated in attachment B.

8. PASS POINT PROCEDURE

The procedure for selecting pass points is explained in attachment C.

9. DATA PROCESSING FOR BLUNDER ERRORS IN AERIAL TRIANGULATION

Local private photogrammetric companies were visited and their computer program for semi-analytical aerial triangulation were reviewed. They are using the "shuts" software program which has been in use for many years. This program has a blunder program which was especially designed for semi-analytical aerial triangulation. Several examples of adjusted aerial triangulation blocks were reviewed and blunder errors were readily identified. This program can also be easily reprogrammed to indicate blunders of less magnitude as your accuracy requirements change.

E. PROCEDURE FOR STEREO DIGITIZING CADASTRAL INFORMATION

1. STEREO PHOTOGRAMMETRIC EQUIPMENT

The stereo digitizing will be accomplished by Kern PG-2 or comparable equipment which will also furnish a hard copy product.

2. PHASE 1. STEREO DIGITIZE PLANIMETRIC INFORMATION

The initial phase will be to stereo digitize all planimetric data that will be used in the cadastral survevy as reference points. This planimetric data will be coded so that it can be recalled. For example roads may start with the general coded input value of 301---, and the particular located value of 30111. This coding system will be developed by a computer programmer so that all required roads within a map sheet shall be properly identified. Road widths will be furnished on the field classified photos so that double-line roads can be drafted, without fill, when applicable. This is required as public domain limits which will be indicated on cadastral maps.

3. PHASE 2. STEREO DIGITIZE DRAINAGE

The secondary phase will be to digitize drainage that has been identified on the field classified photos. It will not be necessary to classify all drainage, but only the ones that are used as property limits or political boundaries. Drainage shall be identified as intermittent or perennial with double line streams drawn to scale. Drainage shall also be coded with a unique number so that it may be recalled. This numbering system could commence with 401 - and be further coded as 40111.

4. PHASE 3. TRANSFERRING OF PHOTO FIELD CLASSIFIED PARCEL LIMITS

The third phase would be the transferring of the photo field classified parcel limits with a unique number. The numbering system would identify the 1:100,000 map sheet, the 1:10,000 sheet, the particular photograph on which it is located and its parcel number.

For example a parcel would be identified as N3A-01-7715-11.

5. PHASE 4. CONSOLIDATION OF PHASES 1 TO 3

The fourth phase would be the consolidation of phases 1 to 3 in a final hard copy print of all cadastral information on a 2' x 3' format.

F. STYLE SHEET FOR 1:10,000 MAP

The style sheet and marginal information are shown on enclosure I.

G. CADASTRAL NUMBERING SYSTEM

1. GENERAL

The rural parcels are numbered consequentively within the geographic limits (2' x 3') of each 1:10,000 scale map sheet.

These parcel numbers will carry the sheet number in which the majority of the parcel is located. This will be done in the final office stage where cadastral numbers will be assigned. An example of such a number would be N4D-01-001 which would indicate the 1:100,000 (N4D), the 1:10,000 (01 and the parcel number (001).

TABLE 2

AERIAL TRIANGULATION ACCURACY

1. Fully Analytic Method:

   /Assuming photo coordinates are accurate to within 10 microns/

   a. 153 mm camera

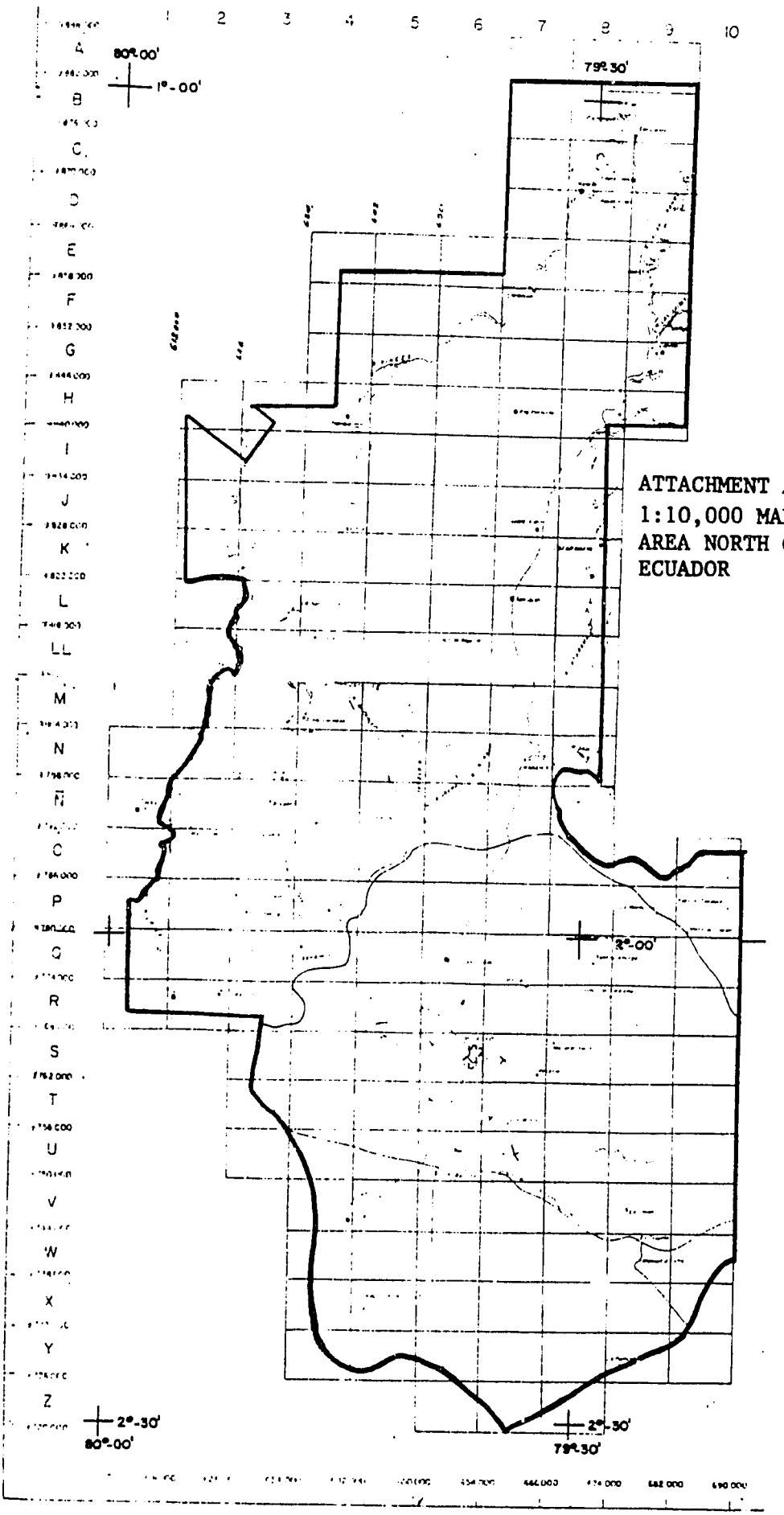
      i. x-y - 1/10,000 (H-Flying height)
      ii. z - 1/5,000 (H)

2. Semianalytic Method Using Simultaneous Adjustments:

   a. 153 mm camera

      i. x-y - 1/10,000 (H-Flying height)
      ii. z - 1/6,700 (H)

PROYECTO CUENCA BAJA DEL RIO GUAYAS

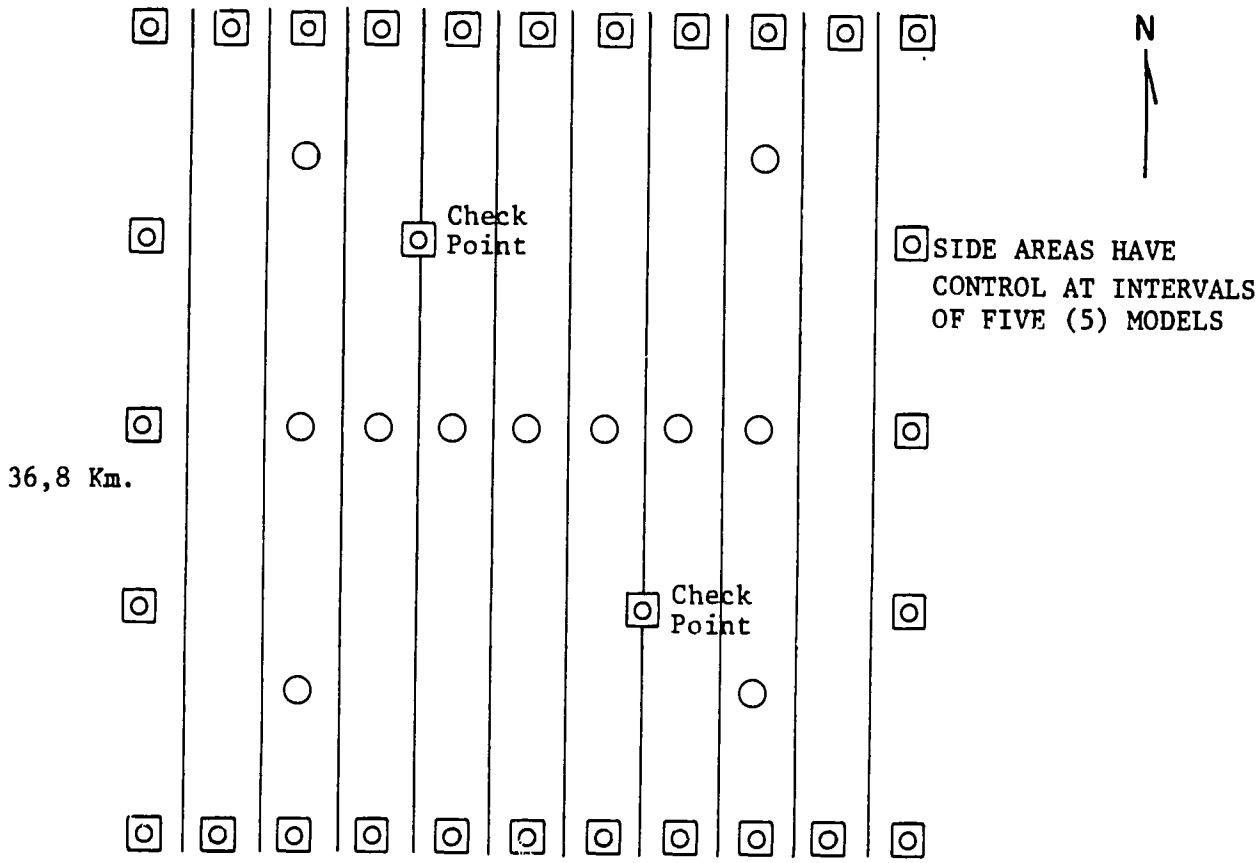


ATTACHMENT A
1:10,000 MAP COVERAGE OF AREA NORTH OF GUAYAQUIL, ECUADOR

Escala del Grafico 1:500.000
Total de hojas 190 Formato 60 x 80cm

ATTACHMENT B

IDEAL BLOCK FOR COMPUTER ASSISTED
SEMI-ANALYTICAL AERIAL TRIANGULATION
32,8 Km.



AREA 32,8 Km. X 36,8 Km.
NUMBER OF FLIGHT LINES - 10
NUMBER OF PHOTOS - 200
CONTROL POINTS: HVPP - 30
VPP - 11

HORIZONTAL/VERTICAL CONTROL POINT (HVPP)
VERTICAL CONTROL POINT (VPP)

ATTACHMENT C

PASS POINT PROCEDURE FOR AERIAL TRIANGULATION

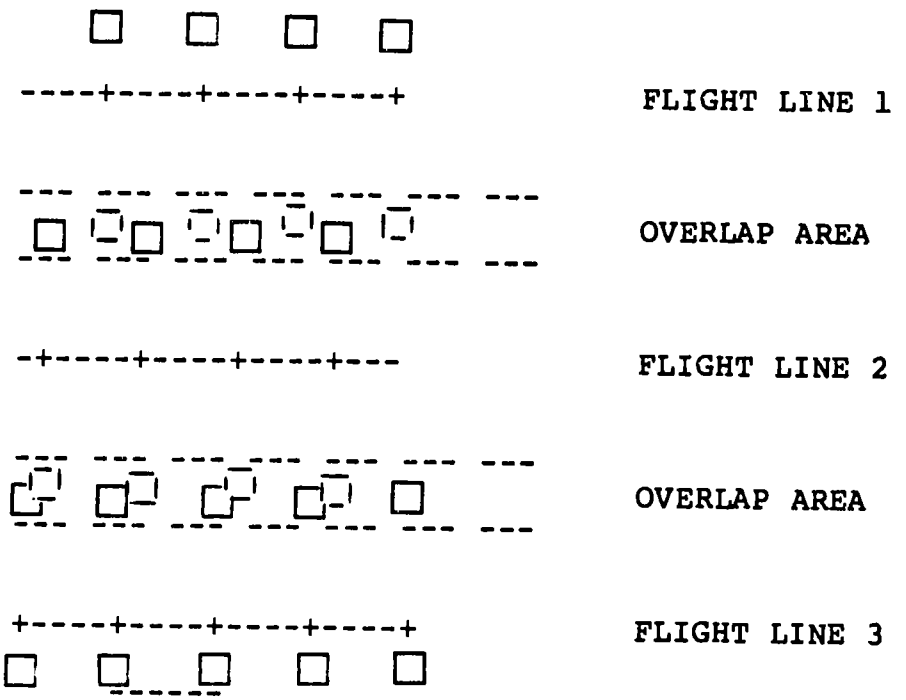


Photo center +
Pass point □ As it is drafted on all photos
Pass point □ Indicates pass point from lateral flight line, which appears as □ on its own flight line

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PART III. AERIAL PHOTOGRAPHIC SPECIFICATIONS (IN SPANISH ONLY)

PART II. PRELIMINARY OFFICE WORK FOR FIELD DELINEATORS

A. PREPARING FIELD PHOTOGRAPHS

1. PROJECT LIMITS

Project Limits are represented by natural barriers, (valley, ridge, river, etc.), administrative boundaries (local) or by established geographic coordinates, which are delineated on the aerial photographs by a thin red ink line. To assure complete annotation of the area, the survey is extended beyond the limit lines delineated on the photographs.

2. MATCH LINES

Match lines should be drafted on odd numbered photos only, as indicated in the "match line instructions".

To avoid repeating annotations in the overlap area, thin black lines are inked on the photograph. The lines are drawn along the approximate centers of the overlap and sidelap areas. Abrupt changes in match line direction are made as necessary to avoid splitting features and to eliminate the necessity of repeating the annotation on adjoining photographs. The match lines (north, south, east, and west) of the photograph are duplicated on the adjoining odd numbered photographs by the use of a stereoscope so that the lines cross the same image points on both photographs. The match line corners are indicated on adjacent photographs from the match lines. The flight and photo numbers of the adjacent photographs are noted in approximate positions along the edge of the photographs (see Example 1).

3. NORTH ARROW

An approximate north arrow is added in the northeast corner of the photograph, with the strip number shown underneath. The photos are oriented for lettering purposes with north at the right. Since the flight lines of this project will be running in a predominately north-south direction, this orientation is readily established (see Example 2).

4. PREANNOTATION

a. To expedite the field work, certain data are preannotated on the photographs. The annotations are done with pencils in the colors specified for the particular feature in Appendix A. The information for the preannotation is

extracted from all available sources including maps, census data, as well as highway and other related materials. All preannotated data must be verified in the field, and then drafted in ink when verified.

b. The data to be preannotated includes the following:

1. Limits of area features (areas subject to inundation, marshes, beaches, etc.)

2. Administrative boundaries, and any other boundary data required for the project.

5. PROCEDURE FOR AMPLIFIED PHOTOS

a. Establishing Limits

During the process of establishing cadastral limits, it will soon become apparent that certain areas contain "minifundios" and that the working scale of 1:20,000 aerial photography will not render the results that are required. When this occurs a portion of the photograph will have to be amplified so that the details of these small parcels may be more adequately portrayed.

b. Area to be Enlarged

The perimeter of the area that is to be enlarged will be carefully delineated on the photograph. A square or rectangular shape containing the area will then be drawn on the photo for the enlargement process. Once the area or areas have been outlined an enlargement guide should be drafted for the photo lab so that they will know the correct enlargement on the aerial photo is measured. This distance, which is called the AB distance, is carefully drafted on a "make size" piece of stable mylar. The desired enlargement distance called the CD distance is then calculated and drafted on to the "mark size" below the AB distance (see Example 3).

B. FIELD PARCEL NUMBERING SYSTEM

1. ASSIGNING NUMBERS

All information concerning parcels that are located within the matchline area of a photo will carry that photos odd number as the primary start number (called an identifier). For example, of photograph 7715 is the number of the photo containing the

parcels, then the first parcel number will be 7715-1, the second parcel number will be 7715-2, etc. Only the numbers 1, 2, 3, etc. will be inked on the photograph itself within each parcel to avoid clutter.

2. PARCELS ON MORE THAN ONE PHOTO

Not all parcels will fall within the limits established by the matchlines. When a parcel extends beyond a matchline onto an adjoining photo (or photos), it is numbered on the photo containing the larger portion. The number on that photo is followed by the letter "A", i.e., 29-A to indicate to the user that it is delineated on two photos. the portion on the adjoining photograph retains that same number. If the parcel falls on three photos, it is identified with the letters A/B, i.e., 29 A/B which is indicated on all three photos, etc. (see Example 4).

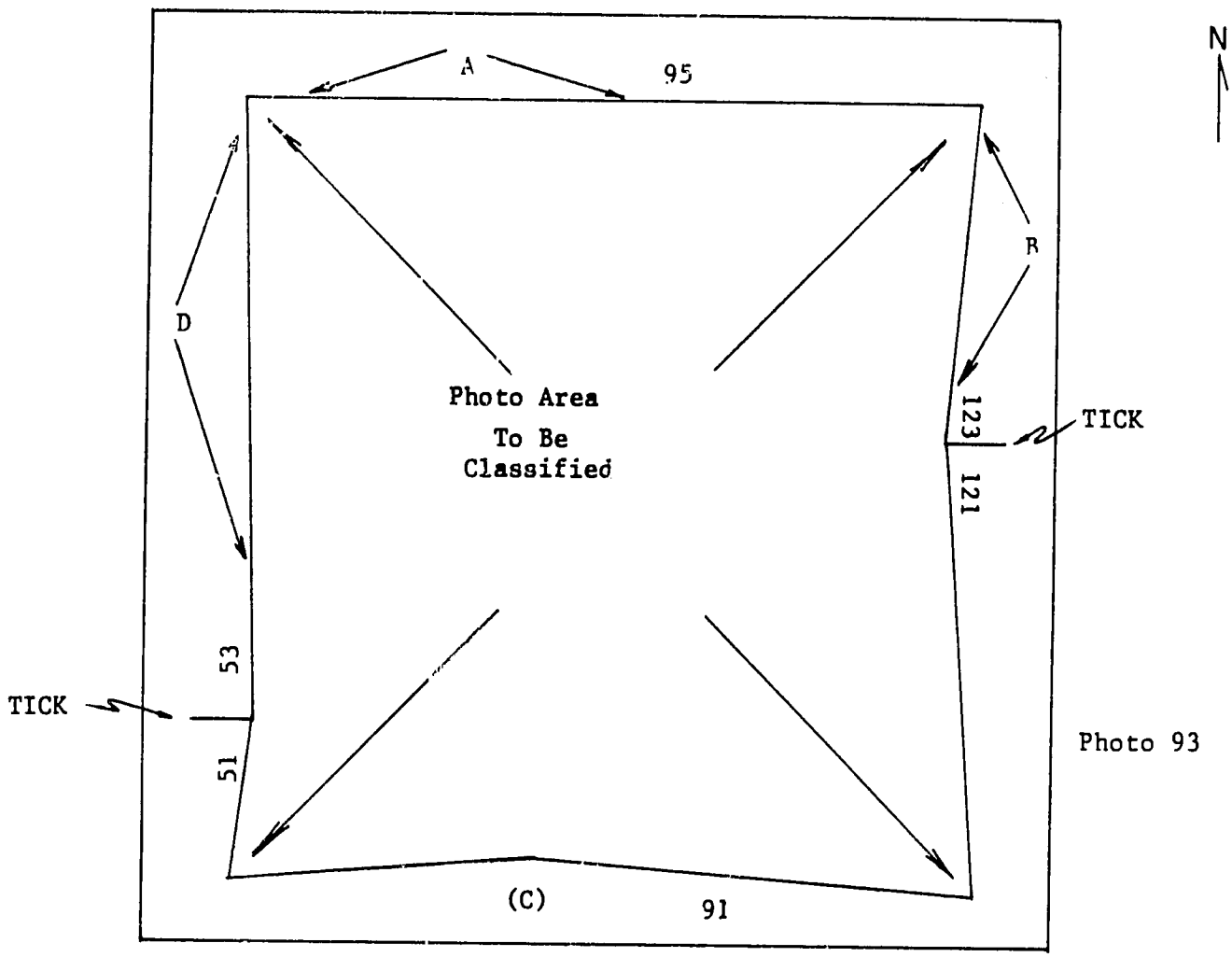
NOTE: It is important for the photogrammetric compiler to know that a parcel is on two or more photos for the digitizing process and for parcel area calculations.

3. COMPLETION OF PHOTOS

The field crews must coordinate very closely with one another to assume that all parcels falling on two or more photos have been delineated and numbered. A parcel might be overlooked, for example, because each crew thinks that the other has completed the parcel.

EXAMPLE 1

EXAMPLE OF A PHOTO WITH MATCH LINES



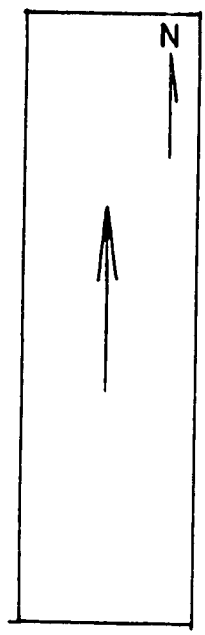
Match lines (A) and (C) compiled from overlapping north and south add numbered photos.

Match lines (B) and (D) compiled from sidelap east (121-123) and west (51-53) add numbered photos.

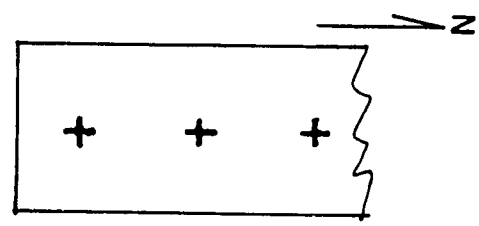
Ticks indicated sidelap photo junctions of photos 51-53, and 121-123 forming east and west match lines.

NORTH ARROW

EXAMPLE 2

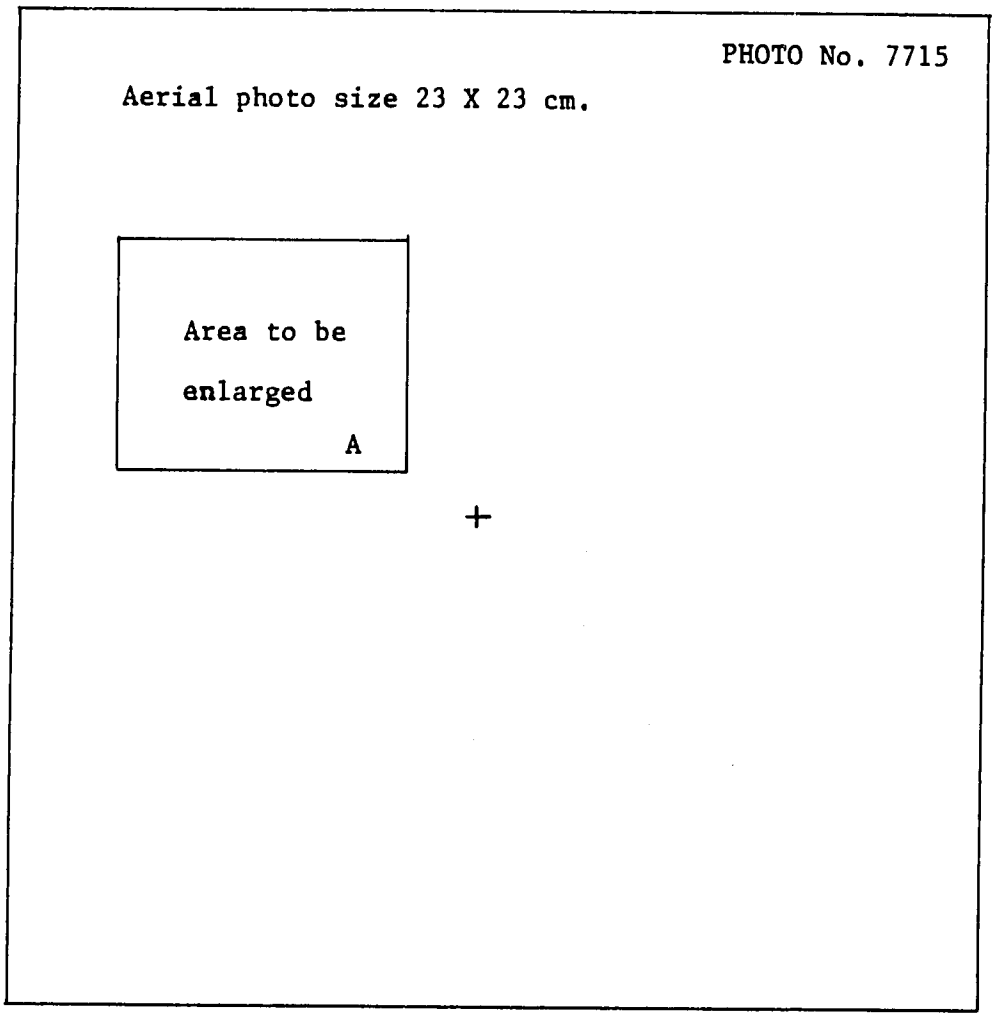


Direction of flight



Orientation of photos for field classifier

Example 3



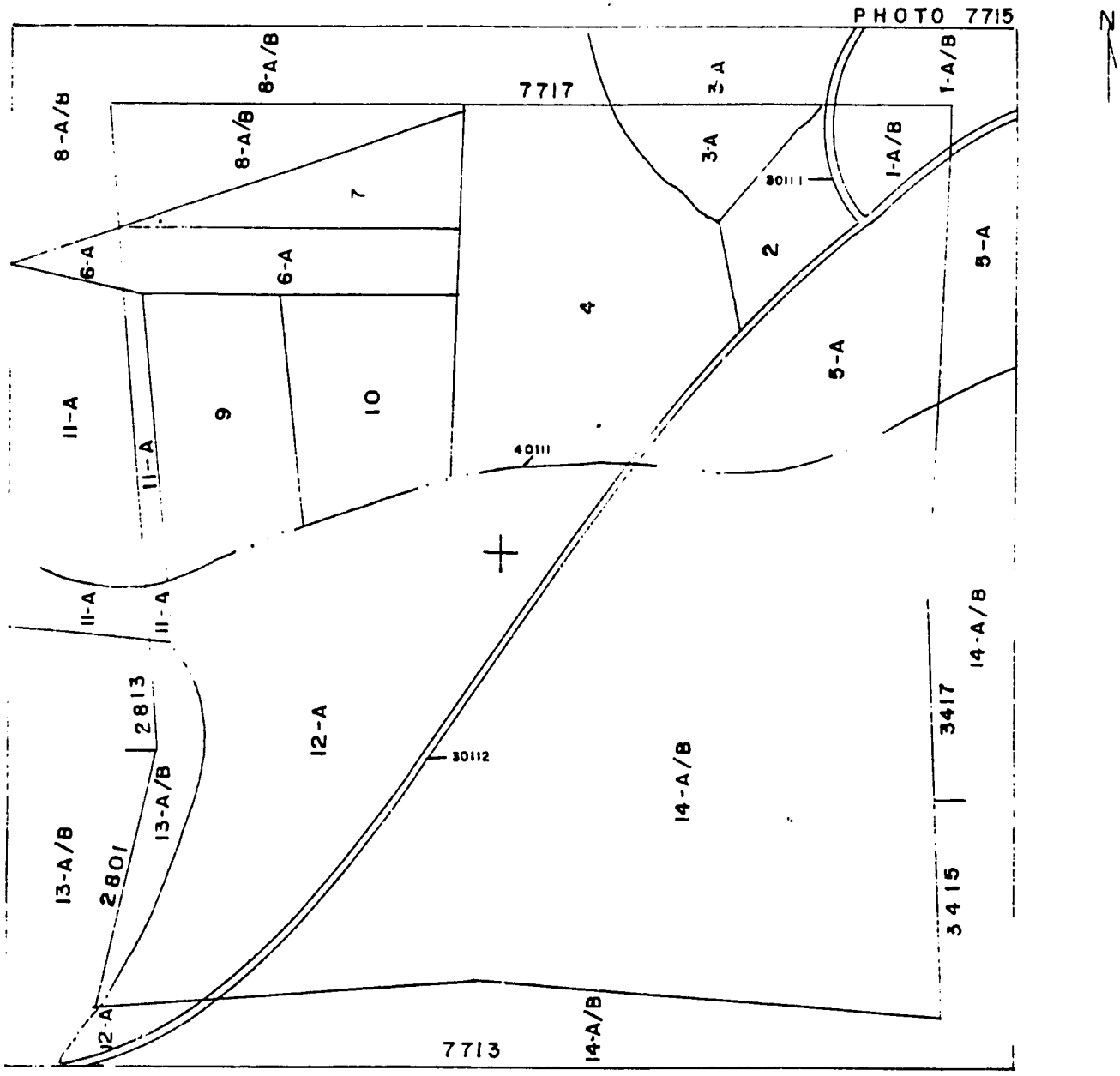
Area A

A _____ B MAKE SIZE

C _____ D

Mylar film 007"

Example 4 FIELD CLASSIFIED PHOTO WITH PARCEL NUMBERING SYSTEM



APPENDIX A

EQUIPMENT, SUPPLIES AND SOURCE MATERIALS

The following items are considered standard equipment and supplies for field delineators.

1. Pocket stereoscope
2. Surveyor's tape measure
3. Brunton compass
4. Binoculars
5. Lensatic compass
6. Point prickers (10 needle preferred)
7. Engineer scale
8. Proportional dividers
9. Assorted triangles (plastic preferred)
10. Double clipboard
11. Red, black, blue, green, brown, and violet colored inks and pencils
12. Pen holders and penpoints suitable for drawing 125 mm wide lines
13. One set of unmarked double weight semimatte contact prints of the aerial photos to be annotated
14. Enlargements of aerial photos of dense cadastral areas.

Upon my arrival in Quito, Ecuador on March 3, 1986 I was briefed on the overall project operations and specifically on its cartographic and photogrammetric needs by Mr. Jack Rosholt, project consultant.

The scope of work was outlined and the period of time that I was to accomplish it was clearly defined. From this I developed a plan of action that would cover the material that was required by the project consultant and Ecuadorian Project Director Mr. Carlos Calisto and his staff (see attached Action Plan).

The first item that I reviewed and wrote the specifications for was the Aerial Photographic contract specifications.

This was done in the Spanish language only. Time was spent at the Ecuadorian National Mapping Agency, Instituto Geografico Militar (IGM), where photography flight line indexes were reviewed for recent photographic coverage that might be useful for the Cadastral program. While reviewing this source it was verified that 1:20,000 photographic coverage as well as 190 sheets of 1:10,000 maps were available (1985 photography) and could be used by IERAC during its first year of work without having to rely on or to wait for new aerial photography.

Prices at the IGM are very expensive, but these prices may be lessened by an intergovernment agency agreement to furnish materials at cost.

The supplemental map control and first order triangulation nets were reviewed and seemed to be quite adequate for additional control that will have to be developed for the aerial triangulation computer blocks.

The area of the cadastral program is very irregular and varies from flat terrain to steep mountainous terrain. There will be approximately 30,000 km^2 of new aerial photography to be flown in a predominate, if not all North-South direction. The cost of new IGM aerial photographic coverage is very expensive and it might be appropriate to consider a private aerial photographic source.

I visited several private photogrammetry companies, Aeromapa and Scan (computer company) General Manager Engineer Rolf A. Andreetti, and technical manager Engineer Jaime Zurita, respectfully. I learned that these companies have the equipment and expertise to do the SMC control planning, stereo-digitized compilation, aerial triangulation, using the semi-analytical methods, and the computer capability to compute the large blocks of photography that are required. Aeromapa did not have a pug point transfer device, as they use image points in their pass point selection, but I was assured that a pug point transfer device could be obtained. Aeromapa has Kern equipment and has the responsibility to maintain and calibrate Kern equipment in South America. The stereo operators are very skilled in stereo compilation and have many years of

practical experience and were trained by the U.S. Government in the DMA-IAGS cartographic shool in the Republic of Panama. The Kern equipment is connected to digitizing equipment and is fully operational, so that stereo digitizing can be easily accomplished.

Staff meetings with IERAC personnel in the various departments enabled me to ascertain their needs. In respect to field control survey work for establishing SMC, their capability is non-existent, as it is in the photogrammetry field. In the cartography field it is very limited. It was necessary to go into the smallest detail in order to achieve an understanding of the cartographic needs of map symbols, sheet neat lines, design of format and marginal data. The draftsman has the basic skills but he has no background except to do as he is instructed. A good basic course in general cartography would be very useful.

The use of aerial photographs for delineating land property parcels is understood but a procedural guide should be prepared for new employees to serve as a guide while in the field. An attempt will be made in my limited time to furnish them with some guidance in this respect.

Included with this report are the required specifications and procedures that are necessary to make this cadastral land titling project successful.

I would also like to mention the able assistance that I received from the AID typing staff who, through their efforts, allowed me to finish my reports in time for review and acceptance by the AID Project Officer, Mr. Bruce Kernan and Mr. Jack Rosholt prior to its remittal to ERIM for packaging and final submission to AID.

It was a pleasure to return to Ecuador where I have worked in the past and I hope that my efforts will assist them in making their Cadastral Land Titling Program a successful one.

Francis W. Nolan
Cartographic Consultant
March 21, 1986

ACTION PLAN

1. Develop specifications for Aerial Photography Contract (in Spanish only).

2. Review of available aerial photography.

3. Delineation of property lines on amplified photography from available aerial photography.

4. Establishing photogrammetric control required for project.

5. Obtaining new aerial photography.

6. Aerial triangulation and adjustment.

7. Stereo compilation of cadastral map (geometric value of the parcels).

8. Stereo compilation of planimetric (roads), drainage, and contour values.

9. Information derived in the field that was not visible on the aerial photography, with drawings of area and corresponding area limits and values.

10. Transformation of photogrammetric coordinates and area calculations.

11. Preparing indexes and property list.

12. Final drafting of cadastral maps and overlays containing planimetric, drainage and contour information.