RAMP:

a computer system for mapping regional areas

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Until 1972, the U.S. Forest Service's Individual Fire Reports recorded locations by the section-township-range system. These earlier fire reports, therefore, lacked congruent locations. RAMP (Regional Area Mapping Procedure) was designed to make the reports more useful for quantitative analysis. This computer-based technique converts locations expressed in section-township-range notations into latitude-longitude coordinates. Two subsystems make up RAMP. The technique can be applied to other types of land-management problems.

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Much information useful for land-use planning remains untapped by computerized retrieval systems because of the cost of correcting inadequate land locators. A typical example of this problem is found in the U. S. Forest Service's Individual Fire Report (Form 5100-29). In 1972, the form was revised to record fire locations in degrees and minutes of latitude and longitude. But until then, the section, township, and range in which the fire started were recorded. This location is appropriate for statistical tabulations, but is not suitable for quantitative analysis. Therefore, much of the information in these earlier reports is not available to the fire manager and planner.

To tap this reservoir of historical information, a computer-based technique called the Regional Area Mapping Procedure (RAMP) was developed. RAMP is designed to provide longitude and latitude values of section corners and midpoints from digitized map locations of townships.

This report describes RAMP, its characteristics, digitization requirements, and computer software, and suggests how the system could be used in solving other types of land management problems.

Instructions on how to prepare input for the computer system are found in the *Procedural Guide for the RAMP Quantization and Coding Process.* The *Guide* is available upon request to: Director, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian.

INDIVIDUAL FIRE REPORTS

The individual Fire Reports are a primary source of wildfire information used in fire prevention, fuel treatment, and fire planning. Generally, the planning techniques currently used require manual processing of this information. But computer-produced tabulations and summary reports are available by using keypunched copies of the form.

Analyzing the spatial information in the Individual Fire Reports by advanced quantitative techniques would require a computer. However, such work has been hampered by the format of the report—particularly its location of the fire by the use of the section-township-range system. The township and section pattern of the Deschutes National Forest, in Oregon, illustrates the complexity of the problem (*fig. 1*).

Sections are nominally 1 mile square; townships are 6 miles by 6 miles and contain 36 sections. The half townships (T.25 1/2S.), however, contain six sections, and one of them is much smaller than the others (see section 31, *fig. 1*). Irregularities such as these preclude the use of the existing locator for computer analysis.

Spatial analysis of the Individual Fire Reports archives requires a change to a congruent locator, such as degrees latitude and longitude. Highly accurate computer-based mapping systems that use legal land descriptors, least-square error techniques, and other sophisticated methods are available, but are costly (Swann and others 1970). For many jobs a high degree of locator accuracy is not critical.

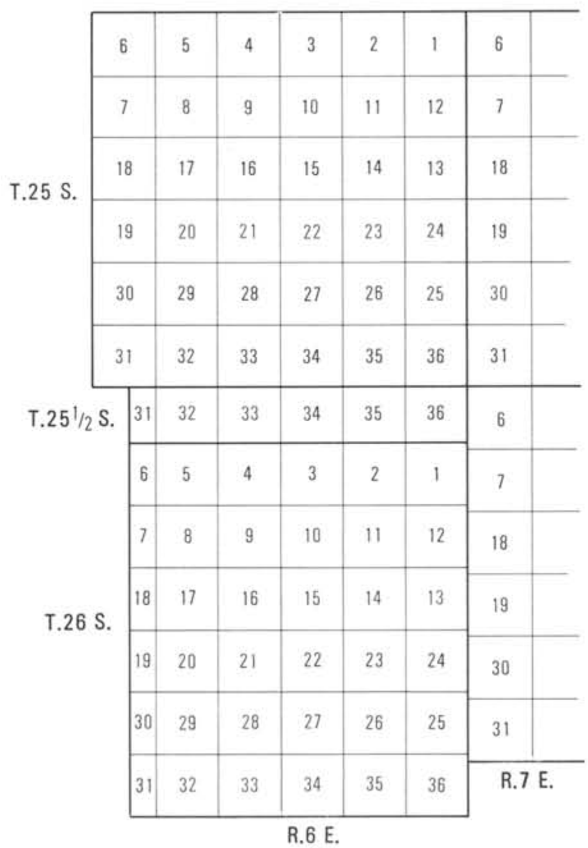

Figure 1—The township configuration found on the Deschutes National Forest, Oregon, includes half townships (6 sections) as well as full ones (36 sections). Some of the sections may be much smaller than others.

RAMP

RAMP (Regional Area Mapping Procedure) accepts the errors inherent in a map, and converts the section-corner projections into degrees latitude and longitude. Briefly, the system involves digitizing the locations of the corners of a few sections in each township. Variations from nominal size are identified and distributed among the sections, by procedures similar to the General Land Office survey rules for handling errors. Finally, the locations of all remaining sections and the centroid of each section are computed. With this system, digitizing one township can result in as many as 35 section locations being calculated automatically by the computer. Locations by latitude/longitude and section/range/township are then cross-referenced.

RAMP consists of two interrelated subsystems: one converts section corner locations on a map to a digital recording of an x-y coordinate in a form compatible for computer processing; the other provides instructions that take advantage of township surveying principles and section numbering configurations to minimize the amount of digitizing.

DIGITIZATION REQUIREMENTS

Many different characteristics exist on commercially available digitizers. Some of the more critical differences are (a) fixed versus variable length digital records–a record is the unit of data to be transmitted to the computer, (b) number of x-y coordinate points that can be entered on a record, (c) availability or limitations or both on keying information into a record, and (d) coordinate alignment procedures. Each difference affects the digitizing and coding procedures. In turn, each procedure influences the computer program used to process the digitized information.

In RAMP, nine different digitized records are used. They provide the essential information for (a) development of scale coefficients for conversion of x-y corner locations to degrees latitude and longitude, (b) alignment of the x axis of the digitizer coordinate system with the longitude axis of the map, (c) identification of the latitude and longitude at the origin of the digitizer coordinate system, (d) determination of the latitude and longitude of the corner points and centroid of a section(s), and (e) comparison of known map coordinate locations with calculated values. An 80-column punchcard, limited to three sets of digitized x-y coordinate points and 41 columns of keyed information, provides the means for linking these records to the computer subsystem.

The time required for digitizing is a function of the number of townships within a forest, the amount of key information required, and the number of nonrectangular sections it contains. For example, on the Clearwater National Forest, in Idaho, it was necessary to digitize 463 records to cover 3646 sections. Many of these records were required to process an extraordinarily large number of nonrectangular sections. This work took about 3-1/2 hours. On the other hand, only 116 records were needed to cover 5411 sections in the Tonto National Forest in Arizona. In this case, about 2 hours were needed to digitize the maps.

The average number of sections calculated for each digitized record for seven forests is 15.4 (*table* 1). However, considerable differences from the average existed for different forests.

ACCURACY

Analysis of the magnitude and direction of calculated locations for 53 points, taken from nine different forest maps, showed no systematic errors over the range of latitude and longitude examined. The computed standard error for latitude was 252 feet and 437 feet for longitude (*table* 2).

The scale of all of the maps digitized was ½ inch to 1 mile. The smallest line digitized on these maps was clearly legible at a viewing distance of 5 feet. This would indicate that the lines were at least 0.03 inch wide (Robinson and Sale 1969). A line of this width is equivalent to a distance of 316 feet on the maps analyzed. One of the more accurate computer-based systems accepts calculated points which have an error of less than 200 feet at the latitude/longitude intersections (Swann and others 1970). It would appear from this comparison that the errors associated with RAMP are reasonable–especially for maps of the scale used in the study.

COMPUTER SOFTWARE

Many commercially available digitizers have built-in functions to insure the alignment of the coordinate system with a map system that covers a small geographic area. When this capability is not available, as in RAMP, the computer software must perform these functions. A closely related item is the ability to interrupt a digitized session, remove the map from the digitizer, and then later restart the process so that all new records are adjusted to the original initial origin.

Somewhat less common is a built-in function for the conversion of x-y coordinates developed by digitizing map points to coordinates of latitude and longi-

Table 1–*Efficiency of RAMP, as measured by the average number of sections processed by one digitized record*

Forest Unit	*Digitized records*	*Sections processed*	*Efficiency (sections/record)*
Deschutes N.F.	116	4044	34.9
Tonto N. F.	214	5411	25.3
Pike N. F.	123	2765	22.5
Sequoia N. F.	131	2005	22.2
Mendocino C.D.F.R.U.	266	3689	13.9
Sierra N. F.	242	2415	10.0
Clearwater N. F.	463	3646	7.9
Total	1555	23915	
Average	222.1	3416.4	15.4

tude. Within RAMP, conversion to latitude is achieved by using a constant scale factor for each map. However, this factor may change between maps. Because the distance between two latitude lines decreases rapidly as they approach the earth's poles, the conversion to longitude is a variable scale factor depending upon the latitude of the point.

To relate congruent location dimension to a section-township-range locator, three different sets of computer instructions are used in RAMP: (a) one determines the latitude and longitude of the four corners and the midpoint of a single rectangular shaped section; (b) another performs similar calculations for triangular or quadrilateral sections; and (c) the third provides latitude and longitude locations for each section within a township. Both of the first two techniques have an efficiency of 1; that is, for each digitized record, one section is provided with latitude and longitude locations. The third technique can result in an efficiency of up to 36. Lower efficiencies than this are due to the existence of irregular townships.

A full township consists of 36 sections *(fig. 1)*. Less than full townships may occur (T.25 1/2S., R.6E., for example). In those instances, generally one or more of the northern rows or western columns of the township or both are absent. Each digitized record must contain three digitized points–coded information containing the unique township and range address–and the number of the section which serves as the intersection of the most western column and the most northern row of the township.

To illustrate, a record for T.25S., R.6E. *(fig. 1)* would contain the digitized northwest and southeast corner points of section 6 and the southeast corner point of section 36. It would also contain the codes T.25S., R.6E., and 6. This information would result in the development of latitude and longitude for each corner and midpoint for all 36 sections. If the record contained an 8 instead of the section number 6, 25 sections would be processed. The section numbers eliminated would be 1-7, 18, 19, 30, and 31. In addition, any oversized or fractional section dimensions in the northern row or western column of the township

Table 2–*Known and calculated coordinates of latitude and longitude for 53 points from nine forest maps (scale: 1/2 inch - 1 mile)*

Coordinates	*Latitude*		*Longitude*	
	Mean	*Standard deviation*	*Mean*	*Standard deviation*
	Degrees			
Known	40.2271	4.6116	111.0928	11.6320
Calculated	40.2272	4.6103	111.0929	11.6311
Error	0.0001	-0.0013	0.0001	-0.0009

or both would be noted by the computer, and appropriate adjustments made in all other sections within the same row or column or both.

The RAMP computer program consists of about 1300 statement lines, written in FORTRAN IV language for an IBM 360/50 Operating System[1], and requires approximately 130K of core to execute. Direct transfer of this program to other systems is limited because of design effects resulting from the interface with the RSS-400 Graphic Quantitizer.

COMPUTER OPERATIONS

Three major categories of calculations are required by RAMP. It provides algorithms to (a) determine and correct for the nonalignment that may exist between the X axis of the digitizer coordinate system and the longitude axis of the map; (b) develop scaling coefficients for converting digitizer coordinates to spherical coordinates of longitude and latitude; and (c) calculate the latitude and longitude of the corners and the midpoints of sections.

Converting Coordinates

Two scaling operations are used by RAMP. Adequate precision is achieved by treating the conversion of Y digitized units to latitude values as a constant within a given National Forest, but it may change in value for a different forest. Two widely separate but known latitude points, selected from one of the two latitude scales on either side of a map, are digitized. The basic FORTRAN equation used to develop the Y conversion coefficient is

SCALE(3) = FLOAT(IRANGE) / (60.*YDELTA) (1)

in which:

SCALE(3)	= Y conversion coefficient
YDELTA	= Difference between the two Y coordinates, resulting from the digitization of known latitude values.
IRANGE	= Difference between the two known latitude coordinates digitized for YDELTA.

Because latitudes converge quickly at the earth's poles, the conversion of X digitized units to longitude values is treated as a variable, depending upon the latitude of the point being transformed. Two widely separate but known longitude points are digitized from the longitude scale on the top of the map. The same operation is repeated on the bottom longitude scale of the map. The X conversion coefficient, being a variable value, is calculated for every point being transformed by incorporating Equation 1 into a conversion coefficient function. The number of X digitization units within a degree of longitude at the top of a map will be less than the equivalent degree measured at the bottom of the map. RAMP uses linear interpolation to approximate this change in dimensions within a National Forest.

The X conversion coefficient function is

```
SCALE(J) = SCALEX(1) – SCALEX(2)          (2)
           *(LATTOP – SCALE(3)*LAT(J))
           / (LATTOP–LATBOT)
```

and

```
SCALE(I) = FLOAT(JRANGE(I))                (3)
           / (60.*XDELTA(I))
```

in which

SCALE(J)	= X conversion coefficient at Latitude J.
SCALEX(I)	= X conversion coefficient at the top (I=1) and at the bottom (I=2) longitude scales of the maps.
LATTOP	= Approximate latitude of the top longitude scale, expressed in decimal degrees of latitude.
LATBOT	= Approximate latitude of the bottom longitude scale, expressed in decimal degrees of latitude.
LAT(J)	= Y Coordinate of the point (J) being converted to spherical coordinates. This variable should be expressed in units measured by the digitizer.
XDELTA(I)	= Difference between the two X coordinates, resulting from the digitization of known latitude values at I.
JRANGE(I)	= Difference between the two known longitude coordinates digitized at I.

Aligning Coordinates

If the digitizer coordinate system originated exactly at the center of a 36-inch wide map (scale: ½ inch = 1 mile), an alignment error of 15 minutes between the two coordinate systems would result in a conversion error of about 828 feet for locations near

[1]Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

the map edge. And if maps are larger than 36 inches, they would be subjected to even greater errors. In addition, a digitizer operator would be hard pressed to keep alignment errors close to 15 minutes. Many digitizers allow the operator to establish the origin of its coordinate system at any convenient map point. A seldom used but more universal requirement is the ability to perform rectangular coordinate axis translation or rotations, or both. This procedure would allow the interruption of a digitization process, removal of the map from the equipment, and continuation of the digitization with all measures transformed to the initial coordinate system. The RAMP computer program provides for all of these procedures.

The most simple alignment correction problem exists when the longitude and latitude at the origin of the rectangular coordinate system is known. The angle of rotation between the X axis and the longitude axis is found by

```
THETA = ARSIN(D/(SCALE(1)*SCALE(2)                (4)
        *(YY1*XX2-YY2*XX1)))
```

and

```
D = XX2*SCALE(2)*(LZERO-LONE)                     (5)
    + XX1*SCALE(1)*(LTWO-LZERO)
```

in which

THETA	= Angle separating the X axis of the digitizer with a longitude line on the map.
LZERO	= Longitude at the origin of the rectangular coordinate system, expressed in decimal degrees of longitude.
LONE	= Longitude at a known point on the map. This point should be located to the right of LZERO and have a known value less than LZERO, and be expressed in decimal degrees of longitude.
LTWO	= Longitude at a known point on the map which has a value greater than LZERO, expressed in decimal degrees of longitude.
XX1,YY1	= X and Y digitization value of LONE, expressed in rectangular coordinate units.
XX2,YY2	= X and Y digitization value of LTWO, expressed in rectangular coordinate units.
SCALE(K)	= Equation 2 solved for point YY1 (K=1) and YY2 (K=2), respectively.

When the map coordinates at the origin of the digitizer are unknown, a much more complex problem exists. Finding the angle of rotation and the longitude and latitude at the origin requires the solution of two transcendental equations containing three unknowns. Since the number of unknowns exceeds the number of available expressions, an iterative process for finding the solution is required. Fortunately, the range over which the iteration must be performed is small. Most "unassisted" digitizer operators can align the two coordinate systems within a range of several degrees. The two equations that need to be solved are

```
XFUN = ABS(LONE-LTWO)                             (6)
       -ABS((SCALE(2)*XX2
       -SCALE(1)*XX1)*COS(ARG)
       -(SCALE(1)*YY1
       -SCALE(2)*YY2)*SIN(ARG)
```

and

```
YFUN = ABS(LATONE -LATWO)-ABS                     (7)
       (((YY2-YY1)*COS(ARG)
       -(XX2-XX1)*SIN(ARG)*SCALE(3)))
```

in which

XFUN, YFUN	= Conditional transcendental equations containing the unknown angle of rotation.
ARG	= An assumed angle of rotation between the X axis of the digitizer coordinate system and a longitude line on the map.
LATONE, LATWO	= Known latitudes at LONE and LTWO respectively, expressed in decimal degrees of latitude.

If the two coordinate axes have been closely aligned before digitizations, only one angle of rotation will exist between ± 10 degrees that will yield equivalent solutions for Equations 6 and 7. If both equations are equal, ARG is nearly equal to THETA. The map coordinates at the origin of the rectangular coordinate system are now found by:

```
LZERO = LONE + XX1*SCALE(1)                       (8)
```

and

```
LATO = LATONE - YY1*SCALE(3)                      (9)
```

in which

LATO = Latitude at the origin of the rectangular coordinate system, expressed in decimal degrees of longitude.

An interrupted digitization effort—one that requires establishment of a new origin—will normally require both a translation and rotation transformation to align the new origin with the initial origin. This allows all the digitized records of a map to be processed during a single computer run. Two flagged points digitized during the initial effort are redigitized. The angle of rotation between the old and the new is found by

$$\text{THETAN} = \text{ARCOS}((\text{C*C} - \text{A*A} - \text{B*B}) \, / \, (-2.*\text{A*B}) \qquad (10)$$

in which

$$\text{A} = (\text{X2OLD} - \text{X1OLD})**2 + (\text{Y2OLD} - \text{Y1OLD})**2 \qquad (11)$$

$$\text{B} = (\text{X2NEW}**2 + \text{Y2NEW}**2) \qquad (12)$$

and

$$\text{C} = (\text{X2NEW} + \text{X1OLD} - \text{X2OLD})**2 + (\text{Y2NEW} + \text{Y1OLD} - \text{Y2OLD})**2 \qquad (13)$$

in which

THETAN = Rotation angle required to align the current rectangular coordinate system of the digitizer to the original rectangular coordinate system.

$\left\{\begin{matrix}\text{X1OLD, Y1OLD} \\ \text{X2OLD, Y2OLD}\end{matrix}\right\}$ = Rectangular coordinates from the initial digitization effort. Each point was previously marked as a potential future reference location.

$\left\{\begin{matrix}\text{X1NEW, Y1NEW} \\ \text{X2NEW, Y2NEW}\end{matrix}\right\}$ = Rectangular coordinates from the new digitization effort of the above flagged locations.

The translation constants for X and Y axes are, respectively

$$\text{XADJ} = \text{X1OLD and YADJ} = \text{Y1OLD} \qquad (14),(15)$$

Methods to perform the actual translation or rotation, or both, utilizing the results from Equations 4 to 15 are available in most mathematical handbooks (Selby and others 1965).

Mapping Sections

A section is considered mapped when all corners of the boundary and the centroid of the area within the boundary are described by longitude and latitude coordinates. Attachment of the section-township-range label to the coordinates creates a suitable cross-reference index record for the individual Fire Reports.

Three methods exist within RAMP for mapping sections: (a) one provides latitude and longitude locations of the four corners and midpoint of each section within a township; (b) another performs similar calculations for a triangular or quadrilateral section; and (c) the last procedure determines the latitude and longitude for a single rectangular section.

The first method reduces the number of digitized points required to process a township by taking advantage of the surveying and identity coding standards of sections within a township.

Three sets of digitized points, the township and range codes, and at least one but not more than two section numbers are needed to process a township. The northwest corner of the section that serves as the intersection of the top row and leftmost column of the township is digitized and referred to as X1 and Y1. The southeast corner of this same section is digitized and referred to as X2 and Y2. The number of this section, (ISECT) is also recorded. The last point digitized—X3, Y3—is the southeast corner of the section that occupies the intersection of the rightmost column and bottom row of the township. If any righthand columns or southern rows of the township are missing, the section number (JSECT) is also recorded.

In RAMP, all townships are initially assumed to be made up of 36 sections. Each row and column in a full township also has a reference number associated with it. For example, section number 6 is defined as a member of column 1, row 1. Section number 5 is a member of column 2, row 1. The intersection of column 1, row 2 would then be occupied by section number 7. Thus, the origin of the reference system is considered to be section number 6. Columns moving to the east increase in number as they move away from the origin. Rows increase as they move south from the origin. With this reference system, the actual number of sections and their configuration in the township can be determined from values of ISECT and JSECT.

The reference number of the most northern row of the township can be found by

$$\text{LY} = (\text{ISECT} - 1) \, / \, 6 + 1 \qquad (16)$$

and the most western column is

$$LX = ABS(FLOAT(MOD(ISECT-1,12)) - 5.5) + 1.6 \quad (17)$$

If JSECT is not present on the digitized record, the program assumes that no eastern columns and southern rows of the township are missing. Modification of Equations 16 and 17 provide the means to determine what columns or rows, or both, are absent. The number of the first southern row missing from a township is found by

$$LYY = (JSECT - 1) / 6 + 2 \quad (18)$$

and the first eastern column missing is

$$LXX = ABS(FLOAT(MOD(JSECT-1,12)) - 5.5) + 0.6 \quad (19)$$

Given the number of rows and columns in a township, the dimensions of all sections except those in the most northern row and the most western column are assumed to have equal widths and heights. The width of the section is

$$XDELTA = (ABS(X2 - X3)) / (LXX - LX - 1) \quad (20)$$

and the height is

$$YDELTA = (ABS(Y2 - X3)) / (LYY - LY - 1) \quad (21)$$

Many of the sections within a township have boundaries and corner points in common with other sections of the township. A full township contains 36 sections and thus has 49 uniquely located section corners. RAMP uses two 7-by-7 matrices to define the X and Y coordinates of the corner points. The X coordinate of the first two columns of the matrix (using standard matrix algebra notation) are

$$X_{i,LX} = XL \text{ and } X_{i,LX+1} = X2 \quad (22), (23)$$

and for the remaining columns of the matrix are

$$X_{i,j} = X_{i,j-1} + XDELTA \quad (24)$$

in which, $LY \leq i \leq LLY-1$ and $LX+2 \leq j \leq LXX-1$.

In a similar manner, the coordinates of the first two rows of the Y matrix are

$$Y_{LY,J} = Y1 \text{ and } Y_{LY+1,j} = Y2 \quad (25),(26)$$

and for the remaining rows

$$Y_{i,j} = Y_{i-1,j} - YDELTA \quad (27)$$

in which $LY+2 \leq i \leq LYY-1$ and $LX \leq j \leq LXX-1$.

With all elements of the two coordinate matrices known, Equations 1 and 3 can then be used to develop the latitude and longitude of each section point.

The second method is used to map a quadrilateral section that has one 90-degree internal angle. The 90-degree angle is required in RAMP because of the hardware limitation of no more than three digitized points on a record. This angle is used as a reference point in the algorithm. Its coordinates are calculated from information gained in the digitization of the three other corners of the quadrilateral. A simpler algorithm can be developed which does not require the 90-degree internal angle when four points can be digitized per record. Moving clockwise from the reference point, the operator digitizes the first corner (referred to as X1 and Y1 here). Then he digitizes the next corner (known as X2 and Y2). And then he digitizes the last corner (called X3 and Y3) before returning to the reference point.

RAMP assumes that the right angle of the quadrilateral section is located at the origin of a rectangular system of axes. The quadrant which contains the section is found by logical analysis of the first and last points digitized. Thus

$$X3 > X1 \text{ and } Y1 > Y3 = \text{Quadrant 1}$$
$$X3 > X1 \text{ and } Y1 < Y3 = \text{Quadrant 2}$$
$$X3 < X1 \text{ and } Y1 < Y3 = \text{Quadrant 3}$$
$$X3 < X1 \text{ and } Y1 > Y3 = \text{Quadrant 4}$$

For sections located in Quadrants 1 and 3, the coordinates of the origin are

$$X4 = X1 \text{ and } Y4 = Y3 \quad (28),(29)$$

and for Quadrants 2 and 4, the coordinates are:

$$X4 = X2 \text{ and } Y4 = Y1 \quad (30),(31)$$

A quadrilateral section containing one 90-degree internal angle can have two "basic" shapes *(fig. 2)*. It is always possible to partition such a section into an oblique triangle and a right triangle. Location of the centroid in this section requires identifying a fifth point, called X5 and Y5. The coordinates of the unknown point are located on a straight line passing through the points X1, Y1 and X3, Y3. The equation of this line is

$$A*X5 + B*Y5 + C = 0 \quad (32)$$

in which

$$A = Y2 - Y3, B = X1 - X3 \quad (33),(34)$$

and

$$C = X3*Y1 - X1*Y3 \tag{35}$$

The point X5,Y5 is also a member of a straight line passing through point X2,Y2. By requiring this line to be perpendicular to Equation 32, the coordinates of the point X5,Y5 can be found by the following expression

$$X5 = (B*B*X2 - A*B*Y2 - A*C) / (A*A + B*B) \tag{36}$$

and

$$Y5 = (A*A*Y2 - A*B*X2 - B*C) / (A*A + B*B) \tag{37}$$

The centroid of the quadrilateral section can now be obtained by the use of the principle of moments (Higdon and others 1955). Logical check of the points X5,Y5 and X2,Y2, along with the quadrant position of the section will determine if the area of the oblique triangle, called A2, must be removed or added to the area of the right triangle (A1). Thus

Quadrant 1 or 4, and $X2 < X5 = -A2$
Quadrant 2 or 3, and $X2 > X5 = -A2$

The moments of the areas around the X and Y axes for sections located in quadrants 1 or 3 are

$$XBAR = (A1*X3 + A2*(X3 + X2)) / (3.*(A1 + A2)) \tag{38}$$

and

$$YBAR = (A1*Y1 + A2*(Y1 + Y2)) / (3.*(A1 + A2)) \tag{39}$$

respectively. For sections located in quadrants 2 and 4, the moments of the areas around the X and Y axes are

$$XBAR = (A1*X1 + A2*(X1 + X2)) / (3.*(A1 + A2)) \tag{40}$$

and

$$YBAR = (A1*Y3 + A2*(Y3 + Y2)) / (3.*(A1 + A2)) \tag{41}$$

respectively. The intersection of the XBAR and YBAR is the location of the midpoint of the quadrilateral section, expressed in the rectangular coordinates of the digitizer. Equations 1 and 3 can be used to develop the latitude and longitude of corners of the section and its midpoint.

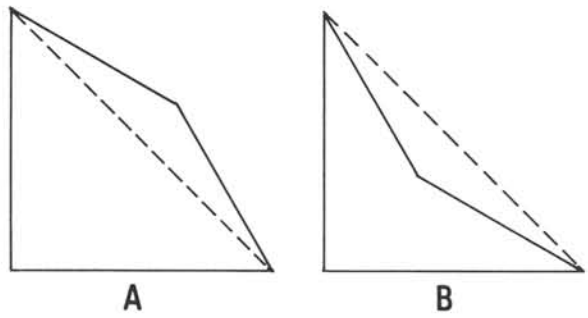

Figure 2—A quadrilateral section that contains an internal 90-degree angle can have two "basic" shapes. Dashed lines illustrate how the section can be viewed as an oblique triangle added (A) or subtracted (B) from a right triangle.

A modification of the above process is used to digitize a right-triangular section. In this situation, the third digitized point (X3,Y3) is the corner of the internal 90-degree angle. Equations 28 to 37 are not required in this situation. RAMP uses a logical comparison of the three digitized points to differentiate a right triangle from a quadrilateral section. Information on the quadrant position of the section will determine the equations to use for solution of XBAR and YBAR. When A2 is given a zero value, Equations 38 to 41 are then applicable for locating the midpoint of the section.

The third method is used to map a single rectangular section. Only two digitized points are required. The problem is easily solved by RAMP.

APPLICATION

RAMP was designed originally to provide a useful spatial variable that could be associated with data from the Individual Fire Reports for the FOCUS program. FOCUS (Fire Operational Characteristics Using Simulation) is a model being developed at the Pacific Southwest Forest and Range Experiment Station's Forest Fire Laboratory, Riverside, California, to simulate the probable consequences of available alternatives in fire planning (Storey 1972). To date, a cross-reference catalogue has been produced within the computer for 12 National Forests and one California Division of Forestry Ranger Unit by RAMP.

The techniques and procedures used in RAMP can be applied by land-use planners to tap many other sources of useful spatial information. As an example, a brief investigation shows that it could be applied to the following U. S. Forest Service reports: (a) Bridge Inventory, R5-7700-24; (b) Report of Suspected

Timber Trespass, R5-6500-129; (c) Record of Sale, Land or Easement, R5-5400-11; (d) Animal Damage Survey, R5-5200-39; (e) Prescribed Burn Report, R5-5100-199; (f) Archaelogical Site Survey Record, RS-2700-31; and (g) Tree Seed Crop Condition Report, R5-2400-58.

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