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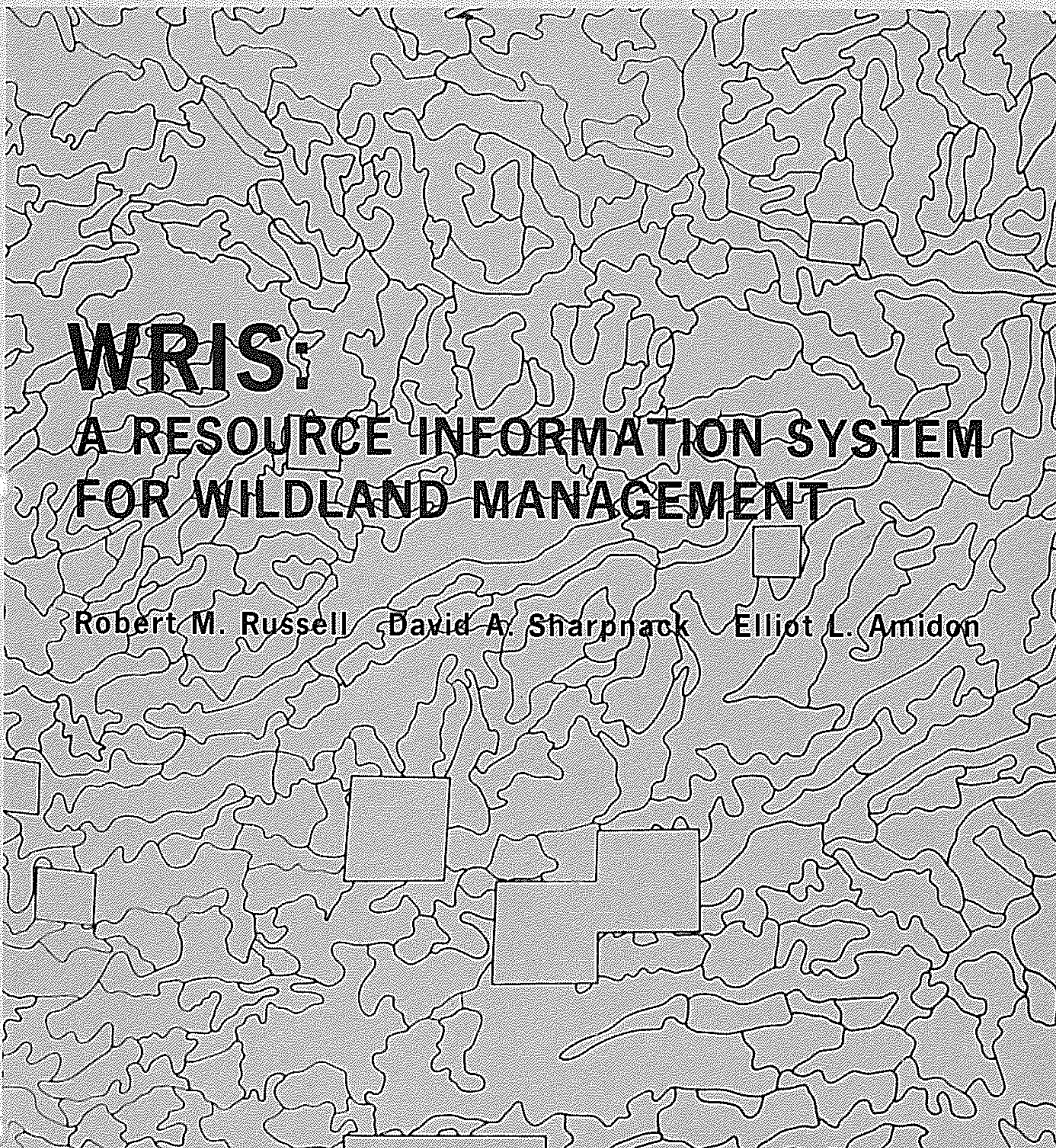

WRIS: A RESOURCE INFORMATION SYSTEM FOR WILDLAND MANAGEMENT

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CONTENTS

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ACKNOWLEDGMENTS

The Wildland Resource Information System (WRIS) was developed by the Station's research unit investigating measurement and analysis techniques for management planning. WRIS was developed primarily for the Branch of Management Plans and Timber Inventories, California Region, Forest Service, U. S. Department of Agriculture, San Francisco.

We gratefully acknowledge the help of the Branch staff; Klaus H. Barber, inventory supervisor, Stanislaus National Forest; and E. Joyce Dye, computer programmer with the Station research unit staff.

At various stages of system development, we used data from the following National Forests in California: Stanislaus, Eldorado, and Sierra.

SUMMARY

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The Wildland Resource Information System (WRIS) is an operational computerized procedure for acquiring spatial data for management planning. Though designed primarily for timber management use, it has application for land-use planning in general. WRIS is a production tool for which detailed instructions are provided for both manual and computer operations. The system is intended for continuous use by institutions rather than individuals. It is designed to process a workload of 200 to 400 maps a year with a staff of two or three people at a central location, such as a regional office or corporate headquarters. Computation is performed on a medium-sized computer, the UNIVAC 1108, over a high-speed batch terminal. Other mandatory equipment needs include access to a scanning device for automatic digitizing, and an incremental line plotter. A hand digitizer is optional, but highly desirable if source maps vary from simple to highly complex. Software consists of over 20,000 standard FORTRAN statements compiled by UNIVAC's EXEC 2 Executive System.

The publication *Wildland Resource Information System: User's Guide* (USDA Forest Service General Technical Report PSW-10) details the operating procedures for using WRIS computer programs and digitizing hardware.

WRIS provides a means of collecting, processing, storing, retrieving, updating, and displaying geographic data, and makes possible the performance of logical operations on these data. System capabilities include data reduction from maps or orthophotographs at varying scales, printed tabular and plotted graphic display, computer-aided manual editing procedures, and a broad range of data-manipulating features. Logical operations include merging and overlaying of map files, selection of polygons with measurement of their area and perimeter, and extraction of rectangular subsets of data within a map border.

The basic data collection unit in WRIS is the polygon—a plane figure consisting of vertices connected by line segments. Each polygon has a unique number for computer processing and a category such as "red fir, volume category. . .," which has meaning for inventory purposes. This data structure differs from a more common one in which the squares of a fixed grid are labeled. A few other large-scale systems have a similar approach, which minimizes storage but does require more complex data-manipulating algorithms. About 10,000 polygons will cover a National Forest and span 1000 different categories. We report here statistics drawn from experience with three California National Forests because they affect system design and have implications for management planning.

Modifications and extensions of the system described here are inevitable because of the continual flow of new technology. Software conversion to the EXEC 8 version of FORTRAN is already underway. Adaptation to IBM 360-type computers is planned, and conversion to PL/1 is an attractive possibility. Several editing and updating alternatives are available, but more will be tested because these are key procedures in the cost of map data reduction.

Finally, we will seek ways to achieve communication between this and other geographic information systems. We need data format compatibility, standardized terminology, and exchange of methodology before wildland resource information can be routinely available to forest managers.

The rapidly rising value of wildland goods and services in recent years has put increasing pressure on wildland managers to make the most of the resources under their control. "The Environmental Program for the Future" (U.S. Forest Service 1974) provides some measure of the size and scope of the land management job facing the U.S. Forest Service. In order to provide in the next 5 years the same proportion of goods and services it has in the past, it "must conduct silvicultural examinations and prepare prescriptions for 19 million acres; carry out inventories on 50 forests covering 31 million commercial forest acres and prepare timber management plans on 61 forests covering 37 million commercial forest acres." These are major tasks facing those responsible for the proper management of the National Forests.

What kinds of information and capabilities are needed to develop an acceptable management plan? Barber (1973) suggests six requirements:

1. The location and acreage of all stands on the Forest.
2. A means of imposing physical and administrative constraints on the forest practices that will be allowed in individual stands.
3. A description of all stands, covering their structure, composition, volume, growth, and yield.
4. A means of predicting what would happen to each stand if it were harvested or, alternatively, if it were left to grow.
5. A set of techniques for analyzing the Forest's growing stock and land-use patterns to produce a management plan.
6. A means of updating the plan to accommodate changes in land base, stand structure, and management goals.

Of the six requirements, the collection and manipulation of geographic data can be the most costly and time-consuming steps in preparing a management plan. The Wildland Resource Information System (WRIS) was developed to handle this kind of problem.

The WRIS user obtains the location and acreage of all stands on the forest by digitizing maps of forest types. Unlike most earlier map systems, WRIS digitizes the maps by using a scanning microdensitometer and two computer programs: FREQTB converts the scanner output to a binary map; PØLLY extracts stand boundaries, which we call *polygons,* from the binary map, and produces a list of all stand areas and a magnetic tape containing all the stand boundaries.

Constraints are imposed on managing the forest in two steps using WRIS. First, maps delineating areas which impose either physical or administrative constraints on management are digitized in the same way as the stand maps. Second, by using the output for the stand map and the constraint map, a computer program (MØSAIC) overlays the two maps to produce polygons which represent a combination of information on forest types and constraints. The acreages of these polygons are used, along with other data, in the analysis necessary to develop a management plan.

Updating is easily handled by WRIS. Changes in either the forest-type or the constraints layer can be made. MØSAIC can be rerun and the new acreages entered into the analysis. WRIS can plot the original and the overlaid maps by the program CHART, or provide various useful lists by two programs (GØSSIP and RUMØR). These outputs from WRIS are particularly useful for developing a work plan to carry out the new management plan.

An important feature of WRIS is that it is not limited to the sequence of steps just described for developing a management plan. The capabilities of WRIS can be used for any process that begins with more than one layer of maps and combines these layers to provide the data for decisionmaking.

This paper describes the development of the Wildland Resource Information System and its capabilities and characteristics, provides production information about using the system, and considers the outlook for future modifications.

The publication *Wildland Resource Information*

System: User's Guide (USDA Forest Service General Technical Report PSW-10) details the operating procedures for using WRIS computer programs and digitizing hardware. Copies of the report and the computer programs are available on request to: Director, Pacific Southwest Forest and Range Experiment Station, P.O. Box 245, Berkeley, California 94701, Attention: Computer Services Librarian. The programs will be copied on a magnetic tape, to be supplied by the requestor. Before sending the tape, the requestor should contact the Computer Services Librarian, giving the tape format desired.

DEVELOPMENT OF WRIS

The potential usefulness of a computerized geographic information system was recognized years ago. But the development of such a system has been hampered by three major obstacles: First, data collection was limited to hand digitizing technology; second, the computational methods available required data to be categorized in a cellular fashion; and third, it was not clear that a system that solved technical problems would also be economically feasible.

Once the need for a geographic information system was recognized, the next step was to establish its scope. This meant considering the degree of centralization, deciding which functions and decisionmaking levels would be assisted, and establishing a production rate in balance with the expected annual map requirements. Compromises had to be made, and the result is considered desirable rather than optimal.

In a highly decentralized organization, such as the U.S. Forest Service, a configuration usable at the National Forest headquarters level may be desirable. Yet the economy of scale yielded by scanner digitizing suggests centralized processing at the regional or multiregional level. Hence, the role of hand digitizing has diminished for economic rather than technical reasons.

WRIS is functionally oriented toward timber in order to minimize the cost of map data reduction, as timber data was most easily available. Any other wildland data, such as geologic and soil classifications, that can be represented on maps, can be handled by the same procedures as timber data. New procedures can be improvised to adjust the system to fairly drastic changes in the input format. Point data such as elevations, or lineal features like roads, might warrant special treatment. We expect the bulk of the work to consist of identification of areas with irregularly shaped but connected boundaries, and the scope of the system reflects this fact.

Within the Forest Service's California Region, timber management planning alone requires about 300 new maps per year. Half of these maps are concerned with biological data–largely timber types. Other management activities collectively generate at least another hundred maps. A minimum processing rate is therefore two sheets per day.

System Design

System design requires the matching of the user's needs to the available resources. The client should be clearly identifiable with definable objectives. This ideal is difficult to attain because there are usually many potential users. It can be approached by selecting the appropriate design strategy. A common one is to conduct surveys of user's information requirements–a method requiring substantial resources (Boeing Computer Service, Inc. 1972; Raytheon Co., Autometric Operations 1973). An alternative, when the designers are already familiar with the user's problems, is to make simplifying assumptions and then provide an information system which seems just adequate. Then the system can be used to reveal the user's decision process. Later, portions of the system can be upgraded incrementally and performance continually evaluated. We took this approach in the design of WRIS.

A major influence on our design was control over the map compilation process, following aerial photography. To allow both automatic scanning as well as hand digitizing, we made slight changes in map annotations and in line widths in map drawings. Another influence on design was the resolution–fineness of detail–required to distinguish lines in aerial photographs. We could place forest-type lines effectively within about 50 feet (15 m) of true ground location. The inaccuracy represented by this distance is not critical, as it would be in depth soundings on navigational charts, for example. The appropriate, much less optimum, resolution could be defined only by substantial analysis.

A further influence on our design of WRIS was the several sources of complexity found in forest maps. One source is the characteristic of lines. Straight lines allow data to be compressed because essentially only changes in direction must be recorded. That fact is undoubtedly helpful in urban geographic information systems. But natural phenomena show few regularities; the only straight lines we encountered were administrative boundaries. The forest-type maps were quite detailed. Polygons are plane figures consisting of three or more vertices connected by line segments. The smallest polygon allowed on a map was 5 acres–about 10,000 polygons occurred on a Forest.

To express the attributes of a polygon, we use a *label*. For each polygon, its coordinate position is recorded and a label assigned. A label consists of from 1 to 36 characters. It is not unique, but may occur many times on a map–once for every polygon with the same attributes.

To describe the attributes of the 10,000 polygons recorded on a National Forest, we needed about 1250 labels to show classifications of forest type. Perhaps the classifications were too fine: almost any management planning would require about a twenty-fold reduction in the number of categories. Yet detail should be in excess of immediate needs. A suggested strategy is to have low-access storage of the original detail so the composition of the groups can be changed. This additional flexibility is worth the additional setup cost.

Clearly, availability of hardware can affect system design. The ubiquitous line printer, designed for printing characters, has served in lieu of expensive graphic output devices since the early 1960's (Thornburn and others 1973). WRIS originated in a multipurpose batch processing environment. The batch operation differs significantly from other installations in that the terminal can communicate easily with varying brands of distant computers. The peripheral graphic devices, digitizers and plotters are single-purpose equipment.

Software availability had little effect on system design. The few computer programs described in the literature were coded mainly by geographers (Tobler 1970). This lack of programs simply reflects the state of the art. There is still uncertainty and disagreement as to the correct method for storage and manipulation of graphic data. The "best" ways change rapidly with new developments in computer technology. We can expect algorithms as well as devices to be continually redesigned.

All large-scale geographic information systems require specialized equipment for map digitizing and graphic display. Often a sophisticated device must be developed before technical feasibility can be demonstrated. A prime example is the Canadian Geographic Information System, which uses a drum scanner designed expressly for the Canada Land Inventory scribed map sheets (Tomlinson 1967). Another Canadian system, on a smaller scale, performs cartographic manipulations without access to a shared computer. The configuration includes a storage display connected to a minicomputer by a specially designed interface (Graphic System Design and Applications Group 1972).

Our approach was to use commercially available services and to avoid hardware modification. For example, the hand digitizer selected was unusual because it did not have any moving parts connected to its cursor, and it was obtained with as few optional "extras" as possible. As a result, this first production model is still in use. All adaptations to changing technology are by means of software.

Maintaining flexibility through software tends to rule out the minicomputer in favor of medium or large computers shared by many users. All development has taken place on a UNIVAC 1108 computer, but conversion to other computers is feasible. The goal of flexibility has also resulted in a modular program structure, in FORTRAN. Similarly, the use of assembly languages or FORTRAN language features peculiar to one computer configuration has been avoided as much as possible. A large production rate may warrant some software specialization, however, to minimize input-output cost.

Testing

Testing has involved the repeated application of two steps. First, the requisite computer programs were debugged separately and as a group by using sample data. Then a series of about 50 maps or one forest overlay was processed. Each repetition suggested changes for the next. The first group of maps caused the most substantial change, from a process centered on hand-digitizing to one relying on an automatic scanner. About 236 township maps, covering two National Forests, have been completely processed.

Because technology is always changing, testing for technical feasibility will follow each change. But the final test, that of economic feasibility, cannot be made in a research and development environment. Only users can provide the stable working conditions needed to rationalize work flow. Cost data should be based on a system operated routinely by experienced personnel. These data should be collected during a year of routine work after the system has been implemented.

Implementation

The major consideration before system installation is the expected volume of work. The computer programs can be compiled and stored for such a small cost that even infrequent use would justify them. But, even for such use, at least one person would be required to operate specialized equipment and assist with occasional complex editing problems. A clearly appropriate workload would be about 200 maps per year processed by a two-person staff.

The source maps are generally prepared under contract, as most of the data processing could be. Within the Forest Service, we recommend that polygon identities be encoded at Forest headquarters, where the resource photography is available to correct erroneous map symbols. All subsequent work can be performed at the Regional level or commercially.

USERS OF WRIS

Most users of this information system are the management planners in a decentralized organization. This practice implies a two-way flow of data between at least two management levels, such as Forest and Region headquarters. Current users include timber management planning staff members, who require facts about the resource, such as the acreage distribution of forest types, the timber volumes and the growth rates associated with them. In turn, these data are interpreted, and in accordance with policy guidelines, are passed forward to successive decisionmaking levels. Often information is prepared as computer input for subsequent analysis by linear or dynamic programming. The formal linking of computerized spatial information and mathematical models has already begun. For example, the combining of "TRI" and "RAM" for compartment management has been described in the report on *The Siuslaw Model,* U.S. Forest Service, Pacific Northwest Region 1973).

The kinds of map information used vary by location in the United States. On the Stanislaus and Eldorado National Forests in California, for example, two types of mapped data are essential to estimating timber inventory. Timber-type maps are prepared from large-scale (1:15,840) resource photography in a General Land Survey, township format. Together with delineations of administrative boundaries, these maps provide spatial information on management possibilities. Next, a management component map is prepared, showing land classifications that will affect harvesting or cultural activities. The combination of these two maps, with corresponding volume and growth data, provides the physical information for computing timber management alternatives.

It is easy to visualize how information from other functions or disciplines could be applied. Soil information could be incorporated as an additional stratum affecting cultural practices. At least three layers of information would be needed for a single function such as timber management; multidisciplinary problems might require several times that amount.

Some shifts can be anticipated in the needs of the users as well as in graphic technology. As demands on the forest resource increase, so will the need for more detailed "in-place" information. Conventional resource photography and mapping may be complemented or replaced by orthophotography. Source negatives may be taken by high-altitude aircraft or satellite. Presumably, classifications for various purposes will still be delineated from this source material, and for that reason few modifications to the existing system will be needed. Large changes will arise when the user expects analytic additions to the system and not just acreage calculations and summations.

CAPABILITIES OF WRIS

WRIS provides the means of collecting, processing, storing, retrieving, updating, and displaying "in-place" resource information, and makes possible the performance of logical operations on it. Two characteristics of these capabilities are notable: First, they cannot be regarded as an optimal mix because the multiple objectives of the land manager, and the many constraints on his decisionmaking, are too complex to allow such judgment. Second, these capabilities exist in other geographic information systems of comparable size (Tomlinson 1972); the major difference is the ease with which they can be exploited.

- Data from maps can be recorded at various scales—provided a few geographic reference marks are provided for alinement. The two scales used so far in processing National Forest data are 4 inches and 2 inches per mile for the same townships. Two coordinate systems are adequate for California: State Plane (Lambert Conformal) and geographic (latitude/longitude) coordinates. Transverse Mercator is included in the system for application in other States, and Universal Transverse Mercator (U.T.M.) is also available.

- Images of a map can be displayed on a line printer, but this is intended only for intermediate or editing purposes. Plots, either for editing purposes or for final use, are drawn by either flatbed or drum ink-line plotters of moderate accuracy.
- Computation is performed on a UNIVAC 1108 Computer in FORTRAN over a high-speed batch terminal.
- Data can be manipulated by editing and by performing logical operations. Editing, the most expensive task, is the hardest to describe because of the diversity of errors possible. A major problem in editing is controlling the quality of the original map data.
- Spatial analytic techniques and logical operations include extraction of data on the basis of political or administrative boundaries; statistical summaries of extracted data, including area and perimeter measurements; merging and overlaying map files; and removing a rectangular subset of data within a map border (windowing).
- Finally, the system can perform routine bookkeeping tasks. For example, maps and magnetic tapes must be logged in and out, digitized data packed for low-access storage, and backup files maintained in case of loss. The procedures allowed for would be adequate for an expected production rate of 200 or 300 maps a year.

Map Data Compilation

Preparation of forest-type maps often begins with aerial photography. In the California Region, resource photography is generally taken in color at a scale of 4 inches per mile (1:15,840). From stereographic coverage of an entire Forest, type maps are drawn by a contractor, who uses standard mapping procedures. Type boundaries down to a minimum of 5 acres are delineated on the photographs in accordance with regional definitions. The lines are rectified and transferred to a plastic map sheet. Width of the black ink lines is determined by scanning considerations: 0.025 inch is typical for a 2- by 2- foot township map.

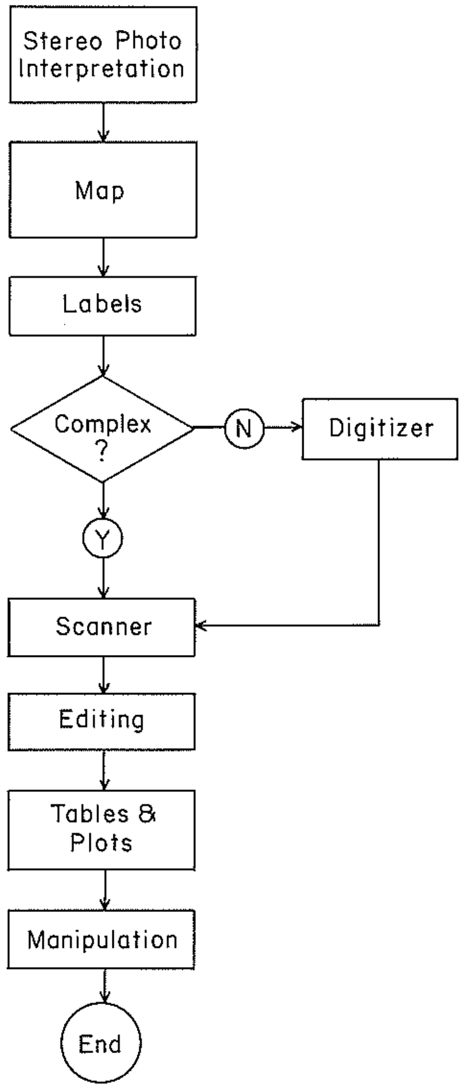
Map compilation results in a closed network of lines, with each polygon identified by a label indicating forest type. (A closed network means that only polygons are on the map sheet. All lines join other lines, including the map (township) border). Labels (attributes) appear on the map in blue, which is not visible in a black-and-white copy negative. The procedure just described is used for the two other types of maps digitized, except that scales differ and paper is used rather than plastic for the base.

Our experience with California Forests should help judge the feasibility of handling other jobs with WRIS. Our forest-type maps were quite detailed, with 200 to 300 polygons per map sheet. Maps corresponding to the same areas, showing management components, had 50 to 100 polygons per sheet. (The components are areas suitable for various types of logging, ownership, use as recreation sites, and similar purposes.) Finally, a simple map was drawn showing only administrative boundaries. More information, particularly soils data, would be needed for timber management planning, but forest-wide "layers" are not now generally available.

Data processing with WRIS can be accomplished using any map format or scale. A township (36 square mile) outline at 2 or 4 inches per mile is used in the California Region. The familiar U.S. Geological Survey quadrangle format would be preferable, however. The public land survey grid is unwieldy because it is an irregular format. Virtually any mathematically defined coordinate system would be more convenient; the township outlines could be included for use, just as any other layer of information could be. Map-scale variations are handled easily. The scale of input can be quite large because maps can be reduced photographically. The only size requirement for the output is that it be convenient for manual editing. This size rarely exceeds that of the original map.

Map Data Manipulation

After the maps have been drawn, the next manual step is to assign each map polygon a label. Because errors, such as missing or conflicting identities, must be corrected, this work is done at the Forest headquarters, where the photography is available for reference. The only problem is that maps often include special characters unknown to the computer. Consequently, a translation scheme must be devised before labeling is done. The labeling itself is a simple process. A polygon is selected arbitrarily. It is identified by a label, and the information is keypunched. A single x, y location falling within the polygon is also recorded and is thereafter associated with the label. Successive polygons are labeled until all have been recorded. Some map errors are corrected, and a few labeling errors are generated—only to be detected during subsequent steps.



The labeled and logically correct map is then ready for digitizing *(fig. 1)*. Like labeling, digitizing is a fairly straightforward process because two digitizers are available: manual or automatic. Simple maps, such as administrative boundary sheets, can be digitized manually by hand-held digitizers; more complex maps are digitized automatically by microdensitometers *(fig. 2)*. For automatic digitizing the map is first photographically reduced to a black-and-white negative. Then it is scanned line by line (raster scan), and the densities are recorded on magnetic tape. The tape is stored for later processing.

Assembling the raster-scan data into valid lines and polygons requires editing, a complex process. Essentially it progresses in steps, with intermediate tabular and graphic output to display errors. The number of steps varies because some errors may require recycling back one or more steps. Editing ceases when the total area is correctly recorded within a specified tolerance. Editing completes the data reduction procedure except for data packing and copying for long-term storage.

Once correct, the map data are available for retrieval and manipulation. In forest inventory work, the usual next step is to lay one map sheet over another to obtain logical combinations. The output from each pair of township maps is acreages. These acreages can be accumulated for an entire forest. This application alone has many variations, depending on the immediate problem.

Figure 1—WRIS produces information from forest-type maps in a multiple-step process. A map derived from resource photography is divided into polygons. Each polygon is labeled by recording its coordinate position. A map is either hand-digitized or is automatically scanned by a microdensitomer. It is then edited to repair data lines and to account for all polygons. The data produced can be manipulated and displayed in various graphic forms.

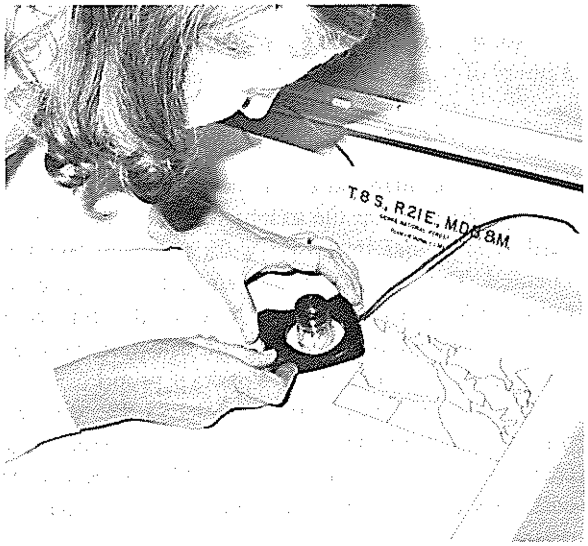
PRODUCTION INFORMATION

Cost Estimates

The average township map can be processed for a direct cost of about $170. This estimate reflects a number of underlying assumptions and conditions. On the basis of past experience in acquiring data for two National Forests, it assumes two or three trained people operating at a rate of 200 or 300 map sheets a year. The major means of digitizing is by the raster-scanning method. Given these various conditions, estimated costs, by functions, are:

	Cost per township (dollars)
Process:	
Scanning	20
Labeling	20
Editing:	
Labor	15
Computer time	80
Plots (1½)	30
Total	165

The manhour estimates given are net, in that relaxation periods or miscellaneous interruptions are



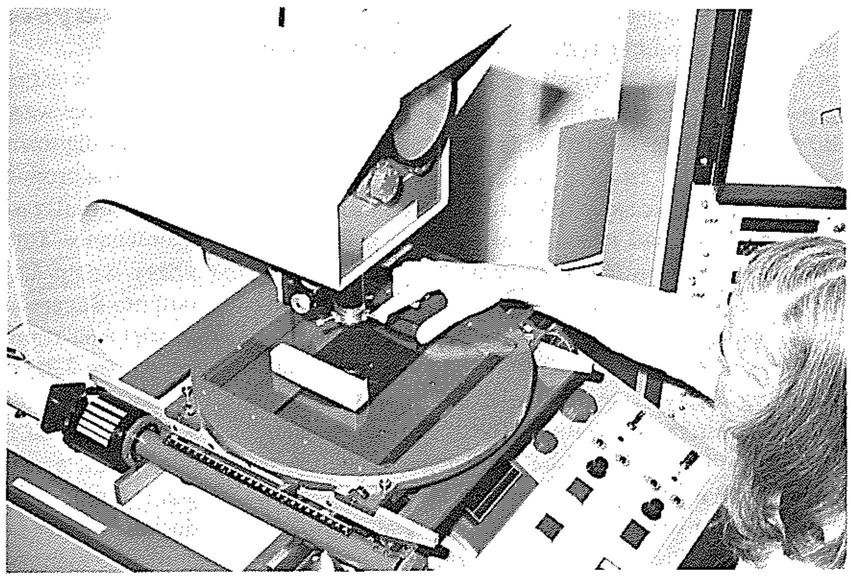


Figure 2—Digitizing is a key step in preparing maps in WRIS. For simple maps, it can be done manually with a hand-held digitizer, *left;* for more complex jobs, optical densities are measured by a scanning microdensitomer, *right.*

excluded. The cost of computer time in 1974 was about $325 per hour. A labor cost of $5.00 per hour is assumed. All hourly data are based on the performance of six well-trained students over a period of 2 years. As experience has shown that individuals vary in performance, only averages and "rules-of-thumb" are warranted.

Cost estimation is greatly simplified because we can ignore fixed or setup costs. All equipment services, with the possible exception of a scanner, can be rented. Consequently, the vexing problems of depreciation, salvage value, and the allocation of joint costs, are not considered here.

Digitizing

Automatic recording of map negative densities in a raster format requires a specialized machine. The PDS-1000 scanning microdensitometer we use was originally purchased for digitizing aerial photographs. Because it is highly accurate, it is unnecessarily slow for our map work. It would cause a bottleneck if production were doubled: the typical million-point scan takes 10 hours. Many other digitizers are now available and, while these have not yet been thoroughly investigated, it is evident that some of the cruder devices can scan in minutes, or even seconds, jobs which now require hours.

Labeling and Editing

Before labeling can begin an encoding scheme is developed. The original map designations usually have characters which cannot be keypunched or replicated by a print chain. Once computer-readable equivalents are memorized, labeling time simply depends on the number of polygons per map. The time requirement has varied between ¼ and 6 hours; 4 hours are needed for a typical map.

Editing requires an ability to visualize spatial relationships, such as is needed to solve jigsaw puzzles. Fortunately, most development effort has been applied to the editing problem, and numerous aids have been documented.

Editing is divided into two parts: repairing the line data, and accounting for all polygons. Line repair begins with printing the scanner output tape, that is, the 0,1 matrix, in strips. This takes 1½ to 3¼ minutes of computer time, depending on the amount of "blank" space. A visual scan of the strips detects gaps in lines, requiring the addition of 1's to fill them in. Deletions are needed occasionally, as when the space between closely adjoining lines has been bridged by the scanner. Recording corrections takes about 2 hours and is clearly affected by the quality and extent of the original ink lines.

During the second phase, the polygon labels prepared earlier are input along with corrections to a polygon-extracting program. The program checks incoming labels, computes areas, and reports various error conditions for editing. The first time through, the more obvious errors are corrected and the job is then resubmitted. Later, as errors become more subtle, a plot may be necessary. This iterative process continues until the total area is within a prescribed tolerance of the area enclosed by the map border. Generally the maps are correct, with the aid of a plot or two, within three or four passes, for an average of 3 hours of work.

Data Manipulation

Once the map data are correct all subsequent expense depends on the extent to which the data are used. The timber inventory work performed is area oriented. The only operation immediately required in our experience was the intersection of all polygons on two or more map layers and the calculation of the polygon areas created. This expense is proportional to the number of input polygons *(fig. 3)*. The demand for other operations, such as selected overlays and plots, is expected to increase soon. We can expect the cost roles of acquiring and manipulating map data to reverse themselves as use increases.

System Maintenance

All cost estimates were based on the assumption that services were rented. Purchasing equipment, particularly digitizers and plotters, may be a better alternative at a production rate of a few hundred maps per year. In that case, the manufacturer's allowance for maintenance (often about 10 percent of purchase price) would be prorated over the expected map output. Buyers have a wide range of choices. A digitizer-plotter combination, for example, could range in price from $30,000 to $80,000.

Software will be maintained indefinitely for use by the National Forests. But available resources may not permit a continual, general distribution of program modifications. All computer programs have documentation in the form of comment cards to minimize maintenance cost. Most users will have to write software to read digitizer output tapes for the various brands available.

FUTURE OUTLOOK

Computerized systems are particularly subject to technological change. Geographic information systems are vulnerable from three directions: (a) graphic hardware alternatives are changing in line with satellite technology; (b) methodology is scarce because little documentation is available; and (c) applications for existing systems are quite rudimentary. Evidently there will be a lag before users drop their mental constraints on possible applications. This bar may be due to past association with the tedious task of extracting graphic information by hand. For example, manual methods for determining line-of-sight or terrain slope from elevation data have been available for decades. Yet, only recently have these applications been computerized (Amidon and Elsner 1968, Sharpnack and Akin 1969).

Software extensions of present capabilities will take priority over hardware modifications. The UNIVAC 1100 Series Executive System (EXEC 8) version of FORTRAN will replace the present EXEC 2. Conversion to IBM 360 computer system is planned and PL/1 language conversion is a possibility.

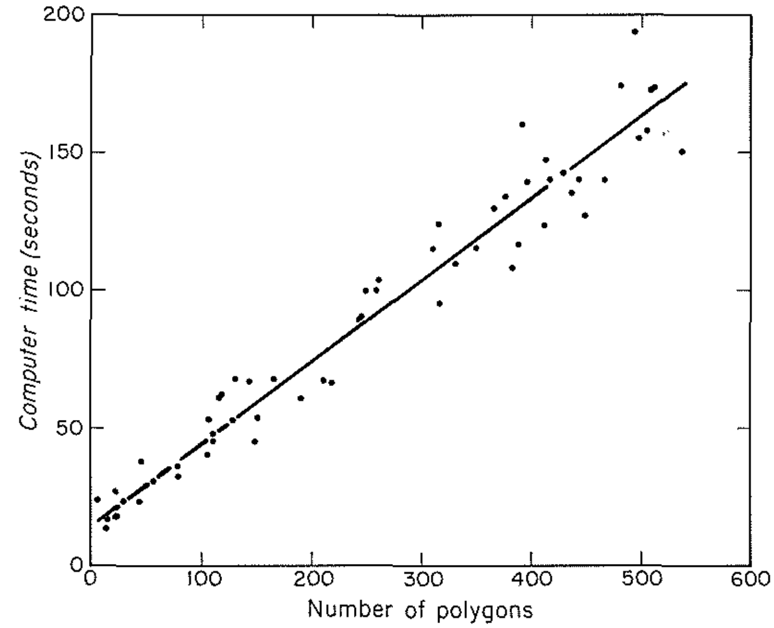


Figure 3—The cost of overlaying maps in WRIS is directly related to the amount of map detail.

Several National Forest data bases are now undergoing changes. It is inevitable, therefore, that more effort will be spent on updating. Several alternatives already exist, such as the overlay procedure, but others will need development as the frequency of updates grows. Hand digitizing methods, less attractive than scanning for capturing initial data, should be useful for modifying local data. Hand digitizing may also prove attractive for adding point and line data.

Once the National Forest data bases are reliable and readily available, requests for storage and retrieval will increase. Then the currently moderate capability of accessing acquired information will require extension. Perhaps an existing general purpose system, such as GIM (General Information Management), can be used, thereby minimizing development costs.

Finally, some means will be found to achieve communication between geographic information systems. This tie-in could begin with tape format compatibility. And eventually, it could evolve into standardization of terminology and software exchange, as well as other areas signifying maturity in this expanding field.

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1975. **WRIS: a resource information system for wildland management.** USDA Forest Serv. Res. Paper PSW-107, 12 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

WRIS (Wildland Resource Information System) is a computer system for processing, storing, retrieving, updating, and displaying geographic data. The polygon, representing a land area boundary, forms the building block of WRIS. Polygons form a map. Maps are digitized manually or by automatic scanning. Computer programs can extract and produce polygon maps and can overlay, plot, and store them, as well as aggregate acreages and print summaries. WRIS is functionally oriented toward timber management, but can be used for other types of resource activities.

Oxford: 624:U681.3:(084.3)
Retrieval Terms: timber management; wildland management; resource use planning; computer programs; map compilation; WRIS; management information systems.

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