ANALYSIS OF ALTERNATIVES FOR AN OKLAHOMA LAND USE INFORMATION SYSTEM

Prepared for

The Office of Community Affairs and Planning

by

Richard A. Watson
Coordinator of Geography Extension

with the collaboration of

Paul Hagle
Extension Economic Geographer

Stephen W. Tweedie
Assistant Professor

Eldean Bahm
Supervisor, Academic Programming
OSU Computer Center

and the assistance of

Peter J. Roberts
Eric H. Weiland
Suzanne G. Thurman

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This report recommends a procedure for developing a state-wide land use informational system. It is organized as follows: general consideration of system purpose and user demands; data scope, detail, comparability, and updating procedure; geographical information systems and recommendation for Oklahoma; data display system considering projection, scale, format, symbolization, method of reproduction and content of maps; systems design and equipment consideration including costs; method of implementation; and a partial list of equipment supplies.

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INTRODUCTION

Recognizing that improved planning at the statewide and sub-state levels requires better locationally identified land use data, The Governor's Office of Community Affairs and Planning of the State of Oklahoma is beginning to examine the possibility of developing a state-wide land use information system. As a part of their initial inquiry, they asked Geography Extension at Oklahoma State University to make a preliminary analysis of some aspects of developing such an information system. This report is a summary of the findings of this analysis.

It was assumed that any land use information system which the State of Oklahoma might develop would be part of an overall geographic information system which would have as its purpose to provide timely and useful information to decision-makers. It was further assumed that the system would be used primarily at the state and sub-state regional levels and would be used in analyzing growth and change, in analyzing area potential, and in the location and definition of public works and programs. The system is not envisioned to be so detailed as to be useful in either project execution or questions of local zoning. Furthermore, at this time the details of urban land uses are not being considered.

While considering the comments made in this report concerning the problems of specifiying, gathering, storing, manipulating, and displaying data, it is important to bear in mind that there is a very significant trade-off between completeness or comprehensiveness, and cost and complexity.

There is real danger of developing either an overly simplified or an overly complex system. Neither is particularly useful to the decision-maker. One may contain so little relevant information as to be worthless in support of wise decision-making and the other may be so costly and complex that it never becomes operational.

GENERAL CONSIDERATIONS

At this time a primary consideration in the development of any type of geographic information system, even one concerned only with land use, should be caution. As Dueker and Drake have said,

> It is extremely difficult at this time to design information systems to support a statewide land planning process. First, too little is known as to what data are needed to formulate land policy and controls. Secondly, technical problems of collecting, encoding, storing, and displaying land data are largely unsolved and are resulting in a severe lack of comparability between system designs. (Dueker and Drake, 1972, p. 30)

Thus, states face a problem of some magnitude if they are required by the federal government to design and implement information systems within a short period of time as they might be under the proposed Land Use Policy And Planning Assistance Act. Many hastily designed systems are likely to be doomed to failure. Given the present situation many states are likely to jump right into the information system business, but learning by doing in developing geographic information systems can be very costly. Many facets of the state of the art must be considered in order to avoid duplicating costly developmental problems already experienced by earlier projects in other states and regions. Oklahoma can ill afford the expense of rediscovering developmental difficulties previously paid for in other states.

Past experience in designing geographic information systems indicates that several key criteria of system design should be considered at an early stage in the developmental process. In coping with these design

criteria, crucial decisons must be made which affect the eventual configuration of the information system and thereby limit its scope and capabilities. Five critical criteria will be identified and briefly examined.

1. System purpose and demands (user requirements).
2. Level of data detail and scope.
3. Level of geographic resolution or detail.
4. Level of temporal detail (timeliness of data and updating).
5. Output and system responsiveness.

Item 1 above may be viewed as the assumptions and preliminaries of system development. Items 2, 3, and 4 are input constraints on the system. Finally, Item 5 involves output constraints and is closely linked with the physical (hardware) structure of the system. Each of these criteria have feedback linkages with some or all of the others. Also, all are subject to overriding constraints in the form of state agency support with regard to policy and level of funding. System purpose will be considered at this point while the other four criteria will be considered in later sections of the report.

System Purpose and User Demands

Earlier experiences in developing geographic information systems have demonstrated the need for careful and critical examination of the present purpose for developing the system and potential uses and users of the system. System designs based on consideration of rather narrow objectives have frequently proved inflexible or too costly to expand to accommodate a broader community of users. Those information systems which have been too broadly designed in an attempt to anticipate the problems of all conceivable potential users have usually proved to be extremely expensive, criteria, crucial decisions must be made which affect the eventual configuration of the information system and thereby limit its scope and capabilities. Five critical criteria will be identified and briefly examined.

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An ideal geographic information system would be one which has sufficient scope and flexibility to accomodate all present and anticipated user needs. But As Dueker and Drake have recently observed

> A system structured to serve all needs equally well my well be prohibitively costly, thereby introducing tradeoff considerations into the systems design process. However, unless a systematic methodology for assessing the informational needs at the state level is devised, an all-purpose system cannot be built, nor can degrees of informational need be effectively determined. (Dueker and Drake, 1972, p. 20)

Perhaps, since at this time only the development of a statewide land use information system is being considered, one need not be overly concerned about the problems of creating a comprehensive geographic information system, yet these potential difficulties must be kept in mind for at least two reasons. First, the cost and flexibility factors are important in specialized as well as comprehensive systems. Secondly, it must be remembered that small, special purpose information systems may soon become obsolete and may not be readily adapted to meet changing societal needs. (Center for Advanced Computation, 1972, p. 91) Hence, it might be wise to design a statewide land use information system as part of a more comprehensive system.

In Oklahoma, the principal source of expressed demand for development of a geographic information system apparently has been induced by external influences. Although many individual state and local agencies have attempted to develop their own information systems to support their specific missions, state-wide action toward establishment of a geographic information system has been primarily a response to such proposed federal legislation as the Land Use Policy and Planning Assistance Act. Earlier influence was exerted by the Ozark Regional Commission. But all evidence

suggests that the Ozark Regional Information System was an abortive, poorly designed, and, more importantly, poorly understood and supported pioneering effort. Perhaps its major failure was its designers' lack of communication and coordination with potential users.

Acknowledging the influence of federal legislation and programs, it may be useful to look at some specifics. The biggest expressed demand for improved geographic information to date is related to land use and natural resource information needed for compliance and participation in programs such as those of the Environmental Policy Act, Water Pollution Control Act, and the Rural Development Act.

Possibly Oklahoma's greatest need now and, for some time to come, is for a geographic information system designed to provide information applicable to land and natural resource use problems. If such is the case, design criteria may differ from those pertinent to a more comprehensive information system. However, before a large commitment of effort and funding is made, careful consideration of diverse users of geographic data should be investigated to avoid potentially wasteful duplication of effort both in systems design (software and hardware) and in future data collection procedures.

As an example, considerable effort and funding is presently being expended in enhancing the information capabilities for use in various types of socio-economic planning and programs. The impact of recent Federal programs for funding development of regional health information systems has been significant. Information gathering and organizing activities for other types of socio-economic planning and programming have been and are being funded through policies and programs of such Federal legislation as the various HUD Acts, Transportation Acts, Education Acts, and others.

And finally, the State and Local Fiscal Assistance Act of 1972 created a pervasive fiscal and budgetary superstructure which further taxes the informational resources of local and regional communities.

Experience in many other states and regions clearly indicates that one of the most difficult problems affecting information system planning is that of coordinating diverse demands for information and in making information systems compatible for these diverse uses and demands. With the immense amount of information presently being collected by various state agencies, mainly for internal use, it could be a costly error to design an information system that is not sufficiently flexible to incorporate these informational resources.

> For each dollar spent on the system, it is common to spend another ten dollars on data acquisition. Collecting new natural resource, social, and economic data in the State of Illinois will cost tens of millions of dollars. It is cost-effective to double or even triple the cost and complexity of the computerized system in order to be able to input and analyze existing data. (Center for Advanced Computation, 1972a, pp. 39-40)

Prior to making decisions which might lock Oklahoma's state-wide information system development into an inflexible, narrowly conceived system capable of providing information on a small group of problems and to only a few users, the State should carefully consider the experiences of other states and regions and the purposes and needs of Oklahoma users. In summarizing their rather extensive review of earlier attempts in developing geographic information systems, the IRIS study group made the following pertinent observations:

> Most computer systems were built as part of a project designed to solve a specific problem and therefore could not be called comprehensive. There was poor communication between the designers and the users of several of the systems. In some cases, competent users underestimated the level of skill required to properly

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> engineer the computer support system. In other cases competent computer scientists, working without access to users who could adequately guide design efforts, produced elegant computer systems which did not address real world problems. (Center for Advanced Computation, 1972a, p. 39)

If either a land use or a comprehensive geographic information system is to be developed, it will be necessary to invest in highly competent systems designers and programmers to design and implement the system. An investment in quality personnel is likely to return dividends in the form of lower operating costs and a usable system. At the same time care should be taken to ensure that too much emphasis is not placed on the computing system. Such an imbalance in emphasis is alleged to have been a factor in the failure of the Integrated Municiapl Information System (IMIS) in Charlotte, N.C. (Center for Advanced Computation, 1972a, p. 147)

A further area of consideration should be the coordination of any specialized or comprehensive geographic information system developed in Oklahoma with similar undertakings in surrounding states. Availability of meaningful data to analyze land use problems or potentials near the state line will require compatible data from the adjoining state. Since some of these states are now also at the stage of assessing their future needs, it would seem quite feasible to coordinate efforts and perhaps share costs. Both Texas and Missouri, for instance, are looking at the usefulness of satellite imagery while progressing at varying rates toward the development of statewide land use or resource information systems.

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DATA CONTENT

Basic to the creation of any type of information system is consideration of the scope and detail of the data contained within the system and the compatability of this data with that available from other potential information sources. Scope and detail of the data depend heavily upon the purposes and anticipated uses of the system. Comparability depends upon close examination of the data content and format of other geographic information systems which might need to be consulted in the future. Of particular importance would be the information systems of the federal government and the surrounding states as well as regional and local systems already developed within the state.

Since the staff of the Office of Community Affairs and Planning have already proposed the "Oklahoma Land Use and Activity Code" it is not necessary to propose a complete data code at this time. However, it does appear to be advisable to suggest a review of the proposed code relative to the factors mentioned above. This suggestion is made in recognition of the strong probability that the agency is already planning a review based on the tests made in Harper and Wagoner Counties.

Data Scope and Detail

Scope is a reference to the comprehensiveness of the data contained in the system. How many categories of data are included? Level of detail concerns the number of classes and sub-classes of data within any particular category. For instance, how many agricultural land use sub-types will

be defined. Decisions concerning these matters need to be reviewed before system development proceeds. The principal reason for suggesting this review is that the "Oklahoma Land Use and Activity Code" as presently proposed appears to be both too limited in its scope and too detailed in its content.

The scope limitation is in the area of auxillary data. To be a truly useful land use information system more than just land uses, location identifiers, and ownership data are needed. Selected attributes of the physical, social, and economic environment are also necessary to perform meaningful analysis of the potential impact of proposed developments or the land use potentials of an area. The inclusion of additional information in the system verges on the development of a comprehensive geographic information system. However, judicious selection of a few key auxillary variables will permit the creation of a land use information system which is truly useful in support of decision-making without committing the state to the development of a complex and costly comprehensive system. Some data such as that pertaining to slope or soil capability can be obtained from other agencies operating within Oklahoma. Some might come from the federal censuses. For this reason it is highly desirable that location codes be added that would relate land use information to the county, county census division and place codes used in the federal censuses. The county census division code is especially important because this new unit has been designed to be a long-term data unit which will not change with each census.

The potential problems with the level of detail in the "Oklahoma Land Use and Activity Code" appear to be related to the bases of the code. Each of the three codes upon which the Oklahoma code was developed is somewhat urban in its orientation. Hence, the proposed state land use be defined. Decisions concerning these matters need to be reviewed before system development proceeds. The principal reason for suggesting this review is that the "Oklahoma Land Use and Activity Code" as presently proposed appears to be both too limited in its scope and too detailed in its content.

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Data Comparability

As stated above it is important to the ultimate success and usefulness of any land use information system that might be adopted in Oklahoma that it be compatible with other federal, state, and local information systems with which data exchanges or cooperative analyses might be desired. Of particular interest at this time are the possible data requirements should the "Land Use and Planning Assistance Act of 1973" be enacted. This legislation provides for the establishment an Office of Land Use Policy Administration which among other things would be responsible for the development of standard methods and classifications for the collection of land use data and the establishment of effective procedures for the exchange and dissemination of land use data. The act also specifies a land use planning process which states will have to follow as a condition of continued eligibility for certain grants. This process calls for the maintenance of data files that are beyond those that would be contained in a limited land use information system.

Since work has already begun on the development of a standardized classification under the auspices of the Inter-Agency Steering Committee on Land Use Information and Classification, it seems likely that any new Office that might be established would build upon this work. Therefore it would seem advisable for the Office of Community Affairs and Planning to analyze

TABLE 1

PROPOSED NATIONAL LAND USE CLASSIFICATION

Level I	Level II
01. Urban and Built-up Land.	
	01. Residential.
	02. Commercial and services.
	03. Industrial.
	04. Extractive.
	05. Transportation, Communications, and Utilities.
	06. Institutional.
	07. Strip and Clustered Settlement.
	08. Mixed.
	09. Open and Other.
02. Agricultural Land.	
	01. Cropland and Pasture.
	02. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas.
	03. Feeding Operations.
	04. Other.
03. Rangeland	
	01. Grass.
	02. Savannas (Palmetto Prairies).
	03. Chaparral.
	04. Desert Shrub.
04. Forest Land.	
	01. Deciduous.
	02. Evergreen (Coniferous and Other).
	03. Mixed.
05. Water.	
	01. Streams and Waterways.
	02. Lakes.
	03. Reservoirs.
	04. Bays and Estuaries.
	05. Other.
06. Nonforested Wetland.	
	01. Vegetated.
	02. Bare.
07. Barren Land.	
	01. Salt Flats.
	02. Beaches.
	03. Sand Other Than Beaches.
	04. Bare Exposed Rock.
	05. Other.

Proposed National Land Use Classification - Continued

Level I	Level II
08. Tundra.	01. Tundra.
09. Permanent Snow and Icefields.	01. Permanent Snow and Icefields.

Source: A Land-Use Classification System for Use with Remote Sensor Data by James R. Anderson, Ernest E. Hardy, and John T. Roach, Geological Survey Circular 671 (Washington, 1972), p. 6.

its proposed land use and activity coding scheme with that proposed by Anderson, Hardy, and Roach in "A Land-Use Classification System for Use With Remote-Sensor Data" Geological Survey Circular 671. (See Table 1) Although the anthor has had personal communications from staff members of the Tennessee Valley Authority and the National Aeronautics and Space Administration that indicate that some modification of the proposed land-use categories may be required, it would seem likely that this classification will form the basis of a standardized national land use classification. With a few adjustments the "Oklahoma Land Use and Activity Code" could be made campatible with the proposed national land use classification which is really a land cover and natural resources classification. The Oklahoma Code could be adjusted by either changing it to a five digit code and making a few minor adjustments or by restructuring the entire code to place more emphasis on non-urban land uses and resources. The later alternative is recommended, however, no major changes should be made until needed modifications are made in the national code.

Data Updating

To be useful the data contained in the information system will need to be maintained at a level of temporal detail which is consistent with the requirements of the users of the system. Ideally, it would be desirable to have continuous real-time updating of the information as an integral part of the system. In the absence of such real-time updating, there must be a policy decision made as to the frequency of updating to be designed into the system.

Assuming space imagery from the Earth Resources Technology Satellite is used for updating the land use information in the system, a theoretical its proposed land use and activity coding scheme with that proposed by Anderson, Hardy, and Roach in "A Land-Use Classification System for Use With Remote-Sensor Data" Geological Survey Circular 671. (See Table 1) Although the author has had personal communications from staff members of the Tennessee Valley Authority and the National Aeronautics and Space Administration that indicate that some modifications of the proposed land-use categories may be required, it would seem likely that this classification will form the basis of a standardized national land use classification. With a few adjustments the "Oklahoma Land Use and Activity Code" could be made compatible with the proposed national land use classification which is really a land cover and natural resources classification. The Oklahoma Code could be adjusted by either changing it to a five digit code and making a few minor adjustments or by restructuring the entire code to place more emphasis on non-urban land uses and resources. The first alternative is recommended, however, no major changes should be made until needed modifications are made in the national code.

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Assuming space imagery from the Earth Resources Technology Satellite is used for updating the land use information in the system, a theoretical temporal frequency of 18 days is possible. Revision of data at such a frequency would not appear to be either necessary or practical at this time, especially for an area as large as the state of Oklahoma. It is, however, necessary for information contained within the system to be current enough to support land use planning and management decision-making. An important consideration in this regard, may be what is determined to fulfill the "continuing revision" clause of Sec. 302 of the "Land Use and Policy Assistance Act of 1973" if it becomes law.

To maintain the land use information system in a state of usefulness for state-wide and regional planning and evaluation, it is recommended that the Office of Community Affairs and Planning obtain enlargements of ERTS imagery at a scale of 1:250,000 on a quarterly basis and use these to update land use information at the first and second levels (See Table 1). As a check on the accuracy of the interpretation of this imagery and to provide more detailed information, it is further recommended that conventional high altitude imagery at a scale of 1:120.000 be obtained and analyzed once a year. As demonstrated by the Earth Resources Laboratory at the Mississippi Text Facility, imagery of this scale can provide quite detailed information at a moderate cost. (Vegas, 1972)

To do this would require that a competent interpreter be added to the staff of the agency. Furthermore, additional help would be necessary to interpret the 1:120,000 imagery once a year. This could be contracted out to a private agency or to one of the state's universities.

GEOGRAPHIC RESOLUTION

The characteristic which separates geographical information systems from other types of information systems is the requirement that the data be referenced in a manner which will permit retrieval, analysis, and display based on spatial criteria. The particular problem of geographical information systems is the appropriate selection of geographical references, or locational identifiers. (Tomlinson, 1972, introduction) Data of whatever scope and detail are identified geographically and assigned to a known, defined geographic location. Thus, location specific information is made available to users.

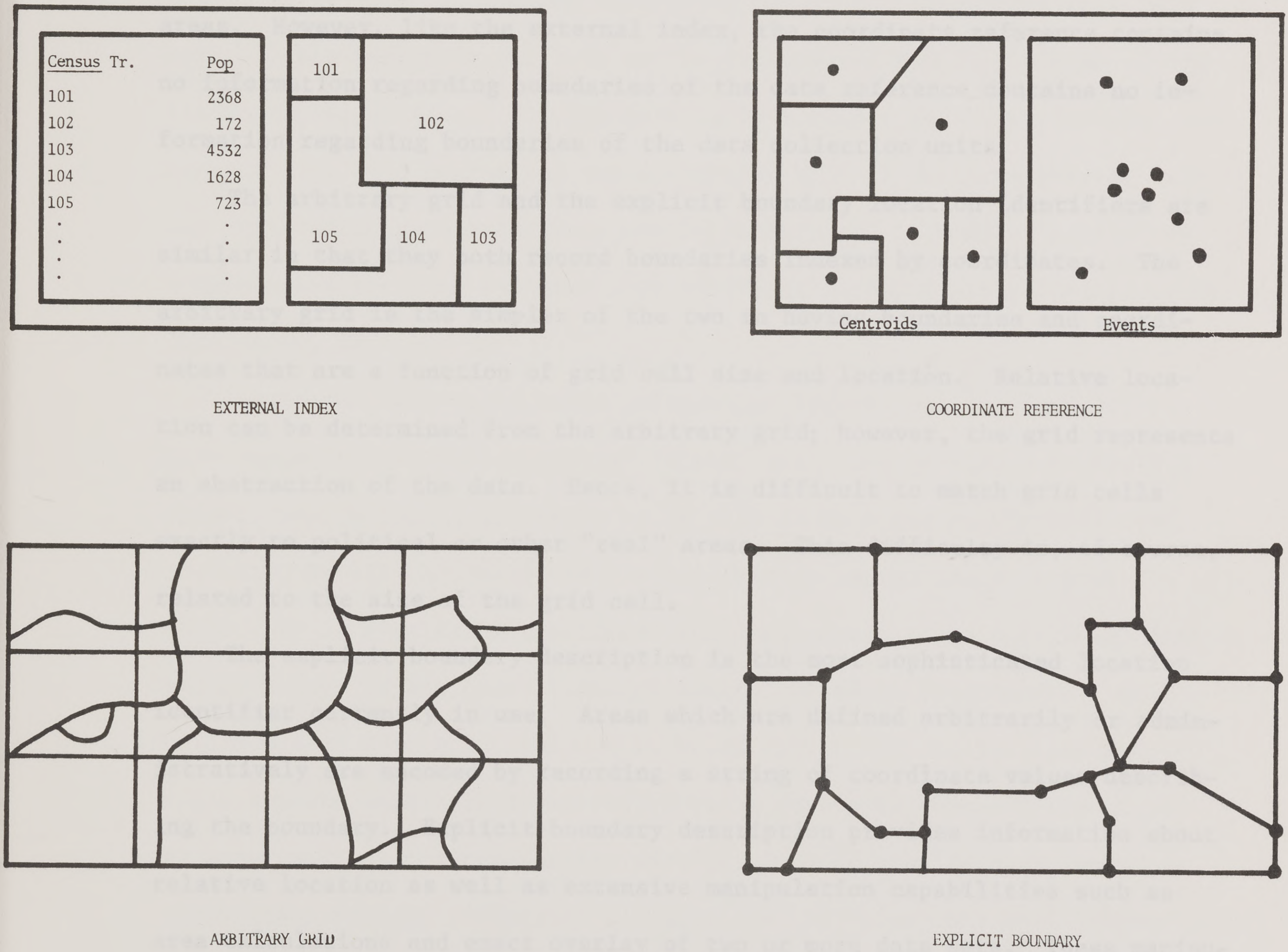
Locational Identifiers

To make data location specific it is necessary to select a form of locational reference. To aid in this selection it would be useful to recognize the classification of locational identifiers utilized by the participants at the UNESCO/IGU SECOND SYMPOSIUM ON GEOGRAPHICAL INFORMATION SYSTEMS. The four basic types of locational identifiers which were recognized are: 1) the external index, 2) the coordinate reference, 3) the arbitrary grid, and 4) the explicit boundary (See Fig. 1).

The external index is merely a nominal code which identifies the data belonging to a particular geographic area or location. The numerical value of the code does not directly convey information concerning relative location. It must be used with a master index, typically a map. The external index is not recommended for use in a statewide land use information system

FIGURE 1

LOCATION IDENTIFIERS FOR GEOGRAPHICAL INFORMATION SYSTEMS



Source: Geographical Data Handling, edited by R. F. Tomlinson, Symposium Edition, A Publication of the International Geographical Union Commission on Geographical Data Sensing and Processing for the UNESCO/IGU Second Symposium on Geographical Information Systems, Ottawa, August, 1972.

because of its limited value in data manipulation. Typical external indices are street address, census tract, and traffic zone.

A coordinate reference is generally the central point, or centroid, of an area or a discrete point where something is found such as the location of a well. This method of geographical referencing is of more use than the external index in manipulation of data such as making linear measurements, grouping into arbitrary areas defined by polygons, or defining homogeneous areas. However, like the external index, the coordinate reference contains no information regarding boundaries of the data reference contains no information regarding boundaries of the data collection units.

The arbitrary grid and the explicit boundary location identifiers are similar in that they both record boundaries indexed by coordinates. The arbitrary grid is the simpler of the two in having boundaries and coordinates that are a function of grid cell size and location. Relative location can be determined from the arbitrary grid; however, the grid represents an abstraction of the data. Hence, it is difficult to match grid cells exactly to political or other "real" areas. This difficulty is, of course, related to the size of the grid cell.

The explicit boundary description is the most sophisticated location identifier currently in use. Areas which are defined arbitrarily or administratively are encoded by recording a string of coordinate values describing the boundary. Explicit boundary description provides information about relative location as well as extensive manipulation capabilities such as area calculations and exact overlay of two or more data sets. These manipulations can also be made with data stored by arbitrary grid cell but with some loss in precision. The complexity of the extensive subsystem requireed by the use of explicit boundary description solely to meet the geographic

identification requirements is perhaps the major drawback of this method of identifying location. (Tomlinson, 1972, introduction)

Examples of the Use of Locational Identifiers

While the existing and proposed geographic information systems make use of all of these types of locational identifier, either singly or in combination, the most frequently utilized technique is the arbitrary grid. The principal reasons for the widespread use of the fixed arbitrary grid are: 1) the ease with which it may be implemented and 2) the ease of statistical manipulation. All the data to be included in the system are referenced to a grid matrix and the attributes of each cell are stored. The ease with which grid based data may be manipulated in complex statistical models makes the grid system a very efficient base for analytical endeavors. (Tomlinson, 1970, p. 39)

Among the early grid based information systems was the "Map Information Assembly and Display System" (MIADS) which was developed by the U.S. Forest Service and is currently being used in Oklahoma by the Soil Conservation Service to store and map information pertaining to attributes of soils. It is also being considered for implementation in a regional information system by the Association of Central Oklahoma Governments. MIADS utilizes a 40 acre grid cell and is based on the U.S. Public Land Survey. State systems which are developed or being developed on the basis of the 40 acre grid, or quarter-quarter section, include the "Natural Resources Information System" (NARIS) of Illinois and the "Minnesota Land Information System" (MLIS).

Even finer resolution is included or planned into other systems. The "Gridded Resource Inventory Data System" of the State of Washington, identification requirements is perhaps the major drawback of this method of identifying locations. (Tomlinson, 1972, introduction)

<u>Examples of the Use of Locational Identifiers</u>

While the existing and proposed geographic information systems make use of all of these types of locational identifier, either single or in combination, the most frequently utilized technique is the arbitrary grid. The principal reasons for the widespread use of the fixed arbitrary grid are: 1) the ease with which it may be implemented and 2) the ease of statistical manipulation. All the data to be included in the system are referenced to a grid matrix and the attributes of each cell are stored. The ease with which grid based data may be manipulated in complex statistical models makes the grid system a very efficient base for analytical endeavors. (Tomlinson, 1970, p. 39)

Among the early grid based information systems was the "Map Information Assembly and Display System" (MIADS) which was developed by the U.S. Forest Service and is currently being used in Oklahoma by the Soil Conservation Service to store and map information pertaining to attributes of soils. It is also being considered for implementation in a regional information system by the Association of Central Oklahoma Governments. MIADS utilizes a 40 acre grid cell and is based on the U.S. Public Land Survey. State systems which are developed or being developed on the basis of the 40 acre grid, or quarter-quarter section, include the "Natural Resources Information System" (NARIS) of Illinois and the "Minnesota Land Information System" (MLIS).

Even finer resolution is included or planned into other systems. The "Gridded Resource Inventory Data System" of the State of Washington, Department of Natural Resources, for instance uses 10 acre sample cells. One of the more detailed proposals is the Wisconsin Land Use Information System which is proposed to have a geographic reference base of one second of latitude and longitude (about 70' x 100').

Another popular series of arbitrary grid systems is based on the Universal Transverse Mercator Grid. The most well known of the geographic information systems based on the UTM grid is probably the "New York State Land Use and Natural Resources Inventory" (LUNR) which is an implemented system with a resolution of one square kilometer. The distribution of land use for each one kilometer grid cell is recorded and stored. One problem with the use of the kilometer grid cell in this system appears to be that users of the system often need to refer to the original land use overlays and carry out reaggregation of the data since the spatial scale is too course for many applications. (Dueker and Drake, 1972, p. 17) Another system utilizing the kilometer grid cell is being developed by the Delaware County Planning Commission for a regional information system.

Other systems such as the "South Carolina Land Use Information System" and the proposed system in Maryland utilize grids of varying size based on state plane coordinates. State plane coordinate grids have the advantage of being tied very well into the triangulation nets of the areas involved.

Although the explicit boundary type of location identifier provides a more accurate representation of real world distributions than the arbitrary grid type, does not lose information, and is especially useful in dealing with maps and map related data at different scales and levels of detail, there are few such systems in existence. The largest and most well-known of these is the "Canadian Geographic Information System" (CGIS) which has cost over twenty million dollars to date and is not yet fully developed.

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Furthermore those aspects of the system which have been developed are so costly to use that the system can hardly be considered a success. One suggestion that might drastically reduce operating costs of CGIS is that the area boundary files might be used as a raw data base to aggregate into a uniform grid or parcel system for manipulation and analysis. (Center for Advanced Computation, 1972a, p. 48)

Recommendations for Oklahoma

After reviewing the characteristics of the above mentioned systems and several others including some which utilize external indices and coordinate referencing, it is recommended that Oklahoma adopt a geographic referencing system based on the Universal Transverse Mercator grid. The principal reasons for recommending an arbitrary grid are the ease with which it can be implemented and the ease of data manipulation characteristic of grid based systems. Furthermore, data based on a regular grid cell are easily displayed. Although the State Plane Coordinate System is much more accurate, the 1 in 2,500 accuracy of the UTM is more than adequate for the type of mapping and locational analysis that is likely to be done with data from a statewide land use information system. In addition, regular grid cells are constant over time which reduces the complexity of the system.

It would seem advisable to follow the lead of the "New York State Land Use and Natural Resources Inventory" and the suggestion of the Center for Advanced Computation and provide for the collection and storage of explicit boundary, or continuous image data. This file would then be used to create the grid file for active use within the system. As the state of the art advances and the costs and complexities of handling explicit boundary data become more manageable, this storage file could form the basis of a very useful subsystem.

Spatial Precision

Having recommended a regular, arbitrary grid based on the UTM, it is now necessary to consider the courseness of the grid. In considering the spatial precision of the system a number of factors should be kept in mind. First, spatial precision has to be determined in relation to the area to be covered, the characteristics of the area to be covered, the data base of the system, system design, and the potential users of the system. Secondly, it must be remembered that the smaller the cell the less heterogeneous it is likely to be and the less blurring of statistics there is likely to be. Blurring of statistics occurs whenever the boundaries that are used to aggregate the data do not reflect the particular set of problems that are being studied. (Tomlinson, 1972, p. 789) Thirdly, it must be remembered that although at the statewide level it may be desirable to produce tables and maps of quite generalized data, to have flexibility within the system it is important to acquire and maintain data at its finest scale and then to generalize by aggregating to the extent appropriate for a specific purpose. Fourthly, it must be kept in mind that no matter how nice it might be in theory to have extremely fine spatial precision, to develop a system with the capability of monitoring individual use or ownership parcels would require a great deal of effort and expense. This effort and expense would increase significantly if the system were to be designed with the capability of specifiying precise boundaries for these parcels.

After consideration of the characteristics of the UTM in light of the factors sited above and others, it would appear advisable to consider the use of one or more of the following grid cell sizes: 1) one kilometer, 2) 500 meter, and 3) 250 meter. To match the national mapping system, it is advisable that the grid cell adopted be a convenient multiple or subdivision

FIGURE 2

of one kilometer. To determine how many cells would be involved at each scale it is necessary to relate these grids to specific areas. For this purpose the state, the Kiamichi Economic Development District, and Oklahoma County have been selected. The approximate dimensions of these areas are shown in the accompanying figures.

For the state as a whole approximately 200,000 data cells would be required to cover the state if a one kilometer square grid were used. (See Figure 2) This number is larger than the area of the state expressed in kilometers because of the irregular shape of the state and the nonconformity of grid cell boundaries and the state boundary. For comparison, it is interesting to note that for New York's system approximately 140,000 cells are required. If Oklahoma were to adopt a 500 meter grid, somewhat less than 800,000 data cells would be required to cover the state. A 250 meter grid would require somewhat less than 3,200,000 cells.

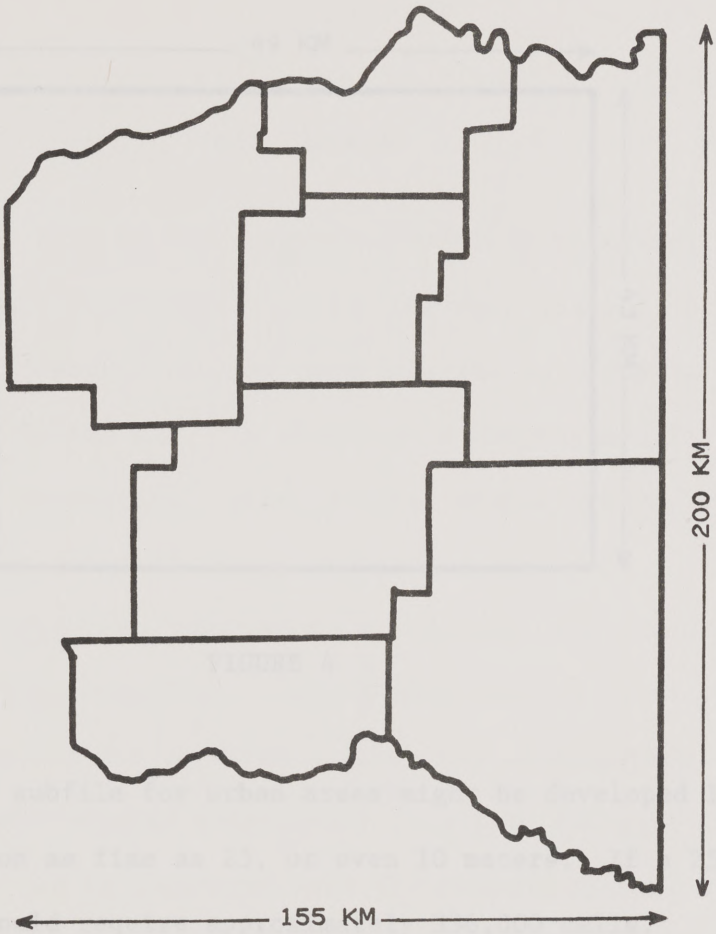

FIGURE 3

For an area the size of the Kiamichi Economic Development District about 31,000 data cells would be needed if a one kilometer grid were used. (See Figure 3) For a 500 meter grid this figure would increase by a factor of four to 124,000 cells, and at 250 meters 496,000 data cells would be required.

Oklahoma County would require about 2,100 cells with a one kilometer grid, 8,400 cells at 500 meters, and 33,600 at 250 meters. Since Oklahoma County contains a major metropolitan center it is likely that most, if not all of the county would be surveyed at an even more detailed scale. It is

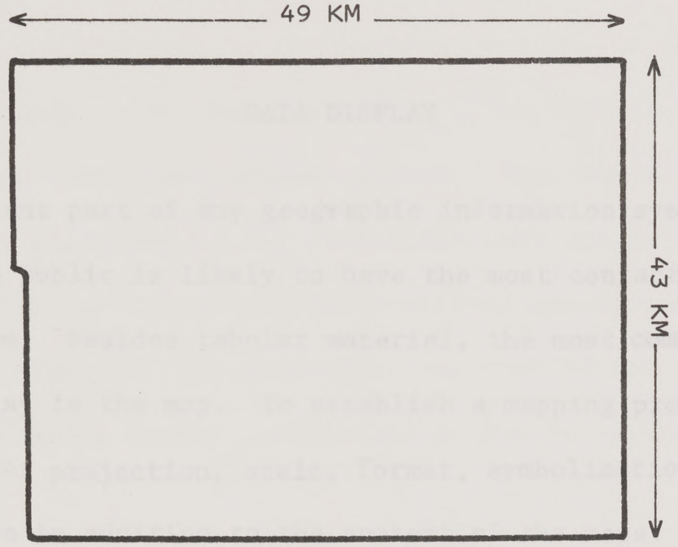

FIGURE 4

possible that a subfile for urban areas might be developed later using a spatial precision as fine as 25, or even 10 meters. If a 25 meter grid were used, it would require approximately 336,000 cells.

For use in an Oklahoma land use information system it is recommended that a 500 meter grid will be used. This fine enough to avoid some of the problems encountered in New York, yet not so fine as to be unmanageable for an area the size of Oklahoma.

Increased precision might also be obtained by developing a point data file. Such data might be handled as in the LUNR system by aggregation to grid cell or unique coordinate references might be assigned to each item of point data included in the system. Whatever degree of precision is desired in the handling of point, or network, data, such work should probably be delayed until development of the area file is well under way. Further comments concerning implementation are found in a later section of this report.

DATA DISPLAY

An important part of any geographic information system, and the one with which the public is likely to have the most contact, is the data display sub-system. Besides tabular material, the most common form of land use data display is the map. To establish a mapping program it is necessary to consider projection, scale, format, symbolization, and methods of reproduction in addition to the content of the maps.

Prior to considering these factors, however, the purpose of the mapping program must be specified. If the main purpose is to provide summary maps showing data for the state as a whole the mapping program will be different from one designed principally to aid in analysis and to support decision-making. It is suggested that the mapping options of the land use information system developed for Oklahoma be principally designed to aid in analysis and the generation of policy. Therefore the system should be capable of producing maps at a number of scales, the selection of which would vary with the topic and area under consideration. Various computer mapping programs can be used to map at different scales. The majority of these programs utilize the line printer. The maps produced are usually not as elegant as hand drafted maps but they are more economical and convey information quite well. They are useful as work maps as they come off the printer, but for publication should be augmented with overlay orientation and legend material. Within the context of an information system, timeliness, not elegance, should be given the most weight. Under some conditions elegance may be important; in these situations the computer generated map can serve as the source material for a color-separated printed map.

Projections

Whatever the emphasis in the mapping program, it is essential that the agency standardize on one map projection if it is deemed desirable to compare or combine data from various sources. The computer can be used to transform data digitized in one projection into the selected standard projection. Projection transformation equations are available which can be built into the system. The projection recommended for adoption for use in land use information system in Oklahoma is the Universal Transverse Mercator.

Scale and Format

The second important factor is scale. Although the system should be capable of producing maps at a number of scales to facilitate problem solving, land use information should also be presented on maps at standard scales so that the data may be easily compared to the terrain and other information contained on the topographical maps published by the United States Geological Survey. Since surrounding states as well as the federal government are likely to utilize the same scales, the analysis of land use of border areas and for multi-state regions would be facilitated. Published maps therefore should be at the scales of 1:24,000 and 1:250,000. The latter scale is the one being used by the Geological Survey to plot first and second level data (See Table 1) obtained from ERTS imagery. The 1:250,000 scale would probably be most useful with level I data as defined in Geological Survey Circular 671 while level II data could be shown at 1:24,000. It is possible that an intermediate scale such as 1:62,500 would be desired also. For statewide summaries a scale of 1:1,000,000 would be useful because it would conform to the International Map of the World and to the series of population maps which have been completed at the same scale.

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Production of maps at these scales would require photographic enlargement and reduction since the scale of line printer maps is strongly influenced by print element size and line spacing. At present square print elements are not available, therefore to map a square grid cell without scale distortion requires that the cell be printed five spaces across by three or four lines down depending on whether the printer is set to print six or eight lines to the inch.

The formats of the maps published at standard scales should conform to those used by the Geological Survey. The formats for special purpose maps can vary with the nature of problem being analyzed. Maps that are wider than the capacity of the printer will have to be done in strips and spliced together, but this is not a difficult task. Formats will be partially controlled by scale. For instance, it is unlikely that a map of the entire state with each 4 x 5 element cell representing one kilometer would be attempted. The required 33.3 feet by 15.8 feet format is clearly impractical. Instead the data would be generalized to larger cells and then photographically reduced.

Symbolization

Not only must projection, scale and format be standardized, symbolization for use on printed and computer generated maps must also be standardized. Since it has been proposed that the "Oklahoma Land Use and Activity Code" be revised, no complete set of standard symbols or colors is proposed at this time. However, certain suggestions about the desired characteristics of a standardized set of symbols and printing colors can be made. First, there must be a standard set of printer symbols as well as standard drafting patterns and colors. The "Standard Colors and Symbols

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Code Recommendations" developed by the Office of Community Affairs and Planning makes no such provision. Secondly, the standardized symbols must conform to the data levels in the land use code. This also appears to be a problem. Thirdly, the symbols and colors used in Oklahoma should conform as closely as possible to those used by the federal government which should, in turn, conform to those used in the World Land Use Survey. In addition, the proposed point symbols should be analyzed to determine their practicality for use on a plotter.

Computer Mapping

The computer mapping capabilities mentioned above are very important to the development of a geographic information system which is going to be useful in support of land use evaluation and planning. It is essential that map production at varying scales and the production of large numbers of maps in a short period of time at moderate cost are both possible. These requirements plus the need to plot information for a large number of data points call for the use of a computer in mapping as well as data storage and manipulation.

Computer generated mapping systems usually make use of either a plotter or a line printer to output the map. Each of these methods has its advantages and disadvantages. Consideration of the characteristics of each leads to the conclusion that for land use mapping, plotters would be less useful than line printers. The main advantage in the use of plotters is the increased accuracy of positioning point and line information. However, for mapping areal data, the machine time requirements, and hence both cost and turnaround time, are considerably higher than for printer programs.

In general, computer programs yielding printer output have the advantages of being quick and relatively cheap compared to plotter programs. All have the above mentioned disadvantage of the standard, rectangular shaped print element found on all printers. These units measure 1/10 inch by 1/8 inch which means that if each print space is to correspond with a data cell on the grid, either the data cells must be rectangular, or square data cells mapped into the rectangular print spaces will produce a map elongated in one dimension (usually north-south).

Since it neither makes sense to establish a rectangular rather than a square grid, nor to tolerate distorted maps, the problem is generally solved by mapping each square data cell as a fifteen or twenty print symbol area depending on whether the printing is being done at six or eight lines to the inch. Each data cell is thus represented by a square one-half inch on a side. This solution to the print element problem has the disadvantage of producing maps four to five times as large as would be necessary if square print elements were available. For large scale studies, such as those for a county, or perhaps even a sub-state planning district, this is not a major problem. For small scale studies the data would have to be generalized as mentioned above.

There are several computer mapping programs with printer output. The two that would seem to be most useful to the state in setting up a geographic information system are SYMAP and CHORMAP. Most others either lack the quality of output of these programs, the mapping options of the SYMAP program, or the low cost and small computer requirements of CHORMAP.

The versatility of the SYMAP program is very attractive. It will accept and operate upon point, line, or areal data to produce one of three basic types of maps. The first of these is the conformant map which maps

data by predetermined areal units. Data can also be smoothed to create a contour map. In addition, the proximal map option permits the mapping of data based on the "nearest neighbor" concept. With this type of map, the symbolism for each character location is determined by the symbolism applicable to the nearest data point. The result is a map of areal units based on the characteristics of data points. This routine is particularly useful in mapping qualitative data such as soil type, for which point sample data is being used. SYMAP provides the user with over twenty-five options which permit great flexibility in designing special purpose maps.

The CHORMAP program contains only the conformant (choropleth) option of the SYMAP program. However, this specialization allows maps to be produced very cheaply - at a rate of approximately one cent per square inch of output (OSU Computer Center, fall, 1972). The cost of CHORMAP depends only on the size of the map; the number of data units is irrelevant. Thus, a map of Oklahoma County, using an output area of 5 by 4 print cells for each 500 meter square data cell at a scale of one inch equals one kilometer, would cost in the neighborhood of $21.00.

The cost of SYMAP output depends both on the size of the output map and on the the number of data points mapped. Based on limited experience at the OSU Computer Center, it is estimated that SYMAP costs would run about twice that of CHORMAP for comparable output. However, for certain types of maps, at various levels of generalization the other SYMAP options, especially the contour option, would probably be quite useful.

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Therefore, it is recommended that the Oklahoma land use information system being proposed be organized so as to facilitate the use of either of these computer mapping routines.

Visual Display Units

In addition to developing the capability to use the line printer to output computer generated maps, it is also highly desirable to have available for immediate visual display a cathode ray tube (CRT). A CRT with an operator's keyboard for interactive communications with the computer permits greater efficiency in the processing of data for map generation and the production of small graphs. In preparing data for mapping one very important consideration is the class interval. By using a CRT, the class interval may be manipulated so as to determine which interval would produce the best map for showing what is desired on the map. These units, if coupled to a hard copier can also be used to generate maps directly.

Although the CRT is very useful, it does have limitations that should be recognized. In general the quality of CRT maps at the present time is not as good as that of maps output on either printers or plotters, but they are sufficient for many purposes. In the near future better resolution should be available. In this regard, the color graphics CRT offers great promise. However, for the present it is somewhat experimental and rather expensive. Another problem with the CRT is the limited size of the screen. The small screen makes it impossible to show much detail on a map of even moderately large area. This too will probably be improved in the near future.

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SYSTEMS DESIGN AND EQUIPMENT CONSIDERATIONS

To specify the system design and equipment needed to handle the data in a system using the recommended geographic resolution of 500 meters and having the desired display capabilities would require a decision as to the agency to supply computer services to the Office of Community Affairs and Planning. In the absence of such a decision it was assumed that a somewhat distant facility such as the OSU Computer Center would be utilized.

There are many possible equipment configurations that might be used. One of the two recommended here would supply the Office of Community Affairs and Planning with a remote card reader and printer to handle large jobs in batch mode and to output computer maps, a CRT with a keyboard for interactive data manipulation and map compilation, and a hard copier for the CRT to provide permanent copies of the graphs and maps developed on the CRT. OCAP would also have access to a drum plotter to permit computer generation of maps involving point and line data as well as more polished graphs than would be available from the CRT hard copier. This option would permit OCAP staff to read in card decks and receive printed output.

The other would provide OCAP with only a remote CRT and a hard copier. This would be a less expensive configuration. Computer programs could be scheduled from the remote CRT and output viewed. The hard copier would be available if the user desired a copy of the displayed information. Large amounts of printed output would be printed at the OSU Computer Center and sent to OCAP and/or a district office.

Both of these configurations would be linked to an IBM 360/65 with the data stored on the disks. The data proposed in the "Oklahoma Land Use and Activity Code" for the approximately 800,000 data cells in the state would require eight disk packs at $200.00 or $12.00 per month per disk pack. Disk packs are suggested rather than tapes, even though the latter are much cheaper intially, because it is possible to directly access a specific data cell on the disk packs and it is not tapes. Hence, accessing data is quicker and less expensive when disk packs are used rather than tapes.

Equipment Costs

Precise costs would depend on the exact capabilities of the equipment used and whether it is purchased or rented. Example costs are shown in Table 1. As can be seen there is a great range in costs especially for card readers and printers which vary significantly in speed. Also evident is the relatively high cost of drum plotters. Because of the need for considerable plotter work to justify the expense, it is recommended that OCAP not acquire its own plotter.

Approximate equipment costs and user charges for the two suggested configurations are shown on Table 2.

Under either option, not considering the remote printer and card reader, OCAP would either have from $7,800 to $15,170 invested in equipment or pay rental charges of between $355.00 and $385.00 per month. Additional rental charges for the card reader and printer, which we would recommend not be purchased, would be between $700.00 and $2,000.00 per month to their costs. In other words, if all equipment were rented, Option A would involve rental charges of $1,055.00 to $1,585.00 per month plus communications costs.

Communications costs include both line charges as shown in Table 4

and equipment charges as shown in Table 3. As shown, line charges vary with the type of line and/or the distances involved. Equipment costs are the rental charges for the control units and data sets required for the remote CRT and Batch terminal. Under Option A these charges, would be between $335.00 and $715.00 per month depending on the data set and used. Under Option B they would be $155.00 per month.

Despite the higher costs involved Option A is recommended because of the increased convenience and flexibility of having remote batch facilities. This configuration is particularly desirable, because of the potential use of the remote printer to generate maps.

Table 2

SAMPLE EQUIPMENT COSTS*

	Equipment	Approximate Purchase Cost	Approximate Purchase Cost
1.	CRTS		
	A. Tektionix 4010-1	$4250.00	$ 200.00/month
	B. IBM 3275	$8075.00	$ 190.00/month

(Additional costs would include $75.00/month for a control unit and $80.00/month for a data set.)

	Equipment	Approximate Purchase Cost	Approximate Purchase Cost
2.	Hard Copiers		
	A. Tektionix 4610	$4550.00	$ 185.00/month
	B. IBM 3286	$7095.00	$ 165.00/month
3.	Plotter		
	A. Calcomp 11 in. drum	$10,000.00	
	B. Calcomp 30 in. drum	$20,000.00	

4. Data Storage Devices

Unit	Approximate Data Capacity (Characters)	Estimated Purchase Price	Monthly Rental	Minimum Rental
Tape-1200 ft.	10 million	$ 8.00	$ ..50	$ 2.00(4 mos.)
Tape-2400 ft.	20 million	$ 12.00	$ .75	$ 3.00(4 mos.)
Disk pack	28 million	$200.00	$12.00	$12.00(1 mo.)

5. Typewriter Terminal

   A. Hardware

      1. Terminal $100/month
      2. Control Unit $ 75/month

   B. Computer Time $1.25/CPU min.

   C. Connect Time $.03/min.

6. Remote Batch Terminal (card reader and printer)

   A. Hardware
      1. The reader and printer would range in cost from $700.00/month to $2000.00/month with speeds varying from 100 cards per minute and 100 lines per minute up to 1000 cards per minute and 1000 lines per minute. Thus, the cost of the hardware is dependent upon the speed of the reader and printer.

Table 2 (continued)

6.

B. Data Set

1. 1200 bits per second (up to 300 lines per min.) $ 15.00
2. 2400 bits per second (up to 600 lines per min.) $ 77.50
3. 4800 bits per second (up to 600 lines per min.) $150.00

C. Computer time $5.00/CPU min.

Table 3

EQUIPMENT COSTS AND USER CHARGES

For Suggested Configurations*

	Equipment	Cost	User Charges
Option A			
	OSU Computer Center		
	1. IBM System/360 Model 65		$5.00/CPU/min. and 75¢ per kilobyte-CPU Hour
	2. Calcomp Plotter		$1.00/15 mins.
	OCAP		
	1. Remote Reader 2. Remote Printer	$ 700.00 to $2000.00/month	
	3. Remote CRT	$4250.00 to $8075.00 or $ 190.00 to $ 200.00/month	3¢/min. connect time and $1.25/CPU/min
	4. Hard Copier	$3550.00 to $7095.00 or $ 165.00 to $ 185.00/month	
Option B			
	OSU Computer Center		
	1. IBM System/360 Model 65		$5.00/CPU/min. and 75¢ per kilobyte-CPU Hour
	2. Calcomp Plotter		$1.00/15 mins.
	3. Card Reader		4¢/100 cards
	4. Printer		5¢/100 lines
	OCAP		
	1. Remote CRT	$4250.00 to $8075.00 or $ 200.00 to $ 355.00/month	3¢/min connect time and $1.25/CPU/min.
	2. Hard Copier	$3550.00 to $7095.00 or $ 165.00 to $ 185.00/month	

*Plus Communication Costs

Table 4

APPROXIMATE COMMUNICATION COST

1. Lease Line as shown in the table below (24 hr./day and unlimited)

*2. State WATS $550.00/mo. (24 hr./day and unlimited) Several planning districts could possibly share one WATS line.

3. Long distance $10.00/hr. to $15.00/hr. This charge is the regular long-distance rate.

4. Federal Telepak 50¢-75¢/air mile/mo. as shown in the table below. This line is available upon request to the Federal Government.

*Recommend communication line.

Terminal Sites	Distance from OSU (miles)	Lease Line $3.00/air mile/mo.	Federal Telepak 50¢-75¢/air mile/mo.
OCAP	48	$144.00	$24.00 - $ 36.00
Vinita	112	336.00	56.00 - 84.00
Muskogee	99	297.00	49.50 - 74.25
Wilburton	129	387.00	64.50 - 96.75
Ardmore	134	402.00	67.00 - 100.50
Shawnee	55	165.00	27.50 41.25
Tulsa	61	183.00	30.50 - 45.75
Enid	49	147.00	24.50 36.75
Oklahoma City	51	153.00	25.50 - 38.25
Duncan	122	366.00	61.00 - 91.50
Burns Flat	131	393.00	65.50 - 98.25
Beaver	198	594.00	99.00 - 148.50

IMPLEMENTATION

In moving toward the development of a land use, or a more inclusive, information system for Oklahoma, several factors must be considered. Foremost among these is the possible dilemma of being forced into developing a system in a short period of time during a period when the elements of the system, such as computer hardware, computer software, data requirements, remote sensor systems, and land use classifications, are in such a state of flux.

Two specific programs currently underway by the U.S. Geological Survey are of particular importance to Oklahoma's consideration of the development of a land use information system. The first is a project to collect and analyze the land use classification systems in use by states throughout the nation. This project includes analysis of the very things considered in this report and is expected to be completed by October of this year. The second is the Ozark Land Use Mapping Program which involves the use of space imagery to plot land use information of maps at a scale of 1:250,000 for an area of approximately 56,000 square miles. The land use classification being used in this program is that contained in USGS Circular 671. (See Table 1) An evaluation of the proposed land use classification and additional information on the costs of using space imagery are likely to result from this project which is scheduled for completion in mid-September. (George L. Loelkes, personal communication, April 3, 1973) The Office of Community Affairs and Planning should consider the results of both of these studies

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Benefiting from Experience

A second major factor is that Oklahoma cannot afford to make the same mistakes that others have made or to spend money developing something that has already been developed elsewhere. Although geographic information system development is still in its infancy, there is now a considerable backlog of experience. As Oklahoma moves toward possible establishment of a state-wide land use information system, those responsible for making crucial decisions which will affect the future success of the system should attempt to capitalize on the knowledge and mistakes of the earlier pioneering efforts in other states and regions.

Some or all of the following should be considered as possible ways to help assure that all useful input to the decision-making process is available.

1. A series of formal and/or informal conferences or workshops involving both in-state contributors and invited out-of-state specialists with experience in geographic information system design. Formal position or resource papers should be encouraged and carefully weighed and analyzed.

2. A community of information users must be identified and encouraged so that greater compatibility of data collection for incorporation into the system will not pose an insuperable obstacle to continuing success. State agency leaders must be encouraged to cooperate and support the system.

3. Assurance that all potential users are adequately represented in deliberations even if the eventual decision is that only a limited number will be accommodated by the eventual system as designed.

4. Care should be maintained to avoid overly grandiose designs which may fail because of inadequate funding or because they are too sophisticated to adequately respond to users' needs.

5. Once carefully considered decisions have been made, necessary support for final design and making the system operational must be forthcoming. Underfunding and attempts to get by with inadequately prepared systems designers and technicians will increase the probability of failure.

Specific Needs

In addition to awaiting the results of the USGS projects and developing mechanisms to facilitate benefiting from the experience of others in information system development, a number of specific actions should be taken by the Office of Community Affairs and Planning. Among these are:

1. The pilot studies in Harper and Wagoner Counties should be evaluated. Initial indications from the Soil Conservation Service are that the plotting of land use data in Harper County by an experienced District Conservationist cost approximately $850.00. This figure does not include processing costs and is based on coding with a familiar SCS land use code - not the "Oklahoma Land Use and Activity Code."

2. A detailed analysis of user needs similar to the one conducted for the Illinois Resource Information System should be made for Oklahoma. (Center for Advanced Computation, 1972a, p.6)

3. A data catalog similar to the Illinois Data Catalog should be compiled for Oklahoma. (Center for Advanced Computation, 1972e)

4. The "Oklahoma Land Use and Activity Code" should be reviewed in relation to the proposed national land use classification and be revised accordingly.

5. A decision must be sought on the rationalizing and coordinating of state computing facilities and services.

6. A decision must be made on the level of geographic resolution and the frequency of data revision.

7. The methods for initially gathering the data and for continuous revision must be determined. Initial data gathering should probably be a combination of field survey and interpretation of remote sensor imagery. The field survey could either be conducted by Soil Conservation Service field staff if satisfactory contractual arrangements could be made or by college students hired specifically to perform the task.

8. An area should be selected for a pilot study to test all elements of the system. To be a fair test the area should be large and complex enough to test the various elements of the system. It is suggested that one of the sub-state planning districts in the eastern part of the state be selected.

9. Arrangements should be made with an agency capable of providing computer facilities, programming assistance, and assistance in system design to begin detailed design of the system. It is recommended that this agency be either one of the larger facilities in the capital complex such as the Highway Department which is operating an I.B.M. 370/155 or one of the larger institutions of higher education such as Oklahoma State University which is operating an I.B.M. 360/65. A major computer facility is suggested because it would appear to be wise to set up the initial prototype on a large machine and evaluate it to see if it could be handled on a mini-computer.

In pursuing these activities that might lead toward the implementation of a land use information system for Oklahoma, it should be remembered that

> by far the most difficult aspect of implementing a system to process large quantities of spatial data are the system design and analysis which are needed to conceive, implement, and debug the system. (Tomlinson, 1972, p. 899)

Appendix A

PARTIAL LIST OF EQUIPMENT SUPPLIERS

ADAGE Inc., 1079 Commonwealth Avenue, Boston, Mass. 02215, U.S.A.
Graphics refresh display terminal with its own processor. A very versatile unit for general engineering design.

AEG., Dennert & Pape, Aristowerke K.G., Hamburg, West Germany.
Make geograph precision drafting unit; includes a special-purpose computer/director.
Uses analog servodrive and low inertia D.C. motors with digital feedback.
Working areas up to 59 x 79 inches. Claims accuracy of ±0.004 inch up to speeds of 2 cm./sec.

ARDS. See Computer Displays Inc.

AUTOTROL, 5566 Harlan St., Arvada, Colo., 80002, U.S.A. Arm and cursor digitizers
Claimed accuracy ±0.004 in.; claimed resolution 0.001 in., 0.0005 in. or 0.01 mm.

BARR & STROUD, Anniesland, Glasgow CI31H2, Scotland.
Light heads
PS9 - Lightweight unit, high-intensity tungsten-halogen lamp, 12 apertures to be used for symbols or line weights, circular spot, no rotation.
PS5 - Lightweight unit, high-intensity tungsten-halogen lamp, 72 symbols (some can be used for line drawing slits, two different slit widths per symbol.) (Note continuously variable slit width as first used in CHS system not available against normal order.)
Intensity of light source makes working on duplicating film of very low sensitivity possible at maximum speed. All controls to PS5 are incremental except velocity for intensity control, which is analog in standard unit.
Claimed maximum positional error of symbols ±0.01 mm. plus minimum error on rotation of ±0.015 mm.

BENDIX RESEARCH LABORATORIES, 20800 10 1/2 Mile Road, Southfield, Michigan, U.S.A.
Manufacture the Datagrid digitizing tablet.
Supply their own electronics, and also can be attached to electronics of other manufacturers, e.g., Ferranti, Ltd.

CALIFORNIA COMPUTER PRODUCTS, INC. - CALCOMP - 2411 W. La Palma Ave., Anaheim, California, 92801, U.S.A.
Purely digital incremental drum plotters widely used in computer centers. Reliable, require little maintenance, and have excellent software back-up. Larger flat-bed plotters 718 also widely used in mapping establishments. Recent development a higher-accuracy version, the 728, and an even higher one, the 745.

Generally ballpoint pens are used intheir systems, occasionally scribers and very occasionally their light head. Mechanisms of light construction generally, except for the 745; tend to be somewhat too flexible for high accuracy.

In their light head, illumination provided by luminescent panels, an image of which is flashed down to form the line increment each time the drive motors are pulsed. Light source rather weak and relatively high speed photographic emulsions must be used.

Controller supplied, but the drives are also easily interfaced with any small computer.

Claimed specifications:

Drum Plotters 11 in. x 30 in.
Series 500 up to 300 inches/sec.
step size 0.01 in., 0.005 in., 0.1 mm.
Series 600 up to 900 inches/sec.
step size 0.01 in., 0.005 in., or 0.0025 in.
Series 700 up to 450 inches/sec.
step size 0.01 in., 0.005 in., 0.0025 in. or 0.00125 in.

Flat Bed Plotters 48 in. x 72 in.
Series 718 or
Series 728 up to 3384 inches/sec.
step size 0.025 in. down to 0.0005 in.

Precision Flat Bed Plotter 45 in. x 59 in.
Series 745
Accuracy ±0.001 in.,
Repeatability ±0.0004 in. claimed.

Details of this table are difficult to obtain but presumably it is a dynamic feedback system and not purely incremental.

Microfilm Plotter
Series 1670 up to 500,000 inches/sec.
For use with 16 or 35 mm. film or microfiche,

CALMA, 346 Mathew St., Santa Clara, Calif., 95050, U.S.A.

Arm and cursor digitizers
Max. error absolute ±0.012 in. claimed.
Resolution ±0.010 in. claimed.
The units are made in various sizes.

COMPUTER DISPLAYS, INC., A.R.D.S. (Advanced Remote Display Station), 223 Crescent St., Waltham, Mass.,02154, U.S.A.

Graphics storage display terminal, series 100A, for direct connection in place of teleprinter to low and medium speed telephone lines. Incorporates Tektronix 611 storage display. Not suitable for fine-detail cartographic lines.

CONCORD CONTROLS, INC., 1282 Soldiers Field Road, Boston, Mass., U.S.A.

High precision dynamic feedback drafting units and digitizers. Have specialized for many years in cartographic system design.

Generally ballpoint pens are used inthe(ir) systems, occasionally scribers and very occasionally their light head. Mechanisms of light construction generally, except for the 745; tend to be somewhat too flexible for high accuracy.

In their light head, illumination provided by luminescent panels, an image of which is flashed down to form the line increment each time the drive motors are pulsed. Light source rather weak and relatively high speed photographic emulsions must be used.

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Series 700 up to 450 inches/sec.

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<u>Flat Bed Plotters 45 in. x 72 in.</u>

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CONCORD CONTROLS, INC., 1282 Soldiers Field Road, Boston, Mass., U.S.A.

High precision dynamic feedback <u>drafting units</u> and <u>digitisers</u>. Have specialised for many years in cartographic system design.

Coordinatograph - Mark 8, 60 in. x 60 in.
Claimed accuracy of plotting 0.001 in. up to 315 in./sec. on straight lines. Heavy construction, PDP8 controller usually used.

The "Programmer" drum digitizer - motor driven
Accuracy ±0.0005 in./ft. claimed.

Graphic Data Digitizer (or Floating Arm Digitizer)
Accuracy ±0.005 in. claimed.

Cartographic Digitizing Plotter 40 in. x 50 in.
Accuracy ±0.004 in. claimed.

CONTRAVES, A.G., Schaffhauserstrasse 580, CH8052, Zurich, Switzerland.
The Coragraph coordinatograph is a precision frequency-analog feedback unit. Supply own special purpose computer/director, the CORA IIA or B.

Series 700 500 x 700 mm.
up to 150 mm./sec. (7 in./sec.)

Series 1200 1130 x 1170 mm.
up to 80 mm./sec. (3.5 in./sec.)

Series 1600 1130 x 1670 mm.
up to 80 mm./sec. (3.5 in./sec.)

The last two have a claimed error band width of less than than 0.06 mm. (0.0025 in.).

These units normally work with pens or chisel scribers (tangential control is fitted). A light head is also available; line widths 0.05 to 10 mm. wide and up to 72 symbols. No other details of this are known.

CORADI, A.G., Zurich, Switzerland.
CORADOMAT 21 Precision drafting unit
Uses a velocity controlled analog servo system with digital feedback. Supplied with its own special-purpose computer/director.

Claims:	Overall accuracy	±0.001 in.
	Resolution	±0.0004 in.
	Repeatability	±0.0008 in.

DATAGRID - see Bendix.

D-MAC LTD., Queen Elizabeth Ave., Hillington, Glasgow, S.W. 2, Scotland.
For many years they have made their "pencil follower" digitizers and many of these are in use under different names (e.g., Edwin, Thomson, etc.).

In their SYSTEM-2, a number of area sizes are available and incremental resolution can be 0.1 mm., 0.05 mm. or 0.001 in.

Claims:	Absolute accuracy:	±0.15 mm./meter
	Dynamic accuracy:	better than ±0.2 mm. up to 2.5 cm./sec.
	Repeatability:	±0.1 mm.

Higher accuracy unit SYSTEM-2HA. Granite working surface and more precise mechanisms with linear ball races moving on precision shafts. Belt drive used instead of the wire of the SYSTEM 2, and separate precision rack on each axis rotates the shaft encoders.

Claims: Absolute positioning accuracy:
±0.1 mm.

Absolute distance accuracy:
±0.2 mm.
Repeatability: better than 0.1 mm.
Resolution: 0.01 mm.

In cooperation with Imperial College (London) manufacturing an on-line digitizing system, the CADMAC, with a pencil follower attached to a PDP8. Work done can be seen on an attached storage display (Tektronix 611). Digitizing table can be turned over and the mechanism used as a plotter. System uses a "menu" type of descriptor input on the digitizer table with 250 locations.

Claims: Absolute accuracy: ±0.004 in.
Repeatability: ±2.5 pts. in 10 in.

DRESSER SYSTEMS, INC., Houston, Texas, U.S.A.
Made an interesting laser graphic plotter that works in the scan mode, the LGP-2000.
Four surface motor-driven mirror moves the laser along the scan line. Paper is incremented forward at the end of each line. Resolution can be set at 100 or 200 dots/in. on the 40 in. scan width. The laser beam intensity is controlled to give 16 shades of grey.
38 in. of paper/minute can be recorded.

EAI. Electronic Assoc. Inc., West Long Branch, New Jersey, U.S.A.
Manufacture the Dataplotter but no up-to-date information available. Believed to be incremental and of medium precision.

FAUL-CORADI, 238 West Division St., Syracuse, New York 13204, U.S.A.
The North American name representing CORADI.

FERRANTI LTD., Ferry Rd., Edinburgh EH5 2Xs, Scotland. A.D.E. master plotters made in a number of area sizes up to 2 m. x 8 m. They use a fixed gantry and movable platten. Drives are purely incremental stepper motors using racks and a Moiré fringe linear digitizers gives feedback of the position.

Claims: Max. static error ±0.0025 in.
Max. static repeatability ±0.0015 in.
Max. dynamic error ±0.001 in.
Increment size 0.0005 in. (minimum addressable increment 0.001 in.)

Used with a PDP8 controller.
Manufacture their own light head for line drawing and a 72-symbol magazine. Accuracy of center positioning including symbol rotation estimated at ±0.002 in.
Microfilm plotter EP140. Plots at high speed on aperture cards. This could be of interest in some lower-accuracy, high-speed cartographic applications.
"Freescan" digitizer. Uses the Bendix datagrid but Ferranti have designed their own electronics. At a recent exhibition it was shown online to a PDP8e with a quick-view Tektronix 611 display. A "menu" system of descriptor selection is used.

GEOSPACE CORP., Computer Division, 3009 South Post Oak Rd., Houston, Texas.
Manufacture the DP-203 CRT plotter. Small areas of a map are produced on the CRT face and exposed on photographic material on a drum. Proposed for ESSA Aeronautical Chart System.

GERBER SCIENTIFIC INST. CO., Box 305, Hartford Conn. 06101, U.S.A.
Make a range of drafting units that are purely incremental in operation using stepper motors. Supplied separately or with general purpose Hewlett-Packard computer/director.

Series 32. Very high precision plotter, guaranteed accuracies. Very heavy and mechanically, well designed precision device. Work area 48 in. x 60 in.

Claims:
- Absolute accuracy ±0.0009 in.
- Repeatability ±0.0005 in.
- Step size-selected at 0.0002 in. or 0.0004 in.
- Maximum speed of drawing after acceleration, 1 in./sec., 2 in./sec. or 4 in./sec.
- Pens, scribers or light head supplied.

Light heads: For line drawing and magazine of 24 symbols. No rotation (understand rotation recently available).

Series 22. A medium precision plotter (flat bed). Work area 48 in. x 58 in.

Claims:
- Accuracies up to ±0.007 in.
- Speeds up to ±13 in./sec. (up to 10,000 incs./sec.)

Series 62. A very high speed drum plotter. Paper 36 in. wide, length up to 100 ft. Ball-point pen or electric stylus.

Claims:
- Accuracy ±0.010 in.
- Repeatability ±0.005 in.
- Step size 0.002 in.
- Max 11,000 in./sec. or 25 in./sec. axially.

Gerber also manufactures an optical line follower head and control system.
Claimed accuracy ±(0/003 in. + 20% line width) in.
Curvature must be greater than 3 times line width.
Claimed speeds between 0.5 and 3 in./sec., dependent on regularity of line and type of plotter used.

GRADICON - See Instronics.

IBM, P.O. Box 100, Kingston, New York, 12401, U.S.A.
Concerned with applications of their large mechanical scanner.
Also Washington D.C. Scientific Center - concerned with use of 2250 display in cartographic applications.

INSTRONICS LTD., P.O. Box 100, Stittsville, Ont., Canada.
Manufactures own Gradicon "free pencil" digitizer; (used to be agent for d-mac)
Work area 24 in. x 36 in. or 36 in. x 48 in.
Claims: Resolution ±0.001 in.
Accuracy ±0.004 in.

KONGSBERG VAPENFABRIK, Kongsberg, Norway
Manufacture precision drafting units. The KINGMATIC MkII most widely used at present. Work area 4 ft. x 5 ft. Driven by analog servo motors with analog synchro feedback.
Claimed accuracy is ±0.1 mm. absolute
Max. speed 3.5 in./sec.
Light head available but details of specifications not clear. In some instances the Barr and Stroud light head is used.

SCIENCE ACCESSORIES CORP., 65 Station St., Southport, Conn., 06490, U.S.A.
Make FRAFPEN "free pencil" digitizer
Interesting method using a spark and sonic detectors.
Claims resolution 0.007 in. on 14 in. x 14 in. area.

SYLVANIA ELECTRONIC COMPONENTS, Johnston St., Seneca Falls, N.Y., 13148, U.S.A.
Manufacture a unique 2-color CRT, two colors being obtained by changing velocity of electrons in beam to penetrate to different phosphor layers.

TEKTRONIX INC., P.O. Box 500, Beaverton, Oregon, 97005, U.S.A.
Manufacturers of Storage CRT displays - all working area 6½ in. x 8 in.

Series 611	Display unit only, high precision, resolution 0.01 in. Erase time about 500 milliseconds. Dot writing time for storage 8 usec.
Series 613	Low-cost display unit only, medium precision, resolution 0.03 in. Dot writing time for storage 5 usec.
Series 4010-1	Low cost display terminal with cross hair pointer, full keyboard and character generator. Option 5 is hard-copy compatible. Vector mode only (not point plot).
Series 4002-A-1	Display terminal for computer operation, includes vector and point mode and character generator. Cursor is pulsating 7 x 9 matrix.
Series 4601	Hard copy unit - high precision for 611 and 4002A. Copy time 18 sec.
Series 4610	Hard copy unit - medium precision for 613 and 4010.

UDM. UNIVERSAL DRAFTING MACHINES CORP., 5200 Richmond Rd., Bedford Heights, Ohio, U.S.A.
Manufactures drafting units - ORTHOMATS - up to an area of 5 ft. x 12 ft. mainly used for engineering drawing. Analog servo drive with digital position feedback. Input pulse resolution 0.001 in. Errors claimed less than 0.005 in. Normally used with pens, but optical head available.
Also make an automatic line following head using a rotating mirror that reflects image of line on to a small diaphragm in front of a photomultiplier.

VECTOR GENERAL, 8399 Topanga Canyon Blvd., Canoga Park, California, 91304, U.S.A.

Computer terminal with refresh display including special hardware for generation of vectors, perspective manipulation, etc. Uses light pen (resolution 0.25 in. or special 0.1 in.) or spot with joystick control. Max. 8000 vectors due to refresh rate.

VIDICON, P.O. Box 1008, State College, Pa., 16801, U.S.A.

Manufacture a drum scanner digitizer taking documents up to 11 in. x 17 in. and digitizes in less than 1 minute. Scan spot size claimed is 0.01 in. (100 lines/in.).

Software package claimed to be available for scan to line conversion.

XYNETICS, P.O. Box 1450, Canoga Park, Calif., 91303, U.S.A.

Manufactures a unique Sawyer motor "free head" plotting device.

Series	500	25 in. x 42 in.
	1100	42 in. x 57 in.
	1200	57 in. x 89 in.

Pens and scribers available. Computer/directors (LOCKHEED) also available.

Claims:
- Resolution 0.001 in.
- Accuracy ±0.005 in. (whole area)
- Repeatability ±0.001 in.
- Max. speed on straight line with ink 40 in./sec. (slower with scriber and on irregular lines).

ZUSE, A.G., Bad Hersfeld, West Germany.

Manufactured a precise drafting table but used mechanical interpolators that seriously limited speed for irregular cartographic line work.

Source: Geographical Data Handling, edited by R. F. Tomlinson, Symposium Edition, A Publication of the International Geographical Union Commission on Geographical Data Sensing and Processing For The UNESCO/IGU SECOND Symposium on Geographical Information Systems, Ottawa, August, 1972.

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