PROGRAM ON STATE AGENCY REMOTE SENSING DATA MANAGEMENT (SARSDM)

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F I N A L R E P O R T

BY

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MAY 19, 1978

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16. Abstract

This report presents the results of a planning study for developing a Missouri Natural Resources Information System (NRIS) that combines satellite-derived data and other information to assist in carrying out key state tasks. We identify four focal applications -- dam safety, groundwater supply monitoring, municipal water supply monitoring, and Missouri River basin modeling -- and plan both the acquisition of the system's visible components (hardware, software, data, and personnel) and its organizational structure. The major contributions of this work are: i) a systematic choice and analysis of a high priority application (water resources) for a Missouri, LANDSAT-based information system; ii) a system design and implementation plan, based on Missouri, but useful for many other states; iii) an analysis of system costs, component and personnel requirements, and scheduling; and iv) an assessment of deterrents to successful technological innovation of this type in state government, and a system management plan, based on this assessment, for overcoming these obstacles in Missouri.

We conclude that LANDSAT data can play key roles in state natural resources information systems, but only if it can conveniently be combined with valuable information from other sources that the state uses now. For this reason, we recommend that NASA increase its involvement in LANDSAT-based NRIS development.

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PREFACE
(Executive Summary)

This is the final report of the program on State Agency Remote Sensing Data Management. The purpose of this program has been to plan the development of a Missouri Natural Resources Information System (NRIS) that combines satellite-derived data and other information to assist in carrying out key state tasks.

The major contributions of this work are:

i) A systematic choice and analysis of a high-priority application area, water resources management, for a LANDSAT-based information system in Missouri.

ii) A system design and implementation plan, based on Missouri, but useful for many other states.

iii) An analysis of system costs, component and personnel requirements, scheduling, and management.

iv) An assessment of the deterrents to successful technological innovation of this type in state government and a system management plan, based on this assessment, for overcoming these obstacles in Missouri.

We arrive at conclusions and recommendations which underscore the need for NASA's LANDSAT technology transfer efforts to take full account of states' information management practices. LANDSAT can play key roles in the system we have designed. However, to be useful to the state, the system must combine LANDSAT data with information from other sources. To demonstrate this approach, we choose a natural resources application of highest priority in the state, water supply management, and assess both the role of remotely sensed data and how that data should be combined with other types.

As a first result of this assessment, we conclude that system design should focus on four key water management problems: (1) dam safety, (2) saline intrusion in groundwater caused by overuse,

(3) sporadic municipal water shortages, and (4) long-term depletion of the Missouri River Basin supply. Statements by the Governor and our interviews with state personnel reveal that these four problems are likely to be the major water-related concerns arising over the next five years. Furthermore, they are significant, visible, complex and probably long-lived; they form a sound framework for system development and continued support. Finally, they form, in the order listed, a logical sequence for system design, because that order is both the chronological sequence in which they are likely to become important and the order in which their information management needs increase in complexity.

LANDSAT data are an important information source in this system, when they are combined with valuable information of other types already in use in the state. In the first application, dam safety, LANDSAT 2 or 3 data can assist in annually locating new impoundments to assist in monitoring a dam permit program. Additional data needed include information on dam permit applications, construction, engineering, and safety inspections. For the second activity, groundwater use monitoring, LANDSAT will probably be useful in categorizing crops so that their water needs can be inferred; irrigation is the major source of groundwater demand. Other data types not derivable from LANDSAT but useful for this application include soils, well yield, precipitation, and subsurface geology. The final two applications, municipal water shortages and basin modeling, will combine more detailed classifications of LANDSAT D imagery (e.g., urban land use) with demographic data and information on industrial use of water.

A key accomplishment of this contract has been the creation of a system design to serve these four applications that grows logically in complexity, hardware and software investments, skill level requirements, and costs. We choose the system components wherever possible from existing resources within the state, to minimize new investments. Costs grow from about $71,000 in the first year of operation to a level of about $220,000 in the fourth (in constant 1978 dollars).

The key system components we choose are a LANDSAT information extraction system (hardware and software to classify raw LANDSAT data) and computerized geographic information system (CGIS) software (a set of computer programs for combining geographically referenced data files). We recommend that the state implement an NRIS based on NASA-Earth Resources Laboratory's (ERL) classification software and USGS's GIRAS* system, the CGIS provided with LUDA** data. The two software packages are already owned by state institutions, but not used operationally or merged so that they, can be used together. Moreover, the hardware to support both software systems has been or will be purchased by the state for other uses, and compatibility problems between the two systems appear minor. Most importantly, both systems match the needs and practical concerns of the state very closely.

In addition to considering these visible system components, we also investigate system management. We begin by assessing the imposing obstacles to success that any such system faces in state government. We find that primary barriers to state-initiated processing and use of remotely sensed data are inherent in the institutions, politics, and attitudes that determine the course of state government. Our system management plan specifically takes these barriers into account.

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*United States Geological Survey's Geographic Information Retrieval and Analysis System.

**USGS's Land Use and Data Analysis System.

After assessing four organizational alternatives, the management plan recommends that initial system activity center in the Missouri Department of Natural Resources (DNR), which has chartered responsibility for natural resources management. We suggest that DNR initiate activities by hiring a new manager to run the initial pilot project, to begin immediately to build long-term political support, and to work toward cooperation among the divisions of DNR and other Missouri agencies. In this latter task, a valuable source of assistance is the Missouri Interdepartmental Council on Natural Resources Information (ICNRI). Further, we recommend that the NRIS minimize new purchasing and hiring until the value of initial system information products convinces state decisionmakers of the system's merit.

With regard to system funding we recommend that development costs be paid in block grants from DNR, using whatever appropriate federal funds that are available. In contrast, we recommend that system operation be paid for as much as possible by exacting fees for the services it renders. By carrying out only those activities that users are willing to fund, the system will gain value in users' eyes and its resources will not be wasted. We note in the report, however, that this plan requires a change in state funding procedures.

In order for NASA to enhance the utility of LANDSAT data in states and help to inspire widespread day-to-day use, the agency should involve itself much more strongly than it has in LANDSAT-based state NRIS development. LANDSAT can find enthusiastic acceptance only when it can conveniently be combined with other valuable data sources already on hand in states. The need for efforts to realize this goal is great if the user base for LANDSAT is to remain enthusiastic and continue expanding. Some specific steps that NASA can take to spur the development of state NRISs are: (1) develop demonstration state NRISs in ASVTs*, designing the demonstration to provide compelling evidence of cost effectiveness and proof that the system works in a realistic agency setting; (2) coordinate GIRAS CGIS developments at USGS with ERL's classification software**, and (3) develop a procedure for using LANDSAT data to classify crops in categories according to their water needs. This classification could be a central input to groundwater monitoring systems in many states.

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*Applications System Verification Tests.

**Eleven states already own GIRAS, and the ERL system's popularity is increasing.

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This report has benefitted from the efforts and advice of many persons in addition to the authors. Advice from consultant Timothy Hays helped to direct our early efforts. Many Missouri state government personnel took an active interest in our work; Michael Breedlove, Deborah Rossino, Robert Myers, Jerry Vineyard, and James Williams were especially helpful. Graduate students at the Center for Development Technology assisted with useful conversations; Richard Ballard, Victor Conocchioli, and Robert Felekey were particularly helpful. Robert P. Morgan and Margaret A. Eastwood provided useful editorial comments. Special thanks are also due to Center for Development Technology staff members Emily Pearce and Donna Williams for their efforts in helping to prepare this report.

CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The program on State Agency Remote Sensing Data Management (SARSDM) was funded by NASA for the period January 1977 to May 1978. The primary project goal was to plan the development of a Missouri Natural Resources Information System (NRIS) to combine satellite-derived data and other information to assist in carrying out key state tasks. The project was executed in the Center for Development Technology (CDT) by an interdisciplinary research team whose members have backgrounds in engineering, computer sciences, geology, and public policy analysis.

The idea for this project was based on a principal conclusion of our previous research. During the period from June 1974 to December 1976, CDT carried out a study of Earth Observation Data Management Systems (EODMS) for a five-state midwestern region* (1). The study focussed in detail on information needs of state, local, and regional agencies and considered alternative systems for delivering a variety of information products, based on remote sensing data, to meet those needs. A principal conclusion of the EODMS study was that there is a wide gap between the digital format in which raw, satellite-derived information is presently produced by the federal government and the tabular and map formats in which natural resources information is currently of most use to states. In order to study how this gap might be bridged, we initiated the SARSDM study to design a system to put both existing state natural resources information and data from satellites in a compatible format, so that they could be used together.

*Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

The formal project objectives, as stated in the contract, were to:

i. Identify in cooperation with NASA a few information products which have been proven feasible to produce in NASA ASVT's* and demonstration projects and which fill a demonstrated, high priority need in state agencies in the five-state region.

ii. Thoroughly inventory already-developed information systems which might be applicable to the project.

iii. Design or adapt an existing data base management system for a state agency to combine the information contained on one or more of the products identified in (i) with other information required to carry out key agency tasks; to store, retrieve, and update this information; and to produce it in forms useful to agency personnel.

iv. Describe how the product production and data base management systems might be implemented within the constraints of typical state government as determined through previous research.

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*Applications System Verification Tests.

1.2 PROJECT OUTCOMES

1.2.1 Contractual Outcomes

Project objectives were to be accomplished through the delivery of two major products to NASA:

i. A data base management system design.

ii. A plan for implementation of the system.

The present Final Report contains these two products. The system design and implementation plan emphasize one basic concept -- that to be successful, a NRIS must produce and deliver products containing broadly useful information with characteristics (e.g. formats, scales, and update frequencies) appropriate to the capabilities of users. To achieve this goal, the system is designed to serve a high priority application -- water resources management. Furthermore, the implementation plan is constructed to build capabilities needed to use the system and LANDSAT data.

Although the design and implementation plan are based on Missouri, we have attempted to write the report to make its results more broadly useful. The system is designed to serve applications such as dam safety, irrigation, and water supply that are national in scope. Furthermore, we report on generally applicable methods for system design and implementation, and we describe principles on innovation in state government that are relevant nationally.

1.2.2 Other Project Outcomes

During the course of the project we produced a number of additional papers and memoranda, as well as three quarterly progress reports. In addition, project staff gave a large number of presentations to NASA, state government personnel, and other researchers in computerized geographic information systems. Our site visits and other trips are listed in Appendix B, and the documents and presentations in Table 1-1.

Of the listings in this Table, three are especially noteworthy. "An Earth Observation Data Management System for State, Regional, and Local Agencies" analyzed key factors in state government that retard faster acceptance of LANDSAT technology. We presented this paper in Washington, D.C. at a symposium of the American Association for the Advancement of Science's Annual Meeting on February 15, 1978. The symposium, which focussed on the future of LANDSAT, attracted key speakers from NASA, the U.S. Congress, USGS, AID, and private industry. The agenda appears in Appendix C.

Two other noteworthy listings are speeches before state legislators from Missouri and neighboring states. These speeches (numbers 4 and 6 in Table 1-1) enhanced the legislators' knowledge of and interest in LANDSAT systems. The December presentation was at a meeting that we organized for Missouri legislators; the October talk occurred during a NCSL*-organized meeting that we were instrumental in publicizing and bringing to Missouri.

Other, less, formal, project outcomes include the strengthening of professional relationships between project staff and personnel in state government. A letter to NASA Administrator Frosch from Missouri's Governor Teasdale (see Appendix A) exemplifies this fact. We have participated in the Missouri Interdepartmental Council on Natural Resources Information. Former staff members have gone on to direct the National Council of State Legislatures' Remote Sensing Task Force and to plan a California natural resources information system in the newly-formed Environmental Data Center in that state.

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*National Council of State Legislators.

Table 1-1. SARSDM Project Publications and Presentations

Papers:

1. Eastwood, L. F., Jr., et. al., "An Earth Observation Data Management System for State, Regional, and Local Agencies: Economics and Policy," presented at the AAAS Annual Meeting, Washington, D.C., February, 1978.

2. Eastwood, L. F., Jr., et. al., "Cost-Sharing Economies in Large-Scale Resources Information Product Production," presented at the Second Annual Conference on the Economics of Remote Sensing Information Systems, San Jose, CA., January 1978.

3. Morgan, R. P. and L. F. Eastwood, Jr., "Statement on Senate Bill S.657," in Hearings on the Earth Resources and Environmental System Act of 1977, U.S. Government Printing Office, Washington, D.C., 1977, pp. 349-51.

4. Ballard, R. J. and L. F. Eastwood, Jr., "Estimating Costs and Performance of Systems for Machine Processing of Remotely Sensed Data," Proceedings of the LARS Symposium on Machine Processing of Remotely Sensed Data, Purdue University, Lafayette, Ind., June, 1977, pp. 208-14. IEEE Cat. No. 77CH1218-7MPRSD.

5. Eastwood, L. F., Jr., et. al., "An Operational, Multistate, Earth Observation Data Management System," Proceedings of the 12th Annual Conference on Earth Resources and Environment, University of Michigan, Ann Arbor, 1977, pp. 659-70.

6. Eastwood, L. F., et al., "A Comparison of Photointerpretive and Digital Production Methods for Four Key Remote-Sensing Based Information Products," Proceedings of the Conference on the Economics of Remote Sensing Information System, San Jose, CA., 1977, pp. 213-28.

Reports:

1. Crnkovich, G. G., "Remote Sensing Data Management Systems for Crop Inventory and Vegetation Cover Mapping," Technology and Human Affairs/ Center for Development Technology, Washington University, St. Louis, Missouri, August, 1977.

2. Eastwood, L. F., Jr. and E. O. Gotway, Program on State Agency Remote Sensing Data Management, Quarterly Reports, 4/18/77 (51 pp), 7/17/77 (60 pp.), and 12/30/77 (78 pp.).

3. Huisinga, J., "Private Sector Short-Term Grain Information Needs and Potential Delivery Technologies," Technology and Human Affairs/Center for Development Technology, Washington University, St. Louis, MO. May, 1978.

Table 1-1. SARSDM Project Publications and Presentations (cont.)

Invited Speeches:

1. Eastwood, L. F., Jr. and E. O. Gotway, "Plans for a Missouri Remote Sensing Based Natural Resources Information System," speech before Missouri's Interdepartmental Council on Natural Resources Information, February, 1977.

2. Eastwood, L. F., Jr., "The EODMS and SARSDM Programs at Washington University," speech before Conference on NASA-Marshall Contractors, February 1977.

3. Eastwood, L. F., Jr., "Results of the EODMS User Survey Relevant to the Design of Geocoding Systems," speech at Conference on Geocoding, U.C. Santa Barbara, CA., May, 1977.

4. Gotway, E. O. and L. F. Eastwood, Jr., "Combining LANDSAT and Currently Used State Data," speech before National Council of State Legislatures' Regional meeting, Clayton, Mo., October 1977.

5. Eastwood, L. F., Jr., and E. O. Gotway, "Remote Sensing at Washington University: Activities and Plans," speech at NASA Headquarters, November, 1977.

6. Gotway, E. O. and L. F. Eastwood, Jr., "The Washington University-Missouri Cooperative Project for Planning a Missouri N.R.I.S.," speech before the Missouri State Legislature, December, 1977.

We have also advised NASA and other federal agencies on LANDSAT matters. Prof. Eastwood led a panel of experts in producing a report advising NASA on preferred LANDSAT D raw data formats. He also advised Presidential Science Advisor Dr. Frank Press' FCCSET committee on the amount and quality of LANDSAT D coverage needed to serve priority data needs in our region.

Private industry has also found our work useful. General Electric, ESL, and other firms have sought our advice on the design of LANDSAT-based information products and processing systems for state agencies. IBM is using our work on sizing and costing computer systems for satellite data processing (see paper #4 in Table 1-1) as an input in the design of a LANDSAT D data processing system.

1.3 PROJECT METHODOLOGY

The SARSDM project has been organized around three major tasks:

Task 1:
Identify and analyze a focal application area for a LANDSAT-based NRIS that is both of critical priority to Missouri and amenable to LANDSAT input.

Task 2:
Design or adapt information extraction and management systems to process LANDSAT data and combine it with other data useful in the above application.

Task 3:
Plan implementation of these systems, considering both their physical and institutional components.

We accomplished Task 1, identifying an application area, by presenting a list of candidate application areas for LANDSAT 1 and 2 data -- derived from our EODMS analysis and assessment of NASA ASVT's -- to Missouri's Interdepartmental Council on Natural Resources Information (ICNRI). Two agencies responded with proposals to cooperate with us. The Department of Natural Resources (DNR) indicated interest in water resources management; the Office of Administration (OA), in LANDSAT applications in updating their recently purchased USGS Land Use and Data Analysis (LUDA) data files (2). Two later events shifted our interest more strongly to the water resources application. Missouri's new Governor Teasdale stated that the priority of water resources management would be very high in his Administration, (see the Governor's letter and statement in Appendix A). Furthermore, NASA and USGS initiated an ASVT dedicated to evaluating LANDSAT's utility in updating LUDA (3), reducing the need for oun efforts in this area.

Identification of the application accomplished, we analyzed agency information management practices currently being applied in managing water resources. We accomplished this analysis by an extended series of visits and discussions with DNR personnel, and by reviewing documentation such as a data users inventory carried out by the state (4) and our own inventory of state data management practices (5). Details of this analysis appear in our quarterly reports (2), (6), and (7), and its results form the foundation of the system designs in this report.

Work on Task 2, system design and adaptation, took many forms. We initially reviewed the capabilities of various available LANDSAT information extraction and computerized geographic information systems by literature review of NASA ASVT's and other demonstration projects; by trips to installations such as NASA's Earth Resources Laboratory (ERL), the Louisiana State Planning Office's pioneering USGS LUDA installation, and the Texas Natural Resources Information System (see Appendix B for a complete list of our site visits); by conferring with system manufacturers and university researchers at conferences (see Table 1-1 for a list of conference papers and speakers); by acquiring and implementing various image processing and data base management systems on the state's computers or at Washington University; and by studying system costs and performance both analytically and experimentally on our computer. Especially noteworthy results of these efforts were the implementation of MINIS and CMS II geographic data management systems on state computers. State and state university personnel also initiated implementation of USGS's GIRAS* software from the LUDA program and a LANDSAT information extraction system developed

*Geographic Information Retrieval and Analysis System.

by NASA-ERL. The results of this task formed the basis of hardware and software choices in this report's system design.

Task 3, the construction of the system implementation plan, continued throughout the project. The nature of the problem required that we employ two different approaches simultaneously. One approach focussed on putting together the pieces of the system, that is, planning the growth of system data files; choosing, scheduling, and costing hardware and software; and identifying personnel and training needs. The other approach took a broader view. It constructed a system management plan by assessing the institutional environment in which the system will operate, and recommending appropriate centers for system control, funding, development, and implementation.

The major contributions of the SARSDM project are:

1. A systematic choice and analysis of a high priority application area for a LANDSAT-based information system in Missouri.

2. A system design and implementation plan, based on Missouri, but a useful model for many other states.

3. An analysis of system costs, component and personnel requirements, and scheduling.

4. An assessment of deterrents to successful technological innovation in state government, and a system management plan, based on this assessment, for overcoming these obstacles in Missouri.

The major task that we leave unfinished, a task for which we were not funded, is the implementation of our plan. The need for such efforts is great if the user base for LANDSAT data is to remain enthusiastic and continue expanding.

1.4 PLAN OF THIS REPORT

Chapter 2 briefly reviews major conclusions and recommendations of this project. Taken together, the Preface, Chapter 1, and Chapter 2 conveniently summarize the project's objectives, methods, and results.

Chapter 3 analyzes Missouri's water resources information needs. It assesses four, high priority, water management problems on which we later base our system designs. The information management needs of these four problems range from relatively simple to quite complex. Thus, they form a natural progression on which to base system growth. The chapter also lists other less critical applications to which a LANDSAT-based water resources information system could be put.

Chapter 4 plans, schedules, and costs the acquisition and implementation of the components of the Missouri Natural Resources Information system. These components include not only hardware, software, and digitized data files, but also personnel for operation and management and training programs. The plan is scheduled to allow systematic development of skills and capabilities, focussing first on less complex, pilot applications and only later on more general or intricate problems.

Chapter 5 describes the institutional environment in which the system must operate and suggests how the system might best be made to fit it. This topic is a factor of primary importance in designing an acceptable, useful system. The chapter begins by analyzing the obstacles faced by such a system in state government. It then recommends a management plan to overcome these obstacles. Finally, it considers major NRIS policy questions.

A final section lists references, and appendices present supporting documentation.

CHAPTER 2

PRIMARY CONCLUSIONS AND RECOMMENDATIONS

This chapter highlights conclusions and recommendations of primary importance. More detailed results and suggestions appear in the chapters to follow. We present conclusions on how to begin serving some key state information needs by a LANDSAT-based NRIS, on how much the system costs to implement and operate, and on managing the system to avoid the obstacles to success present in any state government. We also present recommendations to both NASA and Missouri on how to provide the resources and impetus for system implementation and how to enhance its long-term viability.

In the text to follow, each underlined sentence summarizes a conclusion or recommendation. The indented text underneath each such sentence briefly explains it.

1. The Missouri Natural Resources Information System should focus on a single theme, water resources management.

    Focussing a geographic information system on a single theme, such as water resources, enhances its prospects for success. Furthermore, water resources is one of the two natural resource areas of highest priority in Missouri's current administration.

2. Four key water resources problems likely to arise between now and 1985 are, in predicted chronological order: (1) dam safety, (2) saline intrusion in ground water caused by overuse, (3) sporadic municipal water shortages, and (4) long term depletion of the Missouri River Basin supply.

    Administration statements and our discussions and interviews with state personnel reveal that dam safety is of current major concern, while the other three are likely to be the major state water resources problems arising over the next five years.

3. The system should focus on the four key water management problems, and address them in the order in which they are listed above.

The problems are significant, visible, complex, and long-lived, characteristics that make them appropriate vehicles for information system development. Moreover, their analysis is likely to create sufficient user demand to support a computerized information system in state government.

Chronologically, these problems are likely to become important in the order they are listed above. In this same sequence, the information management needs of these four problems range from relatively simple to quite complex; thus the sequence forms a natural progression on which to base system growth.

4. The system should not be based solely on federal reporting programs (e.g. EPA 208), although it may eventually grow to serve these needs.

Federal programs may not be perceived with the same immediacy as actions demanded by the state's electorate.

5. LANDSAT will play a key role in a system focussed on the four key problems. However, to be useful to the state, the system must combine LANDSAT data with information from other sources.

A LANDSAT-based computerized geographic information system could play a key role in the dam safety application by annually locating new impoundments to assist in monitoring a dam permit program. New impoundments can be located by multitemporal comparisons of LANDSAT CCT's to help in planning inspection by airplane and on the ground and in updating the dam inventory for dam permit administration. Additional data needed for dam inventory/permit system includes a file of permit applications and information on construction, engineering, and safety inspection.

For groundwater use monitoring, LANDSAT can contribute to assessing both the demand for and supply of groundwater. LANDSAT may be useful in categorizing crops so that their watering requirements can be inferred. If it is not, it can be used to differentiate cultivated from pastureland, a useful first step. Either application is a significant contribution, because the primary demand for groundwater is for irrigation. LANDSAT can also contribute to water supply assessment by the impoundment inventory mentioned above.

Other data types not derivable from LANDSAT but necessary for groundwater use monitoring are data on soils, well yield, subsurface geology, and precipitation.

The final two applications, municipal water shortages and basin modeling, will combine more detailed classifications of LANDSAT D imagery (e.g. urban land use) with demographic data and information on industrial use of water.

6. For processing LANDSAT data and combining it with other state data files, the state should implement an NRIS based on NASA-ERL's ELLTAB LANDSAT classification software and USGS's GIRAS system, which is the CGIS provided with LUDA data.

These systems offer attractive advantages. One they share is that both are already owned by the state. ELLTAB will soon be operational on a minicomputer-based image processing system in the state university, and Missouri is one of a growing number of states that have purchased LUDA data and GIRAS software. Another is that the two programs work with nearly compatible data formats. GIRAS, although designed to handle polygonized LUDA data, does the overlay operation using gridded data. DBM, a program associated with ELLTAB, grids classified LANDSAT data on a grid size that GIRAS also uses.

Further advantages of ELLTAB are that it is relatively inexpensive to run and thrifty with computer resources, compared to other classification systems we evaluated. A minicomputer system can support it, so it need not disrupt activities on one of the state's large mainframes. Furthermore, the state university already owns the hardware necessary to support ELLTAB. This hardware could be used for testing, training, and initial small-scale applications; only when loading increases would state government have to purchase a system specifically for NRIS use.

GIRAS serves the practical concerns of the state well. Examples of these concerns are compatibility with existing hardware, software, and data, ease of modification, potential for future development, and low incremental cost. GIRAS matches many state needs with its economical storage structure for conversion of state data to computer readable form, ability to use several referencing schemes, ability to overlay structured files, ability to convert from one structure to another, and ability to produce maps of varying scales. Moreover, it is under continuing development by USGS as GIRAS II, and its new capabilities will enable it to serve the more complex systems needs that will occur later in development.

Finally, a NASA-USGS ASVT in Louisiana is considering using LANDSAT data to update LUDA. It seems very likely that this effort will attack the remaining ELLTAB-GIRAS format incompatibilities.

7. NASA should undertake two specific development efforts of great utility to the proposed Missouri NRIS and to many other states as well.

Coordinating the GIRAS and ELLTAB programs mentioned above is the first of the two. GIRAS II, the second generation of GIRAS, will work only with polygonized data. NASA should develop software to convert the gridded classified LANDSAT output product of ELLTAB into a polygonized format compatible with GIRAS II.

The second effort is to develop a procedure for using ELLTAB to classify Missouri crops in categories according to their water needs. This classification could be a central input in a groundwater monitoring system, and groundwater supply is a key state concern. The effort could be a demonstration project, carried out jointly by Missouri and NASA.

8. Imposing obstacles have deterred routine state government use of computerized systems to process and use satellite-derived data.

Systems for the computer-aided processing and use of remotely sensed data may be characterized as being costly and technologically complex; requiring a long time for planning, training, and implementation; and having low political visibility. Thus it is not surprising that few states make wide use of these systems day-to-day.

Primary among the barriers to state-initiated processing and use of satellite data are those caused by the institutions, laws, politics, attitudes, and traditions that determine the course of state government. For example, because political appointees hold power in states, the political "punch" of an innovation may be more important than its potential cost savings. As a second example, employee-related pressures, such as civil service constraints, union pressures, fear of change, and the communication gap between technologists and users, slow technological innovation in states.

9. In Missouri, astute system management can overcome obstacles to NRIS success.

The Missouri DNR, which has chartered responsibility for natural resources management, can support initial system development. The DNR should initiate NRIS activities by appointing a Special Assistant, reporting to the DNR Director and concerned full time with the information system, to run the initial pilot project, hire the first staff members, and control the system budget. The person should be a leader who is politically astute and alert to opportunity.

The NRIS staff should minimize new purchasing or hiring until initial system success convinces state decisionmakers of its merit. It should begin immediately to develop long term political and user support by giving users an early hand in system design and the legislature an early view of example results. In the long term, the system should support itself as much as possible by exacting fees for its services.

10. <u>By making maximum use of existing resources, the state can limit the amount of new direct costs it incurs for the NRIS to very reasonable amounts.</u>

We estimate that in the first year of operation, total direct costs incurred specifically to develop and operate the NRIS will be about $71,000, in 1978 dollars. This figure includes expenses for hardware, software, personnel, data, and computer time; it does not include "overhead" costs that the state would incur whether or not it develops the system.

As system complexity and capability grow, so does its cost. In its first year, the system contributes to only one state problem -- dam safety. In its second and third years, it accomplishes both dam safety and groundwater monitoring, and in the fourth year, it adds a third application, monitoring municipal water shortages. In 1978 dollars, second year costs are about $150,000; third and fourth year charges, $220,000.

11. <u>We recommend that NASA assist Missouri in funding initial NRIS development as an ASVT.</u>

Such an ASVT is justified because its focus would differ substantially from previous demonstrations. In the past, NASA appears to have funded primarily "surface" applications of LANDSAT, in which all the relevant effects appear on the satellite image. The water resources information system, in contrast, handles data both visible and invisible from LANDSAT. To derive useful information, it must combine both types. Because this need for data combination appears in most practical uses for LANDSAT, we recommend that NASA concentrate more funds on applications of this type.

CHAPTER 3

PRIORITY APPLICATIONS FOR A LANDSAT-BASED, NATURAL RESOURCE INFORMATION SYSTEM IN MISSOURI

3.1 INTRODUCTION

This chapter identifies and analyzes a focal application area, water resources management, for a LANDSAT-based, Missouri natural resources information system. The first part of the chapter briefly justifies our decision to base the system on water resources management problems. We then review current state programs for managing water resources and analyze four, high priority, water management problems on which we base our system design in later chapters. Finally, this chapter also lists other applications for a LANDSAT-based information system.

For a number of reasons, we believe that a single-theme, Water Resources Information System (WRIS) offers a high likelihood of success. Our review of the elements of success in geographic information systems (8) reveals that focussing such a system on a single theme enhances its prospects. Furthermore, our interviews with the Director of Missouri's Department of Natural Resources indicate that the two natural resource areas of highest priority in this Administration are energy and water, with energy currently receiving somewhat more attention (9). However, we focus on water because water data are more available than energy data from both state and federal sources, and computer models for hydrology exist (10).

In a speech at the National Conference on Water (11), Missouri's Governor Teasdale further supported our decision by identifying a Natural Resources Information System (NRIS) as a means of dealing with Missouri's increasing water problems.

The area of water resources management has another property that makes it a fortuitous choice for system design. In our estimation, four key water problems are likely to arise between now and 1985 in the following order: [1] dam safety, [2] saline intrusion in ground water, [3] sporadic municipal water shortages, and [4] long term depletion of the Missouri River Basin supply. The information management needs of these four problems, listed in this same order, range from relatively simple to quite complex. Thus, they form a natural progression on which to base system growth.

Our plan for a system design centered on these four problems assumes that all four, though now perceived with varying degrees of urgency, will grow to be of such concern that they survive competition for state funds. This prediction may be inaccurate. Even if it is, our plan will remain useful as a guide for allocating the correct levels of time, money, and effort for system development.

Before we describe the current and likely future state water resources management activities on which we base the plan, we list involved state government institutions. Three agencies play major roles: the Department of Natural Resources (DNR), the Conservation Commission (CC), and the Office of Administration (OA). Three divisions of the DNR are particularly active in both water and energy programs. The Division of Geology and Land Survey (DGLS) supplies much of the state's natural resources data and administers most of the hydrological data collection programs described later in this chapter. The Division of Environmental Quality (DEQ) bears major enforcement and administrative responsibility for state programs directed at upgrading or controlling natural resources uses. The Division of Planning and Policy Development (DPPD) analyzes and recommends new programs on the basis of data inputs from both DGLS and DPPD.

From a systems point of view, DGLS is a provider of scientific data, DEQ is both a user of scientific data and a provider of state program data, and DPPD is a user of both types of data, as are OA and CC. Figure 3-1 depicts these interchanges.

DNR, CC, and OA cooperate in NRIS planning in the Interdepartmental Council on Natural Resources Information (ICNRI). This Council counts as members representatives from all Missouri agencies with responsibilities that impact the state's natural resources.*

We devote the rest of this chapter to analyzing Missouri's water resources activities relevant to systems design. Section 3.2 reviews current state programs, and Section 3.3 analyzes the four key problems. Section 3.4 lists some less critical areas of application for the information system.

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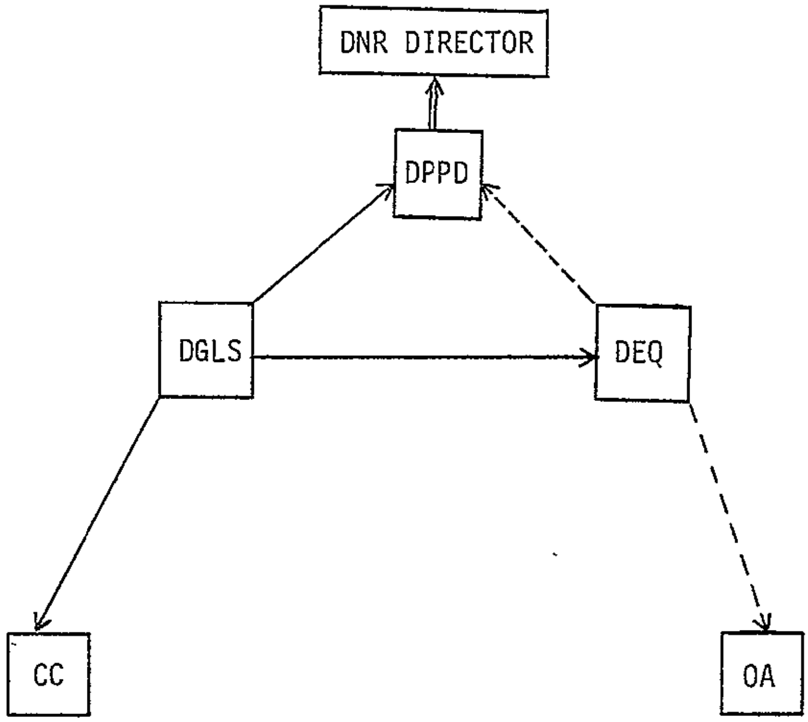
*Further information on state organization relative to NRIS development is available in the quarterly progress reports of this project and of the project now being performed for NASA by DGLS (4).



Information flows:

- ═══ recommendations and analysis
- ------ state program operational data
- ——— scientific data

Key to Abbreviations:

DNR: Missouri Department of Natural Resources
DPPD: Division of Planning and Policy Development in DNR
DGLS: Division of Geology and Land Survey in DNR
DEQ: Division of Environmental Quality in DNR
CC: Missouri Conservation Commission
OA: Office of Administration

Figure 3-1

Information Flows Among Missouri Institutions
Which Are Central to the Development of A
Water Resources Information System

3.2 REVIEW OF CURRENT WATER DATA COLLECTION ACTIVITIES

After identifying water supply as the initial focal issue, we studied current state water resources data collection activities. Especially since the upcoming crises are anticipated to be of supply rather than quality (11), we directed attention to supply-related programs.

Funding for these programs falls into three categories: federal, federal-state co-op, and state. The Corps of Engineers supplies the bulk of federal funds, exceeding all other sources combined. The United States Geological Survey Water Resources Division (USGS-WRD) earmarks certain funds for data collection, usually by USGS-WRD personnel, on a cooperative basis with the state, each partner contributing fifty per cent of the total project costs. Funding for state programs derives solely from general revenue budgets. State activities, less structured than the federally funded programs, amount more to problem responsiveness than government-initiated activity.

Water data collection programs in Missouri fall into two categories: basic and specific. Basic data collection programs generally cover most of the state. Analysis of historic patterns in basic data helps predict effects of proposed actions. Current basic data collection activities attempt to characterize water, ground water, and water quality dynamics. These programs develop data files on subsurface geology, soil type, mineral deposits, and water well yield, to name a few.

In addition to these state-funded basic data programs, co-op funded ones produce both surface and groundwater data. A network of stream gaging stations collects the surface water, while specially equipped wells distributed across the state monitor ground water levels and quality. The state routinely examines these data.

Specific programs, the second category of water data collection activities, deal with one-time problems and are usually narrowly focussed geographically. An example is a program established to detect the causes of salinization of the ground water supply in a four-county region in east-central Missouri, the Audrain-Boone-Callaway-Montgomery group. This project has arisen from a strong local variation in groundwater quality observed in the statewide basic data collection program. These mostly rural countries have experienced rapid increase of agricultural intensity, especially by means of irrigation. DGLS reports a phenomenal increase in reported bedrock well drillings. This increase naturally raises questions concerning the limits of the underground aquifer as a renewable source of water for continued use, and the data collection program has recently been expanded to include the fifteen-county region along a line from Barton County in the southwest to Audrian in the northeast (12).

The longevity of the data in basic and specific programs differs markedly. While continuity is important in basic data, the value of specific data usually decreases as the importance of the relevant problem does. Despite this difference, the two classes of programs are strongly interdependent. The design of a specific program arises from basic data already accumulated, while the results of specific data collection programs often cause modifications in an on-going basic data program. As an example, the four-county study mentioned above has promoted consideration of a more extensive study of the entire northwestern half of the state which seems prone to the same saline intrusion. The delineation of that area was based on a combination of information from the basic data store, including soil type, mineral deposits and subsurface geology. The salinization problem is severe and probably permanent, so this program will likely continue indefinitely and become a basic data collection program.

The next two subsections describe two water data collection programs of particular interest in our plan.

3.2.1 The 1974 Dam Inventory

The state Department of Natural Resources, Division of Geology and Land Survey (DGLS) conducted an inventory of dams for the Corps of Engineers in 1974. Entirely funded by the Corps of Engineers under the National Dam Safety Act of 1973, the program was staffed solely by Missouri personnel. The procedure started with locating dams by visual inspection of aerial photography, Skylab photos, and LANDSAT imagery, and continued with aerial inspection of the 2315 water impoundments located and surveys to establish ownership and other data on each dam. The information was computerized into a sequential file and tabulated in printed format, a sample of which appears as Table 3-1. This work is the sole computer application performed on water resources data by DGLS. It now serves simply as an administrative tabulation and is not yet a system for geographic analysis. Since funding from the Corps has expired, no further work has been done in keeping the inventory updated.

3.2.2 Well Logs

The second program is the voluntary collection of well log data performed by the private well drillers across the state. Beginning in 1908, many well drillers began to store their well logs at the Missouri Geologic Survey in Rolla. Though there is no legal compulsion to do so, the practice continues, and about 30,000 records are now on file. A well

STATE ID SEQ#	PRIMARY ST	CO	CO	SECONDARY ST	CO	CD	******** NAME OF DAM ********	LAT	LONG	COUNTY	TOWN SHIP	RANGE NO D	SECTION NO 1/4	SURFACE ACRES
MO10919	MO	139	09				MONONAME709	3853.9	9127.9	139	48	05 W	27 SENW	7
MO30933	MO	139	09				MONONAME766	3852.7	9130.6	139	48	05 W	31 SESE	7
MO10685	MO	139	09				HICKORY MEADOWS DAM	3857.1	9133.7	139	48	06 W	03 SWSE	10
MO30334	MO	139	09				IRVIN BEABOUT DAM	3856.2	9132.4	139	48	06 W	13 NWNW	9
MO30333	MO	139	09				GLENN NOBLES DAM	3855.6	9131.7	139	48	06 W	13 SESE	5
MO10367	MO	139	09				BOB HOFFMAN DAM	3855.1	9134.1	139	48	06 W	22 SWNE	3
MO30921	MO	139	09				MONONAME713	3854.8	9132.0	139	48	06 W	25 NENW	4
MO30922	MO	139	09				MONONAME714	3854.1	9137.9	139	48	06 W	30 NESW	5
MO30095	MO	139	09				MONONAME11	3853.0	9138.6	139	48	07 W	36 SESE	286
MO10684	MO	139	09				KI WI DAM	3901.8	9135.7	139	49	06 W	09 SWSW	6
MO10947	MO	139	09				WELLSVILLE LAKE DAM	3902.1	9134.7	139	49	06 W	09 SENE	16
MO10199	MO	139	09				NESTOR AND LITERMAN DAM	3900.3	9136.8	139	49	06 W	20 NWSW	4
MO10683	MO	139	09				SCHOW LAKE DAM	3900.3	9134.9	139	49	06 W	22 NENE	10
MO10593	MO	139	09				SCHOWENGERDT DAM	3900.8	9133.7	139	49	06 W	22 NENE	10
MO10942	MO	139	09				MONONAME760	3959.0	9132.8	139	49	06 W	26 SESE	10
MO10946	MO	139	09				MONONAME763	3904.4	9122.8	139	50	04 W	29 NWSE	3
MO10965	MO	139	09				MIDDLETOWN DAM	3906.1	9126.6	139	50	05 W	14 NWSW	14
MO10918	MO	139	09				MONONAME708	3906.0	9127.8	139	50	05 W	14 NWSW	22
MO10157	MO	139	09				FRED WENZEL DAM	3908.0	9131.3	139	50	06 W	01 SESE	17
MO10167	MO	139	09				MONONAME 825	3906.5	9131.6	139	50	06 W	13 SWNE	10
MO10099	MO	139	09				MARSHALL DIGGS WILDLIFE AREA DAM	3904.3	9137.8	139	50	06 W	31 NWNW	13
MO10949	MO	139	09				MONONAME765	3903.8	9134.9	139	50	06 W	33 NWSE	10
MO10681	MO	139	09				MONONAME 223	3904.3	9134.9	139	50	06 W	33 NWSE	10
MO10948	MO	139	09				MONONAME764	3904.3	9132.5	139	50	06 W	35 NENE	20
								TOTAL ACRES FOR MONTGOMERY COUNTY						1,097

Table 3-1. Dam Inventory

log is a written and graphic record of the various materials that the drill bit encounters as it churns its way toward bedrock. Many of the well drillers have devised elaborate pictorial records of their experience. Figure 3-2 is a facsimile of a typical well log. The information contained is valuable both for well drillers, when they encounter problems in drilling new wells, and to the public. The aggregate information contained presents a picture of Missouri's geologic structure related to ground water.

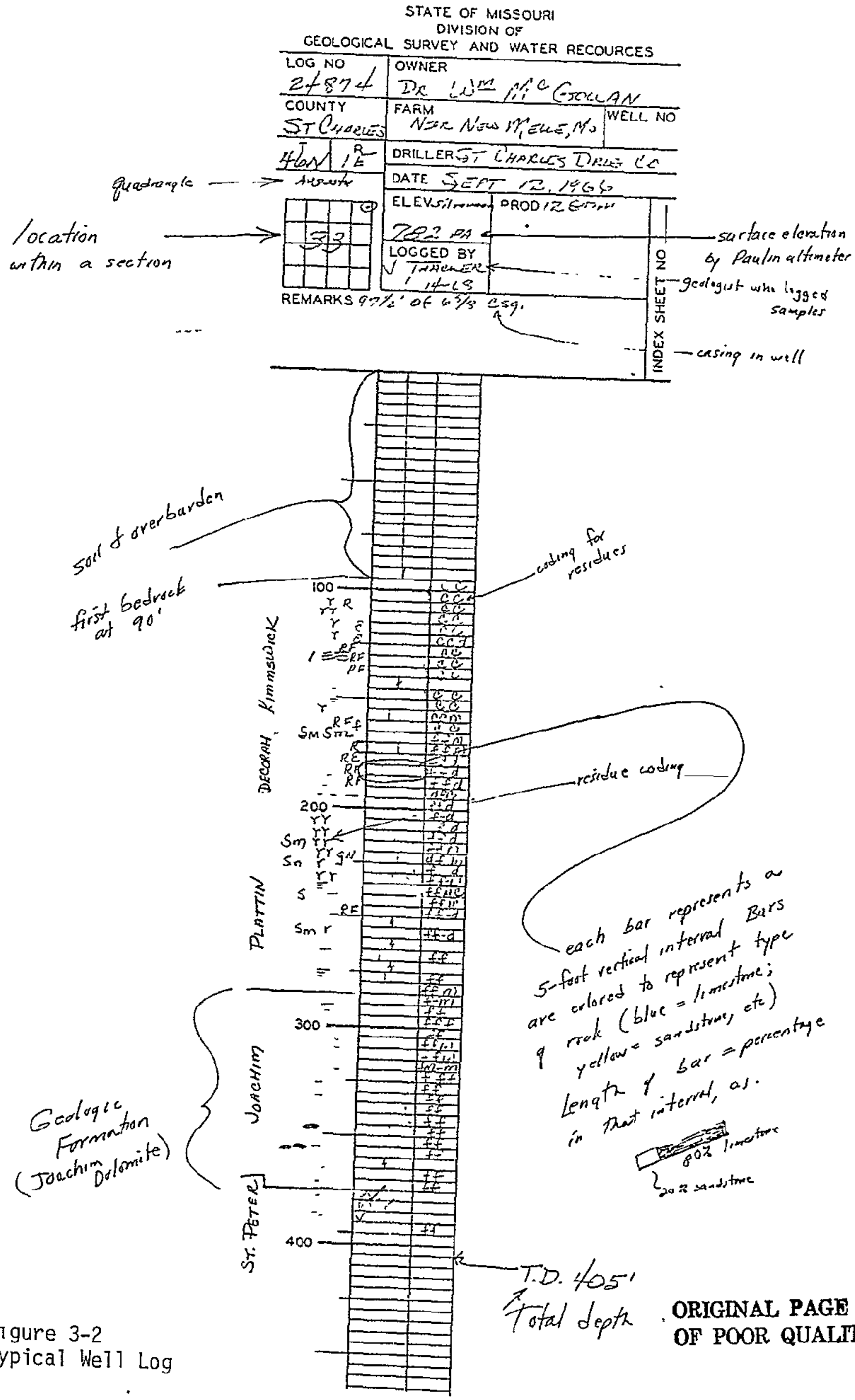


Figure 3-2
Typical Well Log

3.3 EMERGENT ISSUES

Our review of current activity identified four significant water supply related problems. At present perceived with varying levels of urgency, they may soon grow into very visible public issues. These problems, in the chronologic order in which they are likely to become important (13) are: 1) dam safety, 2) ground water quality deterioration, 3) sporadic municipal water shortages, and 4) long term depletion of the Missouri River Basin supply.

These problems share three properties that make them likely vehicles for long-term development of an NRIS capability in the state: visibility, complexity, and permanence. Each will command sufficient attention that a substantial response will be required. The dam safety problem is one case in point. One major newspaper has been carrying both a series of articles on the potential for disaster and several editorial statements urging the Legislature to act (14). This publicity may force Missouri's legislature to pass a dam safety bill. Certainly, potential saline intrusion in half the state's ground water will result in similar concern and legislative action.

In addition to being visible, each of the four problems is complex. The result of a combination of social, economic, and natural factors, they could each be dealt with in a variety of ways. As an example, as sporadic water shortages become more frequent, a permit system to regulate water usage will probably be suggested as one means of dealing with the problem. Others will advocate water development projects that will extend the resource. Planning for either of these approaches will require basic data analysis of their relative benefits, employing demand and supply, social and economic, and natural resource data.

The third aspect of the problems is their permanence. There will be no end to problems of water supply. Whether the basic policy is development or conservation or a combination of the two, information systems will be needed to design and monitor the solution programs.

We conclude that the four problems cited will create sufficient demand for continued support of computerized information systems in state government. A recent paper (15) prepared for NASA indicates that remote sensing can serve as a significant input to a hydrological information system. Thus, an information system serving these problems is an effective vehicle for the introduction of satellite technology into state decision-making.

Sections 3.3.1 through 3.3.4 provide background on each of the four applications identified, discuss likely state responses to the issues, and briefly indicate primary information system implications.

3.3.1 Dam Safety

Missouri is one of only eight states which do not require a permit or license for the construction of a new dam and yet it is, with more than 2300, one of the top five in numbers of dams (16). Missouri has failed to enact regulations on the construction of new dams and safety features of older ones twice before, but the current attempt is given high likelihood of success (17). The new legislation anticipates a two-tiered system of permits. One would cover construction, alteration, enlargement, reduction, repair or removal of a dam or reservoir. The second would be a safety permit to be required of all construction on dams of more than fifteen feet in height or storing more than twenty-five acre feet of water. Safety permits would have a five year duration and reinspection would be required for renewal (18).

A key feature of the legislation provides that an inventory of water impoundments be maintained on an annual basis to monitor for new construction (19). DGLS plans to carry out the annual update in a format similar to the 1974 inventory (see Section 3.2.1). In a fiscal note accompanying the bill, DGLS anticipates $100,000 annual expense, $30,000 for detection and information storage and $70,000 for inspection and mailed surveys (19). In this financial estimate, the method of impoundment detection is assumed to be similar to the manual techniques used in the 1974 inventory.

A LANDSAT-based computerized information system could play two main roles in this application. It could locate the new impoundments annually by LANDSAT-based techniques, increasing inspection efficiency, and it could assist in monitoring the permit/inspection program by the use of conventional data base management techniques.

3.3.2 Ground Water Quality Deterioration

A pattern of ground water quality deterioration is developing in northwestern Missouri. This apparent problem of quality is a symptom of a groundwater supply shortage. Overpumping the groundwater results in pressure drops that allow more deeply buried saline water to intrude into the lens of fresh water on top, degrading its quality. Overpumping seems to be the result of two major factors: primarily increased irrigation and also increased municipal water use in the region. The increased irrigation has been made possible by relatively inexpensive new technologies. The situation is expected to worsen, with a 500% increase in consumption use for irrigation predicted by 1985 (20). In the future, large additional demands may be made on the water supply in the same stressed areas by proposed coal gasification plants.

The solution must be to achieve a balance between supply and demand to allow the fresh water to renew itself. When withdrawals are made in moderation, the overlying lens of freshwater recharges naturally by percolation of fresh water from the surface. If intrusion of salt water continues, the fresh water supply can become completely and irreversibly ruined. Control methods that are after-the-fact (e.g. flushing and recharge) have been shown to be prohibitively expensive for use in Missouri (12).

Missouri has the opportunity to take some preventive measures early in the salinization process, rather than waiting for irremediable damage to occur. A program of balanced water use management in northwestern Missouri could alleviate this critical problem. Two current activities indicate the likely state response. DGLS has initiated a Co-op program with USGS-WRD to study and model patterns of water use throughout the state. Furthermore, the State Legislature and the DGLS have been investigating the feasibility of a permit system to limit agricultural water use in critical regions (21).

Each of these activities bears on information system design. Though the DLGS Co-op project is funded only for exploratory studies using existing data sources, the long range water use study will require input of socio-economic factors, land use patterns, and irrigation practices.

The information system response to ground water shortages should occur in two phases. Phase I, to be performed while more accurate data is being encoded, provides a state-wide assessment at the 1:250,000 level. Phase II extends this capability to allow more detailed site analysis.

3.3.3 Sporadic Municipal Water Shortages

The summer of 1977 saw severe water shortages in Higginsville, Missouri and several surrounding communities in the western part of the state and about forty km. (25 mi.) north of the Missouri River. Higginsville had built a municipal reservoir several years ago and, assuming normal supply conditions would continue, had over the years agreed to supply municipal water to about a dozen nearby smaller communities. In 1977, supply failed to meet expectations, necessitating a municipal water rationing program as severe as those instituted in the arid western states. Higginsville called upon the state government for assistance (22).

Increasingly frequent industrial, municipal and agricultural water supply shortages have inspired a committee of the Missouri House of Representatives to investigate water rights legislation. Missouri has not in the past suffered from water shortages, and so there is not a very extensive body of state law or precedent to serve as a guide. Surface water rights in Missouri are based on the common-law doctrine of "riparian" rights derived from ownership of adjacent land. Rights to ground water are based on the informal principle of reasonable use by the owner of the overlying land.

The state now looks to others, like Texas, which have longer experience with the problem and have developed methods of dealing with it (see Appendix F). Imposing limitations on water rights creates the need for more complete and more timely information to perform and monitor the allocation of rights. Texas employs three hundred people to administer this phase of water conservation.

The state can deal with supply shortages by conservation and development. Conservation programs can either be voluntary or mandated by regulation such as water permits for drilling wells or diverting steam flow, limitations of municipal supply, or even rationed meter allocations. Development efforts can decrease evapotranspiration losses by storage of water in underground aquifers or surface reservoirs. Use of such buffer storages for agricultural irrigation supply would have the effect of decreasing stress on shallow aquifers.

An information system serving this application would require geographically based demographic data sources and software to permit point and line structures. Demographic data will include population, housing, industry, and both municipal and industrial usage patterns. Point and line data structures can characterize municipal water use, which unlike groundwater demand patterns are rather narrowly focussed geographically.

3.3.4 Missouri River Basin Depletion

Over half the state lies in the Missouri River basin (see Figure 3-3), and so the continued supply of water in sufficient quantity from that basin is critical. Increased demand for the river's water comes both from within and outside the state. Consumptive uses within the state are primarily for irrigation and for coal-fueled electrical power generation. Nuclear powerplant generation and coal gasification plants portend increased consumption.

A recent study shows the significance of the energy-water supply interaction to be a severe constraint on any energy or water development plan (23). A nuclear plant is currently being constructed on the Missouri River about five miles from Jefferson City. Coal gasification plants have been proposed both for centrally located Boone County and for the town of Milan in north-central Sullivan County. Both of these sites lie in the region of potential salt water intrusion. Since coal gasification is highly consumptive of water (on the order of 10^3 liters

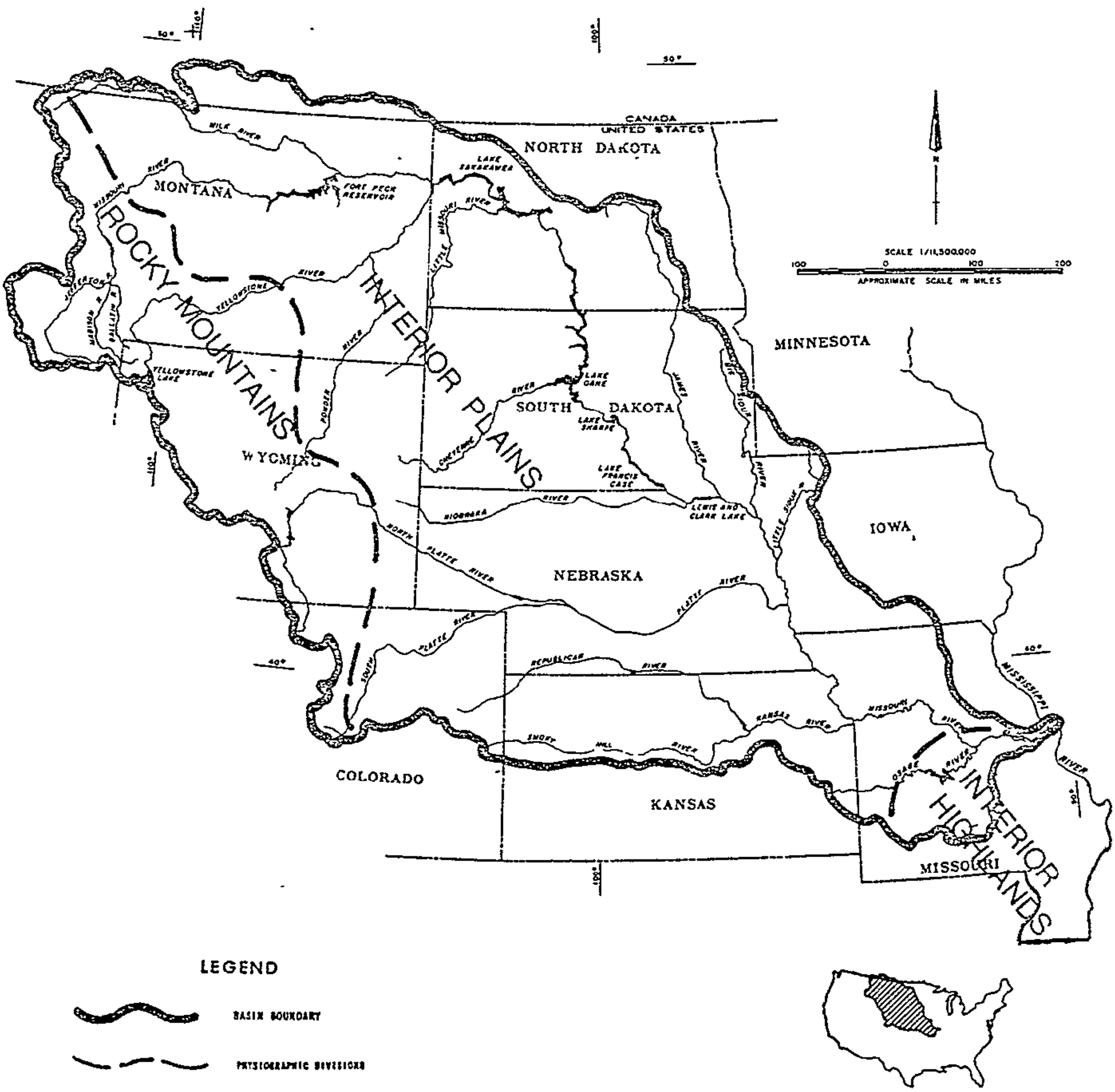


Figure 3-3. Missouri Basin Map (20)

(gallons) per minute in a typical plant) this use could put the entire northern Missouri region in jeopardy when superimposed on irrigation.

Overshadowing the question of uses of the flow within the state of Missouri is the viability of the source of the flow. Missouri occupies the extreme downstream position in the Missouri River Basin and is therefore affected by the uses and amounts withdrawn by all of the Upper Basin states (see Figure 3-3). The issues are difficult interstate questions of water rights. That there does not exist adequate data even to indicate the extent and severity of the problem compounds the difficulty. Estimates of flow into Missouri varied by 7.4×10^9 meters^3 (5×10^6 acre-feet) between the 1971 study by the Missouri River Basin Commission and comparable estimates for the same period made by the National Water Resources Council (20).

Two examples serve to illustrate how upper basin uses affect the supply of water into Missouri. The Pick-Sloan Plan, established by Congress in 1944, authorized North Dakota, South Dakota, and Montana to draw off enough water to maintain certain levels in six major federal reservoirs. Extensive use of center pivot irrigation, with its high evaporation factor, has resulted in additional consumptive use upstream. The net effect has been a startling decrease in flow into Missouri between 1970 and 1975 and predictions of significant continued decreases. Using consistent procedures for estimation, Water Resources Council figures indicate that annual flow near Hermann, Missouri at the mouth of the Missouri River, declined from 7.9×10^{10} meters^3 (53.6 million acre-feet) in 1970 to 7.3×10^{10} meters^3 (49.4 million acre-feet) in 1975. These declines will continue with a flow of 6.8×10^{10} meter^3 (46 million acre feet) predicted for 1985, compared to the estimated free flow of 9.6×10^{10} meter^3 (65 million acre-feet) (20). Voicing these concerns, Governor Teasdale made the following formal resolution at the Basin Commission meeting in February, 1977:

> "Be it resolved that the several States that together comprise the Missouri River Basin petition the Federal Government through the Missouri River Basin Commission to develop within the several States a cooperative water data system adequate for assessing the current and future water uses within the basin. This data base is to be used as a predictive tool to evaluate effects of individual water development projects in the basin as they relate to long range planning, water use, and water needs." (24)

The Commission has responded to the resolution by entering information system planning into its priority schedule. Development of a preliminary information system plan has received top priority in its 1980 work plan. In parallel with the proposed overall basin flow information system, Missouri may need to develop water accountancy systems for its own uses. (25)

3.4 OTHER NEEDS

The previous section chose four emerging issues because they currently seem the most compelling problems likely to arise through the early '80's. This section suggests several lower-priority needs to which the system could also be geared. Several will be included in the plan of Chapter 4 because they are components of the four major issues. Interest in using the system for other applications should grow as its capabilities develop.

3.4.1 Federally Mandated Programs

Much has been written about the potential of remote sensing in the preparation of water quality (EPA 208) plans. However, we recommend against basing an information system plan on this program or other federal reporting requirements. EPA 208 is motivated primarily by federal requirements external to the state's normal planning process, and therefore it may not be perceived with the same immediacy as programs demanded by the electorate.

3.4.2 Other Possible Missouri WRIS Applications

We list without detailed comment other applications that were suggested by state agency personnel.

1. Water Quality Monitoring

The system could provide daily, weekly or less frequent reports on the status of water quality in any monitored water body.

2. Site Evaluation Studies

A program to use weighting factors to calculate an optimum site for a particular facility or activity could be developed.

3. Drought or Flood Monitoring

The system could update information on water levels or help in assessing damage.

4. Reservoir Monitoring

The system could be used to watch changes in levels of water supply due to changes in recharge or demand.

5. Biotic Community Studies

The system could store data on environmental factors relating to population levels of aquatic organisms.

6. Planning Public Drinking Water Systems

The system could supply data on quality, amount of demand, areas of highest demand.

7. Fish and Wildlife Management Activities

A LANDSAT-based system could assist in mapping and assessing environmental quality of wetlands which are prime habitats for wildlife.

8. Measurement of Potential for Flood Damage

The potential can be calculated from data on water bodies, topography, civil structures, crops, industry, homes, etc., some of which might be contained in the system.

9. Mapping of Water Resources

The system could be instrumental in mapping any of above themes.

CHAPTER 4

A PLAN FOR THE DEVELOPMENT OF A NATURAL RESOURCES INFORMATION SYSTEM IN MISSOURI

4.1 OBJECTIVES OF THE PLAN

This chapter plans development of the technical components of a natural resources information system for Missouri. We list, cost, and schedule procurements, hiring, training, software development, and other elements required to construct the information system.

To describe the goals of this chapter more clearly, it is helpful to delineate the scope and meaning of the words, "natural resources information system (NRIS)." In the view of some, these words are synonomous with "computerized geographic information system (CGIS)," that is, a set of computer programs for managing files of geographically referenced data. In our usage, however, an NRIS includes CGIS components and much more. In addition to computer programs and data files, an NRIS comprises computer hardware and associated peripherals; personnel to plan, adapt, and operate the computerized system and to relate system activity to user needs; and training programs for these persons. Furthermore, as important as these visible elements of an NRIS are the system's institutional and policy aspects: the organizational structure for housing, controlling, and funding the system; the policies of administration and access; and the system's relationship to other state information management activities.

Thus, planning an NRIS requires a design that includes all of its elements, visible ones such as hardware, software, and personnel as well as institutional and policy aspects. With one exception, this chapter focusses on the visible system components, leaving discussions of institutions and policy to Chapter 5. The exception is Section 4.2, which briefly reviews broad organizational alternatives for the NRIS and chooses one on which to base the component planning in the rest of the chapter. This procedure is necessary because, as Section 4.2 explains, the institutional organization of the NRIS strongly influences the choice of its components.

Our goals are to plan a practical, useful, and attractive system. We achieve practicality by making full use of available resources - e.g. existing state computer systems and skilled personnel. Utility and attractiveness initially seem difficult to accomplish simulatenously. To be useful, the system must address high priority applications, such as Chapter 3's problems. However, these problems are also complex, and may require a complex information system. Yet past experience (8) suggests that simple systems, which can be implemented quickly, and do not disrupt existing structures, are initially more attractive to users.

We believe that our plan strikes a compromise between the apparently conflicting goals of utility and attractiveness. The system proceeds in manageable steps from an initial, fairly simple, pilot system, easily within the reach of present-day state resources. The initial system handles one water resources problem -- dam safety. The final configuration, achieved over time, is a water resources information system useful in all the priority applications in Chapter 3.

This chapter contains three additional sections. Section 4.2 reviews some alternative organizational frameworks for the NRIS. After choosing one of these frameworks as a basis for our plan, we plan acquisition of system components (hardware, software, personnel, training) in Section 4.3. Section 4.4 schedules and costs the planned developments.

4.2 ORGANIZATIONAL ALTERNATIVES FOR THE MISSOURI NRIS

This section describes four organizational alternatives for the Missouri NRIS: [1] Single Agency, [2] Hierarchical, [3] Linked Network, and [4] Modified Linked Network. These four alternatives are not original with us, having been first suggested by the National Water Data Exchange (NAWDEX). The Texas NRIS was consciously patterned after the Linked Network approach (26). In Missouri, the Information Systems subcommittee of ICNRI, responsible for NRIS planning, has given the four options some consideration but has not yet achieved a consensus (27).

4.2.1 Single Agency

This alternative grants a single (existing or new) agency responsibility for all natural resources information processing. This agency can require others to submit data to the shared information system. The organizational structure of this alternative is the simplest possible (Figure 4-1). The other agencies of state government continue to carry out their statutory responsibilities in the areas of data collection and dissemination, but all use the sole computerized geographic data analysis capability residing in the NRIS agency.

System components in this organization would be chosen primarily to serve the needs of the lead agency. For example, the CGIS would most appropriately be designed around the computer system serving the NRIS agency and new applications would be evaluated in light of that agency's priorities.

4.2.2 Hierarchical Organization

As in the Single Agency option, this option requires designating a single agency center as an "Analysis Center." The Analysis Center possesses the most highly developed computerized geographic information

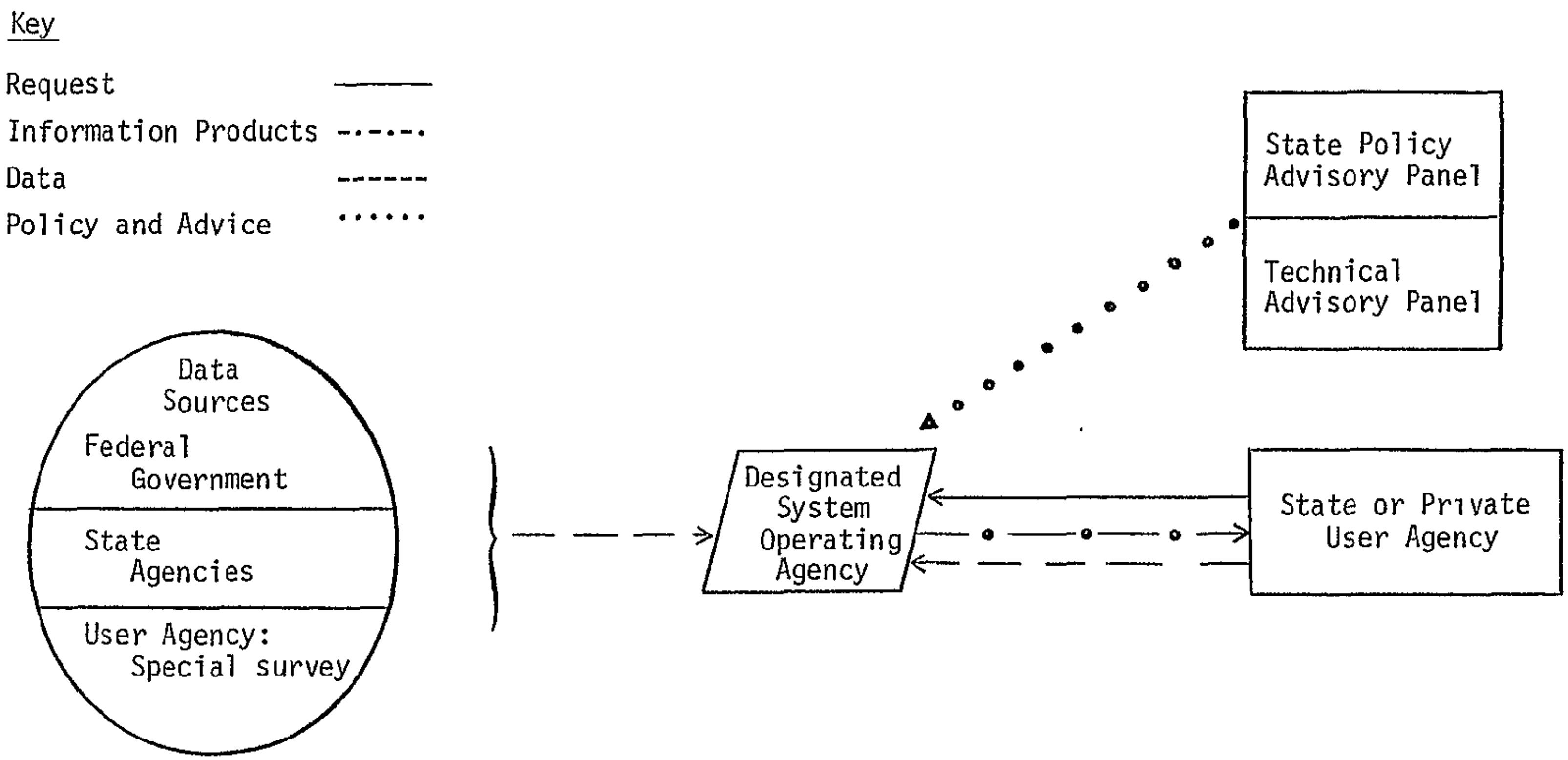


Figure 4-1

Single Agency Option

processing capability. Unlike the Single Agency option, however, this design calls for the establishment of several hierarchical levels of "Access Centers," with technical capabilities, in various state agencies.

Agency personnel or other users submit a data request to a designated Access Center, where it is fulfilled if it lies within that Center's capability. Otherwise the request is successively referred to the next higher center until it can be met. Several levels of Access Centers are theoretically possible, each increasingly generalized in scope of activity as one goes up the hierarchy from mission agency to Analysis Center. Figure 4-2 illustrates the general, multi-level structure. Due to Missouri's current high degree of centralization, it may be considered unlikely that more than one level will be required in our particular case.

Components at the various Analysis Centers are likely to duplicate processing or input functions performed in other Analysis Centers. Duplication is generally undesirable unless sufficient load exists to require duplicate capabilities.

4.2.3 Linked Network

This option consists of several system centers, one in each of a number of state agencies. Each center performs its own activities as mandated by statute and agency planning. A voluntary interagency task force coordinates planning among the separate centers. If ICNRI is considered to be the coordinating/planning organization, this is, in effect, the current structure in Missouri. Figure 4-3 depicts this structure.

This structure is agency-oriented rather than problem-oriented. Though an advantage of this approach is minimal disruption of existing agency organization, that is also its chief shortcoming. Division of

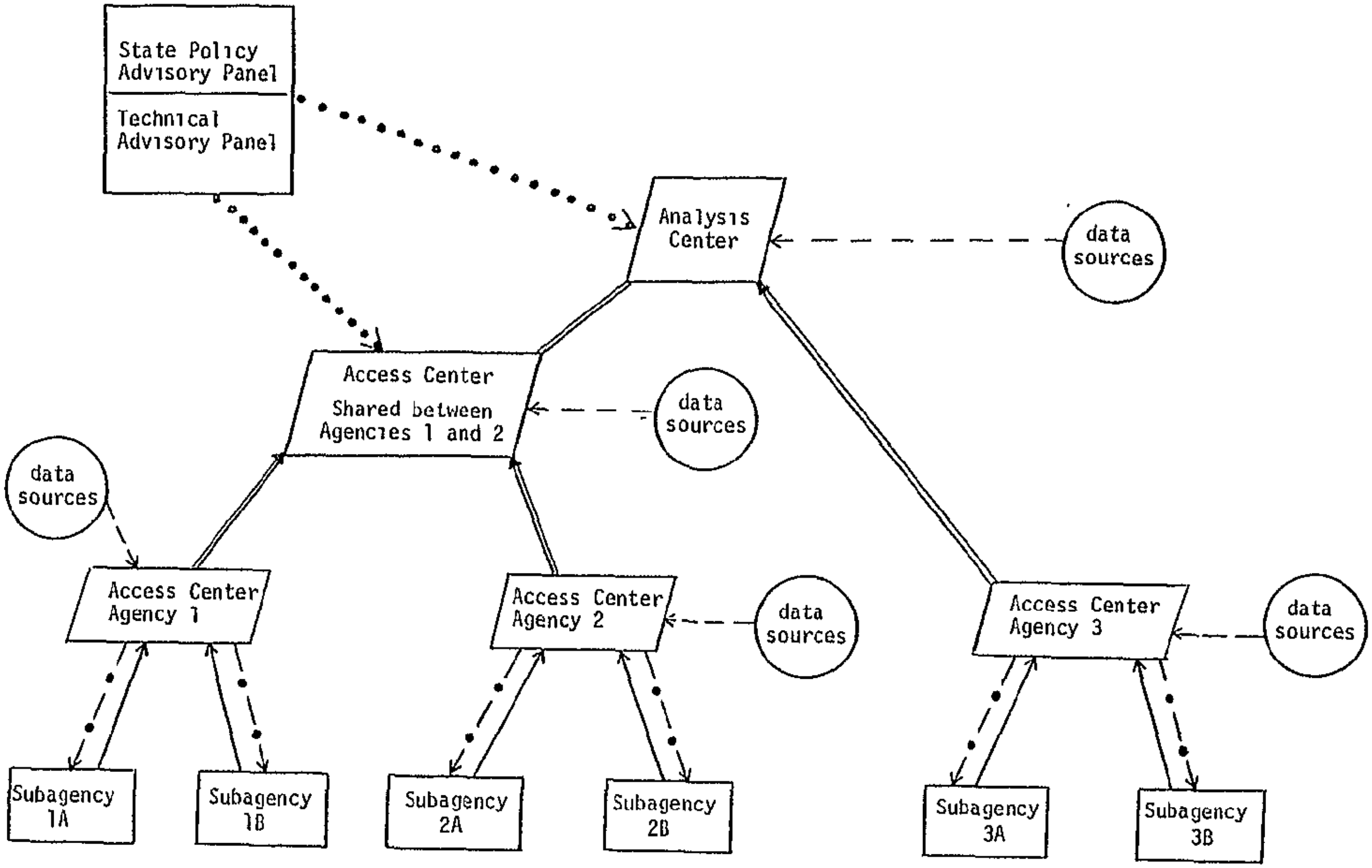


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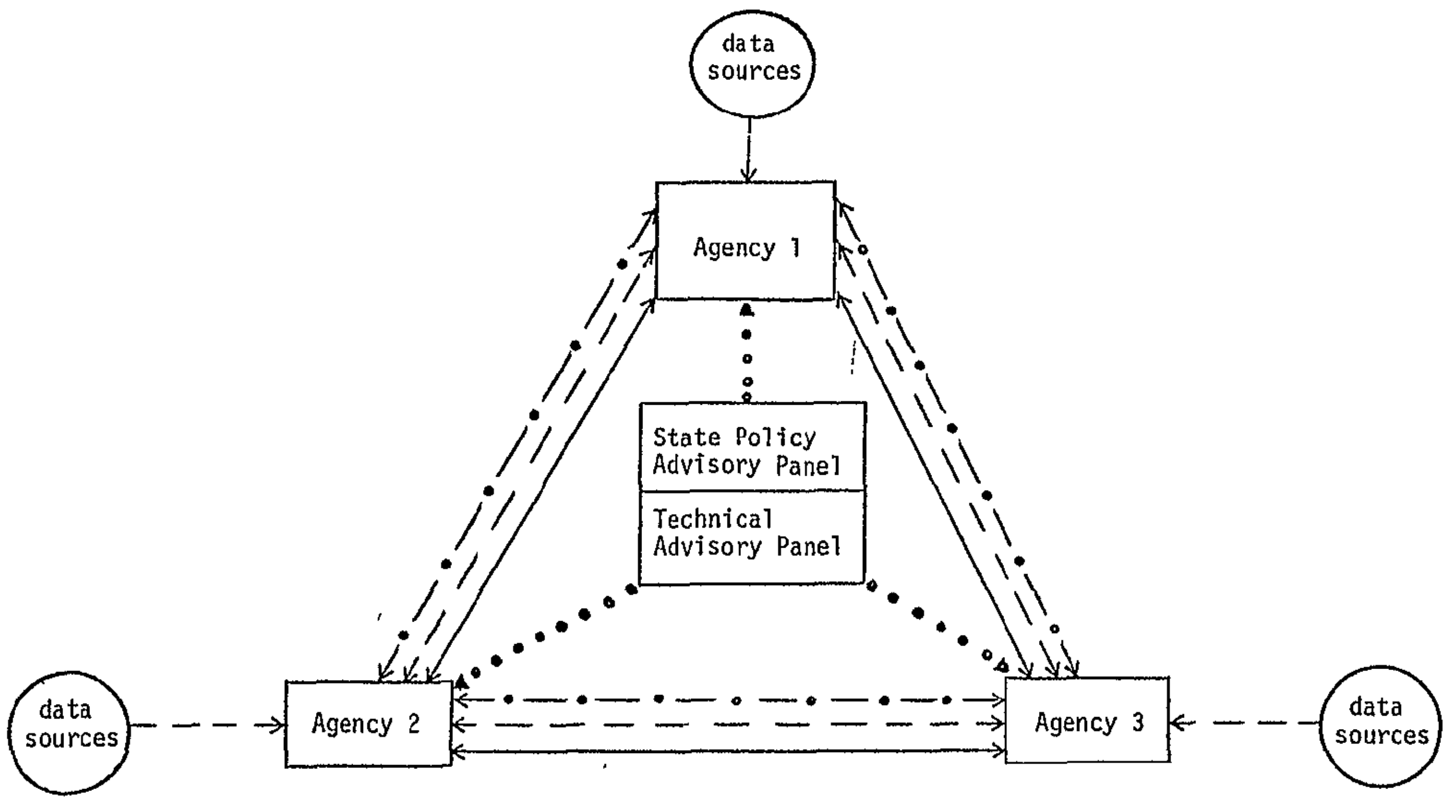
Figure 4-2

Hierarchical Option



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Data ------

Policy and Advice ......

Figure 4-3

Linked Network Option

responsibility for information system development among the various agencies may result in a lack of impetus to construct the system by precluding the development of "critical mass" of talent and technical capability within any single agency. Furthermore, this organization also may suffer from duplication of effort and lack of coordination.

4.2.4 Modified Linked Network

A final alternative combines the preceding two. In the Modified Linked Network, one of the agencies in the linked network acquires the additional personnel, equipment and other resources to provide the "critical mass" missing in the Linked Network. This unit, "System Central" (SC), becomes a resource to the other agencies, guaranteeing that sufficient talent and equipment will exist in at least one point in state government to provide the impetus for system development. Each agency has access to that capability.

This option retains the advantage of the Linked Network. Existing activities, particularly those mandated by statute, continue uninterrupted in each of the agencies in the linked network. This option differs from the Single Agency option, since the separate agencies are not obliged to use the resources of "System Central". In fact, they would be free to develop their own geographic information system capabilities if they see fit. Thus, a potential disadvantage of this system is that redundancy may decrease system economy and efficiency. Figure 4-4 illustrates the structure.

4.2.5 Choice of an Assumed NRIS Organizational Structure for the Remainder of Chapter 4

We base the plan of Section 4.3 on the Modified Linked Network Structure. The most compelling reason for this choice is that it appears

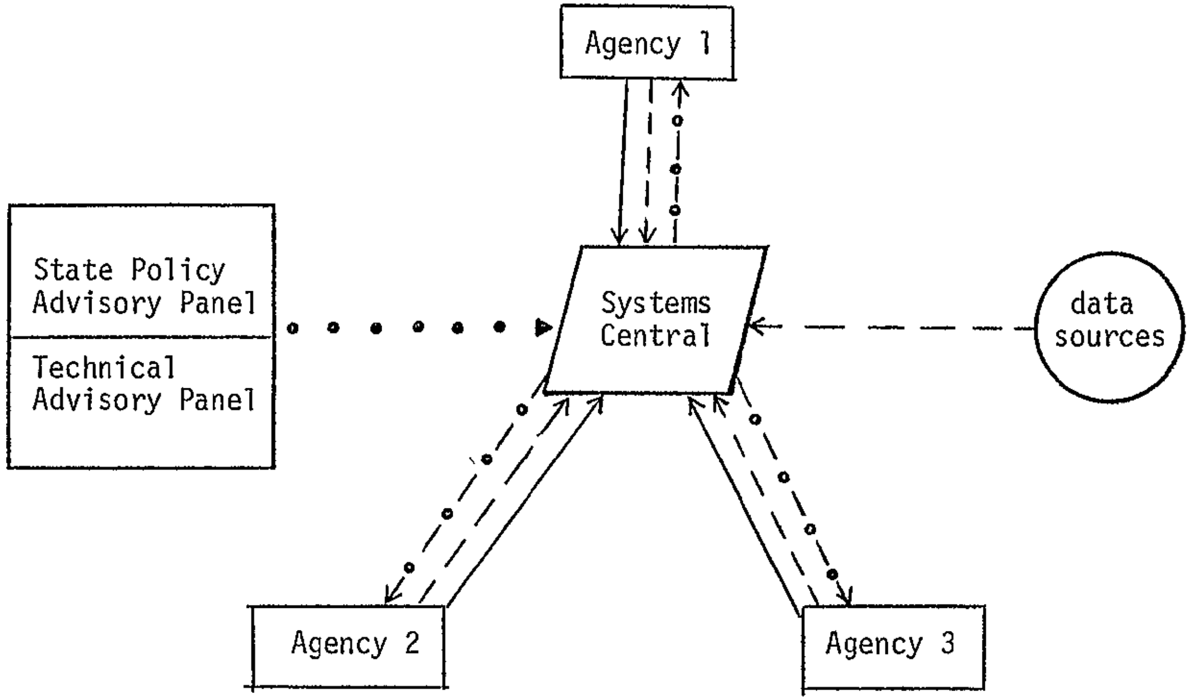

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Figure 4-4

Modified Linked Network Option

to insure continuing impetus and budget support for system development, while causing only minimal disruption of existing institutional structures. We do not regard the potential duplication of effort present in this option as a serious concern.

4.3 A PLAN FOR SYSTEM DEVELOPMENT

This section presents a system development plan based on the four water supply issues identified in Chapter 3. This plan describes, costs and schedules acquisition of system components (data, hardware, software and personnel).

Table 4-1 summarizes the information management processes needed to serve the first three applications. The fourth, basin modeling, is more a system design goal than a specific activity. The table's first column lists and dates the three other applications; the second lists subapplications, if any. The remaining three columns specify the system's processing in each subapplication by listing the input data, the transformation process, and the information products produced at output. More specific tables on data files, hardware, software, and personnel skill levels appear in Sections 4.3.1 through 4.3.5.

For dam safety, the first application, Table 4-1 lists two subapplications: dam location and the dam inventory/permit system. The two activities begin concurrently, but in different locations. Dam location using remote sensing requires hardware, software and expertise located at DGLS in Rolla, while the administrative systems for dam inventory and permits should reside at DNR headquarters in Jefferson City.

The groundwater shortage application (center of first column) is also subdivided. Phase I provides a statewide problem assessment based on readily available data and existing capabilities, while Phase II is site-specific, requiring refined data sources and technical capabilities developed during Phase I.

We do not subdivide the municipal water shortages application. A slower, two-phase approach may be precluded by this problem's visibility and population impact, which could demand immediate, site specific responses.

Table 4-1: NRIS Planning Framework

Application	Subapplications (If Any)	Input Data	Transformation Process	Information Products
Dam Safety 1978-1979	Dam Location	Multitemporal LANDSAT CCT'S	Computerized Image Registration and Classification	Maps and Tables of New Water Impoundments Since Last Inventory
	Dam Inventory	New Dam Location File Permit Administration Data Safety Inspection Data	On-Line Information Retrieval	Surface Water Inventory Construction Patterns
	Dam Permit System	Permit Applications New Dam Location File	Data Base Management of Permits Individual Programs	Permit Administrative Data Program Compliance Monitoring Summary Reports
Groundwater Shortages 1979-1981	Phase I 1979-1980	Surface Water Inventory Generalized Groundwater Characteristics Irrigation Demand	Data Base Management of Hydrologic Supply Information and Demand Information	Identification of Stressed Groundwater Areas Demand Projection Information Surface Water Supply Reports
	Phase II 1980-1981	Stressed Groundwater Areas Land Use and Crop Data Over Stressed Areas Detailed Subsurface Geology Detailed Soils Data	Combining Input Data to Assist in Predicing Localized Effects of Site Specific Projects	Estimates of State Program's Effect on Supply Increase Or Demand Information for Determining Location and Capacity of New Agricultural Reservoirs
Municipal and Industrial Shortages 1981-1983		Demographic and Industrial Data: Usage Rates, Location Economic Data Stream and Reservoir Locations	Combining Municipal and Industrial Data with Geographically-Referenced Hydrologic Supply Demand Data Base	Information for Water Use Program Monitoring Information for Prediction of Municipal Shortages Information to Evaluate Proposed Industry Water Demands

The table also displays rough estimates of dates for each application. Dam Safety, of current (1978-1979) concern, soon should be budgeted by the state. Information on agricultural supply will be required for studies on water use patterns and salinization progress in about 1979-81. Considerations of municipal and industrial water use regulation should follow in 1982. Finally, we target technical capability for hydrologic modeling for 1983-85.

Overall, this schedule fits our scheme of systematically increasing system capability. The plan begins with a relatively simple remote sensing application, detection of surface water from LANDSAT, and proceeds to develop a complex, satellite-based, computerized hydrologic modeling capability. In this way, hardware, software, and personnel can be acquired gradually; data outputs of earlier applications can serve as inputs to later ones; and later applications can employ skills that earlier ones develop.

We should emphasize that this section reports only our implementation plan. Our overall goal, to increase Missouri's ability to handle geocoded natural resource information, may not be obvious in the details of the plan described here. In this section, the only users mentioned are divisions of DNR, and the only theme addressed is water supply. We expect that these agencies and this theme will eventually represent only a small portion of state NRIS activity, once the word has spread.

As a final preliminary before presenting our plan, we consider current relevant computer capability in the state and make some assumptions about future developments. A provision is being made for a DNR computer system; currently the agency does not have one. The DNR is developing a data processing plan for OA's Office of EDP Centralization, which will factor it into a state plan. As a result, DNR will either buy its own hardware or use the services of one of the state's computer centers. Because excess capacity exists in a recently expanded EDP-C center, it is likely that DNR needs will be assigned to an IBM 370/148 there. Our plan makes that assumption, but the plan should be easy to modify if DNR acquires its own hardware. If it does, DNR hardware specifications must allow for System Central's loading.

We assume further that both DEQ and DPPD will have remote terminals to the EDP-C system. The size and scope of DEQ activities will justify locating remote terminals at the DEQ offices in Jefferson City. Though DPPD is a smaller unit with no operational program involvement, DPPD is housed in DNR headquarters, the likely site of another remote terminal. It is reasonable to assume that both terminals are justified entirely by existing programs, independently of CGIS development. If DNR decides to acquire its own hardware, a link between DEQ and DNR headquarters will also be necessary. This link could either be a remote terminal to computer connection or a network of two minicomputers.

These preliminaries complete, the rest of this section presents our implementation plan for a system to serve the four key water resources problems. Section 4.3.1 covers the Dam Safety application; Sections 4.3.2 and 4.3.3, the two phases of the Groundwater Shortage application; and 4.3.4 and 4.3.5 cover respectively Municipal Water Shortages and Basin Modeling.

4.3.1 Dam Safety: An Overview

The Dam Safety application comprises two subtasks: [1] locating new impoundments and [2] maintaining the dam inventory and administering a dam permit system. Locating new impoundments begins with annual detection and mapping of all water bodies in excess of five surface acres from LANDSAT digital data. Comparing two maps taken in different years pinpoints new construction. A map of new impoundments is helpful in planning an efficient sequence of low altitude, visual inspection overflights; thus it assists in the second subtask, maintaining the dam inventory (see Chapter 3) and administering the permit system. This second subtask forms the basis for enforcing the pending new dam safety legislation. Our plan calls for computerizing permit administration, which will likely be assigned to DEQ. Moreover, we recommend the inventory file be stored in an on-line, retrievable mode for analyzing construction patterns, evaluating the effect of the current legislation and recommending future modifications. These activities are of the type normally performed by DPPD.

Our plan reflects the information interchange among institutions depicted in Figure 3-1. Scientific data is collected by DGLS, augmented by DEQ program data and evaluated by DPPD. In the system's initial stages, the information interchanges are off-line using commonly formated tapes, while later stages of the plan provide for automated interchange. The next section plans the first subtask, new impoundment location.

4.3.1.1 New Impoundment Location

Figure 4-5 illustrates new impoundment location. Currently available software carries out classification (see the rectangles numbered (1) on the figure). The product is a digitized image with each pixel containing either a "1" or a "0" to indicate water's presence or absence. The first time the system operates, both the current and the previous year's LANDSAT computer-compatible tapes (CCT's) undergo classification. After

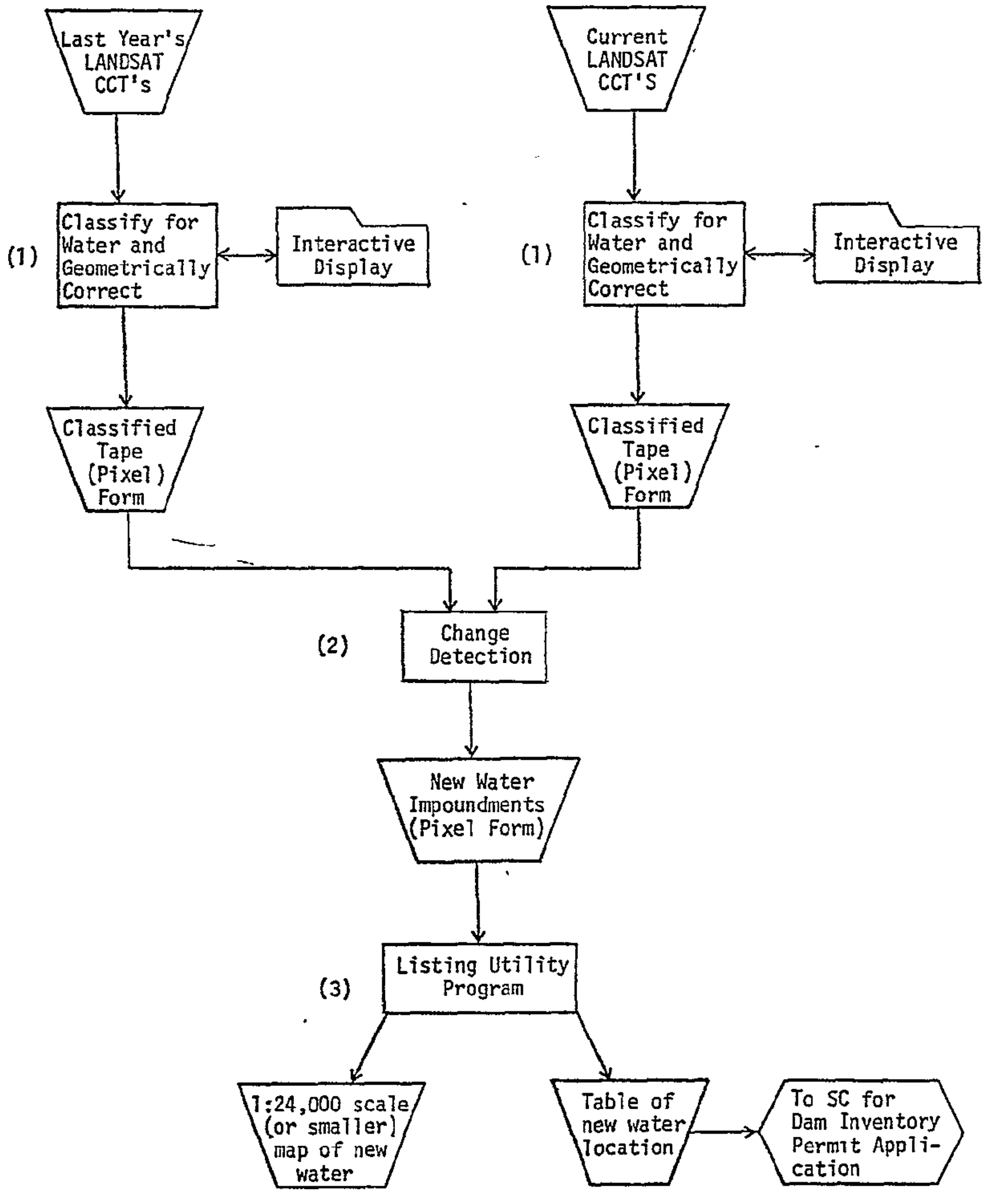

Figure 4-5

New Impoundment Location

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the system has become operational, it saves the output of this process from year to year.

To detect change, the process numbered (2), the computer compares the current classified image with last year's, pixel by pixel, to find new water bodies. On the output of this operation, the data again appears in pixel format, but in this case with four classifications:

0 - Not water this year, Not water last year;

1 - Water this year, Water last year;

2 - Water this year, Not water last year;

3 - Not water this year, Water last year;

Categories 2 and 3 indicate either changes or errors. If they are changes, then 2 is a possible new impoundment, 3 a transitory water formation.

Listing the possible new water impoundments, the process numbered (3), can be done either by generating a map on a line printer at 1:24,000 or smaller scale or by printing a table of the centroid locations of each water impoundment. The map is better for planning flight paths; the table, as a checklist on safety inspections. Finally, the process forwards a digital tape of new impoundment locations in tabular form to SC for the second subtask, updating the dam inventory.

Sections 4.3.1.1.1 - 4.3.1.1.5 discuss data, software, hardware, personnel, and output products of the new impoundment location subtask.

4.3.1.1.1 Input Data

Input data needed are the current year's LANDSAT CCT's from late spring or early summer for the entire state. The system should also retain last year's CCT's from approximately the same time of year. (For the first year of operation, the 1974 CCT's should be ordered, since that was the date of the most recent statewide dam inventory.) Since nine images cover the state, the first year data cost is $3600 and recurring annual costs are $1800, at current prices of $200 per CCT.

4.3.1.1.2 Software Required for New Impoundment Location

As mentioned, the system detects impoundments by registering and classifying LANDSAT CCT's. A set of programs available as a package normally combines software for both steps.

Because of water's unique spectral response, detection of water bodies is a simple classification problem. Nevertheless, in view of anticipated expanded future use, we consider only software packages with more general capabilities.

We investigated three software packages capable of dam location: LIMAP (28), the DAM package (29), and the ELLTAB (30) routines. Since the first is operational at Washington University, we were already familiar with its features. We made site visits to observe the operation of the latter two.

LIMAP is a derivative system of the LARSYS system (31), developed for NASA by Purdue University. Both systems use clustering and maximum likelihood classification, causing relatively high operational costs. We have acquired LIMAP and implemented it on the IBM 360/65 system at Washington University. In general, we have found practical implementation difficult, even in the tolerant academic environment of Washington University's computer center. We have had to make special arrangements to run the system due to excessive extended memory allocations. Under one approach, we required 3 x 10^7 bytes of disk storage while another, less efficient implementation calls for five tapes mounted simultaneously.

These practical difficulties do not bode well for successful implementation in a large, production-oriented state government computer center whose main concerns do not lie in the area of remote sensing classification. We have investigated the possibility of the state contracting with Purdue for implementation of LARSYS, but have rejected the approach as too costly in light of current state priorities (31).

The DAM (Detection and Mapping) package has been developed by NASA's Johnson Space Flight Center for implementation on a UNIVAC 1100 series system. DAM is used by Texas for both land use classification and surface water detection, and personnel are satisfied with its performance and ease of operation. DAM also is adapted from LARSYS, but with more provisions than LIMAP for ease of registration.

Despite the lack of availability of Univac systems in Missouri state government, we have investigated two alternatives for implementing DAM here: to adapt the system to one of the state's IBM systems, or to perform the annual update on a non-state owned system outside of state government, at least as a validation test. We have found that, due to extensive references to peculiar UNIVAC operating system features imbedded in the FORTRAN source code, to convert to an IBM environment would require over three programmer man-years (32).

The Defense Mapping Agency, headquartered locally in St. Louis, has assisted us in investigating implementation outside state government. It owns UNIVAC 1100 series computers and has acquired copies of the DAM system. Agency personnel have tested the system on Missouri data but report such difficulty in implementation that we reject this approach as well.

The Earth Resources Laboratory at Slidell, Louisiana has developed the ELLTAB table lookup system, which offers significant economic advantage over the others due to increased classification speed and smaller hardware requirements. The software applies maximum likelihood techniques to a training sample to determine the shape of the classification regions. Then the proper classification of each possible combination of four band spectral responses (33) is stored in main memory. The compact table storage used in ELLTAB requires only about 12,000 sixteen bit words of minicomputer memory.

Classification of the entire scene is a simple table lookup procedure, resulting in time reductions of several orders of magnitude compared to LARSYS (34). A second advantage is ELLTAB's transferability to various minicomputer hardware systems, allowing a trial period on a rental system before hardware purchase must be committed (30). This is an important feature since Missouri, like many states, is reluctant to purchase hardware and until full operational loads have been demonstrated.

In summary, of the three software packages investigated we find ELLTAB the only feasible one for Missouri.

Once the system identifies water impoundments in both the 1974 and current scenes, discovering the new water impoundments requires a change detection algorithm. Detection of change can be done manually by producing two classified images on mylar, overlaying them, and manually noting changes. However, to provide digitized inputs to SC, we recommend programming a change detection algorithm on the computer used for classification.

4.3.1.1.3 Hardware Required for New Impoundment Location

The choices of computer hardware and software are interdependent; the ELLTAB software system requires specific hardware. Table 4-2, taken from an ERL report (35), presents minimum and desired minicomputer support system specifications for ELLTAB. Total 1978 system prices remain in the range of $75,000 to $150,000.

Table 4-2

Hardware Requirements for Low-Cost
Data Analysis System (35)

Characteristic	Requirements	
	Minimum	Desired
Central processor unit with operator's console	Required	Required
Memory	16,000 16-bit words	64,000 16-bit words (dual port)
Tape drives (computer-compatible tape)	Two 7- or 9-track drives	Two 9-track drives, 3.05 m/sec (120 in/sec), 315 bytes/cm (800 btyes/in)
Disk (rotating memory device)	12,000,000 16-bit words	46,000,000 16-bit words
Line printer	Required	Required
Electrostatic printer	Not required	Required
Card reader	Required	Required
Floating-point hardware	Not required	Required
Microprogrammable writable control storage	Not required	Required
Operating executive system	Not required	Required
FORTRAN compiler	Required	Required
Approximate cost (1975 prices)	$75,000 to $80,000	$150,000

The hardware listed suffices for dam location. A highly desirable addition, however, is the image display system, which displays a portion of an image (512 x 512 pixels) on the cathode ray tube (CRT) of 58 cm (23") diagonal color television screen at a scale of approximately 1:43,000. The user can observe image classification and interact with the system using this device. Purchase cost of the image display system is about $45,000, including a necessary operator's console and channel interface (35). This brings the total hardware cost to the range of $120,000 - $200,000.

The total costs in Table 4-3 assume minicomputer use, but another option is to adapt the ELLTAB software to a larger state-owned mainframe, like EDP-C's IBM 370/148. We recommend against this approach for several reasons. Though ELLTAB is less demanding of system resources than LIMAP, its installation would also disrupt operations at the state computer center. The desired 4.6×10^7 bytes of mass storage (see Table 4-2) requires allocating a dedicated disk drive. The image processing system requires an additional hardware channel. Most important, the complex scheduling procedures necessary in large production oriented centers limit system accessibility.

The new impoundment location activity can realize a potential savings of $30,000 in state operations (see Chapter 3). Therefore it alone does not justify hardware purchase. However, the University of Missouri at Rolla has recently installed a VARIAN minicomputer system meeting the specifications of Table 4-2 and has implemented the ELLTAB classification system as its sole application. Though the systems serves university research and educational users first, the state can rent available time for approximately $50 per hour (see Chapter 5). Sufficient time will be available since both the state's and the University's initial use will be limited.

As both classes of use grow, the state must eventually decide either to acquire its own hardware or to find other sources. We anticipate this contingency later in the plan.

4.3.1.1.4 Personnel Required for New Impoundment Location

Implementing and operating computerized remote sensing classification systems requires the full-time services of one scientific computer programmer with knowledge and experience in FORTRAN programming, minicomputers and geographic referencing and coding systems.

There is a shortage of personnel possessing these computer skills within state government. The plan calls for hiring a person with the necessary scientific computer programming background. Since the programmer is not likely to have image processing and CGIS experience, generous project time estimates must be allowed for learning. Running ELLTAB and developing and coding the change detection algorithms will assist in learning by giving the programmer detailed technical familiarity with LANDSAT image data processing formats and procedures.

An additional personnel requirement arises from the needs for an hydrologist's advice and for ground truthing. We recommend that this role either be carried out by one hydrologist already employed by the state, or better, if more personnel are available, that it be divided among several state planners, geologists, engineers and surveyors chosen for familiarity with the geographic region of interest. The second approach maximizes exposure of state personnel to remote sensing techniques, gaining early user involvement.

4.3.1.1.5 New Impoundment Location Output

The dam location subtask provides annually a list of new impoundment locations by latitude and longitude for impoundments of more than five acres in surface area. This output has two uses. In its hardcopy (map or tabular) form, it is useful for planning inspection overflights. It can be printed in checklist form for collecting additional information at the site. In its computer-readable form, it provides an important link to the dam inventory/permit system subtask, since the LANDSAT observed impoundments file can be compared to the construction permit applications file to monitor compliance with the regulations.

4.3.1.1.6 New Impoundment Location: Summary

In summary, this subtask provides fundamental hardware, software, data sources and personnel skills for LANDSAT classification. In particular, it is a vehicle for on-the-job training of state employees in the use of LANDSAT classification systems. These skills are necessary inputs to the next application. Table 4-3 lists the hardware, software, data, and personnel requirements for this application.

4.3.1.2 Dam Inventory/Permit System

The second and third rows of Table 4-1 detail the procedures of the Dam Inventory and the Dam Permit System. Figure 4-6 illustrates this annual process. These procedures should be performed on the SC computer in Jefferson City to permit routine access to the information by DEQ and DPPD.

Though DNR has previously had only minimal scientific computer experience, the data processing required is of the kind normally performed by state agencies. A new development needed, however, is to provide for updating the dam inventory data base (see Chapter 3) from two sources, DGLS and DEQ, and allowing data base inquiry by DPPD. This development calls for the use of a conventional computerized data base management system (DBMS) at SC.

Table 4-3

Dam Location Requirements Summary

Data	Hardware	Software	Personnel
18 LANDSAT CCT's	Minicomputer system of Table 4-2: Disk storage: 12×10^6 bytes Main memory: 16 K bytes Display: Image display subsystem (optional) (total purchase price range $75,000 - $200,000)	ELLTAB classification system Change detection algorithm (to be coded in FORTRAN)	1 person year scientific programmer 1/6 person year control point identification hydrological advice

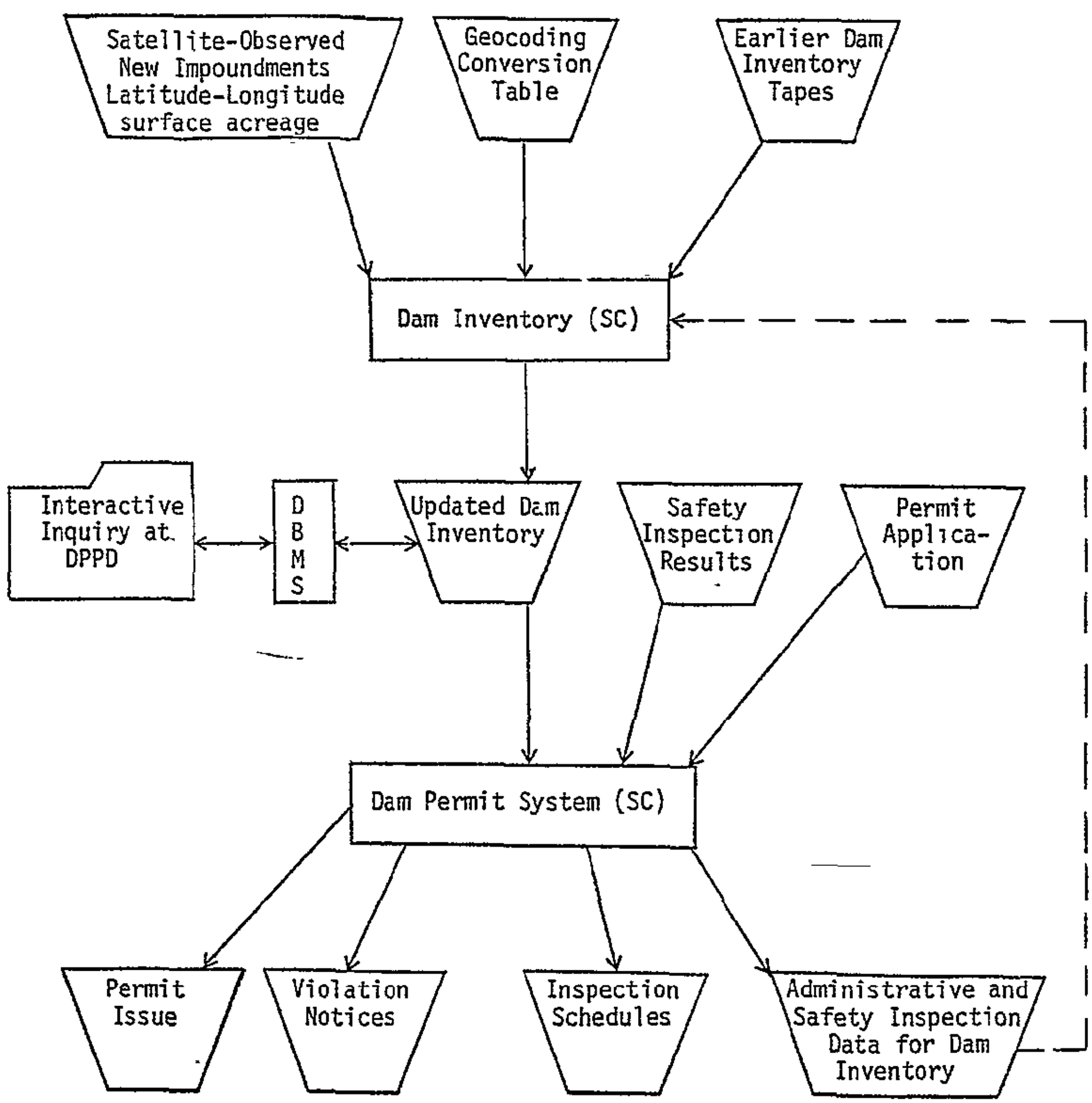

Figure 4-6

Dam Inventory/Permit System

The new impoundment subtask, described in the previous section, provides as output a LANDSAT-updated file containing the location of dams by latitude and longitude and impoundment surface area estimates. The dam inventory subtask requires additional information to update the dam inventory (see Table 3-1). To obtain this information, SC will convert coordinates from latitude-longitude to county, township, section, and range based on tables supplied by DGLS. Though collecting supplemental ownership, construction firm, and engineering data, and performing the safety inspections will be a major departmental effort, encoding this data into digital form at SC is a relatively small concern, amounting to only 10^5 characters of information.

The third dam safety subtask (see Table 4-1) is implementing a dam permitting system. It provides the major motivation for developing the DBMS and for updating and accessing the administrative and inspection information in the system. In view of the pending legislation and past institutional roles, it is likely that DEQ will have operational responsibility for the permit system.

4.3.1.2.1 Input Data for the Dam Inventory/Permit System

This section briefly discusses sources and formats of the categories of input data in Figure 4-6.

The new impoundment subtask provides a LANDSAT-updated file of dam location data. Latitude, longitude and surface acreage amount to 30 characters of data for each entry in this file. Administrative data, (name of dam, ownership, names of contractor, date of last inspection, etc.) derive from the dam construction permit application. The state estimates that about 200 new applications will occur annually with about 150 characters of data per application. The first year will require a more extensive effort to validate existing (1974) information and collect new information on the 600 or so impoundments that have been made since 1974.

Engineering characteristics, e.g. length and type of spillway, height of dam, and impoundment capacity, must be collected at permit application time, but may require a separate form to be filed by the engineering or construction firm. We estimate 50 characters per impoundment.

Safety inspection data are collected by engineers at DGLS at the time of inspection. Safety data to be collected include current condition of the dam, current condition of the spillway, degree of risk to property and persons. We estimate fewer than 100 characters of information. A five year reinspection cycle for existing dams and 200 new dams annually indicates 650 safety inspections annually.

4.3.1.2.2 Hardware for the Dam Inventory/Permit System.

Recall that we have assumed DNR (and hence SC) shares EDP-C's IBM 370/148. The size of this data base management application does not pose a critical hardware requirement on this system. Allowing for as many as 6000 dams and 400 characters of information recorded per dam, only 1.2 million bytes of disk storage are required. The file updating and retrieval application is compatible with other uses of EDP-C's system.

It is highly desirable that both DEQ and DPPD be able to access the file on-line through remote terminals. Though the terminals are not justified by this application alone, they may be installed to serve department-wide EDP needs.

4.3.1.2.3 Software for the Dam Inventory/Permit System

An integrated set of computer programs is necessary to implement the dam inventory/permit system; for example, programs to process permit applications, to notify of permit expirations, to update changes in ownership, and to detect unpermitted impoundments and other violations. All of these programs will access the same inventory files, and hence call for conventional data base management system (DBMS) techniques.

As the state's EDP-C office implements its computer system plans, one or more DBMS's are likely to be made available for other state uses, and the NRIS might share one at no addition cost. Thus, availability of a DBMS depends on policies to be established jointly by DNR and EDP-C. Several such DMBS's are available on the market, including IMS, TOTAL, and SYSTEM-2000, the one used by the Texas Natural Resources Information System (TNRIS) for all of its data files (36). All are available in IBM 370 versions suitable for use on the EPD-C computer (37). DBMS software typically costs about $10,000.

The chief goal of software design should be efficient permit system administration. Efficiency is best achieved by providing a high degree of DEQ and DPPD interaction with the DBMS through remote terminals, particularly the ability to peruse the file and select records according to specifications. Thus, it must be possible for the DEQ program administrator to type in the equivalent of the request:

> "Print all the impoundments of more than 10 acres in Polk, Dallas, Webster or Greene County, that are unpermitted and awaiting a safety inspection."

Such capability is invaluable in planning efficient inspection programs. Also, the experience to be gained by DNR planners and managers in using conventional data base management is an educational step toward integrating satellite systems to Missouri planning decisions.

The chief product of this task will be of the form of Table 3-1, the previous dam inventory. The software developed in 1974 and used to produce Table 3-1 is sketchily documented and difficult to use, according to DGLS. For this reason, and because software must be compatible with dam location file formats produced in the previous subtask, we recommend replacing the software developed in 1974 with a reporting system based on the selected DBMS and dam location program.

Compatibility between the LANDSAT-generated dam location tape and the SC DBMS also requires a coordinate conversion program. The dam location tape specifies locations by latitude and longitude, but the most useful form for permit administration is the public land survey system: township, section, and range (38). Several programs for the conversion are available at small cost (less than $100). These programs require as input a data file of Missouri survey coordinates. The State Land Surveyor's Office at DGLS in Rolla can prepare this widely applicable set of files, and SC Jefferson City can develop the conversion programs.

4.3.1.2.4 Personnel Requirements for the Dam Inventory/Permit System

Tasks for personnel are the detailed system design and the programming of the dam inventory/permit system depicted in Figure 4-6. The NRIS manager, whose general responsibilities are described in Chapter 5, can supervise system design. Programming the permit system requires skills in setting up and accessing data bases. These skills include COBOL programming experience, knowledge of and experience with modern DBMS techniques, and experience with programming and design of remote terminal applications. Further, it is important that personnel for this assignment be selected with an eye to the future. The individual should have the potential develop as a scientific programmer beyond his/her current knowledge of business and administrative systems, because future work calls for interactions between this employee and the image-processing effort at DGLS.

4.3.1.2.5 Dam Inventory/Permit System Output

The key outputs of this activity include weekly or monthly reports on dam permit administration, dam safety regulation compliance monitoring, and a surface water impoundment inventory. This computer compatible impoundment inventory will serve as input to the next application for estimating surface water capacity and supply.

4.3.1.2.6 Summary of Dam Inventory/Permit System Requirements

Table 4-4 summarizes the system requirements developed in subsections of Section 4.3.1.2. The dam inventory application provides the first use of interrogable data files by DNR. The experience gained by DPPD and DEQ personnel in this application provides necessary training for later uses of geographic information retrieval systems.

4.3.2 Groundwater Shortages Phase I

The state will respond to groundwater shortages by attempting to match supply with demand, as depicted in Figure 4-7. The figure identifies information needs in surface and groundwater supply and in agricultural demand. Some information on surface water supply is available from the impoundment inventory, described previously, but new surface water information needs for this task are for precipitation, stream flow, and reservoir level data. Much groundwater information resides in well logs, which are currently only in handwritten and pictorial form. Agricultural demand data are even less accessible. They do not now exist in any one place, and thus they must be inferred from land use maps and known irrigation practices.

Because the needed data sources will take time to develop, we plan responses to groundwater supply problems in two phases. Phase I is a statewide overview based on readily available data. Phase II achieves

Table 4-4

Dam Inventory/Permit System Requirements Summary

Data	Hardware	Software	Personnel
Dam locations			
Permit applications	Use of EDP-C IBM 370/148	DBMS	SC manager
Ownership			
Engineering characteristics Safety Inspection		Approx. six man months COBOL pro gramming effort	Business programmer/ analyst
Total on-line data storage requirements: 10^5 bytes		Co-ordinate conversion program	

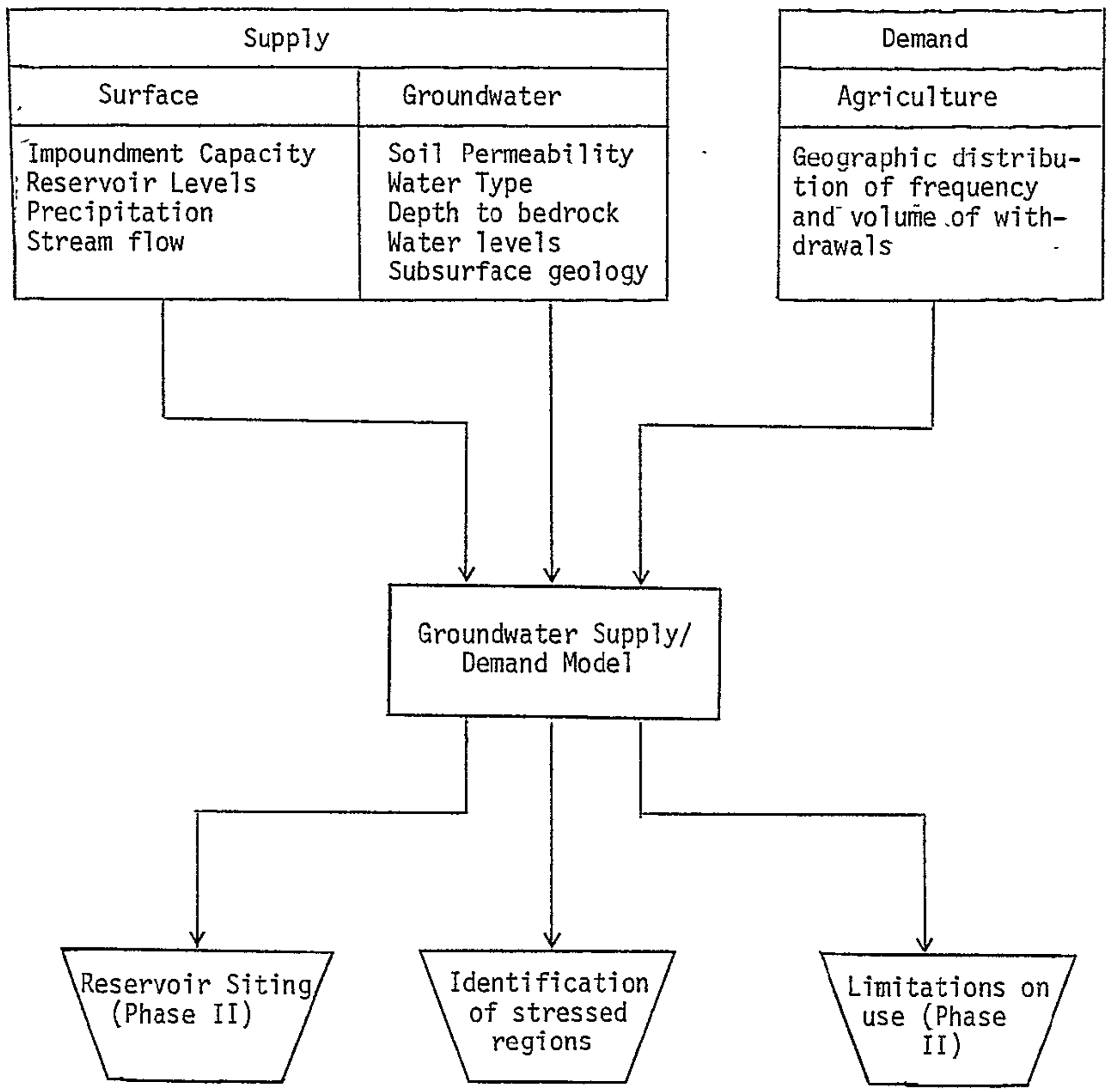

Figure 4-7

Groundwater Information System

higher specificity by converting the well logs to computer readable form and updating land use files with LANDSAT D-derived information. The state's response to groundwater supply shortages is likely to occur in these two phases.

4.3.2.1 Data for Phase I Groundwater Shortages

The surface supply data listed in Figure 4-7 are all available to the state. Impoundment capacity is an output of the dam inventory. Furthermore, stream flow and reservoir level data are collected by USGS-WRD personnel in a co-op program and made available to the state on digital computer tapes.* Precipitation data comes on computer tapes from the National Oceanographic and Atmospheric Administration (NOAA).

Most of the groundwater supply data listed in Figure 4-6 are derivable from the well logs. Phase II will use them as its main data source, but coding of the well logs should commence in Phase I. Well level data are collected regularly by DGLS from strip recorders and stored manually.**

Phase I can obtain some subsurface geology data while the well logs are being encoded; Figure 4-8 illustrates an approach. Three state-wide maps (39, 40, 41) covering bedrock topography, well yield, and water types have been developed from well log data collected through 1962 and published at the 1:250,000 scale. In addition, the Soil Conservation Service in 1977 produced a 1:500,000 scale state-wide soils association map (42). Though the bedrock topographical data are not totally current and the soils data are small scale, both files could be digitized for

*USGS has been investigating the use of data collection platforms that relay via LANDSAT to shorten time delays in this collection program (42).

**Groundwater levels are monitored regularly by a network of forty-five specially equipped wells DGLS has established across the state. Each site employs a Leopold A-35 recorder to record daily water levels.

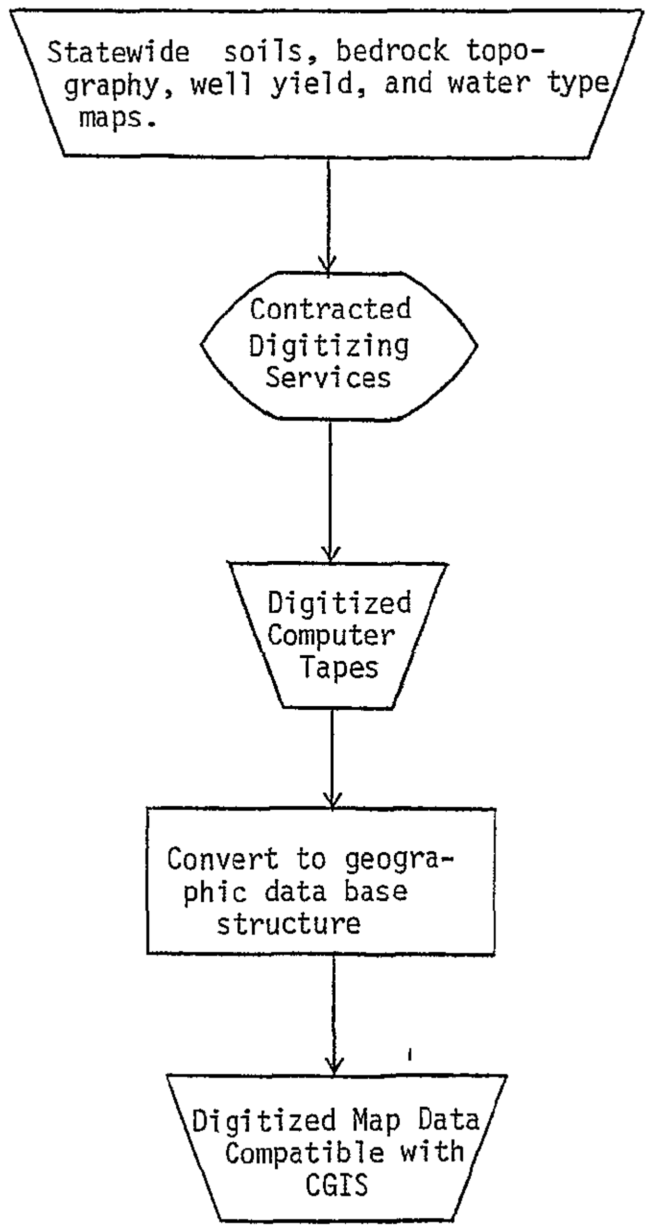

Figure 4-8

Phase I Groundwater Supply Digitization

Phase I's general assessment of geology relevant to groundwater. The bedrock topography, well yield, and water type data will be updated from the well logs in Phase II.

Phase I must develop new data sources to monitor agricultural demand. No comprehensive ground-based system exists to estimate irrigation demand. The ideal data source, direct observation of irrigation as it occurs, is beyond present capabilities.

Under the logic that farmers will irrigate to supplement normal rainfall, Phase I can infer irrigation demand as depicted in Figure 4-9. The Agronomy Extension Division of the University of Missouri has published recommended watering levels for various parts of the state as a function of crop type, crop development stage, and soil type (44), and farmers adhere to them. Soil types are available in the system from the map digitization mentioned above, but crop type and maturation data sources must be developed. Assuming for the moment that they have been, subtracting the amount of natural rainfall (already available in the CGIS) from these recommended watering levels gives an approximate total irrigation demand on both surface and groundwater supplies. Surface reservoirs data, also in the system, can then be used to infer the groundwater portion of total irrigation demand.

The key missing element in this process is a source of crop identification and maturation data. Two options exist during Phase I. The conventional source of such data is the planting survey conducted annually by county agents (45). An alternate source is LANDSAT, but we do not know whether Missouri crop types can be distinguished sufficiently accurately from this source. However, there is reason to think that it can be done. In Alabama, the difficult soy bean/cotton signature distinction has been achieved by the ERL system that will be available

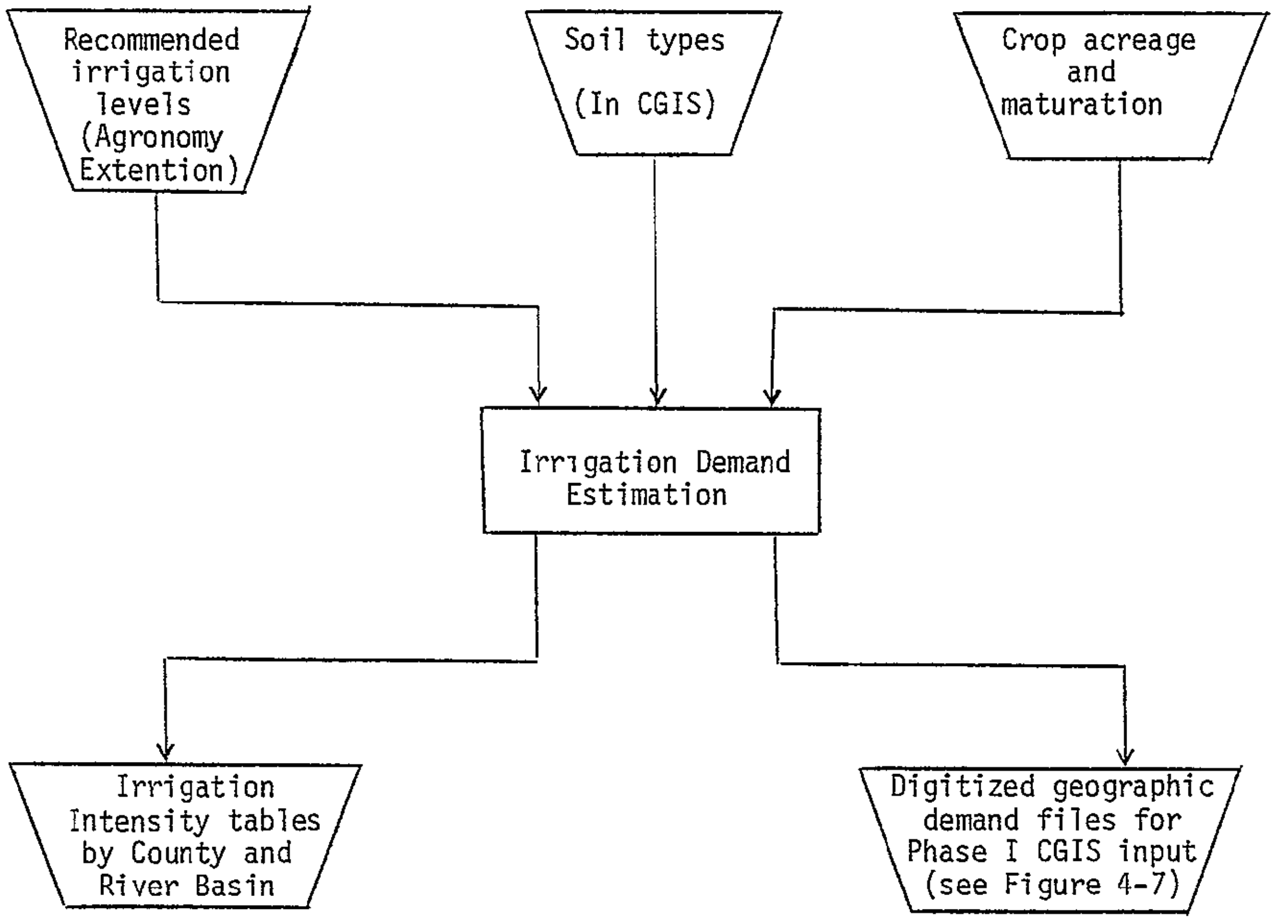

Figure 4-9

Irrigation Demand Subsystem

in Rolla (46). Because of the potential of the irrigation monitoring application, we recommend that NASA attempt to develop similar signature distinctions for Missouri crops, according to major differences in irrigation requirements. Success in this endeavor should accelerate operational LANDSAT use.

If efficient and reliable satellite techinques cannot be made operational in Phase I, then crop information must be obtained from the annual USDA survey of farmers' planting intentions. This approach has several shortcomings. Farmers often change their minds after responding to the survey. The information is not specific either with respect to time or geographic location. The survey indicates only the intention to plant a particular crop, and hence inferences on crop maturity are subject to wide variation. Geographically, the data indicate only the county and zip code of the proposed planting. Missing, for example, is the river basin within which the crop will be planted and on which irrigation demands will be made.

Even under this non-satellite based approach, a limited use of satellite data is helpful. LUDA land use data do not distinguish between row crop and pastureland. All agricultural uses are listed under category 21 "Agricultural Land" (47). Thus, even if Missouri crops cannot be delineated by LANDSAT, it could be helpful in locating cultivated lands. The crop type can then be inferred based on normal crop percentages in the various regions of the state.

In summary, LANDSAT could play a key role in the proposed system as one of the data sources for estimating irrigation demands.

4.3.2.2 Software for Phase I; Choice of a CGIS

Phase I requires automatically integrating these diverse data sources. Thus the need for Computerized Geographic Information System (CGIS) software first arises in this phase of the plan. In this section we choose an existing CGIS for implementation at SC and describe related software developments in Rolla. Here we summarize the considerations that figure in our choice of a CGIS; Appendix D and the references (48, 49) provide more detail.

Table 4-5 summarizes generally desirable features of a LANDSAT-based CGIS, and Table 4-6 lists practical state considerations (8, 50). We have reviewed a number of existing CGIS systems (see Appendix D) to find one that matches these two sets of requirements. Our choice is the Geographic Information Retrieval and Analysis (GIRAS) system supplied by USGS with the digitized LUDA data tapes (47, 51). Reference (51) describes the basic capabilities of both the present USGS system GIRAS I and the planned extension GIRAS II, now in the development stage. Table 4-7 (51) lists GIRAS I capabilities.

Comparing Tables 4-5 and 4-7 reveals a close match. The first five items in Table 4-7 are important during Phase I; items 6 through 9 are more advanced than Phase I requires. Items 1 through 3 provide the ability to produce maps in several scales and projections, thus permitting manual overlay of dissimilar map files. (Compare with Items 2, 3, and 6 of Table 4-5). The ability to convert from polygon to grid structure (Item 4, Table 4-7) is particularly useful in the interface with classified LANDSAT data. (Compare with Items 4 and 5 of Table 4-5). The ability to produce summary tables (Item 5, Table 4-7) is useful to state planners. (Compare with Item 1 of Table 4-5). OA has already contracted to produce

Table 4-5

Generally Desirable Features of A
LANDSAT Based CGIS

1. Structure and store the data in an economic and easily retrievable structure, usually a specific form of the two general classes grid or polygon;

2. Convert data from mapped to computer readable form and structure for entry into the data base;

3. Geographically reference position by several coordinate systems, including latitude-longitude, state plane coordinates, public land survey, universal transverse mercator grid, and convert between these coordinate systems.

4. Overlay two or more structured data files covering the same geographic area to produce a new data file in the same structure.

5. Convert a structured data file to another structure permitting overlay with files produced by non-compatible systems, e.g. polygon to rectangular grid.

6. Produce a map of any properly structured geographically referenced file, including the ability to change scale, projection and position from the stored data.

Table 4-6

Practical Missouri Concerns

1. Compatibility with state owned hardware;

2. Ease of software modification;

3. Compatibility with existing data sources;

4. The producer's plans for future software development and maintenance; and, finally;

5. Cost.

Table 4-7

Current GIRAS Capabilities (51)

1. Rotation, translation, and scaling of coordinates;

2. Conversion from geographic coordinates to specified map projections;

3. Restoration of original digitized map sheet from rectangular coordinate projection;

4. Conversion from polygon structure to grid cells of any specified size;

5. Production of area summary statistics from polygon or gridded data;

6. Geographic interpolation;

7. Filtering of nominal spatial data;

8. Feature generalization; and

9. Accuracy estimation of nominal maps.

summary Level II land use statistics from LUDA data by political subdivision and hydrologic basin.

GIRAS also satisfies the state considerations in Table 4-6. The system is a set of FORTRAN programs compatible with EDP-C's IBM 370/148, and, because GIRAS is extensively documented, modifications to the FORTRAN source can be made. Furthermore, the system is designed specifically to handle the digital LUDA data files, which form the bulk of the state's own computerized natural resources data. In addition, USGS's current development of GIRAS II, and the care being taken to insure a smooth transition (51), should satisfy the state's need for continuing development and maintenance. Finally, OA already has rights to use of GIRAS and so no additional software purchase is necessary.

To be able to mesh classified LANDSAT data with GIRAS at SC, the ELLTAB developed software at Rolla requires parallel software modifications. The Data Base Module (DBM) in the ERL software (35, page 18) provides an opportunity to link the GIRAS and ERL systems. DBM converts and stores classified LANDSAT data in a regular 400 meter square grid. The grid conversion capabilities (Item 4, Table 4-6) of GIRAS then permit compositing LANDSAT-derived crop acreages with the hydrologic basin data stored as part of LUDA at SC. We recommend that the feasibility of this important interface with LUDA structures be demonstrated in the NASA-USGS ASVT now being conducted in Louisiana (52).

4.3.2.3 Hardware for Phase I

The IBM 370/148 hardware to be available at the EDP-C will support GIRAS. If DNR acquires new hardware instead of using EDP-C's, it should consider GIRAS and GIRAS II specifications (51) in hardware design.

Appendix E, on digitization, recommends that digitizing the soils and bedrock topography maps be contracted to outside vendors. SC should control digitization quality and compatibility with its formats by careful contract monitoring. Cost of digitization will range between $1,000 and $6,000 per map sheet.

Digital plotters, which produce maps from computerized data, vary in speed, accuracy, and special features like multi-color plot capability. They range in price from $10,000 for slow-speed, low-resolution devices to over $200,000 for a high speed, four color device with precise cartographic accuracy (53). At least one off-line plotter of about one mil resolution must be available at Systems Central during Phase I. For $50,000, Calcomp offers a multi-color plotter system which should satisfy accuracy standards and is driven by an off-line tape drive (54).

Much of the task of estimating groundwater supply requires computerizing stream flow and reservoir level data maintained by DGLS. Since input is continuous, avoiding delay requires a hardware interface with Jefferson City. This interface can be achieved by connecting DGLS to SC by dedicated long-distance telephone lines at a cost of about $200. per month.

The equipment required at DGLS in Phase I depends on whether LANDSAT classification occurs there or continues at UMR. In any event, DGLS needs remote input, output, and interactive data manipulation capabilities for data transmissions to SC. If the level of LANDSAT classification activity during Phase I justifies the state's acquiring its own classification system rather than continued rental, this sytem will be more efficient if it is directly connected to SC.

Recall that during Phase I, LANDSAT is used at least to detect cultivated land in spring and early summer imagery. This use, in itself, should not overload the UMR system. On the other hand, if NASA can demonstrate sufficient LANDSAT-based crop identification for input to an irrigation demand model by 1980, then increased processing volume for this application would necessitate a state-owned system at DGLS.

4.3.2.4 Personnel for Phase I

Table 4-8 lists personnel requirements for Phase I. Because of the volume of new geographic applications, a scientific programmer has been added to the SC staff. The alternate levels of staffing at DGLS arise from our uncertainty of LANDSAT's utility in irrigation demand assessment.

The coders indicated in Table 4-8 work mainly on the well logs. With clear instruction, these persons need not be experienced either in geology or in computers. Students might be a good source of help.

4.3.2.5 Output of Phase I

The primary output from this application is mapped identification of areas of groundwater stress in Missouri due to overpumping for agricultural irrigation. Another output is an expanded surface water impoundment file, now doing double duty by providing, in addition to dam safety data, information on surface supply and levels. A third output is the early identification of crop acreages stored in the data base and producible in map or tabular form. This information will be useful in updating the state's land use files in later phases. It will also be valuable in itself as a source of agricultural data.

4.3.2.6 Summary of Phase I Groundwater Shortages Requirements

The system additions that this application makes include the first use of a CGIS (at SC) and related CGIS formatted output (at DGLS). Thus, both locations require additional skills. The SC programmers must implement GIRAS and learn to use the digital plotter. The DGLS programmer

Table 4-8

Phase I Groundwater Shortage Requirements Summary
1979-1980

Data	Software	Hardware	Personnel
Digitized soils and bedrock maps for input to GIRAS Spring LANDSAT CCT's NOAA precipitation data Stream flow and reservoir level data 10^6 bytes	GIRAS at SC (Available from USGS) DBM at Rolla (Available from NASA)	Digital Plotting System at SC; $50,000. Remote Batch Entry Equipment at DGLS $50,000 Rent UMR minicomputer	System Manager Business programmer at SC Scientific programmer at SC Scientific programmer at Rolla Coders at Rolla (2FTE)*
Optional: Early summer LANDSAT coverage		Optional: Minicomputer at Rolla $150,000	

*FTE = Full-Time Equivalents

must implement the DBM and convert classified LANDSAT data to DBM format. Table 4-8 summarizes the new system requirements developed in Sections 4.3.2.1 through 4.3.2.4.

4.3.3 Groundwater Shortages (Phase II)

Phase II begins when the problem of agricultural ground water shortages demands specific action programs. We assume that this event occurs in 1981. The information system's activity of Phase II builds on Phase I's hardware and software. Chapter 3 indicated that state action programs will fall into two classes: restrictions on withdrawals coupled with water development programs.

4.3.3.1 Data for Phase II

Restrictions on water use may include both voluntary use curtailment programs and, in more serious periods of shortage, permit requirements for groundwater withdrawals. The permit system must be based on more complete and current knowledge of the groundwater levels and safe yield water volumes than available from Phase I, requiring more extensive distribution of groundwater data collection stations in water-short areas, more detailed knowledge of the subsurface geology of the aquifer, and better knowledge of surface slope characteristics.

More detailed subsurface geology information for Missouri exists in the well logs at DGLS. Our plan calls for completing the coding of this data source, begun in Phase I, early in Phase II. An important additional benefit of computerizing the well log data is the ability to update bedrock topography and well yield maps with new data.

Phase II development programs, e.g. new reservoir construction, imply new, more detailed, and site specific information needs. Phase I's coarse 1:250,000 scale data do not suffice; instead scales of 1:24,000 or larger are in order. Though it is unreasonable to collect and process such detailed data regularly on a state-wide basis, the system must be able to handle this level of detail for specific sites.

A significant new source of timely and accurate surface land use data in Phase II is LANDSAT-D imagery. Our earlier studies (1) indicate that 1:24,000 Level II rural land use classification is achievable from LANDSAT D data because of its increased resolution. Additional sources of this detailed data include, for example, site drillings to determine underlying geology and soil samples.

4.3.3.2 Software for Phase II

Phase II requires software modifications both at SC and at DGLS. SC must adapt the CGIS to site specific analyses, and LANDSAT classification systems at DGLS must be revised to handle the formats of LANDSAT-D.

GIRAS I, designed originally for small-scale, state wide assessment, no longer fills SC needs. GIRAS I has several shortcomings in Phase II's site specific analyses. First, GIRAS I manipulates an entire 1:250,000 map sheet, covering approximately one-fifth of the state, at once. Secondly, GIRAS is a sequential, batch-oriented system, and it requires complete preparation of data files for an entire map sheet before analyzing smaller areas. Finally, GIRAS I converts its polygon-based files to grid form for compositing LUDA files and other data sources. (51)

GIRAS II, to be available by 1981, offers additional flexibility for Phase II applications. In particular, GIRAS II permits interactive update of fractions of a map sheet of data. Moreover, it permits polygon rather than grid compositing when data sources are compatible. Thus, GIRAS II allows specialized data files, covering limited study areas, to be collected and easily stored (51).

Parallel modifications to the ERL-developed software at DGLS are required One, to be done by NASA, is to allow classification of the increased volume of data resulting from the increased resolution and number of sensors of LANDSAT D. Another concerns ERL's DBM module. DBM provides gridded data for forty-acre cells for Phase I; this grid is too coarse for Phase II. We recommend that NASA design a new version, "DBM II," to encode polygons from classified LANDSAT imagery into a GIRAS-compatible polygon format to take advantage of GIRAS II polygon compositing features. The GIRAS structure, derived from the Dual Independent Map Encoding (DIME) format in which each arc is recorded only once, maintains a separate file to associate the arc with the two polygons it borders (54). Developing such a system could be made one of the objectives of the current USGS-NASA ASVT investigating the possibility of updating LUDA data with LANDSAT (3). Ten states besides Missouri have LUDA agreements with USGS, and so this system could encourage widespread future operational use of LANDSAT (52).

4.3.3.3 Hardware for Phase II

Exploiting the interactive features of GIRAS II requires installing at SC (DNR headquarters) a graphics display terminal, similar to the one to be used for LANDSAT classification at DGLS (35). We believe that the EPD-C computer system can develop to support this remote graphics capability; current plans are to install a second IBM 370/148 by 1980.

4.3.3.4 Personnel for Phase II

The system's original administrative programmer/analyst is now likely to be qualified to become a systems analyst at SC. Moreover, increased system usage requires another full-time administrative programmer at SC, partly to relieve the newly-appointed systems analyst of some duties and partly for new program requirements. Furthermore, adding one scientific programmer at DGLS, a possible requirement in Phase I, now becomes necessary because of increased LANDSAT-D data loads and system changes for interface with GIRAS II. The more experienced programmer takes on this activity, while the newly hired person takes on maintenance of Phase I systems and utility programs.

Increasing user interface at this point calls for the creation of a new position, an Applications Specialist, based at SC. This person, generally knowledgeable in the three areas of hydrologic engineering, state planning, and electronic data processing serves to interface between the user and the information system and also helps identify site-specific data sources. The Applications Specialist can open a branch of the Imagery Information Center in Jefferson City, as one way of serving users. Current ICNRI plans are to establish such a center in Rolla in view of the extensive data sources here.

4.3.3.5 Output of Phase II

The outputs of Phase II are detailed site specific information products for proposed water resource projects, depicting geographically the constraints and effects of the projects. The format is large scale (1:24,000) hard copy maps and interactive displays of geographic composite files.

4.3.3.6 Summary of Phase II Groundwater Shortages

This application has extended the skills developed in the grid-based interface of LANDSAT data with GIRAS data to handle polygon based interfaces of LANDSAT-D data with GIRAS II. The scientific programmers at Rolla are able to use the newly installed minicomputer without additional training in light of their earlier experience in renting UMR's system. However, special training in the use of the new interactive graphics system is required at SC. Major new software acquired are GIRAS II and the LANDSAT D modifications to the ERL system. Finally, the state must complete the purchase of a minicomputer for LANDSAT processing in this phase. Table 4-9 summarizes the Phase II plan elements of Sections 4.3.3.1 through 4.3.3.4.

4.3.4 Sporadic Municipal Water Shortages (1981-1982)

The danger of municipal water shortages demands precise information on intensity and geographic distribution of non-agricultural water use. Work on municipal supply is beginning now (1978) with a water use co-op study. This study is likely to develop models that call for new information inputs, such as Census of Population and Housing, Census of Manufacturers, and user demand pattern data. The plan envisions converting these data sources to the CGIS form.

4.3.4.1 Data Sources for Municipal Water Shortages

The 1980 Census of Population and Housing is available on magnetic tape by this time, as is Census of Manufacturer data referenced by location. The 1970 Census data, currently available on digital tapes, should also be on hand for trend analysis. As a supplement to these census tapes, current LUDA files provide the boundaries of census enumeration districts which are not available on the Census tapes. These are 1970 boundaries, however, and there are usually changes in these between enumerations.

We postulate water demand pattern data to be available by 1982. The coop study between Missouri and the USGS, mentioned above, has this goal (13). The data will describe the demands of various users parametrically by type and size, e.g., water demand for several sizes and types of power plants.

Table 4-9

Phase II Groundwater Shortage Requirements Summary

Data	Software	Hardware	Personnel
Spring and early summer LANDSAT coverage	GIRAS II DBM II LANDSAT-D classification system	Interactive graphics at SC Minicomputer at DGLS (if not already acquired in Phase I)	System manager System analyst Scientific programmer at SC Administrative programmer at SC 2 Scientific programmer at DGLS Part-time well log coders at DGLS (2FTE)* Applications specialist at SC

*FTE = Full-Time Equivalents

4.3.4.2 Software for Municipal Water Shortages

Differences between municipal and agricultural demand data require further software modifications. Agricultural demands on the ground water system are generally diffuse, occurring in low volume withdrawals over large geographic areas. On the other hand, municipal and industrial demands on surface water supply are high volume withdrawals at specific points. They significantly affect downstream users, but only marginally affect nearer neighbors on another stream. Therefore, the polygon-based storage of the CGIS has to be augmented during this period to handle point and line data as well. This modification will likely be made by USGS as part of its continuing development of GIRAS, but Missouri will have to adapt data handling procedures to the changes.

4.3.4.3 Hardware for Municipal Water Shortages

We anticipate no significant hardware additions in this period. However, some agencies, e.g. CC and OA, may wish to develop or expand their remote terminal capabilities. No major system constraints arise from these additions to the EDP-C system.

4.3.4.4 Personnel for Municipal Water Shortages

This application requires no SC programming staff additions. A reduction in DGLS staff occurs, since the backlog of well log data will have been encoded. Thus, only one half-time coder will be required to keep current.

4.3.4.5 Outputs of Municipal Water Shortages

The outputs of this application include both estimates of the geographic distribution of water demand and a map showing areas of likely shortages. The map is produced by comparing on the system demand estimates with the earlier developed surface and groundwater supply data.

4.3.4.6 Summary of Municipal Water Shortage Requirements

This application completes full development of LANDSAT processing and CGIS programming skills. Personnel begin to focus less on training themselves and more on educating users, especially regional planners from water short areas. The system now owns a full complement of hardware and software; point/line software for GIRAS and some census software complete the system. New data are Census and municipal water use parameters. Table 4-10 summarizes the requirements previously discussed.

4.3.5 Basin Modeling

The basic purpose of hydrologic basin modeling is to attempt to predict the hydrologic effect of basin modifications. The key steps are to develop mathematical models of both supply (i.e., basin input flow and precipitation) and demand and then to infer the watershed transfer function. In implementing a model, the hydrologist first develops a generalized approximation, based on minimal data and general assumptions, and then "fine tunes" it with experimental observations. The fine tuning is necessary because model parameters are subject to local variations with respect to time and place. A source of local variation lies, for example, in the moisture-bearing properties of the semi-humid Missouri soils -- their absorption capacity and duration of retention -- as compared to the arid soil types prevalent in western states. Current models do not provide specific inputs for these variables and so require adjustments (55).

By 1983, NRIS components are sufficiently developed to generate computerized data for input to hydrologic models. It is doubtful whether the models then available are of an operational form suitable for routine

Table 4-10

Municipal Shortages Requirements Summary

Data	Software	Hardware	Personnel
1980 Census of Population and Housing	Point/line software	no additional requirements	System manager
Census of Manufacturers	Census aggregation		System analyst
Municipal and industrial use parameters	Conversion of demographic and industrial data to water demands		Administrative programmer at SC
			Scientific programmer at SC
			Applications specialist at SC
			2 Scientific programmers at DGLS
			Well log coder (1/2 FTE)*

*FTE = Full-Time Equivalent.

use by state government. It is more likely that university scientists and private industry provide services on particular projects. Thus, we do not envision the state developing any additional computer hardware or software systems for this application. Instead, the state makes the water resources information system data available in digitized form.

Though at this early date there is no way to specify which data files must be available for basin modeling systems by 1983, we are able to indicate a range between minimal and comprehensive requirements. Table 4-11, derived from a recent NASA report (15), lists the minimal data requirements for modeling. The plan insures that these requirements are met.

Each additional source of hydrologic data offers some improvement in model accuracy or level of detail, but cost constraints prevent using all possible sources. Texas's TNRIS has listed its hydrologic data needs in priority order (26). On the basis of that report, modified by our own understanding of hydrologic data needs in Missouri, we list data files for the Missouri NRIS in Table 4-12 in order of priority.

Table 4-11

Minimum Supply Data Required
for Basin Modeling

Precipitation

Surface characteristics of watershed

Slope

Frictions

Stream patterns

Water impoundments

Current levels and capacities

Stream flow

Subsurface characteristics:

- Infiltration
- Soil moisture
- Depth of permeable layers

Table 4-12

Basin Modeling Data Entry Priorities

Priority 1:

- reservoir contents
- streamflow data
- land use inventory
- ground water level
- ground water pumpage
- ground water recharge

Priority 2:

- rainfall data
- rainfall forecast
- soil moisture
- well log data
- crop pattern and practices
- crop yield/water relationships data
- farming practices

Priority 3:

- ground water development
- natural inflow and outflow
- project operation data
- project location, size and capacity
- project purposes and service area

Priority 4:

- topography
- project cost data
- diversion data
- return flow quantity

Priority 5:

- socio-economic sector
  - a) land use
  - b) employment
  - c) population
  - d) economic data

Priority 6:

- formation characteristics
- foundation data
- transmissibility
- subsurface exploration data
- geologic maps
- desalting cost data

Priority 7:

- water quality:
  - a) streams and reservoirs
  - b) diversions
  - c) ground water quality
- biological water quality
- chemical water quality
- water pesticide content
- physical data on water
- water temperature

Priority 8:

- temperature
- humidity
- water rights information
- plant-soil moisture
- conservation inventory
- farming products price
- economic inputs-outputs
- sediment transport
- sediment deposition

Priority 9:

- solar radiation
- lake circulation patterns
- cloud cover
- high altitude weather
- bacteriological data on water
- radiological data

4.4 SYSTEM SCHEDULE AND ANNUAL BUDGETS: A SUMMARY

This section schedules and costs system components. The schedule summarizes actions recommended in the development plan. From the schedule, we develop a four-year budget plan. Both the schedule and the budgets correspond to Missouri's fiscal year which runs from July 1 through June 30. Thus the notation FY 79 (read "Fiscal Year 79") represents the time period July 1, 1978 through June 30, 1979. The budgets reflect only direct costs for new hardware, software, data, or personnel for which, in the absence of an NRIS, the state would not pay.

Table 4-13 schedules necessary data, software, hardware, and personnel acquisitions based on Section 4.3. Since the NRIS must respond and adapt to changing needs, timing of the plan elements is subject to wide variation. For example, DGLS will buy LANDSAT classification hardware only when either the annual rental payments to the University of Missouri at Rolla exceed the total projected annual costs of DGLS maintaining its own system, or the UMR system becomes overutilized. Further, decisions to purchase will also be based on factors not directly related to NRIS activities, e.g., remote entry of administrative data to the DNR Headquarters accounting system.

Nevertheless, for costing, we make judgments of purchase timing within application periods. Our approach differs for each of the components of software, data, personnel, and hardware. For example, no particular financial advantages derive from delaying software or data purchases. The major software packages bear minimal cost since they are either in the public domain or already available. Already-computerized data files also cost relatively little. Therefore, we schedule obtaining software and data early in their application phases.

Table 4-13: Summary of System Schedule and Cost Components

Application (Time Frame)	Personnel	Hardware	Software	Data
Dam Safety (FY 79)	System Manager Scientific Programmer Business Programmer Well log coders (1 FTE* year)	Rent UMR minicomputer Rent EDP-C mainframe	ELLTAB Conventional DBMS system Dam Inventory Dam Permits Administration	1974 & 1978 LANDSAT CCT's
Groundwater Phase I (FY 80)	System Manager Scientific Programmer Business Programer/Analyst Well log coders (2 FTE year)	Digital Plotting System at SC Remote Batch Terminal at DGLS	GIRAS DBM Irrigation Demand Assessment	1979 LANDSAT CCT's Digitized map data Precipitation data
Groundwater Phase II (FY 81)	System Manager System Analyst Business Programmer Scientific Programmers (3) Applications Specialist Well log coder (1 FTE year)	Interactive graphics terminal at SC Minicomputer at DGLS	GIRAS II LANDSAT-D DBM-II Classifier	1980 LANDSAT CCT's (2 coverages) Well logs coding
Municipal Shortages (FY 82)	System Manager System Analyst Business Programmer Scientific Programmers (3) Applications Specialist Well log coder (1/2 FTE year)	No additions	Census Systems at SC Point and line extensions of GIRAS	1981 LANDSAT CCT's 1980 Census data

*FTE = Full-Time Equivalent.

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Though personnel is a major expense item, system implementation depends most critically on the availability of skilled employees. Allowance must be made for these people to learn their jobs and formulate plans. Therefore, we schedule hiring early in the application cycles.

Hardware purchases, in the view of state decisionmakers, imply permanent commitments. Some flexibility can be gained by leasing rather than outright purchase, but leasing companies usually require lease periods of three years or more. The spectre of a quite visible, state-owned computer sitting idle is a major concern. Therefore, we have scheduled hardware acquisitions late in each application, relying on rented hardware and contracted services to get started.

Absent from the budgets are software acquisition costs. The three major packages needed - a conventional DBMS, ELLTAB, and GIRAS will probably all already be available within state government. The programming personnel requirements reflect the cost of implementing these packages as well as designing new application programs.

The plan of Section 4.3 contains several references to hardware purchase prices. To present a realistic picture of cost growth we have lease-amortized these purchase prices over five-year life times assuming 10% per annum charge on money. Thus, a $100,000 purchase price converts to annual debt service of $26,380.

Salary levels are estimated from the published salaries is state employees. Typical salaries of experienced programmers lie in the $14,000 range. The salary of the System Manager is estimated at $18,000 based on salary levels of comparably responsible positions. Coders, to be hired on a part-time basis, are assumed available at $4.00 per hour.

The budgets are formulated in constant 1978 dollars to permit year-by-year comparison of true system growth. Though salaries and most other expenses will move upward over time, accounting for inflation obfuscates true indication of the program levels.

Several adjustments are necessary to convert to standard state accounting procedures. For instance, EDP-C does not bill directly for computer time. However, since use of that time makes it unavailable for other purposes, we include its cost to reflect program commitment. On the other hand, we did not account for use of existing floor space by added hardware and personnel. Nor did we charge for data such as ground truth that would be gathered in the absence of the NRIS or for administrative overhead, since these do not reflect additional levels of commitment.

In summary, the budgets in Tables 4-14 through 4-16 represent a forecast of direct program costs to be weighed against the benefits of the improved hydrologic information systems described in Section 4.3. We think that the modest costs lie within state resources and are warranted by anticipated benefits such as that evaluated in Appendix G for the simplest system application, the dam inventory.

Table 4-14: FY 1979 Annual Budget
(Constant 1978 dollars)

Personnel:	47,400
System manager 12 months $18,000 2 programmers for 9 months $21,000 4 part-time (2 full-time) coders for 6 months $8,400	
Data:	
18 LANDSAT CCT's @ $200 ($3600)	3,600
Hardware:	10,200
UMR Rental 60 hours @ $50/per hr. ($3,000) EDP-C Rentals 2 hours/month ($7200)	
Miscellaneous:	
Travel to Rolla, printing services	10,000
FY 1979 TOTAL:	71,200

Table 4-15: FY 1980 Annual Budget
(Constant 1979 dollars)

Personnel:	76,800
System manager $18,000 3 programmers $42,000 Part time well log coders (2 full-time) $16,800	
Data:	16,800
Digitize 5 map sheets @ $3000/sheet ($15,000) State wide LANDSAT coverage ($1,800)	
Hardware:	49,200
SC Plotter 6 month lease based on $50,000 purchase $6,595 DGLS Terminal 12 month lease based on $50,000 purchase $13,190 Rental of UMR minicomputer (180 hours @ $50/hr. $9,000 EDP-C Rentals 5 hours/month = $18,000 Leased telephone line (Rolla- Jefferson City) ($2/mile per month = $2400/year)	
Miscellaneous:	10,000
FY 1980 TOTAL:	153,000

Table 4-16: FY 1981 and 1982 Annual Budget (Constant 1978 dollars)

Personnel:	
System Manager ($18,000) System Analyst ($16,000) 4 Programmers ($56,000) Applications Specialist ($15,000) Well log coder (1 full-time year) ($8,400)	113,000
Data:	3,600
Statewide LANDSAT coverage (Twice: Spring and mid-Summer)	
Hardware:	94,800
DGLS remote batch terminal lease $13,190 12 month minicomputer lease at DGLS (purchase price = $150,000 = $39,570 annually) EDP-C rental 8 hours/month = $28,800 Interactive graphics display for SC (purchase price = $50,000 = $13,190 annually)	
Miscellaneous:	10,000
FY 1981 and 1982 TOTAL:	221,000

CHAPTER 5

A MANAGEMENT PLAN FOR A MISSOURI NATURAL RESOURCES INFORMATION SYSTEM

This chapter presents a system management plan based on a consideration of NRIS institutional roles and policy issues. We begin by assessing, in a general way applicable to any state, the institutional environment in state governments to determine potential obstacles to the innovation proposed in our plan. We then make specific recommendations on how Missouri should initiate and manage its NRIS to avoid these obstacles. Finally, we discuss NRIS policy questions.

Section 5.1, on obstacles, is a prelude to our system management plan, put first so that the plan may be constructed to overcome the barriers identified. These barriers are significant in any state. Systems for the computer-aided processing and use of remotely sensed data can be criticized as being costly and technologically complex; requiring a long time span for planning, training, and implementation; and having low political visibility. In view of these criticisms, it was predictable that few states would be quick to make wide use of these systems in day-to-day government operations. Planners of such systems should be fully aware of these criticisms and ways to avoid them.

Section 5.2 suggests a practical way to initiate Missouri's NRIS development that accounts for the potential roadblocks identified in Section 5.1. Section 5.2 proposes plans for managing, staffing, funding, constructing, and supporting the system in its early stages. Our approach minimizes new purchasing or hiring during initial system development, recommending instead that the state use existing resources until initial system success convinces state decisionmakers of its merit.

Section 5.3 considers later system operation. We recommend ways to transfer the system from a pilot project to a stably-funded, in-house capability. The transfer requires interagency cooperation and a long-term mandate to operate.

Section 5.4 discusses policy issues generally applicable to a state NRIS: questions of privacy, access, law, funding, fees for service, and system leadership.

5.1 OBSTACLES TO OPERATIONAL USE OF LANDSAT AND CGIS'S IN STATE GOVERNMENTS

This section discusses obstacles that deter operational, machine-aided processing and use of satellite data in state agencies. This general discussion, applicable to most states, not only Missouri, is a review of impressions we have gained in working in states since 1974.

We classify these obstacles under three headings: institutional, economic, and technical. This ordering gives primary emphasis to the most critical barriers. Far and away the most critical issues are institutional. The economic and technical issues are readily addressible in a favorable institutional setting.

5.1.1 Institutional Barriers

Primary among the barriers to state-initiated processing and use of satellite data are those caused by the institutions, laws, politics, attitudes, and traditions that determine the course of state government. Agency spending procedures, the nature and influence of agency leadership, the management structure of state government, and employee pressures are powerful influences, difficult to change. Attitudes and traditions that deter innovation include lack of agency commitment to change, lack of clearly defined objectives, attitudes toward capital spending, and the gap between technologists and agency staff.

5.1.1.1 Agency Spending Procedures

State agency spending procedures may deter acceptance of innovations with high capital cost and low political priority. Agency personnel commonly do not have sole power to make spending decisions involving large budgetary revisions or significant reorganizations. Departmental budgets must survive a test in the political arena -- submission to the governor and then the legislature. For this reason, the political "punch" of a new initiative may be as important as its technical merit.

Even if the politicians look favorably on a new initiative, budgetary delays often prevent near-term changes in spending priorities. Many states in the midwest work on a two-year budget cycle; Illinois was putting together its FY 80 spending plan in January, 1978.

5.1.1.2 The Political Nature of Agency Management

Several hindrances arise from the manner in which top agency administrators are chosen. In many states, the most powerful agency managers are political appointees. Thus the influence of politics extends into the agencies. A choice between a program that will attract votes (e.g. by increasing employment) and one that will cut costs (e.g. by decreasing employment) is not clear-cut for agency leadership concerned both with costs and political pressures. The "bottom line" does not necessarily guide government decision-making.

Another disadvantage, from the technical innovator's point of view, of political appointees' holding top posts is in the outlook of the people chosen by this selection process. As a general rule, technologists do not occupy these most responsible posts. Instead, they are filled by persons with backgrounds in public life. This fact points out an obstacle to state use of new technology, because major innovations need powerful advocates. If wide use of a new technology is to occur, change is required in many facets of state government, and top administrators must be the prime movers. Needed are new incentives to innovate, training programs, inter- and intra-organizational cooperation, and new facilities. Agency leadership must actively seek these changes. However, in states, the technically-trained people who have the motivation may not have the power, and vice-versa.

In fact, motivation to innovate may be difficult to nurture in any state employee. In the absence of the profit motive, and because of the political nature of top posts, personal advancement in agencies does not depend totally on performance or innovativeness.

An additional effect of politics on agency management occurs after a change in state administration. The election of a new governor can mean a months-long period of relative inactivity while new agency heads are appointed and priorities are shifted. New programs are seldom initiated during this period, and old plans or agreements can be jeopardized.

5.1.1.3 Decentralized Structure and Lack of Clearly Defined Objectives

The decentralized or problem-oriented agency structure found in many state governments also forms a barrier. For example, agencies of limited scope like the "Land Survey" or the "Oil and Gas Board" may work on problems too specialized to justify large investments in new information systems by themselves. Cooperation is necessary, but difficult to achieve among agencies with diverse interests.

A related factor deterring agency commitment to satellite remote sensing is a lack of clearly defined objectives in some state agencies. Agency objectives might be stated loosely - for example, "increase public awareness of ..." As we noted, the well-defined "bottom line" motivation of industry is often unimportant.

5.1.1.4 Employee Pressures. Lack of Personnel with Relevant Skills

Employee-related pressures make significant spending on technological innovations difficult. Civil service constraints will keep personnel costs high despite potential cost savings of a new system, destroying some of the justification for its use. When reducing the number of jobs normally comes about only through attrition or reassignment, replacing workers with technology does not yield cost savings. This pressure grows as government workers' unions gain a substantial voice in determining policy.

There also exists a natural, human resistance to change inherent in the thinking of many agency staff members. Many factors contribute, for example, the need for additional training. Many agencies are experienced airphoto users. Retraining staff for the new roles implied by extensive use of satellite data is a major roadblock, because new resource management methods are needed to take full advantage of satellite capability. Fear also contributes, staff members fearing loss of jobs, and managers, the consequences of failed experiments.

Resistance to change is not the only psychological obstacle to technological innovation; another is the communications gap that nearly always exists between technologists who advocate the innovation and non-technologists who generally make the decisions. Agency users may not fully appreciate the technology, while at the same time, the technologists may lack an accurate understanding of users' needs and priorities.

An additional employee-related obstacle to using digital remote sensing systems in states is the lack of some relevant skills. The states we studied use computers, but primarily in administration. Skilled scientific programmers are at a premium. All the EODMS states have some experience in using satellite data, but not routinely. There is little planning for the kind of personnel development or training necessary to change this situation.

5.1.1.5 Delegating Innovation: The Role of the State University

These disincentives to innovation often result in the notion that the state university can fill the void and be assigned the responsibility for change. It has often been the case that a university has performed an interesting demonstration project. However, the universities are not closely tied to the routine activities of agencies. They have their own priorities that do not include repetitive processing of data on existing programs.

5.1.2 Economic Barriers: Marketing Problems and Costs

The preceding discussion of attitudes among agencies makes one thing clear: technology transfer in this field will be difficult. This subsection analyzes difficulties that are slowing development of a market for computer-aided processing and data management systems for satellite data in state agencies.

From the seller's point of view, the market is disaggregated. On the other hand, buyers are discouraged by poor selling strategies, high costs, and fear that they will be sold an obsolete system.

The first of these factors, the disaggregated market, has two aspects. First, the technology lacks standards. This lack of compatibility appears in hardware, software, and information products. For example, manufacturers of end-to-end processing systems (Bendix, GE, ESL, etc.) sell total packages, with few interchangeable components. The nonstandard technology raises costs and decreases marketability. The second aspect of the disaggregation is on the customer's side. Potential users of the technology often can not standardize procedures, and they find cooperation difficult. For example, land use maps used by urban planning agencies differ from those employed in monitoring water quality (1).

Manufacturers are proceeding cautiously as a result of this uncertainty in the market. Faced with a lack of clear, uniform interest from states, they naturally desire to focus their energies on the wealthier users with the greatest near-term profit potential. In addition, some processing system manufacturers are unwilling to make large investments in the technology until they can be sure of the extent of the federal role in information extraction.

Another problem that has hurt the market has been poor selling strategies. State personnel often see system advocates as pushing a technology where there is no perceived need. Perhaps this impression is caused by the "technology pushers'" lack of flexibility. The advocates must be able to match their products' capabilities with the users' real needs.

Some innovations have failed because the developers of the system did not appreciate the value of a commercial sales force. Developers may assume that because they know their system well, they can sell it better than a salesman. This assumption may not be true. Too often a developer's sales presentation gets involved in technical detail at the expense of emphasizing results.

Another marketing issue is the value of a convincing demonstration. Such a demonstration would provide an example of a use of high quality, compelling evidence of cost effectiveness, and proof that the system works in an actual agency setting. However, demonstrations which have depended on large infusions of federal funds are not necessarily convincing to a potential user who is without equivalent resources. Furthermore, although a convincing demonstration is necessary, it may not be sufficient. Systems do not sell after a successful field test unless the buyers, not just the testers, are convinced. Active experiences, not passive show and tell, are most effective.

A final marketing obstacle is high cost. The charges for satellite data tapes and for computer processing, often quoted as the total system cost, in reality are but a fraction of this cost. Other costs of significance are: software development and testing, peripheral hardware, combining supporting data with satellite data, and particularly, the gathering of supporting aircraft and ground truth data. These expenses must be anticipated to avoid unpleasant surprises.

5.1.3 Technical Obstacles.

Technical problems are the least critical of the obstacles we consider. Given sufficient motivation, these problems will likely be solved. Two topics are discussed here: processing system problems and satellite sensor inadequacies.

Processing system problems fall into three categories: hardware, software, and the man-machine interface. Hardware incompatibility, expense, and unreliability are problems in the minds of users. Digitizing is slow. Reliable, easy-to-use software is not fully developed. Georeferencing systems are not standardized.

The man-machine interface is an important problem, harder to solve than one that is strictly due to hardware or software because the user as well as the machine are involved. The more straightforward the communication process between man and machine, the happier the users will be. In addition, training costs and implementation time would be reduced with a better interface.

Sensor inadequacies have mainly to do with states' needs for moderately high resolution data. The LANDSAT-D satellite should go far in solving this problem. One of our EODMS reports estimates that less than 50% of remote-sensing performable agency needs can be met with current LANDSAT data, even in conjunction with some aircraft support and ground truth. On the other hand, 75-80% of these needs could be met with LANDSAT D's improved spectral and spatial resolution and aircraft support. (56)

5.2 GETTING STARTED IN MISSOURI

This section considers the first and perhaps most difficult steps in implementing our plan. The scope of this section is the first year or so of activity. During this time, work focusses on the first and simplest application, the dam safety program. The state makes initial arrangements for funding and administering the system and hires a system administrator, who works to build system capability and attempts to get political and user support. Near the end of the year, when the idea of an NRIS becomes valid in the minds of Missouri decision-makers, the transition to more permanent status begins.

5.2.1 A System Mandate

In the beginning, the system can grow in one agency - the Department of Natural Resources (DNR), which, because of its chartered responsibility, is a natural home for an NRIS. Furthermore, the responsibilities of two divisions under the agency's control, the Division of Geology and Land Survey (DGLS) and the Division of Environmental Quality (DEQ), include dam safety, the first application in our plan.

Therefore, we recommend that the DNR mandate and support the system's initial development. It can begin by hiring an administrator with the skills and motivation to do this development. The next section discusses this individual's role.

5.2.2 System Leadership

In the short range we recommend that DNR initiate NRIS activities by appointing a Special Assistant, reporting to the DNR Director, in charge of and concerned full-time with the information system. This person should have the ability to bridge the wide communication gap that exists among data providers, processors, and users in state government.

The individual must have skills in technical aspects of natural resource management to understand user needs, experience in public policy to interact with decisionmakers, and technical knowledge of digital information handling techniques to evaluate system alternatives. The individual should be qualified to serve later as a DNR Division Director.

Studies of the elements of success in state NRIS's (8, 57) find that a major factor is continuous, strong leadership by an individual who sees what needs to be done and does it. In other words, the system needs an entrepreneur -- an individual with the motiviation and a mandate to see the system through its birth and first year.

Such a job has many facets. We briefly list them in the next few paragraphs, and later discuss them in more detail. First, the individual will need control of DNR's budget for the NRIS. He/she should seek to augment DNR funds for development with grants from other state agencies or the federal government. In addition to acquiring short-term financial support, the Special Assistant should begin building long-term, political and user support.

Another major function will be system design and construction. In the near term, this means putting together a dam safety system with pieces available within the state or from private or university contractors, as described in Chapter 4. In the longer term, it means developing an in-house capability, by following our plan if it continues to match state priorities or updating it to reflect new concerns. The job requires an opportunist.

Hiring will also occupy the Assistant's time. Though initial staffing needs are few, the choices are critical. The first employees will strongly influence later system development.

The next sections present some of these concerns in more detail.

5.2.3 Budget Concerns

During development, the system needs a stable source of funding. We recommend that the DNR make system development a line item in its budget for the first years. The DNR can justify this allocation to the legislature by pointing to its chartered responsibility to manage natural resources.

To speed development, we recommend that the Special Assistant seek federal funding, perhaps as a NASA Applications Systems Verification Test (ASVT) for the system's initial stage. Proposing such an ASVT is justified because its focus would differ substantially from previous NASA demonstrations. In the past, NASA appears to have cautiously funded only "surface" applications of LANDSAT, in which all the relevant effects appear on the satellite image. The water resources information system, in contrast, handles data both visible and invisible from LANDSAT. To derive useful information, it must combine both types. Because this need for data combination appears in most practical uses for LANDSAT (1), we recommend that NASA concentrate more funds on applications of this type.

In contrast to our suggestion that the state seek federal development funds, it is our belief that operation funds should come from within the state as soon as possible. If the system is doing only what its users are paying for, it will be taken more seriously. In the development phase, most funding for operation can come from DNR; other agencies should, however, also be contributors.

This need for multiagency support has two implications concerning activities in the system development phase. First, the state should initiate a change which allows one state agency (or at least, the NRIS) to charge another a fee for service. With this change made, perhaps by an executive order from the Governor, the DNR could acquire Conservation Commission (CC) funds to support operations. In Missouri, the CC has a special funding arrangement, a state sales tax earmarked for its use. Morever, it is a natural system user, as we stated in Chapter 3 and 4, and it has interest and expertise in satellite remote sensing.

The second implication that the requirement for multiagency support has on early development activities is that the basis for long-term political and user support should develop during this period. The next section considers this issue.

5.2.4 The First Step in Developing Long-Term Political and User Support

We recommend involving users early. They can design and hand produce some example system information products -- maps, tables, or other displays of dam safety, groundwater, municipal supply, or basin modeling information. In this way, the user staffs in DGLS, DEQ, CC, and OA will have a say in the part of system design that concerns them most, and they will feel that the system is, at least in part, their creation.

Furthermore, if these example products are convincing and attractive, they can generate political support. By displaying them to the state legislature or to powerful lobbyist groups such as the farmers' lobbies, system advocates could emphasize concrete results, not theoretical promises. Our experience and literature on innovation (8 , 57) show this emphasis on results to be a key factor in successful system support.

To summarize, perhaps the best way of obtaining early user involvement coincides with the best method for acquiring political support. The next section considers ways to stimulate the interagency cooperation needed to implement our suggestion.

5.2.5 Obtaining Interagency Cooperation

A valuable advisory body in obtaining interagency cooperation is Missouri's Interdepartmental Council on Natural Resources Information (ICNRI). The Council, staffed by representatives of all state agencies concerned with natural resources, can publicize the effort, advise the Special Assistant, recommend cooperative efforts among agencies, and identify needed resources in the state. It has put much thought into the design of a Missouri NRIS; it initially recommended that our system plan focus on water resources. Therefore, it should be most willing to continue to assist in NRIS development.

Despite the Council's capabilities, we have recommended that DNR and not ICNRI have administrative responsibility for the NRIS. This recommendation, supported by Council Members (58), is because ICNRI has no operating budget.

In addition to using ICNRI, another means of acquiring multiagency support can be to develop formal, interagency pilot projects. These cooperative programs could further develop plans for the four system applications recommended in Chapter 3 and produce the first sample products mentioned in the previous subsection.

5.2.6 First Steps in Building and Operating the System

This section considers how to put together the first pieces of the system and get it running. We recommend that the state exploit current capabilities of state institutions and private contractors. This suggestion derives from our belief that, until the system acquires widespread user and political support, it should minimize new investment in system components.

Below, we discuss specific system functions for which current state or contractor capabilities can be employed: LANDSAT image processing, CGIS development, and digitization. We then briefly discuss the role of a technical advisory committee.

5.2.6.1 Initial Remote Sensing Data Processing

The plan calls for early increasing use of remotely sensed data. Table 4-2 of Chapter 4 describes the necessary hardware. A system can be rented for about $50 per hour from the Mining Department of the University of Missouri at Rolla, which uses one for research and education. Dr. David Barr, director of the system, has indicated that it can be rented by the state government when it is not being used by the school. The system will be useful in getting started until increased workloads force the state to buy one of its own.

5.2.6.2 Computerized Geographic Information System (CGIS) Software

Our recommended CGIS, GIRAS, is supplied as part of the LUDA system. Missouri's Office of Administration (OA) originally purchased the system from USGS and is responsible for its implementation. The Public Affairs Information Service (PAIS) of the University of Missouri at Columbia (UMC) has been contracted by OA to produce land use statistics based on the digitized data. This work will be done at the University of Missouri at Columbia's (UMC) IBM 370/155 system.

This effort by PAIS will enable their staff to become familiar with the GIRAS system. There is sufficient compatibility between the UMC and the Missouri Office of Electronic Data Processing Centralization (EDP-C) computer systems to permit the eventual transfer of GIRAS to a state system. We recommend therefore that the PAIS staff at UMC be contracted to implement

GIRAS on the state-owned EDP-C system in 1979, after they have implemented it on the UMC computer.

5.2.6.3 Digitization

The state can choose among several capabilities for the map digitization required in the plan. Outside vendors provide a range of services (52). Another possibility is the Department of Bioengineering at UMC. They have digitized land use/soil association maps developed from photointerpretations of LANDSAT imagery.

5.2.6.4 Technical Advisory Resources

We recommend the formation of a technical advisory committee to NRIS staff of persons experienced in computerized information processing. A consistent, continuously available source of advice is particularly important during implementation.

5.2.7 Hiring and Training

Because we believe that in-house capabilities should develop slowly during the first year, we recommend that initial staffing be kept to a minimum. Two professional positions (in addition to the Special Assistant) and a number of part time or nonprofessional ones do, however, appear merited.

One professional person, a scientific programmer/analyst, should be assigned responsibility for the LANDSAT data processing and data base management activities in the dam safety application. Ideally, the programmer will have had image processing experience. If not, he/she should be a skilled scientific programmer who can quickly learn the necessary techniques.

In addition to developing the dam safety application, the programmer/analyst should also design a data base structure and coding scheme for the well log data. Although the data are not needed until the project's second phase, coding should begin early. Part-time coders (students) could begin the task as soon as the digital well log data format is designed.

The second professional post is for an administratively oriented programmer to develop the programs necessary for administration of the dam permitting system. This position calls for familiarity with state operations and EDP systems. Several qualified persons are already employed by other agencies of state government, and so the search should begin among current state EDP specialists.

An important part-time role is for an application specialist, who should be a hydrologist familiar with the procedures, priorities, and needs in Missouri's water management programs, especially the dam safety application. The person * most likely is already a DNR employee, so a partial reassignment, not a new hiring is required. The applications specialist can serve as the direct communications link with users. He/she can work with them from the outset, designing the system products and producing examples, assessing special needs, and building enthusiasm. The applications specialist can also consult with the programmer/analyst and Special Assistant to work toward a system that is useful, attractive, and technically feasible.

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*As Chapter 4 notes, this post could be held either by one person or jointly by a number of DNR employees.

5.3 LONGER RANGE INSTITUTIONAL ROLES IN A MISSOURI NRIS

Missouri's state agencies, its universities, and the private sector comprise unique resources. Missouri's DNR owns voluminous files of information on natural resources and employs scientists with the skills to interpret and update it. The Office of Administration (OA) coordinates the state's computer system, owns the LUDA software, and has primary responsibility for long-range, statewide planning. The Conservation Commission (CC), DNR, and the universities have valuable skills in remote sensing or computerized geographic information systems. Universities perform well at education and research. Private business can supply valuable data gathering and interpretation services.

The Missouri NRIS should tap these valuable resources. Each institution's unique skills and information files should contribute to make the system workable. Moreover, the broader the involvement in developing and operating the system, the more likely it is that the system will be broadly used.

This section recommends longer-term roles in the system for state institutions with resources to contribute. Its scope is the three or four years after the first year described in Section 5.2. During this time, the system evolves from a pilot project to an integral part of state government, perhaps a Division of DNR. The Special Assistant's job changes to DNR Information Division Director. Funding is no longer in block grants for implementation; it now takes the form of monies legislatively mandated for specific projects, or fees for service from other agencies. Branches of the system form in DNR, OA, and CC offices in Columbia, Rolla, and Jefferson City. The system incorporates LUDA activity and the GIRAS software. Near the end of the period, in the fifth year of operation, the system begins to expand from a single resource (water) focus to a multiresource NRIS serving other key state applications.

This section considers issues that will arise during this period of activity: questions of operational responsibility, administrative direction, funding, control of data quality, data sources and users, component location, relation with other state information files and systems, and key personnel.

5.3.1 Funding Sources

In contrast to the block grant funding of the initiation period, longer-term NRIS funding should be by individual project, so the system's income derives from the services it performs. NRIS funding for a project is justified if the system is either the least costly, or the only feasible, alternative.

Mechanisms for allocating funding differ depending on whether the project is legislatively mandated or requested by an agency. Fiscal notes accompanying legislation provide for project costs, while requesting agencies can pay from existing project funds, dividing costs among participant agencies. We believe that the fee for service plan proposed in Section 5.2 facilitates these arrangements.

We anticipate that the four key applications of the NRIS can be funded by legislation that either already exists or is likely. The proposed Dam Safety Act may fund the dam inventory. Probable new legislation requiring water use permits should pay for the groundwater and municipal supply studies. Finally, Missouri may legislate a Missouri River Basin modeling system if the other basin states do.

5.3.2 Operational Responsibility and Administration

The designation of responsibility for NRIS planning and policy development is fundamental in the plan. Key considerations include agency statutory responsibilities, jurisdictions, and level of involvement in natural resource related data.

As a first step in guaranteeing the long-term viability of the NRIS, system advocates should seek a long-term mandate to operate from the state legislature. This goal requires a results-oriented presentation to the legislators. We recommend emphasizing initial successes in the dam safety program and displaying the sample information products suggested in Section 5.2.

The next question is which Department should permanently house the "Systems Central" (SC) of the Modified Linked Network of Chapter 4. We recommend that the DNR, which will have developed the system during its first year, also be its permanent home. The general consensus among the members of ICNRI is that the DNR should have this responsibility. Strong involvement would be required from the other departments, however, especially OA and CC.

Within DNR, we recommend that the SC should be a separate administrative entity in Jefferson City, reporting to the Department Director. This way it can provide an equal level of service to all Divisions of DNR. Furthermore, the history of DNR suggests that other Department and outside users will also be well-served by this administrative structure.

Assigning responsibility for other NRIS elements poses a dilemma complicated by the issue of physical location. The data to be computerized, the ground truth information, and the discipline specialists reside primarily at DGLS in Rolla, while the majority of planners who will benefit from LANDSAT are in Jefferson City. We recommend housing the planning portion of the CGIS in DNR headquarters at Jefferson City, placing the technical data input function at DGLS at Rolla, and providing communication between the two.

Recall from Chapter 4 that a provision is being made for DNR, which currently has no computer system, to obtain one. The DNR is developing a data processing plan to factor into the OA Office of EDP Centralization's state plan. We do not yet know whether DNR will buy its own hardware or use the services of one of the state's computer centers. It is likely, however, that DNR will be assigned to an IBM 370/148 at EDP-C, and our plan makes that assumption. The plan should be easy to modify if DNR acquires its own hardware (see Chapter 4).

Because of the key role that the NRIS will play in the interactions between the several Divisions of DNR, we expect (and assume from here on) that it will become a separate Division. This change requires legislative authorization. Thes best structure can be defined administratively and legislatively after the system's worth has been proven.

5.3.3 System Leadership

The NRIS's gradual move from developmental to operational status during this period implies attendant changes in the functions of its leadership. When the NRIS becomes a DNR Division, the leader's title changes from Special Assistant to Division Director. As the funding base evolves from block grants to project-by-project funding, the Director's fund raising activities change accordingly. Furthermore, increasingly strong interaction with information banks and users in other DNR divisions and outside require administrative attention, as does expanding the system's facilities and capabilities.

Funding system operation project-by-project will be the leader's key challenge. As stated earlier, we recommend this funding policy because it justifies the system to the state by making it apparent that it is supporting itself by services it provides, and because fees-for-service gain access to plentiful CC funds earmarked for resource management.

The leader's tasks will be to continue to assist in gaining approval for the fee-for-service concept, if it has not already been approved, and to act as NRIS advocate, or "salesperson," with planners of projects in which the system can play a role.

The "sales" activity will seek to fund NRIS operation from legislatively mandated or existing project funds. Achieving this goal will entail: (1) assisting in drafting relevant new natural resources legislation (e.g. for water permit systems or basin modeling) to insure that the bills allocate funds for the NRIS; (2) gaining support of managers of key programs of interest to the NRIS; (3) working with other DNR directors to define the system's role in existing Department projects, such as dam safety; and (4) gaining the cooperation of other Missouri Departments.

Expanding the NRIS physically and enhancing its capabilities will also occupy the leader's time. The work essentially entails following Chapter 4's plan for developing system branches in Jefferson City, Rolla, and Columbia; acquiring new hardware, software, and staff as work demands; and attacking the three remaining key water resources management problems. The NRIS Director's responsibility is to plan for coordinating facility and capability expansion carefully enough so that resources are available when needed but do not lie idle.

Another new task for the Director in this period will be to begin a system to insure data quality and integrity. Obsolete or error-filled data has killed many previous NRIS's (57). Error checking and timely updating avoid these problems.

One more activity which will occur at the DNR Department Director level, but with the NRIS Director's involvement, is coordinating with the LUDA program. The next section discusses this concern.

5.3.4 Coordinating LANDSAT Data and the Missouri NRIS with LUDA

Our plan raises an issue for resolution between the DNR and the OA -- responsibility for the LUDA program. Because the geographic distribution of land use is significant information for the development of a hydrologic demand model, DNR will find the LUDA data to be of value in its hydrologic programs. Moreover, the capabilities of the GIRAS software and its planned extension to GIRAS II (51) will be of significant help in the analysis and interface of LANDSAT data with other forms of spatially-referenced natural resource data. We recommend that the responsibility for update and maintenance of the LUDA system be transferred from OA to DNR.

To put this question into a realistic perspective, DNR has not yet indicated much interest either in the LUDA data itself or in the GIRAS software supplied with the data. In particular, DGLS expresses serious reservations about the 1:250,000 scale of the data, indicating that the detail of the 1:24,000 scale is needed for most existing DGLS work. We expect that as the value of using a hydrologic modeling system for planning becomes more apparent, this view should change, at least on the part of DNR's Divisions of Planning and Policy Development and of Environmental Quality. LUDA Data, updated by LANDSAT, should prove valuable for planning water use, specifically in providing more accurate estimates of demand as a function of prevalent basin land-use.

5.4 POLICY ISSUES IN SYSTEM DEVELOPMENT

Significant questions of policy are sure to arise before and during the life of the NRIS. For completeness in this report, this section lists and briefly discusses some questions that we foresee. We are brief both because extensive work on the topic lies beyond the project's scope, and because high quality work on state NRIS policy already exists. Of special note are the reports by Guinn and Kennedy (57) and Power (8). These two documents are exceptionally readable discussions of the wide range of issues that influence system success.

5.4.1 Should the State Develop a NRIS?

This decision must be made by the Governor and the Legislature. This report, although written for NASA, provides much information on which this decision can be based. It identifies potential benefits: cost savings on dam safety (see Appendix G) and new applications made feasible. It highlights water resources applications that are, or are likely to become, central to the needs of the state. It assesses funds, personnel, equipment, and training requirements; identifies obstacles to be overcome; and suggests a system management plan to overcome them.

5.4.2 Should the Federal Government Play a Role in System Development?

Section 5.1 listed the barriers that slow federally-initiated, LANDSAT and CGIS technology transfer to states. In considering these imposing obstacles, the question that comes to mind is: if the states are not ready, why bother with them? Or, in other words, why not focus on the wealthier, technically more competent users - e.g. large industry, federal agencies, and a few wealthy states - and let the rest of the potential users either catch up later or be ignored?

So far, the federal government -- NASA in particular -- has given only limited assistance in developing state information systems. NASA involvement has generally been limited to assisting with the LANDSAT-based components of the system, chiefly by funding demonstration projects that install LANDSAT capability in states. This approach is effective, as far as it goes. However, in general it fails to inspire widespread use of LANDSAT data in day-to-day state government operations. This failure, we believe, is because the states are unable to combine LANDSAT data conveniently with related information from other sources. Assisting in developing a LANDSAT-based NRIS can solve this problem, but NASA has shown reluctance (7) to carry out this step beyond the planning stage.

There are strong arguments in favor of the federal government's changing its approach to benefit states more directly. State and local agencies face a growing range of federal mandates to gather and use natural resources and related data. LANDSAT technology should be used to help where it can. Furthermore, the federal government needs to point to an expanding, enthusiastic user base to justify its growing expenditures on satellite data systems. By making information from satellites more readily accessible to states, not only state agencies benefit but also less well-financed users: small industry, interest groups, and private citizens. The user base for information derived from digital data could expand from the present small coterie of computer owners and experts to more nearly resemble the one for USGS topographic maps.

Such a change would more nearly follow stated federal philosophy. In legislation proposed before the Congress in 1977, federal planners attempted to map out a course of development for an operational LANDSAT system. Authors and witnesses agreed on the necessity for providing "equal ... access to products ... at reasonable cost." (59) But equal access to raw data is not equal access to information. Unless the states are able to make use of the information at reasonable cost, the intent of the proposed legislation will be thwarted. To provide well-financed operations, e.g. oil companies, utilities, etc., with data that they can afford to transform into useful information, while not supplying the regulatory agencies and citizen group intervenors with similar information, further upsets the balance of power among these groups.

5.4.3 How Can Access to the System be Enhanced? What Are The Risks to Privacy?

These important questions are the two sides in a tangled legal web. Here we summarize our view, admittedly that of legal laymen.

Safeguards must be built into the system to guarantee that data on persons is released only to authorized users. This limitation is justified under the law that circumscribes access to information on personal matters that could, if made public, constitute an infringement on an individual's right to privacy. Furthermore, the Conservation Commission has expressed the concern that data in raw form may require interpretation to be meaningfully used.

On the other side of the coin is the question of easing access to the data on which public decisions are based, a key justification for an NRIS. The NRIS permits data from several agencies to be brought to bear in solving a resource management problem. Moreover, it permits agencies and the public to examine and comment upon the data at realistic expense. To what degree this openness is to be permitted is a key policy question.

5.4.4 How Should the Law Be Taken into Account in System Design?

State government decisions on managing resources or allocating the use of land will be controversial. They may cause disputes that lead to court cases. The more central the NRIS becomes in assisting in these decisions, the more likely it is to be involved in such a dispute.

Two key issues are relevant (57): the quality of the data in the system and how those data are used to make decisions. The data should be gathered, processed, and otherwise handled by persons the court considers to be experts. If sometime in their useful life, the data are handled by non-experts, decisions based on the data may be legally invalid. Furthermore, human experts, not the system, should make those decisions. It is possible to program a CGIS to weigh various factors to identify "optimum" locations for a given land use. However, a computer program can not be punished for a careless decision. The law wants people, not machines, to make decisions. The issues discussed above and others (see (57)) point out the importance of having legal advice on the system design. The attorney should have the experience and the resources necessary to give careful consideration to these potential problems.

5.4.5 Who Should Pay for the System?

Questions of payment were raised earlier in the report; we include the issue here for completeness. We recommend that block grants of state funds and, if they are available, federal funds, be used to pay for system development. Operation of the system, in contrast, should in our opinion be funded as much as possible as payment for the services that the system provides. This funding method apparently requires that one state agency be allowed to charge another for services, a new procedure in Missouri.

If full operating cost recovery is not initially possible in this way, we recommend that the federal government consider alloting an operating subsidy that decreases over time. The subsidy can be justified because the system is new and thus a research activity, or because it stores and manipulates data useful in carrying out federally mandated resource management programs.

5.4.6 What Unintended Side Effects May Follow From the System and How Can They Be Managed?

As it becomes more important in the state, the NRIS will affect existing relationships both within and outside government. Some of these effects may be unintended and unpleasant. For example, it could lead to increased professionalism of decision-makers or further centralization of decision making, reducing the power and access of ordinary citizens and citizen's groups. Furthermore, it may threaten privacy or lead to other legal problems, as we have noted. We recommend that an attempt be made systematically to identify such impacts and ways to ameliorate them in the planning stages.

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APPENDIX A

STATEMENTS OF GOVERNOR TEASDALE AND MISSOURI OFFICIALS ON SARSDM PROJECT GOALS AND OBJECTIVES

EXECUTIVE OFFICE
STATE OF MISSOURI
JEFFERSON CITY

JOSEPH P. TEASDALE
GOVERNOR

November 17, 1977

Dr. Robert Frosch
Administrator, NASA
Washington, D.C. 20546

Dear Dr. Frosch:

In recent months a team from Washington University, under contract with your Marshall Space Flight Center, has been working with the State of Missouri to identify key natural resource problems and to plan an information system to address them. This project has brought to my attention the benefits of NASA's Earth Resource programs and its potential as an aid to state governments in solving resource problems. The State of Missouri certainly appreciates the work and effort NASA has put forth.

Presently, Missouri is facing many water related problems. It is highly probable that the ground water of half the state may be salinated due to the withdrawal of ground water at higher rates than the recharge level. Others include supply to our metropolitan areas, consumption by power plants, and the unmonitored building of dams. Beyond these questions within our state, we see difficulties in coordinating water use throughout the multi-state Missouri River Basin.

The Washington University study team addressed these problems and stressed the use of remotely sensed data to aid in their resolutions. While we are aware remotely sensed data can aid us in the resolution of these water problems, it is apparent that in and of itself, this data is not sufficient. Remote sensing data needs to be integrated with locally generated information to be useful. Consequently, I have placed a high priority on the development of a statewide natural resource information system. Further, I introduced a resolution to the Missouri River Basin Commission for the development of an information system to provide for the interchange of water quality data among states.

The Washington University Plan addresses these problems by concentrating on water related information and making them the first priority in an information system. I have, therefore, already taken steps to insure that the information system recommendations of the Washington University team will be given full consideration. I have asked Ms. Carolyn Ashford, Director of the Department of Natural Resources, to coordinate their activities with the total natural resource planning activity in Missouri. At first, our natural resource information system will include only state generated data, later it may include remote sensing information. With help from Washington University, we could include remote sensing data earlier.

Obviously, we are anxious to solve these water problems. Your help so far has been appreciated. I have always supported the adaptation of space program activities to everyday use. It is a pleasure to add this project to the many benefits we have already received from past missions into space.

Sincerely yours,

Joseph P. Teasdale

GOVERNOR

JPT:cw

cc: Ms. Carolyn Ashford

Memorandum of Agreement among:

Center for Development Technology of Washington University (WUCDT);

Interdepartmental Council on Natural Resources Information (ICNRI);

Office of Administration of the State of Missouri (MOOA); and

Department of Natural Resources of the State of Missouri (MODNR).

Definitions:

Computerized Geographic Information System (CGIS) is a set of computer programs and related documentation at all levels (user, data provider, clerical, management, legislative, systems programming) designed to facilitate access to information stored in the computer about geographic entities (point, lineal, areal, or combinations of these). Specific reference for further details is made to Attachment 1, the Washington University proposal to the National Aeronautics and Space Administration (NASA).

The Land Use and Data Analysis (LUDA) system is a system developed by the United States Geologic Survey to acquire and map land use data based on interpretation of high-altitude (65,000 feet) photography. LUDA provides a data base for a computerized geographic information system. The data on the overlays is digitized and stored on magnetic tapes for use on the USGS Geography Program's existing computer programs. Specific reference is made to Attachment 2 containing details of the agreement between the State of Missouri and the United States Geological Survey.

A Dam Inventory was produced in 1975 by the Department of Natural Resources of the State of Missouri. Attachment 3 includes the design and example output from that inventory.

Background Information:

WUCDT has been funded by NASA under Contract No. NAS-832354 to adapt a CGIS for a representative state using LANDSAT satellite data as one of its inputs. The Missouri ICNRI was established for the purpose of coordinating natural resource data sharing in Missouri. The ICNRI, through its membership and efforts to develop a natural resource information system, provides a representative body for coordinating the adaptation of satellite data to a state CGIS. MOOA, a member of the Interdepartmental Council For Natural Resource Information, is responsible for monitoring the LUDA Cooperative Agreement with the USGS, and coordinating the delivery of the LUDA products. MODNR has in the past produced a Dam Inventory of the State of Missouri and is a member of ICNRI. Land Use data and Water Impoundment data are reasonable outputs from a Natural Resource Information System. The parties hereby agree that:

Terms of Agreement:

1. WUCDT will:

a) Conduct a review of relevant operational CGIS's and evaluate the adequacy of each for Missouri's needs;

b) Conduct a review of several ongoing demonstrations of LANDSAT use and determine those that will produce products in areas of interest to Missouri, ie., Land Use, Water Impoundment and Vegetative Cover; and provide the State of Missouri access to the results and products which WUCDT has acquired in the course of its investigation of LANDSAT use.

c) Recommend:

i) An adaptation of a CGIS that will expand the LUDA Program capabilities and facilitate utilization of the data.

ii) A means of producing a dam inventory; and

iii) If feasible, a means of producing Vegetative maps and/or tables.

d) Develop alternative plans for implementation in Missouri of the techniques proposed above, including specific breakdowns of plan costs, manpower, hardware, software, and other requirements.

2. ICNRI will:

a) Through its member agencies, encourage cooperation in terms of providing WUCDT with access to all data collection and archiving activities in the state.

b) Review and comment as a group on the steps taken by WUCDT in the accomplishment of its contract with NASA, specifically addressing:

i) The adequacy of the design as a prototype for a statewide Natural Resource Information System;

ii) Financial and Budgetary aspects of the planned implementation;

iii) Institutional and political constraints that bear an implementation;

iv) The factors affecting each of its member agency's decision to eventually participate in a statewide Natural Resource Information System.

c) Provide, if requested, consultation with personnel in its member agencies, such consultation not expected to exceed 1/10 man year with any one agency with the exception of MOOA and DNR (see below).

d) Participate with WUCDT in the preparation of a proposal to NASA for implementation of the satellite based natural resource information system.

3. MOOA will:

a) As the state coordinator of the LUDA program, provide WUCDT with access to information and documentation, including but not limited to publications, reports, computer programs, maps, and data received as part of the LUDA Program. WUCDT will have the opportunity to interact with USGS LUDA personnel and participate in all seminars and conference activities relating to the LUDA Program.

b) Designate an individual as a contact point for WUCDT's project.

c) Arrange for consultations with MOOA staff members, such consultations estimated to require up to .25 man year for the entire department.

4. MODNR will:

a) Provide WUCDT with access to all documents relating to the Dam Inventory program, and copies of those determined to be needed by WUCDT.

b) Provide WUCDT with copies of all computer programs received from the Dam Inventory program and copies of data tapes determined to be needed by WUCDT.

c) Designate an individual as a contact point for WUCDT's project.

d) Arrange for consultations with MODNR staff members, such consultations estimated to require up to .25 man year for the entire department.

No part of this agreement shall be interpreted to supercede the current, formal, contractual agreements between WUCDT and NASA.

Office of Administration
Division of Budget and Planning
Gary O. Passmore, Director

Department of Natural Resources
Carolyn Ashford, Director

Inter-Agency Committee on Natural Resources Information
Robert Myers, Chairman

Washington University
Les Eastwood, Principal Investigator

HOLD FOR RELEASE UNTIL 9:00 A.M. - MONDAY, MAY 28

NATIONAL CONFERENCE ON WATER

The Chase Park-Plaza Hotel
212 North Kingshighway Boulevard
St. Louis, MO 63108

I appreciate the opportunity to be here today and to represent the people of Missouri at this conference. Protecting and allocating our water resources will receive top priority during my administration. I want to insure that Missouri citizens receive plentiful, good quality water.

The Nation's water resources are subjects of increasing importance and attention. There is a growing shortage of water for municipal, industrial, energy, recreation, and agricultural use, while substantial losses are experienced through wasteful practices and failure to conserve available supplies. As the population of the Nation expands and society becomes more complex, there is an ever increasing need for sound development and more efficient conservation of these vital resources.

In Missouri, the supply of available water constitutes one of the state's most important natural assets. Interest is growing in the state's water resources and in problems related to their development and protection. Even though the state is blessed with abundant water resources, they are not always distributed where the need exists, nor are they always of uniform quality or quantity.

The Ozark region of Missouri has one of the nation's largest concentrations of springs. The large quanitites of water from the springs means streams in the region have strong base flows of good water.

Two of the largest river systems, the Missouri and Mississippi Rivers either drain directly or indirectly the entire state and supply over half of our state population with water.

The Bootheel region also has abundant groundwater which is of extreme importance to the agricultural economy there.

However, the northern and western areas of the state have insufficient supply of good quality water for either present or future use. The bedrock groundwater is high in salinity, and because of the low groundwater discharge rate, stream flow is very poorly sustained during periods of drought. Therefore, in parts of northern and western Missouri artificial storage of surface water is required to supply water for drinking, livestock or agricultural use.

To preserve the abundant water resource will require an increased effort by both state and local government, as well as the individual citizen. We must direct our planning, development and conservation — in the future — to insure that Missouri has adequate water for cities, industry, agriculture, recreation and fish and wildlife.

To meet this goal will require legislative, as well as administrative changes. I would like to outline some of the proposals that I believe need to be implemented over the next three or four years to help assure all Missouri citizens an adequate supply of clean water.

1) Water Rights Law - In the development of the state, problems of water shortage have played little part. However, the adequacy of our water supply is beginning to be doubted; shortages of water are beginning to be felt; and will be experienced more acutely as competing uses of water increases.

In Missouri, the reality of dry weather in 1976 brought greatly increased interest in irrigation, lake and pond building, and water re-use. Some people became aware, perhaps for the first time in their lives, that water resources are finite in the humid midcontinent, as well as in the arid regions of the West.

Where a water shortage exists, the available supply may have to be regulated by law, both to facilitate water conservation and to determine which uses shall be given priority and which person shall have rights to use the water. But there is surprisingly little court-made law or statutory law pertaining to most phases of water use.

Missouri may be fortunate that it has not refined state law relating to waters; for it has not thereby become bound to any rigid water law doctrines. Instead, at this point in our history, we are able to work out judicially, and perhaps legislatively, a system of water law which will be most beneficial to the future development and prosperity of the people of Missouri.

This summer a Sub-Committee of the Misouri House Agriculture Committee will look into the need for specific water rights legislation in Missouri. I have asked the Department of Natural Resources to work closely with the Sub-Committee in seeking broad citizen input into Missouri needs for such laws.

2) Drinking Water Supply - Even with the assurance of an adequate supply of water, Missouri citizens may face problems with the safety and dsitribution of water. New Federal legislation requires that Missouri strengthen its water supply program to meet these new requirements. Although the proposed Safe Drinking Water Act failed in the Missouri Senate, I believe there are many reasons for Missouri to assume a stronger role in this area. I have directed the staff of the Department of Natural Resources to work with the key members of the Missouri Senate to attempt to resolve the problems with the proposed law, and hopefully a new bill acceptable to all parties can be pre-filed in December, 1977. I believe we owe it to Missouri taxpayers to keep state control of the water supply program.

There is another area of water supply that I would like to mention here.

In response to passage of the 1958 Federal Water Supply Act, the Missouri General Assembly authorized an annuity fund called the "Missouri Water Development Fund" to be used to guarantee repayment of local costs for water supply storage included in federal reservoirs. Under the plan outlined in the legislation, the eventual user of the water would repay the state for water storage purchased by the state in a federal reservoir.

As a consequence of these past actions, I have inherited a situation where the state had requested water supply storage in seven proposed Corps of Engineers reservoirs — without a single water customer being identified. This amounts to 550,000 acre feet — enough water to supply the domestic needs of twenty cities the size of Springfield — on which the state would repay construction costs to the federal government.

In the meantime, construction costs have risen so that the present fund is far short of the amount needed to repay these costs. Further, recently serious questions have arisen regarding the adequacy of the studies which showed a need for the storage. To resolve these issues and provide the data needed to administer the existing fund, I have directed the Department of Natural Resources' staff to organize an orderly study of future water supply needs of the federal projects.

3) Water Quality - In 1972, the Congress of the United States decreed that it shall be the national goal to have all streams of a quality to support fish life and be swimmable by 1983. Through the efforts of the staff of the Department of Natural Resources, we expect to have compliance by all point sources by this date with only a few exceptions. In short, we are making good progress in meeting this goal for our municipal and industrial discharges. However, there is another major area of potential pollution now being assessed. This is the nonpoint source, that is the runoff from agriculture, construction, mining, urban streets, etc. This is being studied under grants from EPA under Section 208 of the law.

The state designated three geographic areas having "substantial water quality control problems," including: the Missouri portion of the St. Louis area, protions of Newton and Jasper Counties surrounding the city of Joplin, and the Missouri portion of the Kansas City area. The planning being conducted by the East-West Gateway Coordinating Council (EWGCC), the Ozark Gateway Council of Governments (OGCOG) and the Mid-American Regional Council (MARC), respectively. These agencies will conduct the entire planning effort within their respective areas with the exception of the agricultural-related portions of the planning; DNR will study agricultural-related water pollution on a statewide basis to ensure the statewide consistence of any recommended voluntary or regulatory control program.

The statewide study will be coordinated by the staff of the Department of Natural Resources. It will require the cooperation of regional planning commissions, University of Missouri Extension, farm organization, industry, mining, educational institutions, and all government agencies (state and federal). Overall review will be made by a State Policy Advisory Committee.

The final plans must include recommended types of regulations or legislation necessary to carry out nonpoint pollution control and recommend a management authority (or authorities) to implement the plans. A review of the plans will be made by the Clean Water Commission with submission to my office. As Governor, I have the responsibility to either approve and certify, or comment upon the final 208 plans.

Both the staff of the Department of Natural Resources and I will need the assistance of all Missourians during and after this study to, first, write a plan which assesses the magnitude of the existing problem, and second, develop an acceptable plan for implementation through legislation and/or regulation.

4) Floodplain Management - Today's concerns with drought and depletion of stream flows, however, should not cause us to forget the need for planning when too much — rather than not enough — water is the problem.

Only four years ago, combined floods of the Missouri and Mississippi Rivers caused $36,000,000 in damages in our state.

Floods are obvious interstate concerns where a river is the boundary between states. In such cases, we need joint state planning and interstate agreements to maintain floodways which will safely pass the floodwaters.

Our General Assembly is considering changes in state statutes which would allow landowners of flood plains in rural counties to vote for planning and zoning. Such changes would allow Missouri counties to take advantage of federal flood insurance and to guide new developments in the floodplains.

Planning and zoning has not been popular in rural areas; the negative vote of county residents in the uplands can overwhelm the desires of lowland voters to approve planning and zoning. The net result has been that rural counties do not have a practical way to become eligible for subsidized federal flood insurance or address the problems of floodplain management.

I support the necessary legislative changes needed to promote the wise use of flood prone lands to minimize property damage.

5) Dam Safety - I will support legislation to make dams safer. With 2,600 fairly large, man-made lakes already in Missouri and no regulations whatsoever for their safe construction, it is time to make sure that safeguards against failure are built into every sizable dam. There have been 23 dam failures in the past 20 years in Missouri, and we're fortunate that only one life was lost as a result.

Legislation to require these safeguards has been introduced in past legislative sessions, the most recent being H.B. 646 during the current session. A dam safety bill will be part of my recommendations for legislation in the second session of the 79th General Assembly, and I will support it vigorously.

Let me assure those who build farm ponds and small recreational lakes that the intent of dam safety legislation is to regulate only the construction of large dams whose failure could mean the loss of lives and property of people living or working downstream.

Dam safety legislation will not suddenly make all dams safe, but it will require new ones to have built-in safeguards against failure.

6) Data Collection Sharing - During the recent meeting of the Missouri River Basin Commission, I proposed the following:

> BE IT RESOLVED that several states that together comprise the Missouri River Basin petition the federal government to develop within the several states a cooperative water data system adequate for assessing the current and future water uses within the basin. This data base is to be used as a predictive tool to evaluate effects of individual water development projects in the basin as the relate to long-range planning, water use and water needs.

The Basin resolution covered only part of the problem, so: I see a need to expand this concept within the state. In order to deal with the broader issues of water such as available resources, quality, discharge/recharge relationships, recreational uses, irrigation, energy, agricultural uses and the many other facets of water, I will encourage the further development of the Natural Resources Information System. This is a farsighted attempt to make possible an information exchange between the several departments of state government that deal with natural resources. It makes far more sense to share available data than for every agency to gather its own. The Natural Resources Information System, funding for which I recommended in my F.Y. 77 budget, can be the vehicle for bringing together what we know about water in a way that all agencies can use it.

7) Energy and Water Resources - The State's energy policy is inseparable from environmental and conservation policies.

I will work toward a formal mechanism for closely evaluating and determining site location for major power and industrial facilities — including additional legislation. This evaluation will include all environmental effects on a region and a determination of the natural resources available now and in the future.

The state must evaluate the use of water by new power plants and industry to determine that the competing uses for that water are fully considered. In addition, conservation of water must be included in the design and construction of new plants.

8) Navigation - Missouri is blessed with over 1,000 miles of navigable waterways within and along its borders on the Missouri and Mississippi Rivers. Our Department of Transportation is attempting to capitalize on this transportation system by combining it with Missouri's abundant natural resources to achieve economic development while maintaining an ecological balance.

The Department of Transportation is presently preparing a Statewide Waterborne Commerce and Port Development Plan. This study, which will be completed by early fall, is designed to provide a blueprint for action for port development. It will identify what, where and when port development is needed in Missouri to optimize economic development.

This study effort will provide input into the larger Mid-American Port Study involving seventeen states and the Maritime Administration. The benefit of this study to Missouri will be the identification of additional markets for Missouri for industries within her borders. The economic spinoffs generated by new industries and increased trade through jobs for Missourians, an increased tax base, and additional dollars flowing through Missouri's economy will be of benefit to all Missourians.

I recognize that these two big rivers must be managed to protect the other important river uses too — public water supply, fish and wildlife, and recreation — so that future generations can enjoy a diverse and productive river environment.

The navigation projects on the Missouri and Mississippi Rivers have direct impact on the fish and wildlife and recreation, and other uses of the river. I do not support the domination of one use of the river at the expense of the numerous other uses. Efforts by the state agencies — working with the Corps of Engineers and other federal agencies — to lessen or effect the fish and wildlife losses on the Missouri River should continue.

In addition, I endorse the "Great River Study" on the entire length of the Upper Mississippi River and call for the immediate start of that part of the study which will extend downriver from Gaverton, Missouri to Cairo, Illinois. The Great River Study joins federal and state agencies to take action toward providing a better balance of uses between increased barge traffic, fish and wildlife, and recreation.

The Missouri and Mississippi Rivers must be recognized and managed as resources serving many varied purposes.

9) In addition to what I have outlined above, soil erosion and other water problems in agricultural areas will get more attention. Earlier this year, the heads of five state agencies — with the U.S. Soil Conservation Service — began a major study of water and related land in northwest Missouri.

The combination of climate and fertile soil has made that area one of the outstanding grain producing areas of the world. But only about one-third of the farm land has any kind of small watershed protection activity now.

The study members and the interested public will be working on alternative ways to meet the problems of flooding on small streams, more help with soil erosion losses, and preservation of fish and wildlife habitat.

As a result of this effort, I shall expect a sharper focus on ways the state can better serve that quarter of the state.

10) Self-determination in Water - It's time for state self-determination in water. For too long, state government has been reaching to plans of the federal government for the stewardship of water resources. Our rivers have been dammed and our channels straightened on the basis of federal planning, federal studies and federal projections; and we have been asked to approve these activities. My administration will not be content with federal determination of needs and locations for water development; we will request federal assistance needed, but we will chart our own course.

Toward that end, I will ask the DNR staff to take the lead in determining the nature and amount of the water available for our use, and to compare that with projected needs. When hard decisions have to be made on whether to build reservoirs or straighten channels or develop irrigation systems, we can do so on the basis of facts rather than emotion.

CLOSING

Water is too precious to waste, yet it is usually too inexpensive to treasure. Our challenge in government is so to plan and wisely use water that it is always available yet never so expensive that citizens are denied the pleasures it affords.

APPENDIX B

Site Visit Summary

Purpose of Visit	Destination	Dates
Attend monthly meetings of the Interagency Council of Natural Resources	Jefferson City	*
Attend training sessions on LUDA program	Rolla Jefferson City	6/ 1/77
Attend ICNRI Information System Subcommittee meetings	Jefferson City	5/ 3/77, 6/ 3/77
Brief Missouri Legislature on LANDSAT	Jefferson City	12/ 4/77
Meet with DNR Director and NASA personnel	Jefferson City	11/21/77
Meet with DNR Budget Director and Headquarters staff	Jefferson City	9/12/77
Meet with DGLS staff; plan dam inventory application;	Rolla	6/16/77
Meet with UMR personnel	Rolla	
Brief NASA Headquarters Personnel on project results	NASA HQ, Washington, D.C.	11/29/77
Conference on Economics of Remote Sensing	San Jose, California	2/10/78
Investigate feasibility of using DAM package in Missouri	JSFC, Houston, Texas	9/14/77
Investigate Texas Natural Resource Information System	State Capital, Austin, Texas	7/20/77
Investigate use of LUDA by a state agency	Louisiana State Planning Office, Baton Rouge, LA.	5/16/77

*Interagency Council on Natural Resources Information, dates: 1/ /77, 2/10/77, 3/11/77, 4/11/77, 5/6/77, 6/9/77, 7/8/77, 8/5/77, 9/9/77, 10/7/77, 11/11/77, 12/5/77, 1/6/78, 2/3/78, 3/3/78.

Site Visit Summary
(continued)

Purpose of Visit	Destination	Dates
Visit USGS LANDSAT user center	National Space Technology Laboratories, Bay St. Louis, Mississippi	5/17/77
Investigate minicomputer based classification systems	Earth Resources Laboratory, Slidell, LA.	5/18/77
Present paper on machine processing costs of LANDSAT data	Conference on Applications of Remote Sensing, Lafayette, IN.	6/20/77
Investigate LIMAP System implementation procedures	South Dakota State Planning Office presentation in Champaign, IL.	5/26/77
Presented paper on operational LANDSAT data management costs; Investigated geocoding systems.	ERIM Conference Ann Arbor, Michigan	4/24/77
Presented project plans; Investigated other Earth Resources projects	MSFC Earth Resources Project Review	1/14/77
Presented operational LANDSAT cost data	Conference on Economics of Remote Sensing, San Jose, California	1/19/77

APPENDIX C

PROGRAM OF THE AAAS SESSION ON EARTH OBSERVATION DATA MANAGEMENT

Whither LANDSAT? Future Directions For Earth Observation Data Management Systems

February 15, 1978
9 a.m. - 12 noon

Shoreham Americana Club Room A

Organizers: Lester F. Eastwood, Washington University
Christopher T. Hill, Office of Technology Assessment

9:00 *"Initiatives in Congress for an Operational Earth Resources and Environmental Information System"*
Daryl Branscome, Technical Consultant, Committee on Science and Technology, U.S. House of Representatives

9:20 *"Industry's View of Operational LANDSAT"*
Daniel Fink, Vice-President and General Manager, Space Division, General Electric Company

9:40 *"Policy Issues Surrounding the Decision For An Earth Resources Operational System"*
Anthony J. Calio, Associate Administrator for Space and Terrestrial Applications, National Aeronautics and Space Administration

10:00 *"Remote Sensing in Developing Countries"*
Charles Paul, Manager, Remote Sensing Program, Agency for International Development, U.S. State Department

10:20 *"Some Foreign Plans for Earth Resources Satellites - Are They Complementary or Alternatives?"*
John M. DeNoyer, Director, and William R. Hemphill, Deputy Chief, Earth Resources Observation Systems Program (EROS), U.S. Department of the Interior

10:40 *"S657: Legislation to Establish an Earth Information System"*
James J. Gehrig, Professional Staff, Committee on Commerce, Science and Transportation, U.S. Senate

11:00 *"An Earth Observation Data Management System for State Regional and Local Agencies: Economics and Policy"*
Lester F. Eastwood, Jr., Associate Director, and Robert P. Morgan, Director, Center for Development Technology, Washington University

11:20 *Panel Discussion.*

APPENDIX D

COMPUTERIZED GEOGRAPHIC INFORMATION SYSTEMS

D.1 BACKGROUND

With the advent in the early 1960's of large mass storage devices (disks, drums, etc.) arrived the capability of storing and quickly retrieving information on very large numbers of entities. The chief difficulty no longer lay in hardware capabilities but rather in the software complications inherent in the mass storage addressing schemes. Each computer manufacturer had his own structures. In fact, these structures varied between different products of the same manufacturer. All required that complicated numerical "keys" or "addresses" be devised for storage and then reconstructed for retrieval. By deciphering such a key, the computer program could determine, for example, on which disc cylinder, track, and sector of a piece of data was to be placed or found. Gradually the manufacturers developed software to construct and analyze keys automatically. The computer analyst then became able to direct his/her attention to the structure of the data itself rather than to the structure of the equipment on which the data was to be stored.

In the mid and late 1960's, initial development occurred of Computerized Geographic Information Systems (CGIS), computer programs that store geographically encoded data for rapid retrieval and analysis. Several characteristics further distinguish such systems. One important feature of a CGIS is the entity about which information is stored. Some CGIS's contain data on point locations, e.g., plant sites or centroids of population. Others are lineal, e.g., river, highway, or transmission line networks. Usually the point or lineal systems serve a highly specialized purpose. For example, EPA's STORET system stores and retrieves data on the network of streams and rivers in the United States.

The type of feature stored is related to the areal unit. For example, though it is appropriate to speak of land use at a point, it makes no sense to report population density at a point. Generally demographic data is aggregated by geographic-political units, while natural resource data is reported at several observation points.

D.2 GENERAL PURPOSE CGIS'S

The most widely used class of CGIS coding structures is areal systems. They store data for units of geographic area. Example features that have been stored in areal CGIS's include county population, mean elevation of a region, and land cover over an area.

There are two main classes of areal CGIS's distinguished by whether their unit of data storage is a polygon or a grid cell. Grid systems superimpose a network of regularly shaped cells over the region of interest and store a feature value for each cell. Polygon systems store both feature value and irregular polygon boundaries.

Grid systems are further distinguished by the grid cell shape and size. Rectangles are the most common shape in current use, though some systems use triangles or hexagons. Sizes of the rectangular grid cells vary among systems as well. Examples of sizes in frequent use are 1 kilometer squares, one section (640 acres), quarter section (160 acres), quarter-quarter-section (40 acres).

Polygon based systems are coming into use with increasing frequency. Rather than recording values of variables over fixed geographic units, polygon-based systems also record the shape of the geographic unit. Thus, for instance, a polygon-based system contains for each occurrence of a particular land use, say a hard wood forest stand, a set of points in a specified order. The points, specified as coordinate pairs, represent the vertices of a polygon enclosing the land use. A difficulty is that polygons have straight-line boundaries, but natural features, like forests and river basins, generally have curvilinear shapes. The fit can be made more accurate by storing more points, at an increased cost.

D.3 DATA COLLECTION AND ENCODING CONSIDERATIONS

These differences in basic data structure reflect differences in the use and method of collection of the data. Demographic data are more often accumulated by polygon shaped political unit than by geographic coordinates. For example, we are interested in the voters in an election district, not those in a grid cell. On the other hand, terrestrial feature data can be systematically recorded by geometrically regular observations.

In a polygon system, the data are usually tabulated rather infrequently and at a great expense, e.g., the U.S. Census, or they are collected as a by-product of some on-going function, e.g., building permit and demolition data. Generally the data in such systems is of a socio-economic nature. Data collection for a grid cellular system is more appropriately performed by the encoding of visual images, e.g., maps and aerial photographs. Appendix E reviews three encoding methods used.

Both polygon and grid systems have advantages. The grid system has the advantages of simplicity, retrieval speed, ease of terrestrial data input and storage compactness. The polygon system offers the advantage that it more closely records "real world" boundaries of feature regions and, in that sense at least, is potentially more accurate. However, polygon systems generally are more complex and require larger hardware systems.

The grid system's regularly repeating structure of equally sized rectangles permits quite simple program design. Because all data refer to common single cells, the program can easily retrieve several facts about a particular cell of interest. Thus, for example, it would be simple to determine that a one kilometer square cell with specified Universal Transverse Mercator (UTM) coordinates is 75% forest covered, lies in

Greene County, is state owned, contains 250 single family housing units and a population of 1100. Since all of these data have been stored in the same cell, whose location is easily determined from the UTM coordinates, retrieval is almost immediate. Furthermore, the regularity of the grid system eliminates the need to store any geographic reference except a base point from which all succeeding cell locations can be inferred. Only data values need be stored. Thus, if we wish to find the value of the fifth variable pertaining to the cell that is 10 kilometers north of and 82 kilometers east of the base point, a quite simple series of multiplications and divisions identifies the computer location.

Polygon systems hold promise of greater geographical precision than the more rigidly structured grid based systems, since a curve can be approximated to arbitrary precision by a sequence of straight line segments. However, the advantages come only after substantial loss in speed and storage capacity, in the frame of reference of present day hardware and software systems. Polygon systems require extensive storage since voluminous space must be set aside for the boundary points. The lower retrieval speed of polygon based systems is attributable to the expense of locating the polygon containing the geographic point on which information is requested. If the user specifies UTM coordinates for a point of interest, as in the earlier example, the system must exhaustively search each of the land use polygons, calculating a "point-in-polygon" test function on polygon vertices. If the user desires to know, in addition to the point's land use, the county in which it is located, the point-in-polygon search must also be conducted on the county boundary file.

D.4 SELECTION OF A CGIS FOR THE MISSOURI NRIS

D.4.1 Selection Criteria

Early in the SARSDM project, we enumerated seven criteria for a CGIS in a preliminary presentation to ICNRI at the January, 1977 meeting. The CGIS to be adapted must:

(1) Be appropriate to the agency using it;

(2) Permit automatic input of LANDSAT data;

(3) Be transferable and adaptable;

(4) Permit initial input of data easily and at reasonable cost;

(5) Permit update and maintenance easily and at reasonable cost;

(6) Be expandable to other agencies;

(7) Possess a record of past "success."

In the next several paragraphs, we establish a more precise meaning for each of these criteria.

D.4.2 Appropriateness to the Agency

The spectrum of operational CGIS's includes urban-oriented, statewide, regional, and national systems. It includes special purpose systems used, for example, in the fields of transportation and agriculture. It includes systems oriented toward land use planning or water quality planning; systems for monitoring compliance with regulations, like pollution control; and systems for resource management in wildlife and forestry.

These divisions are not exclusive; many CGIS's serve multiple purposes. But to the extent that a CGIS serves one purpose well, it is often inappropriate for others. For example, a CGIS that provides detailed population information at the block level for an urban area would not be expected to be applicable on a statewide basis because of the volumes of unnecessary data on sparsely populated areas that would be involved in expanding it. Another example is the STORET system. This system was developed by the U.S. Environmental Protection Agency for the storage and retrieval of water quality data. The information is stored in line and network entities and is indexed by river mile markers. This approach, though quite appropriate for its intended use, could not be adapted to a forest management information system.

D.4.3 Automatic Input of LANDSAT Data

Because the SARSDM project demonstrates the application of space technology to state government, this is an indispensible criterion. LANDSAT data input would be difficult to input any other way, because of the volume involved. LANDSAT 2 and 3 each completely overfly Missouri once every eighteen days, each Missouri overflight producing approximately 10^9 bytes of data.

D.4.4 Ability to be Transferred

Both administrative and technical factors enter into the question of whether the system can be brought from where it now operates to function in Missouri. Chief among the administrative considerations of system transfer are questions of ownership and availability. Most CGIS's, developed with public funds, lie in the public domain. Nevertheless such a CGIS may employ proprietary software licensed only to the using organization. Other administrative factors include whether any phase of the system updating depends upon the particular procedures of the state which operates it. For example, a CGIS may require updating by entry of specialized building and demolition data.

Technical factors include the computer system on which the CGIS is currently operating, and the similarity of the CGIS's data structures to existing Missouri data systems. Even if a match is found between the CGIS's computer mainframe and the agency's, closer examination is necessary. Consideration must be given to the executive operating systems under which the CGIS and the agency's computer operate. A set of routines that operates on an IBM 370 under one executive operating system, e.g., OS/MVT, may require considerable modification before it can be made to operate on identical hardware under another, e.g., DOS. In fact under some conditions it might be easier to adapt a set of routines that operate on hardware from another manufacturer rather than perform the conversion between operating systems.

Furthermore, the CGIS may have been designed to run in an interactive (or conversational) mode when only batch mode is available on the agency's computer. Given compatibility between computer mainframes and operating systems, further hardware questions arise in the peripheral devices that the CGIS employs. These might include specialized line-printers for graphic output, terminals, plotters, or specialized disk storage devices. Fortunately, many of the incompatibilities suggested above can be resolved by the use of higher level programming languages that are common to several manufacturers' equipment. Such languages are FORTRAN IV and COBOL. PL/1, though it is a higher level language, is not generally available on non-IBM equipment.

Even after hardware/software considerations have been satisfied, the data structures required by a CGIS should be carefully examined. Lack of compatibility with Missouri agency practices here could entail drastic system revision.

D.4.5 Ease and Cost of Initial Input of Data; Ease and Cost of Update and Maintenance

We consider these criteria together because the techniques used for initial data input will probably also be used for updating. It is possible that the method to be used for data input in Missouri may not be the one used in the original CGIS. Technological improvements since the time of CGIS development in optical scanning and photo-digitizing techniques (see Appendix E) may allow automation of some manual functions. Further, much of the data required may already be stored in Missouri digital data banks. If this is the case, it may be cost-justified to write separate computer programs to recapture this data.

Updating and maintenance raises one further point. It is likely that after the system has been installed and operational for some time in Missouri, programming changes will be desired. These changes are feasible if the CGIS was designed modularly and the documentation on the programs and data structures is complete.

D.4.6 Expandability to Other Agencies

This project is being viewed as a pilot project for application of LANDSAT/CGIS technology to state government in general. Though the primary consideration is the applicability of the CGIS to DNR, one of the most important secondary considerations is that the other members of ICNRI can in the future be well-served by the same CGIS. This consideration indicates that the CGIS should be of a general nature, rather than devoted to a single application.

D.4.7 Record of Past "Success"

We use the word "success" in the restricted sense of user satisfaction. "Success," defined as we have in (8), can most easily be determined by interviews with users of the CGIS. The survey of CGIS's performed in the EODMS project (8) is another source.

D.5 REVIEW OF CANDIDATE CGIS'S

Candidate CGIS's that we consider for implementation in Missouri include the Alabama Resource Information System (ARIS), the Texas Natural Resource Information System (TNRIS), the Land Use and Natural Resources System (LUNR), the Land Use Management Information System (LUMIS), systems developed by NASA's Earth Resources Laboratory (ERL), and the Geographic Information Retrieval and Analysis System (GIRAS).

D.5.1 ARIS

ARIS operates in Alabama under a contract between the Alabama Development Office and Auburn University, which adapted it from two earlier systems known as MIDAS and MAGI. ARIS consists of two subsystems; GRIDS and CENSLIST. GRIDS is grid cell - based on a 1/4 km squares, reduced in urban areas to 1/8 and sometimes 1/16 km squares. CENLIST is polygon-based (on U.S. Census divisions). Grid cell locations are georeferenced by UTM coordinates. ARIS is now operational on the Auburn University IBM 370 system and was written in PL/1 and COBOL.

D.5.2 TNRIS

Developed initially from a water-oriented data base, TNRIS has only recently initiated an effort toward CGIS development. It has been handling user files according to more or less conventional data processing techniques, making use of available, well developed software like DAM and SYSTEM-2000. Though our plan for Missouri does not incorporate direct transfer of TNRIS software, we have attempted to learn from the elements that have lead to its success. We have done, fairly early in the project, a careful analysis of the operations of TNRIS and its predecessor, the Texas Water Oriented Data Bank, with an eye toward implications for Missouri. This analysis appears in this report as Appendix F.

D.5.3 LUNR

The LUNR system, one of the earliest CGIS's, was initiated in 1966 by the New York State Planning Office. Based on a one-kilometer square grid cell, LUNR's first software concepts have since been replaced by a new system called Land Resources Information System (LRIS). Both LUNR and LRIS used New York's IBM 370 system. Data encoding for LUNR was by the manual acetate overlay process described in Appendix E, and so was quite costly in terms of personnel.

D.5.4 LUMIS

LUNR spawned several systems, one of particular interest is the LUMIS system in Los Angeles County. The polygon based LUMIS accepts data from two other city systems: the Land Use Planning and Management System (LUPAMS), and GEOBEDS, a DIME-encoded street network file.

D.5.5 ERL Software

The Earth Resources Laboratory uses a grid-based information system called the Data Base Module (DBM) in conjunction with its low cost LANDSAT data analysis system. DBM permits overlaying up to thirty files of data on forty acre grid cells. Written in FORTRAN, it can be transferred to any minicomputer which runs the ELLTAB classification system.

D.5.6 GIRAS

USGS originally developed the GIRAS system to assist in digital production of land use statistics for the LUDA program. Written in FORTRAN and operational on IBM 370's, it is a polygon based system in that it stores data files and produces maps in that fashion. It composits separate data files, however, by first converting each to grid structure and compositing the gridded version. Since 1975, USGS has been actively developing GIRAS II, a fully polygon based, interactive CGIS. They are attempting to insure a smooth transition for users of GIRAS I. Additional development should occur as the result of a current USGS-NASA ASVT which is investigating means of updating LUDA by using LANDSAT data.

D.6 CHOICE OF A CGIS

We have chosen the GIRAS system as the CGIS software for use in Missouri's NRIS. The main factors in our choice are compatibility with existing state data sources and computer systems and the relative certainty of future development of the system. Because of this continuing federal development, the Missouri system should be able to grow from a simple initial installation to a current system in five years without high development costs.

An item that causes some reservation in the choice of GIRAS is that it is not designed in its present form to efficiently handle point and line data. The body of the report indicates that this capability is necessary in the municipal water shortages application. A possible solution is for the state to incorporate some of the features of the ERA-developed STORET system. A more direct and efficient solution would be for Missouri to communicate this concern to USGS and ask that it be incorporated into the development objectives of GIRAS II.

Our choice of GIRAS was not exclusive. Each of the other systems had much to recommend it. In particular, we also plan the use of ERL's DBM system to provide a link for inputting LANDSAT data to GIRAS. Furthermore, from TNRIS, we adopted the conceptual design of the Missouri NRIS and learned much from its initial focus on water resources (see Appendix F).

APPENDIX E

SUMMARY OF MAP DIGITIZATION OPTIONS

This appendix presents a brief review of digitization, the technology of converting mapped data into digital form, to indicate the range of options relevant to planning. A more complete description of various automatic digitization process options appears in (52).

A completely manual approach to digitizing map data is to superimpose a properly scaled acetate grid over the map and record by hand the most prevalent feature value in each cell. The acetate then becomes a source document for keypunching. This method has been used by the Land Use and Natural Resources (LUNR) system in New York (8) and is appropriate for grid-based CGIS's; LUNR is based on a one kilometer square grid cell. The main advantage of the manual approach is simplicity, while the chief disadvantages are high personnel costs and incompatibility of the gridded output with the more highly developed polygon-based CGIS's.

These disadvantages have inspired the development of more automatic techniques and devices. To digitize a map using one of the automatic devices, the operator registers a clean map sheet, preferably a print quality single-tone overlay containing only the feature of interest, onto a table-shaped device known as a digitizer. This device electronically converts the shapes of the map's lines and curves into digital coordinate pairs. The intervals between sampled points must be sufficiently small that straight line interpolation provides an approximation of desired accuracy.

There are two major classes of digitizers, distinguished by the degree of automation involved. The less automated require the operator to carefully position the cross-hair on a hand-held mechanism, called a cursor, over the first point of interest; press a button causing the coordinates of the cross-hair position to be digitally recorded onto magnetic tape; and then move to the next point of interest. These steps are repeated until the entire map sheet has been digitized. For comparable accuracy, this approach permits an order of magnitude reduction in manpower requirements, as compared to totally manual techniques, and produces data in a form suitable for entry to a polygon-based CGIS. However, other problems, particularly operator fatigue and unreliability due to mechanical wear, become more pronounced. The work is slow and tedious, and operators become more error prone as the day wears on.

The problem of errors is complicated by the fact that quality control usually requires an indirect approach. Since it is impossible for a verification operator to oversee the work directly, instead he/she usually produces a map from the digitized data and checks it against the original.

The other automatic devices practically eliminate the need for an operator except during initial set-up. This class of devices is further subdivided into two classes, raster scan and line-following. The first employs a scanning system similar to LANDSAT's MSS to record reflected light intensity variations from a map to be digitized pixel by pixel. The second subclass uses laser-optical technology. The operator positions a laser beam onto the first point of interest on a line, but from that point the laser positioning control mechanism follows the curve. Both kinds of devices reduce operator fatigue and, since they are based on electronic and photo optical principles, mechanical wear. The line following laser technique has been used by USGS to digitize the LUDA data for entry to GIRAS (51).

To summarize, the choices for digitization amount to completely manual techniques, point-digitizers, raster-scanners, or completely automatic line-following lasers. There is no one best approach for all Missouri mapped data, the economics being highly dependent on the precise form of the map sheets and their condition. Though the completely automatic techniques at first sight appear to be less expensive (as little as $100 per map sheet for the laser process) they depend on a significantly higher quality of map input. Costs of preparing an aged, dog-eared map to these standards may well swamp any potential savings. A further consideration in the use of raster scanners is that most CGIS's require input data in point and line form rather than raster form. Conversion costs thus arise here as well.

The body of this report recommends that the state contract out digitization. We estimate costs for these contracts of between $1000 and $5000 cost per map sheet (52), including preparation costs.

APPENDIX F

A REVIEW OF THE TEXAS WATER ORIENTED DATA BANK (TWODB)

F.1 BACKGROUND

The Texas Water Oriented Data Bank (TWODB) originally developed from a legislative charge to create "a centralized data bank incorporating all hydrological data collected by the several agencies of the State of Texas." TWODB is a computerized information system which allows storage, analysis and retrieval of many types of data related to Texas water resources. An integral part of a larger computerized geographic information system, the Texas Natural Resources Information System (TNRIS), TWODB is a linked network system (see Section 4.2) linked to Systems Central by remote terminals or in some cases by off-line data in a common format. Seven agencies comprise the supporting organization for TWODB: Texas Water Rights Commission, Texas Water Quality Board, Texas Water Development Board, Texas Highway Department, Texas Health Department, Texas Railroad Commission, and the Texas Parks and Wildlife Department. Each agency maintains a data bank of all its own data. The System Central facility, operated by the Texas Water Development Board, maintains a central file indexing most information files stored by the cooperating agencies. However its data holdings are not as current or complete as those retained in the individual banks.

The data maintained by the system include the following types: (i) meteorological data, (ii) surface water resources, (iii) groundwater resources, (iv) related land resources, (v) socio-economic data, (vi) project and facility operating data. At the present time TWODB contains 58 computer processable files (consisting of 2 billion characters of information) of water related information. Output may be in the form of computer query, reports, cards, tapes, maps, plots or as computer compatible online data for input to planning and modeling activities.

TWODB developed on a project by project basis as data were entered into the system from successive applications. The first step in entering data into the system was to catalog water oriented data collected by the participating agencies. The data were cataloged by the state's twenty-three river and coastal basins. Data continued to be entered, and in 1972 it became apparent that a natural resources information system (NRIS) was indicated as a logical extension of the WODB. This NRIS has since been implemented and the water oriented data bank made a part of it. Use of the system has increased until at present over 3,000 requests for information are processed annually. The user community has extended beyond the seven cooperating agencies and now includes users in the federal, government, local, regional and non-participating state agencies, as well as private sector users. The capability to add on applications and users as more data become available makes TWODB an ideal candidate for adaptation to Missouri water resource data handling problems.

The WODB can supply a wide spectrum of applications with necessary information and supporting services. Table F-1 lists major applications the system has served. As in any information system, as more applications develop, more data will need to be entered into the system and as more data are entered, additional applications become possible.

Table F-1

Applications Served by TWODB

1) water supply modeling and planning

2) water basin modeling and planning

3) studies of fresh-salt water interface

4) water quality monitoring

5) "208" water quality studies (non-point sources)

6) site evaluation studies

7) groundwater availability

8) drought or flood monitoring

9) reservoir monitoring

10) water use and return flows (streams, reservoir)

11) aquatic community studies

12) planning public drinking water system

13) fish and wildlife management activities (esp. monitoring of coastal wetlands)

14) prediction of possible damage caused by flood or storm waters

15) mapping of various water resources

16) water availability studies

17) water rights information

F.2 DATA NEEDS AND APPLICATIONS

In order to implement each application, a number of data items were needed. This section associates the data needs with each of the applications listed in Table F-1. We do not intend this analysis to be rigorous or this list of data required to be detailed; rather, it shows the general types of data needed to accomplish the specific application.

The data needs of Texas and Missouri in the water resources area differ because of variations in hydrologic and other conditions between the two states. The water resource of Texas is more limited. Texas and Missouri differ climatologically and accurate knowledge of meteorological factors may be of more importance in one area than another. Significant similarities also exist in the two states to suggest parallelisms between the TWODB and the proposed Missouri system. For each application in Table F-1, a set of data inputs appears in Table F-2. These data needs are extracted from lists presented in "Preliminary Report on the Texas Water Oriented Data Bank," June 1971. These items are the actual data used by Texas in their water resource activities and which are held in the system files.

Table F-2: Application Data Needs

Water Supply Planning and Modeling

precipitation	wind movement
evaporation	streamflow (includes gain and loss)
temperature	reservoir contents
humidity data	diversions from surface water
return flows	groundwater pumpage
chemical water quality	groundwater recharge
bacteriological data	natural outflow and inflow
sediment transportation and deposition	soil moisture
water temperature	ground water quality
occurrence and availability of ground water	daily water use
ground water level	population water demand
	industrial and manufacturing demand
	agricultural water demand

Water Basin Modeling and Planning

precipitation	chemical quality
cloud cover	water temperature
temperature	return flows
wind movement	diversions
storm characteristics	water rights
humidity	soil survey
stream flow	population
stream flow gains and losses	soil classification
water quality data	plant-soil moisture needs
biological quality	topography
	land use

Studies of Fresh-Salt Water Interface

stream flow data	water use
precipitation	water quality (salinity)
wind movement	water quality (biological)
lake and bay circulation pattern data	water quality (chemical)
surface topography of bays and estuaries	biological inventory of water
fish and marine invertebrate harvest	land use
	water rights

Table F-2

Application Data Needs (cont.)

Water Quality Monitoring: "208" Water Quality Point and Non-Point

precipitation
storm characteristics
wind movement
diversions from surface water
chemical water quality
sediment transport
pesticides in water bodies
water temperatures
radiological levels in water
stream flow
stream flow loss and gain
reservoir contents
return flows (sources)
biological and biochemical quality of water
sediment deposition
bacteriological content
physical data
groundwater occurrence and availability
groundwater development
pumpage of ground water
soil moisture
groundwater quality
plant-soil moisture data
agricultural uses
water level data
recharge of aquifers
natural outflow and inflow from aquifers
land use
economic-industrial use

Site Evaluation Study

nature of facility
location
stream flow data
return flows
geologic parameters
topography
soil classification
water cost and benefit data
return flow water quality
population
amount of water needed
access to transportation
diversions from surface water
streamflow losses and gains
competing land use
soil survey
reservoir levels
water quality
land use

Groundwater Availability Studies

occurance and availability
development information
recharge of aquifers
soil moisture
geologic maps
well logs
water level data
pumpage of ground water
natural inflow and outflow from aquifers
groundwater quality
subsurface exploration data
topography

Table F-2

Application Data Needs (cont.)

Drought and Flood Monitoring

cloud cover	topography
evaporation	conservation needs
solar radiation	civil works location
storm characteristics	crop yield projections
high altitude weather	crop yield data
stream flow data	precipitation
tidal data	temperature
soil moisture	wind movement
humidity	plant-soil moisture
weather modification data	land use pattenrs
reservoir contents	crop yield
lake and bay circulation patterns	crop patterns and practices

Reservoir Monitoring and Water Use and Return Flow

cloud cover (for calculation of evaporation)	evaporation
	temperature
wind movement	humidity
stream flow (gains and losses)	diversion from reservoirs
reservoir contents	quality
return flows	land use
water consumption	water rights info.
population	

Aquatic Community Studies and Fish and Wildlife Management

precipitation	evaporation
temperature	humidity
wind movement	stream flow (losses and gains)
diversion (for widlife use)	tidal data
lake and bay circulation data	water quality in streams and reservoirs
bays and estuaries	chemical data
sediment transport and deposition	pesticides
biological data	biotic population
biota present	topography
land use	
surface mapping including bays and estuaries	

Table F-2

Application Data Needs (cont.)

Planning Public Drinking Water Systems

stream gaging	groundwater occurrence
reservoir contents	groundwater development
diversions from surface water	natural quality
return flows to water supply	topography
dissolved chemicals	geology
specific contamination	precipitation
water temperature	evaporation
sediment deposition	temperature
	wind movement
	storms

Prediction of Possible Storm Damage

See Drought and Flood Monitoring

Mapping of Water Resources

topography	location and occurrence

can use any theme extractable from collected data.

Water Availability

location of ground and surface water supplies	land use
availability	topography
quality	precipitation
stream flow	temperature
evaporation	diversions
humidity	water rights information
return flows	population

Water Rights

legal data on water rights ownership

F.3 CALCULATIONS OF SYSTEM LOADING AND RESULTING DESIGN PARAMETERS

In order to estimate future loading of the planned Missouri Water Resources Data Bank we studied the loading of the Texas system as model. In particular we wished to calculate daily bit loads and storage times for various classes of data. Though TWODB publications do not give exact figures on the daily bit rate for the various data items, they do provide information on the volume of stored data from which we were able to estimate implied daily data volume.

F.3.1 Data Volume Based on Calculation of Stored Data

Precipitation and streamflow data is the largest class of data in the TWODB. We estimate that such data represent at least one-third of the daily input and so we base our Missouri estimates on that class.

Current storage of precipitation and stream flow data at TWODB covering a period of roughly 75 years of record. This implies an average yearly load of 4 tapes of precipitation and stream flow data. Thus, total volume is 1.2×10^8 bytes annually or 3.2×10^5 bytes daily. Missouri is roughly one-fifth the area of Texas so we calculate a daily data load on the order of 10^5 bytes/day for precipitation and stream flow data or 3×10^5 bytes/day total. However, because of increased data volume in more recent years, we assume that the present volume is five tapes annually. We estimate 2.3×10^7 bytes per tape based on 2400 foot reels with effective density of 800 bytes per inch, after allowing for inter-record gaps.

F.3.2 Data Volumes from Listed Data Collection Frequencies

As a means of verifying the earlier calculations, we are also able to estimate system loading on the basis of data collection frequencies for many items, we base this estimate on information contained in the

Texas Natural Resources Information System File Description Report (36). Table F-3 summarizes the volume of the most frequently collected data items. Allowance must also be made for header or identifying data accompanying automatically reported data, but we do not make that allowance here.

F.3.3 Data Access Frequencies

From calculations based on Table F-3 we estimate the total number of daily observations at 2×10^4. Assuming 5 characters per observation, this amounts to about 10^5 bytes per day, in substantial agreement with our earlier estimate.

In addition to storage of data files, the data bank must provide for efficient access. Thus, still another useful view of system loading can be gained by estimating access frequencies of the various data types by the various agencies. Table F-4 provides a summary of this information. We do not attempt to draw any immediate analogies with Missouri because of differences in agency charters.

Table F-3: Collection Frequency of Major Data Types in TWODB

Item	# of Locations	Freq.	# Categories; Units
precipitation	1200	daily	inches
evaporation	140	daily	inches
temperature	650	2/daily	°F
wind movement	100	4/daily	miles/hr
streamflow	600	daily	ft^3/sec.
humidity	56	daily	in % of saturation
stream flow loss and gains in volume	600	daily	as difference between continguous stations
water quality			
streams and reservoirs	200+	daily	25 parameters in various units
diversions from surface water	200+	daily	25 parameters in various units
groundwater	3000	yearly	3 parameters in various units
socio-economic data			
employment	statewide	annual	8 categories
population	statewide	annual	200+ categories various units
economic data	statewide	annual	
reservoir contents	50	daily	acre-ft
ground water level	6000	monthly most annually	ft.
diversion water quality	200+	daily	gal.
return flow water quantity	200+	daily	gal.
biological water quality	200+	daily	up to 25 measurements varying units
chemical water quality	200+	daily	up to 26 measurements varying units
ground water pumpage	100+	monthly	acre-ft
ground water recharge	100+	monthly	acre-ft
ground water development	100+	monthly	net change in
crop yield	254	annual	acres/crop
farming practices	254	annual	---
farm product price	254	annual	$
economic inputs/outputs	statewide	annual	$
storm characteristics	1600	(as need-ed	20+ parameters various units

Table F-4: TWODB Access Frequencies

Data Item	Collecting Agency	Approximate Freq. of Access
stream gaging	TWRC, TWDB, HD	2/daily
reservoir contents	TWRC, TWDB	daily
diversions	TWRC, TWQB, DH	every 10 days
return flows	TWRC, TWQB, TWDB, DH	weekly
Water Quality (Streams & Reservoirs)		
dissolved chemicals	TWQB, TWDB, DH P&W	daily
organic loading	TWQB, TWDB, DH	daily
specific contamination	TWQB, TWDB, DH P&W	daily
water temperature	TWQB, TWDB, DH P&W	daily
Water Quality (Bays & Estuaries		
dissolved chemicals	TWQB, TWDB, DH, P&W	weekly
organic loading	TWQB, TWDB, DH	weekly
specific contamination	TWQB, TWDB, DH,	weekly
water temperature	TWQB, TWDB, DH, P&W	wekely
water circulation	TWDB, P&W	weekly
Diversions		
dissolved chemicals	DH, P&W	every 2 days
organic loading	DH	every 2 days
specific contamination	DH	every 2 days
water temperature	TWQB	every 2 days
Return Flows		
dissolved chemicals	TWDB, DH	weekly
organic loading	TWQB, DH	weekly
specific contamination	TWQB, DH	weekly
water temperature	TWQB, P&W	weekly
sediment deposition		every 2 weeks
sediment transport	TWDB	every 2 days
Quantity of Ground Water Occurance and Availability		
well records	TWDB	weekly
location and extent of aquifers	TWDB	weekly
aquifer characteristics	TWDB	every 2 weeks
natural recharge	TWDB	weekly
natural discharge	TWDB	weekly
Development		
water use	TWRC, TWDB, DH	2/week
water levels	TWDB	weekly
land subsidence	TWDB	monthly
artificial recharge	TWDB	weekly
pollution protection	TWDB, RRC	weekly
Quality of Ground Water Natural Quality		
dissolved chemicals	TWDB, DH, RRC	2/week
temperature	TWDB	2/week
specific contamination	TWDB, DH, RRC	2/week

Key: TWRC - Texas Water Rights Commission
TWQB - Texas Water Quality Board
TWDB - Texas WAter Development Board
HD - Highway Department
RRC - Railroad Commission
P&W - Parks and Wildlife Department

Table F-4: TWODB Access Frequencies (cont.)

Data Item	Collecting Agency	Approximate Freq. of Access
Effects of Development		
dissolved chemicals	TWDB	monthly
temperature	TWDB, DH	monthly
specific contamination	TWDB, DH, RRC	monthly
Quantity and Quality of Mining Effluents		
production	TWQB, DH, RRC, P&W	unknown
deposition	TWQB, RRC, P&W	unknown
Topography		
horiz, and vert. control		monthly
surface mapping including beds of bays and estuaries	TWRC, TWD, HD, RRC, P&W	monthly
Geology		
surface mapping	TWDB, HD, RRD	every 36 hours
subsurface mapping	TWDB, HD, RRC	weekly
Meteorology and Climatology		
precipitation	TWDB, HD	2/daily
evaporation	TWDB	every 36 hours
Temperature		
free air	TWQB, TWDB, P&A	every 3 days
two point	TWDB, P&W	every 3 days
solar radiation	TWDB	every 3 days
Wind Movement		
total	TWDB	2/monthly
maximum	TWDB	2/monthly
direction	TWDB	2/monthly
storms	TWDB, HD	every 2 months
cloud cover		monthly

F.4 MISSOURI'S WATER RESOURCE DATA NEEDS AND THE TEXAS MODEL

Missouri will not share all of the water resource data needs which have been listed for Texas. It will, however, share many of the same kinds of data which have been used in the TWODB. Of the several categories of data needs which are not shared by Texas and Missouri, the most prominent among these are the data which pertain to coastal and estuarine waters. Missouri does not have any coastal areas and consequently does not gather such data. Also, Texas has a well developed information set related to water rights. Missouri has no set legal policy in the area of water rights law and does not currently use data of this type.

Missouri data needs in the water and natural resources area have been inventoried previously by Washington University in the Missouri Natural Resources Data Needs Survey (5) and the reader is referred to that volume. We have reviewed that study for the purposes of this paper and conclude that the Texas Water Oriented Data Base could be adapted to fill the Missouri data needs. However, some further data collection would be required to update the current Missouri holdings and to optimize use of the information system. In Texas, data were added to the bank on the basis of agency established priorities. Start up costs for a data bank including all data now held by TWODB would be prohibitive. However, if data are entered in a step-wise manner start-up costs can be amortized over several years and initial costs can be minimized.

APPENDIX G

COST COMPARISONS FOR THE DAM INVENTORY

A brief cost analysis of alternative techniques for locating water impoundments indicates substantial savings by using LANDSAT as opposed to manual technique of photo-interpretation. Table G-1 presents cost estimates. The costs for a LANDSAT-based system assume the use of ELLTAB (35). Photointerpretation costs are based on an earlier study (1) based on an experimental region covering 10% of the state's area.