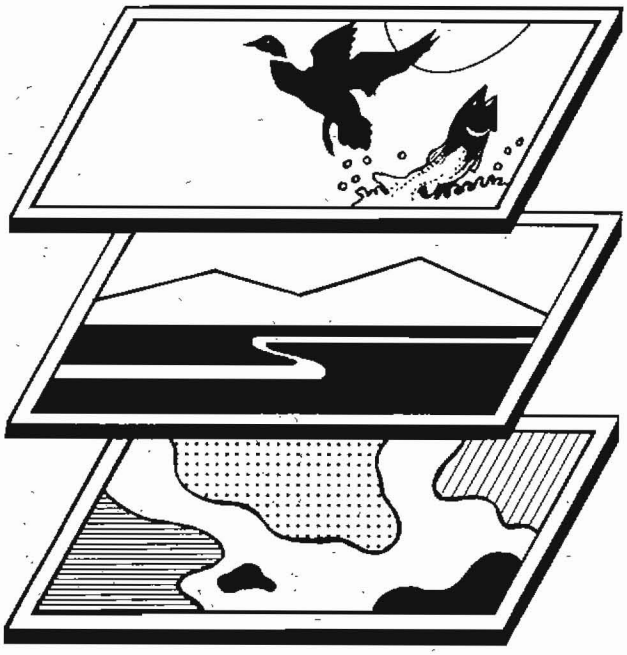
PROCEEDINGS

THE FIRST NATIONAL U.S. FISH AND WILDLIFE SERVICE GEOGRAPHIC INFORMATION SYSTEMS WORKSHOP

June 4-7, 1990



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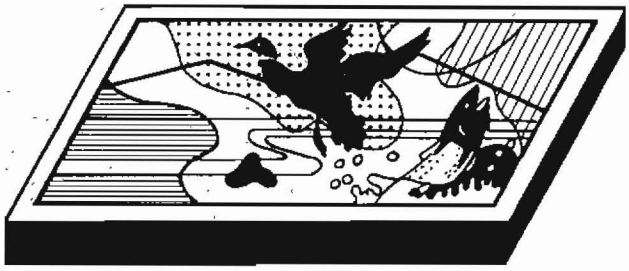

National Ecology Research Center
Fort Collins, Colorado

PROCEEDINGS

THE FIRST NATIONAL U.S. FISH AND WILDLIFE SERVICE GEOGRAPHIC INFORMATION SYSTEMS WORKSHOP

June 4-7, 1990
Fort Collins, Colorado

Compiled By

U.S. Fish and Wildlife Service
National Ecology Research Center
4512 McMurray Avenue
Fort Collins, CO 80525-3400
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PREFACE

The First National U.S. Fish and Wildlife Geographic Information Systems Workshop was held June 4-7, 1990, in Fort Collins, Colorado. The workshop was sponsored by the National Ecology Research Center (NERC). Registered participants numbered over 100 and were representative of a wide array of programs in the Service.

The workshop provided a forum for Geographic Information Systems (GIS) users to exchange ideas and applications directly related to Service research and resource management activities. In addition, participants had an opportunity to contribute to the formation of a GIS implementation strategy proposal. This proposal will be based on the concerns raised and ideas generated at the facilitated workshop, and will be submitted to the Director of the Service for his consideration. Results of the facilitated workshop will be incorporated into a draft strategy proposal, which will be distributed to participants for comments.

The proceedings for the workshop are organized into two sections. Section I includes introductory presentations, an agency report, and summaries of the panel discussion and facilitated session. Section II consists of papers presented at the workshop that were submitted by the authors for inclusion in the proceedings. All papers and introductory presentations are reprinted as submitted, and have not been edited by the compilers. Appendixes to the proceedings include a list of the poster presentations, handouts from the training session, results of a GIS questionnaire, and an outline of group reports from the facilitated session.

Opinions and recommendations expressed in the proceedings for the workshop are those of the authors and do not necessarily reflect the views of the Service, nor does the mention of trade names constitute endorsement or recommendation for use by the Federal Government.

ACKNOWLEDGMENTS

Many people contributed significantly to the success of the First National U.S. Fish and Wildlife Service Geographic Information Systems Workshop. Specific individuals are recognized below.

Special thanks are due Bill Brooks, Chief, Branch of Technical Services, Division of Information Resources Management, Washington Office. Mr. Brooks has been active in promoting geographic information systems (GIS) technology in the Service for a number of years and was an invaluable resource in planning the workshop. We were privileged to have Dr. Douglas Crowe, Special Assistant to the Director, present our keynote address. Dr. Crowe's presentation encouraged the participants to prepare a GIS strategy proposal and present it to the Director.

Several staff members of the National Ecology Research Center (NERC) provided assistance and support. Dr. Rey Stendell, Center Director, and Charles Gish, Leader, Technical Services Section, encouraged and supported the concept of a national GIS workshop. Barbara White, GIS production specialist, provided enthusiastic support, encouragement, and hard work throughout the planning and execution stages of the conference. Jack Hicks, Management Analyst, facilitated the workshop, which proved to be very productive.

NERC has an onsite technical support services contract with TGS Technology, Inc. Several TGS employees at NERC provided technical expertise that greatly contributed to the professional atmosphere prevalent at the workshop. The efforts of Bob Waltermire were greatly appreciated during the workshop and were invaluable during the planning and coordination phases of the workshop. Mr. Waltermire is a knowledgeable GIS applications specialist and served as an effective moderator during the workshop. Tammy Fancher assisted during the planning stages and throughout the workshop. Tom Owens, Larry Robinson, Tammy Fancher, and Randy Black assisted in a tour and demonstrations of GIS operations at NERC. Debbie Pondelek and Dale Crawford provided the graphics for the agenda and logo. Karen Manci compiled the proceedings and edited parts of the introductory section. All their efforts are greatly appreciated.

The conference coordinator at Colorado State University (CSU), Henrietta Cullinane, and her staff, are to be commended for arranging the excellent facilities and attending to the numerous details necessary to make the workshop run smoothly. Special thanks to Dr. Roger Hoffer for arranging a tour of CSU's GIS training laboratory. CSU is fast becoming one of the leading universities offering formal GIS training. The training session on Monday was led by Dr. Joseph K. Berry and provided participants with an entertaining and informative introduction to GIS applications.

Last, but not least, thanks to all the speakers who took the time to prepare and present papers and posters. This sharing of their experiences with GIS technology stimulated further interest and discussion by participants, and was the essence of the workshop.

Frank D'Erchia
Workshop Coordinator

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SECTION I

Agenda

Keynote Address

Opening Remarks

Agency Report

Panal Discussion

Facilitated Workshop Summary

AGENDA

FIRST NATIONAL U.S. FISH AND WILDLIFE SERVICE GEOGRAPHIC INFORMATION SYSTEMS WORKSHOP FORT COLLINS, COLORADO JUNE 4-7, 1990

MEETING ROOM - MARRIOTT HOTEL CENTENNIAL BALLROOM

**** MONDAY, JUNE 4 ****

TRAINING

10:00 a.m. Management Overview of Geographic Information Systems

Joseph K. Berry, Professor, Colorado State University
Fort Collins, Colorado

INTRODUCTION

1:00 p.m. Keynote Address

Douglas Crowe, Special Assistant to Director

1:15 p.m. Opening Remarks: Logistics, Agenda, Objectives

Frank D'Erchia, National Ecology Research Center
Fort Collins, Colorado

PAPER PRESENTATIONS

Moderator - Frank D'Erchia, National Ecology Research Center
Fort Collins, Colorado

1:30 p.m. *Modeling Species' Distributions and Identifying Conservation Priorities with a Geographic Information System*

Bart R. Butterfield, J.M. Scott and B. Csuti
Cooperative Fish and Wildlife Research Unit, Region 8
University of Idaho, Moscow, Idaho

2:00 p.m. *Combined Use of Image Processing and Geographic Information System Technology in Wildlife Management*

Deb Southworth, Refuges and Wildlife, Region 3
Twin Cities, Minnesota

2:30 p.m. *Map Preparation and Cartographic Requirements for Map Digitizing*

Barbara White, National Ecology Research Center, Region 8
Fort Collins, Colorado

3:00 p.m. BREAK

3:30 p.m. *Replacing Rip Cards with a Geographic Mapping System at National Wildlife Refuge Field Offices*

Michael Long, Refuges and Wildlife, Region 6
Denver, Colorado

5:00 p.m. Social - Cash Bar (Marriott Hotel Ganders Lounge)

**** TUESDAY, JUNE 5 ****

PAPER PRESENTATIONS

Moderator - Bob Waltermire, National Ecology Research Center
Fort Collins, Colorado

8:30 a.m. *The Acquisition Priority System in Alaska*

Greg McClellan and D.G. Jerry, Realty, Region 7
Anchorage, Alaska

9:00 a.m. *Automating the Land Acquisition Priority System in Alaska Using a Geographic Information System*

Barry Dearborn and I.J. Wylie
Information Resources Management, Region 7
Anchorage, Alaska

9:30 a.m. *Analysis of Forest Composition and Interspersion for Moose and Black Bear*

Pat Webb and Art Allen
National Ecology Research Center, Region 8
Fort Collins, Colorado

10:00 a.m. BREAK

10:30 a.m. *GIS Applications on the Bear River Migratory Bird Refuge Utah*

Harvey Whitmier, Division of Realty, Region 6
Denver, Colorado

11:00 a.m. *GIS and Remote Sensing Applications on Region 5 Central Zone Refuges*

Bill Leenhouts, Central Refuges, Region 5
Barnegat, New Jersey

11:30 a.m. LUNCH

1:00 p.m. *Habitat Evaluation and Management Strategies Using GIS*

Warren Mangus, National Ecology Research Center, Region 8
Fort Collins, Colorado

1:30 p.m. *Desktop Mapping for Fish and Wildlife Field Office Use*

Ron Osborn, National Ecology Research Center, Region 8
Fort Collins, Colorado

2:00 p.m. *Integrated Information Technology for Natural Resource Management*

Don O. Hunter, National Ecology Research Center, Region 8
Fort Collins, Colorado

2:30 p.m. *GIS at the Charles M. Russell National Wildlife Refuge*

Randy Matchett, Charles M. Russell NWR, Region 6
Lewistown, Montana

3:00 p.m. BREAK

3:30 p.m. *Duck Numbers Estimated from Ground Counts, GIS Data and Aerial Video*

Lewis M. Cowardin, Northern Prairie Wildlife Research Center
Region 8, Jamestown, North Dakota

4:30 p.m. Poster Session

**** WEDNESDAY, JUNE 6 ****

PAPER PRESENTATIONS

Moderator - Frank D'Erchia, National Ecology Research Center
Fort Collins, Colorado

8:30 a.m. *Caribou Movements in Relation to Development Infrastructures*

Christopher Robbins and Dave C. Douglas
Alaska Fish and Wildlife Research Center, Region 8
Anchorage, Alaska

9:00 a.m. *Use of GIS Technology in Addressing Issues in the Gulf of Mexico*

James B. Johnston, Floyd Stayner and Mary Watzin
National Wetlands Research Center, Region 8
Slidell, Louisiana

9:30 a.m. *Status of Geographic Information System Use by the Fish and Wildlife Service in Region 1 and Plans for the Future*

Chuck Houghten, Resource Division, Region 1
Sacramento, California

10:00 a.m. BREAK

10:30 a.m. *Utilizing Geographic Information Systems in Aquatic Resource Management*

Chris O'Bara and Anita Bailey
Tennessee Cooperative Research Unit, Region 8
Tennessee Technical University, Cookeville, Tennessee

11:00 a.m. *U.S. Fish and Wildlife Service Agency Report - GIS Strategy*

William T. Brooks, Information Resources Management
Region 9, Washington, DC

11:30 a.m. LUNCH

1:00 p.m. Panel Discussion

2:30 p.m. GIS Facilities Tours:

- National Ecology Research Center
- Colorado State University GIS Lab

(Limited Sign-up at Registration Desk)

5:30 p.m. Western-Style Barbecue (Marriott Hotel Outdoor Deck)

(Dinner and Entertainment Provided - Cash Bar)

**** THURSDAY, JUNE 7 ****

8:30 a.m. Facilitated Geographic Information Systems Workshop

Jack Hicks, National Ecology Research Center
Fort Collins, Colorado

11:30 a.m. Closing Remarks

TOUR AGENDA

NATIONAL ECOLOGY RESEARCH CENTER GIS FACILITIES TOUR, JUNE 6

3:00 - 3:05 p.m.	Computer Facilities - Tammy Fancher

Group 1

3:05 - 3:20 p.m.	Photo Interpretation Lab - Tom Owens and Larry Robinson
3:20 - 3:35 p.m.	Digitizing - Randy Black
3:35 - 3:50 p.m.	GIS Analysis Demo - Bob Waltermire
3:50 - 4:05 p.m.	Advanced Technology Assessment Section Demo - Don Hunter

Group 2

3:05 - 3:20 p.m.	GIS Analysis Demo - Bob Waltermire
3:20 - 3:35 p.m.	Advanced Technology Assessment Section Demo - Don Hunter
3:35 - 3:50 p.m.	Photo Interpretation Lab - Tom Owens and Larry Robinson
3:50 - 4:05 p.m.	Digitizing - Randy Black

KEYNOTE ADDRESS

By

Doug Crowe
Special Assistant to the Director
Washington, D.C.

First off, let me convey to you my support, and more importantly, the support of Director Turner, in attaining your objectives this week. Beyond the obvious benefits of sharing your collective experiences and comparing methodologies and techniques, you have a unique opportunity. I believe you are operating in a unique environment as far as what's going on in the world at large with the rebirth of an environmental conscience, and in the Fish and Wildlife Service's current efforts towards focusing on a horizon and deciding where it is this organization is going to head in the conservation of the Nation's fish and wildlife resources.

Within that context, you have then a very real opportunity to help shape the future of the Fish and Wildlife Service by providing effective decision-making tools and seeing that those tools are actually used in making resource management decisions. There are a number of success stories you will hear during this workshop.

I was recently at the National Wetlands Lab and I think the National Wetlands Inventory is perhaps the best example that the Department of Interior has of using Geographic Information Systems in monitoring progress towards a national goal: no net loss of wetlands.

The National Ecology Research Center also has provided leadership and support to a wide variety of agencies and organizations in collecting, analyzing, and displaying spatial data. The cooperative efforts of the Alaska Fish and Wildlife Research Center and the Alaska Regional Office over the past few years have resulted in an effective and innovative GIS center, which now supports a wide variety of Service activities.

Obviously, much has already been accomplished. Given the Service's extensive involvement in the development and use of spatial data analysis tools and techniques, I believe we've reached the point where it is safe to say it is no longer in the experimental phase. The time has come to integrate the use of this technology into daily operations.

Your challenge this week is to begin the process of developing a strategy to accomplish this integration. This is no easy challenge. The Service's primary mission is the conservation of fish and wildlife, but our various objectives range from enforcement of the laws and regulations pertaining to game management and endangered species, all the way to the effects of environmental contamination. In this capacity, as we make decisions and develop positions, we increasingly find there are few absolutes. Compromises have to be made, and understandings reached. There are many diverse interests in which we work and to whom we are accountable. In winding our way through that complex morass, we often find our best tool is information. Information that is timely. Information that is accurate. Information that is readily available.

In this context, I find that in this business the vast majority of the decisions that we make rest upon the answer of just two questions: Where is it and how much is there? Whether it is wildlife habitat or the critters--fish and wildlife--that depend upon that habitat, management strategies are devised and decisions are made with those two parameters as their foundation. Where is it and how much is there? Given that those two questions are crucial to resource management decision-making processes, a third factor hangs around the neck of this profession like a millstone. Is this information available to the people making the decisions?

In the everyday crunch of business, which seems to constantly accelerate, decisions have to be made when their time has come. Increasingly, there is no putting it off. No waiting until we gather more information or analyze what information we have. Sound biological data are available in concise and readily accessible terms. Those data will be used. If not, the decisions are made anyway. It is not a matter of choice. Like it or not, that is the way the world works.

With this in mind, we need to ask ourselves if we are doing the best job possible in providing accurate and timely information to support those decisions. My answer is "no" we are not. Given the complexity of the issues we face and the budgetary constraints in which we must work, I cannot be critical, and am not critical, of individual efforts of field biologists and support personnel. We must, however, reevaluate the tools we use, the methodologies we employ in the use of these tools, and the process of conducting research, evaluating habitat conservation measures, protecting endangered species, and all the other myriad jobs we're expected to accomplish. We must view the information we collect as an invaluable commodity: the foundation for decision making in all of the things that we do and the base on which those who follow will build. Unfortunately, much of this commodity is allowed to languish in unusable form and, therefore, never a real factor in the decision-making process. Beyond the printed document, or published paper, and the occasional personal data base, we have made few provisions for means to uniformly organize, store, retrieve, and depict this information, nor have we made provisions to ensure its utilization as a basis for the formulation and implementation of management strategies.

In the words of Strother Martin in the old Paul Newman movie Cool Hand Luke, "What we have here is a failure to communicate." With that in mind, on the closing day of this workshop you will have the opportunity to participate in the process of defining a strategy for the integration of GIS, spatial data collection, and analysis techniques into the operations of the Fish and Wildlife Service. I challenge you to do more than that. I challenge you to go one step beyond that and see that the strategy is actually used to improve our decision-making capacity and enhance our effectiveness as advocates of fish and wildlife resources. I can guarantee that seeing your strategy implemented will be a much more difficult task than devising the strategy. But you can do it and, if you are to be effective, you have to do it because this is America. In the words of Lee Iaccoca, with which I will close, "Nothing happens, until somebody sells something."

So get out there and sell it because you are the wave of the future. You are the data base managers upon which good decisions should rely. Let's see it implemented. I look forward to seeing your strategy at the end of this conference and I urge you to include as part of that strategy your sales brochure for how you will see this implemented in the Fish and Wildlife Service at large.

Thank you.

OPENING REMARKS

By

Frank D'Erchia
National Ecology Research Center
Fort Collins, Colorado

As many of you are aware, geographic information systems (GIS) are being used by almost all federal government agencies and most have a strategy of some sort. The U.S. Geological Survey (GS), Bureau of Land Management (BLM), Environmental Protection Agency (EPA), Bureau of Indian Affairs (BIA), National Park Service (NPS), and the Forest Service (FS) have developed strategies with long-range plans, not to mention commitments of large sums of money to back their efforts. Several agencies have developed Congressional initiatives to procure and support GIS efforts. Proposals for GIS procurements by BLM and FS together total about $500 million, and the EPA and GS have procurements out for GIS hardware platforms.

The Service was one of the first agencies to recognize the usefulness of GIS in land management. An effort in the late 1970's combined the resources of several government agencies to apply GIS technology to manage the resources in northwestern Colorado. This led to the development of a GIS called the Map Overlay and Statistical System (MOSS), which many of you are familiar with. This system was initially developed at the National Ecology Research Center (NERC), formerly known as the Western Energy and Land Use Team. NERC offered training and applications expertise. Data were being digitized around the clock in a frenzy to build extensive data bases at the request of a variety of government agencies. GIS training workshops were conducted on a regular basis, each one full to capacity. It appeared GIS was here to stay. Unfortunately, the Service was in for a rude awakening.

By the early 1980's, other agencies began to develop their own GIS strategies. BLM took over the support for MOSS. The other agencies began to develop GIS strategies internally, many led by people trained at NERC. Data base construction and training activities at NERC gradually slowed down and if it wasn't for a very dedicated and special person, Barb White (who we will be hearing from later), GIS would have disappeared completely from NERC.

You all have different reasons for being here. What is GIS and how can it be useful to Service applications? Those of you new to this technology and who were able to attend this morning's class were given a brief overview of the applications of GIS. The papers and posters presented this week should help to make you aware of additional uses. Others may be here to learn of new applications and take part in developing a strategy proposal. Whatever the reason, it is clear that there is an interest in the Service to acquire and use this computer technology.

On Thursday, we will hear a Service agency report and some thoughts on a GIS implementation strategy by Bill Brooks, followed by a panel discussion during which we will set the stage for the facilitated workshop the following day.

Dr. Doug Crowe's presentation left no doubt that we have the support of the Washington leadership and should convey the message that the Service is finally in a position to take the leap into GIS technology.

If you want to participate in the development of a GIS strategy for the Service, I strongly encourage you to attend the workshop on Thursday.

A number of you have expressed concern regarding the bureaucratic nightmare that could develop with a strategy. I agree there is always that possibility, but we as an agency need to come to grips with the technology before it overwhelms us! The results of the workshop, together with the papers presented, will be distributed throughout the agency. This will be our first opportunity as a collective group to express to management what is desired in the way of support of this technology and how we would like it to happen.

"There are those who make things happen, there are those who watch things happen, and there are those who wonder what happened." We are here this week to make things happen through transfer of technology, our combined ideas, and the resulting report.

AGENCY REPORT

U.S. Fish and Wildlife Service's GIS Strategy

By

William T. Brooks
Division of Information Resources Management
Washington, D.C.

While there is, at present, no robust Service-wide Geographic Information Systems (GIS) program, significant efforts are underway throughout the Service for using GIS. Major centers of GIS support and operational activity include:

The National Ecology Research Center, Fort Collins, Colorado
The National Wetlands Research Center, Slidell, Louisiana
The National Wetlands Inventory, St. Petersburg, Florida
The Alaska Regional Office/Research Center, Anchorage, Alaska

In addition, the Service is represented on the Department of Interior Digital Cartographic Coordination Committee (IDCCC). Claude Christensen of the Washington Office Division of Information Resources Management (IRM) is the Service's representative to the Committee and I am the Service's representative on the IDCCC GIS Working Group. Through the IDCCC, the Service maintains an awareness and involvement in the activities of other agencies and the Department as a whole as they relate to spatial data projects and plans. The Department is represented on the Federal Interagency Committee for Coordination of Digital Cartography (FICCDC) by Lowell Starr of the U.S. Geological Survey. Lowell also chairs the IDCCC.

The Division of IRM's involvement to date in GIS Coordination and Management has been primarily limited to the representation of the Service on the IDCCC, the coordination of Digital Cartographic Products and Support (i.e., OMB Circular A-16), and the review of ADP procurements relative to GIS in excess of $50,000. IRM is also required to perform management reviews of the various centers in accordance with OMB Circular A-123 and other regulations.

Although these efforts are necessary, they do little to provide for those of you embarking upon the use of GIS to perform your jobs in the field. I am cognizant of that, as is Claude Christensen with whom I work closely regarding this and other issues. Claude first proposed the development of a strategic plan for GIS in June 1987, to the Service Directorate. While I won't get into the reasons why this proposal was neither accepted nor implemented, it is obvious that we have been overtaken by events. Given the lack of a strategy, the users of spatial data technologies have proceeded in accommodating their requirements and have to a great extent been successful in spite of us. We have now reached a point where you as users are telling us to provide direction and guidance, and to solicit and obtain management support of this program.

On the closing day of this conference, you will have the opportunity to participate in a workshop and assist in describing where the Service is in implementing these technologies and in defining where we should be in the

future. I have taken the liberty of outlining my thoughts regarding the development of a Strategic Plan, which I will provide to you.

I leave you with these thoughts. The issues are not whether we should use ARC/INFO or MOSS, whether we should buy Apple's or PC's, or whether we should standardize on UNIX or PRIMOS operating systems. These are only tools used as means to an end. We need to define what our ends should be and let these goals determine what tools are best for accomplishing them. GIS is not an ADP or procurement issue. It is a resource management issue. Let us proceed with that in mind.

Strategy Development

Goal:

Develop and promote a strategy for the integration of spatial data collection, analysis, and depiction technologies and methodologies with the operations of the Fish and Wildlife Service.

Objectives:

1. Establish effective representation of the Service by field personnel on the Strategy Development Task Force.

2. Define common concerns and consensus issues that should be addressed by the strategy:

A. Methodologies and techniques--data collection (digitizing, scanning, telemetry, etc.), data assimilation/conversion (integration/merging of existing digital data), analysis depiction/product generation, user interfaces;

B. Data standards--data collection, data assimilation/conversion, classification conventions/standards, data storage (archival and retrieval), data reliability;

C. Technology issues--hardware standards, software standards (commercial and "toolbox"), technology platform levels (PC's, UNIX workstations, minicomputers), acquisition planning; and

D. Support issues--information exchange/dissemination (GIS newsletter), data collection/assimilation, National Digital Data Directory training (coordinate with USGS/NCIC), technology transfer, and end user support, national project coordination (internal and external), commercial market clout hardware/software evaluation.

3. Address concerns with draft strategy plan, circulate for comments, and finalize with endorsements.

4. Sell strategy to Service Management (including, if appropriate and necessary, FY 1993 budget initiatives).

PANEL DISCUSSION

Following the paper presentations and agency report, a panel was selected to represent the Service's GIS community. The purpose of the panel discussion was to stimulate discussion on related topics and narrow the focus of the facilitated workshop to be conducted the following day.

Panel members included the following:

W. T. Brooks,	Division of Information Resources Management, Washington Office, Region 9
B. Dearborn,	Anchorage Regional Office, Region 7
F. D'Erchia,	National Ecology Research Center, Region 8
R. Ducret,	Portland Regional Office, Region 1
C. Houghten,	Sacramento Field Office, Region 1
D. O. Hunter,	National Ecology Research Center, Region 8
B. Leenhouts,	Barnegat Division, Central Zone Refuges, Region 5
M. Long,	Denver Regional Office, Region 6
D. Southworth,	Twin Cities Regional Office, Region 3
B. White,	National Ecology Research Center, Region 8

Frank D'Erchia opened up the discussion with an announcement regarding the evaluation of PC ARC/INFO being conducted at various regional and field offices throughout the country. The evaluation period ends in February 1991 and a report on the results will be compiled from the evaluation reports submitted by the individual sites.

Barbara White discussed the proposed Department of Interior digitizing services contract solicitation currently in progress. There will actually be two separate contracts awarded, one for manual table digitizing and one for automated scan digitizing. Barbara also discussed the Spacial Data Transfer Specifications (SDTS), which is a proposed department-wide standard for exchanging digital cartographic files and associated spatial data. The major thrust for this proposal is through the U.S. Geological Survey. The main emphasis of this discussion was that many proposals for standards and contracts are being made without any, or limited, input by the Service. The bottom line is that whatever decisions are made, the Service will have to live with them unless we become more active as an agency. The GIS strategy proposal should encourage involvement by the Service on any task force making recommendations for proposals that will impact the Service.

Barry Dearborn made several comments on support from the regional offices to field offices. Region 7 has a full staff of GIS specialists in a group under the Branch of Information Resources Management. This group has been very effective in providing support to the field offices regarding training, applications, and user support. However, due to the increasing demands on this group for regional applications, user support to field offices has suffered. Mr. Dearborn's point was that any commitments to user support should not be taken lightly. A great deal of thought and planning and assured commitment by management is required to make the program a success.

Robert Ducret made a short presentation regarding the importance of keeping the communication link open between the GIS community and the surveyors. Surveyors are collecting valuable data that could be integrated into a GIS data base and used for land acquisition and environmental impact

studies.

Workshop participants responded to questions and comments made by the panel on several topics. A show of hands indicated a majority of the participants supported the idea of developing a GIS implementation strategy that focused on user support in the areas of training, applications expertise, and data acquisition. The creation of a technical support center for the Service met with popular approval. A center of this type could provide the support needed throughout the agency very efficiently.

Participants expressed interest in the formation of a task force that would include a representative from each Region who would act as a GIS coordinator for that Region.

The idea of a GIS newsletter was suggested by Bill Brooks and the participants agreed that a newsletter would fill a gap regarding the communication of GIS activities in the Service.

Participants noted that the support for GIS was currently a "bottom-up" approach and support was needed from the "top down."

Participants indicated overwhelming support for the suggestion that a Service GIS workshop be conducted annually.

FACILITATED WORKSHOP SUMMARY

The objectives of the facilitated workshop were to analyze the current status of GIS activities in the Service and to identify issues of concern regarding Service-wide support for GIS. The information generated at the workshop will be used to prepare a strategy proposal for future implementation of GIS in the Service.

Workshop participants were asked to list items related to four topics: (1) internal concerns, (2) internal weaknesses, (3) external opportunities, and (4) external threats. Participants were then divided into four groups and asked to list and categorize items of concern pertaining to their individual agenda topics. Each group elected a facilitator and proceeded to develop solutions to problems identified in each category. Group reports were presented at the end of the workshop. An outline of each group report is included in Appendix D of the proceedings.

Workshop participants will be sent a copy of the draft proposal and will be given an opportunity to comment on it before the final version is formally submitted to the Director.

SECTION II

Papers in Order of Presentation

MODELING SPECIES' DISTRIBUTIONS AND IDENTIFYING CONSERVATION PRIORITIES.

Butterfield, Bart R., J. Michael Scott[1], and Blair Csuti. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, Idaho 83843.

INTRODUCTION

Concern has developed recently about a potential extinction crisis during the next half century driven by massive habitat alteration by humans. Current legal and analytical tools are unlikely to be effective at halting such an extinction episode. New tools are needed that identify and prioritize key areas high in biological diversity for conservation. We are developing one such analytical tool that uses a computerized geographic information system.

BACKGROUND

An estimated 500,000 to 3,000,000 species are likely to become extinct by the end of the twentieth century (review by Lugo 1988). The losses are predicted due to trends in human land-use, especially deforestation, and the associated loss of species. The extinctions are predicted to be particularly severe in the tropics because of the high species diversity, but losses are expected to climb in other areas, too.

A review of extinctions during the last 100 years in the U.S. reveals few similarities among species (Opler 1977). However, habitat alteration or elimination can be implicated as the major, or at least a contributing, factor in the majority of cases. Also, abundance is not an indicator of

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extinction proneness: numbering in the hundreds of millions, the passenger pigeon would have seemed an unlikely candidate for extinction.

A look into the future finds continued pressure on natural habitats as our society continues to grow. While the magnitude of the crisis may be argued, little doubt remains that habitat loss will cause increasingly more extinctions and that the species at risk are difficult to predict.

Our most powerful tool against extinctions in the United States has been the Endangered Species Act. The Act allows for identification of species in imminent danger of extinction and establishes the processes for recovery of those species. By design, it directs a great deal of resources at individual species. Despite the large efforts, the Act has had limited success. In 1989, there were 1071 species listed as threatened or endangered and only 292 recovery plans had been written (Endangered Species Technical Bulletin, Sept.-Oct. 1989, 14(9-10), p. 12). Clearly, the Act has not been keeping up with the growing list of species needing help. As the rate of extinctions increases in the future, it becomes less likely that the Endangered Species Act by itself will be sufficient.

A second approach is necessary that goes beyond endangered species. Preserving entire, functioning natural ecosystems rather than individual species is one way to reduce future extinctions. We are developing a geographic information systems tool called "Gap Analysis" (Burley 1988) to identify natural communities with high biological diversity to receive priority status in conservation. Such an approach would be complimentary to the Endangered Species Act.

GAP ANALYSIS

Using Idaho as a developmental project, our strategy is to use a computerized geographic information system to overlay various mapped themes

of biological diversity with existing protected areas (for more, see Scott et al. 1987, 1988, Davis et al. 1990). Biological diversity can be defined at many levels, from molecular genetics to landscapes. Three common levels that we have chosen to evaluate are vegetation communities, species, and species richness. Any feature of biological diversity not adequately protected represents a "Gap" in the conservation network. The ability to use the computer to produce various combinations of biological diversity themes allows us to identify areas particularly rich in biological diversity to target as conservation priorities.

Existing vegetation was mapped from available information at 1:500,000 scale (Caicco 1989). The existing vegetation includes natural vegetation, potential natural vegetation, and human-modified vegetation. A great deal of data compression is represented at such a small scale, so habitat elements or inclusions that are implicitly present in each vegetation polygon were tabulated. Still, this map represents the most detailed mapping of vegetation ever for the entire state of Idaho.

We identified 376 species of vertebrates that regularly breed in Idaho, excluding fish. Accidentals and species that only overwinter in the state were also excluded. Most species have habitat affinities which, when related to various map themes, can be used to model their distributions. This has three advantages over drawing distributions by hand: 1) reliable extrapolation into unsampled areas, 2) more accuracy to distribution boundaries by using actual habitat boundaries, and 3) it is less time consumptive.

A group of 39 species were selected out as exceptions to the modeling. These species are rare in Idaho and the Idaho Natural Heritage Program tracks them closely. We felt that their distributions could be more

accurately drawn by hand. The remaining species were divided into two major groups, those associated with terrestrial habitats and those associated with aquatic features.

Distributions of the terrestrial associated species were modeled by combining associated vegetation types with known geographic ranges. Vegetation associations were obtained from available literature. Geographic ranges were obtained by using the Idaho Natural Heritage Program county of occurrence database. Relational data files were created for the habitat and county associations and used to assign presence or absence of species to each polygon in a county and habitat map theme overlay.

Distributions of aquatic associated species will be done in a similar method after completion of the necessary aquatic map themes. Map themes currently being built include wetlands, streams, and lakes.

Once built, all the species will be combined into a composite map layer. Each polygon in this map layer will have presence or absence of each species attached to it. The distribution of a single species or any combination of species can then be easily overlayed with the protected areas map theme. Areas of high diversity not in existing protected areas represent key targets for conservation priority.

CONCLUSION

A similar strategy was used by Scott et al (1987) in Hawaii. After extensive surveys they mapped the distribution of endangered forest birds. They then manually overlayed the composite distribution maps with maps of existing protected areas to discover that key areas containing birds were not protected. The discovery resulted in purchase of new protected areas in the most species rich locations.

In our current project, the use of a computerized geographic information system allows us to increase our analysis to an entire state the size of Idaho and to include all vertebrate species not specially adapted to drastically, human-modified environments. We will be able to select a variety of species combinations, as well as existing vegetation for analysis.

Such a system will allow us for the first time to take a multi-species approach to conservation of biological diversity. Besides being more cost effective, our proactive strategy will identify conservation priorities that could ultimately slow the rate of extinction and finally put us ahead of the extinction curve.

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COMBINED USE OF IMAGE PROCESSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY IN WILDLIFE MANAGEMENT

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INTRODUCTION

Geographic Information Systems (GIS) and Image Processing (IP) have developed as complementary processes in the computerized mapping area. While they both deal with computerized map information they have different areas of emphasis and strength. Region 3 is currently looking at three new potential computerized mapping projects. This paper will discuss the different items to consider in choosing between a GIS or IP system, or in deciding to combine the systems, and then illustrate those points with the projects under consideration.

DEFINITIONS

While many definitions can be given for each of the following terms, a repetition here will aid in understanding the discussion. Although the descriptions may sound straight-forward, the continuing evolution in these fields has lead to increasing overlaps in the areas. This variability and constant change should be kept in mind.

Geographic Information Systems have been designed with the analysis of data in mind. They excel in allowing the comparison and combination of multiple layers of data and preservation of the results as new files or hard copy maps. The data may be in raster or vector format (described later) and is usually related to extensive tabular data (attributes).

Image Processing systems have been designed to take graphic data, frequently from satellite data, and assist in the classification and display of that data. They are excellent in applications where frequent data updates are needed. They generally contain export functions to transfer the data into GIS systems for analysis. Increasingly they may be able to take data from sources such as scanned photos or videos (image grabbing) in addition to the traditional satellite sources such as Landsat or Spot. They deal mostly in raster data.

DATA TYPES

Raster data (or grid cell data) has a blocky appearance. Each cell represents an assigned area (one acre, 5 acres, .25 acres, etc). The resolution depends on the original data as well as the application. It is excellent when many layers of data are being compared since the blocks aid in alignment of data and minimize the data slivers that can occur when lining up layers of vector data. It does not present as finished a final map and the data is usually less accurate than vector data since a class has been assigned to each cell along the boundaries of the classes based on the percentage of the class in the cell. For example, a cell may be 50% woodland, 20% grass, and 30% wetland, but be designated as woodland.

Vector data looks like a traditional map, and can be extremely precise. It is composed of polygons (each an area of one type of land classification) and arcs (the lines defining the polygon). Land ownership records are a good example of the type of data that needs this type of presentation. Vector data also gives a very polished final product. Analysis of many layers of vector data, however, does not usually work well as the number of polygons can increase almost exponentially, making for

unreadable maps and data that can not be interpreted. While it is simple to change polygon data to raster data, the reverse does not work as well. Raster to vector conversions retain the blocky appearance of the raster data. This is minimized when the size of the cells is very small compared to the size of the study area.

DATA LAYERS

Many types of data are used in GIS applications. Land use classification and vegetation or habitat types are probably the most common, and can be derived from image processing sources, aerial photos, historic maps, and various other sources. For large geographic areas where data updates will be needed, satellite data are increasingly being used. Technological advances have increased the resolution and accuracy of this data to the point where it provides data accurate to within 10 meters for most ecological types. While low level aerial photos still provide the most accurate data, many applications do not need the precision provided by the photos. Certain developed features can also be identified from data interpreted by an image processor, such as powerlines, roads, water outflows from power plants, etc.

Other types of data are not as readily available from image processing sources. Topography, bathymetry (essentially underwater topography), and soils data are a few of the other commonly used data layers that originate from sources that are not readily input by scanning, video or satellite interpretation. Topographic type data may indeed be input as a series of points that are averaged to fill in the blank areas, transect that are treated the same way, lines, polygons, or cellular data. In this instance the source of the data strongly influences the type of software used.

DATA ACCURACY

Another consideration in choosing both software and data entry methods is the degree of accuracy needed for the project. Legal land ownership records need to be highly accurate; precision limited by the resolution of a screen or most scanners probably will not be acceptable. A simple map showing a record of management on a tract of land, however, may be a prime candidate for scanning or other quick methods of data entry, particularly if it does not need to relate to any other graphic data. If it is a simple tract map now, however, but will eventually be combined with other maps to give a regional view, then the need for accuracy and good geolocation changes drastically. In general it is wise to err on the side of being too precise: data can always be generalized, but cannot be made more accurate after it has been entered.

DATA ENTRY METHODS

Many data entry methods exist today, and the flexibility and accuracy of these methods is constantly increasing. In order to make use of several data entry options on one project it is almost necessary to combine IP and GIS, as the tools and type of data resulting from the tools align fairly naturally with one or the other system. Manually interpreting aerial photos and then digitizing the results is probably still the best know method of data entry, and is still in wide use, particularly when very precise maps or very precise looking maps are needed. The computerized data resulting from this method can be as accurate as the original photos or other data, and yields polygon data.

Satellite data entry is increasing in use as the costs decrease, the resolution increases, and the interpretation methods improve. While this type of data has been used with upland and forestry applications with success for some time, there had been problems with wetland interpretations. Ducks Unlimited has been working with this data extensively over the past few years, and as a result of their

work wetland interpretation accuracy is approaching that available from aerial photos. The result of satellite data entry is raster data.

Scanners are also increasing in use. Either raster or vector data can result from this method of data entry, depending on the original data, the scanner and the software used. A limiting factor in this tool is the resolution of the scanner. A 300 DPI scanner cannot enter data with the accuracy of a good digitizer. Larger, more precise scanners are available, but are still prohibitively expensive for many applications. Once data has been scanned in, the attribute data still has to be manually related to the geographic locations on the map and frequently geographic coordinates need to be entered manually as well. It is at that point that the precision of the scanner and the flexibility of the software in allowing data manipulation become important.

Image grabbing, particularly from video cameras, is also increasing as a method of data entry. This is similar to satellite entry in that an image is frozen and interpreted on the screen. Raster or vector files can be generated. The precision is limited by the quality of the video and the display screen used to 'grab' the image. This, too, is emerging technology.

For satellite, scanning, and image grabbing data entry the major time savings are in the actual entry of the image, not the entry of the related data. The advantages certainly will vary with the visual complexity of the data and the amount of attribute data associated with the files. It may be faster at times to digitize data - each project should be judged individually.

DATA TRANSFERABILITY

Once data has been entered it is important to be able to move it between software packages, and between raster and vector formats. A file may be entered as point data (elevation for example) by digitizing, 'rasterized' and then 'smoothed' to fill in blank spaces, used for analysis in the raster format, and then transfer back to the vector package for final maps and slides.

Frequently data that is used mostly as vector data for display (land ownership for example) will be transferred to a raster format for analysis in combination with other data layers. This is particularly helpful in avoiding the slivers of data that can occur in overlaying polygons of complex data. One example is the attempt to overlay land ownership on the Mississippi River with the land/water interface in one pool. The polygon count went from about 900 to over 3000, using just two layers of data. Although the rasterized version was somewhat less accurate, the map was useable and readable, something that the polygon version was not.

Most good IP and GIS systems today will transfer data between several file formats. They should retain geographic coordinates and accuracy of the data. Even raster to vector can be done successfully if the grid cells are small enough relative to the area of the map.

PROJECT PURPOSES

The purpose of the project also has a strong influence on the type of system used as well as the data needed. There are a number of instances where the main need is a good display of data, either a paper map or screen display. An image processing system, in combination with a good color printer, can give excellent output for demos, tutorials, presentations, and other uses. If the data being displayed does not contain too many layers of data these systems can be used to add updated data rapidly and give high quality maps, slides and other output very successfully.

The opposite end of the spectrum is the project that needs multiple layers of data such as land ownership, vegetation, topography, soils, and then uses that data in various combinations to create

models for wildlife suitability, recreation, site selection, etc. This type of project may begin by accepting some of the data from an image processing system, but needs a good GIS to combine and present the data in a coherent fashion. It is likely that raster data will be needed if there are many layers of data to combine. If frequent updates of data are needed it may be an excellent candidate for using both IP and GIS.

Many applications will fall in a grey area, needing some analysis, possibly a direction relationship with a database to use tabular data, and good output products. Some projects may also be a pilot for larger applications to come. Whenever possible it is best to look at the untimate goal of the project and select the software based on that, rather that changing partway through. There are many products that combine some aspects of both GIS and IP, and the best solution will vary by project.

Other considerations for selecting a system are cost and complexity. Generally image processing systems are more expensive and more complicated. Many of them require two monitors to function and a higher level of computer sophistication to set up. On a tight budget, or with beginning computer operators this may not be a good choice even if it best meets the project objectives. Perhaps a mixture of contracting to obtain the data and using a GIS micro system would be a better alternative to get people going on a project without overwhelming them.

SPECIFIC APPLICATIONS

Region 3 is currently working on several GIS applications. Two of these, Minnesota Valley and Upper Mississippi River, are existing data bases that are being expanded and partially migrated to micro-computers. The Upper Mississippi application will be discussed by other presenters. The Minnesota Valley database is similar, although on a smaller scale. Many layers of data already exist, and the major challenges will be to update and utilize the data. We are working now to transfer the existing data to a PC-ARC format, and possibly to an EPPL7 format, to use in a major visitor center display, and eventually for management analysis. Both precise graphics and intensive analysis will be needed, so it is likely that both vector and raster files will be used. We have not yet decided on the method to update the data. Either satellite or aerial photos would be accurate enough and the deciding factor may be cost.

Agassiz Refuge, in northern Minnesota, is proposing to establish a geographic database. In this case, there is no baseline data. The refuge occupies approximately 100 square miles, much of it boggy and part of it wilderness with no good ground access. We are exploring the availability of landsat data, as there is very little topographic relief to distort the machine interpretation of the data and it will need to be updated in several years to allow tracking of changes. Cross checking of the data after it is interpreted can be done using aerial photos or flying over the areas. A major wildlife fire burned close to a third of the refuge this spring, so it will be a good time to record baseline data and track successional changes. We will probably be using EPPL7, with raster capabilities as well as vector overlays, to run on a micro on the refuge. This is a good example of using an image processing type application (satellite input) combined with a GIS application for analysis.

A second application will be in our ascertainment and planning office, on at least one of the potential refuges we are studying for acquisition. This also will be a tradional GIS type application, with digitized data layers taken from aerial photography, soils maps, and topographic maps. Suitability analyses will form a major portion of the work.

The other new application we are considering is quite different. Due to the Farm Bill, our refuges region-wide have been acquiring many FmHA easements. These tracts of land are small parcels scattered over large geographic areas. Very little GIS analysis is anticipated at this point in time, although managers will need the capability to edit the maps occasionally to record changes to the tracts and may use some of the data for other future applications. It is very similar in nature to the ripcards that are used in many wetland districts to track management on WPAs. We have not made

a final decision yet, but this seems to be a good application to use a combination of scanning and digitizing. A MIPS image processing system is already in use in our wetland districts, and we are exploring the possibilities of using it for entry of the simple management maps. We will also be entering, probably by digitizing, a region-wide map showing all the land ownership for the region. This will be broken down into sections to give each refuge its portion, to assist in locating the parcels and giving a general reference overview. Other layers of data such as scanned aerial photos or county and section lines are possible, and would come from a variety of sources. Generally the layers of data that form the baseline for analysis and for combining different geographic portions of data will be entered in a precise geographic referencing manner. Other layers, such as aerial photos that are only for visual reference on the screen, many be scanned in with somewhat less precision. We are looking at this application as a learning experience for our field people as well as a management tool. Preferably, whatever software and hardware are acquired for this project will also be used for more traditional GIS applications; future expansion and uses form a substantial part of the considerations in making the decision.

SUMMARY

In summary, there are no hard and fast rules for deciding what type of application or data entry method to use. The current and long-term use of the data, the precision needed, the sophistication of the users, the availability of data and capability of verifying it, the frequency of dates and type of product needed are all important and will vary with each application. The best alternative is to first look at the application, define goals for it, and then look at the tools available to best meet those goals.

MAP PREPARATION AND CARTOGRAPHIC REQUIREMENTS FOR MAP DIGITIZING

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An overview of techniques and procedures required for preparing maps and organizing projects for data capture in a GIS was presented. The information will be incorporated into a user's guide or reference manual after further user input and review. Comments, examples, or suggestions for the document are welcome at any time. Plans are to have a draft document by the Second National U.S. Fish and Wildlife Service Geographic Information Service Workshop, tentatively scheduled for June 1991. Input and review of the draft guide will be solicited from participants at the second workshop. The draft guide also will be sent to participants of the first workshop who do not attend the second workshop.

Further information on this project can be obtained from Barb White (commercial phone: 303-226-9297; FTS: 323-5297).

Replacing Rip Cards with a Geographic Mapping System at National Wildlife Refuge Field Offices

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This paper reports on project history and development of a computer mapping project called MapInfo. MapInfo is an "off the shelf" computer software package. This package will provide the tool to allow development of Geographic Information Systems methodology on National Wildlife Refuges (NWR) and Wetland Management Districts (WMD) within Region 6, United States Fish and Wildlife Service (USFWS). Multiple staff from the USFWS are involved in this effort.

The USFWS has direct land management responsibilities at multiple NWRs and WMDs in Region 6. Region 6 involves the states of Colorado, Kansas, Montana, Nebraska, North Dakota, South Dakota, Utah, and Wyoming. Approximately 450,000 acres are in direct fee title and approximately 1.3 million acres in various forms of easement managed by NWRs and WMDs in the Region. Record keeping associated with land management responsibilities is by various paper forms and paper recording systems. Computer technology is in early stages of development on the vast majority of NWRs and WMDs. The basic software packages at all stations include MS-DOS, WordPerfect, dBase III Plus, and Lotus 1-2-3.

Multiple field stations have used a manual record keeping system called "rip cards." Rip cards come in a variety of sizes and preprinted forms. Information is entered manually by typewriter, pen, or pencil. Many preprinted forms allow an aerial photograph to be pasted or photocopied on the card. On the outer perimeter of the card are punched holes. Coding rip cards is accomplished by using a hand-held tool, similar to a hole punch. This tool does not punch a hole, but places a "V"-shaped notch in the prepunched perimeter holes. Notched cards are randomly returned to the deck of cards. Inserting a long needle through a specific hole and raising the cards will result in notched cards falling out of the deck. For example, if cards with a notched portion in a specific location on the card represented males, then inserting the needle through this portions would result in all cards representing males being separated from the deck. The concept allows for a combination of holes to represent various logical combinations.

OBJECTIVES

The objectives of this project include (1) replacing the rip card method with computer concepts and technology; (2) convincing various levels of line authority that GIS technology has immediate value and use on lands managed by USFWS; (3) starting to replace the paper methods of recording and storing data with computer databases; (4) using computer map making, storage, and retrieval capabilities at field stations; (5) starting to learn the use and potential of GIS as a management tool at multiple levels of management within the Division of Refuges and Wildlife; and (6) starting the process of recording previous years data into electronic format.

METHODOLOGY

Various line managers and administrative staff were presented a series of GIS presentations by private entities, college staff, and the National Ecology Research Center (NERC) staff. Conceptual agreement was obtained from those

management officials to pursue GIS technology at field stations. Specific GIS and mapping packages and associated opinions were sought, reviewed, and discussed. Decisions were made that permitted the project to continue utilizing field staff, NERC staff, and Regional Office staff to compose a working group.

A perception during the introduction and commitment to a new technology, is that ignorance is the biggest obstacle. Using GIS technology seems overwhelming. Conceptual acceptance is often part of a feeling that all the knowledge and skill associated with this expertise should be known when accepting the concept and associated technology. Many line officers find it difficult to commit to a technology without their having the expertise, while accepting the concept. It is difficult for many individuals to realize the huge amount of time involved in development.

The constraints and conditions placed before the establishment of a working group included (1) cost factors would be rated highly; (2) the system must operate on a microcomputer; (3) the operating system will be MS-DOS; (4) the system must produce maps at field stations and be used by field staff; (5) the system must have "mouse" capabilities; (6) the system must be associated with a database system; (7) use must be applicable to land management resource problems; (8) the system must be judged reasonable to learn by field staff involved; (9) the feasibility and development process must involve field staff with interest and minimum ADP experience; (10) various zones, within the Region, must be represented; and (11) the system must maximize the use of computer hardware presently at field stations.

Initial efforts between NERC and other members of the working group consisted of education, product evaluation, and consultation. People first starting with a new technology and product are not comfortable. This project was initially started with individuals who consented to contribute effort to the project, but efforts were basically a collateral duty. The technology and learning transfer between NERC staff and others is substantial during early involvement. It is impossible to customize and design software when the precise definition of what is needed is not precisely stated.

COMPUTER HARDWARE AND SOFTWARE

ACQUISITION/JUSTIFICATION/ORDERING PROCESS

Acquiring the necessary software and hardware required writing various justifications and purchase orders. This was done within the Regional Office. The whole justification, approval, and ordering process within USFWS is cumbersome, inefficient, frustrating, and badly in need of overhauling. It is not the people in the system, but the system itself.

WORKING GROUP

Regional Office line authority approved project continuance with a letter authorizing the expenditure of funds was supplied to NERC. Two individuals from NERC were now officially funded and one person from the Regional Office continued coordinating the project. Software customization, by NERC, of MapInfo was expected. All customization and coding is the property of USFWS. The legal ownership of software development within the agency will reduce a multitude of problems over time. Legal ownership by USFWS in any software development project is crucial and advised.

Recruitment of field staff now progressed. Three individuals representing a variety of skills and backgrounds eventually agreed to work on the project as a collateral duty. The first meetings with the working group was to demonstrate the package and decide the feasibility to continue. These individuals were given a presentation of MapInfo capabilities and asked to evaluate future use relative to field station uses and needs. There was agreement among the present six members of the working group that the project should continue.

The first meeting with the working group was to demonstrate the package and decide the feasibility to continue. Additional meetings were for learning, discussion, and development of the items identified for initial development. Again, a primary consideration was to ascertain if the package would fit field station needs.

Each station was supplied a copy of MapInfo and a 12 x 12 inch digitizing tablet. Computers were already at field stations. Individuals were to start learning MapInfo from the documentation supplied. Different microcomputers, all 286 chip series, with various brands of dot matrix printers, were part of the evaluation process. Brand diversity of both microcomputers and printers is common at our field stations. Testing on different configurations was part of the evaluation process. The operating system MS-DOS was common at all stations.

The typical configuration at the field station now consisted of (1) a microcomputer (286 chip), (2) 40 Mega Byte hard disk, (3) 640 to 1 MB RAM, (4) dot matrix printer, (5) MS-DOS, (6) 3 1/2 and 5 1/4 disk drives, (7) color monitor, (8) 101 key board, and (9) software (dBase III Plus, Lotus 1-2-3, WordPerfect). To this base was added (1) one 12 x 12 inch digitizing tablet and (2) additional software (MapInfo, PC Tools Deluxe, New Key).

Though NERC has considerable expertise with a variety of GIS packages, MapInfo was not present in their library. The same version of MapInfo plus MapCode was supplied to NERC. MapCode is a software package used while customizing. It is not expected to be used by field stations. With equipment in place, setting up, learning, and using the software was a very individual thing. The telephone support NERC supplied on helping set up the software, the digitizing tablets, and providing a variety guidance was crucial. Additional support from MapInfo headquarters in Troy, New York, was used. Telephone support played a large part and will continue to play a larger part in project evolution.

During this time, NERC recognized substantial differences that were occurring in the setup of various files by individuals. The need to formulate the standardization procedures was recognized and a start to formalize this procedures was instigated. Start up procedures will be more formalized and standardized as Regional implementation continues.

The NERC staff was not familiar with field operations and responsibilities and field staff were new to GIS technology and NERC skills. The jargon used by individuals with different types of expertise while working together always slows project direction, as well as planning and arranging for meetings at different locations when projects involve individuals from different areas and skills. Travel costs are real and very measurable but are judged necessary for positive end results.

Field staff had been to the NERC office; therefore, the next meeting was held at a North Dakota field station. Focus was rapidly on what each learned and questioning of NERC staff of what they learned, and transferring that knowledge. Various computers from different locations were present at that meeting. Problems occurred spending a substantial amount of time setting up

the machines. Initial meetings on development of uses of a new technology require a greater amount of time than usually expected. A computer should be available for each person during initial meetings. A specific amount of time to set up all the machines should be incorporated into any meeting agenda. Predictions are that this time will be initially underestimated.

Individuals went back to their individual stations to continue working on using the package. The major intent was to start producing some maps using data intended for learning and showing purposes. There was a lull for a time because of the continuing press of the duties for all involved. One field staff member made great strides and started producing a variety of the "show and tell" type maps. Having a color printer at that station substantially added to the accomplishment. Hopefully the enjoyment or pride in that accomplishment equaled mine in showing his products at what was the "first cut" accomplished by a field staff member. With maps produced by field staff as evidence, the Regional Office wanted a demonstration and working session in Denver. A variety of line officers were to attend and question, challenge, and/or support the demonstration.

A presentation to various officials in the Regional Office was given showing examples of maps produced, describing different scenarios for use, and supporting the package and computer mapping concept and use by refuge staff. Unanimous concurrence by the working group regarding the desirable applicability of this product to field station use was given. The decision was made to target the end of Fiscal Year 90 for purchase and/or implementation for other field stations in the Region.

Various database structures were developed and reworked. This continued and another two other individuals were added to the working group. The latest draft is for one database to become the standard when other field stations are supplied copies. The group will finalize on this in late June 1990. As of May 1990, eight individuals will continue work on the effort.

EXPECTED USES FOR MAPINFO

A visual demonstration of the package is presently being shown outside this room by Bruce Tepley.

This package will create maps visually on the video screen and produce working maps for a variety of field stations. Possible maps include a map that is a visual picture instructing maintenance staff where to mow, spray weeds, or carry out a controlled burn; a throw-away map for a visitor; or a multicolored map for use in a public meeting. The electronic filing, storage, retrieval documentation, numeric calculations, and the variety of notes and documentation associated with the operation of field stations will be possible. The evolution from a paper methodology to an electronic methodology capable of producing maps, lists of information, and forms will rapidly evolve.

Field stations will use the following along with the appropriate WHO, WHAT, WHERE, WHEN, WHY, HOW MUCH, HOW MANY, in the following areas:

1) Replace the "Rip Card"

2) Land Management and History such as:
   - Haying
   - Grazing
   - Farming
   - Burning
   - Chemical Applications
   - Others

3) Flora Inventory/Habitats e.g.
   - Wetlands
   - Uplands
   - Timber
   - Grasslands
   - Others

4) Fauna
   - Home Ranges
   - Nesting Sites
   - Dens
   - Others

5) Water
   - Rivers, Streams
   - Ponds, Lakes
   - Depths by Dates
   - Flooding Areas
   - Others

6) Real Property Inventories
   - Roads
   - Trails
   - Bridges
   - Culverts
   - Fence
   - Others

7) Public Use Areas
   - Closed
   - Open
   - Hunting
   - Fishing
   - Others

8) Transportation
   - Highways
   - Railways
   - Rivers Travel
   - Foot Travel
   - Others

9) Land Ownership
   - Federal
   - State
   - Private
   - Easements
   - Other

DATABASE DEVELOPMENT

The development of specific standardized fields of information used by multiple field stations takes time. Knowledge and expertise in present management managerial positions does not guarantee immediate insight and knowledge of database systems and GIS concepts and use. Standardization of files and structures followed by identifying those areas of uses, which will be needing to match up with other divisions, plus identifying and becoming knowledgeable of other sources of public and private electronic data will continue to receive increasing amounts of attention and effort.

TRAINING IN MAPINFO

Training will be provided field stations shortly after software delivery. Some combination of NERC, USFWS, and MapInfo Training staff will evolve. Two to three days of training is expected for each user. Telephone communications are no substitute for meeting as a group, but can and is used as a training support. Electronic mail is another tool in the training process. Learning and training efforts are constantly underestimated. The cost of training is not nearly as high as the cost of ignorance.

The Working Group is presently arranging to have training provided by the MapInfo staff. The initial effort will be to train FWS trainers by MapInfo staff. A specific training schedule will be established for future users after initial training by the Working Group.

FUTURE SUPPORT

The questions of future support and maintenance of customized programming, done by NERC, has not been fully resolved. Continued developed of other themes and uses will likely occur. The transfer of knowledge and expertise by NERC staff to the Regional Office and field staff is the goal over the longer term. Additional development is expected over time by NERC. After a variety of stations comment, criticize and complement, the next development phase will be better for the varieties of input expected.

DATA IMPORT/EXPORT

Electronic importing and exporting of data from and to MapInfo will receive increased attention and focus over time. Using the expertise present at NERC, MapInfo data can be imported and exported to ARC/INFO, MOSS data, and National Wetland Inventory (NWI) data. The knowledge of exactly where electronic data is both stored, present, and accessible to individuals on refuge field stations is judged poor. A substantial amount of knowledge needs to be gained and shared in locating sources of electronic data that can be purchased, obtained, shared, or transferred among stations.

Stations are not equipped to do any large scale digitizing nor do these stations wish to become so equipped. The digitizer present is intended more for small modifications and changes.

CONFIGURATIONS AND COST ESTIMATES FOR FIELD STATIONS

	LOW	MEDIUM	HIGH
80386 SX CHIP	X	X	
80387 SX MATH COPROCESSOR		X	X
80386 CHIP			X
80387 MATH COPROCESSOR			X
MEMORY - 1MB	X	X	X
40 MB HARD DISK	X		
100 MB HARD DISK		X	X
3 1/2 INCH DRIVE	X	X	X
5 1/4 INCH DRIVE	X	X	X
COLOR MONITOR	X	X	X
101 KEY BOARD	X	X	X
ESTIMATED COST	$4,000	$4,800	$5,500

ESTIMATED COSTS

MapInfo Version 4.0 (Retail/Copy)	$ 750.00
PC Tools Deluxe LATEST VERSION	$ 60.00
New Key	$ 60.00
Digitizing Tablet	$ 600.00
DOS 4.1 - Supplied with new machines, else buy	$ 150.00
CUSTOMIZING Menus and Keyboard Macros Utilities/Public Domain Utility Package supplied by NERC as part of development costs	$0000.00
Sub Total	$1620.00
Training if done by MapInfo staff - 2 day session - 8 hours per day Must have 3 or more people at $500 per person	$ 500.00
Training done by FWS core working group	$0000.00
Travel/Per Diem to training site/person 4 day travel status	$ 900.00
Estimated cost of Training per person	
Sub Total	$1400.00
Estimated cost to a station with a computer	$3030.00

NERC INVOLVEMENT

Initial contacts were substantial but not charged to our budget. Charge authorization by NERC started in March 1989 and continues. Initial scoping was very general but allowed the process to continue. This allowed either party to disengage itself without long-term commitments and financial obligations. As project development continues the scoping process should become more technical and precise.

As individuals learn more, they ask for more and expect more then was originally envisioned. Be aware and careful of overselling results during the demonstration process. The human mind conceptualizes brilliantly. Implementation of those concepts to an operating program is not a simple task. Many individuals feel that analysis, synthesis, and synergistic effects will all come from writing a few computer programs and hitting a few keystrokes.

Involvements with NERC are encouraging because (1) expertise and experience exists in the GIS arena; (2) the staff has a strong biological background; (3) knowledge of FWS procedures and protocol exists; (4) maintaining a central point of institutional knowledge for this expertise exists within the Service; (5) any software developed is owned by USFWS; (6) contracting formalities are reasonable; (7) a Service, not a corporate motive, drives them; and (8) NERC has treated us well.

PROBLEMS

It is recognized that the following areas have all sorts of options for a possible, partial, or complete solution. However...**FORE WARNED IS FORE ARMED.**

Problems include:

(1) The hardware/software ordering process.
(2) The time conflict with other established duties.
(3) Distance between committee members.
(4) The behavioral problems of learning a new technology by a group.
(5) The pro and con of justifying between similar programs.
(6) The rapid rate software manufacturers produces newer versions, and maintaining standardization among a unit.
(7) Stronger leadership from the Washington level in terms of standardization, ordering process; the USFWS goes as many ways as there are Regions.
(8) Convincing line authorities to support technologies, new to USFWS, but commercially available and established.
(9) Standardization versus individual creativeness: the dilemma of making positive movement by a few or a larger unit.
(10) Planning for the inevitable connection between present and future electronic databases.
(11) Identification and location of established electronic information, public and private.
(12) Moving all the information and skill to field stations.

There is no lack of problems, just solutions.

ACKNOWLEDGEMENTS

Frank D'Erchia and Bruce Tepley
National Ecology Research Center (NERC)
Fort Collins, Colorado

Thad Fuller
Medicine Lake National Wildlife Refuge
Montana

Dick Gilbert
Waubay National Wildlife Refuge
South Dakota

Ted Goodski
Des Lacs National Wildlife Refuge
North Dakota

Jon Kauffeld
Rainwater Basin
Nebraska

Michael Long
Refuges and Wildlife
Denver, Colorado

Gene Mack
Bismarck Wetland Habitat Office
North Dakota

Sue Zirbes, Chief
IRM
Denver, Colorado

THANK YOU FOR LISTENING

QUESTIONS

BIOGRAPHICAL SKETCH

Michael Long has been with the Service over 20 years. Before coming with the Service, he was a computer programmer. His automatic data processing skills were rarely used while he served at Tishomingo NWR in Oklahoma, Bear River Migratory Bird Refuge in Utah, and Flint Hills NWR in Kansas. The title he prides most in his service career is Refuge Manager.

One of his goals in the Service is and has been that of "Marrying computers with refuge management."

He has been in the Denver Regional Office for the past 5 years and is a member of the group working on the "MapInfo Project."

4 June 1990
Danielle G. Jerry
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THE ACQUISITION PRIORITY SYSTEM IN ALASKA

Danielle G. Jerry, U. S. Fish and Wildlife Service, Anchorage, AK 99503

ABSTRACT

In response to the Alaska Submerged Lands Act of 1988, Region 7 of the U.S. Fish and Wildlife Service (Service) had one year to establish acquisition priorities for 23 million acres of inholdings in Alaskan national wildlife refuges. A team of five biologists from the Division of Realty were assigned to the project. The team worked with computer specialists from Information Resource Management and staffs of each refuge to develop a model to assess refuge resources and management concerns.

Seven resource and three management concern criteria were identified. These criteria were subdivided and values were assigned to each resource or management concern. Resource data on wildlife and fish species and areas with other management concerns were mapped and digitized into ARC/INFO. Land status records from the Bureau of Land Management's Alaska Automated Lands and Minerals Record System were programmatically converted from a tabular database to ARC/INFO.

Data for resource criteria were joined with management criteria data, and then intersected with land status information. Federal lands were dropped from the model leaving private lands overlain with the unioned criteria. Resource and management criteria values were totalled by polygon. Management determined that criteria values would be ranked by high, medium, and low. Inholdings were divided into high, medium and low acquisition priority based on criteria score. One third of all inholdings were placed in each priority.

BACKGROUND

The Alaska Submerged Lands Act

The Alaska Submerged Lands Act of 1988 clarified policy for conveyance and ownership of non-navigable submerged lands to Alaska Natives, Native corporations and the State of Alaska. That would make land conveyance rules used in Alaska similar to those used in the Lower 48 states. In addition, Section 103 of the Act mandated that the Secretary of the Interior prepare a report on the effects of the Act and to "establish priorities for the acquisition of lands currently patented to or selected by a Native, Native corporation or the State that are within the boundaries of Conservation System Units." The four agencies affected are Fish and Wildlife Service, National Park Service, Bureau of Land Management, and Forest Service.

U. S. Fish and Wildlife Service (Service) was one of four land management agencies affected by the Act. The Service manages approximately 77 million acres in 16 national wildlife refuges in Alaska. These 16 refuges, which were either created or expanded by the Alaska National Interest Lands Conservation Act (ANILCA) in 1980, include about 23 million acres of inholdings owned largely by Natives and Native corporations. There are 97 village corporations owning or claiming lands within the boundaries of these refuges. The number and size of these inholdings

are significantly more and larger than found within Conservation System Units managed by the Park Service, Bureau of Land Management or Forest Service.

In order to meet the report requirements of the Submerged Lands Act in approximately one year's time and still maintain a level of objectivity, the Service chose to use a geographic information system (GIS) to model acquisition priorities. The model rates areas based on a combination of resource values and management concerns of the refuge. This paper describes the model and process.

Previous Acquisition Planning Efforts

Prior to the passage of the Submerged Lands Act, the Service had assessed inholding priorities in Alaska on several occasions. In 1983, a generalized inventory of inholdings was conducted to identify broad priorities for acquisition. This evaluation ranked inholdings within loosely defined habitat categories. Inholdings were not evaluated on a statewide basis. In 1985, the Service inventoried all Native corporation owned inholdings on Alaskan refuges and evaluated them as a priority for acquisition, suitable for acquisition or not suitable for acquisition. Those inholdings designated as a priority for acquisition were then evaluated by a Region-wide panel of biologists and refuge managers on the basis of ten resource and management criteria. Efforts were frustrated by the lack of resource data on the newly established or expanded refuges, lack of a clear definition of priorities, and lack of a mandate to complete the task. In addition, these evaluations, although adequate at the time, need updating and are generally considered too subjective and broad in scope to respond to the specific information required by the Submerged Lands Act

From 1985 through 1988, the Department of Interior proposed a large land exchange with six Native groups. Native inholdings on seven Alaskan refuges would be exchanged for oil and gas rights on the Arctic National Wildlife Refuge. This highly controversial exchange was the subject of an unfavorable Government Accounting Office (GAO) report and has never been finalized. The procedure for selection of lands to be acquired by the Service was one of the criticisms levied against the Department of Interior by GAO. Congress prevented consummation of that land exchange in Title II of the Alaska Submerged Lands Act.

In addition to these major efforts, several refuges have ranked acquisition priorities within their boundaries on different occasions.

METHODS

Development of the Acquisition Priority System (APS)

The Submerged Lands Act provided a mandate for the Service to complete an acquisition priority list in Alaska. Since the creation and expansion of national wildlife refuges in Alaska in 1980 by ANILCA, a considerable body of wildlife and fisheries information has been collected. In addition, preparation of comprehensive conservation plans for all Alaskan refuges has provided an information base upon which to evaluate private and State inholdings.

The Division of Realty team assigned to this project considered using an existing national planning process, the Land Acquisition Priority System (LAPS). However, that system was not designed to handle the scale of effort needed in Alaska. There are more acres in inholdings in Alaskan refuges than there are federal acres in the national wildlife refuge system in the lower 48 states. LAPS, the national system, is designed to rank relatively small parcels which have been identified for acquisition. Often, specific resource inventories have been conducted on these individual parcels. In Alaska, the large acreages involved would require preparation of an unmanageably large number of parcels of mixed ownership where resource values have been extensively, but not intensively, analyzed. That system

would be difficult to update because of the large parcel sizes. LAPS will ultimately be used on individual parcels to compete for acquisition funding. But, because of the number and size of inholdings, it was not suitable for this project.

The decision to use a GIS to rank acquisition priorities instead of a more subjective review of inholdings as had been used in the past was made: 1) to minimize the subjectivity of earlier acquisition priority efforts; 2) to allow for easier updating of priorities in the future; 3) to meet the short deadline with a degree of replicability; and 4) to provide a refuge resources database for continuing use by managers and other wildlife resource specialists in the Service in Alaska.

Using a GIS created two immediate and distinct problems. First, criteria had to be developed to objectively evaluate acquisition priorities based on national Service direction and also on specific Region 7 issues. These criteria had to be combined into a model which would ultimately allow comparison of thousands of units of land across 16 Alaskan national wildlife refuges as to their priority for acquisition. Secondly, a method had to be developed to efficiently convert land status information maintained by the Bureau of Land Management in a combination of automated tabular format and manual card files into a GIS.

Although it was not feasible to use the national LAPS model in total, we were able to incorporate ideas from that model in the development of criteria along with criteria derived from previous priority systems in Region 7.

These criteria were combined into an Acquisition Priority System (APS) model that was then critiqued and modified by the refuges, as well as by the Regional Directorate. The final criteria and model allows consistent application across all refuges (Table 1).

DEVELOPING THE DATABASES

Acquisition Priority Criteria

Table 1 displays the seven resource and three management criteria used in the acquisition priority model. A maximum score is established for each criterion. Criteria are subdivided into categories which are generally wildlife species for the resource criteria and management issues for the management criteria. Categories are subdivided into mappable units of measure (classes) usually based on population densities or areas where a specific management problem exists depending on the type of criteria. Population densities were used as a basis for the priority system because of availability of data. It was assumed that population and density data taken over a period of time will reflect habitat quality.

Maximum criterion scores are also subdivided. Point values are assigned at the lowest level, i.e., category or class. How categories or classes values are totalled into individual criterion scores varies somewhat by criterion. Generally, a polygon is assigned either the highest category score for a criterion or the total of all category scores for a criterion.

An individual species is usually included in two criteria. A species is mapped in one of the five individual species criteria, and also included as part of one of the two diversity criteria. The two diversity criteria total number of and habitat quality of species found in one area. This score is then calibrated across all refuges on a 1 to 20 basis.

Table 1. Acquisition Priority System Criteria: Criteria Basis and Maximum Points

Resource Criteria	Criteria Basis	Maximum Points
Threatened and endangered species	Statutory mandate for protection. Derived from national Land Acquisition Priority System	20
Migratory birds		30
Diversity of upland species		20
Diversity of wetland species		20
Marine mammals	Statutory mandate for protection	20
Resident refuge purpose species	Derived from 1985 Regional priority system	10
Fisheries		10
Subtotal		130
Management Criteria		
Public use	Derived from 1985 Regional priority system	25
Refuge management, i.e., capacity of acquisition to enhance management of existing refuge lands		10
Ability of acquisition to reduce threats	Purpose of Acquisition	30
Subtotal		65
TOTAL POSSIBLE SCORE:		195

Criterion 1. Threatened and Endangered Species.--This criterion refers to use of refuge lands by one of the three species listed under the Endangered Species Act that use Alaskan refuges for part of their habitat needs. Scoring is based on the degree of use by the species. For example, a known peregrine nest with a one mile radius buffer is assigned 18 points while areas that are casually used by the birds are rated 2 points. Scores are cumulative with a maximum score of 20 points.

Criterion 2. Fisheries.--This criterion addresses the conservation of fish populations and habitats listed in ANILCA as a purpose of each of the refuges. Emphasis is placed on salmon whose conservation is specifically listed in ANILCA as a refuge purpose of 13 of the 16 refuges. The number of points assigned to this criterion (10) is the same as for resident, refuge purpose species. Fewer points are given these two criteria than for the first 5 criteria because management responsibility is shared with the State of Alaska. Furthermore, most of the fisheries habitat involved is in navigable waters owned by the State. The federal government will not purchase these waters. Scores under this criterion depend on the diversity of fish species, particularly salmon, and escapement or size of the total salmon run in the watershed. It was not practical to delineate individual rivers, streams or lakes for this project because of short time frames and because many of these waters are state-owned navigable waters and generally not acquirable. Therefore, we mapped refuges on a gross scale, i.e., watersheds, and subsequently ranked watersheds based on their fisheries values.

Criterion 3. Migratory Birds.--Certain species covered by the Migratory Bird Treaty Act and given management priority by the Service are included in this criterion. Three groups of migratory birds are considered in descending priority order: 1) special concern species as identified in the North American Waterfowl Management Plan; 2) individual species whose conservation is listed in ANILCA as a purpose of an Alaskan refuge; and, 3) species groups whose conservation listed in ANILCA as a purpose of an Alaskan refuge. Special concern species clustered in group 1 were further ranked in priority based on relative population status and trend. Species with depressed or declining populations were assigned higher points. The three general groups of species are then subdivided into categories (species), and points are assigned based upon high, medium or low densities of birds, or habitat values. Points are not cumulative among categories. The point score for a specific area was based on the highest ranked category, i.e., species, found on that area.

Criterion 4. Diversity of Wetland Species.--This criterion used in conjunction with Diversity of Upland Species rates wildlife habitats by measuring numbers and relative abundance of targeted species using the area. These two criteria are meant to measure the success of the long-standing habitat protection mission of the Service. Species considered in Criterion 4 are wetland-based migratory birds (including seabirds), furbearers, and fish. Species are clustered into three groups based on Service management priority: special concern species, resident ANILCA refuge purpose species or national resource species as defined in a previous planning effort, fish, and wetland furbearers, and other waterfowl species. Points for bird and mammal species are assigned by density in the individual species criteria. However, points are cumulative on an area, with higher point scores going to areas with a high diversity or abundance of species of management concern. When all refuges are mapped total scores for an area are compared statewide and calibrated on a scale of 0 to 20.

Criterion 5. Marine Mammals.--Land-based habitats of marine mammals protected by the Marine Mammals Protection Act are mapped under this criterion. Species are ranked and assigned points based on population status and density of use. Fur seals and sea lion rookeries and haulouts are highest ranked because their populations are declining and their land-based habitats may be used by dense

concentrations of animals. Scores for an area are not cumulative, but are based on the highest ranked species using an area.

Criterion 6. Resident refuge purpose species.—This criterion addresses Service management responsibilities for resident species whose conservation is listed in ANILCA as purposes of the refuge. The list of species varies by refuge. Resident species are considered in this criterion only if listed in ANILCA. Lesser weight is given to this criterion since management responsibility for resident game is shared with the State of Alaska. Species are mapped based on high, moderate or low densities. Scores for overlapping species distribution are not cumulative. If there is more than one refuge purpose species found in an area, the area was rated according to the highest class value given to one of the overlapping species.

Criterion 7. Diversity of Upland Species.—This criterion measures wildlife habitat values in non-wetland areas by assessing diversity of species. Non-migratory birds, migratory non-wetland birds, and resident mammals, which are all also mapped as individual species under the criteria for endangered species, migratory birds, resident refuge purpose species, and marine mammals are included in the diversity calculation. These species categories are subdivided into classes by species density and/or habitat quality and points are assigned as in the individual species criteria. However, points are cumulative on an area. When all refuges are mapped, total scores for an area are compared statewide and calibrated on a scale of 0 to 20 points.

Criterion 8. Public Use.—This criterion addresses public use objectives and management responsibilities of the Service as outline in ANILCA and the Refuge Manual. Public use is divided into two categories, subsistence and recreational use. Points are cumulative between the two categories with a maximum allowable point score of 25 allowable for any one area. Subsistence use is mapped and assigned points based on density (number of villages using an area), seasonality of use, and number of different uses an area receives. Recreational use is also assigned points based on density of use, not on quality of recreational experience.

Criterion 9. Refuge Management.—This criterion refers to the probability that acquisition will enhance management of existing refuge lands. Access and fire management options are examples of non-resource issues that may be significantly impaired by private ownership. Points are assigned to lands whose continued private management may hinder federal management or effectiveness of adjacent refuge lands.

Criterion 10. Ability of Acquisition to Reduce Threats.—This 30 point criterion evaluates whether or not acquisition will significantly reduce or eliminate threats to the fish and wildlife resources of an area. This criterion can be an overriding consideration for acquisition depending on the significance of the threat. Threats are judged by individual refuge managers with the concurrence of the Regional Director.

Land Status

Concurrent to developing the APS model and mapping resource values and areas of management concern, another major effort was ongoing to programmatically convert the Bureau of Land Management's (BLM) tabular formatted Alaska Automated Lands and Minerals Record System (ALMRS) into ARC/INFO. The Submerged Lands Act specified that all selected or conveyed Native, Native corporation and State lands were to be ranked in priority for acquisition.

Ownership patterns in Alaska are still fluid. Four acts, the Native Allotment Act of 1906, the Alaska Statehood Act of 1958, the Alaska Native Claims Settlement Act of 1971, and the Alaska National Interest Lands Conservation Act of 1980, determined most land entitlement in the state. However, the selection and conveyance of these entitlement from the public domain into State, Native

corporation, or individual Native ownership is an ongoing process managed by BLM. Although the outer boundaries of the national wildlife refuges were set by Congress and most Native corporation inholdings have been conveyed, many conflicting claims, overselections and other land status problems exist. In addition, BLM's AIMRS was not current for refuge lands. Dearborn and Wylie's companion paper on APS will detail the methodology used to deal with these issues and the conversion of BLM's AIMRS database into the Service's ARC/INFO land status database. A consequence of using the AIMRS database was that inholdings were located only to section level. As a result, the entire APS model is valid only to the section level and sections of mixed federal/private or State ownership are included within the priority rankings.

THE MODEL

How the Acquisition Priority System Works

Analysis of acquisition priorities begins with the gathering and mapping of fish and wildlife data for resource criteria 1 through 7 and management information under criteria 8 to 10. This information is hand mapped (usually for the entire refuge) in coordination with refuge staff and other Service personnel.

The hand drawn maps are digitized and, with related attribute tables, are entered into ARC/INFO. ARC/INFO allows concurrent manipulation of spatial data (maps) and attribute data (verbal or numerical descriptions). See Figure 1. The result is a set of layers of mapped resource information in ARC and verbal and numerical descriptions in INFO. Each criterion represents one layer in the model.

Numerical scores are assigned in INFO to the classes (species densities for the wildlife criteria or management issue level for the management criteria) which are mapped in ARC according to the guidelines established for that criterion. These individual resource or management use maps with their associated point values are combined to generate a criterion map with a maximum number of points as indicated in the model (Table 1). Each criterion is justified equally across all refuges. For example, high density, such as four moose per acre, will rate the same number of points on each refuge.

Once all criteria are computer plotted, they are overlain on each other. This process creates in ARC a single map with many polygons created by the intersection of the criteria maps (Figure 2). At the same time, in INFO, the program automatically totals the point values for overlapped criteria in each polygon.

Combining APS and Land Status Databases

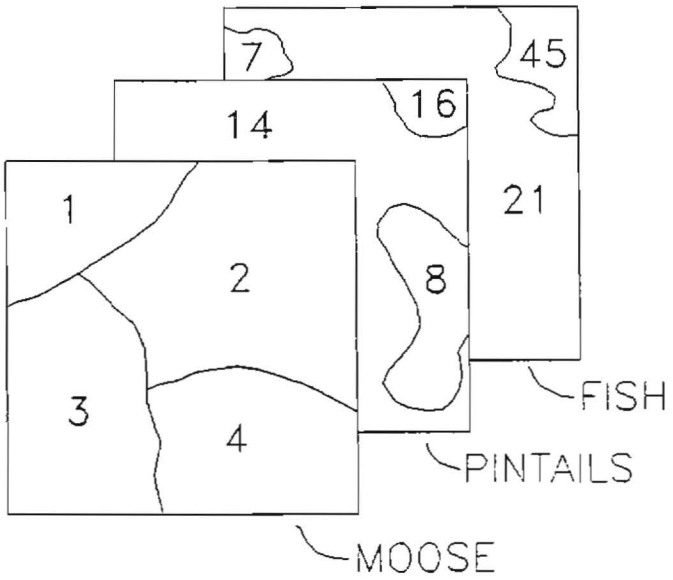
The 10 individual criteria maps for each refuge are unioned together to create a map of the entire refuge divided into polygons with an associated final criteria score. This map is then overlain on a map depicting land status and federally owned lands are eliminated (Figure 2). The remaining State or privately owned or selected areas are then ranked in priority according to the totalled values of the resource and management criteria. Priority listings of inholdings were first done within a refuge, then among all Alaskan refuges.

Finally, a determination of high, medium and low priority statewide was made. Although the ARC/INFO APS model can list areas in numeric priority order, the precision level of both resource and land status data is such that a high, medium, or low ranking system was more appropriate for this first ranking. It was a management decision to rank inholdings into three groups of approximately equal acreages (Figure 3). The actual divisions were made by total criteria point score, and consequently the high, medium, and low acreages are not equal (Figure 3).

When all information is entered into the system, a parcel may then be identified based on similarities in selected resource values, ownership or other factors deemed appropriate by managers or planners. Points assigned to that area are then

Figure 1. Understanding ARC/INFO

ARC: manipulates coordinate or spatial data

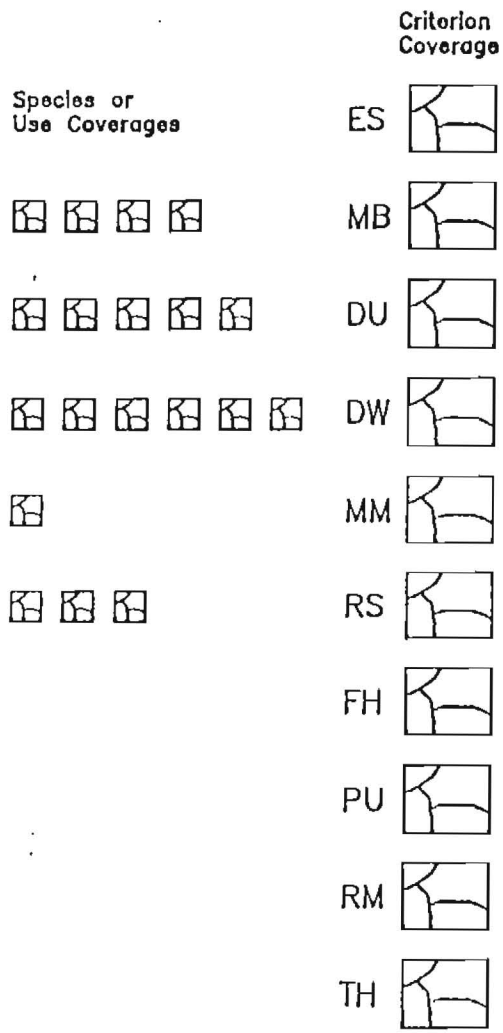


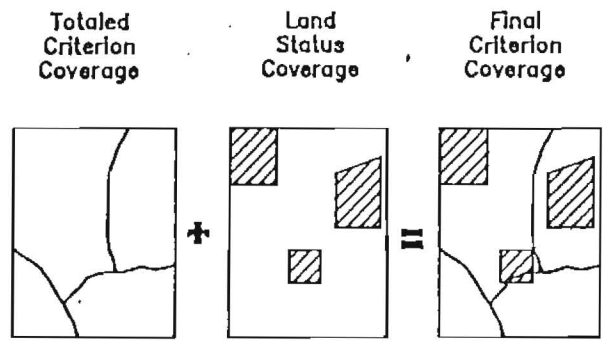
INFO: manipulates attribute data

MOOSE:

ID (Area)	Attribute 1 Category	Attribute 2 Density
1	A	High
2	B	Low
3	C	Moderate
4	D	None

Figure 2
ACQUISITION PRIORITY MODEL





And finally, parcels remaining are ranked in priority according to the sum of criteria points.

Date: May 30, 1990
Graphics by: Div. Of Realty

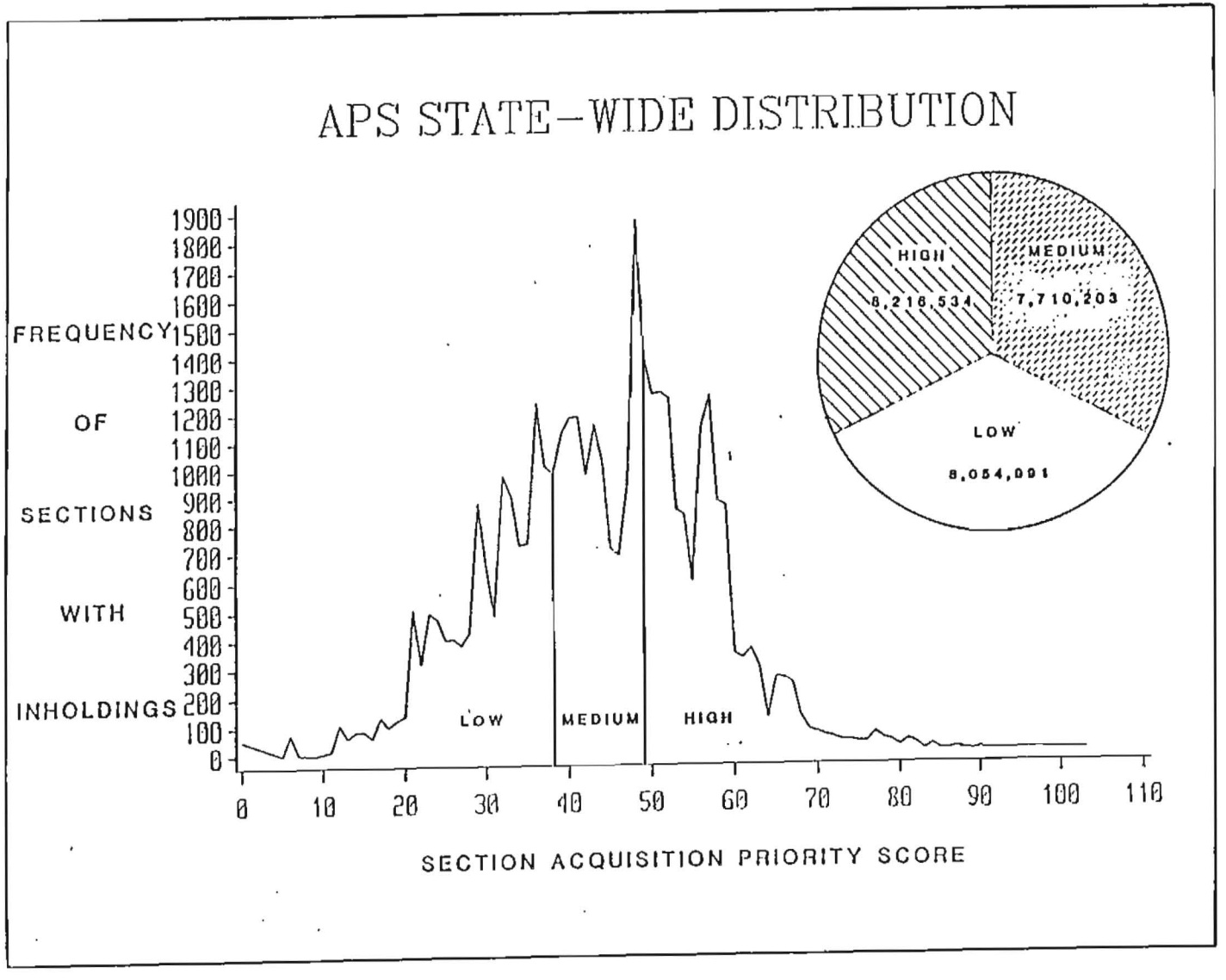


Figure 3 FREQUENCY DISTRIBUTION : Sections with Inholdings by Acquisition Priority System

totalled to arrive at a priority score. Final maps for each of the 16 refuges depict acquisition priority rankings of high, medium, or low for all inholdings, e.g., Figure 4.

RESULTS

Acquisition priorities were determined on about 23 million acres of inholding in 16 national wildlife refuges using the APS models. Approximately 38,000 sections of land were ranked either high, medium, or low priority for acquisition. Two runs of the APS model were made prior to publication of the results in the Draft Submerged Lands Act Report. Several minor changes in the model were made after the first run, criteria mapping standards were made more uniform, and several changes had to be made in the land status database to take into account overselections and multiple selections of the same area. After public review of the Draft Report, two additional changes were made in the APS model. Corrections of the land status database continued up to printing of the Washington Office review draft of the report. The entire process from development of criteria to running the final version of the APS model on the Regional Office's Data General MV8000, a mini-computer, took slightly over a year for about 10 people in the Divisions of Realty and Information Resource Management. The final run of the model necessitated removing other users from the computer for about a month in order to make corrections and to reunion the various layers of the model.

DISCUSSION

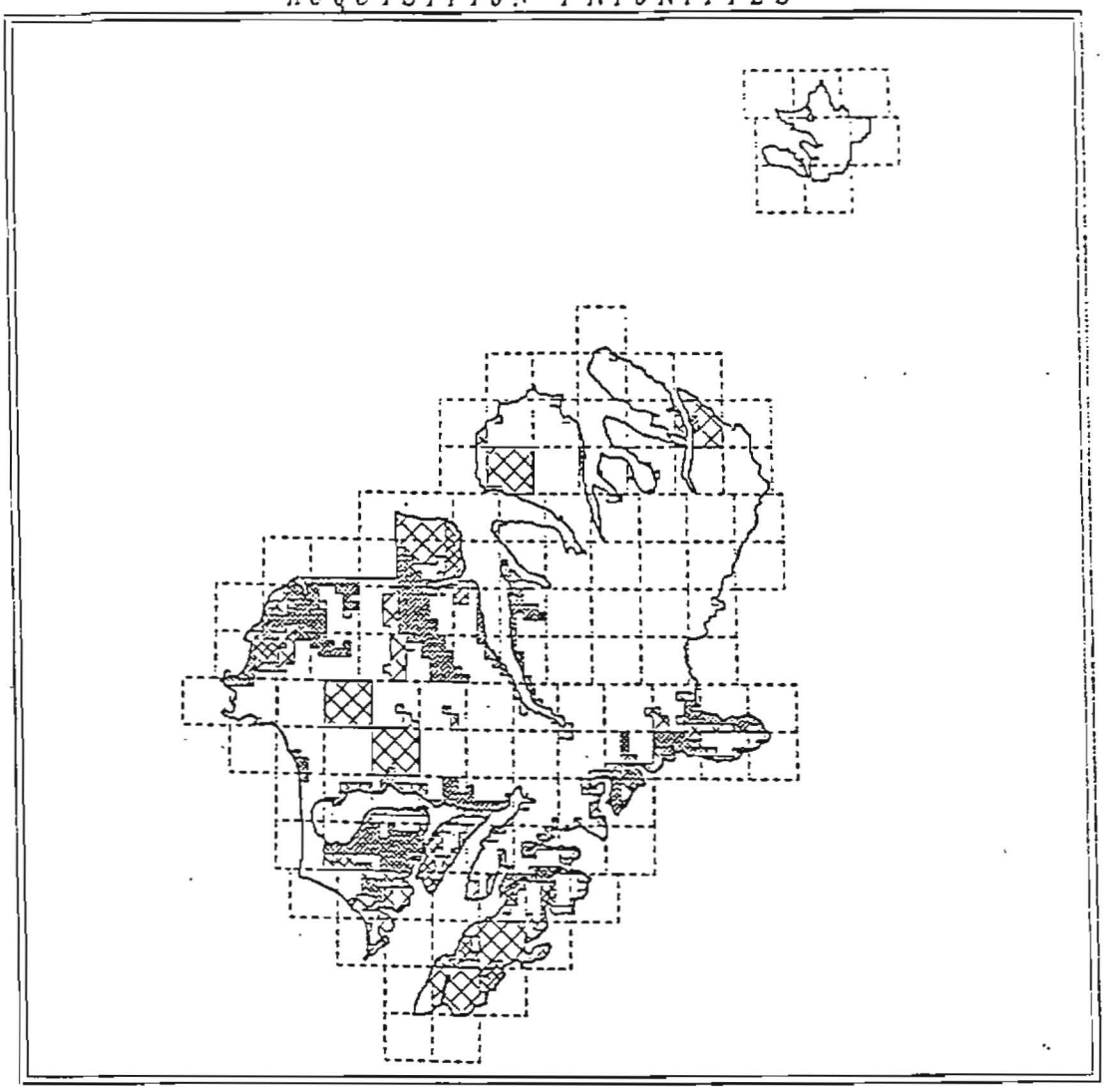
The Submerged Lands Report including maps of the 16 refuges and lists of acquisition priorities is currently being reviewed in Washington, D.C., by the four involved agencies and the Department of Interior prior to submitting the report to Congress. However, aside from meeting the statutory requirement for the report, the Acquisition Priority System developed by Region 7 will serve as the first step in developing individual refuge land protection plans to determine and publicly state long-term refuge goals for inholdings. Since refuges in Alaska include whole villages within their boundaries, there is little expectation that all or even most inholdings will ever be acquired.

A second benefit, because resource data was gathered for all lands within refuge boundaries, is that there is a GIS database that can be maintained, updated, and used for daily refuge management.

The Region is now improving and updating the APS model and database and upgrading the land status database considerably in order to identify individual land owners. Individual plans will be developed for each refuge which will include more public participation in identifying goals of landowners as well as refuge goals. The individual refuge land protection plans will also more clearly display the results of the APS model as well as better land status maps.

FIGURE 4

KODIAK NATIONAL WILDLIFE REFUGE ACQUISITION PRIORITIES



DATA SOURCES:
Wildlife Resources:
F&WS Division of Realty, Refuges & Wildlife
Landstatus:
Bureau of Land Management
F&WS Division of Realty

DATA ANALYSIS:
F&WS Division of Information Resource Management, Branch of Geographic Analysis

SCALE 1:1180500

Projected in UTM Zone 5
20 Dec 89 17 41-19 Wednesday
US F&WS REGION 7
ANCHORAGE, ALASKA

PRIORITY KEY:
- High Priority
- Medium Priority
- Low Priority
- Federal Or Non-Acquirable
- Township Boundaries

Alaska's
Automated Acquisition Priority System
Using
A Geographic Information System

Authors

Barry C. Dearborn
&
I. Jean Wylie

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I. ABSTRACT

In response to a congressional mandate to produce a prioritized list of all inholdings on federal land which could be acquired by the federal government, Region 7 designed and implemented a Geographic Information System (GIS) model. Prioritization was based on a statewide point system reflecting the relative value of each resource, as delineated by digitizing polygons (reference "The Acquisition Priority System in Alaska" by Danielle G. Jerry). A GIS procedure was developed to intersect the resource polygons with land ownership polygons (sections) for each of the 16 Refuges. The highest point value for each section was then ranked both within the Refuge and across all Refuges.

A number of ARC/INFO programs, bridging multiple workspaces, were required to handle the several hundred thousand polygons. Eighteen distinct steps, totaling over 250 macro programs, were designed and implemented. Several weeks of dedicated computer time was required to produce the final list, ranking all acquirable sections in order of descending value to the Service. 85% of all United States Refuge land is in Alaska.

The subject paper centers around the automation of the model using a custom-designed ARC/INFO application package, coded mainly using the ARC Macro Language (AML). Data flow and process control are de-emphasized in favor of expanding on design considerations and techniques, resulting from the collisions of model demands and various system/language constraints. This presentation should provide general enlightenment on how large databases and extensive processing can be handled within the limitations of the facilities and the GIS. (See Danelle Jerry's paper)

II. INTRODUCTION

The primary goal of the model, known as the Acquisition Priority System (APS), was to rank all refuge inholdings to indicate priority for acquisition, as mandated by the Alaska Submerged Lands Act of 1989.

An evaluation of the volume of data to be processed to meet the goal in a period of approximately one year made it clear that automation was necessary. Work to define and design an automated database for land ownership data was underway at the time when the mandate was received. Additionally, other critical resources such as expertise in geographic information systems (GIS), GIS software (ARC/INFO), a minicomputer system (Data General MV/8000), and a capable staff within both the Divisions of IRM (Information Resource Management) and Realty were already in place. Analysis showed that a complex system of closely linked processes would be required to automate the model. A strong selling point favoring automation was the capability to back up and rerun specific processes when perturbations to the model were imposed. Likewise, error recovery, whether from erroneous data or invalid software would be much quicker and more reliable using automation. To manipulate attributes based on spatial data and to combine the above for a multi-layered database, the capabilities of a GIS was mandatory. GIS mapping and report capabilities would also be required to show both the public (for the review process) and Congress (final reports) where the high priority lands were located.

A complete overview of the Alaska Acquisition Priority System can be found in the "Alaska Submerged Lands Act Report, Summary of Inholdings and Acquisition Priorities on National Wildlife Refuges of Alaska", Appendix A-14. At the top level, the model breaks into three distinct phases:

1. Collection and evaluation of biological resource data
2. Entry and updating of land ownership data
3. Integration of biological and ownership data, statewide ranking and prioritization

From a data viewpoint, polygons with numeric attributes (biological values) are geographically overlaid with section polygons with ownership acreage attributes to produce a composite where property in a section belongs to one or more owner classes and has a particular numerically-designated value to the Service.

The following section (GENERAL DATA FLOW) translates the overview cited above into specific GIS processes. Additionally, Appendix A shows the complete data flow diagrams in flow chart format that depicts the APS software.

The objective of this paper is to discuss design considerations, techniques and problem resolutions central to the implementation of the APS conceptual model into a working GIS application system. No attempt will be made to describe the entire process in detail - several volumes would be necessary to thoroughly document the APS software.

This paper will present how a large database was handled given the local hardware and software constraints. A list of recommendations is provided for consideration for anyone attempting a similar large scale automation project using a GIS.

The current APS software must be considered a prototype system. A number of times, backtracking was necessary due to misdirected efforts. Throughout the project, knowledge was acquired that was converted to new techniques for improving the implementation of the model. Current plans call for evolution of APS to a full land information system, accessible to a host of diversified applications. These plans are further developed in the chapter called "Plans for Improvement and Enhancements".

III. GENERAL DATA FLOW

Overview

To obtain ranked parcels for possible acquisition, the refuges had to be described from both a land status, and a resource point of view. The product, ranked parcels, was derived from integrating land status and resource information. See Appendix A for an overview of processes and data sets comprising the current APS system.

Land status information was broadly defined as parcels which are selected or conveyed, and grouped under 4 general owners - state, native allotments, native corporations, and other private owners. The data was obtained from the BLM (Bureau of Land Management) AALRS system and checked against Service records and current Master Title Plats. See Appendices G thur I.

The resource data, defined by the model, was supplied by biologists familiar with the area. Polygons were drawn to delineate areas of high, medium, and low resource value, for every resource category. The APS model assigns points to each category, and sums the categories into criteria. The final score for any parcel is the sum of scores for all criteria as derived for that parcel. ('Points' is used to refer to the value assigned to category polygons. 'Score' is the model-derived value resulting from summing categories into criteria(s). Please reference Danielle Jerry's paper for a complete discussion of the resource model.)

The software parallels the data. A land status subsystem was developed to import BLM land transaction data, and update and summarize the information of interest to the Service. A resource subsystem was developed to apply the resource model to resource maps digitized by biologists. Software performed the task of assigning point values to the resource polygons and derived a final score for each polygon. See Appendix B thur F.

The remaining software integrated land status and resource data, ranking it across all refuges. Software products were derivative data bases, check plots, publication ready plots, and tabulated reports. See Appendix J thur L.

Over the 15 months of the project, it required 3 analyst/ programmers, 5 biologists, and 4 cartographers. Only two analysts were involved full time.

Data Sources

Data comprising the land status or resources database is not easily characterized. Quite a number of varied sources contributed data, ranging from field biologists to the BLM automated land records system known as AALRS. Data collections methods, including how to

view the distribution of wildlife, differed significantly from one refuge to the next. When delineating wildlife populations, it is safe to state that two biologists could legitimately interpret the raw data such that the resulting containment polygons might differ greatly. A further discussion of accuracy and reliability concerning biological-derived polygons is beyond the scope of this paper. However, the reader should keep in mind that the absolute biological value of any particular land section is not defendable by this model - only relative values are.

On the land grid side, townships and section lines, the situation is clearer. The coordinate data, originating with the BLM, has undergone numerous editing phases. Still the rigorous topological structuring of ARC/INFO exposed a few more inconsistencies. These were identified clearly by error labeling techniques built into the ARCPLOT subsystem. Corrections were made to the extent necessary to satisfy the model. Although the error rate was probably less than 1/10th of one percent, such errors were 'fatal' to ARC/INFO. More explicitly, a topologically "clean" coverage could not be constructed until these errors were corrected.

The initial land status was derived from the BLM's AALRS data via a 'window' driven cobol utility program. A window is an ASCII file that lists the townships and sections within the subject area. The refuge windows were coded in 1983 and proved to be quite inaccurate along the refuge boundaries. ARCPLOT programs were used to overplot the BLM refuge boundary and the FWS-digitized refuge boundary. Differences were corrected to agree with the Realty refuge sheets. Considering the large number of correct interior sections, the overall error rate was less than five percent.

The AALRS data contained an acreage value for the area of each section within the refuge boundary. Comparisons to the Realty refuge sheets showed a high rate of error for west tier sections and those cut by the boundary. Considerable time was spent editing the section acreage values via a land status acreage update program, extended to meet this need.

The land status acreage, where the section's area could be allocated to any and any combination for the four owner classifications, was found to be the most unreliable. The BLM readily acknowledged that its AALRS land status data contained errors (no one knows to what extent), but despite this, the data provided a starting point more preferable than manually entering all data. Practices such as over-selection (allowable under ANILCA) and mixed coding techniques (sometimes at the township level instead of section level) caused problems in computerizing standard interpretations. Eventually, an accurate database was constructed based on Realty's refuge sheets and BLM's Master Title Plats. The land status checking and editing has been the most time-consumptive procedure in the entire APS project, accounting for several man years effort.

Link Items

In the Land Status System, all data is tied to Alaska township sections. A scheme for assigning unique integer numbers to townships is in common use within the Alaska GIS community. These numbers are referred to as 'index numbers' and point to the legal description and other attributes for a township. Software and tables were already available for converting township legal descriptions into index numbers and vice versa. Therefore the obvious data key for a section comes from combining the index number of the township and the section number. For want of originality the key is called 'indexsec'. Indexsec was assigned at the time the section grid coverage was created and is carried throughout the Land Status System for each subsequent coverage.

For the resource system, there didn't seem to be a need to link back to the input data at first; only the score of each polygon needed to be carried forward. But the biological model was still being fine tuned, and it became desirable to recalculate resource score without re-unioning all the category and criteria polygons. To achieve this, pointers were carried from category to resultant criteria, and from individual criteria to combined criteria for the Refuge. The polygon id's for all the categories were stored in each unioned criteria. This allowed pointing back to the original criteria polygon, recalculating its points, and re-summing category points for the criteria according to the model. Carrying the pointers required an investment in software and disk space, but the alternative of re-unioning all categories into criteria, and all criteria for the refuge, was impossible in the time frame.

In the integrated data set, it was necessary to point back into both land status and resource data. 'Indexsec' was still the pointer for land status. For the resource data, the polygon identification number for the polygon with the highest score was carried forward. This pointer provides linkage to report what categories contributed to the final score. If the point system changed, the highest scoring polygon was redetermined, and the new pointer carried forward.

The one data set which has data for the whole state (STATE_WORK) has a composite pointer that can be split to point back to the refuge it came from and the data record in the combined land status and resource data coverage. That data record has the land status and resource pointers.

Updating

A major advantage of automating the land prioritization project was to minimize the effort required to obtain a new set of output products whenever the model parameters or input data was changed. Overall, three types of changes are allowed within the current model: population densities (digitized polygons), resource values

assigned to the polygon, and acreage within each of the four land status classifications.

The resource value is simply an attribute linked to a polygon. Updating resource values consisted of changing points assigned to one or more resource categories in tables, one for each species within each category. The update AMLs translated alpha codes into points by referring to these tables. Then scores were re-computed according to the resource model. Links (backwards and forwards pointers) have been designed into the database structure for the purpose of enabling this type of updating (see section entitled "Link Items"). Hence, it is not necessary to re-run the coordinate (ARC) side of the database for resource value updates. Several update AMLs, mainly running INFO programs, expedite the carry-through of value-associated attributes to the state ranking phase. The model has undergone several resource value updates with minimal problems.

Changes in the location of resource distribution affect the geographic data within the database. These changes (additions, coordinate editing, or deletions) are made using the ARCEDIT subsystem. Any such change requires run rerunning the affected refuge sheet from the start and processing through to the end of the statewide procedure.

Land status acreage updates (INFO) are handled by a stand-alone system that only interfaces to the associated attribute file for the Land Status coverage database. This is the same software that was used to create (edit) the initial database. Since all townships and sections within the refuge were initially included in the land status database, updating consists of changing the acreage value for any of the land status classifications. One exception is the Arctic Refuge where a large corridor, until recently not a part of the refuge, was added. However, there was very little land status within this area and no noticeable affect was imposed on the statewide ranking and prioritization. If this had not been the case, the model would have had to been run again through these phases.

Restart and Recovery

Although managers talk (dream) about completely automated systems, system analysts realize that never does such a multi-step, large database system run without abnormal terminations. Whether due to "bad" data, software "bug", environmental crises, or hardware failure, if it requires as much as a week of computer time, the probability of "bombing" approaches certainty.

The APS software design faced this reality up front by incorporating a stepwise approach, saving input, parameters and output files on disk, and periodically backing these up onto tape. If the APS operator requested more than one step to execute consecutively, then

an "ok to proceed" must be signalled from the preceding process, otherwise the run would terminate prematurely. This technique, in itself, eliminated much wasted cpu time and confusion over validity. Both manual check sheets and a 'progress board' were implemented to further document the outcome of each logical step.

Steps were run as batch jobs with results directed to output files in order to verify execution of processes. This provided records of successful runs and evidence of problems in event of incomplete runs. In some cases, it was necessary to rerun steps interactively to capture error messages that ARC was not reporting to the batch output files.

Another scheme frequently used was to rerun only the latter portion of a step, accomplished by editing the unrun commands from the AML into a new program version with a unique name. The associated batch output file was used to locate the last successfully run command. Some parameter initialization was usually required, but within minutes, the new recovery AML was ready to finish processing the commands remaining from the terminated process. This procedure resulted in savings of many hours. The recovery AMLs were saved and on several occasions, re-used with a different refuge sheet, further lowering the programming overhead.

Predictably, it was necessary to reload data coverages from tape several times. Because of the inherent structure of the INFO database, it was necessary to first load the replacement coverages to a temporary (recovery) directory, then ARC COPY them into the current database. Although this procedure was awkward and manually performed, it usually worked satisfactorily if handled with care.

IV. TECHNIQUES AND IMPLEMENTATION

Software

The APS software is a conglomerate of programs written in eight different language structures. Several are stand-alone which only interface via data files, but most are part of a linked, hierarchical structure communicating by passed arguments or parameter files. The table below shows how the software is diversified by purpose, and the numbers associated with each. AML programs were used wherever possible because these are composed of ARC/INFO commands that easily manipulate the coordinate database. AMLs are also faster to write and debug than FORTRAN programs. However, the most significant reason to stick to ARC or INFO code is that it is quite simple to transport this software onto another hardware system. This transfer will become a reality (see section on Future Plans). For algorithms requiring byte manipulation or nested looping, FORTRAN77 proved to be a much more efficient implementation. Likewise, the operating system sort routine was more expedient for sorting and reformatting large data file. Several operating system macro language routines (CLI) were written to perform computer resource monitoring, bookkeeping, and to drive an existing FORTRAN program.

TABLE I

Language Structure	Number of Programs	Purpose(s)
ARC/INFO AMLS	260	Flow control, geoprocessing
ARC COMMANDS	***	Calls geoprocessing functions
INFO COMMANDS	***	Access/builds attribute database
INFO PROGRAMS	21	Manipulate attribute database
FORTRAN77	12	Performs intensive calculations
SORT/MERGE	8	Sorts or reformats large files
CLI MACROS	11	Monitoring, bookkeeping, misc.
SAS	1	Generates a graph for the final report

(*** - not counted, actual number is several hundred)

The total software directory occupies 2.6 megabytes, 647 kilobytes being devoted only to source code. Total number of programs was 289, easily qualifying the APS software for large application system status.

Data Subsetting

Processing all sixteen refuges as a single data set was quickly dismissed as a practical impossibility, first because of sheer magnitude of the total data, and second, because of geographic separation of refuges (nearly 1000 miles). Any attempt to map data at a statewide scale would miniaturize the detail beyond distinguishability. The logical conclusion was to divide the data set by refuge which kept the data set spatially contiguous (except for Maritime and Innoko). However, this division resulted in a great disparity in area size. In fact, four refuges proved to be larger than could be handled as single entities by ARC/INFO and/or system limitations.

Existing manually-derived plats offered a solution for further division into seemingly arbitrary areas called refuge sheets. These were "blocked out" in a pattern resembling the USGS 1:250000 Quadrangles; however the boundaries of the two are not coincidental. Refuge sheets were not divided on township boundaries, but instead along lines of constant latitude and longitude. In order to maintain some semblance of sanity in the database, a township can not be divided across adjacent refuge sheets. The final resolution dictated that the automated refuge sheets be a close approximation to the manually-drafted refuge sheets basically for easy of status proofing.

Large Databases

This resultant division provided four distinct advantages:

1. Smaller data sets translated to faster overall execution because certain processes, such as sorting and topological "cleaning", have response times that are more like exponential than linear functions.
2. Smaller data sets permitted selective archival when additional disk space was required.
3. Separating data into directories by refuge sheet enabled processing on different sheets (including land status updating) to be performed simultaneously. This is because each refuge sheet data set has its own INFO directory, therefore single user write restriction does not apply. See Appendix P.
4. Recovery from errors, necessitating re-running a process, was considerably faster with smaller data sets.

Several minor disadvantages of a fragmented data set should be noted. First, there will be considerably more directories and files.

For each ARC coverage, there are about 10 arc files and 3 INFO files. Additionally, 6 to 10 other data or parameters files are required for each refuge sheet. This proliferation of files may slow down searches and make data management more demanding. Second, progress tracking will require more effort because of more independent data sets, resulting in more complex bookkeeping tasks. All in all, these disadvantages are far out weighed by the afore mentioned advantages.

Relating Databases

The capability to implement relational techniques was essential to meet the project requirements. Establishing a relational database has the following virtues:

1. Polygon attributes not required for a particular process are not handled. The result is faster execution time.
2. Relating files where a many to one relationship exists minimized data redundancy.
3. The necessity to carry all information forward with each processing step is eliminated; consequently only data that is changed and the associated link item(s) are required for the next step. The use of this capability minimizes the requirements for disk storage.

The above factors enable the APS software to perform attribute updates without having to re-create the topological data. For example, when the scores are changed for a particular species, it is not necessary to rerun the two UNIONs and one INTERSECT processes. In other words, it is not necessary to re-derive the polygons defining the intersection of resources and land status data. Instead, using the link items (also thought of as "backwards" pointers) , an AML program recalculates the score for each polygon. Then the ranking process can be rerun. The time savings using this technique is virtually immeasurable when compared to rerunning the entire model. (See Appendix A)

The inability of ARC/INFO to establish INFO relates between two ARC workspaces nearly doomed the multi-workspace design. A work-around was accomplished by writing an AML program which essentially duplicated the INFO externalling structure between an INFO file and a coverage file. The major difference is that the two files now are INFO files in different INFO directories. This program, called SET_REMOTE_EXTERNAL, is quite complex in that it has to deal with INFO internal filenames and system path names. Additionally, the program solves the problem of referencing an external file in a 'linked' (remote) directory. This program will function just as well outside the APS software and should be considered a general purpose utility. If this data linking capability had not be created, the only alternative would have been to copy data files into each INFO directory forcing APS onto a single disk. Such a scenario would have been a terrible waste of computer time and disk space, to say

nothing about the problems generated for update processing.

Processing Initialization and Monitoring

Process initiation of the APS model is not centralized under the current implementation. All drivers and top level programs were written in AML using one of four following techniques: menus, popup menus, prompts or parameters (supplying a list of parameter values). A summary of the differences of operation by major subsystem is provided in Table II below. The following paragraphs expand upon some of the more central concepts shown in the table.

The menu-type drivers were found to be significantly more suitable for subsystems with many functions and/or parameters. Most "friendly" was the popup menu (an ARC command construct) schema that was implemented for land status updating. Both the task and its parameters are 'picked' from menu displays, eliminating all key entry - and the possibility for key entry mistakes. The non-pick menu used on the resource subsystem was more flexibility but not as user friendly. At the other extreme was the parameter specification technique that offered little friendliness but maximum flexibility and quicker response. For subsystems run exclusively by the analysts, flexibility was the most important factor.

The land status creation subsystem uses parameter specification to allow for a fixed sequence of steps to be run from a single start up job. The starting and stopping step numbers are user specified, and for each case are set depending upon: preceding processing history (did it fail a previous step?), confidence in the data set, and availability of resources (time and disk space). The technique proved to be very useful, and in the long run saved considerable computing resources.

All of the subsystems that contained lengthy tasks were programmed to operate in batch processing mode, as well as interactive mode. The user can place a batch job under any of the four batch streams in two batch queues, depending upon the urgency and system loading. Each batch job creates a batch output file containing sufficient detail to enable progress monitoring and error checking. Both of these features proved very useful when problems occurred. Occasionally, the interactive mode was chosen over batch to obtain priority processing or get more information leading up to an error termination (some ARC messages are not sent to the batch output file).

Considerable effort was devoted to the inclusion of error checking code. For large systems in developmental stages with data of unknown quality, extensive error checking code will always pay off. The possibility of continued processing after an undetected error is a condition that the system as a whole attempted to minimize. Visual inspection of the data at designated milestones via scale plots were very useful in detecting erroneous data not verifiable by

logical or range testing code.

Sub-Systems / Characteristics	Resource	Landstatus Creation	Landstatus Update	State Ranking & Priority	Plotting Check & Final	Final Report
Ctrl Method Parameters	Menu	Prompts	Popup Menu	Parameters	Menu	
Operator	Biologist	Analyst	Cartographer	Analyst	All	Analyst
Freq of use	High	1/refuge	High	Once	6/refuge	Once
"Friendly"	Good	Good	Best	Least	Good	Fair
Sequencing	No	Yes	No	No	No	No
Flexibility	None	Some	None	Most	Some	Some
Driver/Prog	Driver	Driver	Driver	Program	Driver	Driver
Checking	Some	Yes	Thorough	Some	Some	None
Batch	Yes	Yes	No	Yes	Yes	Yes
Interactive	Yes	Yes	Yes	Yes	Yes	Yes

Table II Summary of Operations by Major Subsystem

Resource Menus

Realty Biologists controlled and checked the execution of resource processes. They used menus (with brief descriptive names) which prompted them for the arguments needed. The menu called AML enabled feature programs which could be executed directly in ARC by experienced users. This resulted in users not being forced to use the menu for repetitive tasks.

MAJOR SUBSYSTEMS

Assignment of Resource Values

After intersecting land status and resource data, the resultant coverage had multiple polygons per section. Since the rank of the section is determined by a single resource value, one value must be assigned to the whole section. The land status data and resource data was too coarse to decide which resource value is most valid for any section, so it was decided to use the highest value (referred to as 'high sum'). A new coverage was created by reselecting only sections with inholdings and setting high sum. High sum is set by an INFO program which reads all resource values for a section and selects the highest.

Acreage Summarization

Acreage summaries (sub-totals and totals) for the four ownership classes by refuge were required for input to two of the report generators. Prioritization required the data to be further subdivided into three priority classes. To this end, a set of AML programs was designed to create a matrix-structured INFO file called the 'statework' file. This file contained 3 records (one for each priority class) for each refuge; the total summing to 48 records. For each record, five acreage figures were computed - the section acreage and each of the four ownership classes. The summary software was designed to operate in three modes - a single refuge, a list of refuges or all refuges. This flexibility allowed a great savings of time when data was updated for one or more refuges. For each refuge, the data sources required were the 'final resource coverage' and the 'land ownership' files, which resulted in one for each refuge sheet. The processing of each refuge generated a 3-record text file, called 'ADD files', which were merged with the other Refuge 'ADD files' into the 'statework info' file (see Appendix K).

The technique used was to access the 'land ownership' files through previously-established 'links' to remote INFO directories. Additionally, to process multiple sheets, an AML program created the required INFO RELATE commands and store them in AML variables for later INFO program execution. Another AML program defined the INFO CALCULATE statements to total each ownership class across all sheets for a refuge, using the computed INFO relate numbers. Before running the INFO program thus constructed, the data set was reduced by reselecting only the section records for one of the three priority levels. Running all refuges amounted to activating a nested loop within the AML program, that first processed by refuge, and second, by priority class. The complete process resulted in building and executing the INFO program 48 times. The INFO ADD FROM command was used to combine the 16 add files into the 'info statework file'.

Ranking Sections

Ranking - the ordering of section parcels by descending value of the combined resource points - was performed both on individual refuges and across all refuges (statewide). Initially, the former was used but for the final APS reports only statewide ranking was considered.

Before ranking can be performed at the statewide level, all pertinent refuge data must be brought together in a single file. Because of the size of this file, a separate workspace was designated and a flexible command-driven AML program was written to handle process control for the three major components: imputing, ranking, and outputing. All operations were disk file to disk file interactions. Imputing consisted of building the composite file, called the 'STATE_FILE', by appending attribute data from the 'FINAL RESOURCE' coverage refuge by refuge. At any time, the ranking process could be run on the STATE_FILE. Outputing was the copying of the ranking values (both intra and inter-refuge) back to each of the FINAL RESOURCE coverages.

To maintain the proper links between the 'STATE_FILE', which must be sorted, and each of the 'FINAL RESOURCE' coverages, a unique ranking pointer (RNKPTR) was created. Uniqueness was achieved by appending the ARC/INFO-assigned internal polygon number to a refuge number (1-16). The resulting 7-digit number, when REDEFINED by INFO into its components, permitted the complete set of records for each refuge to be identified and handled within the STATE_FILE.

Due to the size of the resultant 'STATE_FILE' (over 38,000 records) and the fact that all refuges were not ready for input at one time, all phases were designed to allow processing via a user-supplied refuge list (same as the 'STATEWORK' processing). This flexibility design made it easy to produce a two-refuge evaluation for a proposed land swap that came up very suddenly. Additionally, when an error was found in the data for a particular refuge or a change in scoring resulted in an updated 'FINAL RESOURCE' coverage, it was much quicker to just replace the data for that refuge rather than re-build the entire 'STATE_FILE'.

When all refuges had been added to the 'STATE_FILE', ranking was performed by sorting on two keys: 1) descending upon resource value, and 2) ascending on refuge number. In other words, when sections had equal resource value, the lowest refuge number was ranked higher. This secondary sorting had no affect on the following prioritization processing but served to keep refuge records together for the desired reporting format.

The primary purpose of the 'STATE_FILE' was to provide the data for the prioritization process, however, it is used in the generation of another important statewide INFO file called 'STATE_TOWNSHIP', a key file for generating a comprehensive reference report by township (see section on Reports and Report C)

Prioritization

The acquisition priority assigned to each acquirable section is directly related to the relative magnitude of the resource value, which was previously computed and passed through the ranking process. Three classifications were established in compliance with the mandate: high, medium and low. To set the limits of resource value that defined these divisions, an AML program was written to determine the cutoff values between the high and medium classes, and the medium and low classes. The guiding criteria was that approximately equal acreages were to be placed in each of the three classes. Within the 'STATE_FILE' previously defined, in addition to the ranking items, are the section acreage and resource value. AML programs were written to perform the evaluation, compute the cutoffs, and assign a priority number of 1,2 or 3 (high, medium and low respectfully) to each acquirable section.

The ARC FREQUENCY command was used to sum up the section acreages by resource value, as well as provide a count of the number of sections belonging to each resource value. An AML program computed both an ascending and descending running acreage total (see Appendix N) after running the frequency command. Additionally, this program computed the one third value of the total acquirable acreage. Determining the cutoff values was merely a matter of looking on an output listing for the nearest acreage figure in both the ascending and descending running totals, then lining over horizontally to the corresponding resource value.

The last part of prioritization was to apply the cutoff values and assign each section to either the high, medium or low class. An INFO item called 'priority' was established in all 'FINAL RESOURCE' coverages. An INFO program was written that took the cutoffs as input parameters and made the appropriate assignments. If a section was identified as non-acquirable, the priority number was left in the initialized state (=0). This was the case for all Federal lands - defaulting to this land ownership category if all of the four land ownership categories were set to zero acreage.

The priority value was a key item in the generation of all of the final reports and plots.

Check and Final Plots

Introduction

Due to the many steps on processing both resource and landstatus data, it was necessary to have many check plots. A basic layout was worked out to generalize checkplots.

The items that can vary between check plot are titles, layout, size or scale preference, and key data item. Resource check plots could specify a file to be read to define the color lookup

Ranking Sections

Ranking - the ordering of section parcels by descending value of the combined resource points - was performed both on individual refuges and across all refuges (statewide). Initially, the former was used but for the final APS reports only statewide ranking was considered.

Before ranking can be performed at the statewide level, all pertinent refuge data must be brought together in a single file. Because of the size of this file, a separate workspace was designated and a flexible command-driven AML program was written to handle process control for the three major components: imputing, ranking, and outputing. All operations were disk file to disk file interactions. Imputing consisted of building the composite file, called the 'STATE_FILE', by appending attribute data from the 'FINAL RESOURCE' coverage refuge by refuge. At any time, the ranking process could be run on the STATE_FILE. Outputing was the copying of the ranking values (both intra and inter-refuge) back to each of the FINAL RESOURCE coverages.

To maintain the proper links between the 'STATE_FILE', which must be sorted, and each of the 'FINAL RESOURCE' coverages, a unique ranking pointer (RNKPTR) was created. Uniqueness was achieved by appending the ARC/INFO-assigned internal polygon number to a refuge number (1-16). The resulting 7-digit number, when REDEFINED by INFO into its components, permitted the complete set of records for each refuge to be identified and handled within the STATE_FILE.

Due to the size of the resultant 'STATE_FILE' (over 38,000 records) and the fact that all refuges were not ready for input at one time, all phases were designed to allow processing via a user-supplied refuge list (same as the 'STATEWORK' processing). This flexibility design made it easy to produce a two-refuge evaluation for a proposed land swap that came up very suddenly. Additionally, when an error was found in the data for a particular refuge or a change in scoring resulted in an updated 'FINAL RESOURCE' coverage, it was much quicker to just replace the data for that refuge rather than re-build the entire 'STATE_FILE'.

When all refuges had been added to the 'STATE_FILE', ranking was performed by sorting on two keys: 1) descending upon resource value, and 2) ascending on refuge number. In other words, when sections had equal resource value, the lowest refuge number was ranked higher. This secondary sorting had no affect on the following prioritization processing but served to keep refuge records together for the desired reporting format.

The primary purpose of the 'STATE_FILE' was to provide the data for the prioritization process, however, it is used in the generation of another important statewide INFO file called 'STATE_TOWNSHIP', a key file for generating a comprehensive reference report by township (see section on Reports and Report C)

Prioritization

The acquisition priority assigned to each acquirable section is directly related to the relative magnitude of the resource value, which was previously computed and passed through the ranking process. Three classifications were established in compliance with the mandate: high, medium and low. To set the limits of resource value that defined these divisions, an AML program was written to determine the cutoff values between the high and medium classes, and the medium and low classes. The guiding criteria was that approximately equal acreages were to be placed in each of the three classes. Within the 'STATE_FILE' previously defined, in addition to the ranking items, are the section acreage and resource value. AML programs were written to perform the evaluation, compute the cutoffs, and assign a priority number of 1,2 or 3 (high, medium and low respectfully) to each acquirable section.

The ARC FREQUENCY command was used to sum up the section acreages by resource value, as well as provide a count of the number of sections belonging to each resource value. An AML program computed both an ascending and descending running acreage total (see Appendix N) after running the frequency command. Additionally, this program computed the one third value of the total acquirable acreage. Determining the cutoff values was merely a matter of looking on an output listing for the nearest acreage figure in both the ascending and descending running totals, then lining over horizontally to the corresponding resource value.

The last part of prioritization was to apply the cutoff values and assign each section to either the high, medium or low class. An INFO item called 'priority' was established in all 'FINAL RESOURCE' coverages. An INFO program was written that took the cutoffs as input parameters and made the appropriate assignments. If a section was identified as non-acquirable, the priority number was left in the initialized state (=0). This was the case for all Federal lands - defaulting to this land ownership category if all of the four land ownership categories were set to zero acreage.

The priority value was a key item in the generation of all of the final reports and plots.

Check and Final Plots

Introduction

Due to the many steps on processing both resource and landstatus data, it was necessary to have many check plots. A basic layout was worked out to generalize checkplots.

The items that can vary between check plot are titles, layout, size or scale preference, and key data item. Resource check plots could specify a file to be read to define the color lookup

table. Different refuges needed refuge name, sheet number, and alternate scale if it didn't fit on the plotter.

The basic check plot process was split into several subroutines. This allowed quick development of new check plots since only some subroutines had to be added, patterned after existing ones. Some subroutines are general and others are specific to a type of check plot. Those which must be tailored to a particular check plot are named according to the check plot requested. The calling routine appends the check plot type to the subroutine name so the correct subroutine will be called, and arguments are passed to specify refuge and lookup table. There are two versions of the routine that specifies the size of the plot. In one the size is set and the plot scale is implied by the plot size. The other reads a plot parameter file which has the desired scale for a particular refuge.

Resource Check plots

Check plots allowed the biologists to check data consistency and served as records of the intermediate processes. An inconsistent check plot could mean a missed step or an error in digitizing. Many check plots were required for monitoring each step of entering and unioning resource data. A check plot was created for each specie or category within each criteria. The macro for this check plot was designed to send the plot to a Tektronix terminal, where the biologist could hardcopy it at 8 1/2" X 11". The rest of the resource check plots were plotted at either 1:250,000 or 1:500,000 depending on whether the refuge would fit on a D size plot. A check plot was made when categories were unioned into criteria. Finally, the last resource check plot was made for each refuge when all criteria had been unioned together.

Land Status Check Plots

Land status check plots were compared against Master Title Plats to correct land status by owner group. Printouts of the land status data was used to verify acreage totals per section. Another check plot was created when the sections with inholdings were extracted for integrating land status and resource data.

Integrated Check plots

After land status and resource data was intersected, a check plot was made of the integrated data. Then another check plot was made of the sections after 'high sum' had been set. These two check plots were compared to verify that 'high sum' had been set correctly.

Ranking check plots

The final plot for each refuge showed the sections as prioritized at high, medium, or low. This plot was designed to be published. It still used the generalized plotter routines, with changes in plot size and layout. It was plotted at 8 1/2" X 11" for the report, but found to be too small for the amount of detail in the larger refuges, so another set was plotted at twice the size for showing the public.

Conclusion

The plotting for the APS project was a major effort. Each refuge required, at a minimum:

```
~50 category plots
10 criteria plots
  1 unioned resource plot
  2 land status plots
  1 acquirable section plot
  2 integrated plots
  2 final ranked
-----
 68 plots X 16 refuges = 1,088 plots
```

Since it was almost always necessary to rerun plots, the actual number of plots produced were probably greater than 2,176. This guess is based on the fact that first plots were never the last.

Reports

During the initial design phase, four types of reports were identified to provide both overview and detail information about acquirable refuge lands. To make it easier to distinguish one from the other, a single letter acronym was identified with each, as below:

A - Acquisition ranking by land ownership/selection (summary of inholdings in all Alaska refuges)

B - Acquisition ranking by land ownership/selection (summary of inholdings by refuge)

C - Statewide ranking by resource value (summarized by township)

D - Land Acquisition selection, criteria values and state ranking (for all sections ordered by township/section)

All four reports show the acreage allocated to each of the four ownership categories. The first three reports (A,B,C) were included in the Alaska Submerged Lands Act Report. The D-Report, comprising

of nearly 400 pages, is intended to be used to answer public inquires regarding how a particular section was scored and ranked. For example, using the D-Report, it would be easy to discover that a particular section was highly valued by the Service because it hosted high densities of Trumpeter swans and Emperor geese. Appendix L displays samples of the computer generated versions for all reports. Computationally, the A-Report and B-Report were derived from the same computer listing (refer to the section on STATEWORK).

The INFO REPORT facility (a complex command) called from within AML programs was used to gather and format the data for all four reports. A single driver program, with considerable flexibility supplied by command parameters, allowed the user to do the following:

- Select any combinations of reports to address
- Determine whether the process would build a report file, output the report file, or both functions
- Permit processing only user-selected refuges for the D-Report
- Build 'link' files for accessing remote INFO databases

The report processor was written to run either in interactive or batch mode. The output files were directed through a system utility, which specified the character size and margins, to a laser printer.

The INFO code for the A and B Reports was straight forward, using the 'STATE_WORK' file, sorting first on refuge, and second, on priority level. Reference the section on generating the 'STATE_WORK' file for more details.

The C-Report required considerably more effort. A major problem was that the ownership acreage data was spread across 16 refuges, and 27 workspaces when the separate INFO directories for each refuge sheet are totaled. Since this easily exceeded the INFO RELATE maximum of nine files simultaneously, an AML program was created that looped by refuge, building the INFO RELATE commands and storing them in AML variables for later execution. A statewide INFO file, with one record for each acquirable township, called 'STATE_TOWNSHIP', was built from information comprising the 'STATE_FILE'. The major task was to summarize by township, that is, to additively collect the statistics (acreages) for each section in that township. Again, an INFO SORT was the key technique used, sorting all records on the key item called 'INDEXSEC'. Complexity was introduced by the 128 character record limit for INFO commands. When totaling acreage for more than 4 refuge sheets, this limit was exceeded. The solution required that an INFO program be written that builds INFO commands under loop control; the product of which was unique for each refuge. In other words, a program built another program, which then did all the summations. The data from the 'STATE_TOWNSHIP' file was passed through a 4-level sort INFO SORT processor. The sort keys in order

were: priority level, resource value (descending), refuge number and township INDEX number.

The D-Report entailed bringing together information from both the land status and resource databases at the section level. Fortunately, only one refuge needed be considered at a time. The resource data to be reported was stored in a separate workspace in up to 10 coverages (one for each of the 10 criteria). Again, the INFO relate limit was exceeded using a straight forward approach. The solution implemented was to build a new INFO file, called 'ALL_SCORES', for each refuge that contained all 10 scores. Then this file was used in the report building AML program. Two passes were required to build this file, for the same reason as above. The internal ARC pointers for criteria polygons were used to extract the value for the score. Linking the score to a section was possible only because the 'high sum' pointer was carried forward consistently from its origin with the resource/land status intersect process.

Since the D-Report process was executed from a refuge workspace instead of the statework space, four other report items, found in other parts of the database, had to be 'linked' for INFO relates. The AML utility program, SET_REMOTE_EXTERNALS, written for previous processing, again proved essential to set up this connection.

Once the resource data was extracted and centralized, and the INFO database links established, the INFO report code was straight forward. The output data for each refuge was sorted by INDEXSEC because that is the key item upon which references will be based. Without the D-Report that brings the whole value system together, responding to detail requests would require tracing back, by hand, through the other reports as well as looking up data for scoring not reported. Such a process would be very tedious, error-prone and time-consuming.

VI. PROBLEMS AND SOLUTIONS

Introduction

Looking back over the entire APS experience, the major difficulties, which translated into wasted resources, can be lumped into seven categories:

- Design
- Implementation
- Vendor Software
- Data-Induced
- Time Estimates
- Loss of Time to Mange Limited Resources
- Natural Disasters

Design implementation, vendor software, data-induced, time estimates, loss of time and natural disasters. These categories are not unique to the APS project but will occur to a certain degree in all long term, large scale computerized applications. The purpose of the following paragraphs is to identify the nature of the problem, the extent of disruption, to what degree it was preventable and what steps were taken to remedy the situation.

Design

Basically, there was no separate design effort at the beginning of the project. The original statement of the problem seemed straight forward and the project was accepted to and started with only general information about intended products. Essentially the project was started blind, with more confidence about feasibility than understanding of the complexity of the undertaking.

Without a project design effort, the project suffered in these areas:

- Data Management
- Disk space
- Standards and conventions
- Modularity

The scope of the project and the amount of data to be generated was not realistically perceived. If the sheer amount of data had been roughly estimated, the impact on existing data storage facilities would have been foreseen and additional disks could have been leased. Design can highlight foreseeable problems and provide room to deal with unforeseen problems.

Implementation

Although standardization receives a lot of 'lip service', it rarely is thoroughly thought out and implemented. The APS project was no exception. Standardization was generally good within a subsystem

but broke down across subsystems. Standards initially set were later changed, often to get around a limitation. When this happened, it was tedious and time-consuming to back track and change all references to the new standard, and indeed painful if archived data was involved. Along with design, modular definition of routines would have built-in flexibility for dealing with changes. Analysis of the APS experience indicates that significant coding to handle exceptions could have been avoided if across-the-board standards had existed before implementation.

Segments of the project were assigned to different analysts without informing them of the final goal. The simplicity of the problem statement made it seem feasible to create the data structures as needed. However, without design, and without knowledge of other efforts, there were variations in file naming, data items, directory structure, and data definition strategies.

The general concept was simple but the basic components were not defined until the milestone that required them were reached. Fundamental implementation decisions were made without knowledge of the ultimate consequences of the design. Previously executed steps had to be rerun when problems required changing data definitions, at the expense of significant duplication.

Therefore, down the line, some macros needed to be redone to meet some unforeseen limitation or requirement for a later step. Data bases were built and then changed, leading to nightmares of different versions of the same data. Some macros had to be changed when the data changed. Others, that seemed adequate in a pilot run, turned out to be awkward or unusable when applied to multiple refuges, with multiple sheets. Long programs had to be split into modules when strategies changed, to facilitate rewriting some functions and expanding others to handle iteration. Routines that dealt with data from both land status and resources had to accommodate 2 different refuge naming conventions.

Vendor Software

The majority of problems (but not all) encountered in the third party software involved the attribute database system - INFO. Although several problems appeared to be "bugs" in the software, the most costly were due to restrictions and lack of functionality.

A major problem was the limit of nine concurrent relates; that is, no more than nine database files could be accessed at any one time. Several times additional coding or intermediate files were necessary to accomplish the task. Both work-arounds introduced undue complexity, extended the design and coding phases and resulted in greater execution times.

The lack of an easy workable solution to access multiple INFO databases from a single disk location proved to be a more serious problem. Writing the total database into a single workspace or even two workspaces (reference second using the INFO ADIR command) was simply impossible given the large number of files (several thousand) and size (over a gigabyte). Even dividing the database into separate workspaces by refuge was not adequate in some cases. Considerable time was spent working out an AML program (SET_REMOTE_EXTERNALS) that sets up a 'link' file in one workspace to an INFO file in another workspace. Again, this work-around cost additional time during execution as well as creating a large number of files for INFO to track and manage. What INFO lacks is a language construct to allow tying together INFO workspaces in a seamless, transparent manner from the users viewpoint.

For reasons still unknown, the INFO SORT command was unable to handle a PAT (polygon attribute table) file when extended by the five acreage items. The solution implemented was to split these attributes into a separate INFO file, tied to the PAT by a relate item. Again, several days were lost trying to solve this problem in other ways. The cost also included setting up a new set of 'linked' relate files and database overhead.

INFO also failed during the process of creating 'link' files for an estimated 10 percent of the files because of a problem in the INFO file header recordation. These files were erroneously tagged as 'extended' files which can not be processed by the TAKE command. The vendor was unable to suggest the cause, but helped create a work-around. In the final analysis, these INFO-related problems contributed heavily to what is being termed as 'wasted resources' throughout the APS project.

Data-Induced

Data caused problems are based on erroneous data, mishandling or mis conceptions. Each of these had an affect upon the APS model, it's execution and the outcome.

Mishandling and misconception occurred during the preparation and unioning of resource polygons. The result was numerous meaningless sliver polygons. The cause of the problem was that boundaries that should have been coincidental were not. The overriding cause was performing the ARC topological 'cleaning' using different 'fuzzy tolerances' for the various data layers. The fuzzy tolerance was defaulted to be computed based on the source map size, not set to a fixed value. Thus after many unions, the resultant boundary would 'creep' from its original position. Several days time was lost verifying the digitized resource maps and validating polygons. Corrective action was to align the boundaries using the graphics editor or the ARC ELIMINATE command. Better control and coordination of data processing could have reduced the sliver polygon problem considerably.

Erroneous acreage data in the land status database was the other major problem. Due to a variety of reasons, many sections contained acreage values that were determined to be wrong during a verification check. The data in question originated with the BLM AALRS database and was intended for other purposes. Some ownership figures pertained to the entire township instead of a particular section and the APS processing had no way of assigning this data to the correct section or sections. A second problem was that under ANILCA, native groups were allowed to over-select lands. This was reflected additively in the AALRS database; that is, sections would have acreage figures two or more times the actual nominal limit of 640 acres. Only by comparing land status data plots to Realty sheets and Master Title Plats was it possible to adjust the acreage value for APS. Verification and editing of nearly 100,000 sections for five acreage figures was very time consuming - in the order of 2 - 3 man years. Despite this problem the checking and updating process was still more cost-effective than data entry from scratch. An estimated 30 percent of all values were updated via this process. Acreage problems were unpreventable since no other source was available, already automated and in a format convertible to the APS database structure.

Time Estimates

For casual estimates, usually the honest estimate was multiplied by 2, to provide for unforeseen problems. The doubled estimate was usually still too conservative. Probably the main reason for this was the sheer size and complexity of the undertaking, including time necessary to manage the logistics of hardware, data, and personnel resources.

Loss of Time to Manage Limited Resources

The APS project tried the limits of all Service resources: disk, cpu, tape, personnel, plotters, supplies, manuals, and patience. Probably 20% of personnel time was absorbed trying to manage these resources.

Realty went to double shifts to use the one digitizing table and to spread the processing out, so as to keep a reasonable response time. During times when the most staff were involved, it was sometimes hard to find manuals.

Most jobs were executed in batch, and scheduled overnight and over weekends to have less impact on interactive jobs. But scheduling too many simultaneous batch tasks hung the operating system (AOS/VS) when conflicting tasks prevented each other from completing (thrashing). Output from batch jobs went to batch output files and sometimes jobs had to be rerun interactively because some ARC error messages were not be redirected to the batch file.

It became difficult to keep track of what procedures were done for what refuges. An erasable board was used to track and monitor land status jobs. At one time, there were 3 different data definitions for one file type because files were brought back from archival after the data structure changed.

Toward the end, the project required more disk space than IRM could beg, borrow, or steal. Besides the data space needed, at least one ARC function (CLEAN) uses 14 times as much space as the data set it is applied to. APS reached the point were it could use 3 gigabytes of disk space for data and temporary balloon space. It was necessary to free up as much disk space as possible, negotiate for more, and archive whole refuges at times to allow room to process others.

Management had to choose between leasing additional disk or taking off most of the other system users. It was decided to take all non-APS users off the system for a period of time, rather than ration out time and disk that APS didn't use. This was very unpopular with the other users, but emphasized the need for independent hardware for APS. It was expected that APS would be finished within a month, after taking over the system, but again the estimate was too conservative. Twice major changes required rerunning the last two phases of the project, requiring another month.

Natural Disasters

In the computer business, it can be taken for granted that the computer will fail at some crucial point, near the end of the project. This project was no different. When the system failed due to a power fluxuation, someone made the mistake of remarking that the only disaster not yet realized was earthquake or flood. The next day a good part of southern Anchorage flooded. And then the earthquake happened in California. Although those two events didn't interfere with the project, the eruption of the volcano Mt Redoubt did. Whenever ash drifted towards Anchorage the computer room was closed down to prevent ash from being brought in through the air conditioning system. Besides the natural disasters, we experienced the usual equipment malfunctions and idiosyncrasies.

II. PLANS FOR ENHANCEMENTS

Introduction

Although the current APS software was designed to meet a specific goal, there is a continuing need to provide land status information. These (and other needs) were analyzed and incorporated into a preliminary database design prior to developing the system called APS. Over the past year and a half, a lot of knowledge has been accrued relating to implementing a large data base within a GIS framework. A new look at what the original work was attempting is needed to compare that to the current APS concepts. The two designs seem to possess sufficient commonalities to expect that the requirements of both could be met by a single software system. Thus APS, as it exists now, may evolve into a more comprehensive resource information system addressing a wide range of management issues. Whether emphasis will be placed on modeling, queries or some other function will need to be determined before major expansion or re-writes are begun. Although the final system, if one can be bold enough to use that adjective, is not completely conceived or may never be, some of the more important, consensus-driven enhancements will be outlined below. The current system was aimed at short term goals, specifically bringing in BLM land status data, updating it, and producing the acreage reports required by the Congressional mandate. The redesign will consider known long term objectives. Some of these goals will not be realized in the near future. APS, or it's offspring will definitely be a long term commitment.

Conversion to SUN:

Realty has purchased a Sun 4/370 with 5 GB of disk as the platform for APS. APS is scheduled to be moved over to the Sun in the next year. The ARC AML's are theoretically transportable. Global variables were used to refer to directories, but other idiosyncracies will be found. For instance, INFO commands in DG AML's can be indented, but they cannot be indented in the Sun implementation of ARC. So the AML's will would need some review and modifications.

While the system is being moved, it will be rewritten to meet long term goals, to be more manageable to run, and to be more efficient. Here are some of the issues that need to be addressed in the rewrite.

Landstatus

Realty would like to have information on all inholdings down to the parcel level. This will encompass:

- Location and extent of parcel
- Owner (Surface, subsurface, or both)
- Whether the parcel is selected or conveyed.
- Conveyance type

Overlapping claims

It will change from simply storing the acreage claimed within a section, to having an entry for every parcel. The additional data items may double the size of the present data base. The complexity of the data base structure will increase, as well.

The new design will also require a new digitizing effort to create the coverages that will describe the parcels.

Resource

The basic resource model will remain the same. The structure of the software will be reviewed to improve execution time. There are many loops used to process multiple categories and criteria, and there are probably opportunities for improvement.

Database Access

Access to the database, especially land status, is anticipated to be required by offices other than Realty, and quite possibly by the remote field sites (refuge headquarters). With several of the refuges are acquiring computer hardware and increased awareness of GIS capabilities, an extended design must encompass serving Service personnel using remote installations. Either the database, or a portion thereof, will need to be down loaded to other GIS-equipped computer systems or an access to the central system will need to be provided. There will be one master data base under management of the Realty Division and copies will be provided to interested parties. Outsiders may have read access but Realty will retain update authority. A local Region 7 office has already down loaded a small portion of the land status for the Yukon Delta Refuge to a PC for a specific, urgently needed mission. The questions associated with updating and disseminating a centralized database to the field, access control and a host more will need to be confronted up front in the design process.

User Interface

Currently, operation of the APS software is decentralized and operates via varied techniques (see section on Techniques and Implementation), some user 'friendly' and others not. For ease of use for all, a single entry point, with access control, should be implemented. A fully-functional pull-down menu system, displaying the appropriate selections for each type of user, seems to be the best alternative. An automated help and documentation facility corresponding to each choice would be a great assistance to all users. These automated documents should include process flow diagrams and an automated progress tracking system. The complexity of running the APS model currently requires even the analysts who wrote the software to frequently look up information to complete a full run.

VIII. RECOMMENDATIONS

As with most long term large scale projects, a number of 'lessons were learned' or unheeded principles reinforced. The below list attempts to capture the more salient brought to light during the APS project. All of the suggestions are generic, meaning that they would apply equally well to any number of computer applications, not necessarily GIS oriented. The ordering is not intended to imply distinctions of importance or affects.

1. Take the time necessary to do a complete design. If the information is not available, go as far as you can, then proceed into a pilot test phase. Impress upon management that extra time here is time well spent or conversely, time not spent here will cost later.

2. Be straight forward and 'hard-nosed' up front with issues that may delay production. This will go a long ways to prevent blame from accruing to the developer if the discussed problems do indeed arise.

3. Educate management concerning the costs of changes, particularly those after the system has been implemented and production has started. For all changes significantly affecting the delivery date, have management make the time line adjustments in writing.

4. Standardize the database structure across the entire project, including filenames and variable nomenclature. Modularize as much functionality as possible so that changes only need be made in a single routine.

5. Document the software, data definitions and procedures as they are being developed. This is the time when complex interactions are best understood and remembered. Document well, especially if an 'older' version might have to be reloaded from archive. Don't 'cop-out' on the excuse that "development is not done" - there will always be some coding work contemplated.

6. If more than one person is designing or implementing the design, they should be continually communicating. Assumed interpretations lead to trouble.

7. Do not underestimate or let management misjudge the size and power of the hardware necessary to contain and run the fully-functional database. Archiving and recoveries from disk 'crashes' can end up costing more in total resources than an initial procurement to provide the capability to process as planned. If the desired hardware can not be obtained, then adjust the time frame for deliverables

appropriately.

8. Examine the input data closely for quality and completeness. Programming for exceptions while in production can be very costly. Not catching such problems before delivery can doom the project itself.

9. Be liberal with error checking code. Always assume that re-runs will be required, so perform thorough file 'house-cleaning' at each step. Error messages should pin point the cause of the problem (ideally) and the unique software location of termination. Always abort on a serious error and don't let the next sequentially-queued job begin.

10. When estimating production schedule, allow for some error conditions and re-runs. If problems do not happen, and you finish ahead of schedule you really look good, otherwise you will (hopefully) make the deadline.

11. Program long tasks for batch mode with a batch output file that can be used to pin point error termination if it occurs. An interactive version may also be useful to acquire more information or achieve a quicker response.

12. For projects that have multiple databases and/or multiple steps, devise a workable tracking system. Consider automation; the overhead in coding maybe well worth it. For steps to be queued in sequence, automated detection of errors may be the only feasible way to prevent continuing processing following an error condition.

13. Beware of archival techniques that may permit you to re-load obsolete data or run de-archived data through a modified system that is no longer 100% compatible.

IX. CONCLUSIONS

We consider APS to be a true success story, because it fulfilled the objective, in spite of insufficient definition of goals, continual changes in method, and tight resources.

The technical problems encountered throughout the automation of the APS project, by enlarge, revolved around the inability of INFO to communicate easily, via AML programs, with the coordinates database and attributes stored in other INFO databases. Only by establishing data linkages using a locally-conceived technique was is possible to configure the database without many versions of the same file proliferating the disks. There is a definite need for the vendor to improve the ARC/INFO interface, the goal being to affect a seamless coupling with full data transfer and referencing facilities that are easy to use.

In an ideal world, 30% of the project should have been spent in the design phase. This would have included a detailed requirements document and analysis of the amount of data involved. Then the time estimates and equipment needs would have been more realistic, and less of an unpleasant shock.

The constant changing of the model emphasizes the strength of GIS. It is flexible, allowing management to try different strategies, until they decide on the best one. But ultimately, the better that needs are defined in the design stage, the more efficient and/or economical the system.

X. APPENDICES

A - APS Data and Process Diagram

B - Biologist's Resource Map (CATEGORY)

C - Digitized Resource Polygon Map (For Category FIPO)

D - Class Assignments for two CATEGORIES

E - Examples of CRITERIA

F - Point Assignments per Category per Criteria & Scoring Maximums per Criteria

G - Excerpts from the BLM Land Status Data

H - Listing of a Refuge Window File

I - Land Status Plot

J - Integrated Land Status & Resource Data

K - Statework File

L - Final Reports

M - Check Plots

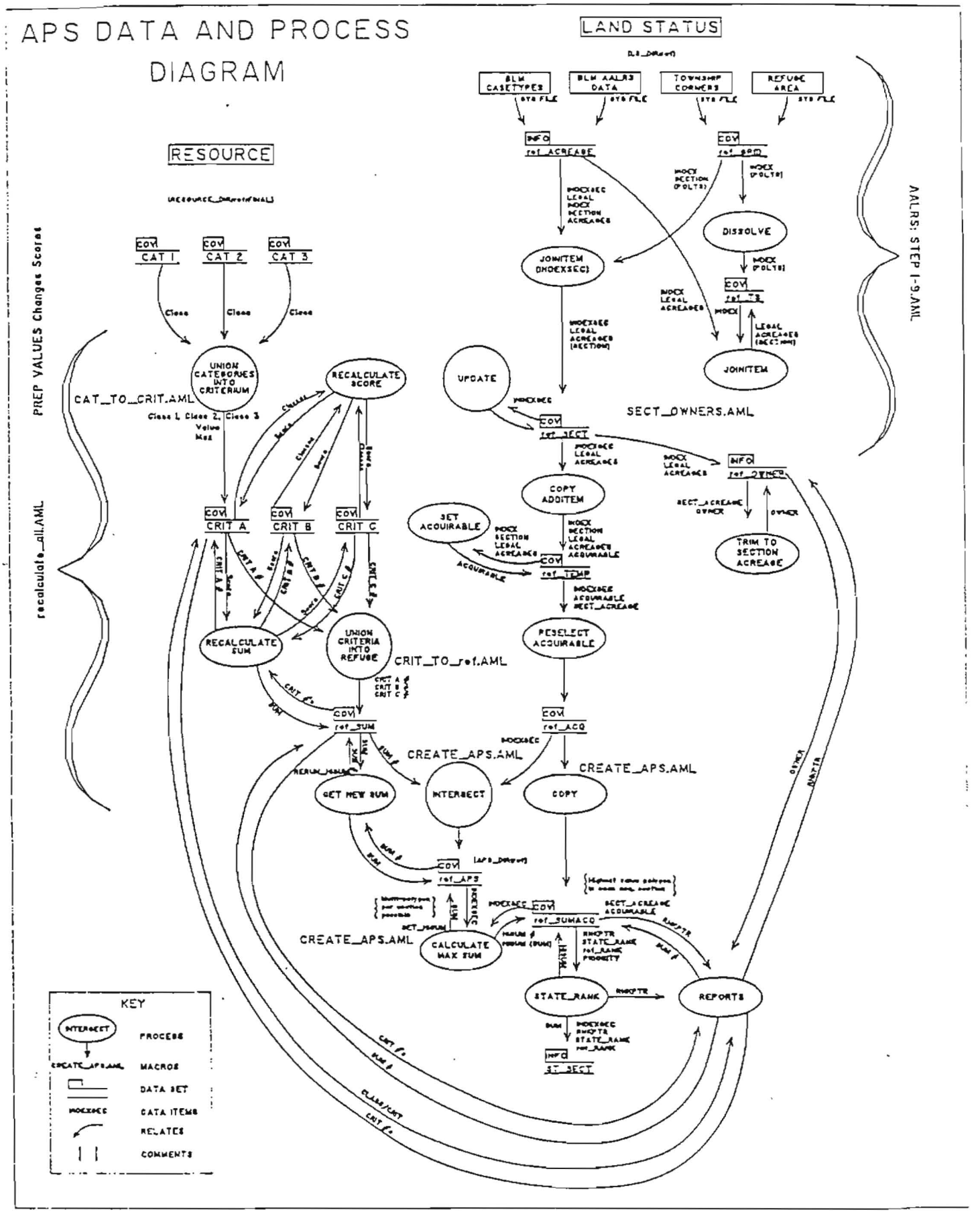
N - Section Acreage

O - Final Plots

P - A Refuge Split into Sheets

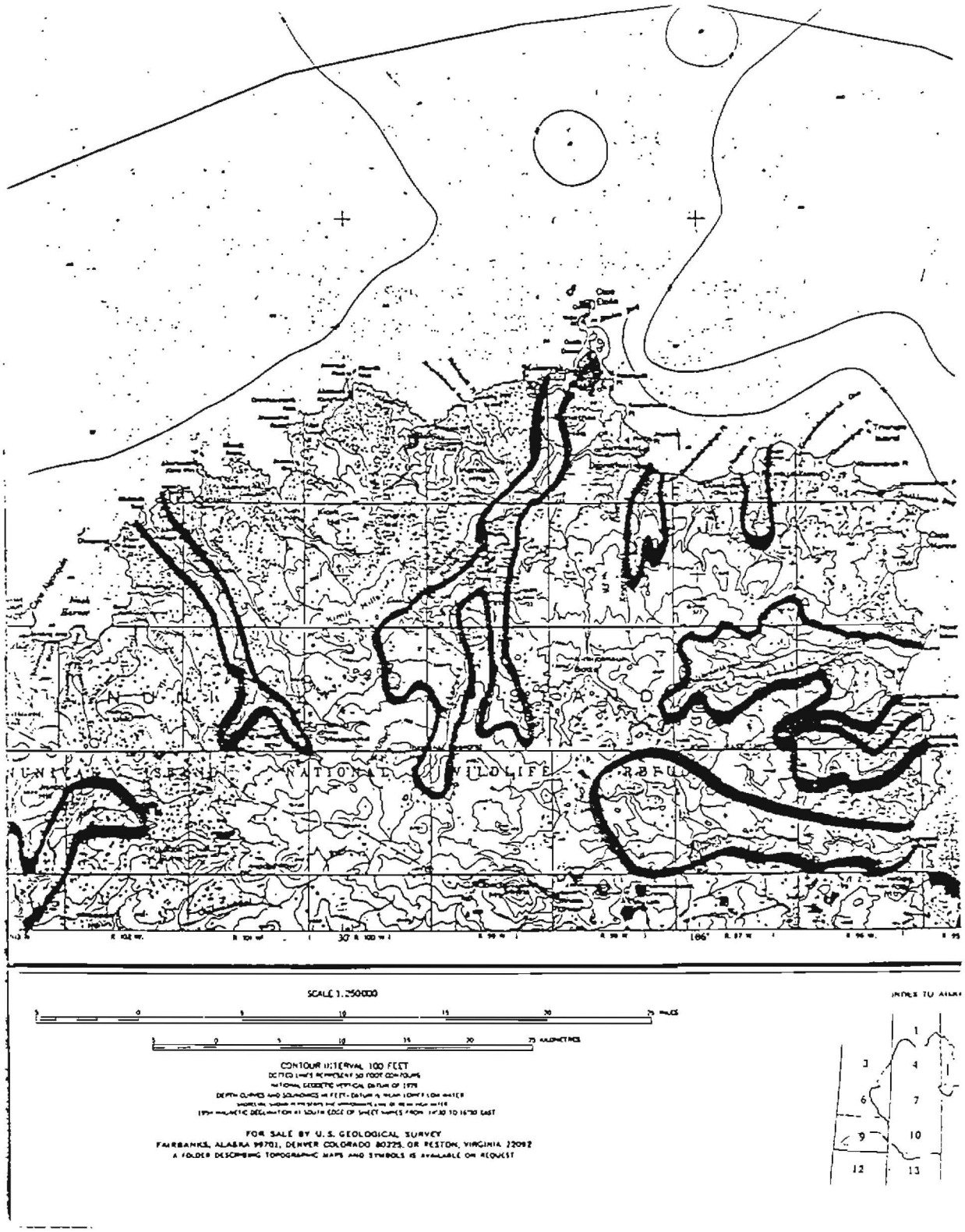
APPENDEX A

APS Data and process Diagram


APS DATA AND PROCESS DIAGRAM
LAND STATUS
RESOURCE
BLM CASETYPES
BLM AALRS DATA
TOWNSHIP CORNERS
REFUGE AREA
ref_ACREAGE
ref_BOM
DISSOLVE
JOINITEM (INDEXSEC)
JOINITEM
ref_T3
UPDATE
ref_SECT
SECT_OWNERS.AML
ref_OWNER
COPY ADDITEM
SET ACQUIRABLE
ref_TEMP
RESELECT ACQUIRABLE
TRIM TO SECTION ACREAGE
ref_ACQ
COPY
CREATE_APS.AML
INTERSECT
ref_APS
ref_SUMACQ
STATE_RANK
REPORTS
ST_SECT
CAT 1
CAT 2
CAT 3
UNION CATEGORIES INTO CRITERIUM
CAT_TO_CRIT.AML
RECALCULATE SCORE
CRIT A
CRIT B
CRIT C
RECALCULATE SUM
UNION CRITERIA INTO REFUGE
CRIT_TO_ref.AML
ref_SUM
GET NEW SUM
CALCULATE MAX SUM
AALRS: STEP 1-9.AML
PREP VALUES Changes Scores
recalculate_all.AML
KEY
PROCESS
MACROS
DATA SET
DATA ITEMS
RELATES
COMMENTS

APPENDEX B

Biologist's Resource Map (CATEGORY)


SCALE 1:250000
CONTOUR INTERVAL 100 FEET
FOR SALE BY U.S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

FORM 1: CATEGORY COLLECTION

Yukon Delta NWR Spp./Other Category: Fish: Anad, Res, Po..

Data source: Denny Strom Date recorded: 12-8-88

Criteria: FH WT

Class Code:

A	=	good to excellent anadromous - orange
C	=	poor fish habitat yellow line
Z	=	No fish habitat: yellow hatching.
	=	
	=	
	=	

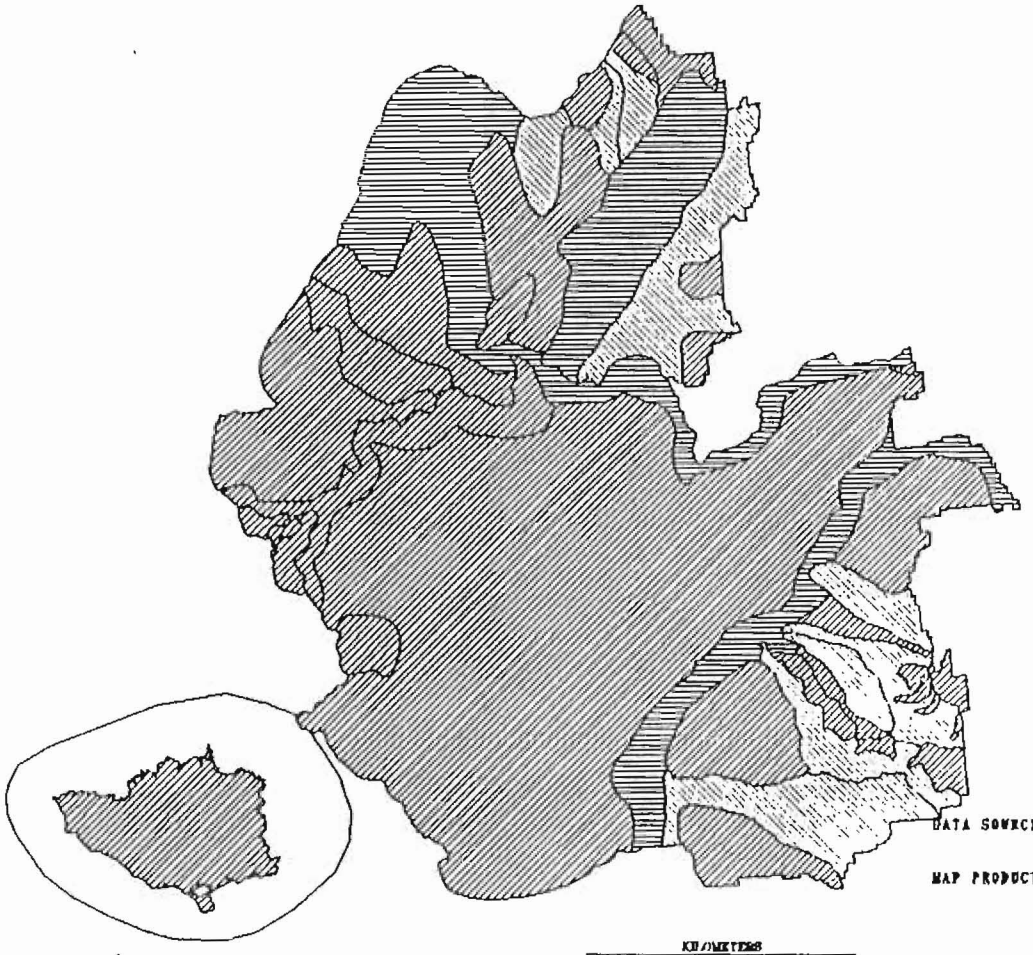
Quad(s) Used	Data Collector (initial/date)	Arcs Digit. (initial/date)
St. Michael	DGJ 12-8-88	
Unalakleet		
Black		
Kuskokwim		
Holy Cross		
Hooper Bay		
Marshall		
Russian Mission		
Nunivak Island		
Baird Inlet		
Bethel		
Cape Mendenhall		
Goodnews		

APPENDEX C

Digitized Resource Polygon Map (For Category FIPO)

YUKON DELTA

FISHERIES RESOURCES



FISH POPULATION

CLASS	DESCRIPTION
A	SALMON ESCAPEMENT GREATER THAN 100,000
B	SALMON ESCAPEMENT 20,000 TO 100,000 OR MAJOR SPAWNING AREA FOR LANDS ACT RESERVE PURPOSE FISH
C	SALMON ESCAPEMENT LESS THAN 51,000 OR RESIDENT POPULATION OF UNKNOWN SIZE
Z	SPARSE OR NO FISH

DATA SOURCE : DENNY STROM, MIKE REARDIN
YUKON DELTA NWR
RECEIVED BY REALTY APRIL 6, 1989

MAP PRODUCTION: U.S. FISH & WILDLIFE SERVICE
DIVISIONS OF REALTY & IRM/GIS
June 09, 1989

KILOMETERS
25 0 25 50 75 100
SCALE 1:[illegible]

APPENDEX D

Class Assignments for two CATEGORIES

$RECNO	YDFRFIPO#	CLASS
1	1	
2	2	C
3	3	C
4	4	B
5	5	B
6	6	C
7	7	A
8	8	A
9	9	B
10	10	B
11	11	C
12	12	C
13	13	C
14	14	C
15	15	C
16	16	C
17	17	C
18	18	C
19	19	C
20	20	C
21	21	C
22	22	C
23	23	C
24	24	C
25	25	Z
26	26	C
27	27	C
28	28	C
29	29	C
30	30	C
31	31	A
32	32	B
33	33	C
34	34	B
35	35	B
36	36	B
37	37	C
38	38	C
39	39	C
40	40	C
41	41	C
42	42	C
43	43	C
44	44	B

$RECNO	YDFRFISP#	CLASS
1	1	
2	2	C
3	3	C
4	4	B
5	5	B
6	6	D
7	7	A
8	8	B
9	9	B
10	10	C
11	11	D
12	12	D
13	13	D
14	14	C
15	15	C
16	16	D
17	17	D
18	18	B
19	19	B
20	20	D
21	21	D
22	22	D
23	23	B
24	24	D
25	25	C
26	26	D
27	27	D
28	28	B
29	29	B
30	30	Z
31	31	B
32	32	B
33	33	B
34	34	B
35	35	B
36	36	B
37	37	D
38	38	D
39	39	A
40	40	B
41	41	D
42	42	B

APPENDEX E

Examples of CRITERIA

APPENDIX E

EXAMPLE OF CRITERIA SCORING
FOR CRITERIA FR - FISHERIES
YUKON DELTA NATIONAL WILDLIFE REFUGE

FR-ID	FISP	FIPO	VALUE	MAX	SCORE
0			0	0	0
1	C	C	5	4	5
2	C	C	5	4	5
3	B	B	7	5	7
4	B	B	7	5	7
5	D	C	3	2	3
6	A	A	10	6	10
7	B	A	9	5	9
8	B	B	7	5	7
9	C	B	6	4	6
10	D	C	3	2	3
11	D	C	3	2	3
12	D	C	3	2	3
13	C	C	5	4	5
14	C	C	5	4	5
15	D	C	3	2	3
16	D	C	3	2	3
17	B	C	6	5	6
18	B	C	6	5	6
19	D	C	3	2	3
20	A	A	10	6	10
21	D	C	3	2	3
22	D	C	3	2	3
23	D	C	3	2	3
24	B	B	7	5	7
25	D	C	3	2	3
26	C	C	5	4	5
27	A	B	8	6	8
28	B	B	7	5	7
29	A	B	8	6	8
30	D	C	3	2	3
31	D	C	3	2	3
32	B	C	6	5	6
33	D	C	3	2	3
34	B	C	6	5	6
35	B	C	6	5	6
36	Z	Z	0	0	0
37	B	C	6	5	6
38	B	C	6	5	6
39	B	C	6	5	6
40	B	C	6	5	6
41	B	C	6	5	6
42	B	B	7	5	7
43	D	C	3	2	3

APPENDEX F (part I)

Point Assignment per Category per Criteria
&
Scoring Maximums per Criteria

```
DU,ALSF,10, 6, 3,  ,  ,  ,0
DU,ARFO, 5, 3, 1,  ,  ,  ,0
DU,LABB, 5, 3, 1,  ,  ,  ,0
DU,BTCU,10, 6, 3,  ,  ,  ,0
DU,LACA, 5, 3, 1,  ,  ,  ,0
DU,LADS, 5, 3, 1,  ,  ,  ,0
DU,FSHO,10, 6, 3,  ,  ,  ,0
DU,FSRO,10, 6, 3,  ,  ,  ,0
DU,GOEA,10, 6, 3,  ,  ,  ,0
DU,LAGB, 5, 3, 1,  ,  ,  ,0
DU,LARA, 5, 3, 1,  ,  ,  ,0
DU,LASH, 5, 3, 1,  ,  ,  ,0
DU,LYNX, 5, 3, 1,  ,  ,  ,0
DU,LAMA, 5, 3, 1,  ,  ,  ,0
DU,LAMG, 5, 3, 1,  ,  ,  ,0
DU,LAMO, 5, 3, 1,  ,  ,  ,0
DU,LAMU, 5, 3, 1,  ,  ,  ,0
DU,LAPB, 5, 3, 1,  ,  ,  ,0
DU,PAWA,10, 6, 3,  ,  ,  ,0
DU,PEFA,10, 6, 3,  ,  ,  ,0
DU,POBE,10, 6, 3,  ,  ,  ,0
DU,REFO, 5, 3, 1,  ,  ,  ,0
DU,REIN, 5, 3, 1,  ,  ,  ,0
DU,ROEL, 5, 3, 1,  ,  ,  ,0
DU,SBTD, 5, 3, 1,  ,  ,  ,0
DU,SEOT,10, 6, 3,  ,  ,  ,0
DU,SERO,10, 6, 3,  ,  ,  ,0
DU,SHOA,10, 6, 3,  ,  ,  ,0
DU,SHOR, 5, 3, 1,  ,  ,  ,0
DU,SLHO,10, 6, 3,  ,  ,  ,0
DU,SLRO,10, 6, 3,  ,  ,  ,0
DU,LAWF, 5, 3, 1,  ,  ,  ,0
DU,LAWV, 5, 3, 1,  ,  ,  ,0
DU,CARI, 5, 3, 1,  ,  ,  ,0
DU,GRBE, 5, 3, 1,  ,  ,  ,0
DU,MUSX, 5, 3, 1,  ,  ,  ,0
DU,DASH, 5, 3, 1,  ,  ,  ,0
DU,WOLF, 5, 3, 1,  ,  ,  ,0
DU,WOLV, 5, 3, 1,  ,  ,  ,0
DU,MOOS, 5, 3, 1,  ,  ,  ,0
DU,BLBE, 5, 3, 1,  ,  ,  ,0
DU,MOGO, 5, 3, 1,  ,  ,  ,0
DU,MART, 5, 3, 1,  ,  ,  ,0

DW,ALCG,10, 6, 2,  ,  ,  ,0
DW,BAEA,10, 6, 2,  ,  ,  ,0
DW,BEAV, 5, 3, 1,  ,  ,  ,0
DW,CACG,30,24,18,  ,  ,  ,0
DW,CAGO,10, 6, 2,  ,  ,  ,0
DW,CANV,14, 8, 2,  ,  ,  ,0
DW,EMGO,26,20,14,  ,  ,  ,0
DW,FISP, 6, 5, 4, 2, 3,  ,0
```

```
DW,GWFG,10, 6, 2,  ,  ,  ,0
DW,LASE, 8, 4, 1,  ,  ,  ,0
DW,LARA, 8, 4, 1,  ,  ,  ,0
DW,LASH, 8, 4, 1,  ,  ,  ,0
DW,LAWA, 8, 4, 1,  ,  ,  ,0
DW,LECG,10, 6, 2,  ,  ,  ,0
DW,MALL,14, 8, 2,  ,  ,  ,0
DW,MINK, 5, 3, 1,  ,  ,  ,0
DW,MUSK, 5, 3, 1,  ,  ,  ,0
DW,NOPI,14, 8, 2,  ,  ,  ,0
DW,PABR,22,16,10,  ,  ,  ,0
DW,PWFG,26,20,14,  ,  ,  ,0
DW,SEAB, 5, 3, 1,  ,  ,  ,0
DW,RIOT, 5, 3, 1,  ,  ,  ,0
DW,RNDU,10, 6, 2,  ,  ,  ,0
DW,SACR,10, 6, 2,  ,  ,  ,0
DW,SHOR, 5, 3, 1,  ,  ,  ,0
DW,SNGO,10, 6, 2,  ,  ,  ,0
DW,SWAN,10, 6, 2,  ,  ,  ,0
DW,TACG,10, 6, 2,  ,  ,  ,0
DW,TRSW,10, 6, 2,  ,  ,  ,0
DW,TUSW,10, 6, 2,  ,  ,  ,0
DW,WATE, 5, 3, 1,  ,  ,  ,0

ES,ALCG,20,10, 5,  ,  ,  ,0
ES,ALSF,20,10, 5,  ,  ,  ,0
ES,PEFA,18,13, 9, 7, 2,  ,0

FR,FIPO, 4, 2, 1,  ,  ,  ,0
FR,FISP, 6, 5, 4, 2, 3,  ,0

MB,BAEA,10, 6, 2,  ,  ,  ,0
MB,BTCU,12, 6, 1,12, 6, 2,0
MB,CACG,30,24,18,  ,  ,  ,0
MB,CAGO,10, 6, 2,  ,  ,  ,0
MB,CANV,14, 8, 2,  ,  ,  ,0
MB,EMGO,26,20,14,  ,  ,  ,0
MB,GOEA,10, 6, 2,  ,  ,  ,0
MB,GWFG,10, 6, 2,  ,  ,  ,0
MB,LARA, 8, 4, 1,  ,  ,  ,0
MB,LASE, 8, 4, 1,  ,  ,  ,0
MB,LASH, 8, 4, 1,  ,  ,  ,0
MB,LAWA, 8, 4, 1,  ,  ,  ,0
MB,LECG,10, 6, 2,  ,  ,  ,0
MB,MALL,14, 8, 2,  ,  ,  ,0
MB,NOPI,14, 8, 2,  ,  ,  ,0
MB,PABR,22,16,10,  ,  ,  ,0
MB,PEFA,10, 6, 2,  ,  ,  ,0
MB,PWFG,26,20,14,  ,  ,  ,0
MB,RNDU,10, 6, 2,  ,  ,  ,0
MB,SACR,10, 6, 2,  ,  ,  ,0
MB,SHOR, 0, 0, 0,  ,  ,  ,0
```

```
MB,SNGO,10, 6, 2,  ,  ,  ,0
MB,SWAN,10, 6, 2,  ,  ,  ,0
MB,TACG,10, 6, 2,  ,  ,  ,0
MB,TRSW,10, 6, 2,  ,  ,  ,0
MB,TUSW,10, 6, 2,  ,  ,  ,0

MM,FSHO,18,10, 2,  ,  ,  ,0
MM,FSRO,20,12, 4,  ,  ,  ,0
MM,PAWA,16, 8, 2,  ,  ,  ,0
MM,POBE, 6, 3, 1,  ,  ,  ,0
MM,SEOT, 3, 2, 1,  ,  ,  ,0
MM,SERO, 8, 4, 1,  ,  ,  ,0
MM,SHOA,10, 5, 1,  ,  ,  ,0
MM,SLHO,18,10, 2,  ,  ,  ,0
MM,SLRO,20,12, 4,  ,  ,  ,0

PU,REUS,10, 7, 5, 3, 2, 1,0
PU,SUUS,15,12, 9, 6, 4, 2,0

RM,ACMA, 9, 5, 3,  ,  ,  ,0
RM,FIRE, 4, 2, 1,  ,  ,  ,0
RM,MAAC, 4, 2, 1,  ,  ,  ,0

RS,BLBE,10, 5, 1,  ,  ,  ,0
RS,CARI,10, 5, 1,  ,  ,  ,0
RS,DASH,10, 5, 1,  ,  ,  ,0
RS,GRBE,10, 5, 1,  ,  ,  ,0
RS,MART,10, 5, 1,  ,  ,  ,0
RS,MOGO,10, 5, 1,  ,  ,  ,0
RS,MOOS,10, 5, 1,  ,  ,  ,0
RS,MUSX,10, 5, 1,  ,  ,  ,0
RS,WOLF,10, 5, 1,  ,  ,  ,0
RS,WOLV,10, 5, 1,  ,  ,  ,0

TR,THRE,30,20,10,  ,  ,  ,0
```

APPENDEX F (part II)

Scoring Maximums per Criteria

APPENDIX F (part II)

```
ES,CUMREF,20
MM,CUMREF,20
FR,CUMREF,10
RM,CUMREF,10
MB,MAXREF,30
RS,MAXREF,10
PU,MAXREF,10
TR,MAXREF,30
DU,CUMAK,20
DW,CUMAK,20
:     :     :
:     :     :-------- Maximum allowable score
:     :
:     :------ Scoring method
:
:-- Criteria
```

COMREF - Cumulative, max applies to a Refuge

MAXREF - Use maximum categories points up to a max for Refuge

CUMAK - Cumulative scale to max over the whole state

APPENDEX G

Excerpts from the BLM Land Status Data

APPENDIX G.

Raw Land Status Data from BLM

*** Data Item Definitions ***

Columns	Contents	Columns	Contents
1 - 10	Serial Number	32 - 34	Range Number
11 - 16	Case type	35 - 35	Range Direction
17 - 18	Conveyance Prefix	36 - 37	Section Number
19 - 26	Conveyance Number	38 - 44	Unused
27 - 27	Meridian	45 - 53	Acreage
28 - 30	Township Number	54 - 58	Township Index #
31 - 31	Township Direction	59 - 80	Unused

*** Sample Data ***

1	2	3	4	5	6	7
000000	235155PL00096487C028S006W05	00000	00000500001007	000	000	0000000
000000	235155PL00096487C028S006W06	00000	00004500001007	000	000	0000000
000000	235155PL00096487C028S006W07	00000	00028500001007	000	000	0000000
000000	235155PL00096487C028S006W08	00000	00013500001007	000	000	0000000
000000	235155PL00096487C028S006W17	00000	00003500001007	000	000	0000000
000000	235155PL00096487C028S006W18	00000	00042500001007	000	000	0000000
000000	235155PL00096487C028S006W19	00000	00019000001007	000	000	0000000
000000	235155PL00096487C028S006W30	00000	00000500001007	000	000	0000000
A 026918	362000CD19561206C028S006W00	00000	00000000101007	000	000	0000000
A 040735	311111CD19590615C028S006W00	00000	00217700001007	000	000	0000000
A 054475	362001CD19630612C028S006W00	00000	00000000101007	000	000	0000000
A 060835	311111CD00000000C028S006W05	00000	00000500001007	000	000	0330001
A 060835	311111CD00000000C028S006W06	00000	00004500001007	000	000	0400001
A 060835	311111CD00000000C028S006W07	00000	00028500001007	000	000	0500001
A 060835	311111CD00000000C028S006W08	00000	00013500001007	000	000	0000001

APPENDEX H

Listing of a Refuge Window File

APPENDIX H.

Refuge Window Data

*** Data Item Definitions ***

Record 1 - Header record for identification only (skipped by program)
Record 2 - n
Columns 1 - 5 Township Index # (converts to a legal description)
Columns 6 - 41 Section flags (0 = not in refuge, 1 = in refuge)

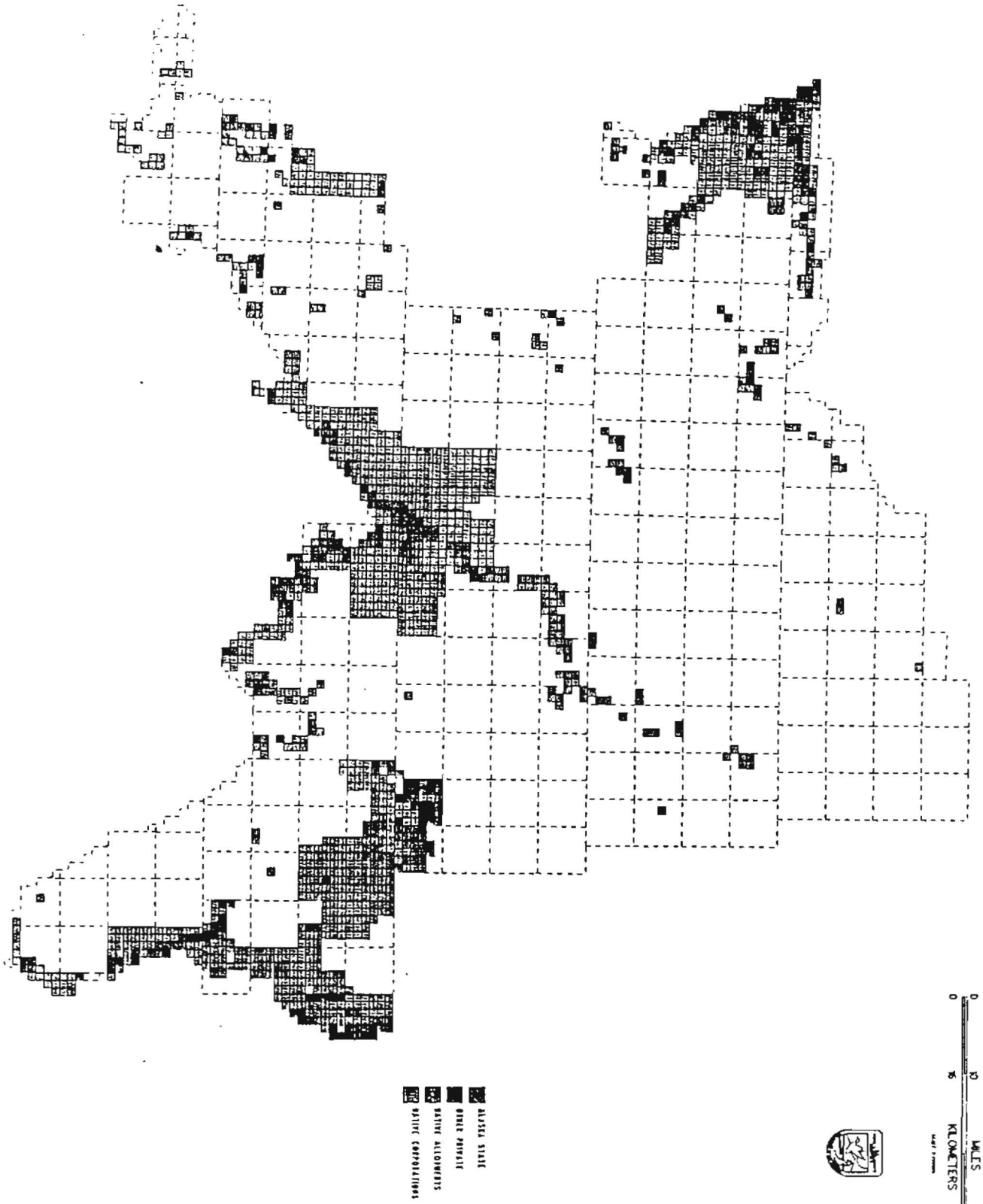
*** Sample Data ****

```
XXXXXANILCA / MARITIME4 utm zone 5
010071111111111111111111111111111111111111
010251111111111111111111111111111111111111
118601111111111111111111111111111111111111
145121111111111111111111111111111111111111
145131111111111111111111111111111111111111
145200000111100000001100111000001100000100
145410000000000000000000110000001111111100
145421111111111111111111111111111111111111
146171111111111111111111111111111111111111
146281111111111111111111111111111111111111
146360000000000000000000000000000000011100
146371111111111111111111111111111111111111
146431111111111111111111111111111111111111
146441111111111111111111111111111111111111
146461111111111111111111111111111111111111
146471111111111111111111111111111111111111
146481111111111111111111111111111111111111
146491111111111111111111111111111111111111
146520000000000001000000001111110000000111
146531111111111111111111111111111111111111
146541111111111111111111111111111111111111
146551111111111111111111111111111111111111
146561111111111111111111111111111111111111
146671111111111111111111111111111111111111
146691111111111111111111111111111111111111
146701111111111111111111111111111111111111
146711111111111111111111111111111111111111
146720001110000000000000000000000000000000
146881111111111111111111111111111111111111
146891111111111111111111111111111111111111
146901111111111111111111111111111111111111
146911110000000000000000000000000000000000
147071111111111111111111111111111111111111
147081111111111111111111111111111111111111
147701111111111111111111111111111111111111
147711111111111111111111111111111111111111
```

APPENDEX I

Land Status Plot

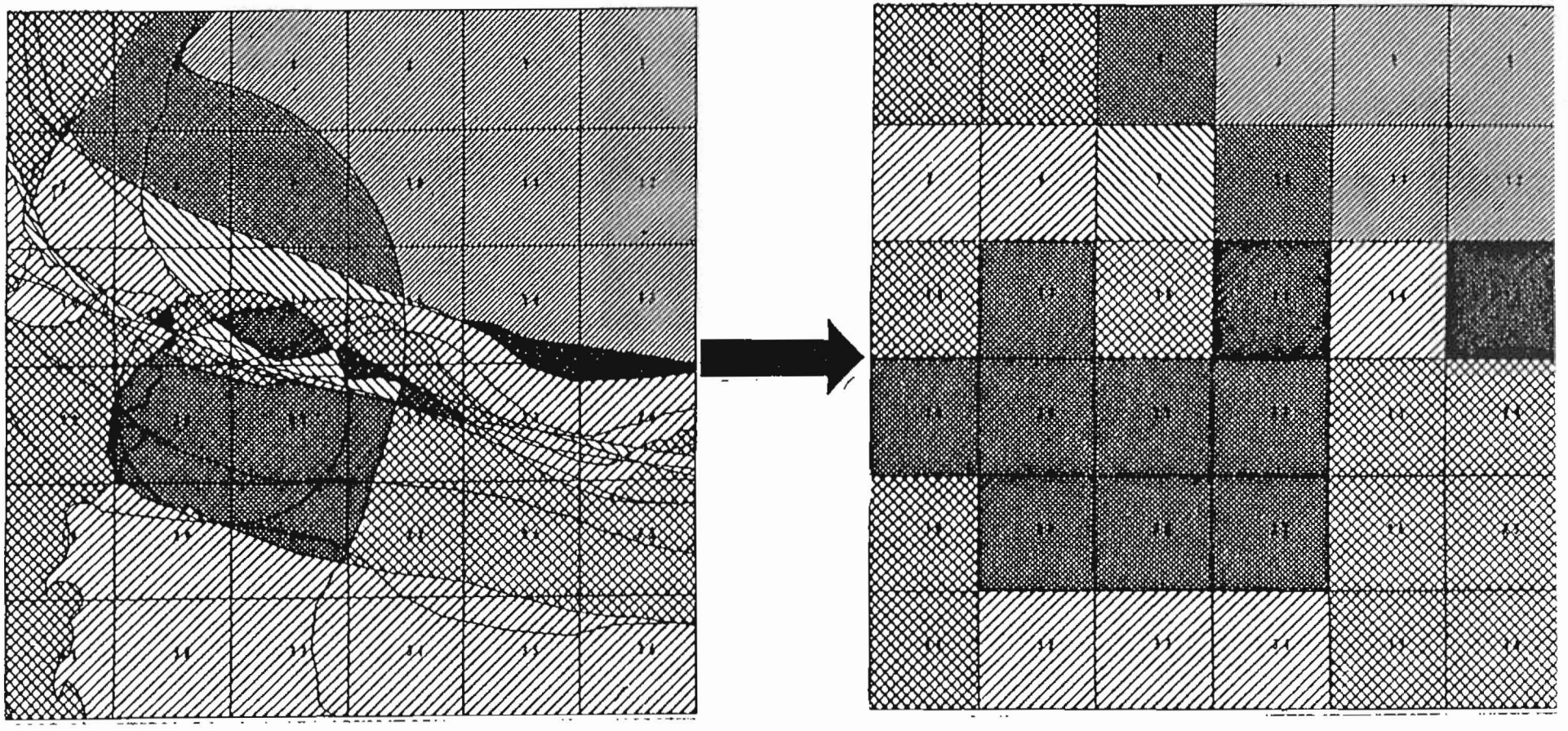
TOGIAK LAND STATUS
ALL CLAIMS



APPENDEX J

Integrated Land Status & Resource Data

GENERALIZATION TO SECTION LEVEL USING HIGH SUM



APPENDIX J

$RECNO	AREA	PERIMETER	KA_APS#	KA_APS-ID	KA_SUM#	SUM	INDEXSEC	ACQUIRABLE	KA_RANK	STATE_RANK	RNKPTR
1	-1.71707E+09	829,161.625	1	0	1	0	0	0	0	0	0
2	2511427.000	6,337.148	2	1	2	18	532722	1	0	0	0
3	1772359.000	5,385.891	3	2	2	18	532721	1	0	0	0
4	733,054.063	4,243.543	4	3	3	14	532721	1	0	0	0
5	2483294.000	6,305.066	5	4	3	14	532720	1	0	0	0
6	2207345.000	5,945.797	6	5	3	14	532719	1	0	0	0
7	265,706.750	2,432.396	7	6	4	24	529020	1	0	0	0
8	255,584.750	2,216.569	8	7	5	25	529020	1	0	0	0
9	171,884.125	2,147.616	9	8	4	24	529019	1	0	0	0
10	780,988.750	3,623.317	10	9	6	22	529019	1	0	0	0
11	96,270.625	1,723.699	11	10	7	20	529019	1	0	0	0
12	25,391.281	1,507.179	12	11	8	17	529019	1	0	0	0
13	1156175.000	4,654.746	13	12	8	17	532724	1	0	0	0
14	493,448.125	2,982.133	14	13	8	17	532723	1	0	0	0
15	662,308.750	3,348.784	15	14	2	18	532723	1	0	0	0
16	161,756.938	1,598.073	16	15	9	29	529020	1	0	0	0
17	39,044.688	1,095.573	17	16	10	34	529020	1	0	0	0
18	2081331.000	5,794.613	18	17	11	34	525325	1	0	0	0
19	456,744.625	3,744.157	19	18	11	34	525326	1	0	0	0
20	2108885.000	5,844.258	20	19	12	34	525326	1	0	0	0
21	725,310.313	4,212.809	21	20	12	34	525327	1	0	0	0
22	458,815.938	3,859.023	22	21	13	35	525327	1	0	0	0
23	1323877.000	4,859.598	23	22	14	35	525327	1	0	0	0
24	828,971.438	5,052.953	24	23	14	35	525328	1	0	0	0
25	367,128.188	3,103.669	25	24	14	35	525329	1	0	0	0
26	4,422.188	328.817	26	25	15	35	525329	1	0	0	0
27	286,581.375	2,861.372	27	26	16	36	525329	1	0	0	0
28	1552468.000	5,185.414	28	27	16	36	525330	1	0	0	0
29	820,343.688	4,268.582	29	28	17	36	525330	1	0	0	0
30	31,655.000	811.019	30	29	21	35	529020	1	0	0	0
31	362,648.125	3,307.220	31	30	22	36	525329	1	0	0	0
32	617,166.875	3,091.745	32	31	23	36	525329	1	0	0	0
33	2427499.000	6,309.902	33	32	20	35	529028	1	0	0	0
34	1137245.000	4,755.289	34	33	23	36	525328	1	0	0	0

35	160,401.000	3,379.289	35	34	21	35	529028	1	0	0	0
36	747,495.375	4,156.223	36	35	21	35	529029	1	0	0	0
37	387,378.438	3,927.994	37	36	10	34	529029	1	0	0	0
38	843,778.125	4,422.043	38	37	9	29	529029	1	0	0	0
39	600,736.938	3,942.586	39	38	5	25	529029	1	0	0	0
40	8,510.219	534.814	40	39	4	24	529029	1	0	0	0
41	1570314.000	5,283.906	41	40	4	24	529030	1	0	0	0
42	378,340.750	3,119.463	42	41	6	22	529030	1	0	0	0
43	76,069.375	1,757.353	43	42	7	20	529030	1	0	0	0
44	8,149.094	577.815	44	43	8	17	529030	1	0	0	0
45	2233498.000	5,935.527	45	44	8	17	532725	1	0	0	0
46	2312454.000	5,996.734	46	45	8	17	532726	1	0	0	0
47	275,371.063	2,591.715	47	46	2	18	532726	1	0	0	0
48	455,705.188	3,459.059	48	47	24	30	525325	1	0	0	0
49	2314093.000	5,977.449	49	48	2	18	532727	1	0	0	0

APPENDEX K

Statework File

APPENDIX K

$RECNO	AREA	PERIMETER	ACQ#	ACQ-ID	INDEXSEC	SECT_ACRE	ACQUIRE	HISUM	HISUM#	RANK	RNKPTR	ST_RANK	PRIOR
1	-1.75339E+09	832,711.375	1	0	0	640.000	0	0	0	0	700001	0	0
2	2588106.000	6,435.418	2	1,027	529020	640.000	1	35	21	126	700002	28921	3
3	2403106.000	6,204.488	3	1,026	529019	593.849	1	24	4	401	700003	35921	3
4	2587856.000	6,434.121	4	1,405	532724	640.000	1	17	8	478	700004	37893	3
5	2588118.000	6,434.215	5	1,404	532723	640.000	1	18	2	455	700005	37743	3
6	2587916.000	6,434.176	6	1,403	532722	640.000	1	18	2	456	700006	37744	3
7	2587933.000	6,435.148	7	1,402	532721	640.000	1	18	2	457	700007	37745	3
8	2587865.000	6,435.109	8	1,401	532720	640.000	1	14	3	571	700008	38148	3
9	2402746.000	6,203.680	9	1,400	532719	593.743	1	14	3	572	700009	38149	3
10	2588167.000	6,434.770	10	666	525325	640.000	1	34	11	154	700010	29665	3
11	2588088.000	6,434.758	11	667	525326	640.000	1	34	11	155	700011	29666	3
12	2588300.000	6,434.801	12	668	525327	640.000	1	37	25	95	700012	26679	3
13	2588282.000	6,434.777	13	669	525328	640.000	1	37	25	96	700013	26680	3
14	2587826.000	6,434.691	14	670	525329	640.000	1	37	25	97	700014	26681	3
15	2411889.000	6,215.449	15	671	525330	596.009	1	37	25	98	700015	26682	3
16	2587893.000	6,434.414	16	1,031	529028	640.000	1	35	20	127	700016	28922	3
17	2587947.000	6,435.355	17	1,032	529029	640.000	1	35	21	128	700017	28923	3
18	2412223.000	6,216.715	18	1,033	529030	596.083	1	25	5	387	700018	35542	3
19	2588070.000	6,434.121	19	1,406	532725	640.000	1	24	4	402	700019	35922	3
20	2587814.000	6,435.230	20	1,407	532726	640.000	1	18	2	458	700020	37746	3
21	2588115.000	6,436.172	21	1,408	532727	640.000	1	18	2	459	700021	37747	3
22	2587895.000	6,435.152	22	1,409	532728	640.000	1	18	2	460	700022	37748	3
23	2588053.000	6,434.094	23	1,410	532729	640.000	1	14	3	573	700023	38150	3
24	2411970.000	6,215.938	24	1,411	532730	595.977	1	14	3	574	700024	38151	3
25	2588213.000	6,435.797	25	677	525336	640.000	1	34	11	156	700025	29667	3
26	2588100.000	6,435.805	26	676	525335	640.000	1	34	11	157	700026	29668	3
27	2587908.000	6,434.727	27	675	525334	640.000	1	37	25	99	700027	26683	3
28	2587973.000	6,434.777	28	674	525333	640.000	1	37	25	100	700028	26684	3
29	2588242.000	6,434.684	29	673	525332	640.000	1	37	25	101	700029	26685	3
30	2420871.000	6,227.785	30	672	525331	598.243	1	37	25	102	700030	26686	3
31	2588196.000	6,434.477	31	1,036	529033	640.000	1	35	20	129	700031	28924	3
32	2587908.000	6,434.375	32	1,035	529032	640.000	1	35	21	130	700032	28925	3
33	2421392.000	6,227.898	33	1,034	529031	598.317	1	29	9	337	700033	33892	3
34	2588091.000	6,436.188	34	1,417	532736	640.000	1	24	4	403	700034	35923	3
35	2588039.000	6,435.164	35	1,416	532735	640.000	1	19	28	448	700035	37658	3

36	2587994.000	6,434.168	36	1,415	532734	640.000	1	19	28	449	700036	37659	[illegible]
37	2588042.000	6,434.133	37	1,414	532733	640.000	1	14	3	575	700037	38152	[illegible]
38	2587847.000	6,435.113	38	1,413	532732	640.000	1	14	3	576	700038	38153	[illegible]
39	2420624.000	6,227.176	39	1,412	532731	598.211	1	14	3	577	700039	38154	[illegible]
40	2588234.000	6,435.125	40	297	521504	640.000	1	17	37	479	700040	37894	[illegible]
41	2588420.000	6,435.133	41	298	521505	640.000	1	29	41	338	700041	33893	[illegible]
42	2430142.000	6,239.406	42	299	521506	600.507	1	30	24	304	700042	32739	[illegible]
43	92360240.000	38,443.254	43	0	0	640.000	0	0	0	0	700043	0	[illegible]
44	2587087.000	6,434.219	44	990	528901	640.000	1	36	16	116	700044	27945	[illegible]
45	2587853.000	6,435.398	45	991	528902	639.444	1	40	19	52	700045	23417	[illegible]
46	2587681.000	6,435.359	46	992	528903	639.441	1	40	19	53	700046	23418	[illegible]
47	2587677.000	6,434.465	47	993	528904	639.438	1	35	20	131	700047	28926	[illegible]
48	2587779.000	6,434.367	48	994	528905	639.435	1	35	20	132	700048	28927	[illegible]
49	2429814.000	6,237.914	49	995	528906	600.464	1	34	10	158	700049	29669	[illegible]

APPENDEX L

Final Reports

APPENDIX L.

Land Ownership Class Acreage by Refuge and Priority

INFO output used to create both the A and B Reports

REFUGE	PRIORITY	SECT_ACREAGE	NAT_ALLOT	NAT_CORP	AK_STATE	OTHER_PRIV
AK	1	6,352.0	5,600.0	752.0	0.0	0.0
AK	2	72,938.0	0.0	30,938.0	42,000.0	0.0
AK	3	164,285.0	23,070.0	130,285.0	10,876.0	54.0
AP	1	40,180.0	128.8	32,413.9	1,733.8	7.8
AP	2	573,409.0	5,714.0	450,280.3	129,340.7	471.9
AP	3	2,164,903.0	3,396.8	1,866,785.0	488,749.4	816.5
AR	1	157,070.0	7,607.0	72,960.9	434.0	90.0
AR	2	120,775.3	2,958.0	70,628.1	6,036.1	0.0
AR	3	756,883.1	8,443.1	520,631.4	131,649.8	0.0
BE	1	12,783.0	99.0	8,295.0	1,890.0	115.0
BE	2	133,177.0	224.9	91,892.8	47,550.0	22.7
BE	3	28,662.0	0.0	18,830.0	15,092.0	0.0
IN	1	464,022.0	12,894.9	351,659.0	49,308.0	17.4
IN	2	141,899.0	1,253.9	105,412.0	20,209.0	0.0
IN	3	118,892.0	624.0	111,628.0	2,420.0	0.0
IZ	1	26,614.0	0.0	12,205.0	0.0	0.0
IZ	2	1,903.0	0.0	660.0	0.0	0.0
IZ	3	97,509.0	0.0	97,336.0	0.0	5.0
KA	1	26,116.5	480.9	16,701.0	0.0	0.0
KA	2	14,670.8	239.9	10,129.3	0.0	0.0
KA	3	369,921.1	4,553.4	316,589.5	0.0	5.0
KD	1	293,092.1	11,362.3	196,850.3	2,918.0	487.1
KD	2	128,517.1	1,806.3	84,130.5	0.0	510.5

KD	3	295,062.3	1,606.7	204,256.5	18,659.6	385.2
KE	1	403,887.7	160.0	384,152.1	775.0	69.1
KE	2	647,808.0	110.0	607,698.3	355.0	136.3
KE	3	325,939.6	0.0	320,284.1	720.0	86.2
KY	1	437,589.1	12,945.9	335,179.6	26,191.1	11.8
KY	2	241,980.4	3,523.0	205,903.6	14,671.0	0.0
KY	3	135,719.6	0.0	119,195.9	11,773.7	0.0
NO	1	227,898.4	2,078.4	88,962.9	69,035.6	10.0
NO	2	62,899.1	75.0	6,420.0	55,841.6	0.0
NO	3	197,993.0	0.0	61,880.5	138,329.6	0.0
SE	1	454,722.0	17,879.9	309,855.0	5,305.0	5.0
SE	2	655,652.0	19,159.0	538,767.0	0.0	0.0
SE	3	182,182.0	4,027.8	166,981.0	0.0	0.0
TE	1	114,756.3	6,180.1	102,207.3	2,379.9	872.8
TE	2	114,844.9	2,457.2	46,802.4	64,992.7	197.7
TE	3	41,579.5	40.0	30,188.5	8,817.6	0.0
TO	1	793,585.1	33,427.0	661,646.3	69,345.2	763.1
TO	2	296,395.4	8,698.0	239,663.6	40.0	1,115.7
TO	3	359,144.0	4,934.2	276,733.3	49,278.3	0.0
YD	1	3,525,925.0	132,810.8	2,668,992.0	482.0	196.0
YD	2	3,054,262.0	129,201.0	2,435,318.0	81,713.9	536.0
YD	3	2,540,960.0	80,378.3	2,081,984.0	26,433.2	80.0
YF	1	1,162,691.0	24,454.1	973,059.6	5,055.4	1.5
YF	2	1,446,408.0	24,679.2	1,253,970.0	11,464.0	6.1
YF	3	335,808.0	1,852.0	267,196.0	49,224.0	23.0

SUMMARY OF LAND ACQUISITION PRIORITIES BY LAND OWNERSHIP/SELECTION INFORMATION FOR TABLES A AND B

REF	PRI	NATIVE ALLOTMENT	NATIVE CORP.	ALASKA STATE	OTHER PRIVATE	TOTAL ACQUIRABLE
KD	H	11,362.3	196,850.3	2,918.0	487.1	293,092.1
	M	1,806.3	84,130.5	0.0	510.5	128,517.1
	L	1,606.7	204,256.5	18,659.6	385.2	295,062.3
KD		14,775.3	485,237.3	21,577.6	1,382.8	716,671.5
KE	H	160.0	384,152.1	775.0	69.1	403,887.7
	M	110.0	607,698.3	355.0	136.3	647,808.0
	L	0.0	320,284.1	720.0	86.2	325,939.6
KE		270.0	1,312,134.4	1,850.0	291.6	1,377,635.3
KY	H	12,945.9	335,179.6	26,191.1	11.8	437,589.1
	M	3,523.0	205,903.6	14,671.0	0.0	241,980.4
	L	0.0	119,195.9	11,773.7	0.0	135,719.6
KY		16,468.9	660,279.1	52,635.8	11.8	815,289.2
NO	H	2,078.4	88,962.9	69,035.6	10.0	227,898.4
	M	75.0	6,420.0	55,841.6	0.0	62,899.1
	L	0.0	61,880.5	138,329.6	0.0	197,993.0
NO		2,153.4	157,263.4	263,206.8	10.0	488,790.4
SE	H	17,879.9	309,855.0	5,305.0	5.0	454,722.0
	M	19,159.0	538,767.0	0.0	0.0	655,652.0
	L	4,027.8	166,981.0	0.0	0.0	182,182.0
SE		41,066.7	1,015,603.0	5,305.0	5.0	1,292,556.0
TE	H	6,180.1	102,207.3	2,379.9	872.8	114,756.3
	M	2,457.2	46,802.4	64,992.7	197.7	114,844.9
	L	40.0	30,188.5	8,817.6	0.0	41,579.5
TE		8,677.3	179,198.2	76,190.2	1,070.5	271,180.7
TO	H	33,427.0	661,646.3	69,345.2	763.1	793,585.1
	M	8,698.0	239,663.6	40.0	1,115.7	296,395.4
	L	4,934.2	276,733.3	49,278.3	0.0	359,144.0
TO		47,059.3	1,178,043.1	118,663.5	1,878.8	1,449,124.5

SUMMARY OF LAND ACQUISITION PRIORITIES BY LAND OWNERSHIP/SELECTION
INFORMATION FOR TABLES A AND B

REF	PRI	NATIVE ALLOTMENT	NATIVE CORP.	ALASKA STATE	OTHER PRIVATE	TOTAL ACQUIRABLE
YD	H	132,810.8	2,668,992.0	482.0	196.0	3,525,925.0
	M	129,201.0	2,435,318.0	81,713.9	536.0	3,054,262.0
	L	80,378.3	2,081,984.0	26,433.2	80.0	2,540,960.0
YD		342,390.1	7,186,294.0	108,629.0	812.0	9,121,147.0
YF	H	24,454.1	973,059.6	5,055.4	1.5	1,162,691.0
	M	24,679.2	1,253,970.0	11,464.0	6.1	1,446,408.0
	L	1,852.0	267,196.0	49,224.0	23.0	335,808.0
YF		50,985.3	2,494,225.6	65,743.4	30.6	2,944,907.0
		601,134.9	18985290.1	1,661,090.2	7,098.6	23,970,266.4

APPENDIX L.

Final Reports - A & B

SUMMARY OF LAND ACQUISITION PRIORITIES BY LAND OWNERSHIP/SELECTION INFORMATION FOR TABLES A AND B

REF	PRI	NATIVE ALLOTMENT	NATIVE CORP.	ALASKA STATE	OTHER PRIVATE	TOTAL ACQUIRABLE
AK	H	5,600.0	752.0	0.0	0.0	6,352.0
	M	0.0	30,938.0	42,000.0	0.0	72,938.0
	L	23,070.0	130,285.0	10,876.0	54.0	164,285.0
AK		28,670.0	161,975.0	52,876.0	54.0	243,575.0
AP	H	128.8	32,413.9	1,733.8	7.8	40,180.0
	M	5,714.0	450,280.3	129,340.7	471.9	573,409.0
	L	3,396.8	1,866,785.0	488,749.4	816.5	2,164,903.0
AP		9,239.6	2,349,479.2	619,824.0	1,296.2	2,778,492.0
AR	H	7,607.0	72,960.9	434.0	90.0	157,070.0
	M	2,958.0	70,628.1	6,036.1	0.0	120,775.3
	L	8,443.1	520,631.4	131,649.8	0.0	756,883.1
AR		19,008.1	664,220.3	138,119.9	90.0	1,034,728.4
BE	H	99.0	8,295.0	1,890.0	115.0	12,783.0
	M	224.9	91,892.8	47,550.0	22.7	133,177.0
	L	0.0	18,830.0	15,092.0	0.0	28,662.0
BE		323.9	119,017.8	64,532.0	137.7	174,622.0
IN	H	12,894.9	351,659.0	49,308.0	17.4	464,022.0
	M	1,253.9	105,412.0	20,209.0	0.0	141,899.0
	L	624.0	111,628.0	2,420.0	0.0	118,892.0
IN		14,772.8	568,699.0	71,937.0	17.4	724,813.0
IZ	H	0.0	12,205.0	0.0	0.0	26,614.0
	M	0.0	660.0	0.0	0.0	1,903.0
	L	0.0	97,336.0	0.0	5.0	97,509.0
IZ		0.0	110,201.0	0.0	5.0	126,026.0
KA	H	480.9	16,701.0	0.0	0.0	26,116.5
	M	239.9	10,129.3	0.0	0.0	14,670.8
	L	4,553.4	316,589.5	0.0	5.0	369,921.1
KA		5,274.2	343,419.8	0.0	5.0	410,708.4

APPENDIX L.

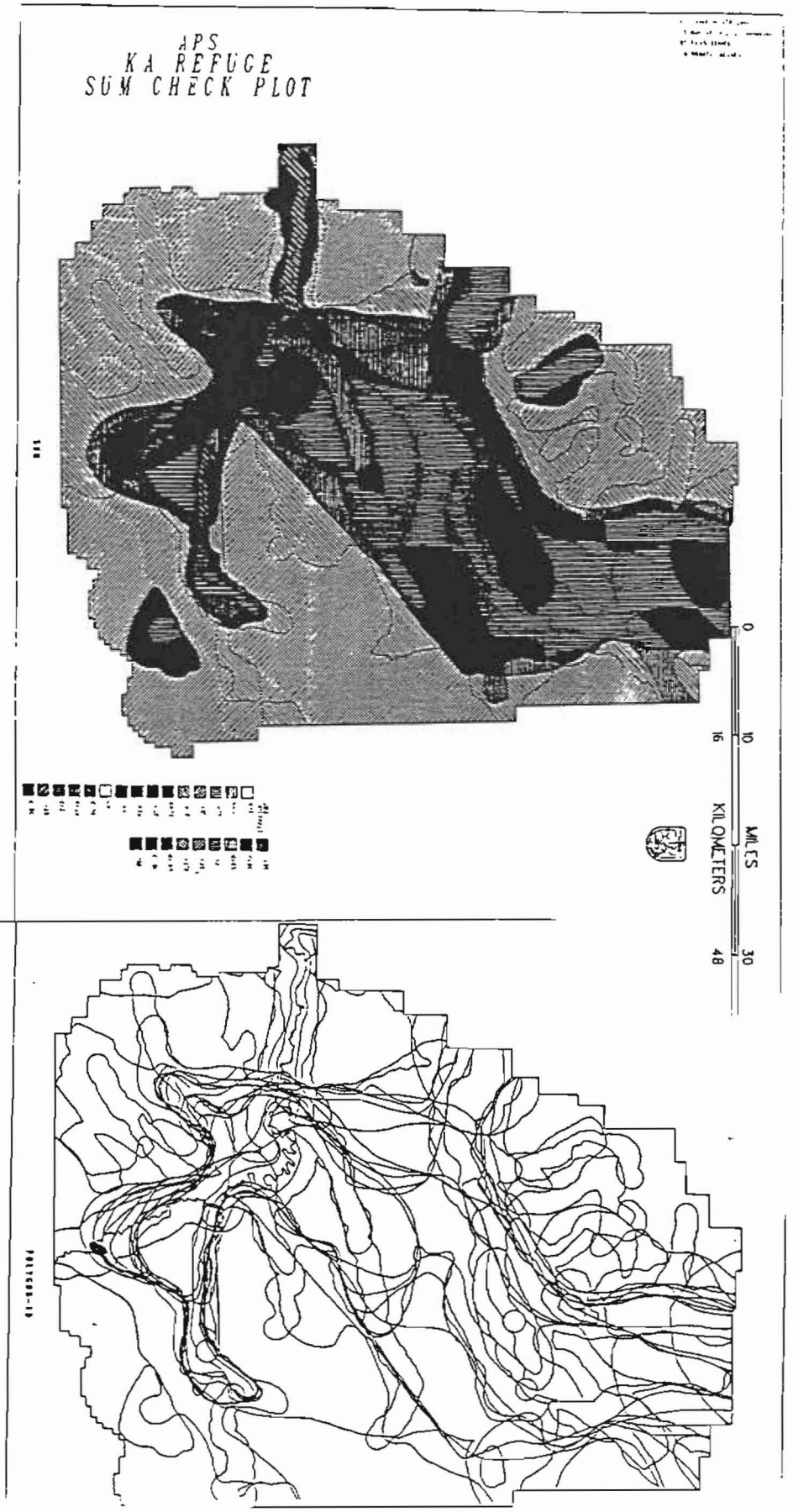
Sample of Final Report - C

SUMMARY OF LAND ACQUISITION PRIORITIES
TABLE 23 - TOWNSHIPS

REFUGE	TOWN SHIP	RANGE	ACQ. PRI.	NATIVE ALLOT.	NATIVE CORP.	ALASKA STATE	OTHER PRIVATE
AK MARITIME	009S	061W	H	0	1400	0	0
AK MARITIME	032N	023W	H	5600	0	0	0
KODIAK	031S	033W	H	735	14134	0	14
KODIAK	030S	032W	H	110	3913	0	0
KODIAK	031S	032W	H	0	9459	0	0
KENAI	004N	007W	H	80	6067	0	0
KENAI	004N	008W	H	30	4907	0	0
KENAI	005N	007W	H	0	16633	0	0
KODIAK	019S	075W	H	0	49	0	0
KODIAK	036S	028W	H	210	6883	0	0
KENAI	005N	004W	H	0	887	0	0
NOWITNA	008S	017E	H	381	3339	3194	0
KODIAK	030S	033W	H	584	240	0	4
KENAI	002N	011W	H	0	5530	135	0
KOYUKUK	005S	006E	H	570	20940	0	0
KOYUKUK	005S	007E	H	398	22722	0	0
KODIAK	031S	034W	H	95	938	0	12
KODIAK	036S	027W	H	850	2108	0	0
KODIAK	032S	034W	H	580	2400	0	5
KENAI	006N	008W	H	0	21026	0	0
KODIAK	037S	032W	H	160	5478	0	0
KODIAK	033S	034W	H	650	0	0	15
SELAWIK	017N	010W	H	0	12720	0	0
SELAWIK	016N	011W	H	660	12050	0	0
SELAWIK	017N	011W	H	0	19429	0	0
AK MARITIME	070S	110W	H	0	307	0	0
AK MARITIME	083S	133W	H	0	100	0	0

APPENDEX M

Check Plots


APS
KA REFUGE
SUM CHECK PLOT
0
10
30
MILES
16
48
KILOMETERS

APPENDEX N

Section Acreage

APPENDIX N.

Section Acreage vs Frequency of SUM Value

This report is used to establish the "cut-off" values for the resource value called SUM for setting priority classes: High, Medium and Low (also referred to as item PRIORITY with values 3,2 and 1 respectively) Key items are the ascending and descending running acreage totals. The ARC FREQUENCY command and an INFO program was used to generate the report.

SRECNO	SUM	FREQUENCY	SECT_IACRES	RUN_FREQ	RUN_UP	RUN_DOWN
1	103	1	1,400	1	1,400	23,981,728
2	102	1	5,600	2	7,000	23,980,320
3	101	2	1,279	4	8,279	23,974,720
4	100	2	1,243	6	9,522	23,973,440
5	96	4	2,495	10	12,017	23,972,208
6	95	6	3,797	16	15,814	23,969,712
7	94	1	625	17	16,439	23,965,904
8	91	2	1,262	19	17,701	23,965,280
9	90	7	4,479	26	22,180	23,964,016
10	89	2	1,280	28	23,460	23,959,536
11	88	5	3,188	33	26,648	23,958,272
12	87	9	5,682	42	32,330	23,955,072
13	86	4	2,558	46	34,889	23,949,392
14	85	4	2,558	50	37,447	23,946,832
15	84	23	14,711	73	52,158	23,944,272
16	83	6	3,829	79	55,986	23,929,568
17	82	29	17,650	108	73,636	23,925,744
18	81	39	24,819	147	98,455	23,908,080
19	80	19	12,107	166	110,563	23,883,264
20	79	38	24,188	204	134,750	23,871,168
21	78	45	28,695	249	163,445	23,846,976
22	77	66	42,108	315	205,553	23,818,272
23	76	35	22,241	350	227,794	23,776,176
24	75	35	21,327	385	249,122	23,753,936
25	74	41	22,538	426	271,659	23,732,608
26	73	41	25,219	467	296,878	23,710,064
27	72	49	30,638	516	327,516	23,684,848
28	71	57	36,275	573	363,792	23,654,208
29	70	69	39,660	642	403,451	23,617,936
30	69	78	46,953	720	450,404	23,578,272
31	68	126	77,951	846	528,354	23,531,328
32	67	241	152,693	1087	681,047	23,453,376
33	66	258	158,677	1345	839,724	23,300,672
34	65	261	163,188	1606	1,002,912	23,142,000
35	64	124	77,634	1730	1,080,546	22,978,816
36	63	293	175,164	2023	1,255,710	22,901,184
37	62	362	208,021	2385	1,463,731	22,726,016
38	61	325	195,581	2710	1,659,312	22,518,000
39	60	345	199,784	3055	1,859,096	22,322,416
40	59	863	539,970	3918	2,399,066	22,122,624
41	58	877	556,799	4795	2,955,865	21,582,656
42	57	1,257	773,261	6052	3,729,126	21,025,856

43	56	1,144	718,326	7196	4,447,452	20,252,592
44	55	601	336,103	7797	4,783,555	19,534,272
45	54	826	520,641	8623	5,304,196	19,198,176
46	53	845	517,505	9468	5,821,701	18,677,520
47	52	1,249	790,485	10717	6,612,186	18,160,016
48	51	1,270	800,612	11987	7,412,798	17,369,536
49	50	1,263	803,732	13250	8,216,530	16,568,926
50	49	1,395	887,648	14645	9,104,178	15,765,194
51	48	1,868	1,179,473	16513	10,283,651	14,877,546
52	47	939	596,598	17452	10,880,249	13,698,073
53	46	687	436,045	18139	11,316,294	13,101,475
54	45	710	434,057	18849	11,750,351	12,665,430
55	44	1,027	611,849	19876	12,362,199	12,231,373
56	43	1,157	747,704	21033	13,109,904	11,619,525
57	42	981	661,544	22014	13,771,448	10,871,820
58	41	1,185	729,436	23199	14,500,883	10,210,276
59	40	1,184	734,592	24383	15,235,475	9,480,840
60	39	1,125	691,258	25508	15,926,733	8,746,249
61	38	982	614,829	26490	16,541,562	8,054,991
62	37	1,009	634,606	27499	17,176,176	7,440,162
63	36	1,233	744,848	28732	17,921,024	6,805,556
64	35	729	456,064	29461	18,377,088	6,060,708
65	34	722	444,653	30183	18,821,728	5,604,644
66	33	900	555,415	31083	19,377,152	5,159,990
67	32	973	574,252	32056	19,951,408	4,604,575
68	31	484	287,693	32540	20,239,088	4,030,323
69	30	655	415,541	33195	20,654,640	3,742,630
70	29	869	533,830	34064	21,188,464	3,327,089
71	28	423	264,038	34487	21,452,496	2,793,259
72	27	380	229,062	34867	21,681,568	2,529,221
73	26	403	277,188	35270	21,958,752	2,300,159
74	25	400	259,711	35670	22,218,464	2,022,972
75	24	473	275,248	36143	22,493,712	1,763,261
76	23	493	317,145	36636	22,810,848	1,488,013
77	22	318	202,205	36954	23,013,056	1,170,868
78	21	505	313,643	37459	23,326,704	968,664
79	20	136	78,629	37595	23,405,328	655,020
80	19	124	75,071	37719	23,480,400	576,391
81	18	98	59,398	37817	23,539,808	501,320
82	17	131	78,056	37948	23,617,856	441,922
83	16	60	62,661	38008	23,680,512	363,867
84	15	84	51,531	38092	23,732,048	301,206
85	14	84	50,646	38176	23,782,688	249,675
86	13	60	47,301	38236	23,830,000	199,029
87	12	107	64,717	38343	23,894,720	151,728
88	11	15	28,018	38358	23,922,736	87,011
89	9	3	844	38361	23,923,568	58,993
90	7	4	3,017	38365	23,926,592	58,149
91	6	74	47,095	38439	23,973,680	55,132
92	5	1	175	38440	23,973,856	8,037
93	0	54	7,862	38494	23,981,728	7,862

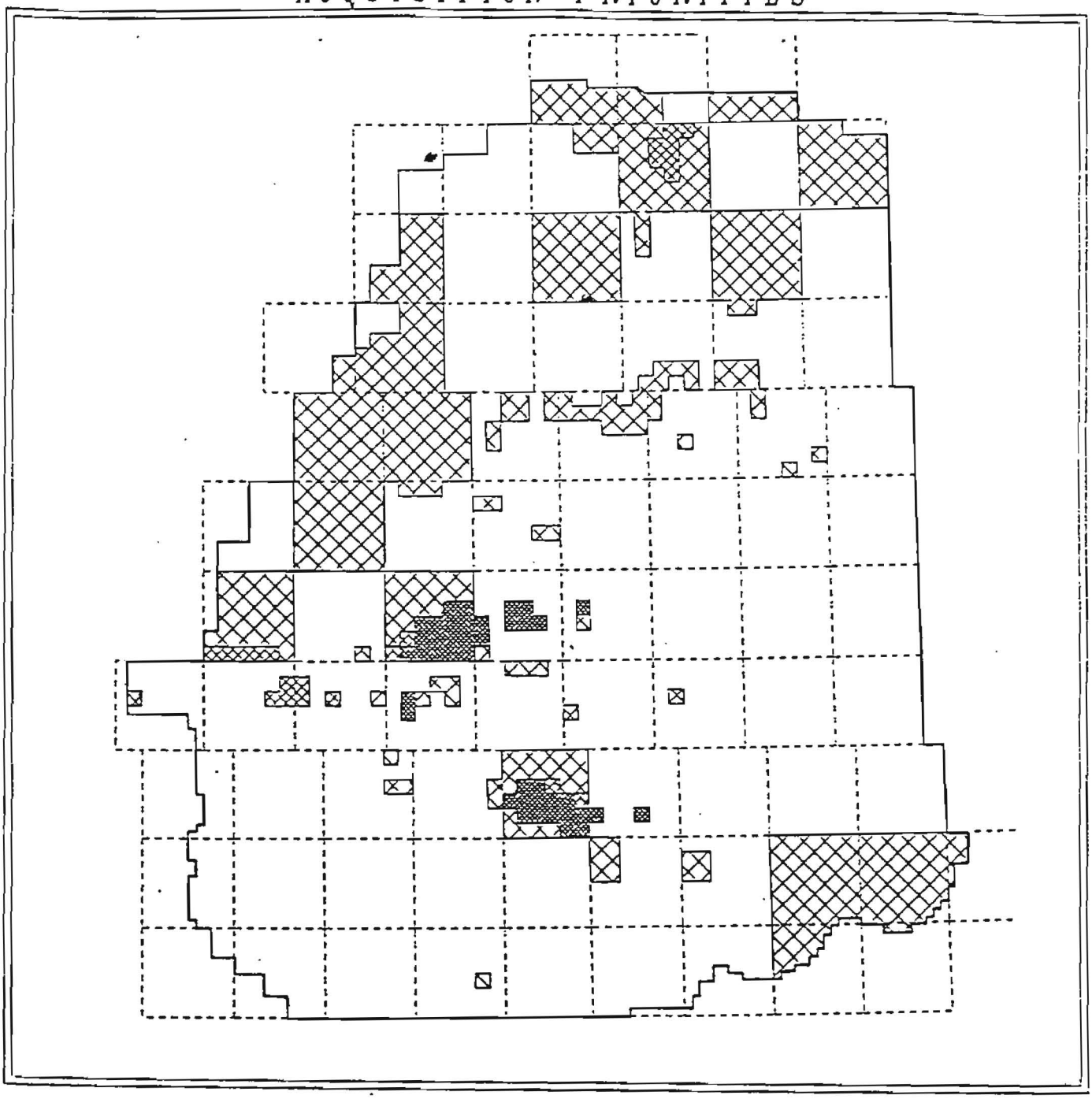
ONE THIRD OF TOTAL SECT_ACREAGE = 7,993,909.33

APPENDEX O

Final Plots

FIGURE 11

KANUTI NATIONAL WILDLIFE REFUGE ACQUISITION PRIORITIES



0 10 MILES 30 40

0 16 KILOMETERS 48 64

SCALE 1.630000

DATA SOURCES:
Wildlife Resources:
F&WS Division of Realty,
Refuges & Wildlife
Landstatus
Bureau of Land Management
F&WS Division of Realty

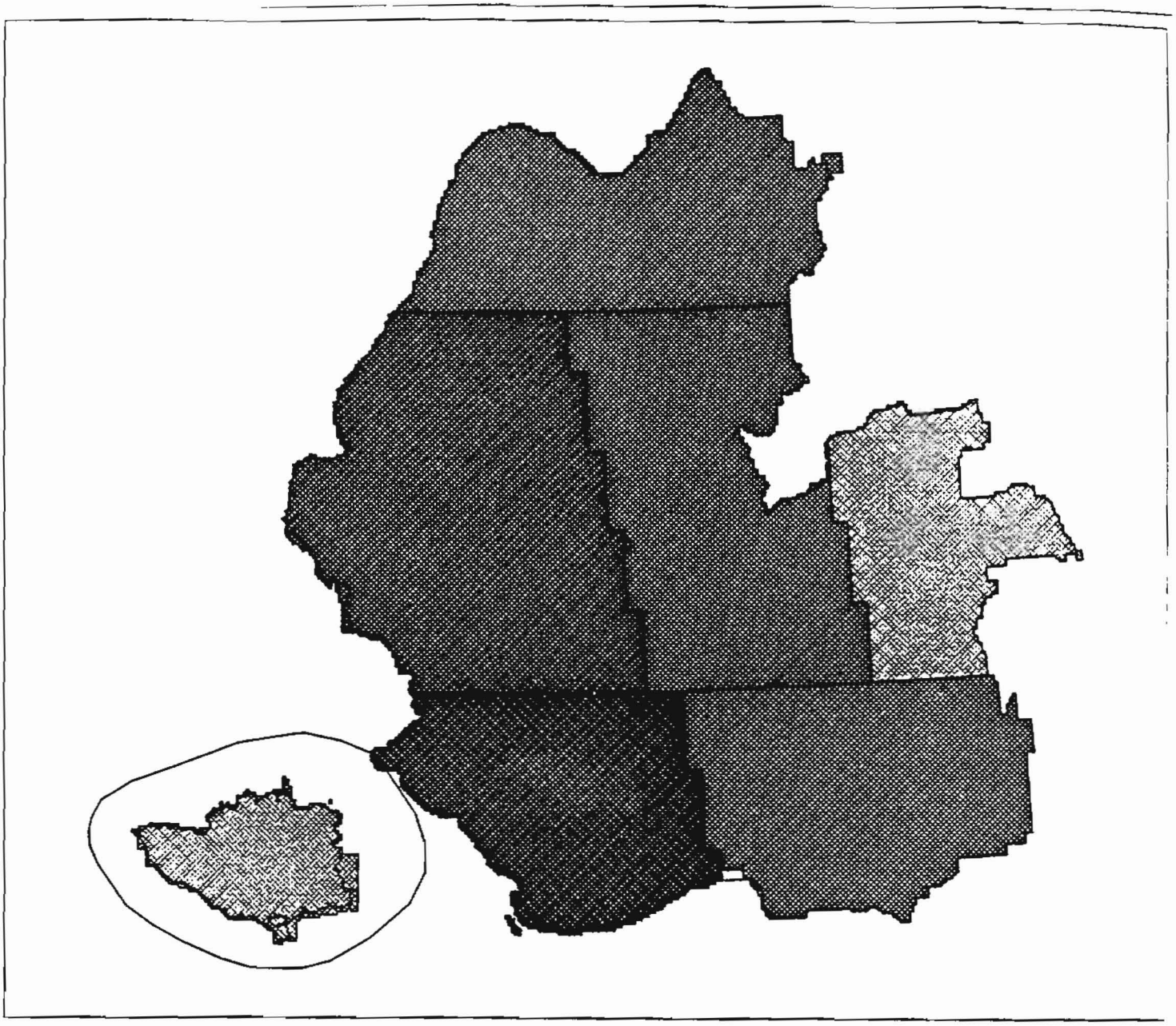
DATA ANALYSIS:
F&WS Division of Information
Resource Management,
Branch of Geographic Analysis

Projected in UTM Zone 5
20 Dec 89 16:45:21 Wednesday
US F&WS REGION 7
ANCHORAGE ALASKA

PRIORITY KEY.
High Priority
Medium Priority
Low Priority
Federal Or Non-Acquirable
Township Boundaries

APPENDEX P

A Refuge Split into Sheets



APS

YUKON DELTA NATIONAL WILDLIFE REFUGE
REFUGE SHEETS

Projected in UTM Zone 3
29 May 90 14:20:15 Tuesday
US F&WS REGION 7
ANCHORAGE, ALASKA

SCALE 1:2902000

ANALYSIS OF FOREST COMPOSITION AND INTERSPERSION OF MOOSE HABITAT USING GIS

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A landscape's habitat value for wildlife dependent upon multiple cover types is a function of cover type composition as well as spatial relationships (juxtaposition and interspersion) between vegetation associations. If key spatial and qualitative relationships between vegetation associations, landscape structure and wildlife habitat quality can be determined, negative impacts to wildlife habitat in man-influenced ecosystems can be minimized. Development of geographic spatial data bases and predictive models that permit the evaluation of wildlife responses to alterations in composition and interspersion of vegetation communities will facilitate identification of the most beneficial management alternative(s).

Ideally, long-term management decisions are made on a landscape scale rather than on a site specific basis. Stand shape, numbers, species composition and juxtaposition of vegetation communities affect resource availability and wildlife use of the landscape (Franklin and Foreman 1987; Hunter 1990). While direct manipulation of vegetation communities specifically to meet habitat management goals is prohibitively expensive, appropriate timber harvest guidelines can enhance habitat conditions for species dependent on a variety of forest types and successional stages if appropriate guidelines are available. To be effective, habitat management recommendations should be specific to individual management units, have clearly defined objectives and be incorporated early in the planning process when timing and spatial distribution of harvest units are defined (Thomas 1984; Innes 1985).

Effective, long-term management of forested habitats on a landscape scale requires two prerequisites: (1) tools and techniques that allow analysis of quantitative and descriptive complexities that are characteristic of forest ecosystems; and (2) analysis methods that define habitat values and compare effects of management alternatives to management goals. Geographic Information Systems can help evaluate the spatial and temporal complexities of the landscape.

The process of combining data themes to display forest stand attributes and inter-stand relationships, allows a user to design, project and evaluate effects of various management alternatives on forest composition and structure. While a GIS can be used to compare changes in spatial and vegetation parameters, interpretation of the value of a individual stand to a wildlife species and it's relationships to other vegetative polygons, cannot be made until habitat quality criteria are established.

Finding a methodology that allows for an unbiased analysis of numerous management alternatives is difficult. Simple classification criteria such as poor, fair and excellent may be applicable for ranking a few highly dis-similar alternatives. Mathematical habitat models interpret habitat data on a continuous rating scale and permit comparison of similar management strategies (Patch 1986; Starfield and Bleloch 1986). While habitat based models have received widespread use, improved performance and the ability of managers to feel confident in the use of these models is dependent upon the validation of basic assumptions on which the habitat models are formulated (Schamberger and O'Neil 1986; Blenden et al. 1986; Flather and Hoekstra 1989).

A GIS data base was created for a 490 km^2 portion of the Superior National Forest in northeastern Minnesota, and the ARC/INFO GIS system was used to determine the composition and interspersion relationships of forest communities to the winter habitat use patterns of moose (*Alces alces*) in order to investigate the validity of selected assumptions within the moose HSI model (Allen et al. 1987). This paper describes how the GIS was used to evaluate portions of the model that pertained to dormant-season (mid-September to mid-May) cover and forage resources and forest composition. We also discuss additional issues which may be resolved with further research.

STUDY AREA

The study area is on the Isabella and Kiwishiwi Ranger Districts of the Superior National Forest. The landscape is one of slight relief and nearly continuous forest interspersed with palustrine, lacustrine and riverine wetlands.

Forest vegetation is comprised of components of both the boreal and temperate deciduous forests. Common upland coniferous trees are jack pine (*Pinus banksiana)*, white pine (*P. strobus*), red pine (*P. resinosa*), balsam fir (*Abies balsamea*) and white spruce (*Picea glauca*). Upland deciduous stands are dominated by quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), and paper birch (*Betula papyrifera*). Black spruce (*P. mariana*), white cedar (*Thuja occidentalis*) and black ash (*Fraxinus nigra*) are dominant in forested wetlands.

METHODS

Data Base Preparation

The conversion of mapped information into digitized polygonal data that can be used to display existing and projected characteristics of the study area is basic to the implementation of a GIS. Data themes include stand and compartment boundaries, species composition, density and age of stands, wetlands, and Minnesota Department of Natural Resources (MDNR) moose survey unit boundaries. Moose located during winter aerial surveys were entered as point data.

Forest compartments and stands - Forest compartment/stand maps [1:15,840 (4" = 1 mi)] and stand exam data were provided by each Ranger District. Twenty-six forest types were identified based on dominant tree species. Each stand was characterized by numerical codes that represented: Ranger District; compartment number; forest type; tree size and density. Tree size and density were represented by a code that ranged from 0 for a nonstocked stand to 9 for a sawtimber stand >70% stocked. This approach permitted each polygon to be assigned a unique 11 digit code that characterized location, tree species composition, relative age and density. For example, the polygon code 04_092/014.916 represents: Isabella Ranger District (04); compartment 92; stand 14; quaking aspen (91); poletimber, stocked >70% (6).

Wetlands - Wetlands were previously classified by the U.S. Fish and Wildlife Services' National Wetlands Inventory (NWI) following mapping conventions described in Cowardin et al. (1979). Wetlands were identified on

high-altitude, 1:60,000, color-infrared photographs, groundtruthed and transferred to 1:24,000 stable based mylar map sheets. Mylar overlays were matched with appropriate 1:24,000, 7.5 minute topographic maps enabling digitizing of lacustrine, riverine and palustrine wetlands in the study area.

MDNR moose survey units - The boundaries of 21 MDNR moose survey units were plotted on 1:2400, 7.5 minute topographic maps of the area east of Ely, Minnesota. Moose survey units were previously established by the MDNR following conventions described by Gasaway et al. (1986). Survey unit boundaries were digitized and overlaid with timber stand and compartment data themes to determine which units covered the study area. All, or portions of, 16 moose survey units covered the area in its entirety. Ten contiguous units were completely within the study area and they were aerially surveyed for moose.

Moose Location Data - In late December of 1988 an aerial census of the 10 survey units was completed using MDNR annual moose survey personnel, procedures and aircraft. Eighty-five moose were located within, or immediately adjacent to, the survey units. Unsuitable weather conditions delayed the scheduled December 1989 aerial census until early January 1990 when 75 additional moose were located. Moose were identified as bulls, cows, calves or unknown, and plotted on 1:24,000 topographic maps. Cows with calves were considered a single observation.

HSI Model

Initial evaluation of assumptions in the moose model pertain to composition and interspersion of dormant-season cover and forage. High quality winter range for moose is composed of a mosaic of cover types that provide adequate cover and high availability of browse. Interspersion of suitable winter cover and accessible browse of sufficient quality and quantity minimize metabolic demands, thereby maximizing winter survival (Coady 1974; Thompson and Vukelich 1982). Accessibility of browse typically decreases throughout the winter in response to burial by snow and decreased mobility of moose, particularly cows with calves. During periods of excessive snow depth, foraging cows/calves become restricted to conifer-dominated stands and their immediate edges. Optimum interspersion is

assumed to occur when cutover stands (i.e., forage stands) are within 100 m of conifer-dominated cover stands. Accessibility of browse is assumed to decrease with increasing distance from dormant-season cover. While optimum interspersion of cover and forage is undefined, zones adjacent to moose locations are assumed to have greater interspersion of high quality forage and cover stands than zones around random locations.

The HSI model was used to assign an index varying between 0.0 and 1.0 to forest stands in relation to the assumed capacity to provide dormant-season forage and cover based on tree species composition and age class. A value of 0.0 represented unsuitable forage or cover. Quality was assumed to increase linearly, with 1.0 representing optimum conditions (U.S. Fish and Wildlife Service 1981).

Forage indices were high in young age-class deciduous and mixed stands and decreased in response to greater age and density. For example, it was assumed that seedling/sapling aspen stands provide a high abundance and availability of forage (Fig. 1, curve 1). As these stands become older, the number of stems per unit area decreases and the leaves and twigs of the remaining trees exceed the reach of moose resulting in a decrease in available forage and a forage indices. Seedling/sapling stands were assumed to have no cover value, regardless of stem density, due to low height of stems. As stands approach maturity, the potential to provide suitable cover is assumed to increase (Fig. 1a, curve 2). However, mature stands have relatively low dormant-season cover value regardless of stem density due to the deciduous nature of the stand.

Conifer dominated stands were assumed to provide dormant-season cover of greater quality than provided by deciduous and mixed stands. Cover quality within conifer stands was assumed to increase in response to greater stem size and density and be related to canopy structure of dominant species. For example, white cedar and balsam fir are believed superior to jack pine in provision of dormant-season cover due to their relatively dense, pyramidal crowns (Fig. 2).

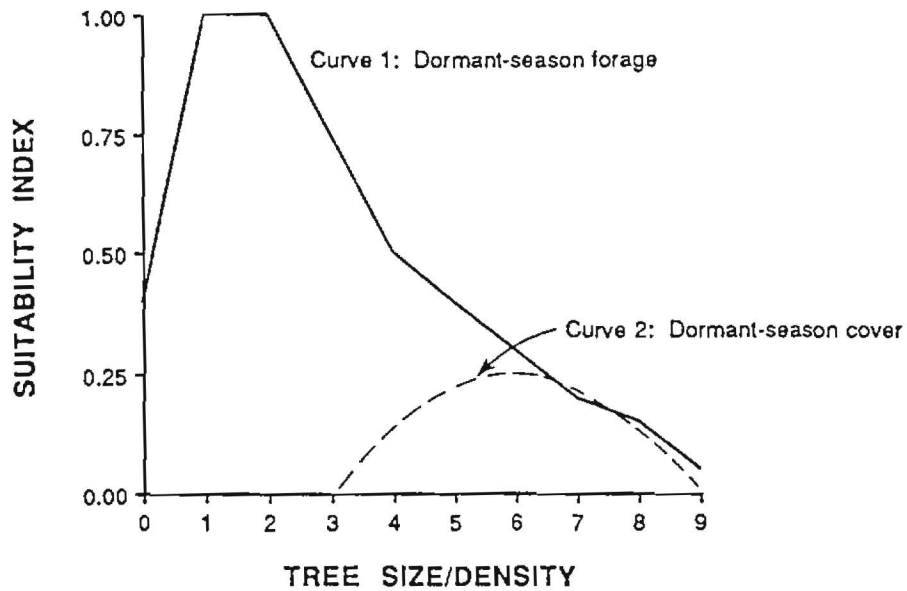

Figure 1.a. Assumed relationships between stand stem size and stocking rate in aspen stands and forage availability (Curve 1) and cover quality for moose (Curve 2). Stocking rates = 0: nonstocked, <16% stocked; 1: seedling-sapling, 16-39% stocked; 2: seedling-sapling, 40-69% stocked; 3: seeding-sapling, >70% stocked; 4: poletimber, 16-39% stocked; 5: poletimber, 40-69% stocked; 6: poletimber, >70% stocked; 7: sawtimber, 16-39% stocked; 8: poletimber, 40-69% stocked; 9: poletimber, >70% stocked.

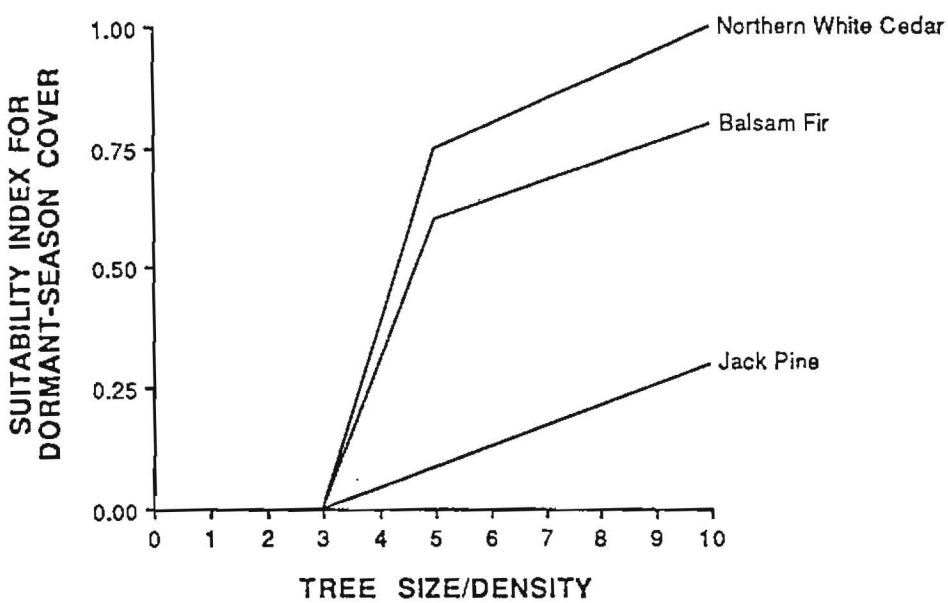

Figure 2. Relationships between conifer species and cover quality for moose. Stocking rates same as for Figure 1.

Buffers - Relative area and percent composition of each forest type was assessed within circular buffers with radii of 1,000 m (314 ha), 500 m (79 ha) and 200 m (12.5 ha) around moose locations (Figure 3) to determine relative area and percent composition of each forest type. These values are compared to the calculated values for buffers around an equal number of random points scattered throughout the study area. The hypothesis being tested is that the moose are selectively using those areas with higher dormant-season cover and food suitability. If the model assumption is true, and there are enough moose to occupy the best habitats, then there should be a greater difference in the habitat suitability between the random and moose locations for the smaller buffers (200 and 500 m) then within the larger buffered areas (1,000 m).

The degree of interspersion within buffered moose locations can be assessed by using the GIS to establish additional buffers around only those forest stands that meet forage and cover criteria. Under optimum conditions stands providing abundant forage are within 100 m of suitable dormant season cover. The amount of forage stand edge within the 100 m buffer can be used to evaluate the degree of interspersion between forage and cover resources under assumed optimum interspersion. Larger buffers also can be established around specific polygons that meet size and composition constraints in order to assess interspersion under less than optimum conditions.

DISCUSSION

The 490 km^2 study area represents 4.0% of the 12,140 km^2 Superior National Forest. More than 6,100 individual polygons were digitized. Forest stands, the most complex of the data themes, required 172 hours of digitizing followed by wetlands (42 hrs), compartment boundaries (17 hrs), and moose locations (10 hrs). An additional 48 work hours were spent in quality control, archiving, supervision and updating data. Groundtruthing forest stand data and obtaining forest composition data for private lands, for which forest inventory data were unavailable, required another 160 hours of effort.

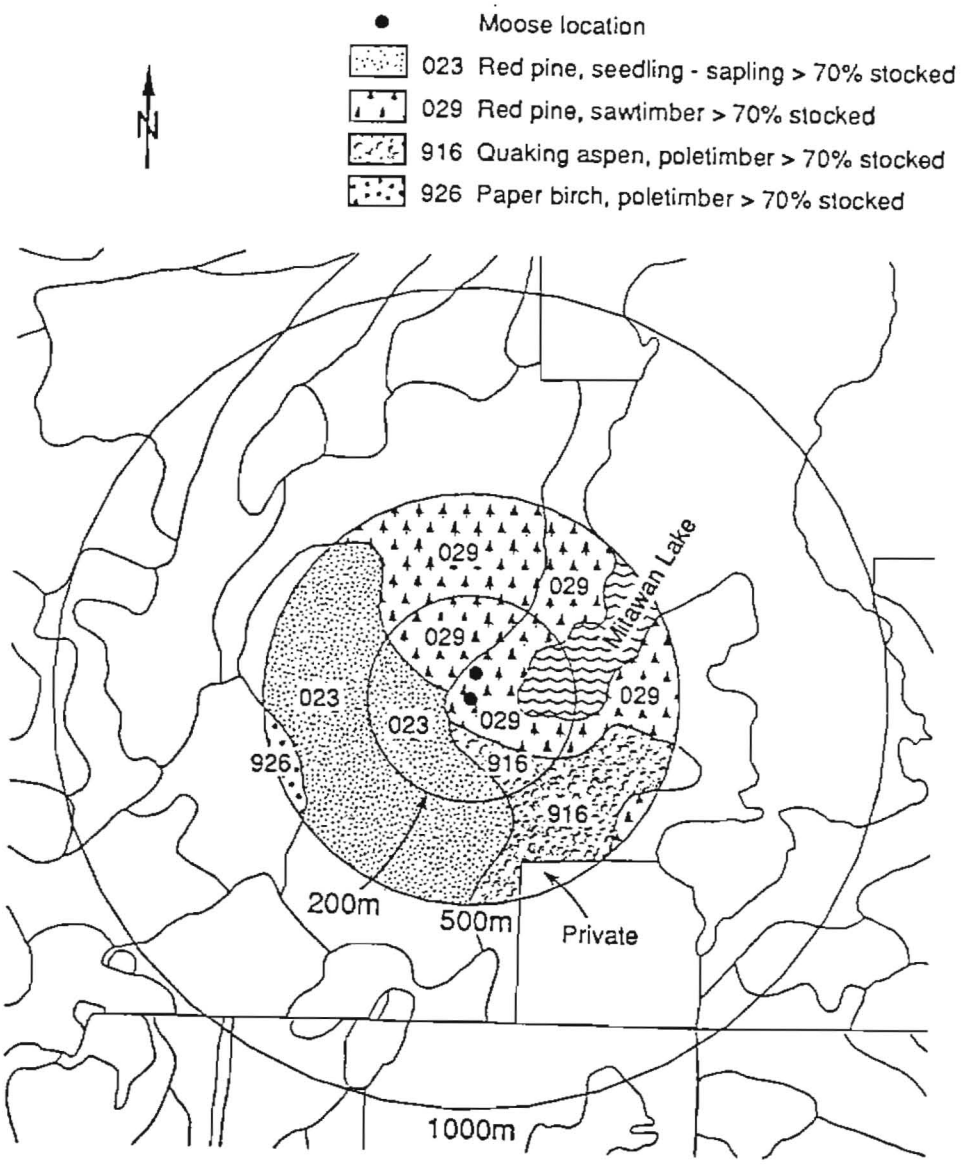

Figure 3. Buffers established around aerially located moose. Buffers are overlaid with timber stand data to determine forest species/age composition and interspersion of forage and cover

Groundtruthing of forest stand data was completed in 6,418 ha representing 13% of the study area. Of the 482 stands inspected, 17 (383 ha) were found to be inconsistent with information in the forest stand data base. This represents a potential error of 5.9% in stand data. These errors were due primarily to current cutting and harvests that had taken place since stand exam data were transferred to the U.S. Fish and Wildlife Service.

Forest composition data on private and State lands within the National Forest boundary was obtained by on-site inspection and interpretation of aerial photographs. Stand boundaries and composition data for these lands were transferred to 1:15,840 stand maps to supplement stand exam data for U.S. Forest Service lands.

HABITAT ANALYSIS

Composition - While it is relatively easy to determine the proportion of a buffered area comprised of different vegetation associations, determining whether or not the habitat is useable is more complex than a tally of cover type categories and area. Key questions need to be answered pertaining to the distribution, minimum and maximum threshold sizes and quality of required vegetation associations before any evaluation of the quality can be made. Within a given area, a required vegetation association may be present in sufficient quantity to meet seasonal habitat requirements of a species. However, if the required vegetation type is not adequately dispersed throughout the evaluation or management area, it may have minimal contribution to habitat quality. For example, one large contiguous stand of high quality dormant-season cover may add little to habitat quality if the stand is not located near an adequate source of forage. Conversely, the same total area of dormant-season cover may also be of little or no value, if it exists as many dispersed polygons of insufficient size to provide the minimum habitat conditions required by the species.

While a given vegetation association may be represented by a number of polygons within an evaluation area, habitat quality and resource availability is dependent upon each polygon's successional stage and what management actions

(e.g., application of herbicides) it has been subjected to. Therefore, an accurate evaluation of habitat quality should incorporate projected affects of management actions and their influence on resource availability into the GIS data base. Once the significance of such issues as minimum area of polygons and management actions have been identified, a GIS can be used to select out those polygons that do not meet criteria of useable habitat prior to calculation of interspersion and composition values.

Interspersion and Interspersion - Diversity indices quantify spatial distribution of vegetation. The theory behind a diversity index is that for a vegetation polygon of fixed area, the longer the polygon perimeter, the better the habitat will be for edge dependent species. The standard of comparison for any given sized polygon is a circle of equal area, because a circle is the geometric figure that has the least edge or perimeter, for a given area. Using a circle as the basis of comparison, the Diversity Index (DI) for any given area can be calculated by:

$$DI = \frac{TP}{2\sqrt{A*\pi}}$$

where: TP = total perimeter around area and any edges within area

A = area

There are two problems with this technique: (1) the DI is sensitive to the shape of the study area, i.e., a square study area automatically has 13% more edge than a circle, and (2) not all vegetative stands within a study area provide habitat.

A GIS can use arc lengths that make up polygon perimeters and area values to calculate diversity indices for given areas. However, not all cover types provide useable habitat for every species, nor are all polygons of equal quality as habitat. Variability of a vegetation community to provide required resources may be dependent upon species composition, age, stand size, or proximity to other plant associations.

For moose and other species that are dependent upon landscape heterogeneity, adjoinment between specific cover types is not critical if the required vegetation associations are within an acceptable distance. The ability of a given polygon to provide required resources is dependent upon: characteristics of vegetation within the polygon; its size; and the vegetation attributes of the plant communities around the polygon. For example, a 1 ha stand dominated by semi-mature or mature balsam fir may exhibit vegetation features characteristic of ideal dormant-season cover for moose. However, due to its' small size, the stand may be inadequate to provide sufficient interception of snow and wind. Such a stand would provide a microclimate unsuitable for thermal protection for moose, if the stand is isolated in a matrix of dissimilar vegetation associations (e.g., a recent clearcut). The disadvantage of stand size would be ameliorated if the stand adjoined, or were partially surrounded by, other stands of similar structure. Larger stand size (e.g., >3 ha) would increase the probability of the stand providing suitable protection if it were maintained as a shelter patch within a cutover area. However, the distance between the residual stand and other semi-mature to mature conifer dominated cover will affect potential use of the stand. If situated too far from other cover, the stand may be inaccessible during late-winter due to deep and crusted snow within the surrounding cut-over area. Potential use of such a stand would be increased if it were maintained in close enough proximity of other cover (e.g., <100 m), so that it remained accessible to moose during all but the most severe of winter conditions.

One of the model assumptions being tested is that the average distance between stands that provide dormant-season cover and food, is lower within the smaller buffers around the aerially located moose than within the buffers around the randomly selected points. There are several methods using GIS technology to calculate average distance between cover types. Rasterized data create a continuous surface of distances from specific polygons (i.e., dormant-season cover) that can be overlaid with other cover types of interest (i.e., dormant-season food). A continuous surface of distances is the method of choice to relate these distance values back to a continuous function such as a suitability index curve. Another alternative creates a series of buffers around polygons that provide one of the life requisites and tabulates the area of other cover

type of interest present within each buffer. This method requires multiple buffers to approximate the continuous surface and is entirely adequate for analysis involving only a few distances describing inflection points in the SI graph. Criteria that define potential suitability of polygons must be incorporated into assessment of spatial configuration. For example, if buffers were established around recent timber harvest sites to determine availability of suitable dormant-season cover, an isolated 1 ha dormant-season cover stand within the harvested area should be excluded from consideration as potential cover.

Issues - Prior to the wider availability of GIS capabilities, biologists have had to resort to relatively simple techniques to estimate the amount of edge and distances between vegetation associations assumed to provide critical habitat. GIS technology provides more efficient methods to analyze spatial characteristics permitting a completely different set of more detailed questions to be addressed. In trying to understand how wildlife species are really visualizing their habitat, we need to fully understand how vegetation composition and interspersion really relate to species utilization. Using a GIS opens up tremendous capabilities as to the type and the detail of questions that can be explored.

More investigation needs to be completed in reference to how polygon areas and perimeters are addressed and what are appropriate standards of comparison. If polygons of unsuitable habitat are excluded from calculations of habitat value, remaining polygons may provide suitable conditions, but their quantity and distribution may not meet minimum composition and interspersion requirements. The same problem occurs for species that require adjoinment between specific vegetation associations. How should distance values between polygons be determined? In the current HSI model, it is suggested that the average distance between polygons will provide an estimate of the quality of interspersion between cover and forage resources. If the closest food polygon can provide the minimum threshold level of food required to make the cover polygon useable habitat, then is it also necessary to calculate distances to the other polygons providing food? If distance values are based on all stands, then the relative quality of the area may be underestimated. Is minimum distance more important than average, and are distances from edge to edge, or random points within each polygon more

appropriate to calculate distances? Lastly, how should differences in quality between the polygons that provide food be addressed? Should food values within polygons be weighted by distance before determining an average distance, or are there threshold values having an influence in habitat quality?

GIS and habitat models provide methods of quantifying forest attributes in a manner that permits systematic comparison and identification of trade-offs between habitat requirements and harvest of forest products. The rapid utilization of these capabilities is extremely important due to escalating demands for forest resources. As an example, timber harvest in the Lake States increased 72% between 1975 and 1987, primarily as a result of demands for pulp and board products (Smith and Blyth 1989). Demand for timber products from this region is expected to double by the year 2040. As forest management becomes more intensive, rotation lengths are shortened, land area dedicated to production of forest products increases, and greater emphasis is placed on efficient regeneration (Thomas 1984; Flather and Hoekstra 1989; Hunter 1990). Enhanced public concern for environmentally sound use of natural resources is expected to place further constraints on forest management (Flader 1983; Gates et al. 1983; Flather and Hoekstra 1989; Smith and Blyth 1989). A focus on the effects of spatial and temporal distribution within forest landscapes rather than individual stands will assist definition of long-term management goals and avoidance of unintended impacts of forest harvest upon wildlife habitat quality.

A GIS provides a means to complete analysis of complex spatial characteristics described by habitat models, and to incorporate realistic evaluations of spatially complex habitat requirements into land-use planning. Continued decreased cost and greater availability of desk-top computers and PC versions of GIS systems can be expected to enhance the ability to evaluate management options on relatively large spatial scales. The value of GIS and habitat models to design and evaluate habitat management scenarios is dependent upon availability of accurate data bases, increased knowledge of how species utilize the spatial characteristics of the landscape and coordination and compromise between resource interests.

ACKNOWLEDGMENTS

We are grateful to E. Lindquist, Superior National Forest, for assistance in data acquisition and logistics. Appreciation also is extended to the Minnesota Department of Natural Resources, particularly, J. Janecek, D. Litchfield, F. Thunhorst and S. Wilson for their cooperation and completion of aerial surveys of moose.

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GIS Applications on the
Bear River Migratory Bird Refuge, Utah
June 5, 1990

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Introduction

Bear River Migratory Bird Refuge, near Brigham City, Utah, was created by an act of Congress in 1928. The primary purposes of the refuge; waterfowl nesting, production, and maintenance were achieved until 1983. Unusually high precipitation in surrounding mountains beginning in 1983 caused a dramatic rise in the Great Salt Lake. Five years of high precipitation resulted in almost total inundation of the 65,000 acre Refuge. Over forty-five miles of dikes, fifty water control structures and numerous buildings, including a new visitor center, were destroyed or seriously damaged. In 1988 the water began to recede and the Fish and Wildlife Service (Service) began to reevaluate the purposes, goals and objectives of the Refuge. The Service initiated a planning process to evaluate alternative futures for the Refuge, including up to 40,000 acres of additional land acquisition.

In mid 1989 The National Ecology Research Center (NERC) informed Region 6 Realty that a trial evaluation project was underway. The project would test the application of "Arc/Info," a GIS software. The timing was right and the Refuge planning process was just getting started so Region 6 Realty volunteered to evaluate "Arc/Info" for a no-cost one year period. Region 6 Realty made the following assumptions: (1) a person would be hired to manage the system and do collateral ADP duties, (2) digitized data

would be purchased or obtained free of charge wherever possible, (3) little time or money would be available for digitizing, and (4) a written evaluation would be provided NERC upon completion of the one year period.

Refuge Application

Region 6 Realty is in the middle of the one year trial project and has applied "Arc/Info" in three areas: (1) wetland inventory mapping, (2) landownership and tax mapping, and (3) conflict management mapping. The database includes public land survey for eight 7 1/2 minute quadrangles plus detailed information on about 100,000 acres. Most of our effort is oriented toward the 40,000 acres of private land being considered for addition to the Refuge.

Wetland Inventory Mapping

We obtained digitized National Wetland Inventory data from St. Petersburg, Florida and loaded the data into "Arc/Info". The inventory data includes fifty wetland classes and has little practical use in its detailed form. We have produced maps illustrating general groups of wetland classes, e.g. wetlands with a temporary water regime (salt flats), wetlands with a seasonal regime, and wetlands with semipermanent or better water regime (bulrush, cattail, open waters). "Arc/Info" provided the flexibility to illustrate any level of detail desired. We have the ability to illustrate wetlands on each tract of land in the existing Refuge and in the proposed addition to the Refuge.

Landownership and Tax Mapping

Land ownership information is just as important as biological information when planning for land acquisition. We obtained county

plat maps covering 40,000 acres of the proposed refuge addition. A cartographer transferred the ownership boundaries to 7 1/2 minute quadrangles. The boundaries were then digitized. We also created a database file for over 300 tracts of land (80 landowners) that includes owner name, tax assessment, owner address, hunting leases, and information on willingness to sell land to the Service.

We modified the boundary of the proposed addition in response to agricultural concerns and the Service's desire to include more wetlands in the boundary. Past experience with boundary changes showed that every boundary change causes substantial work for cartographers and results in alot of manual tabulations involving landownerships, acres, and habitat. "Arc/Info" provided an easy way to modify the boundary and gave us prompt information on acres of wetlands and landowners involved in the boundary change. In cases where the boundary was expanded we had to transfer data from county plats to quadrangles and then digitize the data.

The landownership database and "Arc/Info's" map production capability allows us to produce a map of virtually any size or scale on any tract or tracts of land within the proposed refuge addition. These maps are useful for any purpose except legal cartographic surveys.

Conflict Management Application

A major issue in land acquisition proposals is "conflict." Conflicts include agricultural land removed from production, willing vs. unwilling sellers, taxes vs. refuge revenue sharing, easement vs. fee title acquisition, existing hunting leases, etc. We can produce maps to display any of these conflict areas. If a

Congressman wants to know which landowners are opposed to land acquisition, we can produce a map that presents willing, unwilling and unknown landowner attitudes. We can also produce a map that shows fee and easement acquisition areas.

Another area of interest is the presence of long term hunting leases. Our past experience shows that land managed primarily for hunting is usually compatible with easement acquisition. Therefore we can produce a map illustrating the compatibility of easement acquisition and hunting leases.

Summary

We have not begun to tap "Arc/Info's" analytical capabilities at this stage of our evaluation. In fact, the analytical capabilities are probably far more powerful than we need or will use. Our experience is limited to map production and the flexibility of map production. "Arc/Info" in combination with a color plotter, gave us the flexibility to change size, scale, colors, and boundaries on maps. We can produce maps that display any information in the database in a matter of an hour or hours. However, any information that must be digitized is costly information. We made an early decision to limit digitizing to small amounts of information. If "Arc/Info" is to be more fully utilized there must be a financial commitment to digitizing.

Our experience with refuge managers suggests that standard 7 1/2 minute quadrangles are preferred field maps for the person "on-the-ground." In the case of Bear River Migratory Bird Refuge eight quads displayed on an office wall was the preferred map base. The most valuable product that "Arc/Info" provides a refuge manager

is clear mylar overlays displaying whatever data the manager wants. The manager is not interested in a map showing fifty wetland types, however, the manager is interested in a map showing three or four types. "Arc/Info" has provided that flexibility.

Following are positive and negative aspects of Region 6 Realty's use of "Arc/Info":

Pros

-Flexible - "Arc/Info" makes color maps disposable. We can always make another one! Boundaries and other types of information on maps can be changed without sending the cartographer through the roof.

-Credibility - Full color, professional map products provide credibility. "Arc/Info" provides credibility to a project whether that credibility is deserved or not deserved. The individual who provides information for the database still must be accountable for quality.

-Multiple Production of Maps and Visual Aids - "Arc/Info" allows us to plot one or several maps of high quality color. There maps can easily be made into color slides at local photo production facilities.

-Produce 7 1/2 Minute Overlays - Overlays can be produced for wall size base maps.

-More Thinking/Planning - Using any GIS system requires more thought into the types of data needed and how costly that data will be to enter into the database. How important is it to your project? What kind of data will influence the success or future of the project?

Cons

-Standard 7 1/2 Minutes Quads Preferred - On-the-ground managers like familiar map products. Regardless of how detailed or sophisticated color maps are, many refuge managers and biologists still prefer the standard quadrangles.

-Digitizing-Costly!! - Creating a database by digitizing is very costly but necessary if GIS is going to be used for long term applications.

-Little Data Digitized - Very little detailed data has been digitized in Region 6. The National Wetland Inventory is the only standard, detailed database. Little information is available commercially or publicly.

-More Thinking/Planning - This is restated as a "con" because we, as managers and administrators, don't like to spend a lot of time planning. If we are going to utilize any GIS system we will have to think ahead! We must decide what information is critical to our project and evaluate costs and benefits of obtaining the data.

The Region 6 Realty experience with "Arc/Info" will be compared to our ongoing use of AutoCad to determine how our needs can best be met. If we are only going to produce maps, is AutoCad a sufficient tool? If we are going to analyze data, are we willing to spend money digitizing? A number of questions will have to be answered prior to making a long term commitment to "Arc/Info" or any GIS system.

GEOGRAPHIC INFORMATION SYSTEM AND REMOTE SENSING APPLICATIONS ON REGION 5 CENTRAL ZONE REFUGES

Bill Leenhouts, U. S. Fish and Wildlife Service, Barnegat, New Jersey.

INTRODUCTION

Refuges have implemented GIS and remote sensing (RS) technology for years. Maps (USGS, Survey and Maps, in house, etc.) and aerial photographs (SCS, ASCS, etc.) have all been an integral part of refuge planning and management operations. The manipulation of this data has been manual and subjective, and decisions derived from this information have tended more toward the art rather than the science of wildlife management.

Computerized geographical information systems (GIS) have been around since the late 50's. Even their earliest applications were natural resource based (Parent & Church, 1987). Wildlife planning and management applications using Ian McHarg's map overlay as well as other approaches were operational in the 70's. Much of this early development was done by the U. S. Fish and Wildlife Service. It was evident even then that the implementation of computerized GIS technology on National Wildlife Refuges was practical.

Early GISs were mainframe based and were only cost effective for large regional projects with relatively large funding sources and support facilities and personnel. With the development of the microcomputer and microcomputer GIS and image processing (IP) systems, implementation costs of this technology have sharply declined. This along with an installed base of microcomputers on refuges now makes it technically possible and cost effective to implement GIS technology on refuges.

More recently the dichotomy between GIS, RS and IP is becoming increasingly blurred. RS is supplying the data, much of it in digital format, and IP manipulates the RS data for use in GIS systems. Many GIS software systems incorporate RS input and IP capabilities. Some systems are becoming land information systems (LIS) with very large database capabilities for both spatial and nonspatial data; dependent on GIS, IP, RS, DBMS and network technology; and incorporate sophisticated modeling algorithms (GIS World, 1989).

These technologies have the potential to allow refuge managers to better plan, execute, and evaluate any spatially or geographically oriented project. For the past 2 years the use of these technologies to address specific operational needs have been explored on Central Zone Refuges in Region 5. Emphasis has be on biological projects, but the technology is just as applicable to public use, maintenance, and other refuge operations.

REFUGE APPLICATIONS

Acquisition and input of spatial data is typically the most costly and time consuming portion of GIS implementation (Ripple, 1989). This more than any other reason is probably responsible for the slow adoption of GISs on refuges. The reduction of data acquisition and input costs will facilitate project implementation. Data acquired by remote sensing can be significantly less expensive than manual digitization. Only projects which could utilize existing or remote sensed data were attempted. The primary source of remote sensed data was existing air photography and air video, although the satellite data was explored.

Several Central Zone specific refuge projects were initially identified for technology assessment. The ability to acquire data by remote sensing were reasons for their selection. These included the following:

- Developing habitat classification maps
- Assessing the impact of snow goose eat-outs on salt marsh systems
- Monitoring OMWM project construction and recovery
- Monitoring piping plover habitat (changes in beach configurations)
- Monitoring pest plant invasions and control programs
- Evaluating woodcock habitat management practices
- Assessing muskrat impact on cattail marshes
- Evaluating of prescribed fire operations
- Assessing impoundment management practices
    - Topographic features
    - Moist soil management practices

SYSTEMS EVALUATED

Three systems were acquired and evaluated. These included: Microimage's Map and Image Processing System (MIPS), Minnesota State Planning Agency's Environmental Planning and Programming Language (EPPL7) and the National Ecology Research Center's Quickmap. All 3 systems run on IBM compatible computers in the MSDOS environment.

The MIPS is a raster and vector based GIS. It was selected because of its IP and import/export capabilities and its ability to digitize video images. Along with the MIPS package a VHS aerial video equipment package was also acquired for collecting aerial imagery using inexpensive aircraft. Most of the work to date has been conducted with this system.

The EPPL7 is an inexpensive raster based system. It can be used on any DOS system in Region 5. It was selected primarily for its cost, portability and to assist with NERC's evaluation of the EPPL system. The system has been use primarily for map

reclassification and demonstrations.

Quickmap is a public domain (USFWS) vector system and was selected because of its cost and map development and graphical analysis capabilities. Acquired in February 1990, little work has been done with this system.

ACCOMPLISHMENTS

As with many adventures in new technology, actual accomplishments were much less than originally expected However, a lot has been learned over the past 2 years.

Data Acquisition

Before acquiring new data an attempt was made to determine what data was currently available. Of particular interest was existing digital data of either vector or raster format.

A search of possible Federal, state and local sources of digital data was undertaken. The standard sources were contacted pertaining to the availability of digital products (USGS, NWI, TIGER, SPOT, EOSAT). Contacts were made with state and local agencies. University remote sensing labs, computer science departments, etc. were also contacted. In the East USGS - DLG and DEM (especially at 1:24000) is very limited with no complete coverage of any refuge in the Central Zone. Low cost satellite data was only available to 1985. NWI data (1979) for all the refuges in New Jersey was obtained from the National Wetland Inventory, St. Petersburg, FL. Vector data from old master planning projects of Great Swamp and Long Island Complex refuges was acquired thanks to NERC and the National Park Service.

Aerial video imagery was collected for Forsythe, Great Swamp, Supawna Meadows, Oyster Bay, Target Rock, Seatuck, Wertheim, and Morton National Wildlife Refuges in April and August, 1989. Aircraft availability was a significant constraint. There is only one OAS certified aircraft with a photography port in the Middle Atlantic states. It is operated by the Office of Migratory Birds and is unavailable for refuge work most of the late spring and summer when the best vegetation imagery can be obtained. An external camera mount was developed, certified for aircraft use, tested, but hasn't been used operational as yet. It may prove useful.

National High Altitude Photography (analog) data has been acquired for Supawana Meadows and Montezuma NWR with all other Central Zone refuges except Long Island on back order. Arrangements have been made with the Remote Sensing Lab at Rutgers University to scan the photos into a compatible digital format.

Projects

An evaluation of wetland restoration within a coastal

waterfowl impoundment (East and West Pool of the Forsythe NWR) was undertaken using aerial video imagery. Aerial video images taken on Aug. 9, 1989, from 4000 and 8000 feet elevations were used. These images were digitized using the Vision 16 video board and MIPS. High-pass filtering was used to improve image contrast. The MIPS feature mapping subroutine (supervised classification) was used to classify the impoundment habitat into differing habitat classifications. The video resolution taken from 8000 feet (10 feet pixel resolution) was acceptable for classification into major categories (water, bare ground, vegetated). Imagery taken from 4000 feet (5 feet pixel resolution) provided better resolution, but complete coverage of the entire impoundment was not available at that altitude. Some vegetation types (Phragmites) were distinguishable at that resolution, but by August dwarf spikerush had grown across much of normally flooded area making additional vegetation classification difficult. Imagery especially at the 8000 foot elevation appeared to be affected by urban pollution.

Aerial video photography was evaluated to determine its ability to evaluate salt marsh changes related to open marsh water management (OMWM) projects. April and August air video photography of OMWM projects was acquired for both the Brigantine and Barnegat Divisions of the Forsythe NWR. Selected areas of the imagery were digitized and analyzed. It appeared that a video resolution of 5 feet is adequate to differentiate between vegetation and spoil areas at OMWM sites. It will probably require greater resolution to adequately differentiate between vegetation types.

Existing digital data for Central Zone refuges (Great Swamp and Long Island Complex) have been converted to MIPS format files. Editing procedures had to be used on most files to correct errors either in the data or caused by data conversion. Some additional editing is still required.

SUMMARY

Experiences over the past 2 years have demonstrated that GIS technology is perfectly suited and applicable to refuge programs. Hardware and software sophistication and costs are now manageable. However data (digital format especially) acquisition is still the greatest impediment to implementing of GIS technology on refuges. Several solution to this problem are possible. These include: 1) Using data acquired form other sources (i.e. other governmental agencies, other projects carried on in or near the refuge, etc.). 2) Using remote sensing technology such as satellite, aerial photography, and air video imagery. 3) Integrate map data storage to digital format for all elements of the FWS.

The use of GIS technology will significantly expand the capabilities of refuge biological data processing. But these expanded capabilities will require an additional commitment of refuge resources. Staff responsibilities will probably have to be shifted, additional staff acquired, and other support provided for

successful implementation.

The sophistication of the technology is significantly greater than that of nonspatial database management systems. To adequately implement the technology, commitments for additional personnel training and/or specialization will be needed.

Full refuge implementation of GIS will require some additional outside support at least for the near future. Most commercial data comes on 9 inch tapes which need to be converted to a more PC compatible format. Color hardcopy output devices currently are not cost effective for refuge operation. This type of support could be provided either by a service bureau from within the Service or via contract.

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HABITAT EVALUATION AND MANAGEMENT STRATEGIES USING GIS

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Introduction

The use of Habitat Evaluation Procedures (HEP) to estimate habitat quality and evaluate impacts is well known (U.S. Fish and Wildlife Service, 1980). Habitat data are collected in a designated study area and are used to evaluate habitat quality through mathematical modeling of species habitat requirements to produce habitat suitability indices. Multi-cover type models incorporate two spatial concepts, interspersion and composition. Interspersion, or the distance between cover types, and the composition, or proportion of cover types providing needed life requisites, can be provided by geographic information systems (GIS). However, the automation of data access is not a trivial process because of data format and software incompatibilities. The objective of this study was to develop automated procedures for using a GIS to provide spatial information for species models that are being used to monitor habitat quality and evaluate management strategies.

The Food Security Act of 1985 authorized a Conservation Reserve Program (CRP) that provides payments to farmers who plant permanent cover on highly erodible cropland and maintain the cover for 10 years. The present enrollment of over 33 million acres in this program could have major benefits for wildlife.

State fish and wildlife agencies are cooperating with the U.S. Fish and Wildlife Service to document the effects the CRP is having on wildlife (Farmer et al. 1988). The habitat monitoring began in 1987 and data from this effort were used in this study.

Materials and Methods

The habitat data were collected in 1988, in fourteen southeastern states (AR, GA, IL, IN, KS, KY, LA, MS, MO, NC, SC, TN, TX, VA). The CRP contracts were stratified into eight sample populations based upon the year the field was planted and the conservation practice. Sample data were obtained from 214 randomly selected CRP fields.

The species models used to evaluate the habitat quality in the region were the northern bobwhite *(Colinus virginianus)*, eastern meadowlark *(Sturnella magna)*, and eastern cottontail *(Sylvilagus floridanus)*. The bobwhite model was modified from Schroeder (1985), the meadowlark model was modified from Schroeder and Sousa (1982), and the cottontail model was modified from Allen (1984). Habitat variables for these models include the percentages of grass canopy, forb canopy, ground that is bare or covered by light litter, canopy of preferred bobwhite food plants, canopy of persistent herbaceous or woody plants, and the height of herbaceous plants. The bobwhite and cottontail models are multi-cover type models, which are used for species that get their life requisites from more than one cover type. The bobwhite utilizes habitat within a home range distance of 750 feet, which is a circle that includes an area of 40 acres.

State agency wildlife biologists collected data from 40-acre circles centered at random points on the margins of CRP fields. They produced a cover type map for each circle, using a standardized list of 33 cover types. In each cover type area in the circle, the biologist randomly located a line transect and collected presence or absence data for the habitat variables for at least 50 points (Hays and Farmer, 1990). The data were then entered into a dBASE IV data base and processed to provide life requisite suitability indices (LRSI) for the cottontail and bobwhite within each cover type area. Habitat suitability indices (HSI) were computed within each cover type for the meadowlark.

Each of the 40-acre circles and the cover type polygons were digitized into PC-ARC INFO (Environmental Systems Research Institute, Inc., Redlands, CA) coverages to provide area and edge measurement data. A typical coverage is shown in Figure 1. A map unit letter was assigned to each cover type. The area of each map unit was immediately available after correcting digitizing errors and building the topology for each coverage.

In addition to area, the eastern cottontail model requires the computation of an edge index for any cover types in the study area that provide winter cover or food. The edge index is computed as ratio of the total perimeter of cover types with winter cover/food to a function of the total area.

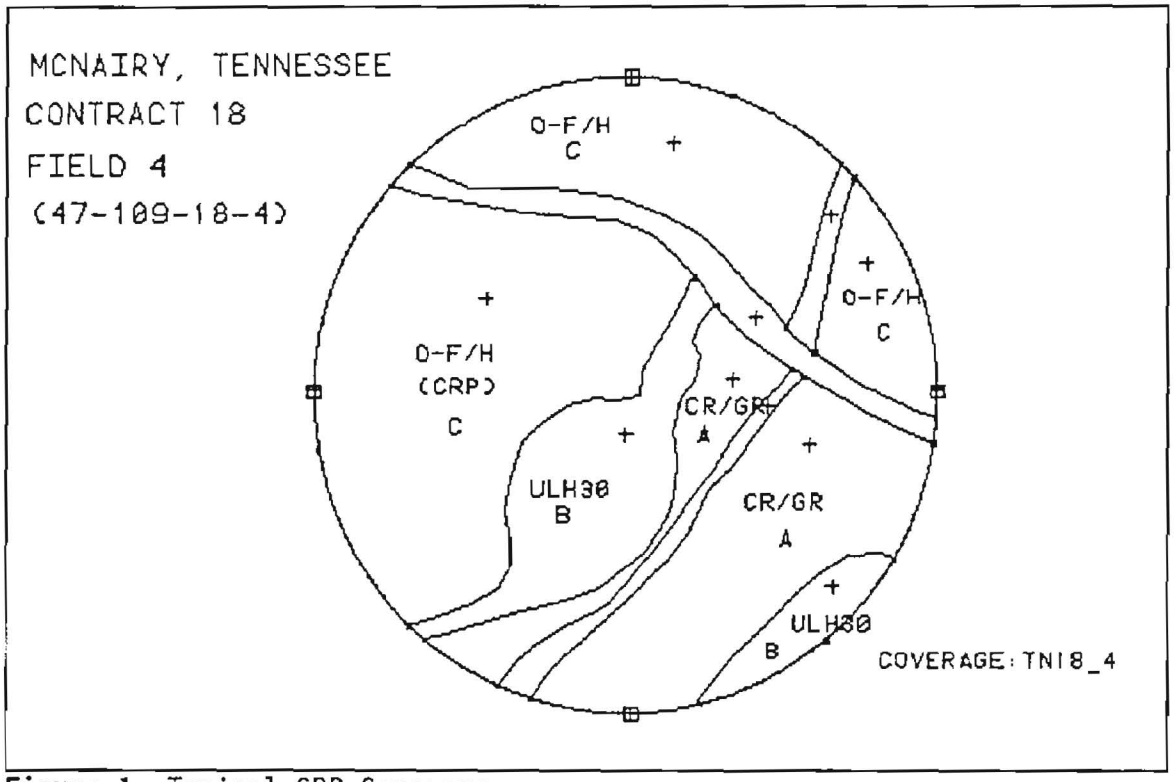

Figure 1. Typical CRP Coverage

$$EDGE\ INDEX = \frac{TPWC}{2\sqrt{A\pi}}$$

where:

TPWC = the total perimeter of cover types containing winter cover/food

A = total area of study area

The procedure that was developed for computing the perimeters of all polygons with winter cover/food is to use the "dissolve" operation to eliminate arcs between adjacent polygons that do not provide a winter cover/food life requisite (the LRSI is zero). The LRSI values are computed in a dBASE IV program and imported into the GIS database to provide the data for the

dissolve. In Figure 1, the map units labeled B and C provide winter cover/food. Figure 2 shows the resulting coverage after the "dissolve" operation was completed on the original coverage. The GIS line attribute table provides the arc lengths that contribute to the unique perimeter of all cover types with winter cover/food.

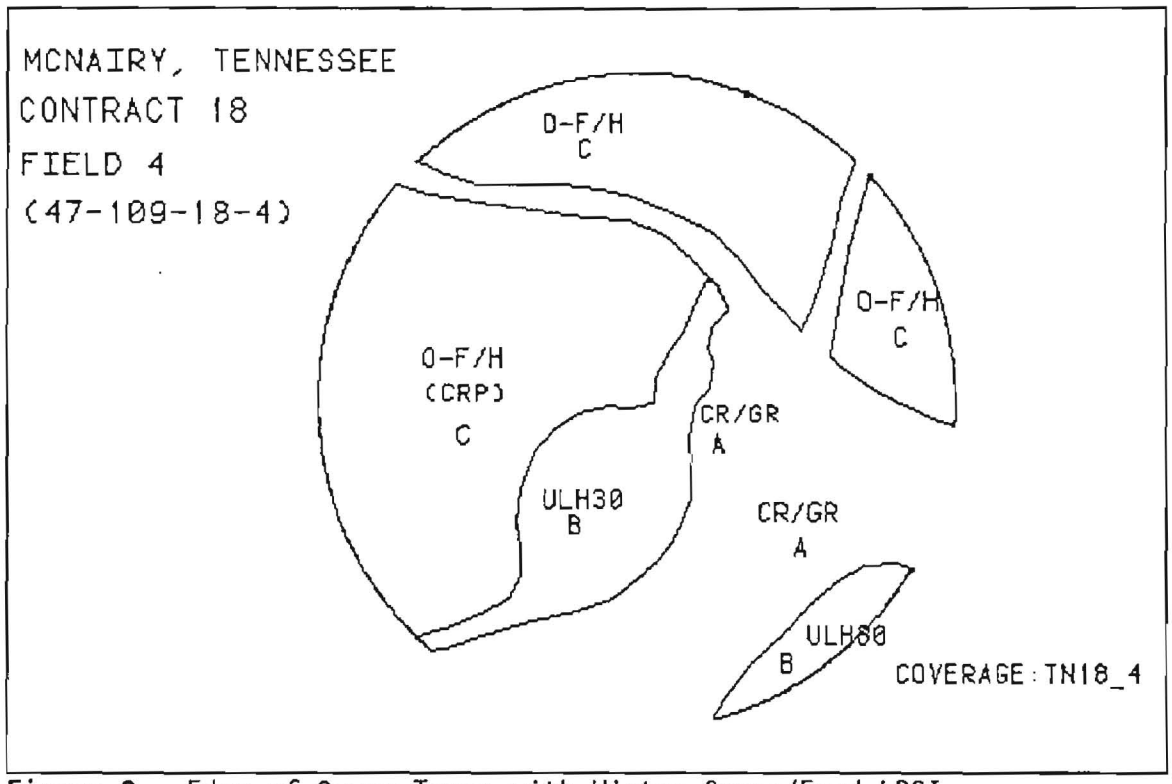

Figure 2. Edge of Cover Types with Winter Cover/Food LRSI

Habitat Suitability Index computations are completed in a dBASE IV program following the transfer of cover type area and the edge index data from the GIS data base to the original dBASE IV data base. The northern bobwhite and eastern cottontail models are multi-cover type models, which incorporate life requisite suitability indices in each cover type into a single HSI for the entire area. The meadowlark model HSI is a weighted mean of HSI values computed in each cover type.

Results and Discussion

The automated procedures for HSI computations that incorporate GIS data were successfully developed from the methods described in the previous section. This allows extracting area and perimeter data from a GIS for use with HSI models. It is conditional in that information from the partial calculation of HSI is used to drive logical decisions in GIS processing. These spatial variables are returned to the original data base (dBASE) to calculate the final HSI. Although this process is complex and requires several transfers of data from one data base to another, it is sufficiently automated to be practical. This method is expected to be improved when the dBASE version of PC-ARC INFO becomes available and the transfer of data among data bases will no longer be required.

This capability for integrating GIS data with habitat evaluation software has important potential benefits. The automated HSI computation provides timely evaluation of habitat and allows more detailed and sophisticated analyses of project impacts and the effects of management activities.

The HSI-GIS linkage will help meet the goals of the CRP study, which include evaluating the effects of possible management activities and assessing habitat quality on CRP fields over time. Possible management activities include haying or grazing, which were allowed in 1988 to alleviate the effects of the drought in the midwestern states. Based upon potential changes in the CRP, simulation of resulting habitat data and the analysis of changes in habitat quality will provide information on the impacts of these actions. The

simulations may require utilizing the procedures for computing HSI several times for each coverage based upon changes to LRSI and cover type areas.

The Habitat Management Evaluation Method (HMEM) software (Sousa, 1989) presently relies upon species models and management activity models to analyze cost effective management strategies for improving habitat. This software evaluates the results of proposed management upon both changes in cover type area and in habitat quality as measured by changes in habitat variable data. GIS software is an obvious tool for handling area data. The multi-cover type models that are used in HMEM also require extensive analysis of interspersion effects and cover type area computations. It is clear that the management activity models used in HMEM analyses can utilize GIS data also. The implementation of the CRP analysis using a GIS indicates the feasibility of using GIS data with the HMEM software for developing and comparing management strategies.

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Desktop Mapping

for Fish and Wildlife Field Office Use

by

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INTRODUCTION

Three years ago the National Ecology Research Center (NERC) began a project to see how microcomputer Decision Support tools might be used by our agency for manatee conservation. That work has lead to the development of a "Desktop Mapping System" (DMS) with unique characteristics and potentially wide-spread application. Here, desktop mapping means the ability of personal computer users to manage, retrieve, manipulate, and incorporate geographic information with their other regularly used applications. In this paper I shall discuss factors that have influenced this project's development work and that ultimately challenge any system's implementation in the U. S. Fish and Wildlife Service (USFWS); briefly describe the capabilities provided by our QuickMAP DMS prototype; and finally share ongoing QuickMAP applications at field offices and how they are benefiting from desktop mapping.

CHALLENGES TO SYSTEM IMPLEMENTATION

First, let me contrast what I call information management with decision support. Traditionally, Information Management Systems (IMS) have been developed to handle repetitive, routine tasks, that change very little over time, and in the USFWS, are often centralized systems implemented in a top-down fashion. In contrast, Decision Support Systems (DSS) address problems created by highly dynamic processes, variable information, and the very nature of decentralization in our agency. While IMS's are easier to implement and justify, I would claim that they rarely help our rank and file biologist in their day to day resource management activities.

Figure 1 shows one type of a DSS driven by the end users needs. The thrust in this framework is moving the valuable commodity of resource information at its core to where it is needed by, and in a form that is relevant to, USFWS resource managers. The framework incorporates applications that are general in nature, and tailors them to specific problems by end users themselves rather than by a staff of systems developers. I see three objectives for desktop mapping in this framework. First, it must complement whatever current application tools are in use. Second, it must expedite the use of and access to existing information whenever and wherever available. Third, it should help to develop new insights on problem solving while providing support to current decision-making.

The next point I shall make is that it took a decade of experience with geographic information systems (GIS) technology before NERC initiated development of a desktop mapping system. During those formative years, the NERC developed or employed several different GIS's. Each of those systems were successfully transferred to a variety of state and federal agencies responsible for the management of fish, wildlife, and other renewable resources. A wide spectrum of applications were evaluated, satisfactorily transferred, and many people were trained. Nevertheless, past attempts to transfer GIS technology to our own USFWS field offices largely failed, and experience suggest that our agency lacked a foundation to implement or support GIS technology on a large scale.

Brown (1986) indicates that successful implementation of GIS requires expertise in nine different technical areas. USFWS field offices simply can not support that level of commitment even if one-time expenditures for hardware and software were justified.

Our current DMS development work specifically addresses this dilemma. In particular, let me profile a typical USFWS Fish and Wildlife Enhancement (FWE) field office. It helps to clarify the work environment and organizational culture in which a systems capabilities must provide tangible user benefits. In general, six to a dozen people are responsible for decisions covering a large geographic area. For example, FWE offices at Jacksonville and Vero Beach, FL oversee most activities in the state. Personnel consist of a supervisor, biologists, and secretarial staff. Budgets over the recent past have been stable or declining; however, salary costs have risen and consume more of the operational budget. Office staff frequently face decisions about allocating time among too many tasks. In addition, much of the staffs expertise is acquired over time as they learn where valuable sources of data are maintained and whom to contact outside our agency. Too often this expertise is lost as individuals leave or are reassigned, leaving newcomers at risk initially in making uninformed decisions. Finally, computer proficiency is quit limited. Many field offices will designate a single individual to spend only part of their time to support all field office technologies. But most FWS personnel acquire their computer literacy by tapping informal networks of dedicated, knowledgeable microcomputer users.

Now let me return to our project experience concerning the West Indian manatee (Trichenchus manatus) at the Jacksonville FWE field office. Under authorities in the Endangered Species Act of 1973, as amended (16 U.S.C. §§ 1531-1543), FWE field offices provide biological consultations to other federal agencies on whether construction or other project activities jeopardize the existence of endangered species. In addition, the Jacksonville FWE field office coordinates the recovery plan process for manatees, participates in manatee protection planning, and insures compliance with the Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361,1362,1371-1384,1401-1407). FWE field offices also review federal projects and permits under the authority of the Fish and Wildlife Coordination Act of 1934, as amended (16 U.S.C §§ 661-666c). Much of that work involves either Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. § 403) or Section 404 of the Clean Water Act of 1977 (33 U.S.C. § 1344) administered by the U.S. Army Corps of Engineers.

What all this really means is that much of a biologist's time is spent on the phone, attending meetings, and writing reports to answer the question "What fish and wildlife resources are there, and what activities may impact them?" In the case of manatees, the basic information used in this process even comes from outside sources. So desktop mapping for field office use must go beyond the need to manage, display, and manipulate geographic information. To succeed it must also integrate with existing software and hardware, be compatible with data that may be acquired from or transferred to others, and be both affordable and simple to use.

SYSTEM DESIGN AND CAPABILITY

Service-wide standards for office technology are IBM AT clones with MS-DOS operating systems. These recent standards will direct procurement and technical support for several more years. As a result, new applications will be affordable only if they operate on this standard. On the other hand, service-wide standards still allow many configurations of monitors, printers, and plotters, whose different resolutions and capabilities complicate in-house development of software that will be distributed to field offices.

User-friendliness is engineered into the prototype, known as QuickMAP, with a graphical user interface. This vivid technique was pioneered at Xerox and "user-friendly" became a household phrase with the introduction of Apple's Macintosh computer. The interface provides inexperienced users with an intuitive metaphor that they can rapidly exploit. Screens with multiple windows, drop down menus, forms, dialogues, and alert messages, which are all driven by events the user initiates with a pointing device, allow non-routine tasks to be handled routinely.

For reasons of compatibility, affordability, and ease of use, a commercial programmer's toolkit (Balma and Fitler 1986) was chosen to implement the prototype on MS-DOS machines. This toolkit supports a wide spectrum of output devices through the use of a standard computer graphics interface. The standard uses the full resolution of any output device. Information can be exchanged with other applications through the use of metafiles. Program libraries provide a standard graphical user interface common in other commercial windowing applications. Device independence provided by the toolkit further encourages standards among hardware manufacturers because new devices either must use current drivers or provide their own to be compatible with the most widely used software. In turn, this insures that the diversity of PC configurations in USFWS field offices can be supported.

In theory, the toolkit simplifies the development task. Work can focus on the application at hand because details of using different hardware are handled by the toolkit. In practice, the benefits of the toolkit have been offset by significantly greater effort to develop the sophisticated and consistent graphical user interface. Nevertheless, standards have simplified application support and maintenance as development moves forward. Indeed new, improved hardware is now accessible through new, more capable device drivers. The field office need purchase only the device drivers to support their equipment for a nominal cost (about $50). The only additional hardware required to begin work with the QuickMAP prototype at most field offices is a mouse (about $100). To enter information from a published or hand drawn map also requires a digitizing tablet ($500-$5000 depending on size and precision).

The toolkit has also limited the scope of development because other commercial software built to the common graphical standards can be used to enhance maps produced by QuickMAP. For example, a drawing package costs about $200 and can be used to annotate maps, incorporate legends, etc. QuickMAP's metafiles are also compatible with desktop publishing software and the latest version of WordPerfect. QuickMAP can be used with a variety of data base management systems through data interchange formats. End users can manage attribute information in a system they already know and feel comfortable with because no particular data base management system is tightly coupled to the prototypes use.

Map data are voluminous and must be accurate. QuickMAP stores data as real numbers and performs calculations in double precision to preserve site-specific accuracy even when nationwide areas are covered. The internal data structure is compact and efficient for personal computers. This data structure also assists data exchange with full-featured GIS's. The building blocks for geographic point, line, and area features in QuickMAP are termed arcs. The arc structure eliminates redundant storage of coordinates for map features that are coincident. Additional information, termed topology, is stored about the spatial relationships among these arcs.

QuickMAP's modular design organizes desktop mapping functions into four major categories. One module provides digitizing and editing capabilities. Digitizing is the process of defining and storing coordinates from a map as arcs in a data base. This module not only provides the initial data entry function but also can edit arcs after defining topology.

Another module assembles and modifies map topology. QuickMAP does not require error-free topology for most tasks so a compromise is struck to simplify data management. The process is driven by the user. Topology is visually displayed as the user constructs it. Verification identifies problems that the user must correct before topology can be saved. For large production tasks, the power of a full-featured GIS is desirable to automatically assemble topology. Under these circumstances, QuickMAP can still be used in a distributed operation. For example, initial data entry is done locally on an MS-DOS machine. Then arcs are transferred to a full-featured GIS, perhaps at a remote site, for construction of topology. Finally, topology is transferred to QuickMAP for subsequent use with other map data.

Map display and manipulation in QuickMAP constitutes a third module. The user composes maps by selecting features from a data base. The user determines which colors, point symbols, line styles, and area shade patterns depict various features. Composed maps may be output for final display, or as metafiles may be enhanced by other graphic applications. Map layers can be aggregated and resulting lists saved for reuse, or screen images can be saved and loaded to dramatically improve system performance. Analytical computations, such as distance and area measures, of either entire features or individual polygons and line segments may be queried on the screen and reported in units other than the database's reference. Buffering points and counting points within polygons are other analytical capabilities we plan to implement. If more sophisticated analyses are required, data can be transferred and incorporated in spatial models developed in full-featured GIS's elsewhere. Again, results can be transferred back to QuickMAP data bases for distributed use at field offices.

The final module in QuickMAP provides many utilities that facilitate data interchange in a decision support framework. Utilities provide the capability to define geographic controls and convert among a variety of projections. Additional utilities link other systems via standard formats including Digital Line Graph (DLG) and MOSS Export standards. Information can be both imported and exported. Exchange with drawing applications via metafiles has already been mentioned. Examples of data interchange with several GIS's and data base management systems follow.

QuickMAP's design and development work is now being finalized for wider distribution and evaluation. Software will be packaged with installation directions, documentation, and sample databases. However, end users will still need to acquire their own GEM products and map databases. Release is scheduled for October 1, 1990. Although costs for the distribution are not yet fixed, the package as described will be less than $100. We hope QuickMAP's availability will foster greater understanding of managing geographic information at field offices and provide feedback to us on its features and use. Current feedback already suggest benefits from formal training in computer mapping concepts and data management are needed. Such training can be combined with desktop mapping and provided as early as next fiscal year if sufficient interest exists.

FIELD APPLICATIONS AND TESTING

As stated earlier, initial QuickMAP field testing focused on manatee conservation and involved our Jacksonville FWE field office, the Sirenia Project at the Gainesville NERC field station, and the Florida Department of Natural Resources (FLDNR). All parties are both sources and outlets for geographic information critical to manatee conservation. Current evaluations deal with both site-specific and statewide applications.

FLDNR manages the Manatee Carcass Salvage Program. This program focuses on manatee mortality data (Bonde et al. 1983) by recovering dead animal and determining their cause of death. A toll free number and high public awareness insures that most dead animals are reported and recovered. Since its inception in 1974, over 1300 individuals have been recovered. A data base is maintained by FLDNR which includes the latitude/longitude at which the carcasses were recovered. FWE field offices get this information from FLDNR either by phone contact, computer printed reports, or as dBASE files which are stored locally using Rbase. Users may query this database concerning a particular need and selectively import locations into QuickMAP for display with other geographic information. Results may be re-projected to conform with a specific QuickMAP database (either statewide are site specific). The entire process is further being streamlined by linking these steps in a utility program jointly developed with the Regional Information Resource Management coordinator. Figure 2 is an example of a map produced with QuickMAP containing all female manatee mortality since 1974 attributed to boat or barge collisions in southern Florida. Providing this capability has lead to far better quality assurance of information used. Now spotting erroneous locations are far easier than detecting them in tabular lists of coordinates.

The Sirenia Project conducts ecological studies on manatees and uses both radio and satellite telemetry of individual manatees to better understand movement patterns and seasonal habitat use. Satellite locations are received on tape from System Argos (Reid and O'Shea 1989). Coverage is both extensive, because some animals are wide ranging, and intensive, since locations are fixed several times each day. Information is processed and maintained as SAS databases for statistical analysis, but procedures now exist to report out selected information and ultimately display it with additional geographic information in QuickMAP databases. Figure 3 shows this capability for a wide-ranging adult female manatee (S-10) monitored during movements between Georgia and Miami, FL from November 1987-July 1988.

Early applications of QuickMAP suggested that all parties involved in manatee conservation can benefit from sharing existing information, utilizing computer mapping system, and acquiring reliable, detailed information for shoreline reference. Our center has assisted in this last efforts by refining digital information from National Ocean Survey (NOS) for use in both FLDNR's GIS and QuickMAP. Figure 4 shows a sample of this shoreline database together with an adult female manatee (S-8) monitored from December 1986-June 1987. To date 153 7.5' quads have been processed by ARC/INFO and down-loaded for use in QuickMAP. Detailed shoreline information from NOS is now being used by all parties.

Perhaps more significant to the USFWS's mission is that these databases can be used in activities beyond manatee conservation. For instance, the Jacksonville field office is now using the shoreline information in their permit review work occurring in coastal areas. Another QuickMAP application will begin soon at the FWE field office at Vero Beach, FL. Its focus will be on new ecological service

projects and permit reviews. One planned activity will compile information that the office uses in their work into a geographic database. Sources for this resource information include existing Rbase file, office reports, and outside contacts relevant to all endangered species and valuable fish and wildlife resources in a two county area. Another activity will involve acquisition of digital base maps for hydrography and transportation from U. S. Geological Survey's 1:100,000 series in a DLG format. This base information is quit inexpensive and available nationwide. We hope it will be easily imported into QuickMAP and prove useful, thereby eliminating yet another major obstacle to desktop mapping in FWS field offices---the availability of digital base maps.

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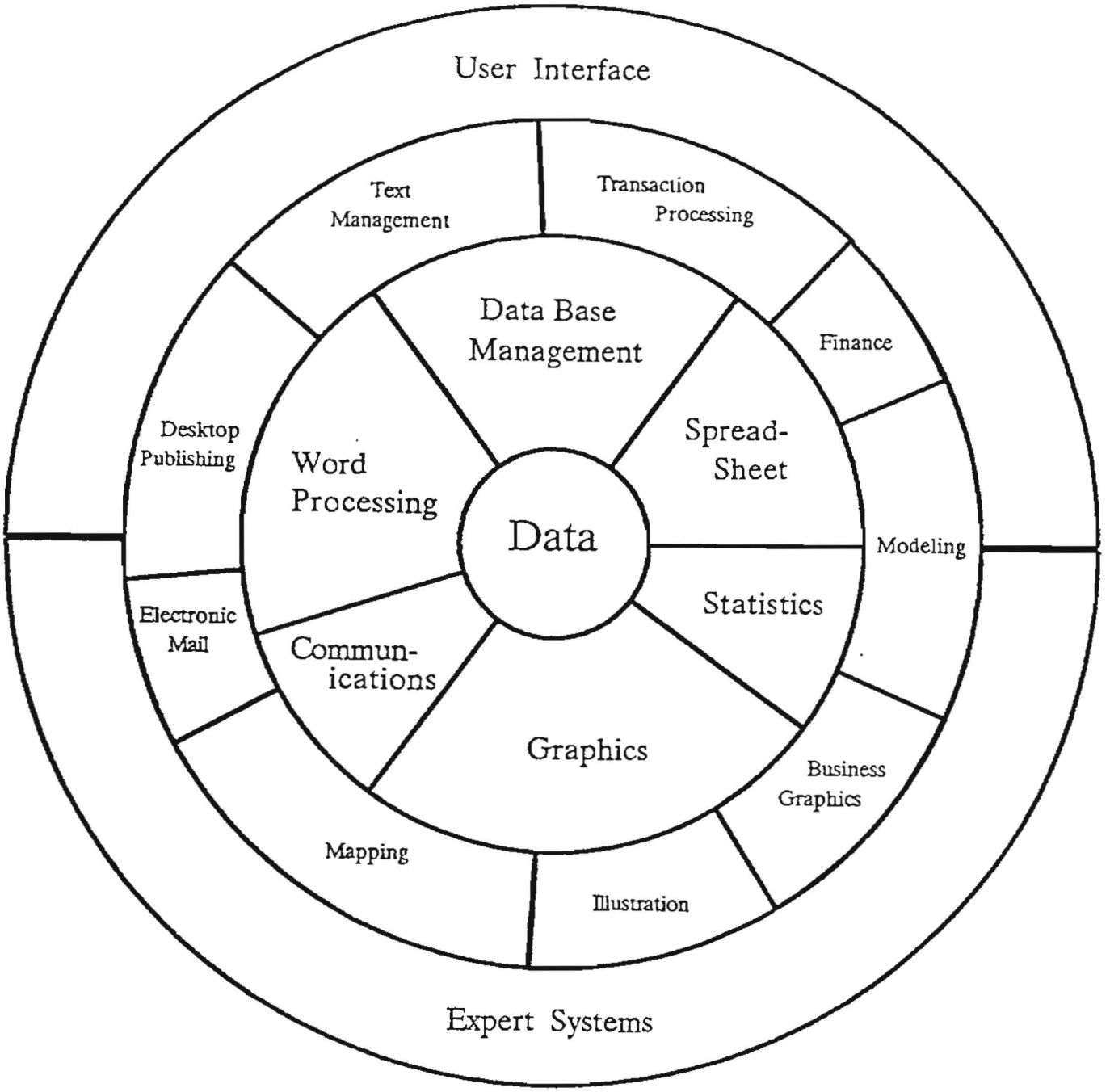
FIGURES

Figure 1. Framework for decision support in U.S. Fish and Wildlife Service field offices. A layer of application tools surround a core set of data. Systems are built around the application tools. An outer shell provides common mechanisms by which users interact with the diverse systems.

Figure 2. Manatee mortality caused directly by boats or barges in southern Florida from 1974-February 1988. Pluses (+) are recovered carcasses determined to be crushed upon collision or lacerated by propellers.

Figure 3. Locations of a tagged adult female manatee (S-10) monitored by satellite through Service Argos from November 1987-July 1988.

Figure 4. Locations of adult female manatee (S-8) monitored by satellite through Service Argos from December 1986-June 1987. The NOS shoreline data span six USGS quads. The densest clusters of use are in protected waters of Banana Creek on the Merritt Island National Wildlife Refuge and near the warm water effluent from power plants in the lower left.


User Interface
Text Management
Transaction Processing
Data Base Management
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Desktop Publishing
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Modeling
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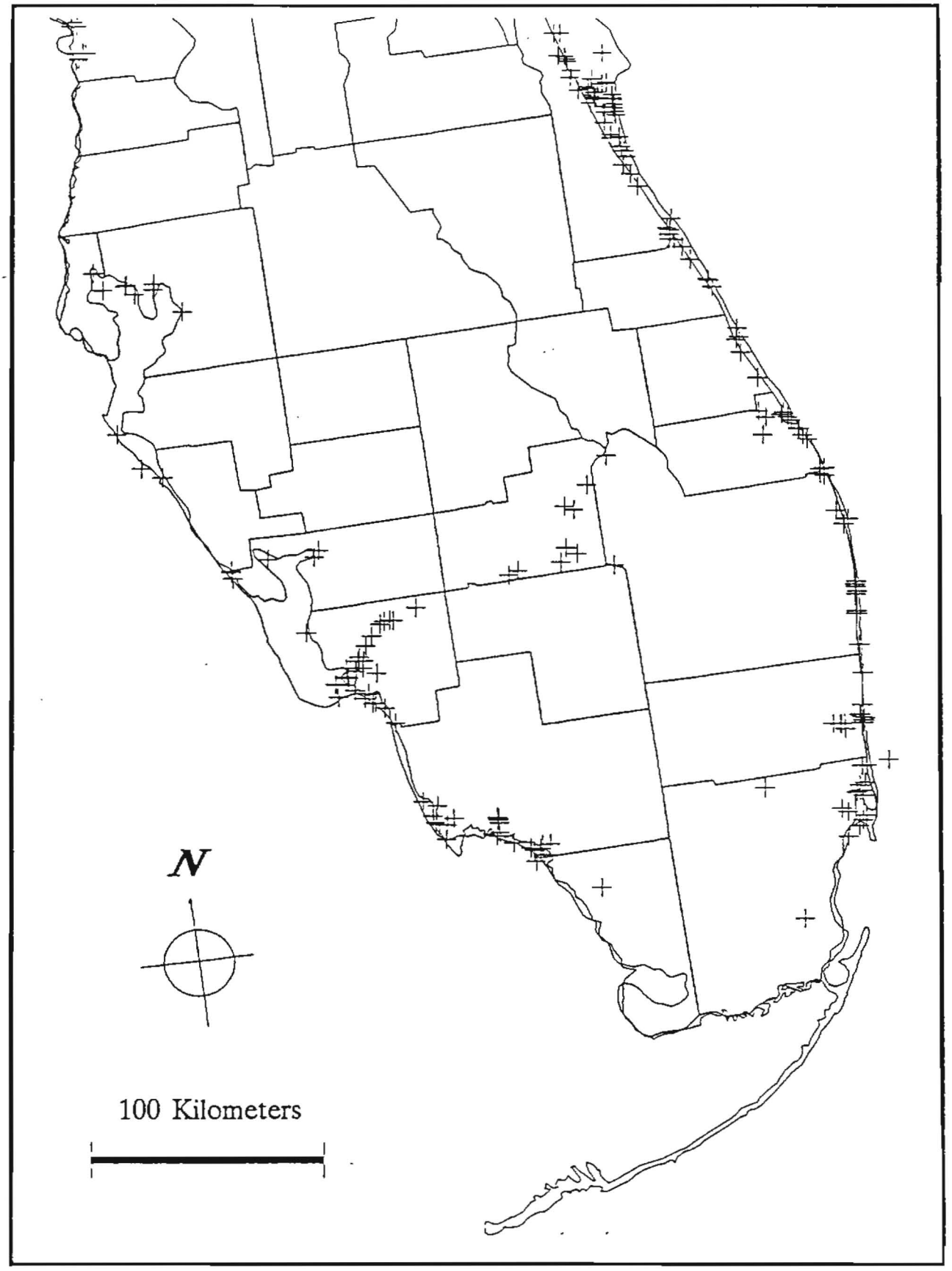
Business Graphics
Mapping
Illustration
Expert Systems

(Figure 1.)



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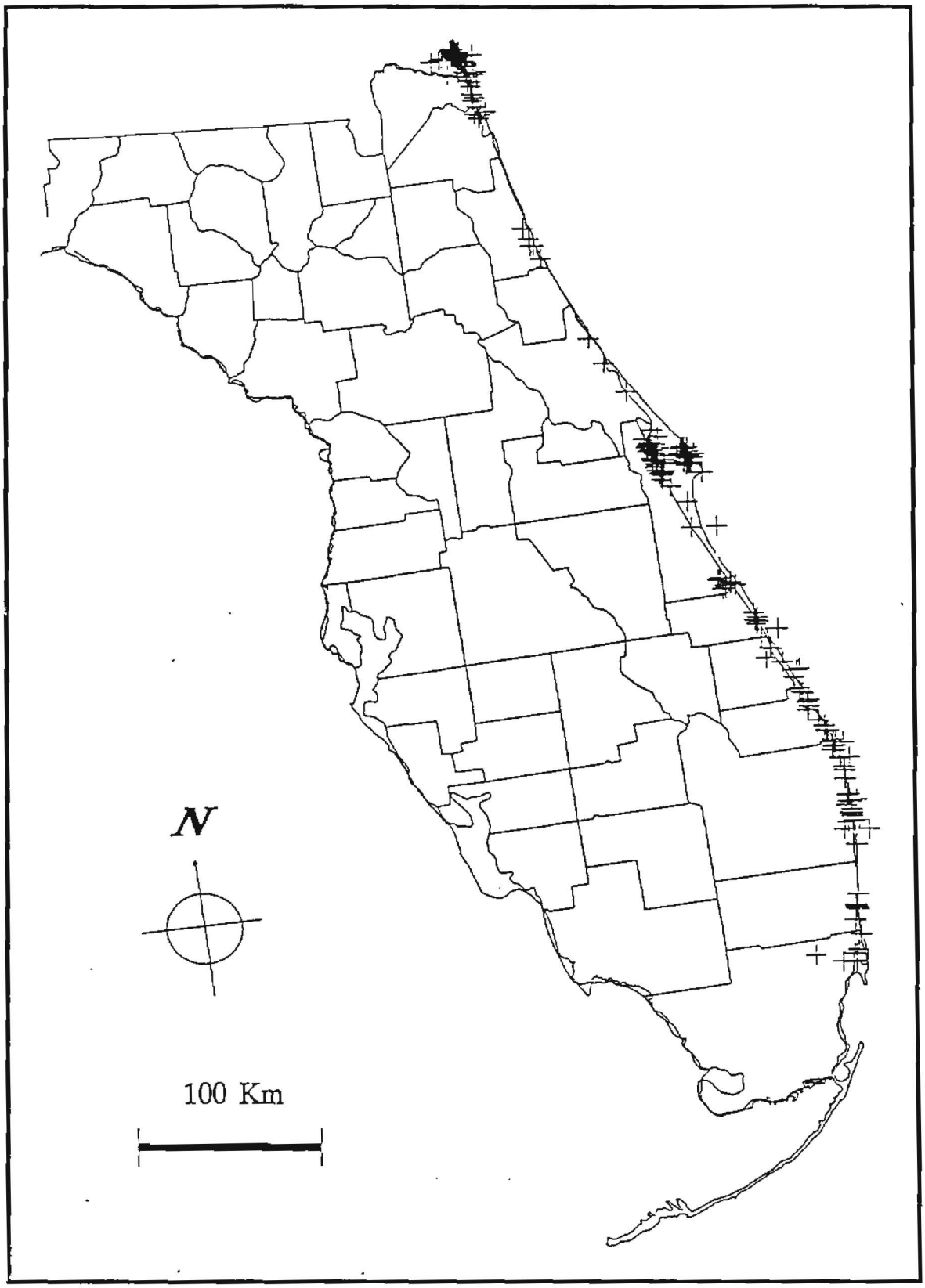

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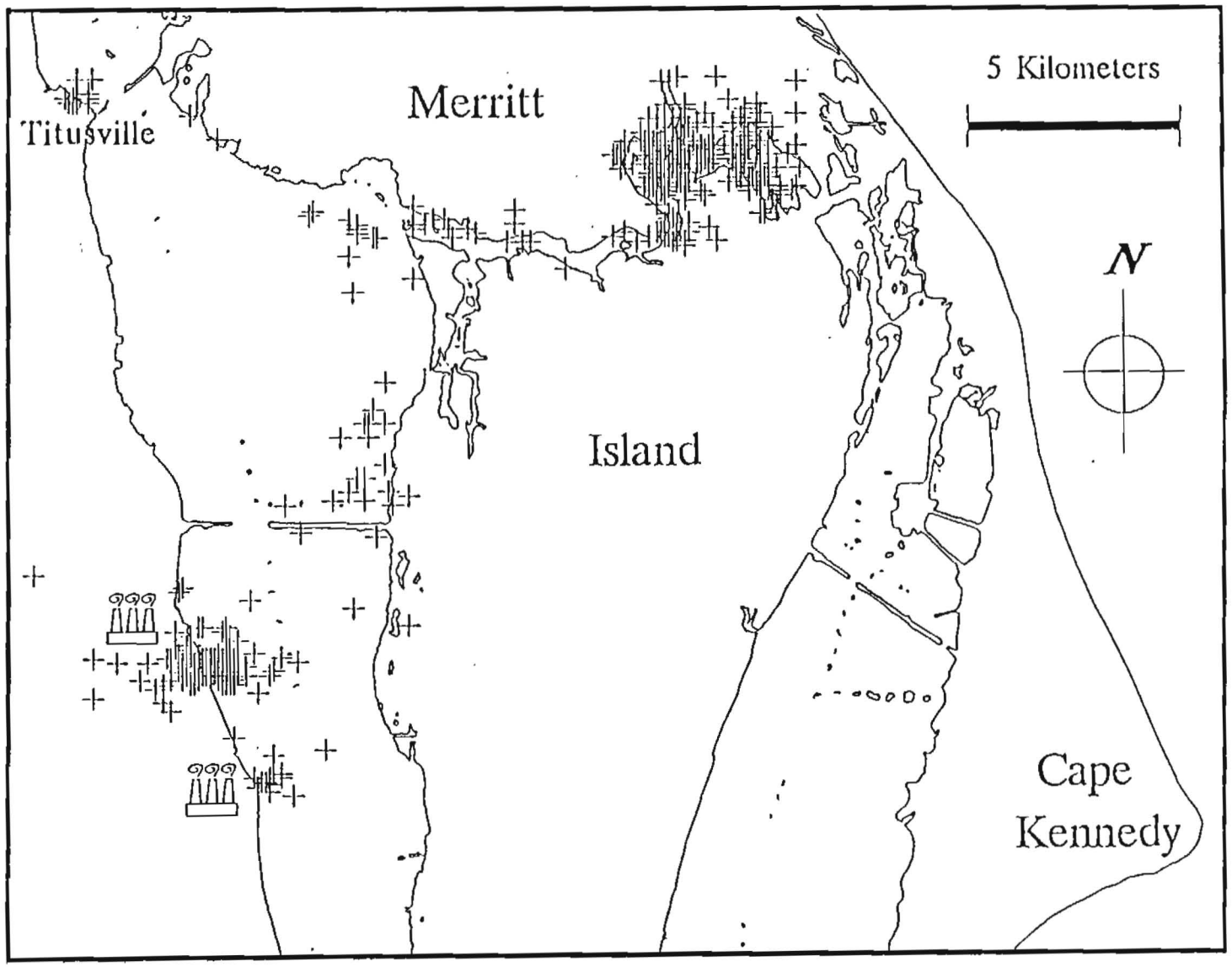

(Figure 4.)

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Hunter, D. O., J. E. Heasley, W. B. White, T. C. Daniel, and G. J. Buhyhoff. 1988. Integrated information technology for natural resource management. Pages 109-120 in G. J. Buhyoff, ed. Proceedings resource technology 88. American Society of Photogrammetry and Remote Sensing, Bethesda, Maryland.

INTEGRATED INFORMATION TECHNOLOGY FOR NATURAL RESOURCE MANAGEMENT

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ABSTRACT

Over the past few decades, natural resource agencies in the United States have amassed an unprecedented amount of data, and natural resource management has become increasingly complex. These conditions have rendered conventional resource-management tools and methods less effective. Resource managers are turning to more advanced information technology for help. This technology, however, is complex and seldom designed for natural resource management.

The INtegrated FOrest Resource Management System (INFORMS), a computer-based decision support system specifically adapted for natural resource management is described. Operating as an integrating shell, INFORMS can be configured to a user-specified geographic and problem universe. Once configured, INFORMS becomes a custom framework that supports a variety of decision support capabilities ranging from simple data storage and retrieval to sophisticated environmental analyses. INFORMS integrates the precise complement of spatial data, tabular data, and resource models needed to arrive at projected environmental consequences resulting from proposed management actions.

INFORMS was tested on the Red River District, Nezperce National Forest, Idaho. The data and models that were integrated included eight resource models, a multi-resource tabular database, and a spatial (map) database. Given the same type of analysis problem, INFORMS was more than four times faster than the conventional "hand" methods; consequently, more analyses were completed for a wider range of alternatives. It allowed greater flexibility for the forest manager to "fine-tune" alternatives for specific resource problems--with minimum staff involvement. The use

of INFORMS on the Nezperce National Forest demonstrates that natural resource management can benefit from the integration and adaptation of information technology.

INTRODUCTION

Population increases, diminishing resources, a more concerned public, and burgeoning databases are pushing natural resource management (NRM) from the pencil age into the computer age. A typical national forest in the United States relies on about 40 different types of data embodied in databases, models, individual expert knowledge, or on map sheets--some forests have more than 13,000 maps on file in one office. Moreover, resource management decisions must consider biological, social, economic, and political influences. As the scope and complexity of NRM increase conventional information systems become less effective.

Recent advances in information technology such as geographic information systems (Burrough 1986, Optiz 1986), artificial intelligence programming (Stock 1987, Coulson et al. 1987), decision support systems (House 1983), new remote sensing techniques (American Society of Photogrammetry and Remote Sensing 1985), and new approaches for storing tabular data (Potter and Trueblood 1988) show promise for aiding NRM. Until recently, these technologies evolved out of separate needs and were applied separately. But with today's complex problems, more often than not, a combination of technology or systems is needed. Thus, the current trend is toward integration. Previously independent information technologies are being combined into single systems to create more powerful and versatile decision tools. For example, artificial intelligence is showing promise for enhancing geographic information systems (Robinson et al. 1986) and for modeling animal-environment interactions (Coulson et al. 1987). Also, several recent studies show very favorable results from combining artificial intelligence, geographic information systems, and remote sensing (Jackson and Mason 1986, McKeown 1987, and Goodenough et al. 1987).

In this paper we describe the INtegrated FOrest Management System (INFORMS), a decision support system that integrates spatial data, tabular data, and resource models. We tested INFORMS on the Red River District, Nezperce National Forest, in central Idaho. INFORMS was faster than conventional "hand" methods; it allowed greater flexibility and repeatability for problem solving, and allowed managers to simulate complex ecological interactions while reducing the use of valuable staff time. INFORMS demonstrated that natural resources such as a national forest can be analyzed as an ecological system using integrated information technology.

The INFORMS concept of integration grew from work begun in 1983 (Daniel et al. 1984), which looked at the problem of assessing the impacts of forest pests damage using computer-based methods that interfaced with the forest-planning process. This work focused on developing a system that combined existing independent systems typically used

for assessing insect damage, such as timber-stand data, maps and geographic information systems, and models. From this work several development guidelines were recognized that later became the developmental framework of INFORMS. The system must at a minimum (i) communicate in language familiar to the user; (ii) produce the same results as the manual counterpart; (iii) be modular, allowing new models or other components to be linked as needed; (iv) support decisionmaking, not make decisions; (v) use common, standard file structures; and (vi) be easy to use, not placing a burden on the user to learn a complex system. Within the context of these guidelines INFORMS has evolved into an intelligent (following the problem-solving procedure of the human expert), flexible, problem-solving environment functioning much like an integrating shell. As such, INFORMS can be configured to different geographic locations and problem sets.

INFORMS

System Architecture and Operation

INFORMS is written in FORTRAN 77 and runs on Data General MV series computers. In its present form it is composed of four major system components: the central control module, the model library, the spatial component, and the tabular component (Figure 1). Figure 1 reflects INFORMS components specific to this study, another location with a different set of problems might require different components. General description and a discussion of each component's operation follow.

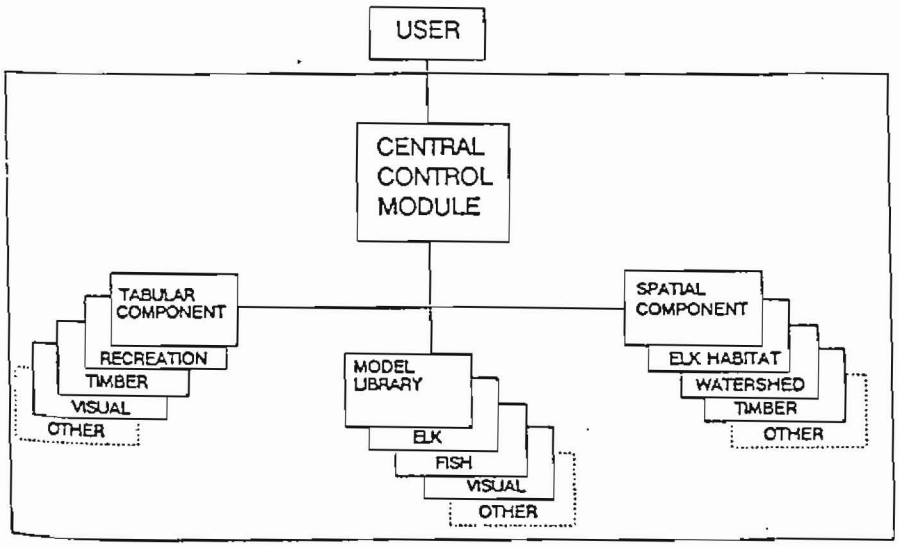


Figure 1. INFORMS system diagram showing major components.

Central Control Module. The central control module (CCM) is the system software manager. The CCM provides the architecture for linking all other components of the system and embodies the knowledge of which problem requires which component. The user interface is through the CCM, where user queries are converted into system instructions that define the bounds of the problem, perform analyses and present results. The user interface is menu-driven with text and graphics capability.

The CCM is composed of four submodules: (i) project definition, (ii)analysis specification, (iii) analysis execution, and (iv) report generation (Figure 2). The interactions of these submodules among themselves and with the other components are guided by programmed rules--techniques used in artificial intelligence that emulate the human problem-solving process.

The project definition submodule lets the user define the geographic extent of the problem. A project area is graphically defined by digitizing a boundary on the computer screen or by selecting a group of spatial entities (timber stand, watershed, etc...) that collectively represent a geographic area. The project boundary is used to delineate and extract the required geographic data from the spatial database.

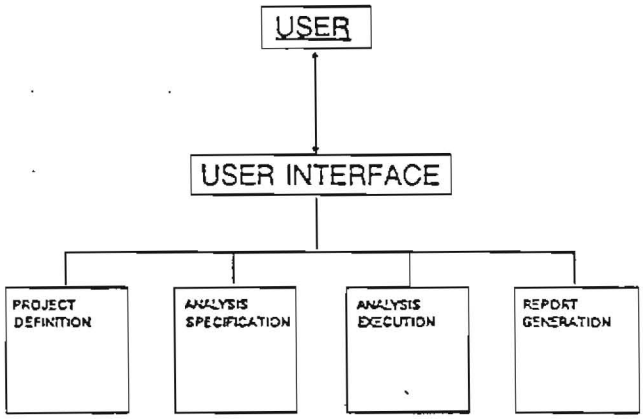


Figure 2. Diagram of the Central Control Module.

The analysis specification submodule allows the user to define the scope of the analysis and specify alternatives within each analysis. An analysis usually emphasizes a resource-management objective such as "minimize sediment yield," or "maximize economic return." For each analysis the user defines alternatives which are variations of the management objective. This submodule calls the appropriate models from the model library and initiates a data-preparation routine. After the data input requirements are determined for each model these input files are collated and all redundancies removed. A user

menu is then produced that is unique to that analysis scenario. Through this interface the user is prompted to enter additional information that characterizes specific management alternatives.

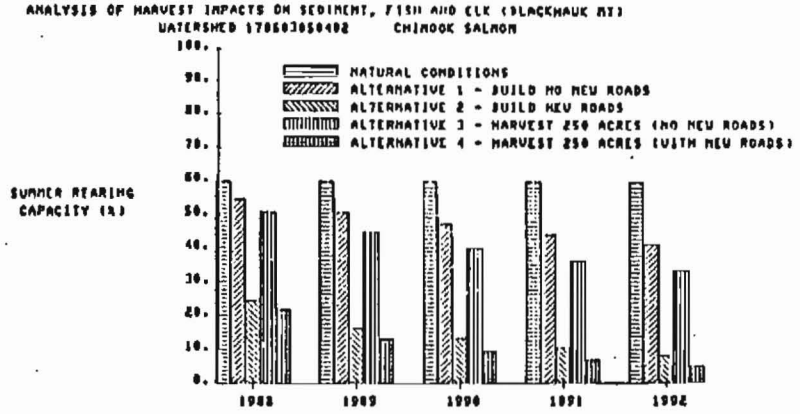
The execution submodule runs the complement of models selected during analysis specification. At this point the user further defines alternatives by selecting which alternative scenarios are to be executed and the time periods of each simulation. The models are then executed. Finally, the report generation submodule lets the user specify the type and format of the analysis products. The user specifies which analysis and which alternatives are to be reported. The final products can be tables, charts, or graphics (i.e., maps) (Figure 3).

Model Library. The model library is a collection of models (programs) that simulate resource responses such as forest stand growth, stream sedimentation, and fish production. Each model in the library consists of four interrelated submodules: simulation, input, output, and data preparation. The simulation submodule contains the equations and relationships that represent the observed natural phenomenon. It also reads the input information and stores the simulation results used by the output module or other related simulation models. The input submodule provides parameters that specify variable conditions (alternatives) for a simulation. Data for the CCM's report generation submodule is provided by the output submodule. Finally, the data preparation submodule manipulates the spatial and tabular data into specific formats required by each model. The CCM monitors and directs the interactions among the model library submodules.

Spatial Component. The spatial component contains the spatial database and programs for manipulating and displaying spatial data. The spatial data are map files organized into themes such as moose habitat, soil type, roads, and timber stands. The number and types of themes are a function of the problem universe that INFORMS is configured to solve. The map files are stored in polygon format consistent with the Map Overlay and Statistical System (Lee et al. 1985), a general-purpose GIS used by the U.S. Forest Service and other Federal resource agencies. Each map file contains attribute data consistent with the input requirements of the models in the model library. For example, the number of miles of new road constructed on different soil types is needed for calculating erosion in the sediment model. These data are derived by overlaying a map of soil types with a map of proposed roads. The resultant map contains the required input fields needed to compute erosion.

INFORMS contains only the spatial analyses functions needed to support the user interface and model requirements. There are presently 17 commands in INFORMS including the more general GIS commands such as plot, distance, shade, buffer, and overlay (Heasley 1988). For added flexibility, however, it is possible in INFORMS to access MOSS directly.

a



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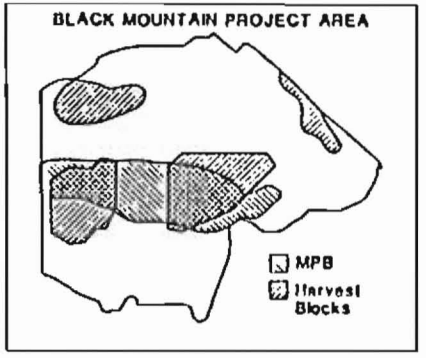

c

ANALYSIS: ANALYSIS OF HARVEST IMPACTS ON SEDIMENT, FISH AND ELK (BLACKHAWK MT)
ALT: ALTERNATIVE 4 - HARVEST 250 ACRES (WITH NEW ROADS)

WATERSHED - 17060305040 RAINBOW STEELHEAD

YEAR	PERCENT OVER NATURAL	SUBSTRATE EMBEDDEDNESS	FINES BY DEPTH	EMBRYO SURVIVAL	SUMMER REARING CAPACITY	WINTER CARRYING CAPACITY
			(PERCENT)			
NATURAL	.00	23.27	18.58	75.26	96.59	45.39
1988	13.74	24.47	20.15	71.24	96.20	43.52
1989	13.73	25.70	21.80	64.89	95.79	41.73
1990	13.73	26.94	23.44	55.78	95.35	40.82
1991	13.73	28.17	25.09	44.37	94.89	38.37
1992	13.73	29.41	26.74	32.27	94.42	36.78

ENTER: (CR) CONTINUE, (1) EXIT, (2) NEXT ALTERNATIVE,
OR (3) REPORT OPT.

d

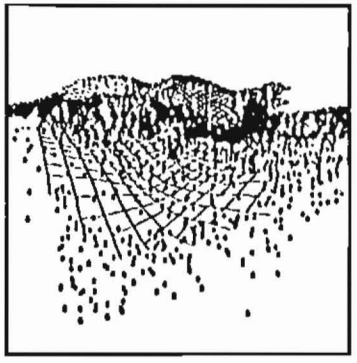

Figure 3. Examples of INFORMS output products: (a) summer rearing capacity bar chart showing effects of alternatives on chinook salmon, (b) map of Black Hawk Mountain project area showing MPB and proposed harvest blocks shaded, (c) winter carrying capacity table showing the effects of alternative 4 on rainbow steelhead, and (d) perspective view of project landscape after harvest.

Once in MOSS, the user can use all the features of the system.

Tabular Component. Functionally, the tabular component is similar to the spatial component; however, the structure and the source of the data are different. Tabular data such as timber inventory data and economic data are retrieved from databases (locally or remotely located) and manipulated or altered to meet model input or product output requirements.

INFORMS On The Nezperce National Forest

The Nezperce National Forest was specifically suited as a test site for INFORMS. Forest managers used spatial data, tabular data, and models independently to support their decisionmaking process. Also, the Nezperce is exemplary in terms of complex management problems. More than half of the forest's 1.9 million acres are available for commercial harvest. It is heavily used by recreationists. There are large herds of elk, *Cervus canadensis*, and mule deer, *Odocoileus hemionus*, and an increasing population of moose, *Alces alces*. In addition, it has two wilderness areas, and, on the Red River District (the study area) there is an impending outbreak of mountain pine beetle (MPB), *Dendroctonus ponderosae*, which threatens the reintroduction of anadromous fish into the Red River.

Successfully reintroducing anadromous fish into the Red River is an overriding management objective for the Forest. Formerly abundant throughout the rivers of Idaho, chinook salmon, *Oncorhynchus tshawytscha*, and steelhead trout, *Salmo gairdneri*, were severely reduced by dam building on the Columbia River. Today, the U.S. Forest Service is trying to reestablish these fish into historically used drainages such as the Red River. Salmon spawning habitat is very sensitive, thus every action that creates sediment or effects stream cover must be carefully analyzed--a complex and time-consuming process. For each proposed action, such as locating where to harvest 1.9 million acres of commercial timber, a multi-resource team of specialists must retrieve tabular data from various databases, hand draw and measure areas and distances from numerous layers of map data, and feed these spatial and tabular data into models that predict or simulate environmental consequences. The entire process can take weeks or months for each action and must be repeated if alternatives are considered.

System Configuration. For this application, INFORMS was designed and structured for general forest-management decision support, with specific modification for the MPB and anadromous fish problems. INFORMS on the Nezperce integrates the following: a multi-resource database, a spatial database (32 themes covering 20 1:24,000 U.S.G.S. base maps), and eight models (Figure 4).

INFORMS resides on a Data General MV series minicomputer at the Red River District office. A high-resolution graphics terminal is used to take advantage of all INFORMS functions. A version of INFORMS was loaded onto the

Forest's computer in 1987 where system evaluation and refinement have been a continuing process.

PROGNOSIS (Wykoff et al. 1982)	-	simulates the size, structure, and yield of northern Idaho forest stands over time.
NEZSED (Cline et al. 1981)	-	computes the amount of sediment delivered to critical stream reaches caused by fire, logging and road construction.
FISH (Stowell et al. 1983)	-	simulates the response of salmonid populations to changes in sediment loading in streams.
ELK (Leege 1984)	-	predicts the effects of road construction on elk use in northern Idaho.
COVER (Moeur 1985)	-	projects the growth and structure of wildlife cover over time.
CONTAGION (Hamilton 1985)	-	predicts the geographic spread of MPB over time.
DLOGPRICE (Artley et al. 1987)	-	evaluates the economic viability of proposed timber sales.
VISUAL (Daniel and Itami 1988)	-	computes the visual sensitivity of an area and visually displays projected changes to the landscape.

Figure 4. Models in INFORMS for the Nezperce National Forest application.

Figure 5 displays a generalized interactive dialogue between INFORMS and a user. In this example all models except Elk and Cover are used. First the project area is interactively defined by the user. The MPB model generates a map of the areas of predicted MPB spread, which is used as a guide for locating harvest units. Alternatives are created by varying the logging methods, spatial arrangement and timing for harvest, and the location and design specification for proposed roads. After the temporal scope is set, the models are run for these alternatives and the results reported to the user. Figure 3 shows some typical outputs from INFORMS. These products are identical to those produced by the independent systems integrated in INFORMS.

SUMMARY/CONCLUSIONS

By integrating models that simulate ecosystem responses to proposed actions, managers are able to gain a better understanding of the interrelations of the resources they manage. A synergy was noted using INFORMS whereby complex ecosystem interrelations were more realistically simulated through information system integration than through independent system use. Thus, the forest is more easily understood as an integrated ecological system rather than a mixture of separate, unrelated resources.

Models of natural resource phenomena are based largely on geographic parameters and relations. Data collection and input for executing these models independently over

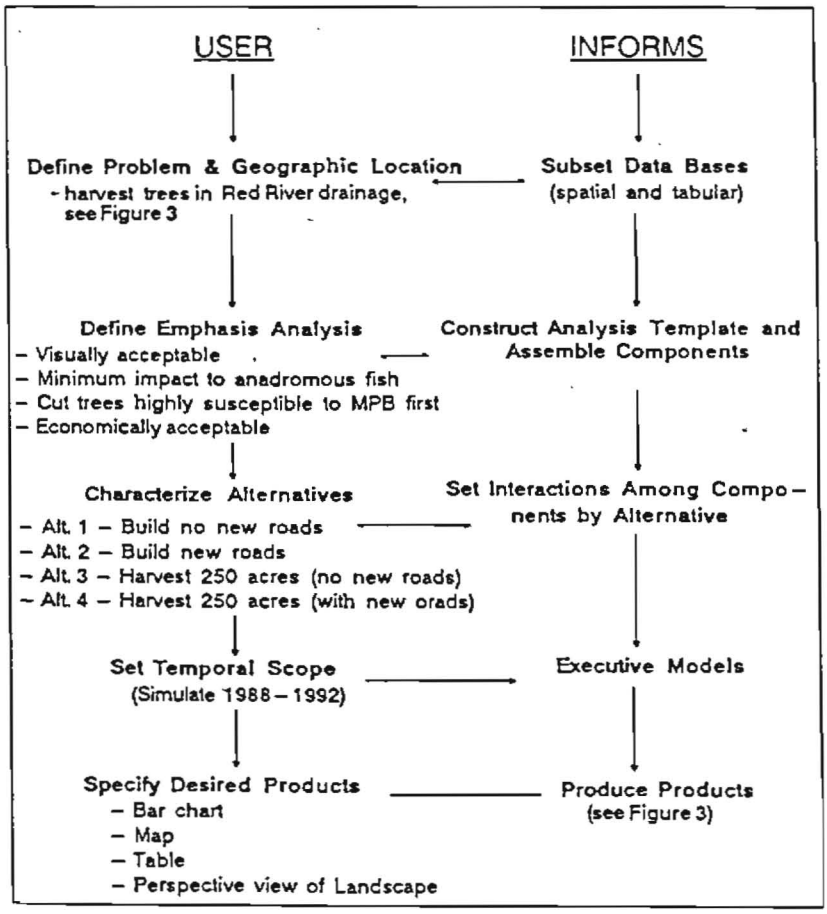

Figure 5. Generalized example showing the interaction between a user and INFORMS.

numerous alternatives is tedious and time consuming. Systems that automatically integrate spatial and tabular data with a library of models within an interactive shell can be cost efficient, more informative, and require minimal training.

The use of INFORMS on the Nezperce National Forest demonstrates that complex natural resource problems can be resolved easily and efficiently using an integrated approach to information technology. For more than a year INFORMS has been used in place of manual methods previously used. When compared to previously used "hand" methods, INFORMS was more effective, easier to use, required less

staff time, and was more flexible for aiding in a variety of problem-solving scenarios. Decisions could be reached three to four times faster (Bruce Short, personal communication), and with the increased speed and repeatability of environmental analyses, managers could "fine tune" their decisionmaking. The Nezperce prototype of INFORMS successfully demonstrated the viability of adapting new information technology to NRM and highlighted

integration as a precept of future NRM information management systems.

It further demonstrated that natural resources can be better understood and more efficiently managed by using integrated information technology. This technology, however, is rapidly changing as is the nature and scope of natural resource management; therefore, the development and calibration of systems such as INFORMS must evolve and adapt to changing needs and have the ability to take advantage of technology innovation.

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GIS AT THE CHARLES M. RUSSELL NATIONAL WILDLIFE REFUGE

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At the direction of Director Frank Dunkle, the Charles M. Russell National Wildlife Refuge (CMR) began a three-year evaluation of Geographical Information Systems (GIS) in 1987. Today, CMR is a strong supporter of GIS. The road between initiating GIS and the current enthusiasm for GIS has been rough. This paper describes CMR's GIS, applications, and problems. Those contemplating the GIS world will hopefully find these comments useful and enlightening.

CMR began as the 1.1 million acre Fort Peck Game Range in 1936. Grazing and wildlife management was administered jointly by the Bureau of Land Management (BLM) and Fish and Wildlife Service (FWS), respectively. Joint management proved unproductive and in 1976, full management authority was transferred to FWS. An Environmental Impact Statement was completed in 1985 and a Record of Decision handed down in 1986 stipulating a 33 percent reduction in livestock grazing. Grazing impacts on wildlife were to be monitored for future re-evaluation. Refuge managers are concentrating on habitat management plans, administering the grazing program, and monitoring wildlife habitat and populations.

CMR's GIS consists of MOSS software on a Prime 2450 mini-computer accessed through a combination of terminals and personal computers. MOSS has severe limitations, therefore we are contemplating purchase of ARC/INFO. The National Ecology Research Center (NERC) arranged for a free trial of PC ARC/INFO at CMR and we have been impressed with its capabilities. The initial GIS evaluation involved Data General computers and a scaled-down, sample database. CMR realizes the utility of GIS hopes to complete data entry for almost three dozen data themes, covering the entire refuge, this summer. Source maps and photos were prepared by refuge staff and forwarded to NERC for quadrangle drafting/transfer, digitizing, and database construction. GIS data themes in CMR's database are listed below.

1. Refuge Boundary
2. County Boundaries
3. Public Land Survey
4. Habitat Unit Boundaries
5. Pasture Boundaries
6. Unallocated (non-grazed) Areas
7. Land Ownership
8. Fences and Natural Barriers
9. Livestock Exclosures
10. Roads
11. Recreation Sites
12. Streams
13. Water Features (Wells, Springs, Ponds)
14. High Water Line on Ft Peck Reservoir
15. Vegetative Cover
16. Conifer/Juniper from Quads
17. Archeological Sites
18. Cultural Sites
19. Proposed Wilderness Areas
20. Natural Areas
21. Range Condition Indices
22. Range Site Indices
23. Raptor Nest Locations
24. 1979 Prairie Dog Surveys
25. 1984 Prairie Dog Surveys
26. 1988 Prairie Dog Surveys
27. 1989 Prairie Dog Surveys
28. Black-Footed Ferret 7-K Rule
29. Sage Grouse Leks
30. Sharp-tailed Grouse Leks
31. Sharp-tailed Grouse Routes
32. Sharp-tailed Grouse Nests
33. Sharp-tailed Grouse Radio Locations (proposed)

GIS APPLICATIONS

The most useful GIS products have not been elegant maps, tables, and reports, but rather mind stimuli. GIS provided a catalyst to spark innovative thought, a vehicle to highlight resource data voids and to establish current resource quality, highlighting areas for improvement. GIS products created at CMR are varied in complexity and field of application. Samples involving sharp-tailed grouse management, big game and road management, and field maps were presented to the Regional Director in August 1989. Many other applications have been generated and are described below.

1. Black-footed ferret recovery and prairie dogs: Black-footed ferrets are an endangered species once inhabiting prairie dog towns. Prairie dogs and their unique habitat alterations are the source of highly emotional and political battles over natural resource management. Portions of Phillips County, Montana (about 3/4 million acres), on and off CMR, are being considered for black-footed ferret reintroduction. GIS provided composite maps and acreages for management discussions. The issue is on-going, heavily involved with the BLM's Resource Management Planning effort. GIS will continue to play an important role in reintroduction planning and after ferrets are released.

2. Prairie dog management: CMR is compiling a prairie dog management plan. GIS is providing the necessary maps and acreages for prairie dog town expansion and contraction estimations over time, and for assessing the importance of habitat and prey for many secondary wildlife species. GIS is being used to illustrate distribution of burrowing owls, mountain plovers, raptors, upland sandpipers, and other species. Reintroduction of swift fox may occur and GIS would be heavily utilized in that effort.

3. Prairie dog research: CMR is cooperating with BLM and Yale University on a PhD prairie dog ecology research study in Phillips County. This study focuses on component interactions related to endangered species recovery using black-footed ferrets as a case study. The graduate student will study the influences of soil, slope, aspect, topography, vegetation, a BLM sponsored prairie dog shooting program, roads, livestock water development, grazing, public attitude, endangered species ramifications, etc. on prairie dog ecology and management. CMR's GIS is an integral part of this research.

4. Sharp-tailed grouse and grazing management: Maintenance and improvement of native sharp-tailed grouse habitats and populations are primary CMR goals. The major impact to sharp-tailed grouse on CMR is, and has been, domestic livestock grazing. Refuge managers are working to minimize grazing impacts. GIS illustrated grazing impacts on grouse habitat in one 51,000 acre habitat unit. The dramatic, cumulative effects of grazing, as graphically illustrated with GIS, surprised many of us. Upwards of 95 percent of potential sharp-tailed grouse habitat is degraded by cattle in this habitat unit. It was gratifying to have the GIS model substantiated with empirical data such as the known locations of leks and probable nesting areas.

5. Sharp-tailed grouse research: CMR funded two Master's degree research studies on sharp-tailed grouse ecology. GIS was used for nesting, brood-rearing, and wintering habitat selection analyses. Additional analyses are planned when field work is completed and when additional digitized data becomes available.

6. Sharp-tailed Grouse surveys: At the suggestion of a Montana State University professor, CMR initiated a concentrated effort to survey large portions of the refuge to assess sharp-tailed grouse abundance and distribution. The survey consisted of road routes where an observer listened for displaying grouse on dancing grounds at one-mile intervals. Each listening stop was entered into GIS via manually derived UTM coordinates. This effort sampled almost 500 square miles and established an index of grouse abundance and distribution. This effort was continued in 1990 and we are tabulating and digitizing the results for comparison. This survey will provide long term trends for grouse populations needed for management evaluation.

7. Big game, hunting, and road management: Deer and elk hunting is a popular activity on CMR. The refuge is well roaded and access is provided to large portions of elk and deer security cover. Part of CMR's mission is to manage for big game populations near carrying capacity, provide recreation opportunities superior to those offered elsewhere, and to minimize the mechanical aspects of sport hunting. The impacts of roads in one 51,000 acre habitat unit were illustrated with GIS and revealed a surprising 50 percent of the security cover was within one-half mile of a road. Research demonstrates elk avoid areas within one mile of roads during hunting seasons, especially in open habitats. Alternatives were developed with GIS to increase security habitat availability, and still provide public access.

8. Elk and livestock grazing: Cattle tend to congregate near water sources and elk typically avoid cattle. Cattle displacement of elk includes physical habitat degradation, forage removal, and temporal displacement. GIS illustrated habitat degradation around water sources due to livestock grazing on up to 40 percent of the habitat in a 51,000 acre habitat unit.

9. Mineral withdrawal: CMR is currently filing for a permanent mineral withdrawal to replace the temporary withdrawal expiring in 1991. An overlay map, hand-drawn on GIS-produced base maps, was developed for use in this process and for public meetings. The mineral withdrawal area was digitized and coupled with land ownership information to yield various acreage breakdowns based on ownership. GIS quickly provided comparison acreage figures and highlighted inconsistencies. Significant errors in the filing for mineral withdrawal would have occurred without GIS. The GIS maps will be helpful at up-coming public meetings.

10. Cattle movements and distribution: The refuge proposed building a livestock exclosure in a critical riparian area. The permittee opposed the exclosure construction because he felt it would impede cattle movement. FWS decided refuge personnel would monitor cattle movements for several grazing seasons, prior to and after construction of the exclosure.

If the exclosure significantly impeded livestock movement, it would be removed. GIS is being used to compile, analyze, and illustrate this monitoring effort. Factors involved include; temperature, water distribution, riparian area distribution, time of day, and time of year. Each of these factors and a variety of combinations as they influence cattle movements are being illustrated with GIS.

11. Vegetative cover classification and livestock grazing impact measurement with LandSat: In cooperation with NERC and the BLM, we contracted with Colorado State University (CSU) to classify two LandSat Thematic Mapper scenes into vegetative cover classes. A graduate student is conducting the work and both CSU and NERC are providing the hardware, software, training, conversions, and expertise. This project is scheduled for completion in early 1991. The result will be an objectively measured vegetation cover map in digital form with a 28.5 meter pixel size. To date, CMR has relied on a rudimentary vegetation classification that is virtually useless because of broad categories, arbitrary delineations, and reliance on non-digitized, 12 year-old photos. The availability of basic vegetation data is of paramount importance to habitat management.

    The most exciting aspect of this LandSat project is the possibility of direct measurement of grazing impacts. Differences in vegetation classes between heavily and lightly grazed areas were noticed while developing the classification. The potential exists for direct grazing intensity measurement over every acre, within a grazing season, and over several years. We will be examining possibilities this summer.

    Cost has been very economical. The data (May 1988 version) cost $7,200 and CMR contributed $3,000 to the graduate student's stipend. The BLM contributed another $3,000 and NERC contributed $2,500 and invaluable logistical support. The total was $15,700. As a comparison, the estimated cost for transferring and digitizing the old, essentially useless vegetation data for about one-third the area covered by LandSat was $26,000.

12. Research Natural Areas and cultural/archeological sites: CMR has several Research Natural Areas and several others are proposed. A presentation was given to the Montana Chapter of the Wildlife Society on Natural Area status. GIS provided the base maps for the presentation. Cultural and Archeological sites are important to CMR's history. The availability of GIS provided the impetus to organize and consolidate the location of these areas, which were then manually digitized by UTM estimation at CMR. The locations of these areas were incorporated into the mineral withdrawal proposal using GIS.

13. Wetland and waterfowl management: BLM purchased Duck's Unlimited wetland data for the hi-line area of Montana and is working on conversions to make it accessible in GIS. CMR plans to utilize that data for FWS waterfowl enhancement projects. Montana has an active Farm Bill and Wildlife Extension program to improve waterfowl resources on private land. GIS will be used to plan projects, track completed projects, and to monitor success.

14. Field map production: When digitizing and verification are completed this summer, GIS will be used to produce field maps with a variety of features drawn on 7.5 minute topographic quadrangles. Keeping track of roads, fences, water developments, recreation areas, key wildlife locations, etc. on a 1.1 million acre refuge is a major chore. Accurate, customized, and replaceable maps will help immensely.

15. Historical records and organization: GIS and computers provided the tools for organizing existing data and has highlighted many data needs. Scattered data was available, but was unorganized, in cumbersome media, or otherwise virtually unused. Organizing, verifying, and culling existing data has helped refuge management. During that process, weaknesses became obvious and we are attempting to rectify them. As a defacto library function, GIS is actively serving to maintain information in an organized, tractable, retrievable, and useable form. This function alone is one of the greatest GIS assets we have realized and it will become more and more apparent as time goes by.

EXPERIENCES IN GIS IMPLEMENTATION

Be prepared to spend time, money, and manpower. GIS does not happen overnight and a successful system requires teamwork, dedication, patience, money, and an immense amount of work. Refuge staff were apprehensive about GIS when instructed to evaluate it. Their reservations were understandable. New technology or change is often avoided and staff time seemed taxed to the limit. The last thing anybody wanted was the addition of yet another priority one program. The GIS evaluation proposal from the Washington Office came with special appropriations, hence CMR was launched into GIS.

The initial stages involved stumbling, miscommunications, ignorance, and frustration. GIS was initially an unfavorable program. The potential of GIS was not understood until paper products emerged. It has taken three years, but most of the problems have been solved. The utility of GIS has been realized, and CMR is looking forward to its continued use and support. With GIS assistance and sound biological data, political battles concerning natural resource management can be more effectively argued.

One of the most time-consuming stumbling blocks was procurement of computer hardware. Our Contracting and General Services department followed the manual and handled ordering and dealings with vendors. As is the Government's way, we received "low bid", often faulty equipment, frequently incompatible with other equipment, and not meeting specifications. Some vendors willingly cooperated in reaching resolutions, but others did not. Company reputation, its relation to industry standards, attention to details, service history, and expertise evidently did not enter into government computer equipment procurement. With the wide variety and quality of components eventually received, CMR's computer system quickly became akin to assembling a vehicle with used parts from a Ford motor, a Chevy transmission, a Dodge chassis, and Japanese wiring.

Given time and persistence, our hodgepodge of equipment was melded into a functional system. It was frustrating and required a great deal of effort involving time, trials, and errors. It was a learning process, worth experiencing in the long run, but we would not want to repeat. Today's computer procurement procedures are better and requesting advice from people with actual experience is strongly encouraged. Time spent planning and designing a system and understanding the procedures and red tape will pay big dividends.

The class of computer hardware to purchase for GIS is an often asked question. My general advice is to purchase the most powerful, largest storage capacity, up-to-date system affordable. Computer technology is changing at a rapid rate. When the bureaucratic red tape is cut through (expect up to a year or more delay) and the system is received, it is no longer state-of-the-art. I have never heard any complaints about a computer system being too fast or having too much storage capacity, but complaints about slowness or space limitations are common. Talk to people using a variety of GIS systems for advice before making decisions.

The first steps in implementing GIS are to decide on required data and to prepare the source information. Procuring and installing the necessary hardware, training, and source material preparation will require a significant amount of time. Even more time and effort will be required for data entry, digitizing, database construction, and quality control. Utilizing field personnel in refuges for digitizing is <u>not</u> advised. Field expertise is better spent on information content and quality versus data entry. All of our digitizing was contracted to NERC and we have yet to detect an error not traceable to inaccuracies in the source materials we provided. Their work has been superb and more economical and timely than achievable locally.

The major drawback to contract digitizing is limited ability to update. We can handle minor updates and currently input point data ourselves. Our accuracy and precision is poor compared to NERC's consistently professional products. Larger updates require NERC's assistance. Now that the bulk of our digitizing is complete, we may gear up a small digitizing station to handle updates. Those contemplating building a GIS database should weigh the pros and cons of contract data entry and consider the level of effort required to (create), organize, verify, and enter the information.

Cost is a major factor in implementing a GIS. It is expensive. It is more expensive not to implement GIS in terms of manpower, time, and ability to pursue prudent management of natural resources. The up front costs of hardware, software, source materials, digitizing, additional salaries, and maintenance are most expensive. Maintenance contracts are a necessary evil and eventual upgrades must be expected. The magnitude of increased abilities to effectively and professionally manage resources in the near term begins to offset initial costs and in the long term, more than offsets the investment.

Time and expenses associated with GIS necessitate a long term commitment. Like a library, GIS and resource management capabilities improve as more information is entered. Basic resource data, in an easily accessible GIS, spawns better understanding of natural systems, effective management, and more

efficient use of limited resources. As stewards of natural resources we must attack our management responsibilities with the best information and technology available. To approach GIS lackadaisically, without a long term commitment, will result in a failing system, a waste of time, money, and manpower, and less effective resource management.

CMR's GIS costs are clouded with a parallel effort to administratively computerize refuges. Many of the computer and time expenditures are not related to GIS. Providing computers, peripherals, training, and time for word processing, electronic mail, budget tracking, property records, and other administrative functions required significant staff time and resources, irrespective of GIS. The following figures approximate costs for CMR's GIS over the last 3 years.

1.	Prime 2450 mini-computer and upgrades	$40,500
2.	386 personal computer	7,000
3.	Terminals	2,800
4.	Plotter	5,500
5.	Miscellaneous support equipment and peripherals	6,000
6.	Supplies	6,000
7.	Annual maintenance fee total ($10,000 per year)	30,000
8.	Software	800
9.	Digitizing and database construction	77,300
10.	NERC overhead, salaries, travel, supplies	66,900
11.	LandSat data and classification	10,200
12.	Salary	75,000
13.	Travel / training	7,500
Total		$335,500

Special funds from the Washington Office to implement GIS totaled $300,000; $150,000 in 1987, $50,000 in 1988, and $100,000 in 1989. The balance was absorbed by station funds. Items 9 and 10 above need clarification. When CMR started a GIS in 1987, $75,000 (of the $150,000) was transferred from the Washington Office to NERC, 58 percent of which was consumed in NERC staff salaries, travel, and supplies. At that time, CMR and the digitizing section of NERC had no control of those funds. Since 1988, a total of $69,200 has been transferred to NERC for CMR work and $23,400 (34 percent) has been charged to overhead. Overhead is part of doing business and today, we are satisfied NERC does their best to minimize those charges. There was potential to have produced more products in 1987.

A total of $144,200 was transferred to NERC for CMR digitizing and database construction, resulting in a paper to digital conversion cost of about 13 cents per acre for about 30 data themes (.4 cents per acre per theme). Costs vary based on number of themes, complexity, and geographic area covered. NERC has completed many digitizing and database construction projects and should be contacted for assistance in estimating data entry costs.

Because of poor planning in initial stages and other, now foreseeable, problems, the cost of 13 cents per acre could be reduced if we repeated the process. The LandSat vegetation classification (a detailed and complex theme) cost about .3 cents per acre (CMR's share cost about .2 cents per acre). Incorporating all CMR's start-up costs (hardware, salaries, travel, digitizing, LandSat data, etc.) results in an overall estimate of 30 cents per acre spread over three years.

Conversion of paper based data into digital format, be it Dbase, Lotus, or GIS, is an initial hurdle and the first conversion process. There will be other conversions. Software upgrades, changes in computers, switches among GIS packages, and data updates all necessitate conversions. Be prepared to spend time and effort on conversions.

Conversion problems compound themselves exponentially if the original digitizing and database construction was not well designed and/or of poor quality. The previous sentence cannot be overemphasized. As a database grows in size, so does the workload of converting from one system to another. Talking with experienced users and planning a detailed course will pay off.

Setting up GIS cannot be "another duty as assigned". Additional staff are necessary to implement a successful GIS. Once the decision to implement GIS has been made, and a definitive, well thought out plan for implementation is designed, the final two ingredients are long term commitments of funds and patience. It takes time for hardware procurement and installation, training, source material preparation, digitizing, conversions, etc. One should not expect buy a GIS, punch a button, and get a map. Managerial support and encouragement of GIS with a long term commitment will facilitate and quicken realization.

GIS utility has been demonstrated on CMR and we are committed to continued use of this management tool. Black-footed ferrets, sharp-tailed grouse, elk, several species dependent on prairie dog towns, and many other wildlife values on CMR are benefiting from GIS. We encourage Regional support of our efforts and inquiries from other stations considering GIS. GIS did not happen overnight and we envision steady growth in our GIS library. It takes teamwork, dedication, funding, and patience. **Bottom line, refuge resources will benefit and GIS has been a significant contributor.**

DUCK NUMBERS ESTIMATED FROM GROUND COUNTS, GIS DATA, AND AERIAL VIDEO

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ABSTRACT

We describe a system for estimating numbers of ponds, breeding ducks, and recruits produced in the Prairie Pothole Region of the United States. Results were classified by land ownership and local management district. Input data consisted of aerial video, digitized maps, ground counts of ducks, and published estimates of nest survival rate and habitat preference. GIS techniques were used to analyze image data and produce numeric output for input into previously developed models. Model output was processed by microcomputer to produce standardized tables and graphs. We present data from the first three years of use of the system by the U.S. Fish and Wildlife Service. Breeding populations and production were severely reduced by lack of ponds during drought conditions. Land under easement or owned by the Fish and Wildlife Service made an important contribution to duck production, but the majority of ducks were produced on private lands. The system is now in operational use in western Minnesota, the Dakotas and western Montana.

INTRODUCTION

Waterfowl management in North America is dependent on various surveys designed to estimate the amount of available habitat, breeding populations, and annual production. Current survey methods employ counts made from low-flying aircraft (Martin et al. 1979, U. S. Fish and Wildlife Service and Canadian Wildlife Service 1987). These surveys, though meeting their intended purpose of furnishing data required for setting annual hunting regulations, fail to meet some of the needs of managers responsible for local areas because the survey design was not intended to produce estimates for local areas. Furthermore, survey results are not broken out by land ownership class, which is of great importance for evaluating results obtained from management.

The lack of survey methodology for local areas resulted in development of various systems by waterfowl managers and tremendous variability in quality of data and survey results. Cowardin et al. (1989) described development of a system designed to overcome these problems. The objectives of the system were: (1) to develop cost-effective methods for obtaining estimates of habitat availability, breeding populations and production of key duck species on U. S. Fish and Wildlife Service (USFWS) refuges, waterfowl production areas (WPAs), easements, and adjacent private lands in the prairie pothole region; (2) to design an efficient automated system for processing of field data and reporting results; and, (3) to prepare guidelines for collection of data and use of the system for managers. Since publication of that paper, the system has been improved and modified.

The present paper briefly reviews the system, describes modifications and improvements to the system made since publication of the previous paper, and presents some of the results obtained. The system is now operational and is being used to obtain

estimates for west-central Minnesota, North and South Dakota east of the Missouri River, and the northeast corner of Montana. The system is administered from offices in Bismarck, North Dakota, and Fergus Falls, Minnesota.

METHODS

The system (Figure 1) combines various data sets and models to produce estimates of numbers of ponds (wetland basins containing water), breeding populations of ducks, and young produced for five species of dabbling ducks (mallard, Anas platyrhynchos; gadwall, Anas strepera; blue-winged teal, Anas discors; northern sboveler, Anas clypeata; and northern pintail, Anas acuta). All data except for nest survival rates were derived from 4-mi^2 plots, selected for a previous study where the data were used as input to a mallard productivity model (Cowardin et al. 1988).

The original sample of plots was stratified by land ownership class at the level of townships. Townships were selected at random, allocated to the strata, and finally plots were selected from the townships. For the present study, we modified the sample design. The sample universe was divided into Wetland Management Districts (WMDs) (Figure 2). We restratified the plots by dividing the entire universe into a digitized grid of 4-mi^2 plots and overlaying the grid on previously digitized (1:250,000) ownership maps. The overlay was accomplished in map overlay and statistical system (MOSS). The resulting estimates of ownership within plots were used to construct weights used to expand estimates of pond numbers, breeding ducks, and recruits produced to WMDs. Plots were allocated to the 4 strata by the following rules. (1) The refuge stratum included any plot that contained any refuge land regardless of other ownership within the plot. (2) The WPA stratum included any plot not classified as refuge and that included 1/4 section or more of WPA. (3) The easement stratum included any plot not classified as refuge or WPA that included 1/4-section or more of easement tract. (4) The private stratum included any plot not classified in the previous three strata. Easement lands included the entire easement tract, even though only the wetlands are actually under easement that protects them from being drained, filled, or leveled. In this analysis both WPAs and refuges are included in the class fee-title (owned in fee-title by the U. S. Government). Fee-title lands include both the wetlands and surrounding uplands.

Data Sets

Habitat on each plot was mapped from higb altitude National Aeronautics and Space Administration (1:65,000 color infrared) photographs. The data were digitized and converted to MOSS files. These files represented habitat conditions at the time of photography. We modified the files to account for implementation of the Conservation Reserve Program over much of the area and changes in the amount of planted cover on WPAs that occurred since the date of photography. Data for these changes were obtained from managers of the WMDs. The habitat data derived from the maps (contain estimates) of the total number of wetland basins and the area of wetland on each plot as well as the area and class of all upland nesting cover. Classification of habitat followed Cowardin et al. (1988).

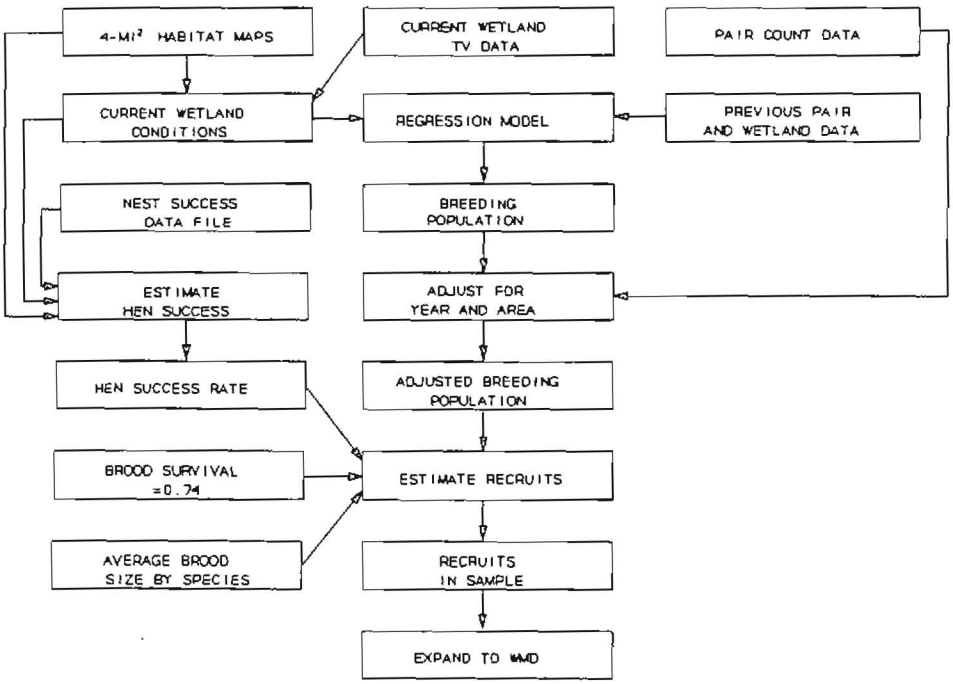

Figure 1. A system for estimating habitat conditions, duck populations, and duck production.

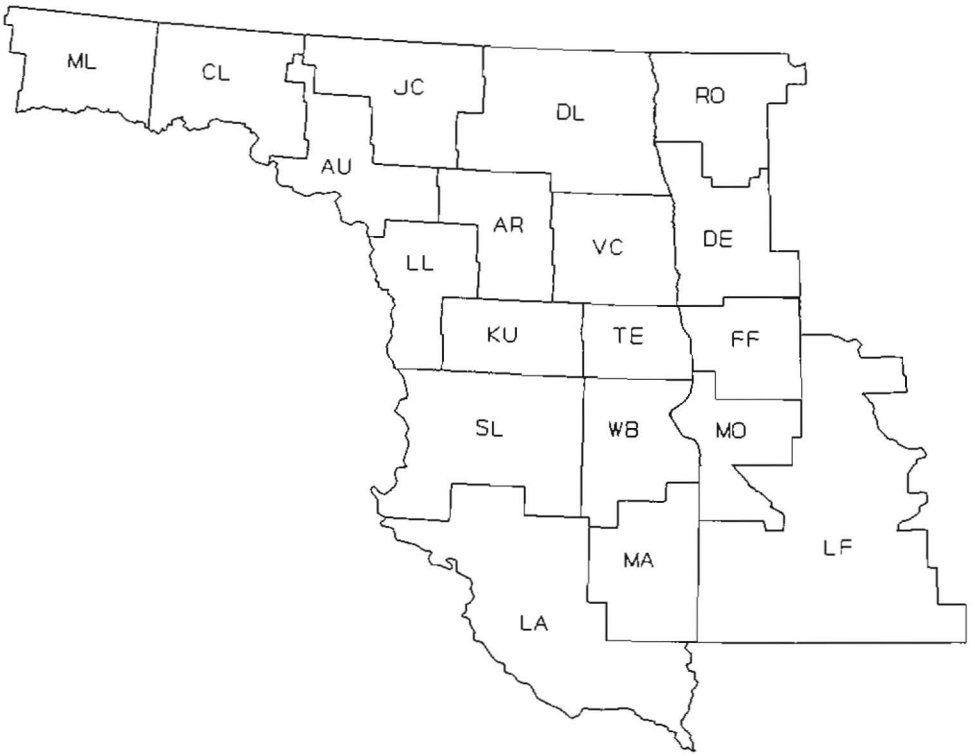

Figure 2. Wetland Management Districts in the Prairie Pothole Region of the Dakotas, Minnesota, and Montana.

The most important habitat data required by the system was the number and size of ponds present on the plots annually at the time that ducks arrived. These data were obtained from aerial video. Although lacking the resolution of photographs, aerial video has a number of advantages (Meisner 1985). It is cheaper than photography and the data are immediately available. Furthermore, the data can be captured by microcomputer without scanning. Our video system was essentially the same as the system described by Sidle and Ziewitz (1990). The main difference between our video methods and theirs was that we used a short (5.9 mm) lens and flew at an altitude of about 12,000 feet AGL to cover a 2-mi wide plot and allow for navigational error.

We also required ground counts of ducks for adjustment of regression models described below. Early (May 1-19) and late (May 20 - June 10) counts were made on about 200 wetland basins on each wetland management district. Ducks were recorded by social groups such as lone males, pairs, and flocks. Estimated breeding pairs were derived from these groups by the methods explained by Dzubin (1969) and Hammond (1969). No corrections for unbalanced sex ratios were made.

Estimates for the number of recruits produced from each area required estimates of nest success for each habitat class. It is impractical to obtain annual estimates of nest success because of the large samples required and the cost involved. We used data obtained from more than 15,000 nest records on file at Northern Prairie Wildlife Research Center. These data represented average conditions over broad geographic areas. These data and the analysis conducted by Klett et al. (1988) furnished the daily nest survival rates by habitat and region used in the present study. We used their estimates for the 1980-1984 period.

Models

The system is based on the assumption that there is a relation between the amount and type of habitat on an area and the number of ducks that settle there and on their subsequent production of young. Johnson and Grier (1988) reviewed this assumption from the perspective of continental populations. We developed a set of baseline regression equations like those presented by Cowardin et al. (1983) except that pond classes were pooled rather than constructing separate regressions for each pond class (Figure 3). Data for building these regressions were gathered at the Arrowwood WMD (1982-84) in North Dakota. We made the assumption that the form of these regressions remains the same from year to year and area to area but that the density of birds on ponds of the same size will vary. The regressions were adjusted for year and area by using data obtained from the annual pair counts. For example, the actual counts for the Valley City WMD and the baseline regression (Arrowwood WMD 1982-84) derived for mallard pairs are shown in Figure 4. The actual count for each pond in the ground sample was regressed on the prediction from the regression equations and a line was fitted (Figure 5). The slope of the line (γ = 1.46 in the example) was used to adjust the counts for annual and geographic variation.

We used γ as an index to differences in duck density relative to the baseline regressions. To estimate the breeding population on a plot, the baseline regression was used to predict the number of birds on a pond based on its size as determined from the aerial video. Estimates for all ponds were then summed by ownership class for all ponds on the plot and the result was adjusted for annual and area variation by multiplying by γ. Results for the plots in a WMD were then weighted to account for different rates among ownership classes and the

results were expanded to arrive at an estimate for each WMD.

To calculate the number of recruits produced, we used a deterministic version of the model reported by Johnson et al. (1987). Habitat availability estimates required by the model came from the MOSS data sets for each plot. Habitat preference values were taken from Klett et al. (1988). Lacking adequate data for varying brood survival rate and brood size, we used the same constants reported by Cowardin et al. (1988). A deterministic model from Cowardin and Johnson (1979) estimated hen success as $H = \alpha P e^{\alpha(1-P)^2}$ where H is hen success, α is and index to nesting intensity, and P is nest success. We used data from radio-marked birds (Cowardin et al. 1985) to construct a regression of α on percent of basins containing water. The number of basins was determined from the base maps and number of basins containing water was determined from the aerial video. The percent of basins containing water was then entered into the regression to estimate α for each year.

Data Processing

Implementation of the system described here would not have been possible without recently developed computer aided techniques. We used PC-SAS (SAS Institute, Inc. 1988) procedures for analysis of data and the map and image processing system (MIPS, Miller et al. 1990) procedures for capture, analysis, and preparation of data sets from image and map data. The MIPS software had the advantage of processing either vector or raster data in the same system.

The video data were captured in digital form by means of an image grabbing board (Targa 16) in a microcomputer and stored on optical disk. The FEATUREMAP procedure in MIPS then allowed the following steps: (1) Select data for the 4-mi^2 plot from the entire video scene. (2) Classify wet areas by means of automated and photo interpretive techniques. (3) Register vector data imported from the MOSS files for each plot. (4) produce a text file with one record for each pond. The text file contained the size and location of each wet area derived from the video data and various attributes including the wetland class and polygon identifier from the MOSS files. These data were used as input to SAS routines designed to estimate the expected number of pairs on each pond, combine the estimates by plot and later, to extrapolate the data to WMDs, states, and the prairie pothole region.

The duck count data were entered directly into SAS data sets by means of custom software that checked for error conditions and permitted easy correction and editing of the data. In addition, SAS routines were used to calculate the number of estimated breeding pairs from the social groups recorded in the field. Past experience had shown that in-field calculations of estimated breeding pairs can lead to errors and inconsistencies because the rules for determining estimated breeding pairs are complex (Hammond 1969). Inclusion of these in an algorithm executed at the time of data entry helped avoid these problems.

We designed custom SAS routines to integrate the various input data sets, execute the regression and production models for each plot, and expand the projections from the plots to the entire WMDs. Finally, other routines were developed for outputing the results in standardized tables of statistics. These routines calculate a variety of estimates used by biologists to evaluate results of surveys. For each species, ownership class, WMD, and state combination we calculated: (1) total area, (2) area wet, (3) number of ponds (4) number of ponds per square mile, (5) area wet per pond (equivalent to

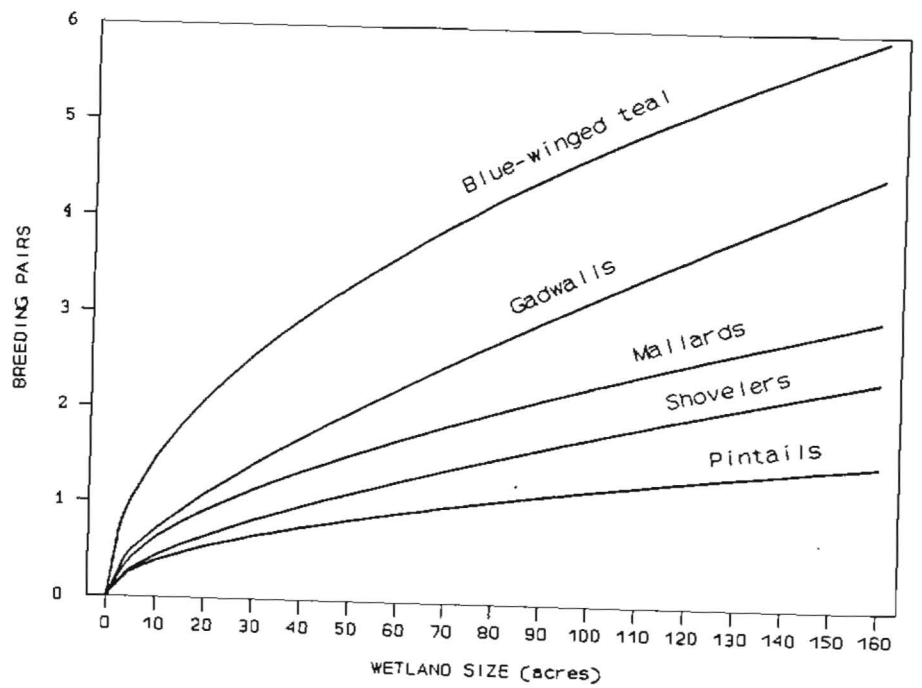

Figure 3. Regression equations relating breeding duck numbers of five species of dabbling ducks to wetland size.

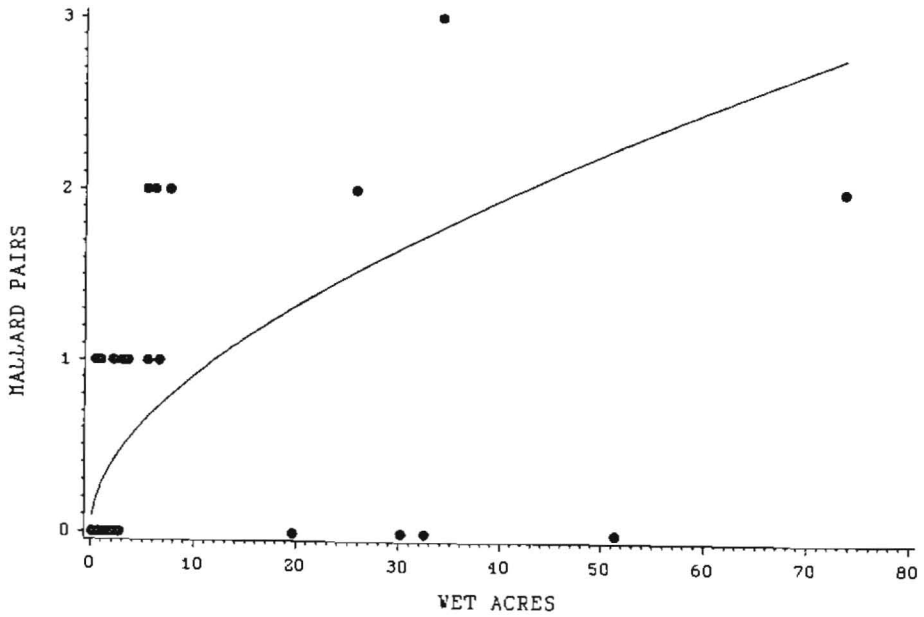

Figure 4. Counts of breeding mallard pairs on ponds in the Valley City District, North Dakota (1989), in relation to a regression based on large samples gathered at Arrowwood Wetland Management District (1982-84).

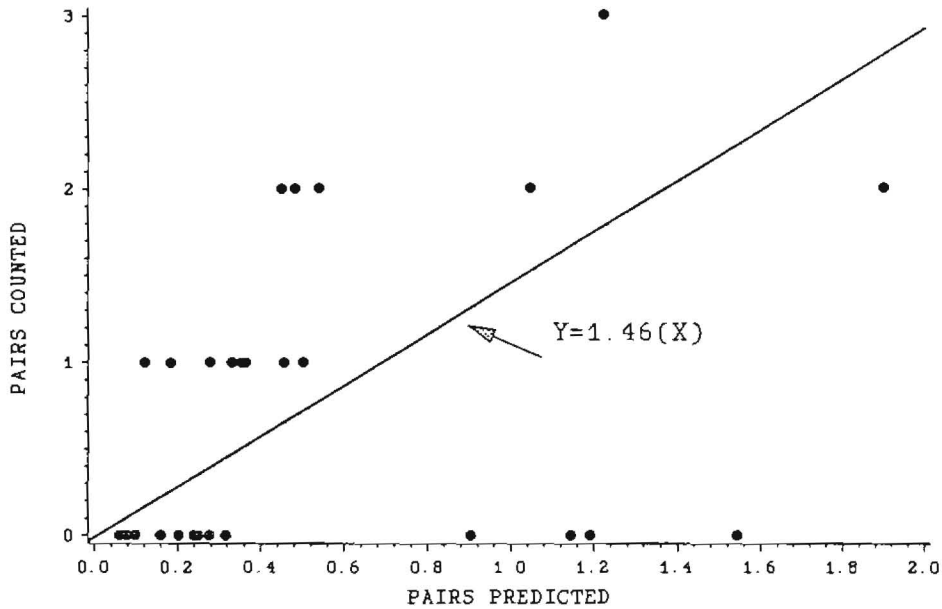

Figure 5. Actual counts of pairs on the Valley City District, North Dakota, plotted against pairs predicted from the regression in Figure 4. The slope of the line was used to adjusted counts for area and yearly variation.

average pond size), (6) number of breeding pairs for each species, (7) pairs per square mile, (8) pairs per wet area (equivalent to density of pairs on wet areas), (9) pairs per wet pond, (10) recruits produced, and (11) recruits produced per square mile. Because the amount of data contained in these tables is somewhat overpowering, we also presented the information in histograms and maps designed to easily compare results between previous years and among the WMDs region.

RESULTS AND DISCUSSION

A complete presentation of results obtained during the first three years that the system was used is beyond the scope of this paper. Instead, we highlight some of the results that illustrate the types of information produced annually by the system, evaluate progress toward project objectives, and review the importance of some of the findings to managers.

Results obtained from the 1989 surveys illustrate the difference in wetland habitat by ownership class (Table 1). The data in Table 1 represent ponds present in 1989, a dry year, not the entire wetland base. Pond density was similar on both easement and fee-title lands and was about twice that of private lands. In 1987, the wettest year represented by our data, pond densities were 20.3 and 12.0 ponds/mi^2 for easement and fee-title lands, respectively. This inconsistency can be explained by a difference in permanence between ponds in the two ownership classes. First, many of the refuges contain large lakes. These more permanent wetlands are often not as valuable to waterfowl as the temporary and seasonal wetlands but they will attract large numbers of ducks during drought conditions. Second, both easement and fee-title lands were intentionally purchased for wetland protection, and therefore generally had greater wetland densities than private lands. Finally, there has been a continuing loss of wetlands on private lands. The difference in pond density was greatest in Minnesota where loss of wetlands to drainage has been more extreme than in the Dakotas and Montana.

There is a marked difference in average pond size between the ownership classes. The largest ponds were on fee-title land because of the large impoundments and lakes on many of the refuges. Pond size was smallest on easement land but similar to that for private land. The slightly larger size of ponds on private land than on easements was because small wetlands on private land are easily drained and large lakes and reservoirs are often included in the private stratum but not in the easement stratum.

Pair density data for 1987 and 1988 are used to illustrate relative abundance of the species surveyed and the effect of drought on breeding populations (Figure 6). The blue-winged teal was the most abundant of the species surveyed followed by the mallard and gadwall.

Water conditions in 1987 were below average to average on some WMDs. In 1988 severe drought hit the prairie pothole region, and breeding populations of all species declined to about half their abundance in 1987. The remaining population was crowded into the few remaining ponds resulting in an increase in pairs per pond in most species from 1987 to 1988 (Figure 7). The decrease in breeding population combined with the decreased probability of renesting resulted in a drastic drop in the number of recruits produced (Figure 8).

The drought conditions and resultant drop in breeding population occurred in all districts except one in southwestern Minnesota (Figure 9). We

Table 1. Amount of ownership compared to pond density by ownership class in 1989 for the Prairie Pothole Region of the United States.

Ownership	% of area	Ponds/mi^2	Mean size (ac)
Easement	9.4	11.5	3.1
Fee-title	1.0	11.8	16.5
Private	89.7	5.5	5.3

suspect that the apparent increase in breeding pairs for that district may be an artifact of the interpretation of breeding pairs. The district contained a large number of large lakes. Birds that were counted there may have been transients as well as birds that would not breed. In drought years these birds may congregate on large lakes and it is difficult to distinguish them from potential breeders.

The increase in breeding population that occurred in 1989 was spatially variable. Recovery was good in the far west and the eastern part of the region, but in central North Dakota water conditions continued to deteriorate (Figure 10).

The results have important implications for waterfowl managers. The fee-title land represents a small percentage of the total land surface but produces a disproportionately high percentage of the ducks (Table 2). This difference was dramatic in Minnesota (Table 3). We suspect that differences among ownership strata can be explained by the greater abundance of wetland on the fee-title lands, especially in Minnesota where loss of wetlands to drainage has been more severe than in the Dakotas and Montana. The data also show the importance of easement tracts throughout the Prairie Pothole Region even in Minnesota where there are few easement tracts. Pairs attracted to wetlands on these tracts are making an important contribution to production. Lastly, the data clearly demonstrate that the majority of the pairs and the ducks produced come from private land. Habitat on these lands must be preserved and enhanced in order to meet duck production goals.

CONCLUSIONS AND OUTLOOK

The system has not been operational long enough for a thorough evaluation of its potential, but in some respects it has already met the objectives. Habitat, population, and production estimates for land ownership classes and WMDs are being produced in a consistent and objective manner. It is now possible to make comparisons among land ownership classes and areas. Such comparisons were previously not possible because of lack of data and inconsistency of methods. The system uses automated procedures from entry of the field data to production of annual reports. We are continuing to work on front-end

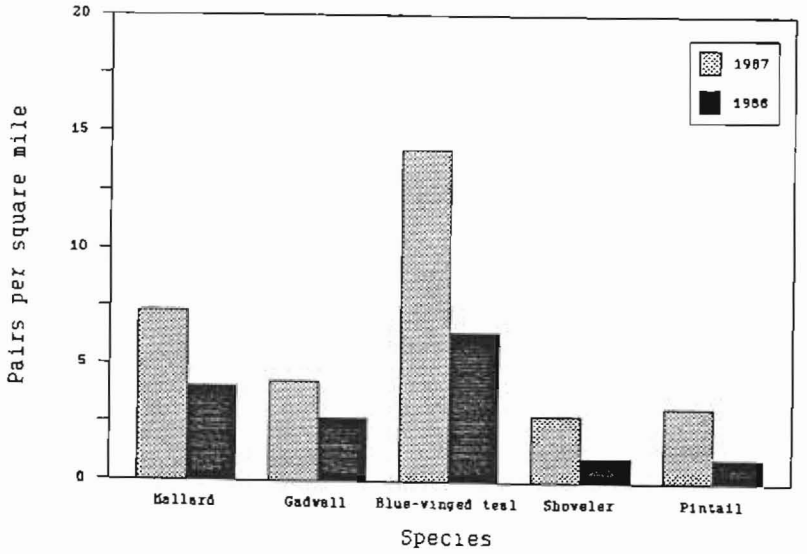

Figure 6. Breeding pairs of five species of dabbling ducks per mi^2 in the Prairie Pothole Region from 1987 to 1988.

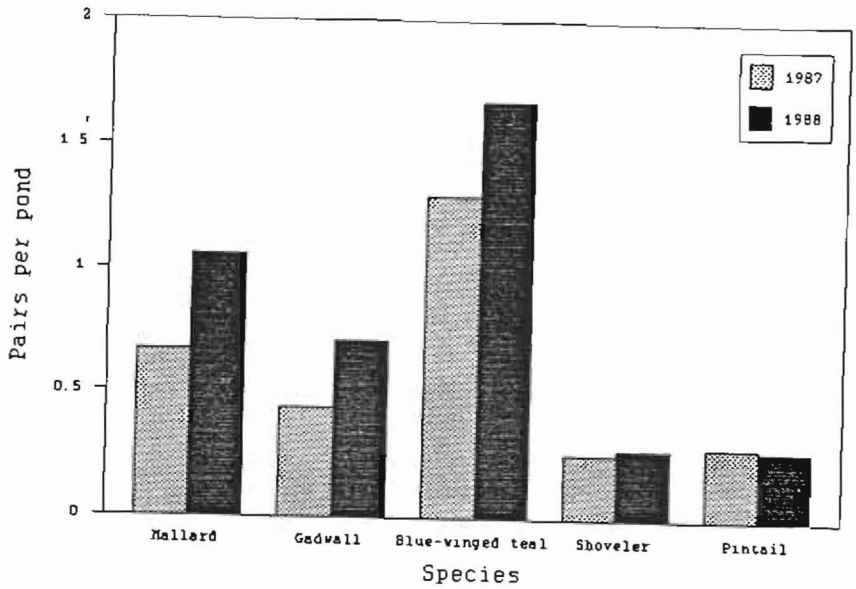

Figure 7. Breeding pairs of five species of dabbling ducks per pond in the Prairie Pothole Region from 1987 to 1988.

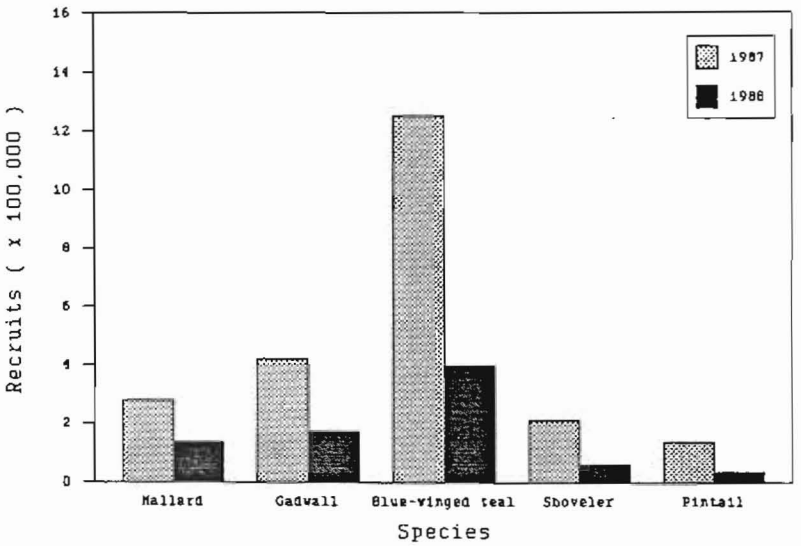

Figure 8. Recruits produced for five species of dabbling ducks in the Prairie Pothole Region from 1987 to 1988.

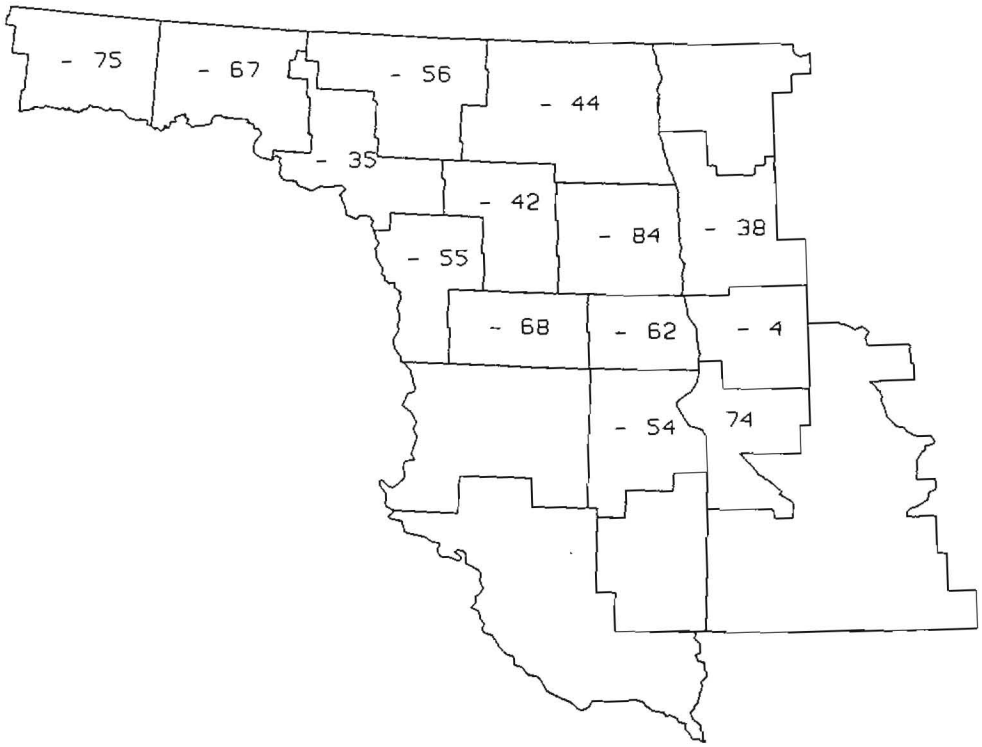

Figure 9. Aerial distribution of change in breeding pairs of five species of dabbling ducks from 1987 to 1988.

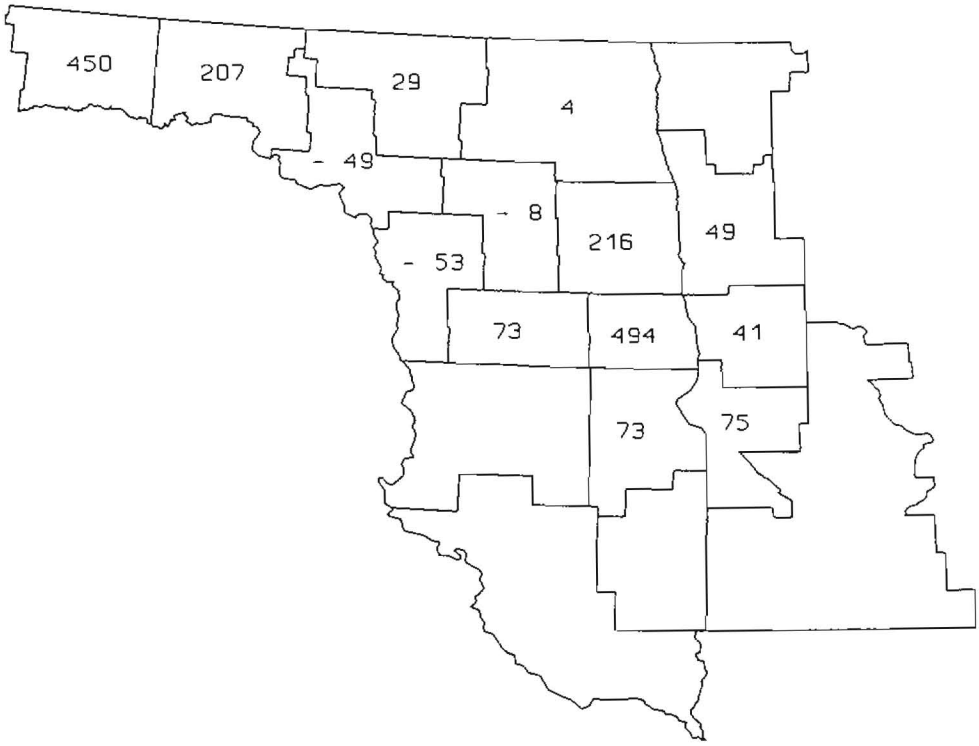

Figure 10. Areal distribution of change in breeding pairs of five species of dabbling ducks from 1988 to 1989.

Table 2. Comparison of area in ownership classes and total ducks produced by ownership class in Minnesota, Montana, North Dakota, and South Dakota.

Ownership	% of area		% of recruits		
	1987-88	1989	1987	1988	1989
Easement	11.6	9.4	21.9	19.5	18.4
Fee-title	1.3	1.0	3.2	4.4	3.2
Private	87.1	89.7	74.9	76.2	78.4

Table 3. Comparison of area in ownership classes and total ducks produced by ownership class in Minnesota.

Ownership	% of area		% of recruits		
	1987-88	1989	1987	1988	1989
Easement	1.9	0.8	4.9	4.5	3.8
Fee-title	1.7	1.0	11.7	12.5	9.3
Private	96.4	98.1	83.3	83.0	86.9

programs that will simplify procedures and add additional safeguards against entry of erroneous data and corruption of existing data files.

The habitat offices at Fergus Falls, MN and Bismarck, ND are continuing to evaluate results obtained from the system, make procedural improvements, and recommend where the base sample of 4-mi^2 plot should be increased. In addition these offices, in cooperation with Northern Prairie Wildlife Research Center, intend to update the habitat maps and the data derived from them, and bring the nest survival data base up to date.

ACKNOWLEDGEMENTS

We are grateful for the assistance furnished by the U. S. Fish and Wildlife Service, National Wetlands Inventory, especially H. R. Pywell and R. Gebhard who furnished the MOSS data. MicroImages Inc. prepared custom additions to MIPS software for use in the system. Numerous individuals from Regions 3 and 6 of the U. S. Fish and Wildlife Service, the Departments of Natural Resources of Minnesota and Iowa, and the staff of Northern Prairie Wildlife Research Center conducted pair counts. Region 3 pilot, R. Foster flew us over the plots for aerial video. P. Prigge, D. Hertel, and J. Bellant spent long hours in analysis of video data and preparation of data files. D. Twedt and R. Thielman helped with preparation of figures and T. Hanson prepared the manuscript. J. Austin and D. Twedt provided comments on earlier drafts.

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CARIBOU MOVEMENTS IN RELATION TO DEVELOPMENT INFRASTRUCTURES

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Abstract: Movements and distribution of caribou (Rangifer tarandus granti) of the Central Arctic Herd (CAH) in relation to roads, pipelines, and other development infrastructures were analyzed using the ARC/INFO geographic information system (GIS). Between October 1986 and October 1989, as many as 10 locations/day were obtained for 3-6 adult female caribou within the Kuparuk oilfield west of Prudhoe Bay, Alaska, using the Argos Data Collection and Location System and Tiros-N series satellites. Digitized infrastructure maps of facilities within the Kuparuk field were obtained from Arco Alaska, Inc. and British Petroleum Exploration Co., and imported into the ARC/INFO GIS. The distance between each caribou location within the oilfield and the nearest road, pipeline, or other facility was calculated and added to the attributes for each location. The major road system and coastline were used to delineate mutually-exclusive polygons, and the polygon associated with each caribou location was also added as an attribute. The attribute table was imported into the SAS statistical package to determine the number of road crossings (i.e., caribou movement between polygons) and the mean distance between each caribou and the nearest road or other structure during different time intervals. Results were compared to movements and distribution of CAH caribou that occur east of the oilfields to determine the effect of infrastructures on caribou movements and distribution patterns.

Further information on this project can be obtained from Steve Fancy (commercial phone: 907-456-0254; FTS: 870-0254) or Dave Douglas (commercial phone: 907-786-3473; FTS: 869-3473).

SELECTED GEOGRAPHIC ANALYSIS PROJECTS: U.S. FISH AND WILDLIFE SERVICE'S NATIONAL WETLANDS RESEARCH CENTER

By

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ABSTRACT

Geographic Information Systems (GIS) technology used by the U.S. Fish and Wildlife Service's National Wetlands Research Center (NWRC) has provided an invaluable methodology for assisting natural resource management personnel in the planning and management of fish and wildlife resources. Within the past 5 years, approximately 60 studies have been conducted by NWRC that have directly resulted in a better understanding of and more efficient management of the natural resources in wetlands of the United States. These applications have ranged from simple natural resource inventories to documentation of wetland change trends and complex predictive modeling of harbor expansion and contaminants impact to biological resources. Several of these products have been presented before local, State, and congressional committees as well as numerous scientific and public organizations. This paper will describe and summarize selected GIS projects related to resource inventories, wetland change analyses, and cartographic modeling methodologies.

INTRODUCTION

The purpose of this paper is to highlight the geographic information system (GIS) used by the National Wetlands Research Center (NWRC) and to provide specific examples of its use in wetlands and coastal resource planning and management projects. A GIS is a means to efficiently store, retrieve, manipulate, analyze, and display geographic data. Systems can be either manual, such as map filing systems, or automated with map storage, retrieval, manipulation, and display accomplished by means of computer technology. Recent advances in computer technology have lowered the costs of acquisition and increased system capabilities to the point that computer use is becoming widespread. Systems initially were cumbersome and inefficient in their organizational and analytical capabilities. In recent years, however, new systems have been developed that are easy to use, efficient in data storage, and multifaceted in their analytical capabilities.

In 1980, NWRC implemented a GIS for the coastal characterizations and other programs underway at that time. These programs were producing large amounts of data for the coastal zone of the United States; consequently,

storage and analysis of the data were become increasingly difficult. A decision was made to procure and implement a GIS system that would organize and store these data as well as permit a variety of analyses.

Presently, NWRC is constructing region-wide and site-specific data bases for wetland and coastal areas of the United States. These data bases consist primarily of wetland habitat and upland land-use maps that have been photo-interpreted by the U.S. Fish and Wildlife Service's (Service) National Wetland Inventory (NWI) and geometrically corrected for camera distortion. Most habitat maps are 1:24,000 scale, which permits USGS topographical mapping series data to be used as collateral information in analyses. Digital data bases at NWRC generally comprise historical, contemporary, and special projects. Historical data are obtained from 1950's black and white aerial photography. This time period was chosen because of the general availability of good photography. These data document environmental conditions prior to widespread coastal zone development. A comprehensive historical data base has been developed at NWRC for 80 percent of the Gulf of Mexico region and all of San Francisco Bay.

Contemporary data bases contain late 1970's and 1980's wetland habitat information. These data are obtained from color infrared aerial photography which usually provides the best delineation of wetland composition and distribution. These data are compared to the historical information to determine the degree and rate (where possible) of habitat change within specified project areas. Contemporary digital data bases at NWRC primarily are available for the Gulf of Mexico region; however, additional data have been developed for selected areas of Arkansas, Wisconsin, California, New Jersey, and South Carolina.

Special project data are obtained from numerous sources and may be composed of several types including bathymetry, salinity, bottom sediments, ownership, soils, geology, land-use, and land-cover. These data are used in a wide variety of applications ranging from resource inventories to complex multivariate mapping and cartographic analyses. Special projects comprise a small, but significant, percentage of the GIS applications at NWRC. Numerous special project data bases have been constructed throughout the Eastern United States.

The GIS implemented by NWRC has been used for several different types of wetland and coastal resource applications. This paper describes and summarizes three of these: resource inventories, wetland change analyses, and cartographic modeling methodologies. Each type of application is briefly introduced and followed with specific project example

NATURAL RESOURCE INVENTORY ANALYSES

INTRODUCTION

One of the more common applications of the GIS technology at NWRC is providing natural resource inventories for selected geographic areas. These inventories are used for various purposes such as environmental impact

assessments or port planning. Resource inventories generally document "baseline" environmental conditions and are used by the Service's Ecological Services (ES) Offices to infer project impacts on the fish and wildlife resources in a specific area. Typically, the final products of these inventories consist of statistics and map graphics. This information assists in the permitting process by graphically illustrating the distribution of critical habitats and potential losses from project implementation. Since fiscal year 1985, 25 resource inventory projects were completed; five are discussed in the following sections. Four of these projects were in the Gulf of Mexico region, and one was a reservoir project in Georgia.

MISSISSIPPI SOUND AND MOBILE BAY, ALABAMA, REGIONAL RESOURCE INVENTORY

Selected habitats were inventoried and mapped for a comprehensive resource assessment of the Mississippi Sound and Mobile Bay region in Mississippi and Alabama. This project was funded by the Mobile District of the U.S. Army of Corps of Engineers (USACE) and was designed to provide fundamental information about these habitats. The selected habitats were aquatic, emergent, and forested wetland vegetation, and uplands. Four separate maps were generated to illustrate the distribution of these habitats. An additional composite map was prepared to depict all of the individual habitat categories. This information was requested for use in assessing the environmental impacts of port development in the harbors of Mobile, Alabama, and Pascagoula, Mississippi, and of oil and gas development in southern Mobile Bay. In addition to the sponsoring agency, these data were provided to the Service's Daphne, Alabama, ES Office to assist with their related permitting activities and management of the local fish and wildlife resources.

ESCAMBIA BAY, FLORIDA, COMPREHENSIVE RESOURCE INVENTORY

A resource inventory of the wetland habitats and developed areas adjacent to Escambia Bay, Florida, was conducted for the Service's Panama City, Florida, ES Office. Funding for this study was provided by the Mobile District of the USACE. The purpose of this project was to document the spatial proximity of wetland habitats to existing industrial and transportation complexes. The resulting final graphic illustrates the flexibility of the GIS system for mapping line and polygon data, such as bathymetry, railroads, and highways, as well as wetland habitats. This study demonstrates the ability of the system to integrate several different resource themes on one map for comprehensively examining the resources of a selected geographic area. The final map, in addition to tabular acreage data, was used by the Panama City ES Office to assist in designing appropriate planning and management strategies to minimize potential adverse impacts from harbor and industrial expansion.

LOWER MISSISSIPPI RIVER PORT DEVELOPMENT STUDY

A resource inventory was conducted to evaluate the environmental impacts of a proposed dredging project for the lower Mississippi River. This study

was done with the Service's base funds for the Service's Lafayette, Louisiana, ES Office as part of a project review. The project proposed dredging the lower Mississippi River to 55 ft for navigation. It was argued that this dredging project would increase commerce by permitting deeper draft vessels access to port facilities along the river. The important consideration in this proposal was the location of dredge disposal sites. The Lafayette ES Office was particularly concerned about the impact of dredge disposal on wetland habitats. Two options proposed by the New Orleans District of the USACE were examined in this study. Both options proposed disposing of dredge material in areas immediately adjacent to the river. The first option was to deposit the material within 1,500 ft of the river, and the second was to deposit it within 2,000 ft. Each option was examined to determine the amount of each habitat type to be affected and its areal extent.

The study used existing wetland habitat maps that had been previously digitized through a cooperative agreement with the State of Louisiana's Department of Natural Resources. A disposal zone was created for each option. Wetland habitats within each disposal zone were then selectively retrieved. The total acreage of each habitat type was calculated to determine the amount of each type that would be affected by the proposed project. A map with an accompanying acreage summary table was produced. The analysis revealed a much more significant impact upon freshwater marsh areas than had been previously anticipated. The final products were used by the ES to review and evaluate the overall impact of the proposed development.

DALTON LAKE, GEORGIA, RESERVOIR IMPACT STUDY

A resource inventory of wetland habitats was conducted for a proposed reservoir project in northwestern Georgia. This inventory was conducted for the Service's Panama City, Florida, ES Office. Funding was provided by the Mobile District of the USACE. The proposed project site was located in Whitfield and Murray Counties of northwestern Georgia on the Consauga River. The project would create a 4,000-acre lake to supply water for domestic and industrial use to the surrounding area. The focus of the inventory was the mapping and quantification of the different wetland habitat types that were to be affected by the project.

Aerial photography for the inventory was acquired and interpreted by NWI. Wetland habitats were interpreted for portions of three 1:24,000 scale USGS quadrangles. In addition, two elevation contours representing the normal (700 ft) and maximum (720 ft) flood pool levels for the reservoir were digitized. Wetland habitats within each flood contour were selectively retrieved. The total acreage of each wetland habitat type was calculated as well as the habitat composition of the area. These data were used by the ES to evaluate the environmental impact of the proposed project and to assist in developing management plans. Finally, a map was produced to depict the areal extent of affected habitat types. The map was included in an FWS report from the ES Office to the Mobile District of the USACE.

HOUSTON, TEXAS, REGION TOXIC WASTES INVENTORY

An inventory of toxic waste disposal sites and their proximity to endangered species habitats was compiled for the Houston, Texas, region. This inventory was done for the Service's Columbia National Fishery Research Laboratory (CNFRL). The purpose of the inventory was to demonstrate GIS capabilities in addressing toxic waste problems and to provide CNFRL with data for an FWS publication on toxic waste hazards in the Houston region.

Toxic waste data were derived from an NWRC study that compiled all the different types of toxic waste sites in the Houston region. These data were divided into point source, surface impoundment/injection well, and landfill categories and plotted in relation to critical habitats of endangered species. Only one actual disposal site was located within a critical habitat; however, many liquid waste discharge sites were adjacent to critical nursery or spawning grounds.

WETLAND CHANGE ANALYSES

INTRODUCTION

An important, ongoing GIS application has been wetland change analyses. These analyses document temporal trends in wetland habitat types, composition, and spatial patterns. The importance of these studies has long been recognized within the FWS. Wetlands and their abundant flora and fauna constitute important natural resources and play an important ecological role. Until these change analyses were begun in the late 1970's, there was no comprehensive effort to document the magnitude and dynamics of the changes occurring in wetland habitats.

Two geographic approaches have been used in wetland change projects. The first has been a regional perspective. Regional studies have focused on establishing general trends of changes within broad geographic areas of interest. The second approach has been site specific. Site-specific studies have focused on particular geographic areas as defined by permitting or project actions. Several of these studies have examined the characteristics of multitemporal wetland changes within the given geographic areas.

Within either geographic approach, wetland change analyses can also focus on two different perspectives of temporal sequences. The first emphasizes the establishment of a base-line trend in wetland habitat changes occurring between two time periods. This perspective uses an historical and a contemporary data base to examine wetland change. The inferences made from these analyses are limited to a mean change per year and overall changes occurring within that time period. The second perspective uses multitemporal data to establish wetland change rates. This perspective is particularly useful in determining whether wetland changes occurring within project areas are accelerating, constant, or slowing and in locating those geographic areas with the most dynamic changes.

The data used in NWRC's analyses primarily have been NWI map data from specific years varying according to project needs. Generally, the base-line trend analyses have used 1950's and 1970's or 1980's data. Data from the 1950's were chosen because of the availability of good aerial photography, which is the earliest photography of pre-development coastal habitat conditions. The 1970's or 1980's data were chosen simply because they were the most recent photography available. The data used for multitemporal trend analyses have been entirely dependent on project needs and photography availability.

Final products from these analyses consist of statistics and map graphics. The statistics summarize total acreages for individual wetland habitat types, percentage change in habitat types, and the percentage of each habitat type in the total study area. A map accompanying the statistics displays the geographical extent and areas of wetland habitat changes. Categories are usually aggregated to simplify the map data and to facilitate the map's use and interpretation.

Results of recent analyses have demonstrated the dramatic losses of emergent marsh and forested wetland habitats in the Gulf of Mexico coastal zone. The greatest total losses in acreage have occurred in Louisiana; however, all the Gulf States have experienced large percentages of losses (e.g., Alabama, 36%; Florida Panhandle Region, 43%; Mississippi, 8%; Mississippi Deltaic Plain, 20%; Texas Galveston Bay region, 17%). These losses have been occurring because of a number of different processes such as oil and gas exploration and extraction, canalization, agriculture, urbanization, subsidence, sea level rise, and leveeing.

These products and analyses have been used by various Regional, ES, and Refuge personnel within the FWS for planning, management, and permitting activities.

Most wetland change studies have been dependent upon reimbursable funding for data base construction. Consequently, the geographical areas covered have varied according to project needs. Since 1983, 18 wetland change analyses have been completed. Five of these analyses are described in the narratives which follow. These regional and site-specific studies primarily have been located in the Gulf of Mexico; additional projects have been conducted in the St. Lawrence Seaway, Arkansas, South San Francisco Bay, Wisconsin, and California.

BARATARIA BAY, LOUISIANA, WETLAND CHANGE ANALYSIS

A wetland change analysis was conducted for the Barataria Bay region in Louisiana. This study was completed as part of an ongoing cooperative agreement with the State of Louisiana's Department of Natural Resources to study wetland change within the State's coastal zone. Funding was provided by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Zone Management program. Located southwest of New Orleans, Barataria Bay and its wetlands have been affected by several different cultural processes. These processes have included oil and gas exploration and extraction, as well as

agricultural, urban, and transportation developments. The study examined the magnitude and spatial characteristics of wetland changes in the region.

The data base used for the study consisted of 1956 and 1978 wetland habitat maps derived from aerial photography. The photographs had been interpreted, and mylar maps were produced. These mylar maps were previously digitized as part of the State's cooperative agreement. Total acreage and percent change statistics for wetland habitats were calculated for the region. These statistics, in conjunction with a map product, were used to examine the spatial and the quantitative characteristics of wetland changes that have occurred over the 22-year period.

The products demonstrated the dramatic losses of emergent marsh and forested wetland habitats in the Louisiana coastal zone. Wetland losses within the Barataria Bay basin were calculated to be approximately 10 square miles per year. The loss of wetland acreage has been in the form of a change from emergent and forested wetlands to either upland habitats or open water. In addition to the State sponsors, these statistics and map products have been provided to the Service's Lafayette, Louisiana, ES Office for use in permitting activities and management plan development.

NWRC is presently updating this data base using 1988 high altitude color infrared photography.

TEXAS GULF COAST WETLAND CHANGE ANALYSES

In conjunction with the comprehensive program of wetland change analysis for the Gulf of Mexico, two major studies were conducted in Galveston Bay and Port Isabel, Texas. These studies were requested by the Service's Clear Lake, Texas, ES Office and the Service's Regional Office in Albuquerque, New Mexico, to assist in management of the local natural resources. Funding for data-base development and digitization of the coastal Texas habitat data was provided by Minerals Management Service as part of the coastal characterization and environmental impact assessment programs.

The Galveston Bay and Port Isabel projects consisted of statistical and spatial comparisons of 1956 and 1979 wetland habitats. Individual 1:24,00 scale base maps were merged into single map files. Specific habitat categories were collapsed into more general habitat types, and acreage figures were determined for each year. From these data, the amount and percentage of habitat gain or loss were calculated for each habitat type. This statistical information was used with the cartographic data to document the spatial and quantitative nature of habitat change in the area. Both studies indicated significant losses of emergent marsh and beach habitats with concomitant increases in forested wetlands and freshwater ponds. While some of these changes may be attributed to human activities such as channelization and dredging, meteorological data suggest that extreme rainfall conditions between 1956 and 1979 may account for the increased wetlands and ponds, especially for Port Isabel.

In addition to the Galveston Bay and Port Isabel studies, similar wetland change analyses were completed for Galveston Island and the Aransas National Wildlife Refuge. These data were provided to Refuge, ES, and Regional personnel to supplement management and permitting practices in the area.

CALIFORNIA GRASSLANDS WETLAND ACQUISITION STUDY

Wetland changes were studies in the California Grasslands region of central California for the FWS Wildlife Resources Division of Realty in Region 1. The purpose of the study was to examine wetland change trends for identification and selection of potential wetland acreage for future acquisition.

The data used for the study were 1977 and 1983 wetland habitat maps. The 1977 wetland map was provided by the NWI. Regional personnel updated the 1977 map with 1983 high altitude infrared aerial photography to produce a 1983 wetland habitat. Of primary interest in this study were vernal and seasonal palustrine emergent wetlands. Statistics were produced for the total acreage of individual habitat types and their percentage of change over the 6-year period. Additionally, a map was produced depicting the areas where changes occurred. These products were forwarded to the Region 1 Office for their use.

Then 1977 digital maps were late forwarded to the NWI and National Ecology Research Center (NERC) for a cooperative project they were undertaking in the same area. This project demonstrates the cost savings of computerized data and their ability to be shared throughout the Service.

LAKE ONALASKA, WISCONSIN, SUBMERGED AQUATIC CHANGE ANALYSIS

Changes in submerged aquatic plant habitats were studied in Lake Onalaska, Wisconsin, for the Service's ES and Refuge personnel in Region 3 with funding from the Service's base funds. Lake Onalaska is part of the Upper Mississippi National Wildlife Refuge System. It is particularly important to the Service because of the large number of canvasback ducks that use the area during their seasonal migration. The purpose of the study was to examine the quantitative and spatial changes in submerged aquatic plant distributions over a 42-year period.

Data for the study were obtained from aerial photography flown in 1940, 1947, 1954, 1961, 1967, 1974, and 1982. The data were provided in map form by Regional personnel. The total submerged aquatic plant acreage was calculated for each time period. Additionally, a map product was produced to depict the spatial distribution of submerged aquatic plant habitats for each year. These products were forwarded to the Region for their use in managing the aquatic resources in the lake. Digital data also were sent to the Region for incorporation into other digital data bases available on the State of Minnesota's Land Use Information System. This project augments the Region's data base construction activities.

L'ANGUILLE RIVER BASIN, ARKANSAS, BOTTOMLAND HARDWOODS STUDY

A study examining historical trends in bottomland-hardwood losses in the L'Anguille River Basin, Arkansas, was conducted for the Service's Vicksburg, Mississippi, ES Office. Funding for data base construction and analysis was provided by the Vicksburg District of the USACE. Much of the study area has been proposed for a series of channelization and drainage projects to more effectively control flooding and erosion. The purpose of this project, therefore, was to document regional trends in bottomland-hardwood losses from past agricultural and commercial timber practices.

Data for the L'Anguille study consisted of 1937, 1957, and 1967 bottomland-hardwood habitat maps developed at 1:250,000 scale under a special contract. The 1979 data consisted of 1:100,000-scale NWI habitat maps. To determine the exact spatial nature of the potential losses, bottomland-hardwood types were divided into two categories: (1) Bottomland-hardwood were defined as timber resources directly adjacent to major rivers or tributary systems and (2) Terraceland hardwoods were identified by their location on or above the first terrace but within the L'Anguille river floodplain.

Acreage statistics were calculated for each time period and incorporated into the final graphic products. The greatest loss has been to terraceland hardwoods: 85 percent depletion since 1937, with the most significant losses occurring between 1937 and 1967. Available agricultural data indicate a tremendous increase in soybean production and agricultural field clearing during the 1950's and early 1960's.

Additional information produced by this study was provided to the Service's Vicksburg, Mississippi, ES oFfice in the form of individual black and white, report-size maps and quantitative data of habitat acreages and loss statistics. These data were incorporated into a regional management plan for the L'Anguille River Basin submitted to the USACE.

CARTOGRAPHIC MODELING METHODOLOGIES

INTRODUCTION

The final type of GIS analysis to be discussed in this report is cartographic modeling. This procedure provides several methodologies to synthesize, analyze, and correlate multivariate data bases both quantitatively and spatially. With these techniques, several different map variables can be combined arithmetically and depicted on a single map.

Cartographic modeling uses a type of data format referred to as a cell or raster format. This format converts point, line, or polygon data to maps defined as a series of cells or rectangular shapes. Each cell is assigned a value determined by the majority data type it contains. This conversion of polygonal habitat data to a cell format results in some degree of data generalization. As a result, the geographic accuracy of cell data is limited by the resolution or size of the cells selected. Selection of a small size (0.25 acres or less), however generally minimizes the overall distortion.

Because of the efficiency of cell data processing, other types of information can be incorporated easily into these analyses. For example, satellite imagery, which is already in a cell format, can be used as an information source, or sampled point data can be incorporated through interpolation with a nearest neighbor technique.

The possible uses of this methodology are limited only be the user's creativity. A few examples are suitability, sensitivity, or impact assessment analyses. For example, in 1982 NWRC modeled oil spill sensitivity for the Louisiana Offshore Oil Port. This study produced a composite map depicting protection priorities for onshore and nearshore areas in the Barataria Bay quadrangle in the event of an oil spill. Data for the analysis consisted of eight resource variables: wetland habitats, oyster leases, recreational beaches, historical and archeological sites, endangered species, bird rookeries, marinas, and water intakes. These resource variables were digitized and converted to cell formats. Each resource variable was recoded and weighted according to its oil spill vulnerability. The ranking criteria were devised by using methods previously developed by NWRC (biological resources) and Minerals Management Service (cultural resources). Values of the resource variables were summed to produce a single map indicating oil spill vulnerabilities. Categories within this map were simplified into three rankings: low, medium, and high vulnerability.

The final products produced by this or similar studies could facilitate oil spill cleanup activities and could aid deployment of response personnel by locating those areas most vulnerable and, hence, needing most protection. The map products could also help response personnel locate access sites. This particular type of methodology could be used for hazardous waste and oil spill management, environmental impact assessment, effluent discharge assessment, oil lease and pipeline construction monitoring, or for evaluating other coastal activities such as agricultural, industrial, or recreational development.

Cartographic modeling can also be of importance to the Service's Habitat Evaluation Procedures (HEP). Geographic areas can be evaluated for particular species by using the Habitat Suitability Index (HSI) model output for identifying optimal environmental conditions. Previously, these models have only been used for calculating values for entire study areas. Cartographic modeling, however, can calculate ranges of HSI values from model variables for a study area and geographically depict those areas meeting the optimum criterion.

Finally, cartographic models can be used for explanatory purposes. For example, marsh loss dynamics could be studies by using regression analysis. Those areas that experienced the highest percentages of marsh loss would be the dependent variable while potential independent variables could include solid types, plant species, sedimentation, sea level, geology, and subsidence. By using a least squares technique, these variables could be examined for significant relationships with wetland loss.

Despite the tremendous potential available with these cartographic modeling techniques, applications of this methodology have been limited.

Their absence primarily is due to nonfamiliarity of users with these capabilities and to the general lack of available multivariate digital cartographic data bases. It is these modeling techniques, however, that offer the greatest potential for understanding significant relationships between environmental and biological variables and for predicting potential impacts of human activities on local fish and wildlife resources.

NORFOLK HARBOR AND CHANNEL-DEEPENING STUDY

An impact assessment of a port development project was conducted for the Service's Gloucester Point, Virginia, ES Subfield Office with funding from the Norfolk District of the USACE. The USACE proposed deepening harbor anchorages and deepening and extending shipping channels in the Norfolk Harbor/Hampton Roads, Virginia, area and in the lower Chesapeake Bay. The channels would be dredged and maintained to a depth of 45 to 55 ft in most cases; dredge spoil would be disposed of at an offshore ocean site. The project had the potential to cause increased saltwater intrusion into bottom water layers of the James, Nansemond, and Elizabeth Rivers--the major estuarine tributaries to the harbor. Saltwater intrusion, in turn, could influence changes in the distribution of the major planktonic, benthic, and nektonic species in these estuaries, either by eliminating their habitats by virtue of the altered salinity regimes or by displacing their preferred habitat upstream. The object of the study was to quantify and depict any potential changes in selected species distributions based on hypothetical scenarios before and after dredging.

Twenty species were selected for their ecological or economic importance. Salinity, water depth, and bottom-sediment type preferences of selected life stages of the 20 species were compiled from the scientific literature. These three variables were used as environmental constraints to develop potential distributions for each species.

Date for the study were obtained from a number of sources. Surface and bottom salinities from 125 sampling stations were obtained from experimental runs of the USACE's Chesapeake Bay physical model, which was configured and manipulated to represent conditions before and after dredging. The data also simulated salinity patterns during historical drought years to represent a worst-case scenario of greatest likely dredging impact. Bathymetry (water depth) data were obtained from NOAA. Bottom-sediment type data were obtained from the Virginia Institute of Marine Science.

Computer files of the study area and of the three variables were created. The bottom-sediment type data were converted to a cell format, and cell-formatted files were calculated for the salinity and bathymetry data through a process of interpolation (nearest neighbor algorithm with a quadrant forcing function). The three variables were composited through a method of addition. Each variable was added together to create a new map that integrated all variables and depicted the areal extent of base-line potential habitat, potential habitat gain, and potential habitat loss. Acreages also were calculated for base-line, gain, and loss categories. Species analyses were run based on critical life stages and seasonal occurrence.

Results from the study showed some projected net change in 80 percent of the target species' areal distributions due to salinity changes after dredging. A pattern, most clearly seen in the mesohaline portions of the James River, was upstream habitat gains by euryhaline or marine species in the summer and concomitant habitat range losses downstream for oligohaline or freshwater species. Gains or losses of habitat offset each other for most of the species. Net gains or losses in habitat were generally less than 5 percent of the potential base-line habitat.

CARTOGRAPHICALLY-BASED RISK ASSESSMENT FOR CONTAMINATED SEDIMENTS

Resource managers need to know not only if resources are at risk in an ecosystem, but also exactly where those risks are greatest. By combining traditional contaminant survey approaches with GIS technologies, NWRC is conducting a cartographically-based risk assessment of the potential impacts of contaminated sediments on selected natural resources in Mobile Bay, Alabama.

In an ecological sense, the term "risk assessment" is applied generally to the process of identifying, characterizing, and quantifying the potential adverse effects of environmental hazards. Risk assessment goes beyond traditional environmental impact assessment and contaminant surveys in quantifying the probability of an undesired event such as contamination of important natural resources. NWRC's cartographically-based risk assessment tries to tie the probabilities of a contaminant problem to specific locations in our study area.

To accomplish this, NWRC is using GIS to develop spatial data bases on wetland habitats, submerged aquatic vegetation, bathymetry, salinity contours, National Pollution Discharge Elimination System (NPDES) sites, heavy metals concentrations, sediments, shoreline erosion and accretion zones, fish habitats, bird nesting sites, natural gas platforms, the transportation network, and park and refuge boundaries. Heavy metal and sediment data were entered as points and contoured using MOSS/MAPS. Salinity contours were generated from the output of a dynamic model of the bay's hydrography. Point data such as NPDES sites, bird-nesting locations, and natural gas platforms will be buffered to various distances based on physical characterizations.

Information about the persistence, volatility, and solubility of each chemical entering the bay is also being assembled to determine the likelihood for transport and bioavailability in the bay. Information about a toxicant's partitioning among water, suspended particulates, sediments, and the biota are being evaluated by examining information about the bioaccumulation potentials, structure-activity relationships, and metabolic half-lives of candidate chemicals and chemical groups. While not directly incorporated into the GIS, this assessment will provide guidance about which contaminants should have a higher probability of negatively affecting important natural resources.

Both the simply overlay and the cartographic modeling capabilities of GIS will be used to highlight areas of low, medium, and high risk of contamination of selected resources by selected contaminants. For example, NWRC already

overlaid NPDES sites with wetland habitats and discovered areas where toxic materials are being discharged into channels near wetlands that are of value to fish and wildlife species. We have also overlaid chromium and nickel concentrations with bay-bottom types to locate accumulation sites. In many ares, Mobile Bay's mineralogy consists of high percentages of silts, clays, and organic carbons. Inorganic and organic contaminants have a longer residence time in these bottom types.

Cartographic modeling will be undertaken in a manner similar to Stayner et al. (1986). First, all data will be converted to cell format and recoded to an appropriate value determined by ranking the categories in each data layer according to contaminant sensitivity (for resources) or toxicity (for chemical sources and accumulation areas). Various combinations of these cell maps will then be arithmetically composited to produce a single output. Contaminant risk index values will be grouped into logical classes to produce a final computer-generated map that depicts low, medium, and high risk areas.

Risk assessments such as this one can provide a more rational basis for making management decisions by quantifying uncertainty. These assessments can be used both to justify more expensive chemical testing programs and to pinpoint where the samples should be taken. Managers can also identify those resources that are at greatest risk and where that risk lies so that risk reduction and restoration efforts can be targeted specifically to those areas. Using risk assessments, resource management decisions can be based more on empirical analysis than subjective judgement.

CONCLUSION

Geographic information systems provide a powerful tool for resource managers. A GIS can be used to store, retrieve, manipulate, analyze, and update both spatial and tabular data with relative ease. Although managers may initially have been drawn to GIS's for their map production capabilities, their analytical capabilities are now receiving equal attention. Data from several themes can be analyzed simultaneously to answer, complex questions. NWRC's analysis is an example of this. Scott et al. (1987) gave another particularly innovative example. They superimposed wildlife distribution data for a number of species on land cover and property ownership maps to design habitat preserves that would maximize the benefits to a diverse assemblage of species. Multispecies approaches like this one probably offer the best long-term hope for preserving biological diversity.

A GIS is also ideal for studies of land-cover changes and their causes over time. NWRC's analysis of wetland change used GIS to depict change from one time period to the next. Walker et al. (1986) also showed how a GIS can be used to analyze cumulative anthropogenic impacts on natural habitats, in this example in Prudhoe Bay, Alaska. In the regulatory arena, a GIS can be used as an "institutional memory" (after Gosselink and Lee 1987) of the landscape. When an application for a permit is received by a regulatory agency, the GIS can be used to examine the ares in question; if the permit is granted, it can be permanently entered into the data base so its existence and impacts are known when the next permit request is made.

One of the greatest potentials of GIS for environmental scientists and managers may lie in its cartographic modeling capabilities. Once a multivariate data base has been assembled, a large number of models could be constructed with varying data levels to examine the probabilities of risk to components of the ecosystem from a variety of factors, as we are doing in Mobile Bay. These analyses can provide a spatial dimension to ecological problem-solving and a more rational basis for environmental decisionmaking.

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A BRIEF OVERVIEW OF THE USE OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) AND COMPUTER-AIDED MAPPING (CAM) IN REGION ONE U.S. FISH AND WILDLIFE SERVICE

JUNE 1990

PRESENTED AT

THE FIRST NATIONAL U.S. FISH AND WILDLIFE SERVICE
GIS CONFERENCE
NATIONAL ECOLOGY RESEARCH CENTER
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INTRODUCTION

In the U.S. Fish and Wildlife Service's Region 1, the in-house use and operation of Geographic Information System (GIS) technology is rather sparse. Presently, the only operating GIS in the Region is based at the Malheur National Wildlife Refuge (NWR), Oregon, where they are running the Personal Computer (PC) version of the ARC/INFO GIS for Refuge Management Planning. However, through cooperative programs with the Service's Research and Development Division (Region 8) and with other agencies, Region 1 has participated in a number of projects which have used this growing technology. Furthermore, we fully expect that the use of GIS and other Computer-aided Mapping (CAM) technology will be expanding in the Region.

Projects and activities which are including the use of GIS or CAM technology in Region 1 include the following:

* NATIONAL WILDLIFE REFUGE PLANNING
* NATIONAL WILDLIFE REFUGE SURVEY WORK
* ENGINEERING CONSTRUCTION DRAWINGS/WATER RIGHTS MAPPING
* NATIONAL WETLAND INVENTORY MAPPING
* WETLAND TREND ANALYSIS
* DATA BASE DEVELOPMENT AND MANAGEMENT
* RESEARCH ACTIVITIES
* CONTAMINANT STUDIES AND ASSESSMENTS
* ENDANGERED SPECIES STUDIES AND HABITAT EVALUATIONS
* BIOLOGICAL MONITORING
* INTERAGENCY COORDINATION

I will also briefly discuss our role in the Service's PC ARC/INFO evaluation and the establishment of a Region 1 GIS Task Force.

NATIONAL WILDLIFE REFUGE PLANNING

I started work with the U.S. Fish and Wildlife Service (Service) as a Planning Coordinator for National Wildlife Refuges in 1980. Work on Master Planning efforts for Grays Lake NWR in Idaho, and

Kern NWR and Pixley NWR in California incorporated the manual process of overlaying hand drawn mylar maps to conduct suitability analyses and impact assessments. In 1984, the Region had the opportunity to use the Map Overlay and Statistical System (MOSS) family of GIS software in the planning process for three refuges of the San Luis National Wildlife Refuge Complex (San Luis, Kesterson and Merced NWRs) in the San Joaquin Valley, California. This process allowed us to digitize important data themes, develop a digital data base, develop high quality color maps, and conduct analysis with the use of a computer versus mylar maps on a light-table.

Our work on this project was performed in cooperation with the Service's National Ecology Research Center (formerly the Western Energy Land Use Team) in Fort Collins, Colorado. I will not go into all of the details of the planning process, nor will I discuss the procedures used in setting up a data base and preparing information for digitizing. However, I will provide a few highlights of the process. Typically, a Refuge data base is developed from existing data such as U.S. Geological Survey (USGS) quad sheets, U.S. Soil Conservation Service (SCS) soil surveys, and information on file at the Refuge. Usually a great deal of information is not readily available and aerial photo interpretation also is a necessary step in developing a comprehensive data base to work from. This data base is organized into major themes and maps, such as vegetation, soils, hydrology, land use and other resource information. The maps and information needs are designed, developed, and digitized, and final maps plotted in color or black and white at a common scale (typically 1:24,000) and compiled into a Refuge Atlas.

A key part of the planning process usually includes a suitability analysis for various wildlife species and possibly for facilities such as Refuge roads or trails, water delivery canals or buildings. The suitability analysis process starts with the development of a model which is derived from literature searches, biological and refuge management experience and other sources. The models may be derived from Locational Criteria, which is developed as a part of the National Wildlife Refuge System Master Planning process.

As an example, habitat suitability for the endangered San Joaquin kit fox was conducted for Kesterson NWR. The locational criteria identified factors such as food and foraging, soil types for denning, disturbance, and slope and aspect for den sites. These factors may be weighted by importance and arranged according to optimum, acceptable and minimum suitability. Categories of vegetation, soils, disturbance, slope and aspect from the Refuge resource data base were then coded to meet the suitability criteria. The data files were then rasterized into one-acre grid cells. The raster data for each theme was then renumbered according to the values associated with kit fox suitability. An overall San Joaquin kit fox soil suitability map was developed from soil texture, soil alkalinity, and soil permeability attribute files. Disturbance factors were developed by mapping and buffering road and land use data themes. Finally, a habitat suitability map for San Joaquin kit fox at Kesterson NWR was developed from the soils, vegetation, and disturbance maps.

Slope and aspect factors were not included at Kesterson due to the relatively flat land surface of the area. The suitability map displayed very little optimum habitat, some acceptable (or moderate) habitat, and a great deal of minimum and unacceptable habitat for the San Joaquin kit fox. Kit foxes are relatively uncommon in the Kesterson area. A recent effort to trap and radio-collar kit foxes in this area found very few kit foxes in the vicinity of Kesterson Reservoir and Refuge. Additionally, the highest areas of use by San Joaquin kit fox were found to be consistent with those areas identified as optimum and acceptable habitat from this GIS modeling and mapping effort.

NATIONAL WILDLIFE REFUGE SURVEYS

The Region 1 Realty Office includes the surveying division. This office is involved in base level data entry of Refuge boundaries for National Wildlife Refuges in the Region, as well as other work. The office is digitizing the coordinate survey, using the State Plane Coordinate System, for all new refuges in the Region. The survey office is available to help set up base level coordinates for GIS or CAM projects and will also digitize data themes. They are using an Auto-CAD (Computer-aided Drafting) system with a 386

computer. They have both digitizing and plotting capabilities in the office. The surveyors have also been utilizing Global Positioning System (GPS) technology in some large projects such as the 100-mile long riparian zone associated with the Sacramento River NWR. Also included in the Region 1 Realty Office is the Regional Cartographer. This office, which continues to generate manually drawn mapping products, has also recently acquired an Auto-CAD system.

ENGINEERING

The Regional Engineering Office is using an Auto-trol system on an Apollo work station principally for construction drawings. The Engineering Office is also beginning to conduct water rights mapping for the Region's National Wildlife Refuges. The office has both digitizing and plotting capabilities.

NATIONAL WETLANDS INVENTORY MAPPING

A great number of the 1:24,000 USGS quad sheets in the Region have had the National Wetlands Inventory (NWI) classification digitized. All of the State of Washington is completed and much of California has been or is being digitized. We have had a number of cooperative programs in the Region which have resulted in NWI information being digitized. Wetland trend analyses have been conducted in some areas of the Region such as San Francisco Bay. In a project initially supported by the U.S. Environmental Protection Agency (EPA), wetland change has been mapped and digitized for the South San Francisco Bay for the years 1956 and 1985. The 1985 wetlands information for the entire Bay Area is digitized and has been used in a number of projects including the San Francisco Bay Concept Plan for Waterfowl Habitat Protection. In this project, Region 1 worked with the National Wetlands Inventory Office in St. Petersburg, Florida and their MOSS GIS to lump the complex NWI categories into eight general wetland habitat types, and to map and digitize tracts of land which are unprotected and which include important wetland habitats. Products for this project included eighteen 1:24,000 color GIS map overlays with this information, as well as two 1:100,000 GIS maps for the North and

South Bay Area depicting the study area's wetland protection tracts and upland, wetland and deepwater habitats. Further expansion of this GIS data base to include USGS Digital Line Graph (DLG) information and other data is expected in the near future. The data base will be useful to Refuge biologists, realty and acquisition specialists, wildlife researchers and others.

RESEARCH ACTIVITIES

Region 1 has a great deal of coordinated activities with the various Research Centers and Field Stations of Region 8 (Research). Included in activities such as GIS are the Northern Prairie Wildlife Research Center, Patuxent Wildlife Research Center, National Fisheries Contaminant Research Center, National Ecology Research Center, National Wetlands Research Center and the National Wetlands Inventory. Some of the research activities underway in California which are using GIS, remote sensing and related technologies include: waterfowl abundance and distribution studies; waterfowl habitat changes; and the California condor study.

CONTAMINANT STUDIES AND ASSESSMENTS AND BIOLOGICAL MONITORING

Contaminant investigations and biological monitoring programs appear to lend themselves well to the use of GIS technology. Currently, Regional contaminant specialists are investigating the possible use of this technology in their work. GIS and associated technology have been used in the Region with Kesterson Reservoir contaminant studies. The Service has worked cooperatively with the U.S. Bureau of Reclamation (Bureau) to develop a biological monitoring data base for Kesterson Reservoir. Mapping of selenium levels in the Reservoir was done using the Bureau's ARC/INFO GIS. Point data of selenium levels from soil and vegetation samples were digitized and the point values buffered to produce maps of high, medium and low selenium levels in the Reservoir. Mitigation planning for the Kesterson Program is also making use of the ARC/INFO GIS. Further efforts are underway to develop a General Wildlife Management Plan for the Kesterson area. It is expected that the planning process will make use of the Bureau's GIS.

The San Joaquin Valley Drainage Program (SJVDP) is a cooperative effort between the Service, Bureau, USGS, California Department of Fish and Game, and the California Department of Water Resources. This program has been established to address the irrigation and drainage problems in the San Joaquin Valley. The SJVDP is developing alternative plans in an attempt to solve the agricultural drainage problems that contribute to disasters such as have occurred at Kesterson Reservoir. An extensive data base has been developed and includes data files pertaining to wildlife, vegetation, hydrology, geology, agriculture, land use, contaminant levels and drainage problem areas. The SJVDP is conducting mapping, modeling, and analysis for agricultural, biological and hydrological studies. The ARC/INFO GIS is being used to map such things as problem areas and identify alternative planning solutions.

INTERAGENCY COORDINATION

One area in which Region 1 is rich has to be interagency and inter-divisional coordination. As identified earlier in this paper, Region 1 has principally worked with other agencies or with the Service's Research Division (Region 8) in regard to GIS and related technology. In addition to these activities, other projects involving coordination and cooperation with other agencies have been evolving. Most recently the U.S. Bureau of Reclamation has helped to prepare maps with their ARC/INFO GIS for the Stone Lakes Refuge Feasibility Study. GIS work for the Service by the Bureau is being performed under the cooperative agreements between the Service and the Bureau on wetlands and the North American Waterfowl Management Plan.

Other coordination takes place in the form of committees and work groups. Region 1 actively participates in the Department of Interior Digital Cartography Coordinating Committee Western Regional Subcommittee (IDCCC-W), Federal Agency GIS Working Group, California Computer Mapping Coordinating Committee, California Remote Sensing Group, and others.

PC ARC/INFO EVALUATION

Two sites in Region 1 have been included in the Service's national evaluation of the PC ARC/INFO GIS software. One of these sites is the Malheur NWR in Oregon and the other is the Refuges and Wildlife field office (where I work) in Sacramento, California. At Malheur they have converted MOSS GIS data files to run on PC ARC/INFO. They are conducting habitat management planning. The analysis will include four major themes with 32 coverages. The principal evaluation project involves an analysis of management units in comparison to National Wetland Inventory coverage. Furthermore, the staff plans to update management unit boundaries and plans based on this analysis.

In the Sacramento office we are about six months behind schedule in the PC ARC/INFO evaluation. Our plans are to work on at least one project site and perhaps additional sites if time permits. The initial plan is to use the MOSS data base previously developed for the San Luis NWR and covert it to run in PC ARC/INFO. Three potential evaluation projects have been identified for San Luis. One is an analysis of potential sites for permanent marsh creation. Under this study we would use soils information, proximities to water delivery and drainage features, groundwater and surface hydrology, vegetation, elevation, and wildlife use to model site suitability. Other potential projects include a cultural resources management/sensitivity analysis and analysis of potential visitor's center locations.

PROPOSED REGION 1 GIS TASK FORCE

Due to a recent upsurge of GIS and computer mapping interest and activity in the Region, the possibility of establishing a Region 1 GIS Task Force has been discussed. Our plans include investigation of possible GIS and other computer-aided mapping scenarios for Region 1. Included as Task Force objectives would be: 1) Conduct an overview of current and potential GIS applications, 2) Conduct a needs assessment for the Regional Office and Field Offices, 3) Explore and examine GIS and desktop mapping hardware and software options, 4) Examine GIS and CAM location options (e.g. centralized versus decentralized operations), 5)

Review related technology needs such as remote sensing, image processing, etc., 6) Examine personnel needs, and 7) Identify other options and opportunities. Membership in the Task Force is expected to include representatives from each of the major divisions of the Regional Office (Information Resource Management, Refuges and Wildlife, Fish and Wildlife Enhancement, Fisheries and Federal Aid, National Wetlands Inventory), as well as representation from selected field offices and Region 8. A report from the Region 1 GIS Task Force to the Regional Director is envisioned as the principal product from this effort.

CONCLUSION

In summary, Refuge planning activity is expected to be the biggest user of GIS and related technology in Region 1. Various levels of planning, mapping and analytical projects are expected to make use of GIS in the near future. Furthermore, other programs in the Region also expect to make use of GIS or CAD-CAM type systems. And perhaps most importantly, Region 1 is underway with the development of a GIS Task Force and needs assessment, as well as exploring a number of options for the future use of this growing technology.

APPENDIXES

List of Participants

List of Poster Presentations

Training Session

Survey Results

Facilitated Workshop Report

Beyond Mapping

(continued from page 8)

considerations that fueled most of the early debate about the relative merits of the two data structures. The demands of a few, or even one, megabyte of storage were very important in the early 1970"s. To reduce storage, very coarse grids were used in early grid systems. With this practice, streams were no longer the familar thin lines assumed a few feet in width, but represented as a string of cells of several acres each. This, coupled with the heavy reliance on pen-plotter output, resulted in "ugly, saw-toothed" map products when using grid systems. Recognition of any redeeming qualities of this data form were lost to the unfamilar character of the map product.

Is a Pie Filling Or Crust?

Consideration of areal features present significant theoretical differences between the two data structures. A lake on a water map may be described by its border defined as a series of line segments, or its interior defined by a set of cells identifying open water. This difference has important implications in the assumptions about mapped data. In a line-based system, the lines are assumed to be "real" divisions of geographic space into homogenous units. This assumption is reasonable for most lakes if you accept the premise that the shoreline remains constant. However, if the body of water is a flood-control reservior the shoreline could shift several hundred meters during a single year — a "fat, fuzzy" line would be more realistic. A better example of an ideal line feature is a property boundary. Although these divisions are not physical, they are real and represent indisputable boundaries. One footstep over the line can jeopardize friendships or international treaties.

On the other hand, consider the familar contour map of elevation. The successive contour lines form a series of long skinny polygons. Within each of these polygons the elevation is assumed to be constant—forming a "layer-cake" of flat terraces in 3-dimensional data space. For a few places in the world, such as rice patties in mountainous portions of Korea or the mesas of New Mexico, this may be an accurate portrayal. However, this aggregation of a continuous spatial gradient discards much of the information used in its derivation. An even less clear example of a traditional line-based image is the familar soil map. The careful use of a fine-tipped pen in characterizing the distribution of soils imparts artificial accuracy at best. At worst, it severely limits the potential uses of soil information in a geographic information system. As with most resource and environmental data, a soil map is not "certain", as contrasted with a surveyed and legally filed property map. Rather the distribution of soils are probabilistic— but the lines form artificial boundaries presumed to be the abrupt transition from one soil to another. Throughout each soil polygon, the occurrence of the designated soil is treated as equally likely. Most users of soil maps reluctantly accept the "inviolately accurate" assumption of this data structure, as the alternative is to dig soil pits everywhere within a study area.

What"s Wrong with My Map?...Mapping Uncertainity

A more useful data structure for representing soils is gridded, with each grid location identified by its most probable soil, a statistic indicating how probable, the next most probable soil, its likelihood, and so on. In this context, soils are characterized as statistically continuous gradients, rather than as aggregated, human-compatible images. Such treatment of map information is a radical departure from the traditional cartographic image. It highlights the revolution in spatial information handling brought about by the digital map.

Of Polygons and Cells...

All maps generalize detail over some geographic unit. When do collections of molecules, particles, dirt clods, piles or acres become the units on a soil map? What variablity in composition is tolerated? In GIS, this assumed uniform unit is termed a "point". It is defined as the smallest addressable unit of space and should not be confused with geometry"s definition of a point as having neither length nor width. These points are just the opposite...the smallest addressable areas identifying a map characteristic.

Sets of points form "regions" on an "overlay". For example, a WATER map (formally termed an overlay) is comprised of several different water types (formally termed regions), such as lakes, streams and wetlands. Each lake, stream or wetland is identified as

Beyond Mapping

"It Depends" - Implications of Data Structure

By Joseph K. Berry

The main purpose of a geographic information system is to process spatial information. In doing so it must be capable of four things:

1. *Creation of digitial abstractions of the landscape (encode),*
2. *Efficently handling these data (store),*
3. *Developing new insights into the relationships of spatial variables (analyze) and...*
4. *Creating "human-compatible" summaries of these relationships (display).*

The data structure used for storage has far-reaching implications in how we encode, analyze and display digital maps. The question has fueled heated debate as to the "universal truth" in data structure since the inception of GIS. In truth, there are more similarities than differences in the various approaches.

As discussed in the previous issue, all GISs are "internally referenced" which means they have an automated linkage between the data (or thematic attribute) and the whereabouts (locational attributes) of that data. There are two basic approaches used in describing locational attributes. One approach (vector) uses a collection of line segments to identify the boundaries of point, linear and areal features. The alternative approach (raster) establishes an imaginary grid pattern over a study area, then stores values identifying the map characteristic occurring within each grid space. Although there are significant practical differences in these data structures, the primary theoretical difference is that the grid structure stores information on the interior of areal features, and implies boundaries, whereas the line structure stores information about boundaries, and implies interiors. This fundamental difference determines, for the most part, the types of applications that may be addressed by a particular GIS.

X's, Y's, Rows and Columns

It is important to note that both systems are actually grid-based. It's just in practice that line-oriented systems use a very fine grid of "digitizer" coordinates. Point features, such as springs or wells on a water map, are stored the same for both systems — a single digitizer "x,y" coordinate pair or a single "column,row" cell identifier. Similarly, line features, such as streams on a water map, are stored the same — a series of "x,y" or "column, row" identifiers. If the same gridding resolution is used, there is no theoretical difference between the two referencing schemes, and considering modern storage devices, only minimal practical differences in storage requirements. Yet, it was storage considerations that

Beyond Mapping

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a set of points stored in the GIS... polygons in the line-based structure, or cells in the grid-based structure. It is important to note that both systems are actually polygon-based, it is just in practice that most grid- based systems utilize a regular grid of square polygons (cells). Vector systems could store coordinates identifying the four sides of each cell forming an array of contiguous, uniform polygons. If these polygons are the same size as cells in raster system, there is no theoretical difference between the two referencing schemes and no practical advantage in locational accuracy.

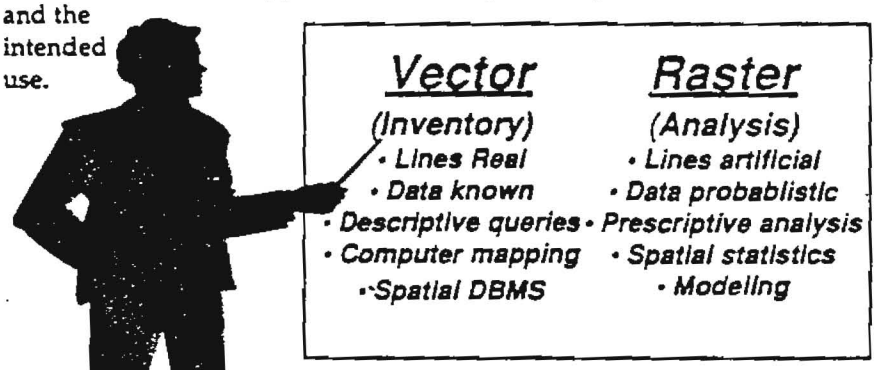
Yet, like storage, spatial precision continued to fuel early debate about the "best" data structure. Course cells did not portray the apparent accuracy in the cuts and jogs of the thin blue line representing a stream on a USGS topographic map. Your experience, however, may have lead you to question this implied accuracy. The same stream is often characterized by the same pen width in both 7 1/2 and 15 minute series of maps — does the stream change width, or just mapping scale? Similarly, if you enlarge the smaller scale map and overlay the two maps, you will notice that many of the cuts and jogs have been "smoothed".

The "Appropriate" Structure Is "Best"

Finally, there isn"t an absolute "best" data structure. It depends. Contemporary hardware and software technology play important roles. However, "absolutes" defined by perceived practical limits are continually shattered. The functions of today"s twenty-six key pocket calculator was the domain of the mainframe computer just two decades ago.

A more enduring comparision of the two data structures is based on their theoretical differences and resulting implications on encoding, storage, analysis and display.

Consider the figure below outlining some of these factors. The dicotomy drawn is the result of the nature of the mapped data and the intended use.



If you are a fire chief, your data consists of surveyed roads, installed fire hydrants and tagged street addresses (lines real and data certain). Whenever a fire is reported, you query the data base to map the route to the fire and report the closest fire hydrants (descriptive application involving computer mapping and spatial data base management).

Contrast this use with that of a resource manager working with maps of soils, vegetation and wildlife habitat (lines artificial and data probabalistic) to identify the optimal timber harvesting schedule for an area (prescriptive application involving spatial statistics and modeling).

The fire chief's application is best solved with a "vector" based data structure considering precise locations with minimal analysis. Think of the consequences of a "raster" data structure in such an application... a .85 probability that a fire hydrant is located in a one-block grid cell. Resource managers, on the other hand, have an entirely different set of problems. Their applications, involving complex analyses and minimal spatial precision are best met with a "raster" structure. Think of the consequences of a "vector" data structure — absolute certainty that a quarter-acre parcel is ponderosa pine on a specific soil. Both results are equally inappropriate. The "best" data structure depends on the nature of the data used in the analysis and the analytic tools required by the application. In the July issue, we will investigate these tradoffs and develop some general guidelines about the implications of data structure in GIS technology.

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BEYOND Mapping

"GIS technology is technical Oz. You're hit with a tornado of new concepts, temporarily hallucinate and come back to yourself a short time later wondering what on earth all those crazy things meant."

(JKB)

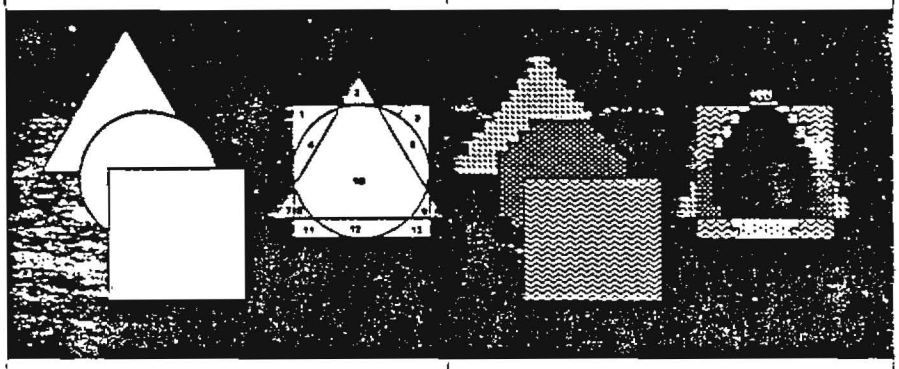
By Joseph K. Berry

As promised (or threatened) in the last issue of *GIS World*, this article continues to investigate the implications of data structure on map analysis. Recall that, first and foremost, maps in a GIS are digital data organized as large sets of numbers, not analog images comprised of inked lines, colors and shadings. Data structure refers to how we organize these numbers — basically as a collection of line segments or as a set of grid cells. Theoretical differences between these two structures arise for storage of polygonal features. Line-based structures store information about polygon boundaries and imply interiors. Cell-based structures do just the opposite, implying boundaries while storing information on interiors. So much for review. What does this imply for map analysis?

In short, which of the two basic approaches is used in processing significantly affects map analysis speed, accuracy and storage requirements. Structure also defines the set of potential analytic "tools" and their algorithms. For example, consider the accompanying figures depicting three simple geometric shapes stored in typical formats of both structures. As noted previously, the vectors describe boundaries around areas assumed to be the same throughout their interiors (figure a). Cells, on the other hand, define the interior of features as groupings of contiguous cells (figure b). The spatial precision of the boundaries is obviously better for the line structure. The "sawtooth" effect in the grid structure is an unreal and undesirable artifact. It's fair to say that the line structure frequently has an advantage in spatial precision and storage efficiency of base maps. Therefore, it is generally better for inventory.

Other differences are apparent during analysis of these data. For example, the composite maps at the bottom of the figure are the result of simply overlaying the three features, one of the basic analytic functions. In the line structure, 17 new polygons are derived, composed of 39 individual line segments. This is a significant increase in the storage requirement for the composite map as compared to any of the simple original maps. But consider the realistic complexity of overlaying a landuse map of several hundred polygons with a soil map of over a thousand. The result is more "son and daughter" polygonal progeny than you would care to count (or most small computers would care to store). On the other hand, the storage requirement for the grid structure can never exceed the maximum dimensionality of the grid, no matter how many input

See Beyond Mapping Page 47



Simple figures illustrating the two GIS data structures, vector (a), and raster or cellular (b), including composite figures of each type.

maps or their complexity. Even more significant are the computational demands involved in splitting and fusing the potentially thousands of line segments forming the new boundaries of the derived map. By contrast, the overlaying of the maps stored in grid structure simply involves direct storage access and matrix addition. It's fair to say that the grid structure frequently has an advantage in computation and storage efficiency of derived maps. Therefore, it is generally better for analysis.

Also, it is fair to say that the relative advantages and disadvantages of the two data structures have not escaped GIS technologists. Database suppliers determine the best format for each variable (USGS uses vector DLG format for all 7.5 minute quadrangle information except elevation, which is in raster DEM format). Most vendors provide conversion routines for transferring data between vector and raster. Many provide "schizophrenic" systems with both a vector and a raster processing side. Some have developed specialized data structure offshoots, such as "rasterized lines, quadtrees and TIN." In each instance, careful consideration is made to the nature of the data, processing considerations and the intended use — it depends.

Another concern is the data characteristics derived in map analysis. In the case of line structure, each derived polygon is assumed to be accurately defined — precise intersection of real

Continued Next Page

boundaries surrounding a uniform geographic distribution of data. This is true for overlaying a property map with a zip code map, but a limiting assumption for probabalistic resource data, such as soils and landcover, as well as gradient data, such as topographic relief and weather maps. For example, recall the geographic search (overlay) for areas of cohassett soil, moderate slope and ponderosa pine forest cover described in the first article of this series. A line-based system generates an "image" of the intersections of the specified polygons. Each derived polygon is assumed to locate the precisely defined combinations of the variables. In addition, the likelihood of actual occurrence is assumed to be the same for all of the polygonal progeny, even small slivers formed by intersecting edges of the input polygons.

A grid-oriented system calculates the coincidence of variables at each cell location as if each were an individual "polygon." Since these polygons are organized as a consistent, uniform grid, the calculations simply involve storage retneval and numeric evaluation, not geometric calculations for intersecting lines. In addition, if an estimate of error is available for each variable at each cell, the value assigned as a function of these data also can indicate the most likely composition (coincidence) of the variables — "There is an 80 percent chance that this hectare is cohassett soil, moderately sloped and ponderosa pine covered." The result is a digital map of the derived variable, expressed as a geographic distribution, plus its likelihood of error (a sort of "shadow" map of certainty of result). This concept, termed "error propagation" modeling, is admittedly an unfamiliar and, likely, an uncomfortable one.

It is but one of the gusts in the GIS whirlwind that is taking us beyond mapping. Others include drastically modified techniques, such as weighted distance measurement (a sort of rubber ruler), and entirely new procedures, such as optimal path density analysis (identifying the n-th best route). These new analytic concepts and constructs will be the focus of future articles.

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APPENDIX D - SURVEY RESULTS

GIS QUESTIONNAIRE

		YES	NO
1.	Do you use a computer in your office?	81	3
2.	Do you use your computer for word processing only?	11	72
3.	Do you record spatial information on base maps?	56	27
4.	Do you keep files of information related to the spatial information on the maps?	64	17
5.	Do you use a database management system on your computer to store information?	67	17
6.	Do you use GIS at your office?	30	53
7.	Do you use GIS through another office or agency?	33	49
8.	Would your office use a GIS if it were available?	69	3
9.	Do you think a GIS would be applicable to your everyday responsibilities?	74	6
10.	Do you think a GIS would be useful for specific projects?	81	1
11.	Should the Service have a GIS strategy?	74	3
12.	Should the Service form a GIS task force?	57	12
13.	Would you participate in a GIS task force?	39	31
14.	Should the Service have a GIS conference yearly?	54	10
15.	Should GIS support be centralized within the Service?	43	26

APPENDIX A - LIST OF PARTICIPANTS

AS OF JUNE 20, 1990

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FISH & WILDLIFE ENHANCEMENT
P O BOX 25486, DEN FED CTR
DENVER, CO 80225
303-236-8166

19. BARBARA BOYLE
U.S.FISH & WILDLIFE SERVICE
1011 E. TUDOR RD.
ANCHORAGE, AK 99503
907-786-3324

20. MARTY BRAY
LOWER RIO GRANDE VALLEY
ROUTE 2 BOX 202A
ALAMO, TX 78516
512-787-3079

21. WILLIAM T. BROOKS
US FISH AND WILDLIFE SERVICE
1849 "C" STREET NW, ROOM 340
ARLINGTON SQUARE
WASHINGTON, DC 20240
703-358-1729

22. DAWN BROWNNE
USFWS/NERC
4512 MCMURRAY
FORT COLLINS, CO 80525
303-226-9100

23. BART BUTTERFIELD
ID COOP WILDLIFE RESEARCH UNIT
UNIVERSITY OF IDAHO
MOSCOW, ID 83843
208-8B5-6336

24. JEREMIAS A. CARRERA
PACIFIC ISLAND ENGINEEERS, INC
POST OFFICE BOX 6085
TAMUNING, 96911
GUAM
9011671-637-5550

25. LARRY C. COE
FISH AND WILDLIFE SERVICE
REALTY
POST OFFICE BOX 1306
ALBUQUERQUE, NM 87103-1306
505-766-2174

26. RAYMOND CORNING
US FISH AND WILDLIFE SERVICE
1011 EAST TUDOR
ANCHORAGE, AK 99503
907-786-3474

27. LEWIS M. COWARDIN
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N PRAIRIE WILDLIFE RESEARCH CT
BOX 2096
JAMESTOWN, ND 58402

28. DOUG CROWE
US FISH AND WILDLIFE SERVICE
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WASHINGTON, DC 20006

29. LLOYD CULP
US FISH AND WILDLIFE SERVICE
GREAT DISMAL SWAMP NAT REFUGE
POST OFFICE BOX 349
SUFFOLK, VA 23434
804-986-3706

30. LESLIE L. CUNNINGHAM
REGION 2, ALBUQUERQUE
8604 GREENARBOR ROAD NE
ALBUQUERQUE, NM 87122
505-828-0179

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32. KATHY DAVIS
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1405 SO. HARRISON RD.
EAST LANSING, MI 48906
517-337-6652

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WYO.DEPT.GAME & FISH
DIV.ENVIRON.SERVICES
5400 BISHOP BLVD.
CHEYENNE, WY 82006
307-777-4515

36. JOSEPH J. DOWHAN
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NORTHEAST ESTUARY OFFICE
BOX 307
CHARLESTOWN, RI 02813
401-364-9124

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PORTLAND, OR 57232-4181
503-231-6230

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FORT COLLINS, CO 80525
303-226-9100

39. DEBORAH FINCH
ROCKY MTN. FOREST & RANGE EXP.
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LARAMIE, WY 82070
307-742-6621

40. JOHN FOSTER
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P.O.BOX 110
LEWISTOWN, MT 59457
406-538-8706

41. RALPH FRIES
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LAKEWOOD, CO 80228
303-236-8152

42. JIM GARNER
COLORADO DIVISION OF WILDLIFE
2300 SOUTH TOWNSEND AVE.
MONTROSE, CO 81401
249-3431

43. DALE GARRISON
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44. DAVID GILBERT
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46. TOM GOETTEL
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50. THEODORE W. GUTZKE
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51. MICHAEL HAWKES
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COMMERCE CITY, CO 80022-2180
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USFWS/NAT WETLANDS INVENTORY
MONROE BUILDING SUITE 101
9720 EXECUTIVE CENTER DRIVE
ST PETERSBURG, FL 33702
813-893-3138

97. LARRY ROBINSON
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106. RON STARKEY
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APPENDIX B - POSTER PRESENTATIONS

Capturing Data for a GIS: Pool 13 of the Upper Mississippi River System. Presented by Tom Owens, TGS Technology, Inc., National Ecology Research Center, Fort Collins, Colorado.

Utilizing Geographic Information Systems in Aquatic Resource Management. Presented by Anita Bailey, Tennessee Cooperative Fish and Wildlife Research Unit, Tennessee Technological University, Cookeville, Tennessee.

Remote Sensing for Land Inventories in Region 7. Presented by Gerald Minick, Information Resources Management, Anchorage, Alaska.

U.S. Fish and Wildlife Service GIS Activities in Alaska. Presented by Barbara Boyle, Information Resources Management, Anchorage, Alaska.

GIS at Charles M. Russell National Wildlife Refuge. Presented by Randy Matchett, Charles M. Russell National Wildlife Refuge, Lewistown, Montana.

National Wetlands Inventory Map Products. Presented by Herman Robinson, National Wetlands Inventory, St. Petersburg, Florida.

Use of GIS for Research and Management at Loxahatchee National Wildlife Refuge. Presented by Mark Maffei, Loxahatchee National Wildlife Refuge, Boynton Beach, Florida.

Mapinfo Demonstration. Presented by Bruce Tepley, TGS Technology, Inc., National Ecology Research Center, Fort Collins, Colorado.

PC Swans Data Base. Presented by Barry Dearborn, Information Resources Management, Anchorage, Alaska.

GIS Analysis of Wetland Habitats within the San Francisco Bay Area. Presented by Gregory Martin and Lawrence R. Handley, National Wetlands Research Center, Slidell, Louisiana.

Concept Plan for Waterfowl Habitat Protection in San Francisco Bay, California. Presented by Chuck Houghten, Refuges, Sacramento, California.

Kesterson Reservoir Selenium Contaminant Level Analysis. Presented by Chuck Houghten, Refuges, Sacramento, California.

Caribou Tracking. Presented by Chris Robbins, Alaska Fish and Wildlife Research Center, Anchorage, Alaska.

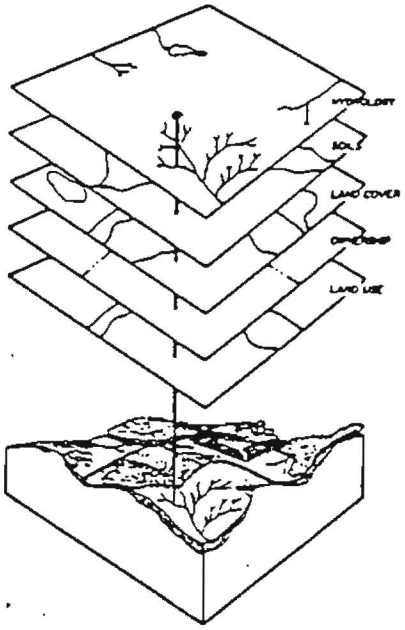
Color Map Products from U.S. Fish and Wildlife Service GIS Applications Completed at the National Ecology Research Center. Presented by Bob Waltermire, TGS Technology, Inc., National Ecology Research Center, Fort Collins, Colorado.

APPENDIX C - TRAINING SESSION

MAPS AS DATA: COMPUTER-ASSISTED MAP ANALYSIS

Management, Mapping and Analysis
for Geographic Infromation systems (GIS)

Special Introductory Workshop
for
US Fish and Wildllfe Service
Fort Collins, Colorado
June 4, 1990



Prepared by
Joseph K. Berry

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Fort Collins, Colorado 80523
(303) 490-2155

Materials prepared in cooperation with
Spatial Information Systems, Inc.
6907 Sprouse Court
Springfield, Virginia 22153

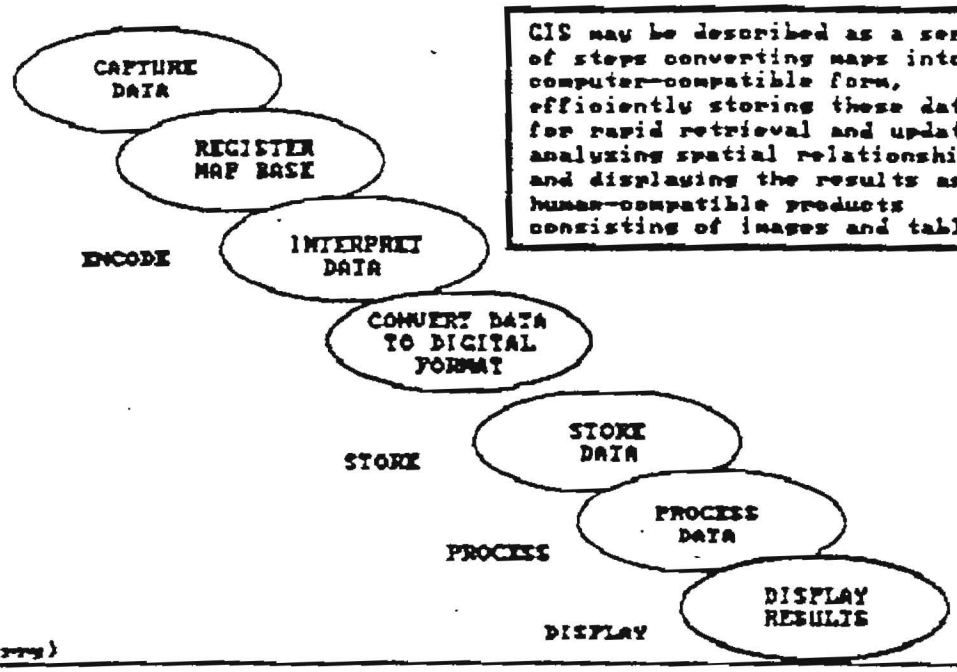
WHAT IS GIS?

- a tool to create and update maps
- a technology for combining and interpreting maps
- a revolution in map structure, content and use

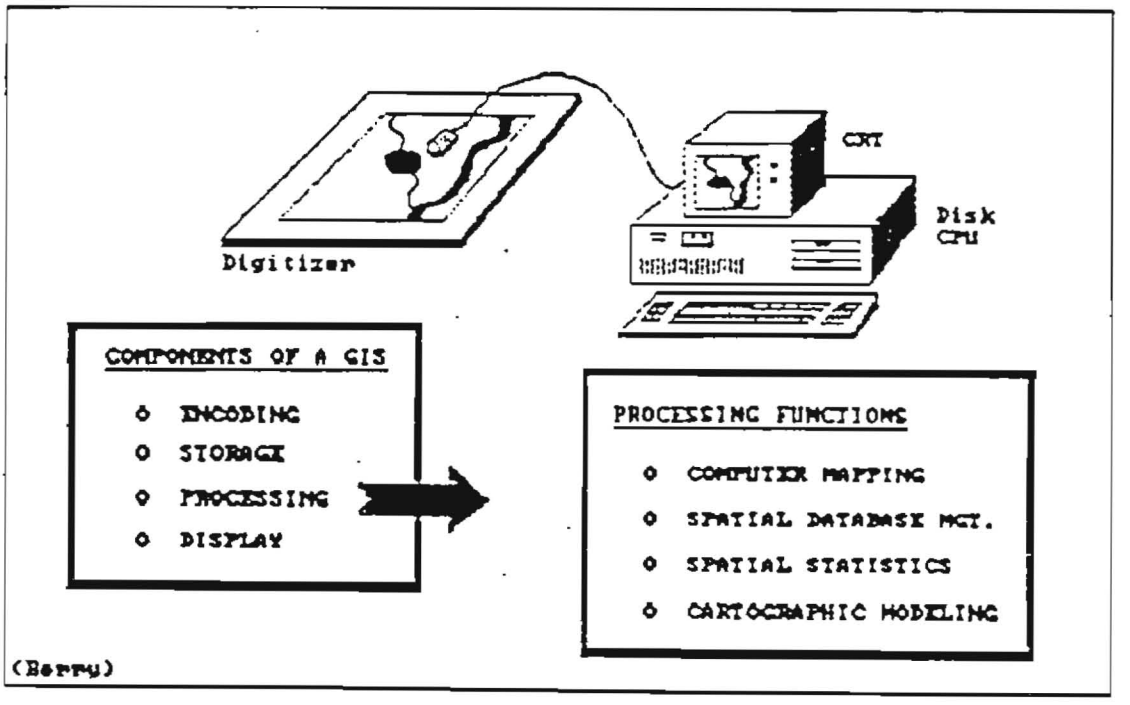
... GIS may be described by its process, data structure and analytical functions.

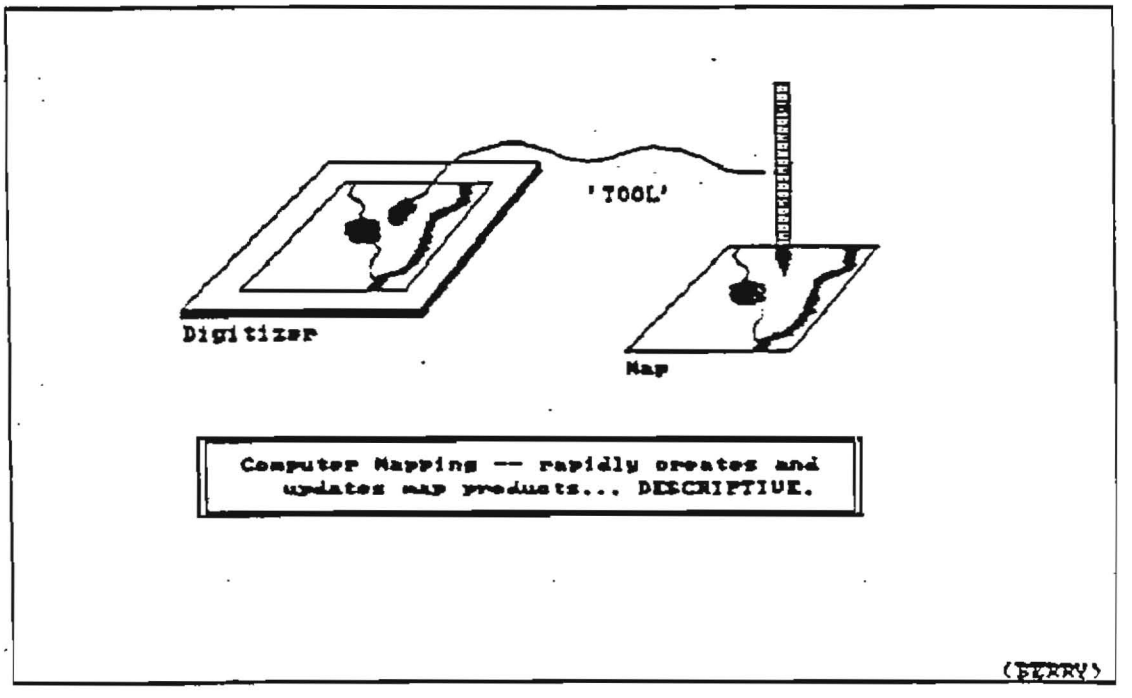
(BERRY)

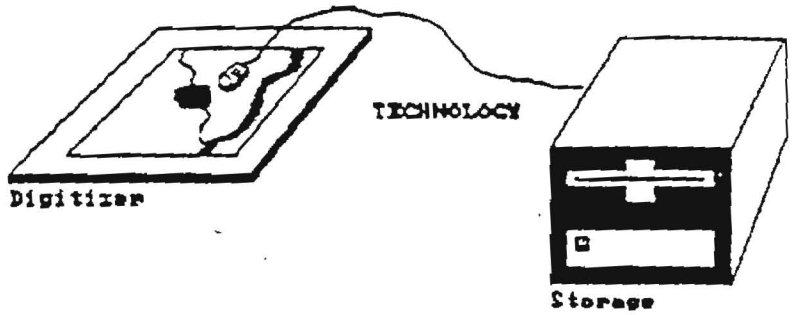
GIS may be described as a series of steps converting maps into computer-compatible form, efficiently storing these data for rapid retrieval and updating, analyzing spatial relationships, and displaying the results as human-compatible products consisting of images and tables.



(Berry)


CRT
Disk
CPU
Digitizer
COMPONENTS OF A GIS
o ENCODING
o STORAGE
o PROCESSING
o DISPLAY
PROCESSING FUNCTIONS
o COMPUTER MAPPING
o SPATIAL DATABASE MGT.
o SPATIAL STATISTICS
o CARTOGRAPHIC MODELING
(Berry)

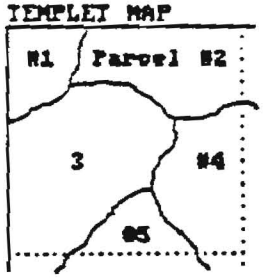

'TOOL'
Digitizer
Map
Computer Mapping -- rapidly creates and updates map products... DESCRIPTIVE.
(BERRY)



Spatial Data Base Management -- combines and interprets mapped data... DESCRIPTIVE AND INTERPRETIVE.

(BERRY)

TEMPLET MAP



'Map Compartments'

A data base can be 'searched' for for map compartments with certain requirements (large, old, ponderosa pine stands on Cohassett soil) then a map produced locating these areas.

LOCATIONAL ATTRIBUTE

WHERE

WHAT

THEMATIC ATTRIBUTE

'Data Fields'

DATA BASE

ID	SIZE	COVER	SOIL	AGE	ETC.
#1	65	MDW	ALU	3	-
#2	123	PP	COH	68	-
#3	296	PP	SRP	55	-
#4	119	DF	COH	5	-
#5	67	PP	SRP	55	-
#6	-	-			

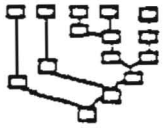
Templet maps can be 'summarized' for typical characteristics (average slope for each mapping compartment) and a new field added to the data base

(BERRY)

Digitizer

REVOLUTION

$\hat{Y} = fn(\text{species, age, soil} \ldots)$
$= b_0 + b_1X_1 + b_2X_2 + \ldots$

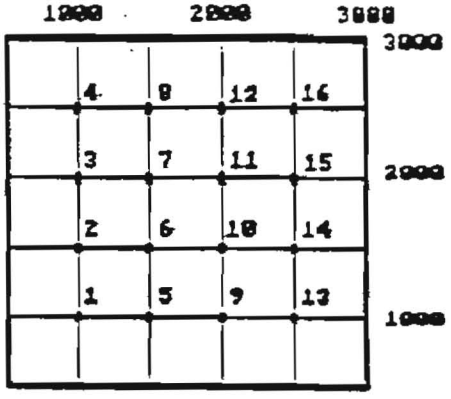


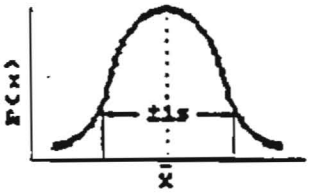
Spatial Models

GIS is 'spatial statistics and mathematics', allowing users to model complex resource and environmental systems...PRESCRIPTIVE.

(BERRY)

Sensor	X	Y	Period1	Period2
1	1000	1000	11	4
2	1000	1500	19	9
3	1000	2000	8	8
4	1000	2500	9	9
5	1500	1000	27	25
6	1500	1500	12	2
7	1500	2000	14	4
8	1500	2500	2	8
9	2000	1000	10	6
10	2000	1500	17	22
11	2000	2000	34	43
12	2000	2500	22	33
13	2500	1000	20	16
14	2500	1500	29	43
15	2500	2000	42	87
16	2500	2500	34	68
	TOTAL		300	361
	AVERAGE		18.8	22.6
	STD.DEV.		+11.9	+26.2





NUMERIC SPACE

Traditional statistics analyse data in 'numeric space' by fitting density functions (such as the standard normal curve, shown at the left) to the data. The objective of this procedure is to identify the central tendency or typical response. The standard deviation indicates how good this general estimate is.

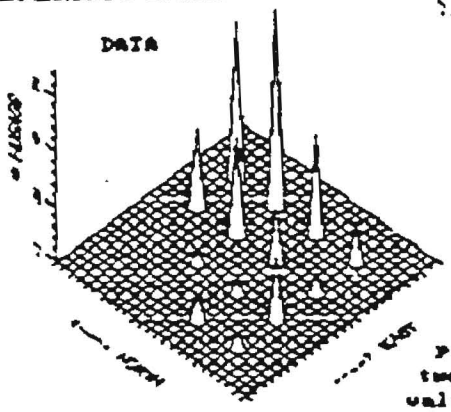
(Berry)

(Berry)

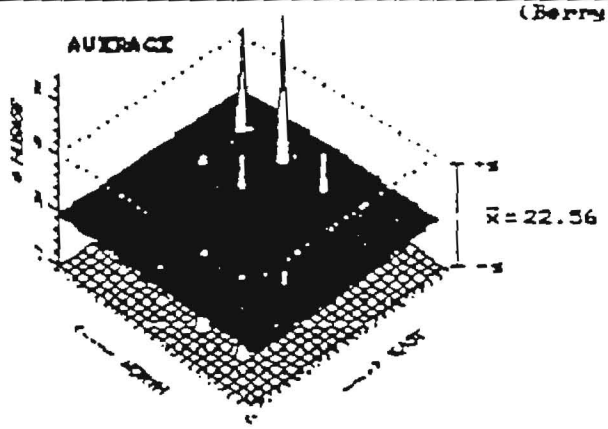
Data indicating animal activity were collected at sixteen locations as shown below. The 'height' indicates the number of encounters, varying from 8 in the northwest to 87 in the northeast portion.

GEOGRAPHIC SPACE

DATA



AVERAGE

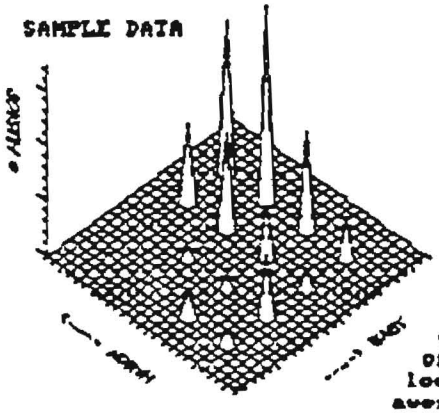


Traditional statistics identify the 'typical' response (average= 22.56 encounters) and assumes this is uniformally distributed in space ...expect 22.56 everywhere ± 26.2. The average represents a horizontal plane with the standard deviation as two additional planes with the likely value within this range.

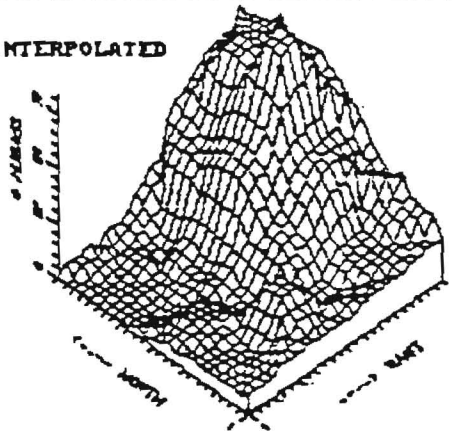
(Berry)

Spatial statistics involve characterizing the geographic distribution of variables.

SAMPLE DATA



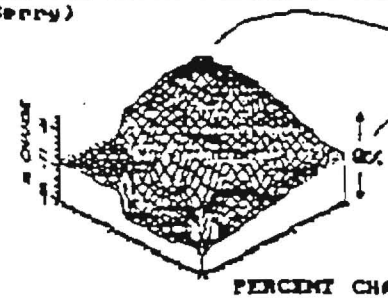
INTERPOLATED

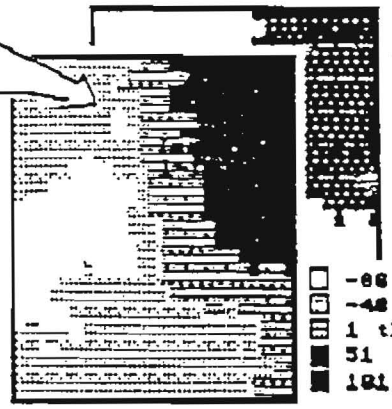


INTERPOLATE DATA CONTINUOUSLY USING 6 WITHIN 35 FOR INTERP

The interpolated surface was created by calculating the 'distance weighted average' of nearby sample data. Values closer to the location being interpolated influence the average more than values further away.

(Berry)





■ Big Increase In Activity

Areas of big increases are isolated from percent change map...

□ -88 thru -49
□ -48 thru 0%
□ 1 thru 50
■ 51 thru 100
■ 101 thru 105

```
RENUMBER %CHANGE-MAP
 ASSIGN 0 TO -88 THRU 49
 ASSIGN 1 TO 50 THRU 105
 FOR BIGINCREASE
CROSSTAB BIGINCREASE WITH COVERTYPE
```

Coincidence Table For Map1 = BIGINCREASE
With Map2 = COVERTYPE

Map1 Value	# of Cells	Label	Map2 Value	# of Cells	Label	# of Cross
0	459	NOT SO BIG	1	82	LAKE	82
0	459	NOT SO BIG	2	221	MEADOW	217
0	459	NOT SO BIG	3	322	FOREST	160
1	166	BIG INCREASE	2	221	MEADOW	4
1	166	BIG INCREASE	3	322	FOREST	162

...then compared with other maps to determine the spatial relationship (coincidence). Note that 164 of the 166 ha. of big increase occurs in forested areas.

MAP FEATURES-- maps are abstractions of the landscape formed by the unique pattern of...

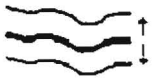
POINTS-- Dimensionless (e.g. wells)

LINES-- Length (e.g. streams)

AREAS-- L x Width (e.g. lakes)

VOLUMES-- L x W x Depth (e.g. lakes)

HYPER-VOLUMES-- L x W x D x Time (e.g. reservoirs)

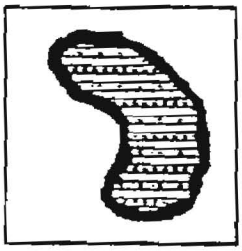


'FUZZY THEORY'-- uncertainity of feature's true shape

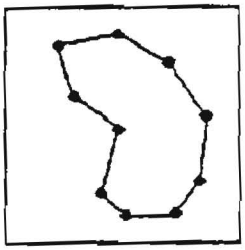
(Berry)

(BERRY)

REAL WORLD

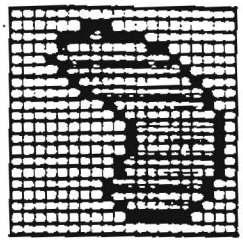


VECTOR



'Boundaries'

RASTER



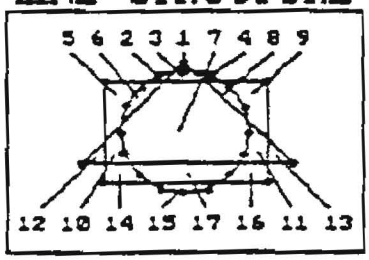
'Interiors'

Data Structures -- Vector format stores features as a series of lines. Raster format stores features as a set of cells.

(x,y) VECTOR = RASTER (col, row)

POLYGON = CELL

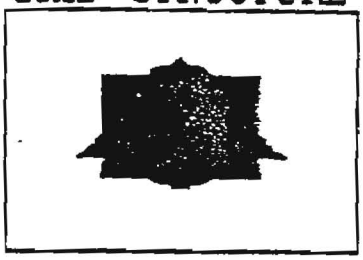
LINE STRUCTURE



Theoretically the same for both LINE and POINT features

... different for AREAL features

GRID STRUCTURE



GIS

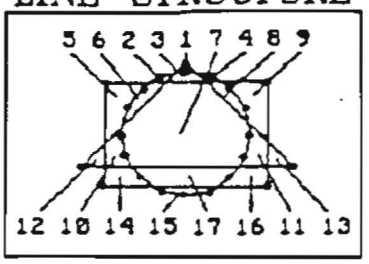
INVENTORY | ANALYSIS

- LINES REAL
- DATA CERTAIN
- DESCRIPTIVE
- MAPPING
- DATABASE MANAGEMENT

- LINES ARTIFICIAL
- DATA PROBALISTIC
- PRESCRIPTIVE
- STATISTICS
- MODELING

(Berry)

LINE STRUCTURE



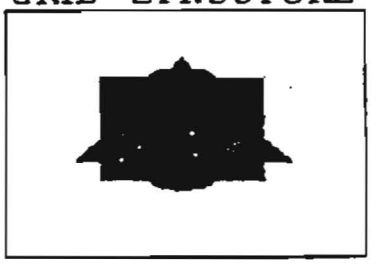
'Boundaries'

Line Intersections

ADVANTAGES Inventory
- High Spatial Precision
- Low Initial Storage

DISADVANTAGES Analysis
- Compute Heavy
- Expodential Storage

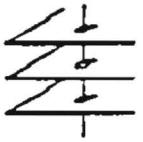
GRID STRUCTURE



'Interiors'

—1—2—4—

Storage Numbers



DISADVANTAGES Inventory
- Low Spatial Precision
- High Initial Storage

ADVANTAGES Analysis
- Compute Easy
- Constant Storage

SPATIAL TOPOLOGY -- Relationships Among Map Features

IMAGE	DESCRIPTIVE
DATA	INTERPRETIVE
RELATIONSHIPS	PRESCRIPTIVE
INFORMATION	

Increasing topology...

more and more information stored or derived in the system

- o STORED
- o DERIVED

- o GRAPHICS -- On/Off Dots
  'Painting'
- o MAPPING -- Connect-the-Dots
  'CAD-CAM'
- o SPATIAL DBMS -- Connect the Dots to Records
  'Thematic Mapping'
- o GIS -- Connect the Dots to Records and Concepts
  'Analysis'

(Berry)

ANALYTIC FUNCTIONS -- all GIS processing involves changing values (numbers) on a map(s) as a mathematical or statistical function of values on thatmap or another map(s).

RECLASSIFYING MAPS -- 'Recoloring'

Newmap values a function of values on a single existing map; no new spatial information is created.

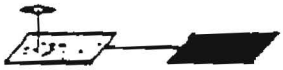
OVERLAYING MAPS -- 'Light-Table Gymnastics'

Newmap values a function of values on two or more existing maps; new spatial information is created.

MEASURING DISTANCE -- 'Rubber Rulers'

Newmap values a function of the simple or weighted distance or connectivity among features.

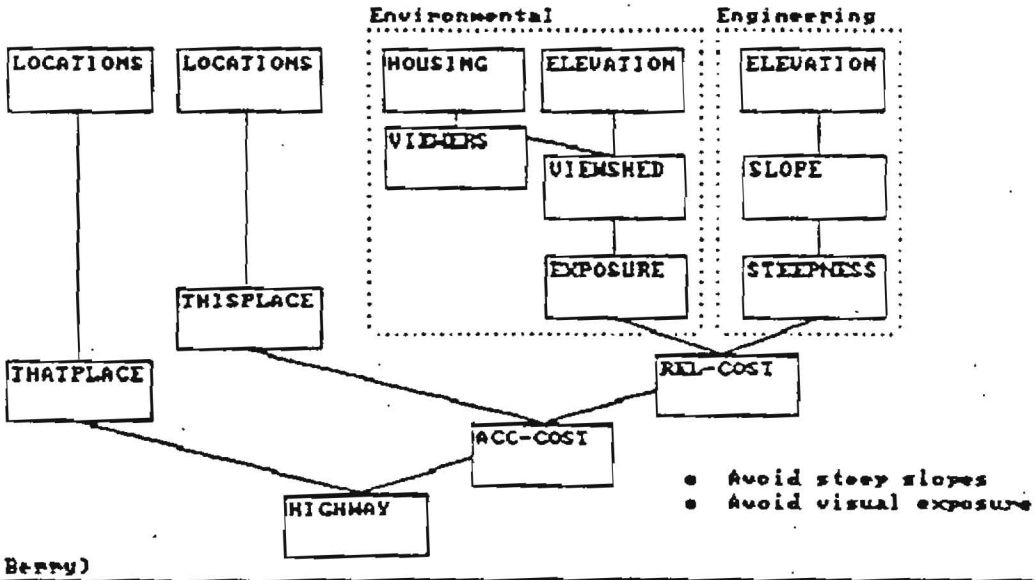
NEIGHBORHOOD CHARACTERIZATION -- 'Moving Windows'



Newmap values a function of the values within the vicinity of a location on an existing map.

(Berry)

HIGHWAY SITING MODEL -- Flowchart



- Avoid steep slopes
- Avoid visual exposure

(Berry)

Beyond Mapping

Maps As Data - *"Map-ematics"?*

By Joseph K. Berry

Old Proverb: A picture is worth a thousand words.

New Proverb: A map is worth a thousand numbers...maybe more.

Our historical perspective of maps is one of accurate location of physical features primarily for travel through unfamiliar areas. Early explorers used them to avoid angry serpents, alluring sirens and even the edge of the earth. The mapping process evokes images of map sheets, and drafting aids such as pens, rub-on shading, rulers, planimeters, dot grids, and acetate transparencies for light-table overlays. From this perspective, maps are analog mediums composed of lines, colors and symbols that are manually created and analyzed. Since manual analysis is difficult and limited, the focus of the analog map and manual processing has been descriptive... recording the occurrence and distribution of features.

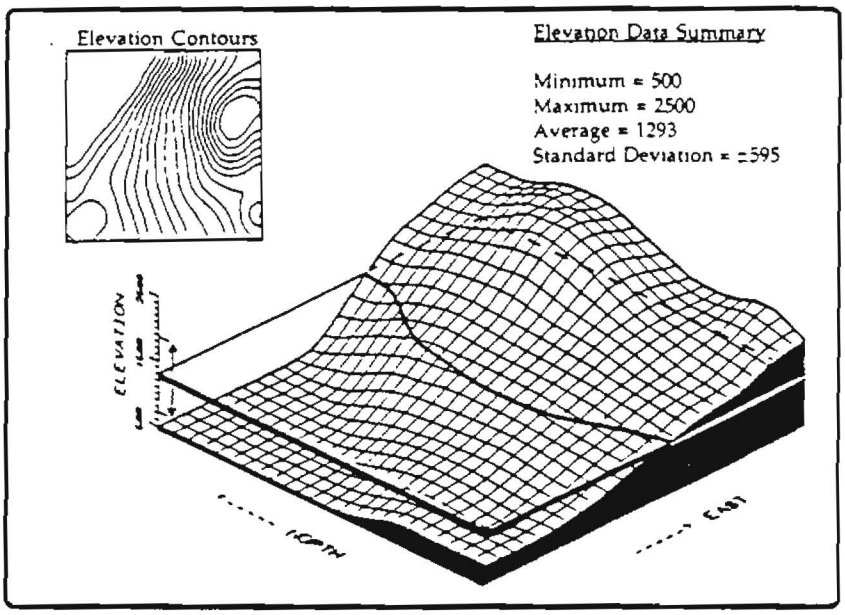
More recently, the analysis of mapped data has become an integral part of resource and land planning. By the 1960's, manual procedures for overlaying maps were common. These techniques marked a turning point in the use of maps, from techniques which emphasized the physical descriptors of geographic space, to those which could spatially characterize management actions. This movement from descriptive to prescriptive mapping set the stage for modern computer-assisted map analysis.

Since the 1960's, decision-making has become much more quantitative. Mathematical models for non-spatial analyses are commonplace. However, the tremendous volume of data used in spatial analysis limits the application of traditional statistics and mathematics to spatial models. Non-spatial procedures require that maps be generalized to typical values before they can be used. Thus, the spatial detail for large areas are often reduced to a single value expressing the central tendency of a variable at that location, a tremendous reduction in information from the spatial specificity in the original map.

Recognition of this problem led to the stratification of regions at the beginning of the study by dividing geographic space into assumed homogeneous sampling parcels. Heated debates often arise as to whether a normal, binomial, or Poisson distribution best characterizes the typical values in numeric space. However, relatively little attention is typically given to the broad assumption that this value must be presumed to be uniformly distributed in geographic space. The area-weighted average of several parcels' typical values is used to statistically characterize an entire study area. Mathematical modeling of spatial systems has followed an approach similar to that of spatial statistics, aggregating

Beyond Mapping

(continued from page 8)



spatial variation into model variables. Most ecosystem models, for example, define 'level' and 'flow' variables which are presumed to be typical for vast geographic expanses.

However, maps actually map the details of spatial variation. Manual cartographic techniques allow manipulation of these detailed data, yet they are fundamentally limited by their non-digital nature. Traditional statistics and mathematics are digital, yet they are fundamentally limited by their generalization of the data. This dichotomy has led to the revolutionary concepts of map structure, content and use which form the foundation of GIS technology. It radically changes our perspective. Maps move from analog images describing the locations of features to geographically-referenced digital data quantifying a physical, social or economic system in prescriptive terms.

This revolution is founded in the recognition of the digital nature of computerized maps...maps as data, maps as numbers. To illustrate, consider the accompanying figure. The upper left inset is a typical topographic map. One hundred-foot contour lines show the pattern of the elevation gradient over the area. The human eye quickly assesses the flat areas, the steep areas, the peaks and the depressions. However, in this form, the elevation information is incompatible with any quantitative model requiring input of this variable. Traditional statistics can be used to generalize the elevation gradient as shown in the table in the upper right. We note that the elevation ranges from 500 to 2500 feet with an average of 1293 feet. The standard deviation of ±595 feet tells us how typical this average is... most often(about two-thirds of the time), we would expect to encounter elevations from 698 to 1888 feet. But where would I expect higher or lower elevations? The statistic offers no insight. Only that the larger the variation, the less typical is the average... the smaller the better. In this instance, it's not very good, as the standard deviation is nearly half the mean (coefficient of variation= .46).

The larger centered inset is a 3-dimensional plot of the elevation data. The gridded data contains an estimate of the elevation at each hectare throughout the area. In this form, your eye sees the variability in the terrain, the flat area in the NW, the highlands in the NE. For contrast, the average elevation is represented as the horizontal plane intersecting the surface at 1293 feet. Its standard deviation can be conceptualized as two additional planes 'floating' ±595 feet above and below the average plane (arrows along the 'Z' axis). A non-spatial model must assume the actual elevation for any parcel is somewhere between these variation planes, most likely about 1293 feet.

But your eye notes that the eastern portion is above the mean, while the western portion is below. The digital representation stored in a GIS maps this variation in quantitative terms. Thus the average and variance provide conceptual linkages between spatial and non-spatial data. The regional average used in traditional statistics reduces the complexity of geographic space to a single value. Spatial statistics retain this complexity by depicting it on a map of the variation in the data. Thus, a regionalized plane represents the mean, and is contrasted with the continuously varying surface which represents the variance.

In computer-assisted map analysis all maps are viewed as a set of ordered numbers. These numbers have numerical significance, as well as conventional spatial positioning information. It is the numerical attribute of GIS maps that fuels the concepts of "map-ematics" For example, the first derivative of the elevation surface in the figure creates a slope map. The second derivative, creates a terrain roughness map (where slope is changing). An aspect map (azimuthal orientation) indicates the direction of terrain slope at each hectare

Beyond Mapping

(continued from page 34)

parcel. But what if the figure wasn't mapping elevation— rather the concentration of an environmental variable, such as lake temperatures or soil concentrations of lead? For lake temperatures, the first derivative would map the rate of temperature change. The aspect map would indicate the direction of change throughout the lake. For lead concentrations, the first derivative would map the rate of change in concentration, and the second derivative (change in the rate change in concentration) could provide information about multiple sources of lead pollution or abrupt changes in seasonal wind patterns. The aspect map of lead concentrations would indicate the direction of change in concentration. If the figure were a cost surface, the first derivative maps marginal cost; the aspect map indicates direction of minimal cost movement throughout the area. If it were a travel-time surface, the first derivative maps the reciprocal of speed, the second, the reciprocal of acceleration, and the aspect map indicates optimal movement through each parcel.

This quantitative treatment of maps is the subject of this series in *GIS WORLD*. We will investigate data structures, error assessment, measuring effective distance, establishing optimal paths and visual connectivity, spatial interpolation, and linking spatial and non-spatial data. The foundation for these new analytic capabilities is the digital nature of maps in a GIS...a map is indeed worth a thousand numbers...often more.

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APPENDIX E - FACILITATED WORKSHOP REPORT

GROUP ONE

INTERNAL STRENGTHS

GROUP ONE MEMBERS:

Randy Matchett
Frank D'Erchia
Greg McClellan
Larry Coe
Bob Howard

Joe Reinman
Doug Robertson
Barry Dearborn
Mike DeCapita
Charles Ault

Michael Long
Peg Margosian
Susan Klugman
Bruce Bell

APPLICATION

1. Broadly applicable
2. Do our jobs better. Improve resource management.
3. Monitors change.
4. Encourage cooperation between and among other agencies.
5. Time and opportunity to complete project. Not many time constraints.

MANAGEMENT SUPPORT

1. FWS mission.
2. Commitment.
3. Modernize FWS. Put FWS on equal footing with other agencies.
4. Pro-computer administration (such as it is).
5. New directives and support reissues (e.g., wetlands, global warming, etc.).
6. New way of thinking may lead to better way of doing business.
7. Open-minded director.
8. First annual GIS workshop.
9. Current public interest.

SUPPORT

1. Region 7 has active branch of GIS under IRM.
2. NERC poised and in place to provide support to national GIS system.
3. Knowledge exists to implement GIS.
4. Knowledge base.
5. NERC/other support.
6. Success of past applications.
7. Positive public image.
8. Computer literacy.
9. Belief in computer technology.
10. Existing systems to build from or use as examples.
11. FWS training facilities.
12. Training.

IMAGE

1. Many applications to apply GIS to.
2. Researchers interested in developing applications.
3. Effective communication tool for complex subjects.
4. Flashy output.
5. Legitimize presentations to public.
6. Saves times and money in some cases (make impossible tasks doable).
7. Reputation to maintain.
8. Assist managers in making better informed decisions.
9. A number of needs demonstrated for Service applications of GIS.

STAFF

1. A strong commitment of a segment of Service to implement GIS.
2. Several intelligent hard-working dedicated people.
3. Professionalism.
4. Comradary.
5. Dedicated staff.
6. Open to new ideas.
7. Dedication to resource.
8. Dedicated personnel.
9. Region 7 IRM.
10. Resource expertise.
11. Some data already available.
12. Personnel.
13. Resourceful personnel.
14. Staff education.

- How to improve access to quality GIS training?
- How to increase user/administrative accountability of adoption and application of GIS?
- How to provide employee incentives?

<u>Dedicated Staff</u>

A. Strengths:

- Knowledgeable expertise
- Region 7 - Division of GIS (Staff-5)
- Users
- Commitment

B. Weaknesses:

- Poor training
- Poor peer interaction
- Management commitment
- Can't get resources
- Collateral duty
- Low pay
- No enough people
- No reason to stay with FWS

C. Results:

- Losing people
- Decreased morale
- Lack of progress
- Not competitive in GIS field
- Poor "public" interest
- Not attracting "right" people
- Resource loses/loss
- Lost productivity
- Uniformed decisions

How to increase the budget for GIS?

- Cost/benefit analysis
- Tie to initiatives
- Show resource benefits
- Write strong budget thrust
- Document need
- Lobby conservation coalitions
- Implementation plan

How to maintain/increase numbers of dedicated staff?

- More pay
- Better training
- Commitment to support use of GIS
- GIS branch
- More/better communication
- More FTEs/support contract
- Career ladder for GIS
- OPM (Office of Personnel Management)

How to increase administration/user awareness of need for GIS?

- Work GIS into project planning
- Show success stories
- Conference/seminar for Regional Directors
- Show and tell demonstrations
- Resource related results
- Executive training
- Write memoranda
- Needs assessment
- Political lobbying
- Outside power
- Comparison to other agencies and powers

Support

- Training - minimal
- Access
- Cost
- Budget
- Management commitment
- Communication

Strengths

- Training
- NERC
- Region 7
- On the job, informal
- Expertise
- Workshop

Support

- NERC
- Region 7, 6, 3

How to solve problem (improve strengths)

Mission

Need FWS goal

- In place (FWS mission statement)
- Directorate support
- GIS an effective proven tool

Image

- Public
- Other agencies
- Congressional
- International

GROUP TWO

EXTERNAL STRENGTHS

GROUP TWO MEMBERS:

Jim Gropper
Peggy Prigge
Bob Waltermire
Barb Boyle
Dale Garrison
Bob Ducret
Jim Andreasen
Deb Southworth
Gene Mack
Diane Schneider
Barb White
Elizabeth Block
Bruce Thompson

TECHNOLOGY

1. Conservativeness of FWS in general.
2. Behind in technology.
3. Fear of new technology (scattered - all levels).
4. Techno-phobia.
5. Fear of technology.

LEADERSHIP

1. Subject to capture by kingdom builders.
2. Lack of centralized leadership.
3. Poor leadership.
4. Lack of communication.
5. Trust.
6. Political ineptness.
7. Strong regions - lack of centralized authority.
8. No program or project coordination - all levels.
9. Lack of focus for needs identified at the "bottom" level.
10. No direction.
11. Internal competition vs. cooperation.
12. No set goals.
13. Turf problems.
14. Level of cynicism amongst old timers who discount validity, application and importance of GIS.
15. Lack of roles and responsibilities.
16. Lack of leadership.
17. Mid-level opposition to GIS.
18. No overall national GIS plan.
19. Limits decision options by showing real data.
20. Other duties as assigned (interface by other work to concentrate on GIS duties).
21. No well-defined longterm goals.
22. Management politics supersedes resource needs.
23. Lack of management support at all levels.
24. Lack of supervisor support.
25. Management wastes time questioning tools (GIS, need for computer) vs. concentrating on resources.
26. Lousy upper and middle level managers.
27. Every person for themselves mentally - poor teamwork.
28. Inertia of top leaders (R.N. Smith).
29. Communications between division reference fish research.
30. Lack of management direction.
31. Ineffective at selling our program - mission.

TRAINING

1. Inattention to training.
2. Lack of training opportunities.
3. Lack of understanding of long-term commitment to maintain database.
4. Lack of computer expertise in offices.
5. Lack of understanding of time needed to develop database.
6. Lack of awareness or knowledge.
7. Lack of "trained" personnel.
8. Long learning curve.
9. Ignorance.

HIRING

1. Poor people management.
2. Poor hiring practices.
3. Lack of FTEs.
4. Personnel very dispersed.

BUREAUCRACY

1. Don't know how to work the bureaucratic system.
2. Paperwork.
3. Bureaucratic "crap."
4. Ambiguous contract regulations.
5. Poor organization of programs.
6. Cumbersome organization from top-down.
7. Inability to follow thru.
8. Lack of adequate planning.

BUDGET

1. Funding obstacles.
2. Funding (personnel and tools).
3. Lack of money.
4. Budget process in FWS and DOI.
5. Budget process.
6. Budget relatively limited.
7. Concentration on resource rather than getting funding for expansion of technologies to help us manage the resource.
8. Too lean and mean in funding. Only enough to do the job. No R&D as other agencies.
9. Funding.
10. Money and positions don't get to the field.
11. Contracting does not understand station's computer needs.

MISCELLANEOUS

1. Too often computer acquisition decisions are made with a heavy emphasis on cost effectiveness rather than resource effectiveness.
2. GIS of a field office would have to cover a large geographic area.
3. Research interests more sophisticated than field needs.
4. Available FWS data sets.

- Recognition of value
- Lack of direction and support
- Communications
- Budget - FTEs
- Bureaucracy
- Commitment to training is inconsistent
- Fear of new technology

Recognition of value

- GIS community problem
- How do we get management and potential users to recognize value of GIS?
- All levels of management
- Practicing GIS technology community
- Demos with potential user data
- Project leader meetings
- Participation workshops
- Establish task force
- Get GIS people on the agenda
- GIS coordinator per region
- National user support center
- GIS as line item in budget
- Share of resources to mitigate training expenses
- Prepare GIS solution to resolve a (politically sensitive) problem
- Address middle/lower level managers GIS applications

2. Approaches:
1. Top-Down
2. Bottom-Up

BOTTOM-UP

1. Demonstrations to project leaders on site-specific.
2. Amway theory.
3. User groups at technical level.
4. Cost-share resources.
5. Track record.
6. Local level demonstration with basics - microcomputer and GIS that's affordable.
7. Take on outside service projects.

TOP-DOWN

1. Task force on GIS.
2. GIS as line item on budget.
3. National GIS support center.
4. Different level of demonstrations.
5. GIS coordinators at regions and Washington Office.
6. Get GIS included in strategic planning documentation.

GROUP THREE

EXTERNAL OPPORTUNITIES

GROUP THREE MEMBERS

Mark Maffei - Facilitator
Christine Bates
Lloyd Culp
Mickey Hayden
Herman Robinson
Jerry Minick
Bill Leenhouts
Mike Hawkes
Tammy Fancher
Ron Osborn
Tom Howard
Pedro Ramirez

Training

- Increasing requests for GIS databased analysis by state/local agencies
- Training opportunities
- Training/conferences
- Training opportunities
- Modern facilities

Data:

- Availability of large amount of base map and resource information
- Data sources
- Other data sources
- Existing data
- Existing GIS data
- Data sharing with federal and state agencies
- Existing photography

Commercial market

- Availability of technology
- Vendors
- Improved systems
- Private vendors
- GIS technology becoming more user friendly
- Less red tape
- Strength in numbers to vendors
- Outside free software

Public Support

- Urgency for good resource management
- Public concern for environment
- Public support increased with better quality data presentation
- Public supports environmental issues
- Publish laymen type articles (commercials) about GIS successes in FWS
- Favorable climate (public and congress) on environment

Funding

- Congressional add-ons
- Congress generally wants to help
- More money
- Outside funding possibilities
- Tie into private industry (National Association for Fish and Wildlife Foundation?)

Expertise

- Strong user community (peer group)
- University expertise
- Existing contracts
- Nature conservancy data bases - GIS
- Opportunity to learn from other Agency successes/failures
- Other agencies using GIS
- GIS "gurus" want to help
- Evaluation of GIS software results
- Share information with other agencies
- Other agency purchases

Pro-Action versus Reaction Management:

- Opportunity to show expertise in biological areas with GIS use
- Interesting projects
- Wide range of applications
- Opportunity to become a leader in national resource - not a follower-reactionary
- Technology growing can influence policy and standards
- Technological advances
- Information age rapid communications

Priorities

1. How to garner/enhance public support/concern for environment (threat to resource)? (4)
2. GIS has proven track record for information management (6)
3. Pro-active vs. reactionary (7/8)
4. Existing data sources/hardware/software/training (1/2/3)
5. Additional funding sources
6. Technological advances

How to garner/enhance public support and concern for environment?

Who:	Environmental organizations Congress Industry/developers General public-grassroots State/federal/local agencies International organizations/agencies
What:	Demonstrate support
Why:	Don't have it. Public does not know what we do.
When:	As soon as possible
Where:	Nationwide, public meetings, professional meetings, public affairs office, departmental briefings
Experts:	University professors, vendors, environmental organizations

Positives	Negative Forces
Environmental organizations	Time
Increase in public awareness	Agency competition
Industry	Industry
Congress	Congress
	Money
	Policy

Strategies

To garner/enhance public support

1. Show public capabilities of GIS in Fish and Wildlife Management
2. Education
3. Show cost effectiveness of GIS
4. Direct contact with environmental organizations
5. Show direct benefit to resource

Strategy evaluation - all will help solve problem.

How does FWS use GIS's?
Track record to obtain technology?

Who:	Other agencies and private industry have GIS and use it successfully. Universities State/federal/local
What:	Existing technology, data bases, programs, and plans in other agencies/organizations Existing contracts, funding, expertise
Why:	To improve management techniques and information management Consolidate data bases
When:	Other agencies have used it for 10 years
Where:	Throughout government and private sector

<u>Strategies</u> - GIS track record and how does FWS get into it.

1. Identify how GIS has improved natural resource management for other agencies
3. Identify other agency programs
2. Identify other agency strategies for obtaining GIS
4. Identify published reports on GIS
5. Identify existing facilities with GIS

GROUP FOUR

EXTERNAL THREATS

GROUP FOUR MEMBERS

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- Other agencies will receive the resources to move ahead with GIS, By our inaction we will receive little
- Competition with money and FTEs
- Absorbed by more progressive agency
- Being taken over by another agency
- No long term plan
- Outside standards and policies imposed
- Domination by other bureau policies
- Being directed by another agencies standards/objectives
- Imposed higher priorities
- Competition from state and private agencies in research
- Pre-emptied by local/state agencies with greater budgets and expertise
- Duplication of effort (data already available)
- Inadequate data in GIS may look better than is
- Data quality
- Software compatibility
- Changing technology
- Not keeping up with technology
- Rate of technology change restrains action
- Advances in technology will make obsolete or require new equipment
- Data bases may become hard to get driving price up
- Slow change becoming "out of sync" with rest of world
- If at odds with another agency may be slow in sharing information or not at all
- Vendor manipulation
- People who don't understand GIS or computers
- Lack of knowledge of GIS area
- Continued perception as "duck agency"
- Lack of leadership and communication
- Diversion/direction of funds for emergencies from longer term programs
- Lack of credibility if we remain unorganized
- Lack of Department of Interior support
- Negative attitudes
- Too many threats of development; not enough personnel
- Lack of appeal to future scientists
- Increased habitat fragmentation - no regional approach to problem

1. Competition for resources (funding)
2. Threat of being taken away by other agency
3. Standards imposed by external agency
4. Competition by local and state agencies
5. Data quality and availability
6. Rapid change in technology
7. Negative public perception

Competition for Resources

Problem:

What: Why isn't the service competitive for GIS resources?

- Service wide
- Lack of dissemination of information, appreciation, and knowledge
- Lack of appreciation of GIS utility
- Lack of advocacy group
- Other interior agencies overshadow us and false perceptions of its capabilities

Strategies

1. Push for modernization (Dbase 2000)
2. Catalog of existing GIS applications
3. Demonstration/training
4. Develop internal/external advocacy groups

Negative Public Perception

Problem:

1. Image

   a. Self
   b. External

2. Congress

   a. Mission
   b. Capability

3. Interior

Strategy:

1. Success stories
2. Better sales job/leadership
3. Clarification of mission

Why is FWS not keeping up with rapid changing technology?

Problem:

1. No futuring
2. No technology focus/organization (individual and organization)
3. Resistance to change
4. No formal technology transfer mechanism (change agent)
5. Demographics problem training/aging?

Strategy:

1. Push for modernization
2. Demonstration/Training
3. Develop internal/external advocacy groups
4. Leadership