Toward a Federal Land Information System: Experiences and Issues

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Toward a Federal Land Information System: Experiences and Issues

By JAMES A. STURDEVANT

U.S. GEOLOGICAL SURVEY BULLETIN 1852

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By James A. Sturdevant

Abstract

From 1983 to 1987, the U.S. Geological Survey conducted research to develop a national resource data base of Federal lands under the auspices of the Federal Land Information System (FLIS) program. The program's goal was to develop the capability to provide information to national mineral-use policymakers. Prototype spatial data bases containing mineral, land status, and base cartographic data were developed for the Medford, Oreg., area, the State of Alaska, and the Silver City, N. Mex., area. Other accomplishments included (1) the preparation of a digital format for U.S. Geological Survey mineral assessment data and (2) the development of a procedure for integrating parcel-level tabular Alaska land status data into a section-level geographic information system. Overall findings indicated that both vector and raster capabilities are required for a FLIS and that nationwide data availability is a limiting factor in FLIS development.

As a result of a 1986 interbureau (U.S. Geological Survey, Bureau of Land Management, and Bureau of Mines) review of the FLIS program, activities were redirected to undertake research on large-area geographic information system techniques. Land use and land cover data generalization strategies were tested, and area-filtering software was found to be the optimum type. In addition, a procedure was developed for transferring tabular land status data of surveyed areas in the contiguous 48 States to spatial data for use in geographic information systems.

The U.S. Geological Survey FLIS program, as an administrative unit, ended in 1987, but FLIS-related research on large-area geographic information systems continues.

INTRODUCTION

The U.S. Congress, the Department of the Interior, the Department of Agriculture, and other Federal agencies require a tremendous amount and variety of resource information on Federal land to formulate policies affecting mineral exploration and development, water and land use management, and agricultural production. The data are collected and synthesized by many Federal land management agencies. These agencies are comprised of divisions, offices, regions, or other organizational units that have administrative management responsibilities for portions of Federal land. Thus, when national-level resource information is required, the compilation and accurate summation of these data from the agencies are difficult and time consuming. The process involves obtaining detailed, site-specific resource data of varying quality and scales and then aggregating and summing the data. A single, easily accessed source of current national-level resource data is one alternative for solving the problem.

From 1983 to 1986, under the auspices of the Federal Mineral Land Information System program, the U.S. Geological Survey (USGS) conducted research to develop a single source of national-level natural resource data for Federal lands. The goal was to provide information concerning mineral resources on Federally administered land to national policymakers. To achieve this goal, digital spatial data bases and geographic information system (GIS) software for data base query, analysis, and output were used. During the first 3 years of the program, data base development for several pilot project areas was emphasized. However, the program was limited to working with a mineral data subset of natural resource data, and two conditions were established. First, the program was to use GIS's existing in the USGS and, second, only data readily available from Federal agencies were to be used.

In 1986, the program name was changed to the Federal Land Information System (FLIS), and the program was reviewed formally by an interbureau (USGS, Bureau of Land Management, and Bureau of Mines) study team. As a result of this review, program direction and emphasis were changed from operational data base development to researching large-area GIS techniques. The techniques studied included automating data accession from other digital data bases and the processing and storing of large volumes of data in GIS's (Arndt, 1987).

The FLIS program, as an administrative unit, ended in 1987, but the USGS continues to conduct research related to large-area GIS's. There are no plans to establish a single national system.

This bulletin summarizes the activities and documents the major accomplishments of the FLIS program. Research results and data base development accomplishments are emphasized, and recommendations for the future direction of FLIS-related research are provided. The figures in this bulletin are examples of graphic products generated by using GIS technology and do not meet USGS map standards and accuracy requirements.

BACKGROUND

The USGS Management Implementation Plan, which called for the establishment of a Federal Mineral Land Information System research program, was finalized in February 1983. Although there was some support for the program to address many types of natural resource data, the final approved program called for a data base containing only mineral, land status, and base cartographic data. Excerpts from the plan follow:

> The Survey needs to be more responsive to the Secretary of the Interior's stated objective to open Federal lands to public access and increase domestic energy and mineral production. . . . There exists no source whereby questions can be answered rapidly and effectively concerning the location of Federally-owned lands, the agencies administering them, Federal mineral rights, and the specific restrictions on mineral exploration and development. . . . A geographic information system . . . would serve as a mechanism for rapid and effective formulation of policy to guide the accelerated domestic production of energy and mineral resources.

The program was developed to meet the needs of Departmental- and Congressional-level policymakers. These needs were defined by questions already being asked of the USGS, such as, what is the availability of minerals, particularly those of critical importance to the national interest? The program's objectives were (1) to use GIS technology to provide information about Federal mineral lands and (2) to develop procedures to access existing mineral and land status data for incorporation in GIS's. The goal was to be able to rapidly answer mineral-use policy questions. Primary data files needed to answer anticipated mineral-use policy questions were land status data (including surface ownership or administration, mineral rights, and restrictions affecting mining) and mineral assessment, mineral occurrence, and base cartographic data.

By 1983, the USGS had some experience with raster-based GIS's but had limited experience with vector-based GIS's. The Interactive Digital Image Manipulation System (IDIMS), a raster-based system, had been used traditionally for image processing. By 1985, however, the USGS had become proficient with several vector systems, including the Map Overlay and Statistical System (MOSS) and the ARC/INFO system. However, little was known about either system's capabilities for handling the large volume of data required for a FLIS.

Generally, a lack of data seemed to be more limiting to the development of an operational FLIS than a lack of available GIS technology. As early as 1980, mineral assessment data were being prepared by the USGS on a 1:250,000-scale quadrangle basis, but by 1987, 13 quadrangles in the contiguous States and 17 quadrangles in Alaska had been completed. Mineral occurrence data were readily available; for example, some data on mines and mineral deposits were available from the USGS Mineral Resource Data System (MRDS) for every State. Current land status data of a consistent format are difficult to obtain in graphic or digital form, because each land management agency maintains the records on its own lands. The Bureau of Land Management (BLM), however, maintains current records for all public domain lands, until those lands are transferred to other Federal agencies (such as the U.S. Forest Service or the National Park Service).

To aid in developing the FLIS, two pilot projects were conducted. Each addressed a different aspect of data base development and research (Kleckner, 1984). The main objectives of the Medford, Oreg., project were (1) to demonstrate the feasibility of a FLIS program by establishing a data base of a 1:250,000-scale quadrangle area and (2) to investigate the use of mineral data from the USGS Conterminous U.S. Mineral Assessment Program (CUSMAP) for the Medford quadrangle. The State of Alaska was chosen for the second pilot project because of the large amounts of available data and the opportunity to explore large-volume data handling techniques.

MEDFORD, OREG., PILOT PROJECT

Data Files and Sources

The Medford, Oreg., pilot project was conducted between April and September 1983 to demonstrate the concept of a national-level system for providing information on mineral-use policy. The study area, the 1° by 2° Medford, Oreg., quadrangle, was selected because of the availability of mineral and land status data. The mineral data sources were (1) a USGS CUSMAP report (Singer and others, 1982) and associated maps of the Medford quadrangle and (2) the USGS MRDS (Calkins and others, 1978). The results of CUSMAP studies are published as folios and include mineral assessment maps, statistics, and text. The MRDS is a set of digital records on mineral occurrences, including locational and bibliographic information.

The land status data were digitized from the BLM 1:100,000-scale Surface-Mineral Management Status map series, published in 1978. The data categories on the BLM maps include surface administrators, Federal mineral ownership, and Federal mineral restrictions. Base cartographic data representing township boundaries, county boundaries, and National and State highway networks were taken from the same BLM maps. Information about the Medford data base is shown in table 1.

Data Base Structure

The Medford project involved data input, data transformation, data registration, spatial analysis, and output. The data processing capabilities of the vector-based MOSS and the raster-based IDIMS were used and evaluated. Several methods of entering data were used. Because the CUSMAP data and the BLM land status data were in polygonal form, they were digitized manually by using a vector digitizing system. Multiple attributes associated with the CUSMAP polygons were entered by keyboard into files in both the vector and the raster systems. Because data from the MRDS were already in digital form, they were entered directly into both systems. All data were transformed to the Universal Transverse Mercator projection for use in both systems. For use in the IDIMS, the data were rasterized to a ground-equivalent cell size of 200 by 200 m (about 10 acres).

Data Query, Analysis, and Output

Hypothetical land- and mineral-policy questions were addressed by using vector and raster retrieval and analytical capabilities (fig. 1). Some of the questions follow:

- Which Federal agencies administer land resources in an area?
- How many acres are involved?
- Where do the lands occur?
- On what Federally administered land does a particular mineral occur?
- Where does the Federal Government have mineral rights?
- Where is the land not withdrawn from mining?
- What minerals occur, or have a known potential for occurring, in the area?
- Where do the minerals occur?

The generic spatial analysis functions used to address such questions were (1) attribute data handling (search, sort, merge, and others), (2) overlay analysis, (3) area calculation, (4) single- and multiple-file query, and (5) distance analysis (Sturdevant and Kleckner, 1984).

Part of the Medford pilot project was a study to define the complementary spatial-data handling capabilities of the raster-based IDIMS and the vector-based MOSS. Results indicated advantages to using both a raster and a vector capability for a national-level natural resource information system. The advantages of raster processing (IDIMS) include fast and flexible data modeling operations and direct links to several output devices. The advantages of vector processing (MOSS) include a flexible data retrieval capability, convenient area computation commands, direct linkage between multiple attributes and spatial features, and relatively small data storage requirements (table 2). However, the limited overlay functions and the inability to handle multiple attribute functions prohibited the use of MOSS for further FLIS program activities.

The Medford pilot project demonstrated that several data files can be incorporated and analyzed by using GIS technology to provide answers to certain mineral-use policy questions for a 1:250,000-scale quadrangle area.

Table 1. Data base files in the Federal Land Information System Medford, Oreg., data base

[BLM, Bureau of Land Management; CUSMAP, Conterminous U.S. Mineral Assessment Program; MRDS, Mineral Resource Data System]

Data base files	Source	Form	Attributes
Mineral assessment .	CUSMAP......	Areal	Multiple.
Mineral occurrence. .	MRDS	Point	Do.
Federal surface ..... ownership.	BLM land ..... status maps	Areal	Single.
Federal subsurface . . ownership.	...do	...do.......	Do.
Federal restrictions. .	...do	...do.......	Do.
Townships	...do	Linear and areal.	Do.
Counties	...do	...do.......	Do.
Roads..............	...do	Linear	Do.

ALASKA PILOT PROJECT

Data Files and Sources

The second pilot project, conducted from late 1983 to mid-1987, was the development of a mineral and land status data base in Alaska (Sturdevant and others, 1986). Alaska offered an opportunity to build a statewide data base and to test techniques for large-area high-volume data base development and analysis.

A key objective of the Alaska project was to automate and convert various mineral and land status data to a common digital spatial format. The mineral data were from four sources: (1) USGS Alaska Mineral Resource Assessment Program (AMRAP) maps, mapped on 1:250,000-scale quadrangles, (2) USGS Regional Alaska Mineral Resource Assessment Program (RAMRAP) maps, mapped statewide on 1:1,000,000-scale maps, (3) USGS MRDS digital files, and (4) the "Mineral Terranes of Alaska, 1982" map series.

Both the AMRAP and RAMRAP data in Alaska indicate that mineral deposits may be grouped by their geologic characteristics and that different types of deposits differ in grades, tonnages, and other characteristics (Singer and Ovenshine, 1979). Reports from both programs contain

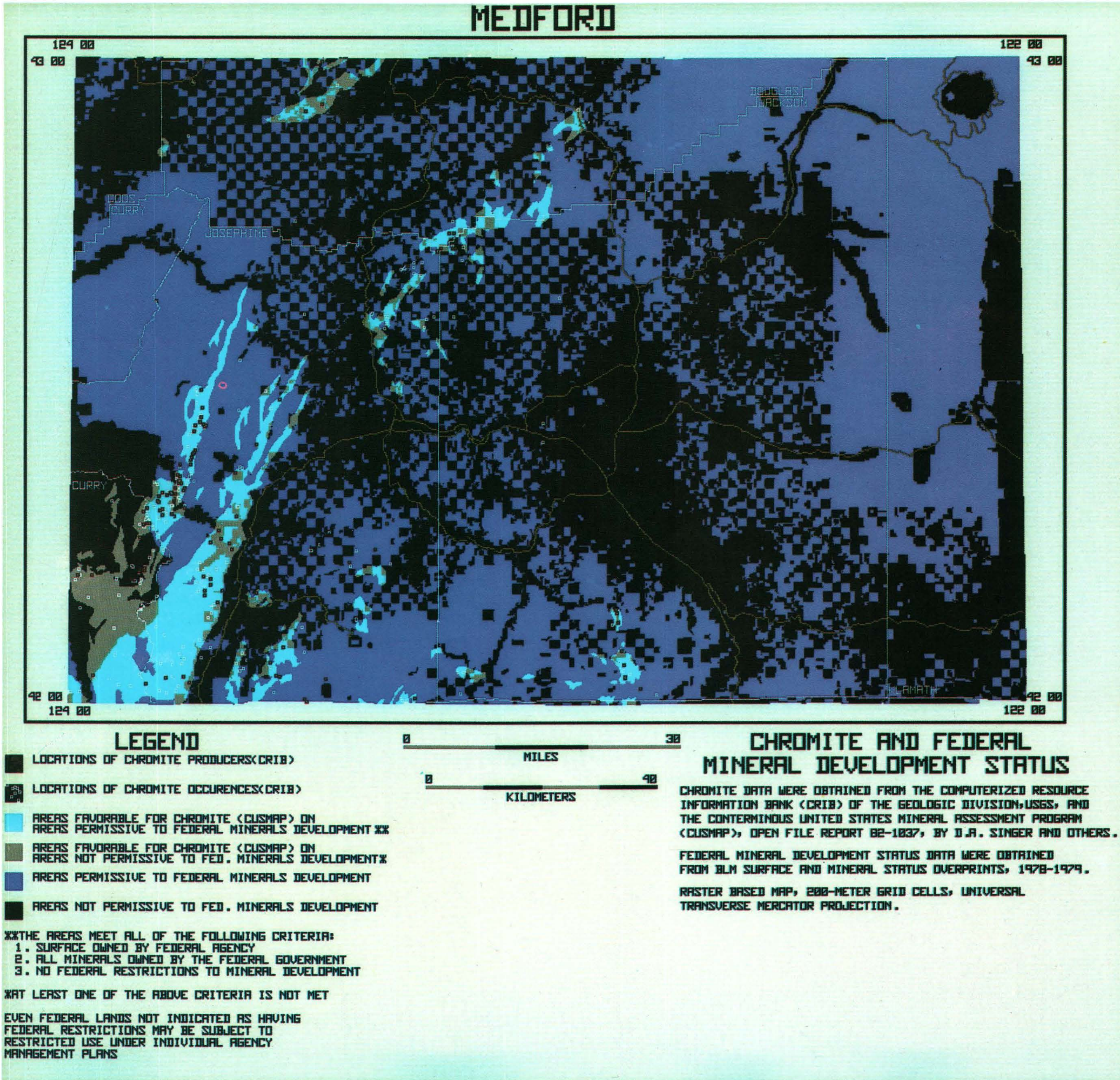

Figure 1. The result of overlaying data showing Federal administration areas, Federal mineral rights areas, areas open for mining, and chromite favorability areas. Light blue areas indicate land favorable for chromite and open to mining under the management responsibility of the Federal Government.

Table 2. Comparative digital storage requirements, in megabytes, of the Medford, Oreg., data base for Interactive Digital Image Manipulation System (IDIMS) and Map Overlay and Statistical System (MOSS)

	Point data (28 files)	Line data (1 file)	Areal data (11 files)	Total
IDIMS	15.12	0.54	5.94	21.60
MOSS	1.19	.02	2.18	3.39

maps of geologic tract areas (fig. 2), attribute tables, and grade and tonnage models of 18 types of deposits known or suspected to occur in Alaska. The quadrangles covered by the AMRAP reports are Ambler River, Big Delta, Blying Sound, Chandalar, Chignik, Circle, Ketchikan, McCarthy, Medfra, Nabesna, Philip Smith Mountains, Prince Rupert, Seward, Sutwik Island, Talkeetna, Talkeetna Mountains, and Tanacross (fig. 3). The RAMRAP data for Alaska,

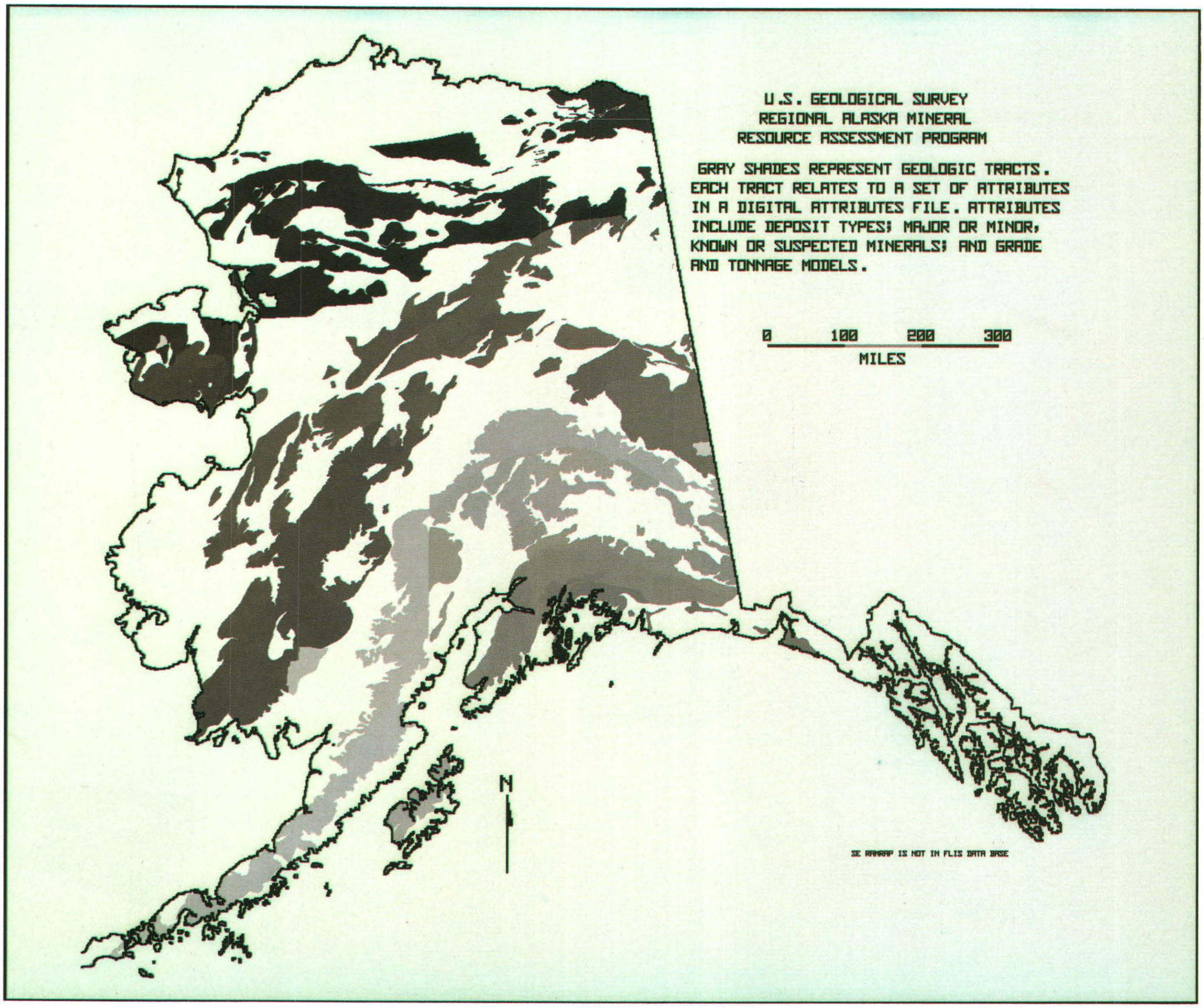

Figure 2. Polygons generated from the U.S. Geological Survey's Regional Alaska Mineral Resource Assessment Program.

with the exception of the Southeast Panhandle area, and the AMRAP maps were digitized and entered into the FLIS data base.

The mineral occurrence data from MRDS were available for the following 1:250,000-scale quadrangles (fig. 3): Ambler River, Anchorage, Blying Sound, Bradfield Canal, Craig, Dixon Entrance, Goodnews Bay, Gulkana, Healy, Kenai, McCarthy, Mt. McKinley, Nabesna, Petersburg, Seldovia, Seward, Talkeetna, Tyonek, and Valdez. These data were obtained in computer-compatible form and entered into FLIS computer systems.

Another file of mineral data in the Alaska FLIS contains information on hardrock mineral regions and coal basins that have been digitized from the "Mineral Terranes of Alaska, 1982" map series (Arctic Environmental Information and Data Center, 1982) (fig. 4). The map units, or terranes, are defined as assemblages of related rocks that contain mineral deposits or show evidence of common processes that are known to produce minerals. The data were on six 1:1,000,000-scale regional Alaska maps that cover the entire State.

The land status data in the Alaska FLIS were obtained from the BLM Alaska Automated Land and Mineral Record System (ALMRS), formerly called the Alaska Automated Land Record System. The system is a comprehensive tabular data base containing data on 223,000 case files and withdrawal orders covering 18,651 townships (U.S. Bureau of Land Management, 1983). Its purpose is to assist in land status management and to track the progress of the massive Alaska land conveyance mandated by Federal law. With the assistance of BLM adjudicators, ALMRS records, indicating surface administrators, were identified and aggregated into categories such as Federal land (National Park Service land, U.S. Fish and Wildlife Service Refuges, and so on),

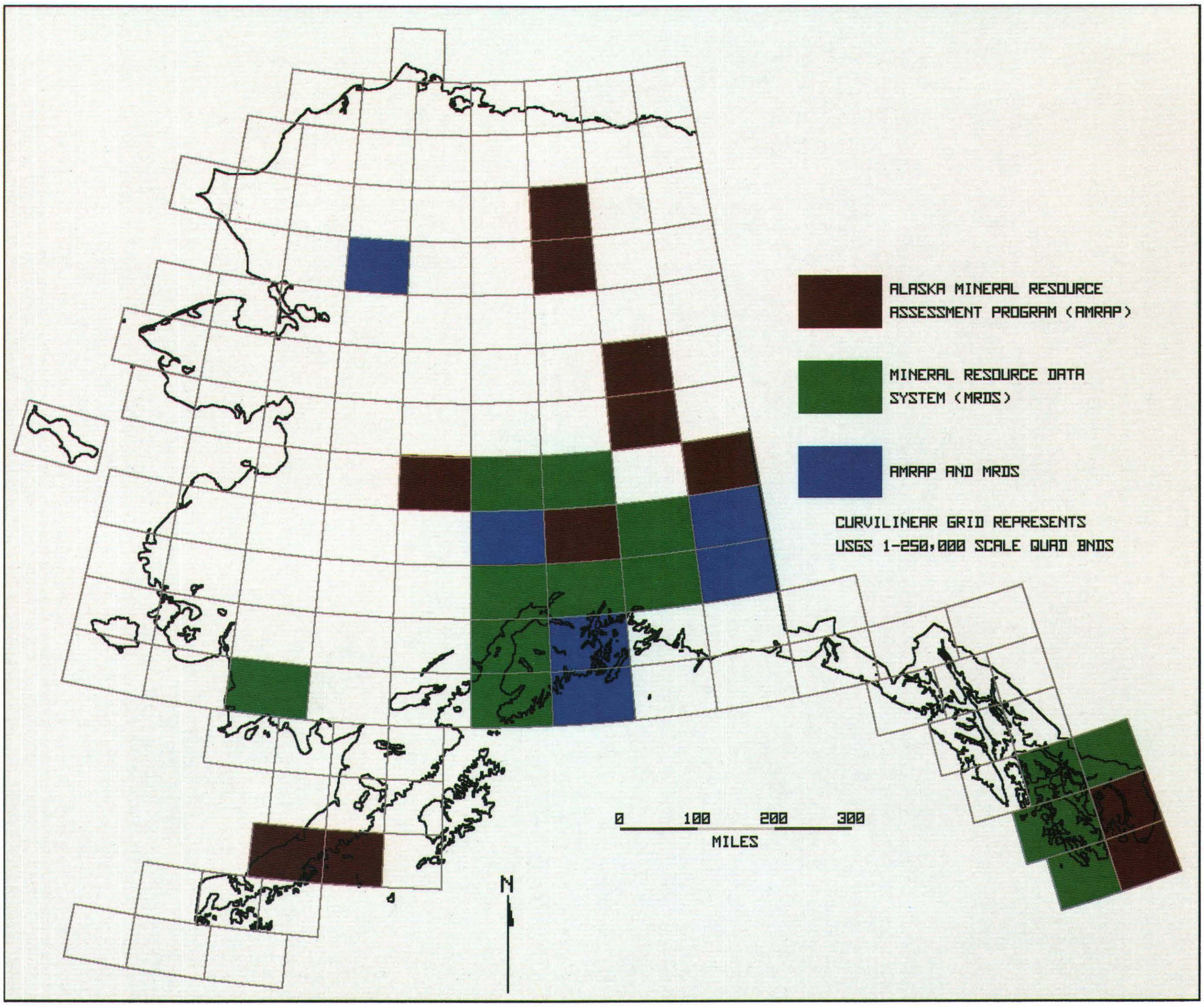

Figure 3. Status as of July 1987 of the entry of mineral data from the U.S. Geological Survey's Alaska Mineral Resource Assessment Program and the Mineral Resource Data System into the Federal Land Information System data base.

State land, native land, and private land. The spatial locations of the surface administrator polygons, recorded by legal land description, then were converted to the standard protracted sections defined by geographic coordinates. By using software developed by the BLM, the files were converted to formats compatible with GIS's used in the FLIS program. The result was a data file that contained locations of land areas managed by various Federal, State, and private organizations (fig. 5).

Subsurface ownership and areas restricted from mining are not represented spatially in the ALMRS. Under the guidance of BLM mining law experts, these two data types were derived from the surface administrator data. For example, if the land area is a National Park established before 1981, in nearly 90 percent of the cases, the subsurface minerals are owned by the Federal Government, and the land is closed to the mining of metallic ores. The subsurface ownership categories are Federal, State, native, and private. The Federal restrictions categories (open, closed, and not affected by Federal laws) apply to metallic minerals only.

The Alaska FLIS also contains hydrography, transportation, and water bodies data from the USGS digital line graphs, which are available in a topologically structured vector format (Domaratz and others, 1983). They were derived from the 1:2,000,000-scale sectional maps of the 1970 National Atlas of the United States of America.

Data Base Structure

The raster-based IDIMS and the vector-based ARC/INFO system were the GIS software packages used

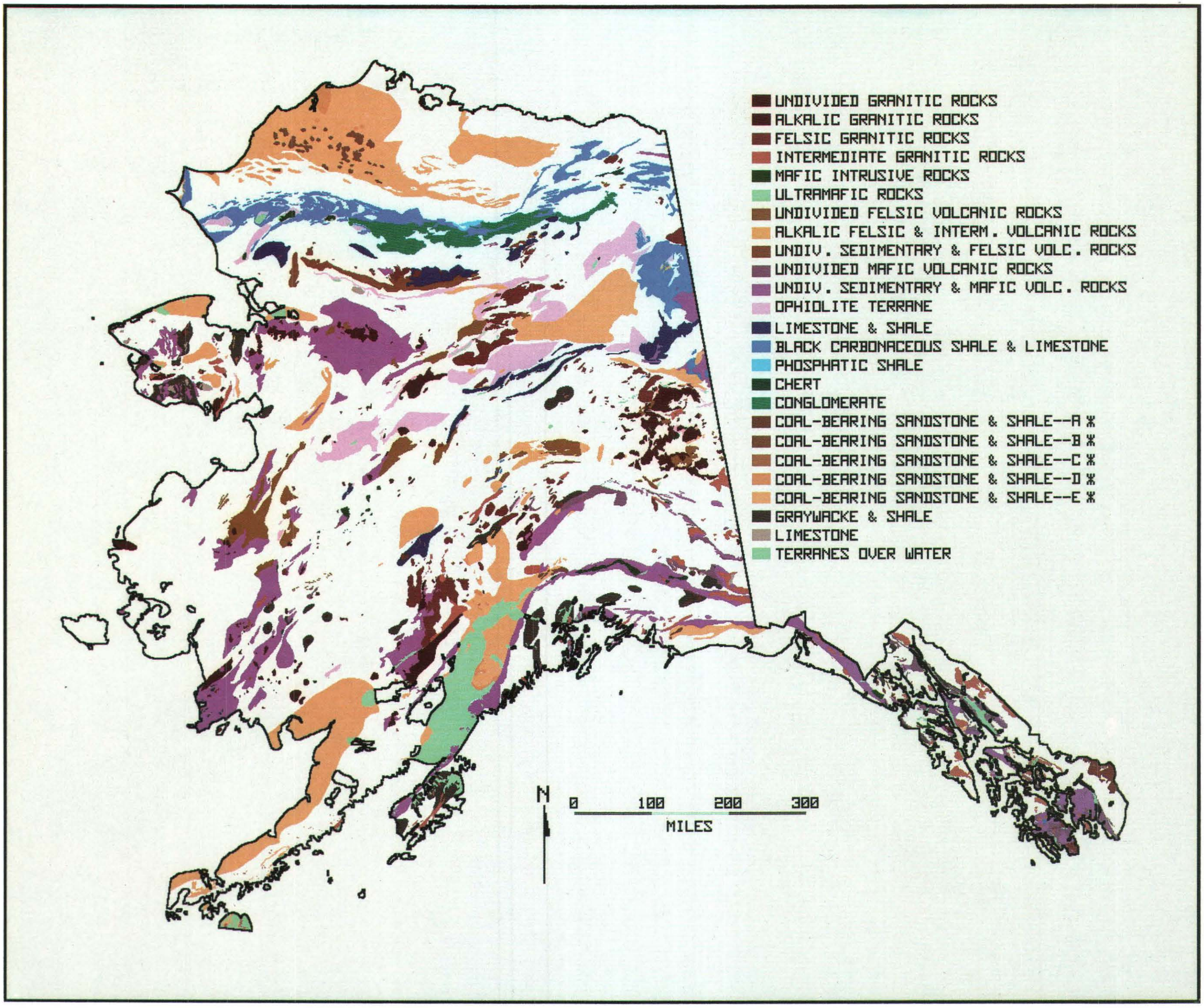

Figure 4. Mineral terranes of Alaska (Arctic Environmental Information and Data Center, 1982).

for the Alaska FLIS project. The IDIMS was available at the start of the project and was used exclusively until 1986, when the ARC/INFO system was acquired. Most data files were originally digitized by using the vector-digitizing subsystem of the IDIMS and then rasterized for analysis and output. Multiple attributes, such as those associated with the mineral data, were handled by another subsystem of the IDIMS, the Earth Resource Information System. The raster data describe cells of 40 acres and cover most of the State in six coverage blocks. Each block comprises 2,500 by 2,500 cells. The data also were rasterized to 1-mi^2 cells to produce 1,500- by 1,500-cell files covering most of the State. The files are registered to the Albers Equal-Area Conic projection.

All of the Alaska mineral data were converted to the vector-based ARC/INFO system by using the Earth Resources Observation Systems (EROS) Data Center's vector data interchange software. The statewide mineral data (RAMRAP) were appended into one statewide coverage and stored in the Albers projection. The AMRAP and the MRDS data were stored in 1:250,000-scale quadrangle-based coverages in the Universal Transverse Mercator projection. Information about the Alaska data base is provided in table 3.

Data Query, Analysis, and Output

The FLIS data files were queried, analyzed, and output to demonstrate capabilities. Traditional GIS operations, such as reclassification and overlay analysis, were used to generate answers to such questions as:

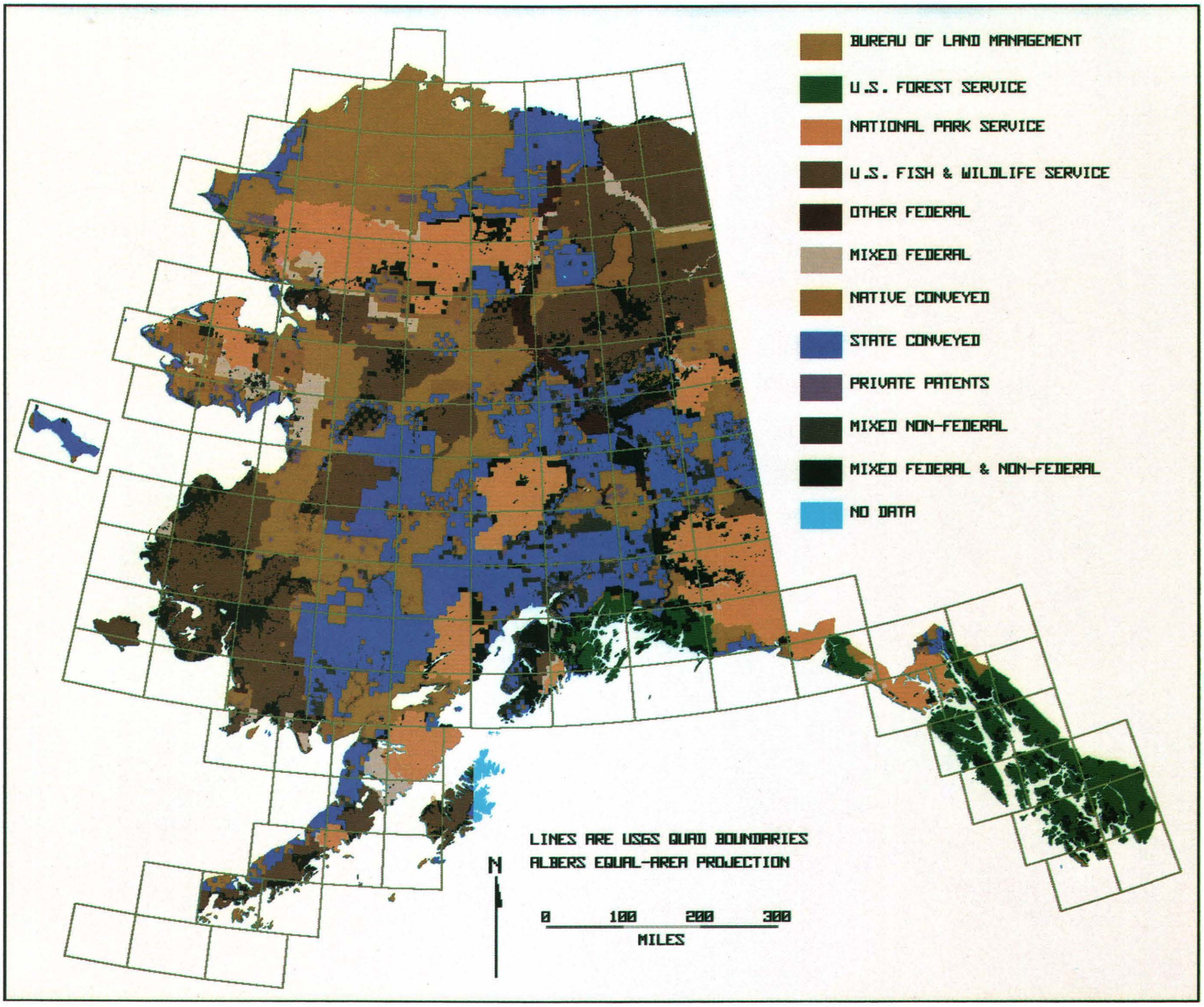

Figure 5. Surface administrators from the Bureau of Land Management's Alaska Automated Land and Mineral Record System, as of 1984.

- What Federal land in Alaska is restricted from mining?
- Where are Federally administered lands that are favorable for the occurrence of a particular mineral?
- Where on non-Federal land is there high potential for a particular mineral?

The raster and vector Alaska data bases are located at the EROS Data Center in Sioux Falls, S. Dak., at the EROS Alaska Field Office (AFO) in Anchorage, Alaska, and, in part, at the USGS Geographic Information System Laboratory in Reston, Va. The data bases will be expanded or updated at user or cooperator request. The AFO will use the data bases where appropriate to support the USGS Alaska Peninsula Mineral Assessment Project, the Chugach National Forest GIS project, and other GIS projects that require statewide mineral and land status data. Requests for information about the Alaska data bases should be directed to the AFO, 4230 University Drive, Anchorage, AK 99508–4664.

FLIS RESEARCH ACCOMPLISHMENTS

Alaska

During 1986 and 1987, FLIS staff addressed two research topics defined by Alaska government agencies. One was the generalization of land use and land cover data, classified from satellite data, for input to vector data bases. The second was the development of a procedure for accessing BLM Alaska ALMRS data and converting them to a vector data base. Alaska government agencies are

Table 3. Summary of Alaska Federal Land Information System data files and selected characteristics
[USGS, U.S. Geological Survey; BLM, Bureau of Land Management]

Data files	Source	Form	Attributes	IDIMS	ARC/INFO	Coverage
RAMRAP	USGS	Areal	Multiple	X	X	Statewide, except SE and North Slope.
AMRAP	...do	...do	...do	X	X	17 1:250,000-scale quadrangle areas.
MRDS	...do	Points	...do	X	X	19 quadrangles, about 100 points per quadrangle.
Mineral terranes	University of Alaska.	Areal	Single	X	X	Statewide.
Federal surface ownership	BLM	...do	Multiple	X		Do.
Federal subsurface ownership	...do	...do	...do	X		Do.
Federal restrictions	...do	...do	...do	X		Do.
Quadrangle boundaries	USGS	Linear and areal	Single	X	X	Do.
Hydrography	...do	Linear	...do	X		Do.
Roads	...do	...do	...do	X		Do.
Coastline	...do	...do	...do	X	X	Do.

interested in vector data because of their growing involvement in the ARC/INFO system. The U.S. Fish and Wildlife Service, the Alaska State Department of Natural Resources, the North Slope Borough, and the AFO are working with the ARC/INFO system, and several agencies are planning to acquire it.

The first research topic developed because of the inclusion of Alaska land use and land cover data in the ARC/INFO system by land resource agencies in Alaska. Land use and land cover data classified from Landsat multispectral scanner data (Shasby and Carneggie, 1986) are available for more than two-thirds of the State. The data are in raster form (50- by 50-m cells), 1:250,000-scale quadrangle-based, and projected to Universal Transverse Mercator. Each quadrangle contains a large number of homogeneous and spatially contiguous grid cells, or clusters, that are converted to polygons when incorporated in ARC/INFO or other vector systems. The Valdez quadrangle, for example, contains 98,000 clusters; consequently, the FLIS research addressed strategies to reduce the number of clusters while limiting data degradation.

Four generalization strategies were chosen: (1) area filtering, (2) category aggregation, (3) systematic resampling, and (4) modal searching and replacing (Mayers and others, in press). Category aggregation to a lower category precision (such as USGS land use and land cover category level II to level I) resulted in the largest reduction in the number of regions. Area filtering, applied to the results of category aggregation, resulted in an image of high overall agreement with the original aggregated data and little individual category error. Of the three strategies tested with unaggregated categories, area-filtering results had the highest overall agreement with the original data and relatively little individual category error (fig. 6 and table 4). Area filtering permits individual category filtering and weighting, thus allowing user control of the generalization process. The area-filtering functions were developed by the EROS Data Center and were based on the segmentation procedure developed by Rosenfield (1978) and implemented by Nichols (1981). Two of the statistical tests used to compare the results of the generalization strategies were Cohen's KHAT Statistic (Cohen, 1960) and the fragmentation index (Monmonier, 1974).

The second area of Alaska FLIS research was the development of procedures to access ALMRS data and to incorporate them in the ARC/INFO system. The required procedure should permit convenient access to digital surface administration data by the public, as well as generate ALMRS data as ARC/INFO files. Software was required that would access the appropriate files, aggregate the inherently parcel-level tabular data to Alaska protracted sections represented by geographic coordinates, and restructure the data to the arc-node format required by the ARC/INFO system. The BLM wrote the software and the FLIS program assisted in data testing. By the end of 1986, ALMRS data of the Valdez quadrangle were converted and implemented on the EROS Data Center's system. The Valdez data contained 9,500 sections, or polygons, and 24 attribute items. The data for this one quadrangle required about 3.2 million bytes of storage. This is a large amount of byte storage for just one quadrangle, and there are 153 quadrangles in Alaska. Storage requirements are much less

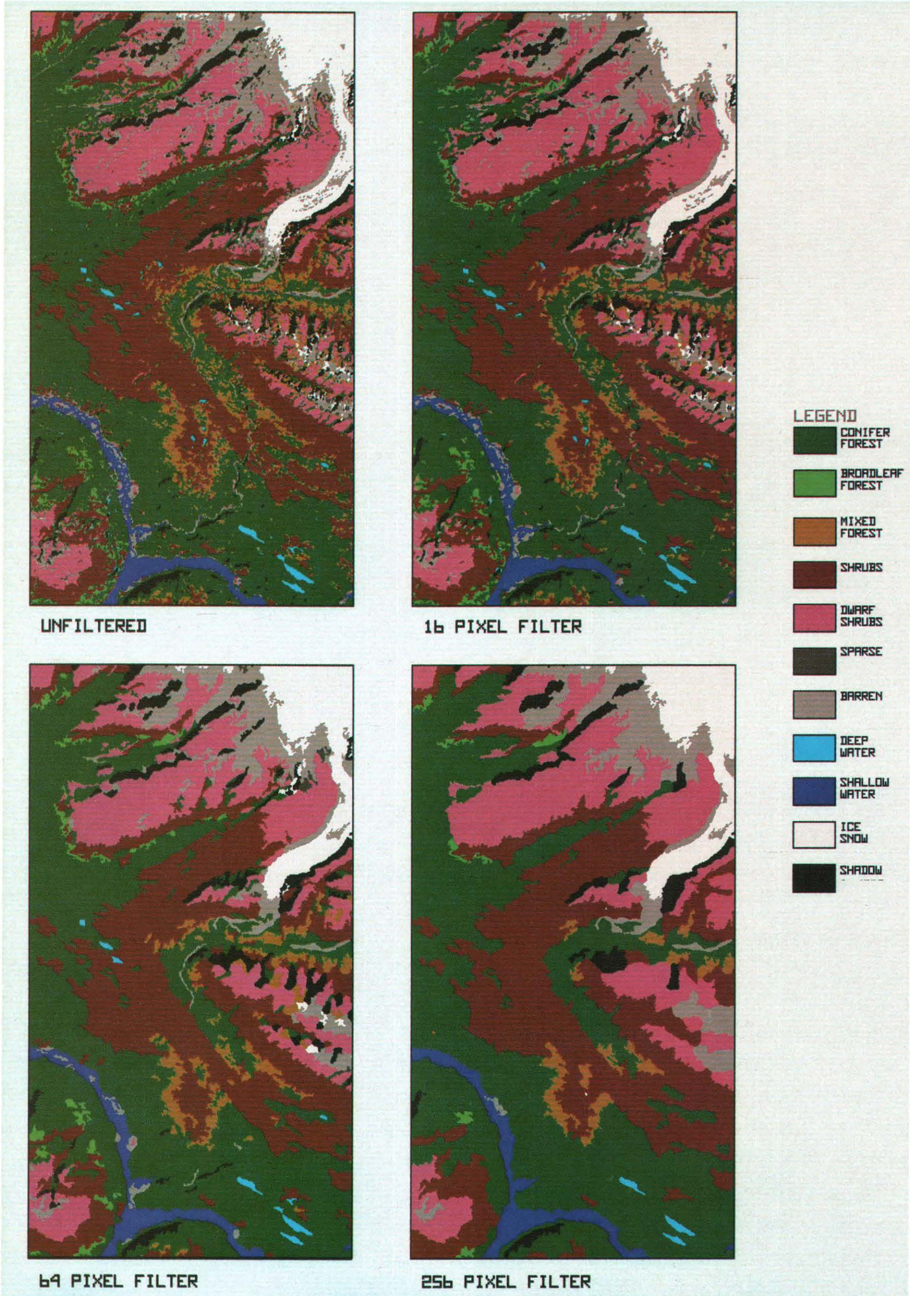

Figure 6. Spatial results of area-filtering land use and land cover data of a portion of the Valdez, Alaska, 1:250,000-scale quadrangle.

if specific data themes are generated as individual data files and if the boundaries separating redundant sections (polygons) are eliminated.

Both the land use and land cover generalization research and the Alaska ALMRS work provided insights into raster and vector data storage requirements (table 5). Review of the storage requirements of various data types shows that complex data such as land use or land status in vector form, having a minimum mapping unit smaller than a section, require more storage space than the same data in raster form, having a 50- to 100-m grid cell size. Thus, the generalization that data in raster form require more storage space than the same data in vector form is not always true. In general, a data file having a complex polygon structure can require more storage in vector form than the same data in raster form. Storage space needed for vector data is proportional to the number of polygons, lines, and points in the study area. Conversely, storage space needed for raster data is proportional to the size of the study area and inversely proportional to the ground size of the grid cells.

Table 4. Statistical results of area-filtering land use and land cover data of a portion of the Valdez, Alaska, 1:250,000-scale quadrangle

Minimum area threshold size, number of pixels	2	16	68	100	128	256	512
Number of polygons[1]	7,138	1,916	466	310	249	121	59
Percent reduction of clusters	23.1	79.3	95.0	96.7	97.3	98.7	99.4
Percent unchanged	99.7	95.3	88.5	86.7	85.5	81.6	77.5
KHAT[2] (percent)	99.6	94.3	85.9	83.6	82.1	77.3	71.3
Fragmentation[3]	.77	.21	.05	.03	.03	.01	.01

[1]The number of clusters before area filtering = 9,278.

[2]Cohen's KHAT Statistic = ((NEXij)-XI+Y+i)/(N-E(Xi+X+i)), where

N = the total number of elements in a contingency table,

EXij = the sum of all the diagonal elements in a contingency table, and

E(Xi+X+i) = the total sum of each category row and column product.

[3]Fragmentation index (F) = (m-1)/(n-1), where

m = the number of clusters and

n = the number of cells.

New Mexico

In 1986 and 1987, the New Mexico project served as an opportunity for cooperative research among the BLM, the Bureau of Mines (BOM), and the USGS. The BLM ALMRS data of the Silver City, N. Mex., area became available in 1987. The BOM Inventory of Land Use Restraints Program (ILURP), a State-by-State inventory of mineral availability, was evaluating New Mexico at the same time. Both the BLM and the BOM were interested in how GIS expertise in the USGS could assist their programs. By late 1987, a three-bureau project plan still was being developed, but preliminary research was progressing at the working levels.

The goal of the ongoing BOM ILURP program is to compare Federal land availability for mineral exploration and development with mineral production areas. The final reports include 1:500,000-scale section-level State maps that show mineral production areas on Federal land status. Maps are prepared by using traditional cartographic techniques. The reports also include area statistics of mineral availability recorded for the individual land status parcels. The mineral availability data sources are BLM Master Title Plats and individual agency management plans (such as a National Forest Resource plan). The mineral production areas are determined by reviewing data on past production and major deposits from Federal and State sources. The BOM plans a study for each of the 11 Western States and 5 Alaska regions; of these, Washington, Colorado, Arizona, and two regions of Alaska have been completed.

One of the objectives of the FLIS program in New Mexico was to demonstrate the use of GIS technology for automation of the ILURP process. The major research task was to convert the land status data collected by the BOM from a parcel-level tabular format referenced to legal land descriptions to a section-level spatial format referenced to geographic coordinates. The procedure developed by the FLIS staff is depicted in figure 7. It is similar in concept to the procedure for converting Alaska ALMRS data to spatial data, but the differences are that (1) the ILURP land status data were in a dBASE III format and the Alaska ALMRS data were in a Data General format and (2) the ILURP land status data locations were converted to surveyed section coordinates and the Alaska ALMRS data locations were converted to protracted section coordinates. The land status data were aggregated to sections, linked to the section coordinates digitized from 1:100,000-scale base maps, and entered into ARC/INFO. The study area was the 1° by 2°, east half of the Silver City, N. Mex., quadrangle. The mineral production areas were digitized and entered into

Table 5. Comparative digital storage requirements, in kilobytes, of several types of Federal Land Information System data in raster and vector formats

Data base files	Coverage	Number of regions	Raster 50-m grid	Raster 1-mi grid	Vector
Land use and land cover	Valdez, Alaska quadrangle	98,000	8,300	7	40,960
Surface administrator	...do.	7,000	8,300	7	2,474
Mineral assessment (AMRAP)	Circle, Alaska quadrangle	20	8,300	7	26
Mineral assessment (RAMRAP)	Alaska	260	1,408,000	1,500	420
Mineral terranes	...do	1,400	1,408,000	1,500	2,261

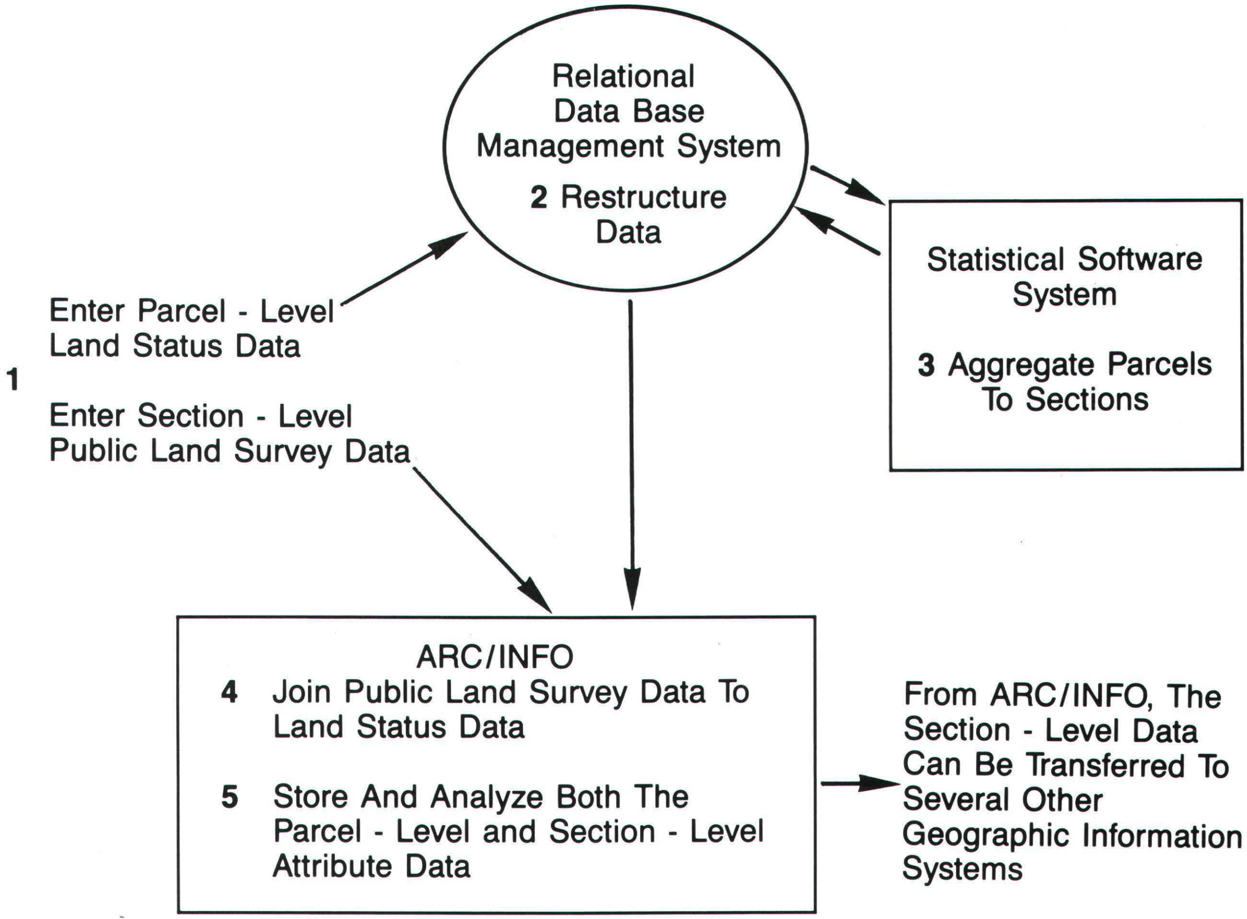

Figure 7. Procedure for converting parcel-level tabular land status data referenced to legal land descriptions to section-level spatial land status data referenced to geographic coordinates, for the Silver City, N. Mex., Federal Land Information System project. Numbers indicate the order of steps needed to complete the process.

ARC/INFO. Dozens of map products were generated to illustrate the results of various queries and overlays. One map product is depicted in figure 8.

The USGS FLIS and the BOM ILURP cooperative effort showed the advantages of using GIS technology for BOM ILURP studies. In addition, it demonstrated how the technology provides a rapid means to evaluate analysis scenarios, generate new products, and update the dynamic land status data.

The mission of the BLM ALMRS for the contiguous 48 States is "to develop and to implement an efficient system for recording, maintaining, and retrieving land description, ownership, and use information to support Federal program and public users of such records" (U.S. Bureau of Land Management, 1984). Since 1984, the FLIS program has recognized ALMRS as an important future data source and has been planning to incorporate ALMRS data in the FLIS Silver City, N. Mex., data base that was developed for the cooperative work with the BOM. The data base covers the 1:250,000-scale Silver City, N. Mex., quadrangle and includes mineral data from CUSMAP and MRDS, land status data from the BLM surface and mineral management status map series, land use and land cover data from the USGS, and base cartographic data from the USGS. Currently, ALMRS data are being incorporated into the data base and analyzed with the other data categories by using ARC/INFO software. Results will indicate the future utility of ALMRS data for large-area GIS applications.

CONCLUSIONS, ISSUES, AND RECOMMENDATIONS

For more than 4 years, the USGS conducted GIS projects and research under the FLIS program. The original program goal to develop a national resource data base was not reached, but much was learned about design requirements and strategies for system implementation.

The major accomplishments of the FLIS program are

1. Raster and vector data bases of land status, mineral assessment, mineral occurrence, and cartographic data of

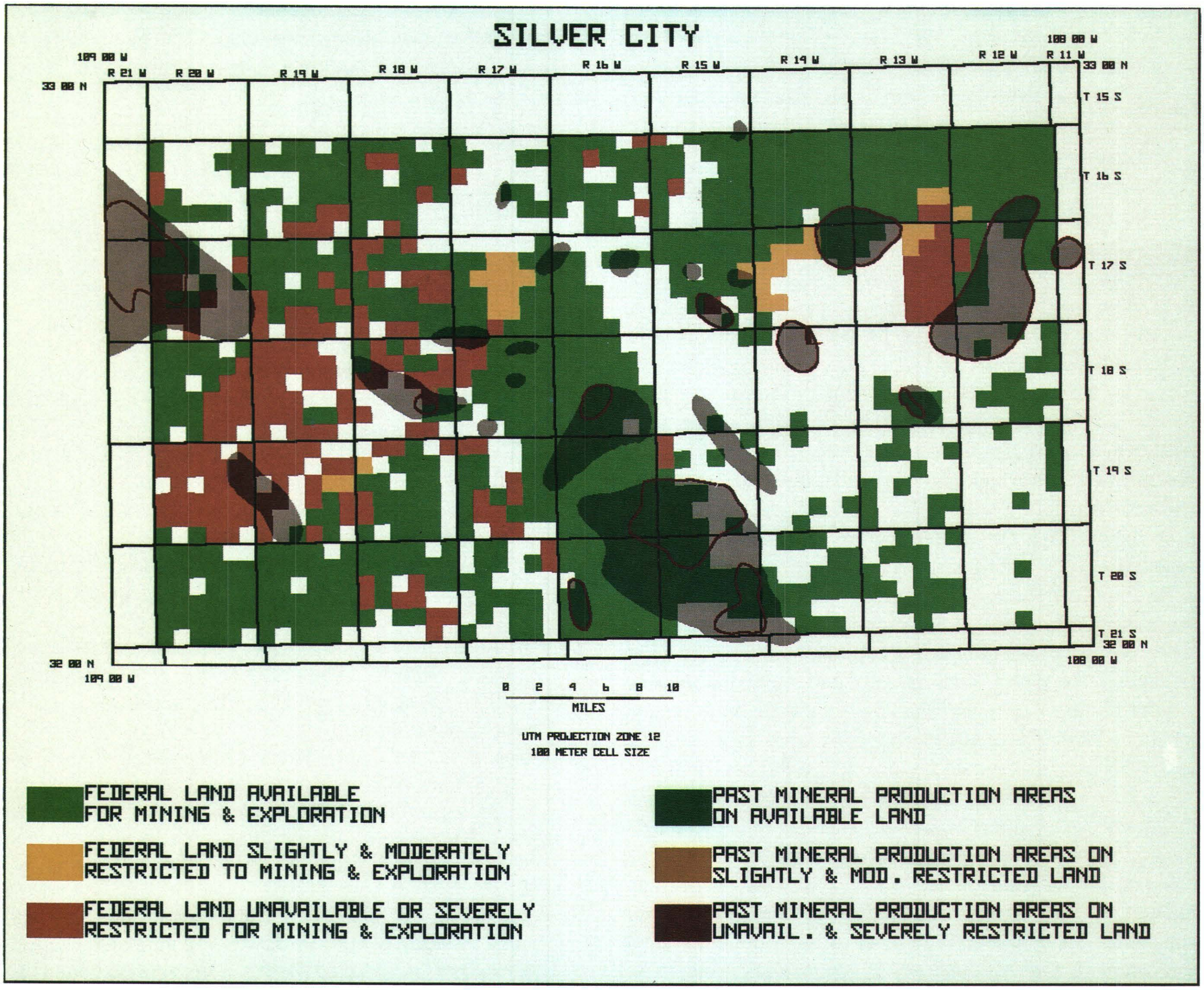

Figure 8. Mineral availability on Federal mineral lands and past mineral production areas of the Silver City, N. Mex., 1:100,000-scale quadrangle. Data are from the Bureau of Mines' Inventory of Land Use Restraints Program. Restrictions are from master title plats and agency management plans. Mineral areas are based on mine and deposit locations. White areas are non-Federal land, black lines are township boundaries, and red lines delineate high mineral areas.

Alaska were developed. Individual data files in digital form are being used by Alaska government agencies for land resource management. The data base can be enhanced as more data become available.

2. A digital format for USGS mineral assessment data was established, and data from all published AMRAP maps and two CUSMAP maps have been digitized. Because of the FLIS program, new Alaska mineral occurrence data have been added to the USGS MRDS at an accelerated rate.

3. Procedures for accessing Alaska ALMRS data and incorporating them into a raster and a vector GIS were established.

4. A procedure was developed to convert (a) parcel-level digital tabular land status data (in the contiguous 48 States) referenced to legal land descriptions to (b) section-level land status data referenced to geographic coordinates. The procedure was used to convert land status data from the BOM ILURP.

5. A vector GIS and a raster GIS were evaluated, and spatial analysis requirements for a FLIS were documented. Land use and land cover data generalization strategies for grid cell to polygon conversion were studied, and results were documented.

6. The BOM and the USGS have entered into cooperative agreements in several areas, largely because of strong FLIS and ILURP working-level relations. The FLIS and ILURP cooperative work underway will continue beyond the FLIS program.

7. The FLIS program demonstrated to the BOM ILURP how GIS technology can be used in the BOM statewide mineral availability studies.

8. Data bases were developed for the Medford, Oreg., and the Silver City, N. Mex., quadrangle areas. These bases served as key components of USGS demonstrations of GIS capabilities at the USGS National Center and the EROS Data Center.

If the goal of a future Federal Government program is to develop an operational nationwide natural resource data base, then specific and preliminary steps should be taken to achieve that goal. (1) The need for such a system should be documented and supported by a Congressional mandate that identifies the funding source and the participating agencies; (2) the administrative responsibilities and the cooperation between and within agencies should be approved and documented in advance; and (3) a detailed system design study should follow and include the definition of specific user needs, GIS functional requirements, data sources, input data types, data formats and resolution, data volume, data output, frequency of system use, system security, processing efficiency, quality control, and interfaces to other systems. The study also should include an implementation plan for system integration, data base assembly, and system testing. A maintenance plan designating system location, facilities, management, personnel, user services, and user costs also should be included in the design study.

Past USGS FLIS program experiences indicate that the system will require (1) automated capabilities to access rapidly and integrate digital data from other agencies; (2) a resident data base and a network of data bases permitting interactive query with almost immediate output; (3) vector and raster capabilities, preferably in a common system environment, directly tied to a sophisticated data base management system; and (4) capabilities and data base structures for large-volume data storage and processing.

Data availability is currently the most limiting factor to system development, and interagency agreements for data collection and sharing are essential. Digital data sharing will be facilitated by the establishment of data standards. Key data sources will be the BLM ALMRS and the USGS and the BOM mineral data. Other data sources should be developed, such as the U.S. Forest Service Land Ownership Management System, the BOM Mineral Availability System, and individual State data bases.

Because the system users will be high-level government policymakers concerned with national issues, more research on data aggregation and generalization is needed. If a national natural resource FLIS ever is to be developed, it should be managed by those who routinely interact with the major user group. For example, if Congress is the user, then the designers and the operators of the FLIS should be at a Government level that can associate with Congress.

Finally, the USGS should consider expanding its mission of providing national digital cartographic information to include mineral, certain types of land status data, and perhaps other natural resource data. The availability of these data from the National Digital Cartographic Data Base, in a standard digital format, could fulfill many national resource policymaking requirements.

REFERENCES CITED

Arctic Environmental Information and Data Center, 1982, Mineral terranes of Alaska: Anchorage, University of Alaska, scale 1:1,000,000, 6 sheets.

Arndt, R.E., 1987, Implementing a Federal Land Information System: Proceedings, American Society for Photogrammetry and Remote Sensing, Fall Technical Meeting, Reno, Nevada, p. 27–31.

Calkins, J.A., Kays, Olaf, and Keefer, E.K., 1978, CRIB—The mineral resources data bank of the U.S. Geological Survey: U.S. Geological Survey Circular 681, 39 p.

Cohen, Jacob, 1960, A coefficient of agreement for nominal scales: Educational and Psychological Measurement, v. 20, no. 1, p. 37–46.

Domaratz, M.A., Hallam, C.A., Schmidt, W.E., and Calkins, H.W., 1983, Digital line graphs from 1:2,000,000-scale maps: U.S. Geological Survey Circular 895–D, 40 p.

Kleckner, R.L., 1984, The Federal Mineral Land Information System: Annual Meeting of the American Society of Photogrammetry and Remote Sensing, Washington, D.C., March 1984, Proceedings, American Congress on Surveying and Mapping, Falls Church, Virginia, p. 20–26.

Mayers, M.G., Fosnight, E.A., and Sturdevant, J.A., in press, A study of four raster-based data generalization procedures, *in* Selected papers in the applied computer sciences: U.S. Geological Survey Bulletin 1841.

Monmonier, M.S., 1974, Measures of pattern complexity for choropleth maps: American Cartographer, v. 1, no. 2, p. 159–169.

Nichols, D.A., 1981, Conversion of raster coded images to polygonal data structures: 7th Annual William T. Pecora Memorial Symposium, Sioux Falls, South Dakota, Proceedings, Benjamin F. Richardson, ed., Falls Church, Virginia, American Society for Photogrammetry, p. 508–515.

Rosenfield, Azriel, 1978, Extraction of topological information from digital images: 1st International Advanced Symposium on Topological Data Structures for Geographic Information Systems, Proceedings, Geoffrey Duton, ed., Harvard, Massachusetts, Harvard University Press, v. 6, p. 790–805.

Shasby, M.B., and Carneggie, D.M., 1986, Vegetation and terrain mapping using Landsat MSS and digital terrain data: Photogrammetric Engineering and Remote Sensing, v. 52, no. 6, p. 779–786.

Singer, D.A., and Ovenshine, A.T., 1979, Assessing metallic resources in Alaska: American Scientist, v. 67, no. 5, p. 582–589.

Singer, D.A., Page, N.J, Smith, J.G., Blakely, R.J., and Johnson, M.G., 1982, Mineral resource assessment of the Medford 1°×2° quadrangle, Oregon: U.S. Geological Survey Open-File Report 82–1037, 2 p. and 2 maps.

Sturdevant, J.A., Batten, L.G., Carneggie, D.M., Meyer, David, Johnson, Jay, and Walker, Kim-Marie, 1986, The Alaska Federal Land Information System: American Society for Photogrammetry and Remote Sensing Fall Technical Meeting, Anchorage, Alaska, Sept.–Oct. 1986, Proceedings, Falls Church, Virginia, American Society for Photogrammetry and Remote Sensing, v. 52, no. 6, July 1986, p. 791–799.

Sturdevant, J.A., and Kleckner, R.L., 1984, Spatial analysis requirements for a Federal Mineral Land Information System: William T. Pecora Memorial Remote Sensing Symposium, 9th, Sioux Falls, South Dakota, 1984, Proceedings, Silver Spring, Maryland, The Institute of Electrical and Electronics Engineers, Inc., ISBN 0–8186–0588–X, p. 168–173.

U.S. Bureau of Land Management, 1983, The Alaska automated land records system briefing book: U.S. Bureau of Land Management, Alaska State Office, 35 p.

U.S. Bureau of Land Management, 1984, Automated land and mineral record system: U.S. Government Printing Office, 1985/578–612/25180, 31 p.

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