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TIMBER RESOURCE INFORMATION SYSTEM

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16. Abstract

The natural resource manager needs a monitoring tool that will enable him to update his information system and test the results of management, and that will act as a warning system for environmental stress and hazardous conditions. This investigation was an operational evaluation of the use of high-altitude aircraft photography and ERTS-1 imagery as an information monitoring tool in the high-quality forest of the Pacific Northwest. The repetitive coverage (several cloud free scenes a year) of ERTS imagery makes it potentially the tool needed by the manager; however, better interpretative information is needed either by automated interpretation from the CCT's or better imagery resolution. The State of Washington and the Northwest Indian Tribes, who participated in this experiment, have on-going remote sensing programs that will continue to incorporate satellite data into their computerized information systems. Color illustrations EDC-010025 and EDC-010026 are available for purchase from the EROS Data Center.

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SUMMARY

The primary objective of this investigation was to perform an operational evaluation of the use of high-altitude aircraft photography and ERTS-1 imagery as an information monitoring tool in the high-quality forest of the Pacific Northwest, and secondarily, to test the same techniques for use in overall natural resource reservation planning.

After selecting the Quinault Indian Reservation with adjoining lands as the key demonstration area (figure I), it became apparent that the State of Washington Department of Natural Resources and U.S. Forest Service could have an interest in the investigation. On August 21, 1972, the State of Washington indicated they would examine their lands north of the Reservation as part of the Timber Resource Information System (TRIS) study and the Forest Service agreed to participate by examining the ERTS-1 imagery and reviewing sampling procedures. The BLM Service Center in Portland, Oregon, an ERTS-1 browse file center, accepted the responsibility of serving as a data (aircraft film and ERTS-1 imagery) handling facility for this investigation. We recommended to NASA that they substitute Colville Reservation for Warm Springs because Colville was very progressive in computerization of resource data and had recently obtained orthophotoquads for their Reservation. However, before NASA responded, Warm Springs took a renewed interest in the study and had limited participation throughout the investigation. Colville remained an active addition to the study team.

ERTS VICINITY MAP

Figure I

The Washington State approach was to interpret predominant cover-type groups within a 100-acre sample point sample point on a 100-chain grid on ERTS. They were able to interpret the following cover-type groups: recent clearcut, forest reproduction, conifer second growth, conifer old growth and hardwood. They then made a statistical comparison with their computerized GRIDS survey data.

The approach on Indian lands was to delineate natural resource management units large enough to be identifiable from ERTS-1 imagery. These management units were then compared to ERTS-1 imagery in several different formats and scales to test the degree of detail that could be interpreted for monitoring purposes. Enough detail could be identified and delineated on ERTS to establish the management unit boundaries and the broad cover-type groups, i.e., recent clearcut, forest reproduction, conifer second growth, conifer old growth and hardwood. No calculation of interpretive accuracy was calculated because the ground truth was used to make the identifications. Although all the examples shown in the report are from the Quinault Reservation, most of the statements about Indian lands apply to all three Northwest Reservations--Quinault, Colville, and Warm Springs.

The orthophotoquad discussed above is an aerial photograph or mosaic prepared in standard quadrangle format from which positional distortions have been removed to provide an accurate uniform scale.

CONCLUSIONS

The Indians were able to identify and delineate major boundaries of previously established management units on ERTS imagery. This was accomplished mainly because these units are defined by large geographic features such as watersheds, streams, and ridges. Major cover-types could be verified when ground truth was compared to the enlarged ERTS scenes. Recently harvested areas could be readily identified, however, the manager knows this logging has taken place and more importantly, needs the ability to update road construction and plot the exact location of clear-cut blocks to develop his resource information by geographic location.

Identification of many features, needed if ERTS is to be an adequate monitoring tool, could not be determined, i.e., road construction update, general forest size class, soil moisture data, vigor by species, more exact location of clear-cutting lines, and general condition and changes of harvested areas. The capability to determine many of these features will be improved after the computerized Natural Resources Information System (NRIS) has been in operation long enough to reflect change and management unit adjustment based on computer analysis of the resource information.

The State of Washington reported poor results in their efforts to identify major cover-types. Their hope for better utility and interpretability of ERTS imagery seems directed to computerized analysis of the computer compatible tapes (CCT). Observations of the State's report are presented in a section under Results.

RECOMMENDATIONS

1. That Washington State and the Northwest Tribes continue with the ERTS investigation and include automated interpretation and classification of the CCT's with monies that are available in the existing NASA contract.

   A. That negotiations continue with Bendix to do this automatic interpretation. (see Appendix A).

   B. That ground truth of test sets and data compilation be developed together to give a regional overview of the demonstration area instead of the present independent approach by each Agency.

   C. That resource overlays be prepared at the 1:50,000 and 1:125,000 scales.

   D. That report will include statement of statistical accuracy.

2. That the State and Indians through their computerized information systems continue to seek significant monitoring applications for ERTS and other satellite imagery.

ACKNOWLEDGMENTS

To Bill Fischer, EROS Program office, for his continuing understanding and interest in operational applications of remote sensing projects on Indian lands. To Fred Gordon, NASA Technical Monitor, for his understanding and apparent acceptance of my inconsistence and poor track record for meeting NASA's reporting requirements. Also to Roger Harding of the Washington State Department of Natural Resources for his continuing interest in finding better resource management tools for resources activities in the State of Washington. Last, but certainly not least, to my wife Priscilla for her outstanding editing on the report.

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NOTE:

Illustrations originally in color identified in their caption by an EDC-0100 number. Copies of the original color are available for purchase from the EROS Data Center, Sioux Falls, South Dakota 57198, using the EDC number. Prices are available on request.

HISTORY

The Quinault Indian Reservation is one of the few Indian Reservations in the United States that is comprised of small tracts of land in individual ownership. The Reservation has approximately 200,000 acres divided into 40 and 80-acre parcels. The tremendous number of small tracts make some type of management tool necessary that would enable a land manager to tie all the resource data together into a reservation management program. The management of these resources also includes the payment of harvest receipts of several million dollars a year to individual owners. The forest resources on the Quinault lend themselves to ERTS-type monitoring because timber harvesting involves clear-cutting of timber in rather large blocks of 20 to 50 acres; these blocks are easily identified on ERTS imagery. The Reservation also has pronounced landforms, i.e., ridge formations and large streams to aid in the development and identification of management units.

The Quinault, with timber harvest receipts of $7 million - $15 million each year, has been studied and restudied to find a means of taking a large amount of resource data and translating it into meaningful information for decision making. The studies varied from a forest management study accomplished by Philip A. Briegleb, retired director of Pacific Northwest Experiment Station, U.S. Forest Service, to multispectral photography and thermal imagery flown by Bendix for the Tribe to use in a study of their resources. The Bendix data were financed with Bureau of Indian Affairs (BIA) funds before the TRIS investigation started. It was this tribal interest in sophisticated remote sensing that sparked the idea of the TRIS investigation at the Quinault Reservation. With these data in hand and a need to help solve this difficult information extraction and decision-making problem we undertook the Timber Resource Information System investigation with the Quinault Reservation and adjoining lands as the primary demonstration area (figure II).

Knowing the Warm Springs and Colville Tribes were attempting to establish remote sensing programs, we included them in our proposed investigation. The ownership within their Reservations is basically tribal with resources receipts going into a general fund, however, they are faced with the same need for Reservation-wide planning as the Quinaults. The Colvilles concentrated their effort into preparation of an ownership grid, water district maps, reservation planning map, and implementation of the NRIS computer program for their resource data. The Warm Springs concentrated on collection of reservation planning data and conducting a water supply study including snow pack levels in the mountains,and lake and reservoir levels. The State of Washington Department of Natural Resources with several years of remote sensing experience in resource management on lands adjoining the Quinault Reservation was an enthusiastic participant from our first meeting in April 6, 1972. The Forest Service looked at the ERTS imagery at our various meetings held in the Northwest and gave verbal comments concerning the different sampling techniques being used. By including Washington State and Forest Service lands with the Indian Reservations lands in the Demonstration Area, we attempted to make the investigation a regional consideration

TIMBER RESOURCES INFORMATION SYSTEM
DEMONSTRATION AREA

SCALE

10 5 0 10 20 30 MILES

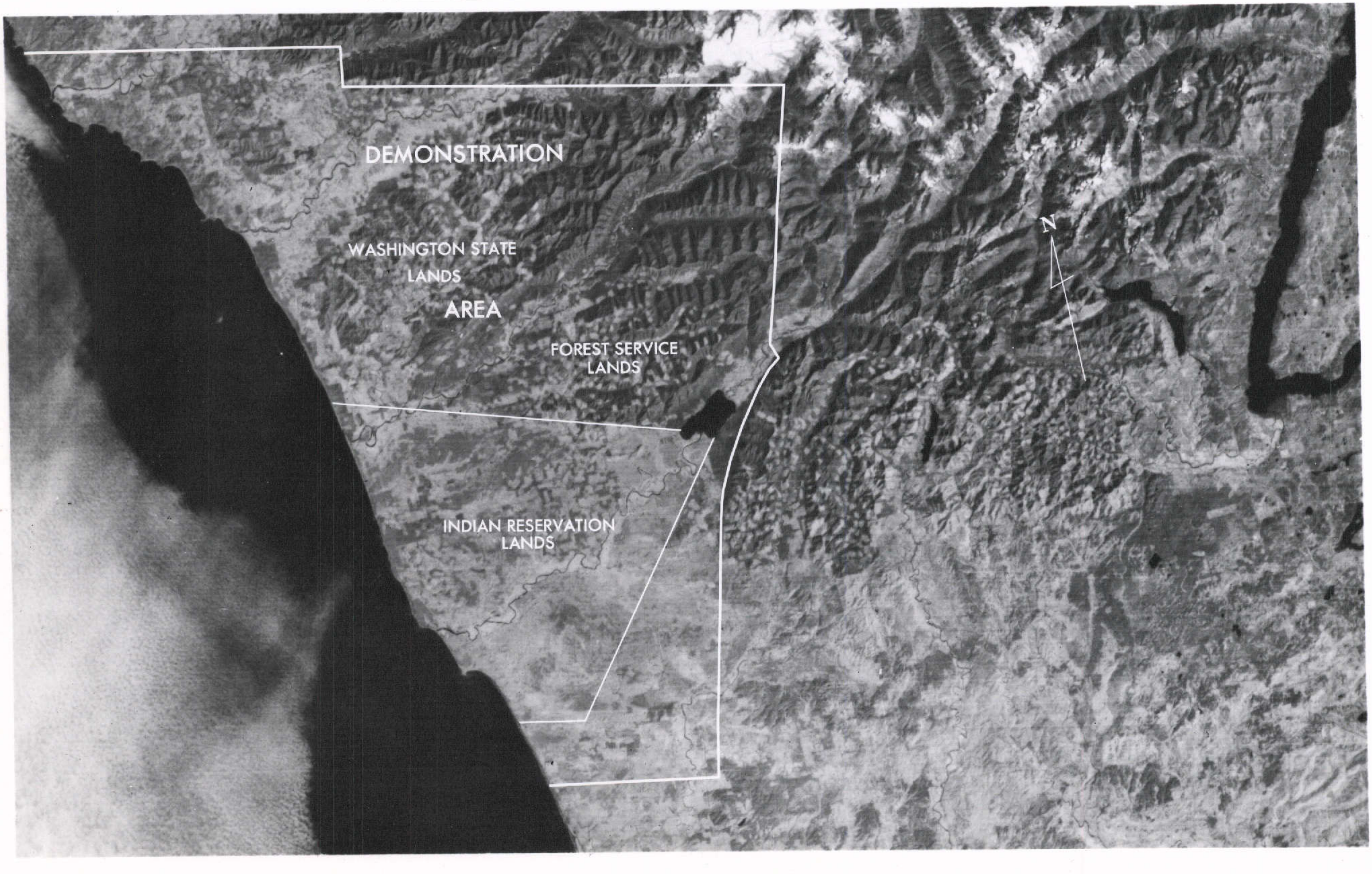


Figure II

of application as well as the individual agency test discussed within this report. The automated interpretation, as proposed in the Recommendations section, would interpret the whole Demonstration Area as one region and enable a statistical analysis of accuracy comparing ground truth and automated interpretations from common test sites.

Most of the ERTS investigations dealing with monitoring of Earth resources seem to deal with large sections or regions of the country with little application to the owner of rather small parcels, like the 200,000 acres of the Quinault Indian Reservation. The main thrust of this report is an evaluation of the utility of high-altitude aircraft photography and ERTS-1 imagery as a resource information monitoring tool for the land manager of several thousand acres in an area of limited geographic range. Knowing that the utility of ERTS imagery would increase as we enlarged the area, we kept the opportunity open to evaluate the entire demonstration area on one common base, as proposed in the recommendations section. This regional view, in concert with the land manager's detailed information, can provide a broader understanding of current resource supply for market, regional environmental data concerning resources, and changing land use.

An operational remote sensing program is continuing on the Reservations beyond this investigation using a procedure that can include satellite input once test areas show better utility of satellite imagery for monitoring. The Colville Tribe is operating and the Quinault Tribe is implementing the computerized Natural Resources Information System (NRIS) for data storage of resource overlays. The NRIS manipulates the digitized graphic, with most of the interesting operations centered around "area" maps, i.e., maps that can be specified as a set of closed regions with a single attribute per region. Functions which individual programs or combinations thereof can perform include scaling, translation, rectification to common base, extraction by area or attribute criteria, extraction by geographic limits (windowing), inquiry of a point's attribute, area calculations, and compositing (logical union) of two or more maps. The ultimate use of space imagery will be where the land manager can, through automated techniques, use the imagery as a monitoring tool to update his information system and test the results of management, through change detection within the information system, and can use it to act as a warning system for environmental stress and hazardous conditions.

APPROACH

In March 1972, other Federal and State agencies were contacted to see who would be interested in participating in the proposed Timber Resources Information System (TRIS) investigation together with the Quinault and Warm Springs Tribes. After several discussions with the agencies, the following participation evolved: the State of Washington Department of Natural Resources would conduct an independent sampling to test the interpretability of ERTS imagery for classification of broad cover-types, the Bureau of Land Management (BLM) Service Center in Portland, Oregon, would serve as a central data handling facility for high-altitude aircraft film and ERTS imagery during the investigation, and the U.S. Forest Service would examine the ERTS-1 imagery and review the sampling procedures. The programs for the three Indian Tribes--Quinault, Warm Springs, and the newly added Colville, were then defined and contracts were let for them to compile ground truth, and in the case of the Colville Tribe to implement the NRIS computer program.

The Service Center for BLM in Portland, Oregon, was a central data handling facility to accommodate all the organizations involved; the Quinault Tribe in western Washington, the Colville Tribe in eastern Washington, the Warm Springs Tribe in Oregon, Washington State in western Washington, and U.S. Forest Service in Portland, Oregon. The high cost of duplicating the data and the limited places to have it done, necessitated this central handling facility.

The following data were available during the study:

NASA high-altitude photography - August 1972 and May 1973

- The four ERTS configuration spectral bands in the Vinten sensor (70 mm format).

- Aerochrome infrared 2443 in the RC-10 (9.5 in. format) scale 1:130,000.
- All film in positive transparencies.

ERTS imagery - 17 scenes of imagery

- 1 RBV, 16 MSS.
- 2 copies each of 70 mm negative transparencies.
- 2 copies each of 9.5 in. positive transparencies.
- Color composite of July 1972 RBV prepared by RCA

Bendix flown data available for the Quinault

- 70 mm positive transparencies film format at scales 1:52,500 and 1:100,000

  EK2402, Schott Filters GG-475 and 18 (in series)

  EK2402, Schott Filters OG-570 and 38 (in series)

  EK2424, Schott Filter RG-645 and Corning Filter 9830 (in series)

  EK2448, Wratten HF-3

- 70 mm film transparency of thermal infrared data at scales of 1:78,000 and 1:197,500. Source was digital magnetic tapes.

The BLM facility had little viewing equipment and even though it is also an ERTS browse file, there was very little demand to look at the satellite imagery. I think the lack of adequate viewing equipment was the main reason the cooperating agencies and general public showed so little interest in viewing the ERTS imagery. There was good ERTS seasonal coverage for the Quinault investigation with six good cloud-free scenes to use. They were: RBV July 19, 1972, MSS October 19, 1972, MSS January 19, 1973, MSS May 19, 1973, MSS July 19, 1973, and MSS August 19, 1973. It is interesting to note that NASA carried the Quinault area, or the Olympic Peninsula, as a high priority for high-altitude U-2 flights for 2 to 3 years prior to the ERTS investigation and had not completed a mission there because of reliance on reports of weather conditions. However, with the repetitive coverage of ERTS we have six excellent ERTS scenes within a year and two U-2 flights were successfully completed in support of the investigation.

The approach on the Quinault Reservation was to evaluate all existing resource data, tie it to a common base, and decide what data would lend themselves to the development of meaningful management units that we estimated to be within the resolution capability of ERTS imagery using standard photointerpretation methods. The existing resource data used included: Philip Briegleb's administrative overviews and recommendations on multiple use management of the resources, a detailed timber survey with harvest records, a not yet completed water inventory project that included fisheries resource data, and a soil reconnaissance mapped to Soil Conservation Service soil series.

The Tribe's choice of a base map on which to plot data and resource management units was either a 15-minute topographic quadrangle prepared in 1955 with very little photo identifiable detail or a 1" to 1,000' planimetric map that had been prepared in the 1950's using "slotted template" control of low-altitude (1:12,000) photography. Working with these maps and the Bendix analog nonmetric photography and thermal imagery it became apparent that a photointerpretive correlation between ERTS imagery and management units tied to a base map would require a new base map similar to the orthophotoquads we have on the Colville and other Reservations. Because time did not permit the development of an orthophoto project, a contract was let with a local photogrammetrist, Spencer B. Gross of Portland, Oregon, to use his A-10 Wild Plotter to prepare a planimetric base map from NASA U-2 false color photography flown in support of the investigation. He attempted to use the May 1973 film but found the corners had a double image so he prepared the map from the 1972 flight. The map was prepared at 1:12,000 scale with U.S. Coast and Geodetic triangulation stations as the base control net. The map displayed many planimetric features, such as timber cutting blocks, roads by class, streams, rock pits, and cadastral survey (figure III).

The ground truth data that had the most significance to the Quinault resource program and also met the needs of the management unit concept within the resolution capability of ERTS imagery were the watershed management units. The Camp Creek area, shown here as an example (figure IV), contains about 4,000 acres. Watershed unit boundaries are defined usually by ridge formations which in turn affect the stream drainages. The units are mapped in rather gross detail in three categories: uncut timber areas, cutting blocks by year harvested, and water resource zones. Monitoring the changes within these categories when correlated with detailed ground truth will give the following information to the land manager: 1) The

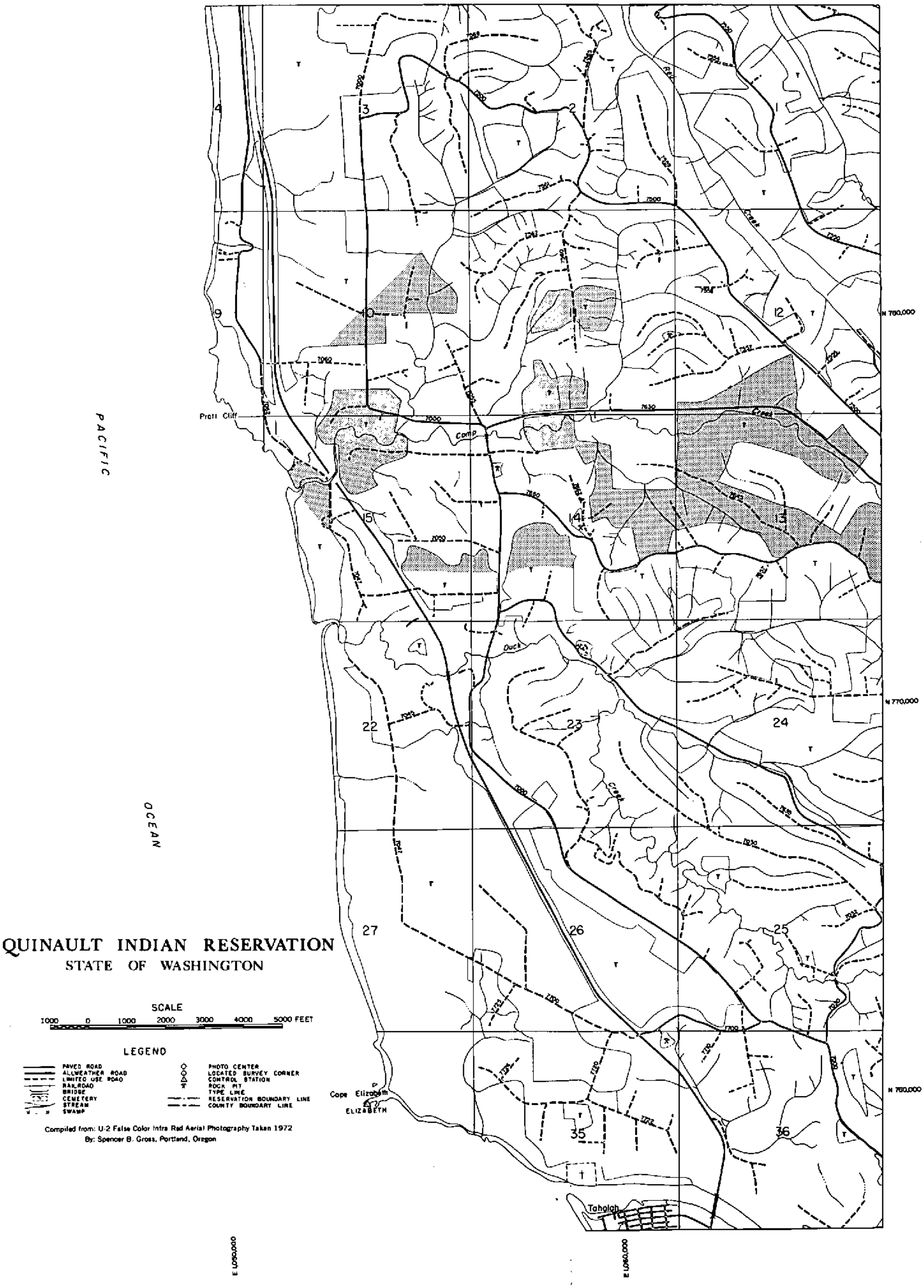
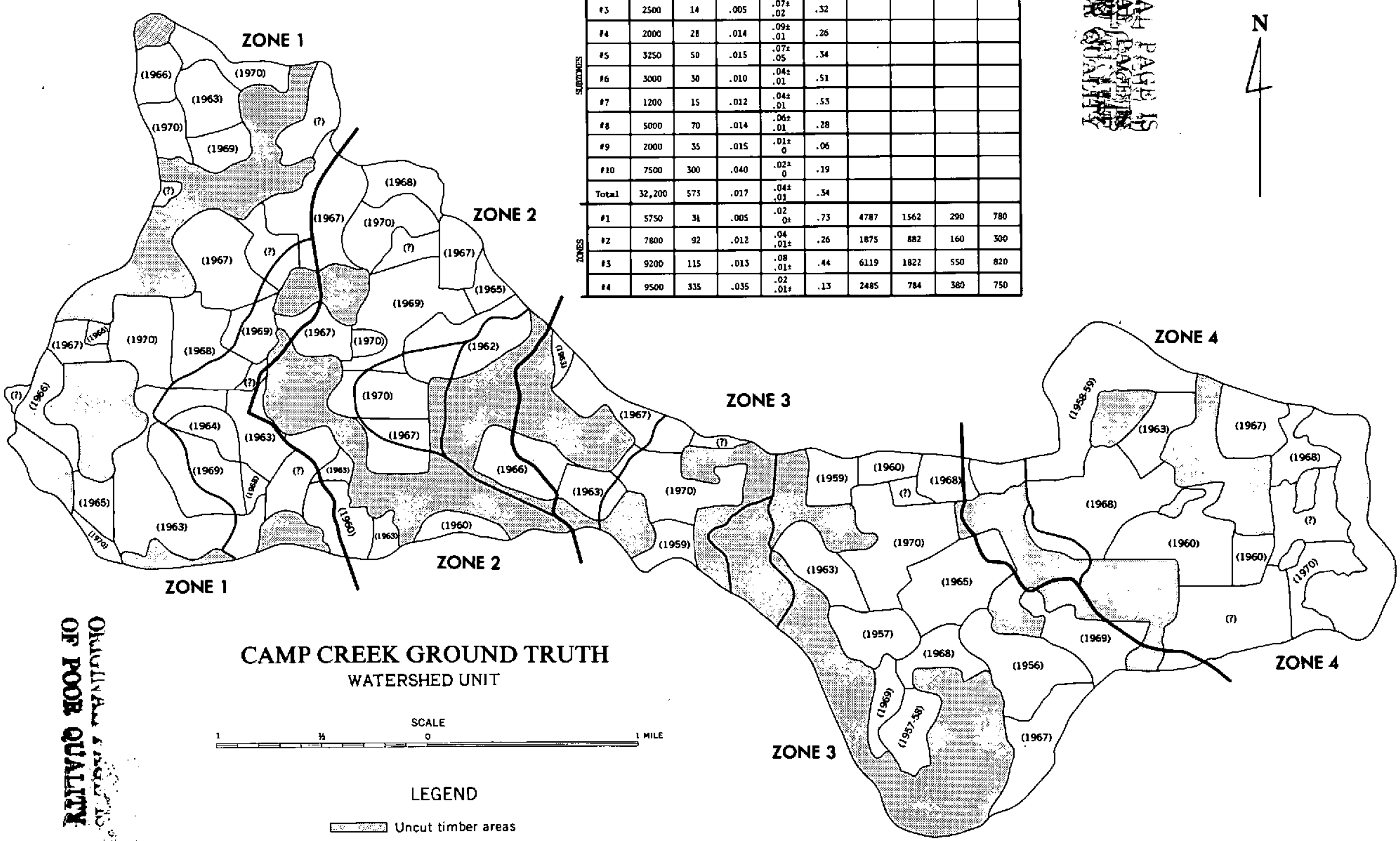

QUINAULT INDIAN RESERVATION
STATE OF WASHINGTON
SCALE
1000 0 1000 2000 3000 4000 5000 FEET
LEGEND
PAVED ROAD
ALLWEATHER ROAD
LIMITED USE ROAD
RAILROAD
BRIDGE
CEMETERY
STREAM
SWAMP
PHOTO CENTER
LOCATED SURVEY CORNER
CONTROL STATION
ROCK PIT
TYPE LINE
RESERVATION BOUNDARY LINE
COUNTY BOUNDARY LINE
Compiled from: U-2 False Color Infra Red Aerial Photography Taken 1972
By: Spencer B. Gross, Portland, Oregon
PACIFIC
OCEAN
Pratt Cliff
Cape Elizabeth
ELIZABETH
Taholah
Camp
Creek
Duck
Creek
Raft
N 780,000
N 770,000
N 760,000
E 1,060,000
E 1,080,000
4
3
2
9
10
12
15
14
13
22
23
24
27
26
25
35
36

Figure III

	Lineal Distance (Feet)	Rise (Feet)	Gradient	F/M^2	G/M^2	Cedar Slash 1000 BF	Hemlock Slash 1000 BF	Uncut Acres	Cut Acres
SUBZONES #1	2500	11	.004	.03± .01	.75				
#2	3250	20	.006	.02± 0	.50				
#3	2500	14	.005	.07± .02	.32				
#4	2000	28	.014	.09± .01	.26				
#5	3250	50	.015	.07± .05	.34				
#6	3000	30	.010	.04± .01	.51				
#7	1200	15	.012	.04± .01	.53				
#8	5000	70	.014	.06± .01	.28				
#9	2000	35	.015	.01± 0	.06				
#10	7500	300	.040	.02± 0	.19				
Total	32,200	573	.017	.04± .01	.34				
ZONES #1	5750	31	.005	.02 0±	.73	4787	1562	290	780
#2	7800	92	.012	.04 .01±	.26	1875	882	160	300
#3	9200	115	.013	.08 .01±	.44	6119	1822	550	820
#4	9500	335	.035	.02 .01±	.13	2485	784	380	750



CAMP CREEK GROUND TRUTH

WATERSHED UNIT

SCALE

1 ½ 0 1 MILE

LEGEND

Uncut timber areas

(1964) Years of timber harvest

Zones

Subzones

Figure IV

effect clear-cut logging has on fish population, 2) the effect reforestation of slash areas has on fish population, 3) the effect management has had on the establishment and development of the new forest growth, 4) changing area of forest type for calculation of allowable cut, 5) and detection of erosion on problem areas. Monitoring these general changes, which are within the resolution capability of high-altitude photography, and relating them to management changes will give the land manager the information he needs to more wisely select his courses of action.

The water resource zones include the following "ground" measured data: lineal distance of streams within a zone, their rise in feet, gradient, fish per square meter (individual fish count), grams per square meter (mass of fish rating), amount of slash by board feet volume by species (slash being the wood waste on the ground that was not harvested), and area cut and uncut. These zones are made-up of subzones that geographically separate the drainages by the criterion shown in the tabular presentation on figure IV. The zones and subzones progressively increase in numbers from West to East. These data have been used in a discriminant analysis to show organic carbon levels, variation of resident fish population, conditions under summer and winter flow and water quality. The original watershed units were plotted to an enlargement of the USGS 15-minute quadrangle map and the uncut timber areas transferred by a sketch master. The tabular information has been stored in a computer data bank at the University of Washington and the Tribe is presently finishing the transfer of the units to their new planimetric base map for recalculation of areas and to prepare for storing the data in the NRIS. The NRIS will enable them to recall a graphic display and quiry the system with an answer that can be based on compositing of several overlay themes. In other words, they can tie the watershed data to species of uncut timber and their soils map to check additional variables in their analysis.

Figure V shows the resolution and amount of resource data that can be interpreted from NASA high-altitude false-color infrared photography. This NASA photograph is at a scale of 1:105,600 and was flown in May 1973. The 1972 photography used to prepare the planimetric base map (figure III) has the same amount of resource detail. The watershed unit being discussed is located south and west of the center of the photograph. The roads and water are very obvious in the picture. Other data are as follows: darker red tones are old growth uncut timber; bright red in the cutting blocks are older logging areas that have been reforested; grayish tones are older logging with slash showing; light brown is bare soil of the most recently logged areas (brown coloration is more pronounced on positive transparencies); and the rather pure stands of hardwood (deciduous trees) along the Quinault River show as bright red on the lower section of the photograph. It is interesting to note the very gray area just north and east of the photo center, is an area that has been burned.

Steroscopic viewing of the high-altitude photography is a great aid in interpreting the resource data needed by the land manager. Figure III shows the planimetric detail that can be plotted

Figure V

from the high-altitude photography and when correlated with ground data gives the manager the data he needs for overall resource management. The shaded area is uncut timber within the Camp Creek watershed unit previously discussed. By comparing the 1973 photography with the most northwesterly shaded areas within the watershed unit, you will find that old growth timber has been cut since the 1972 photography that was used to make the planimetric map. This is in the center of Section 10 where the limited use road takes off on a northwest bearing. Another recent cutting area is at the bottom of Section 10 where the 7,000 road turns north.

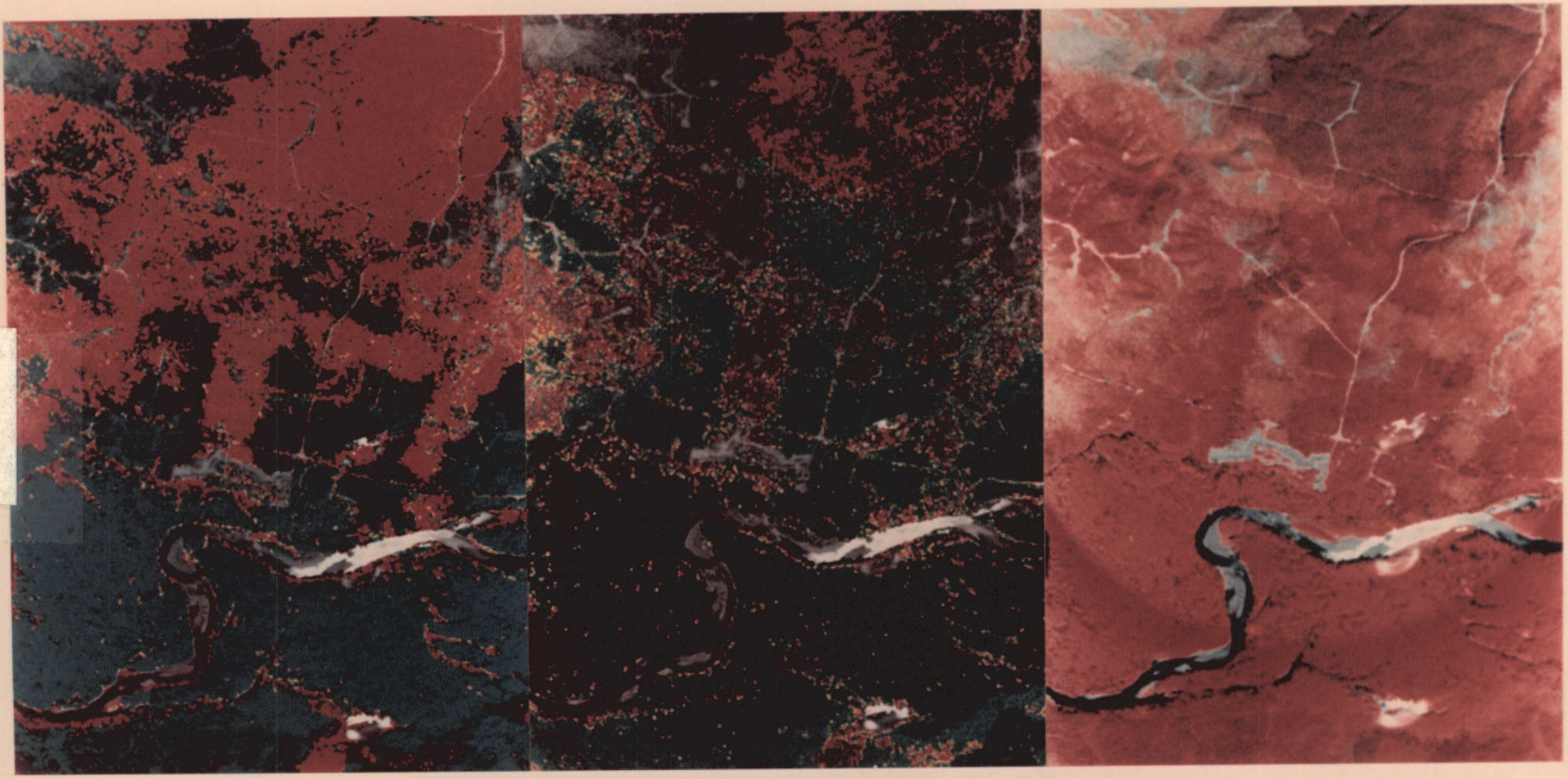
The last illustration (figure VI) shows samples of automated tree-type classification done by McDonnel Douglas from their low-altitude analog scanner imagery. This scanner imagery was taken late in the investigation, 1973. It was flown on a rather small area to give the investigators a feeling for automated classification of scanner data, in advance of possibly recommending classification of ERTS data. The background detail comes from their thermal channel (10.2-12.6 µm) with the other wavelength bands being ERTS configuration. Because of this color rendition, the deciduous class in panel one should be labeled as blue. The classifications were based on test site ground truth collected by the Tribe and the final classifications were checked in the field with a 80 to 90 percent accuracy for a 5-mile long strip.

After receiving the "ground truth" most of the ERTS identification and interpretations were done in the Washington, D.C. area. They were done in conjunction with the USGS Special Mapping Center at

FIVE CHANNEL MULTISPECTRAL SCANNER
QUINAULT INDIAN RESERVATION

9000 FT ALTITUDE
25 JULY 1973

TREE TYPE CLASSIFICATION



GREEN – DECIDUOUS
RED – CEDAR
YELLOW – MIXED

GREEN – HEMLOCK
RED – IMMATURE CEDAR
YELLOW – MIXED

SIMULATED INFRARED EKTACHROME
CH. 1, 2, 4

TREE TYPE CLASSIFICATION
CH. 1, 2, 3, 4 RATIOED
CH. 5 MAP BACKGROUND

Figure IV

Reston. ERTS scenes were displayed in a ITEK viewer with 20X and 30X enlargement capability and a Post viewer that had been modified to handle a 9 X 9 in. format with 18X enlargement. The 9 X 9 in. transparencies were also studied using a Diazo process for change detection and general interpretations. The enlargement of the positive transparencies gave the best detail for interpretation, however, USGS was successful with photographic enhancement to give more detail as shown in figures I and II. These are an August 1973 scene which is a combination of band 7 at twice the intensity of band 5. Several tested combinations showed this to be the best for vegetative and water resource detail. The results of these interpretations and sample products from ERTS were given to the Quinault scientist as the investigation progressed.

ERTS resolution allowed for the identification and delineation of previously established watershed units and broad cover-type groups. The Diazo color process did help highlight some of the detection of change, however, it had the same resolution limitations as the black and white transparencies.

The State of Washington's approach was to interpret ERTS band 5-MSS of January 1973 and July 1973 scenes. These scenes were viewed in a 9 X 9 in. transparent positive format with an 18X enlargement on a microfiche reader. They laid a 100-chain grid on the screen of the reader and classified the predominant cover-type group within a 100-acre sample point. Preliminary investigation convinced the interpreters the originally planned 10-acre sample point was too small so they developed a plan for using a 100-acre sample point. They interpreted the following cover-type groups:

	Approx. Origins
Recent Clearcut	1966-present
Forest Reproduction	1956-1965
Conifer Second Growth	1886-1955
Conifer Old Growth	1885 or before
Hardwood	1955 or before

The winter scene was important for distinguishing the hardwood cover-type but did not help in identifying mixed-conifer-hardwood. The mixed classification was dropped from the study. The complete report by the Department of Natural Resources is included as Appendix B.

The Warm Springs Tribe looked at ERTS imagery.However, the bulk of their resource delineations came from 1:250,000 enlargements of the 9 X 9 in. high-altitude infrared photography flown by NASA in August 1972 and May 1973. They concentrated their efforts on water resources (levels of lakes and reservoirs, and snow levels) and reservation planning.

The Colville Tribe used orthophoto maps at scales of 1:24,000 and 1:125,000 to develop preliminary resource overlays. The Tribe with their own money has contracted with Raytheon Autometric to do detailed interpretations in select areas and an overall reservation land use overlay for the 1:125,000 orthophoto mosaic to be interpreted from ERTS imagery. The major portion of the Tribes effort under the TRIS contract was to set up the NRIS computer program on the Washington State

University facility. They do have the NRIS program running on an operational basis at the present time and will put the new resource data compiled by Raytheon in the information system. The NRIS Program Summary Report is included as Appendix C.

PROBLEMS

One of the main problems with experimenting with ERTS as an operational tool is the difficulty of finding viewing equipment to enlarge the imagery to at least 1:250,000. The Indian photo base maps are at a scale of 1:125,000 so that any correlation requires a minimum scale of 1:250,000. We have had some photo enlargement of ERTS to that scale, however, every generation away from the original positive gives less detail. For this reason the report shows ERTS only as a general location map. We found the best ERTS interpretations was from viewing machines that have an adjustment to control light intensity and enlarge to at least 1:250,000.

NASA Goddard, in filling the product order for the Quinault Reservation, extended the longitude too far east with the result that only 3 of 17 sets of data received covered the Quinault Reservation (the three additional usable scene were obtained from the State of Washington). This gave us a lot of data, but little had direct application to this investigation and I am sure prevented others from getting data they needed.

We found the NASA system of ordering and mailing very inflexible with the problem of unfilled retrospective orders and obsolete mailing labels overcomed by hand carrying products directly from Goddard.

The State of Washington felt very strongly that the utility of ERTS would be greatly increased if a township and range (cadestral survey) projection could be displayed on the ERTS imagery. With their scattered ownership holdings, they found it very difficult to find their parcels of land and indicated this was a reason they increased the sample point from 10 to 100 acres.

RESULTS

The repetitive coverage of ERTS imagery makes it potentially the monitoring tool needed by the resource manager. ERTS resolution allowed for the identification and delineation of previously established watershed units and broad cover-type groups, however, to be an adequate monitoring tool resolution must be improved to identify road construction update, general forest size class, soil moisture data, vigor by species, more exact location of clear cutting lines, and general condition and changes of harvested areas. The NASA high-altitude photography has the resolution capability to give the land manager all the resource data needed when supported with ground measurements and existing surveys. The problem here is the high expense and the inability to easily get coverage when needed.

The State's dismissal of their analysis is disappointing and needs explanation. In consultation with Roger Harding after receiving their June 20, 1974, report, it came to light that the State had tried two or three times to update their 1964 high-altitude photography. The NASA flights did not extend that far north and the weather prevented their attempted flights under rigid seasonal constraints. By not having their GRIDS (Grided Resource Inventory Data System) updated by new photography they reluctantly compared their ERTS interpretations to the 1964 GRIDS data and dismissed the results.

In table No. 1, I see consistent trend information that shows more recent clearcut and forest reproduction in 1964 and less old

COMPARISON HIGH ALTITUDE 1964 TO ERTS 1973
(in acres)

	QUINAULT		WEST JEFFERSON	
	1/60,000 1964	1/1,000,000 1973	1/60,000 1964	1/1,000,000 1973
Recent Clearcut	22,000	20,000	8,000	14,000
Forest Reproduction	43,000	56,000	6,000	14,000
Conifer Second Growth	35,000	49,000	15,000	5,000
Conifer Old Growth	59,000	47,000	134,000	129,000
Hardwood	20,000	7,000	1,000	2,000
Total	179,000	179,000	164,000	164,000

TABLE NO. 1

growth in 1973. This is certainly a true condition of the forest they were sampling. The State has recently completed an update of the GRIDS without the use of high-altitude photography and will make it available in the Table No. 1 format for a direct comparison to the ERTS interpretation. The analysis will be sent to NASA upon completion.

APPENDIX

PRELIMINARY

STATEMENT OF WORK

COMPUTER PROCESSING OF ERTS DATA

Background and Scope

Data from the Earth Resources Technology Satellite (ERTS-1 satellite) has been successfully interpreted for use in a number of resource management applications. Interpretation techniques used have been both manual and computer associated. Manual techniques have been successful when large features or features with high feature to background contrast are being sought. Computer assisted interpretation is generally required where subtle band to band contrast variations are being sought, or where features are too small to reliably recognize by shape.

For the ERTS-1 experiment under discussion, manual techniques for interpretation of ERTS data have been evaluated for use in forest resource management, and it is desired to perform a comparative evaluation of computer processing of ERTS data.

The work to be performed consists of computer processing of selected areas of ERTS scenes E1385-18371 and E1169-18375. The data source will be GFE 9 track 800 BPI magnetic tapes of the scenes in question. Also supplied - GFE will be the ground truth information required to perform training set selection of the desired features for computer analysis for feature selection.

August 1974

The test area section of both scenes will be processed for the features of interest to yield the categories described in the task statements. The relative accuracies and use of feature extraction for both scenes will be comparatively evaluated. The scene evaluated as yielding the best feature separation will be further processed to provide map overlays of ten selected categories to scales of 1:125,000 and 1:50,000 for areas of 1700 sq. miles and 60 sq. miles respectively. Area printouts giving the area of the test site for each feature or category, and a classification accuracy table giving the classification accuracy derived from the training set data for each category will be provided. A report will be written describing the conduct of the investigation, (a statement of statistical accuracy of the results achieved, and recommended future actions).

<u>Tasks to be Performed</u>

1. Screening Imagery and Training Set Selection

At least three ERTS bands of film negatives will be generated of the test areas from the GFE computer tapes of the two ERTS scenes. A 3 x enlargements of single band and color composite imagery of the test area will be made from the film negatives. The enlargements will be annotated by the contractor with ground truth information supplied by the government, and training sets for feature selection extracted from the computer tapes in the ground truth areas for computer analysis and processing.

2. Data Analysis and Processing

Using the training set data derived from the GFE ground truth information, the ERTS computer tapes of the test site area will be processed to yield the following categories:

Primary Categories

a. Block cut areas
b. Old growth (uncut) timber
    1) Coniferous
    2) Deciduous
c. Water
d. Bare Soil
e. Wetlands
f. Grass
g. Roads

Secondary Categories (Subsets of a and b above)

a. Block Cut Areas
    1) Recent Cut
    2) Reforested
    3) Heavy Slash
b. Old growth (uncut) timber
    1) Deciduous
    2) Cedar
    3) Douglas-Fir
    4) Hemlock

3. Generate Computer Printouts which list the following:

a. "Truth Tables" which list the percentage classification accuracy for each category when the classification algorithm is applied to the training set data. The truth table will be provided for all the categories used in the data processing.

b. Area tables, which list the total area for each category in terms of percentage each category is of the data processed (the test area), acreage of each category, and square kilometers of each category.

c. Information computer printouts obtained doing the analysis step, together with an explanation of the meaning of the printouts.

4. Categorized Color Imagery

Color imagery (not geometrically corrected) of the test area portion of the two secnes will be generated which designates a color for each category. The imagery will be color transparencies to a nominal scale of 1:1,000,000. 3 x enlargements (color prints) will also be made. The categories shown will be selected from the categories described in Task 2, with a minimum of ten categories considered. Categories may be combined for higher overall classification accuracy if the classification accuracy of any individual category or categories is judged as too low to be useful.

5. Map Overlays

Of the two scenes available, the portion of one scene, covering the test area, which is judged to have the most useful processed results from the standpoint of separation of desired categories and overall classification accuracy will be used to generate geometrically corrected map overlays. Categories to be used for overlays will be selected by the government and will be not less than seven or more than ten in number. The total area and the scale of the overlays are as follows:

a. Set of overlays at a scale of 1:125,000 of the entire test area (estimated 1700 sq. miles)

b. Set of overlays at a scale of 1:50,000 of one quadrangle (10 x 6 miles) of the test area.

The overlays will be provided in color transparency form, one color per overlay category. The overlays will be provided with a transparent base map with the overlays registered to the base map. The original base map will be GFE. Ground control points will be selected from the base map and used in the geometric correction processing to assure the best fit of the registered overlays to the base map.

6. Reports

A report will be prepared to describe the conduct of the investigation, the methods used, the results achieved, the cost per unit area of the processing based upon both current experimental techniques and projected future costs, and recommendations for future work.

Period of Performance

The work described herein will be completed within 90 days of receipt of the data tapes and ground truth information, or within 90 days of contract award, whichever is later.

STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
Bert Cole, Commissioner of Public Lands

REPORT ON ERTS PROJECT NO. 229

Prepared by Glenn Yeary
Resource Inventory Section

The State of Washington, Department of Natural Resources, has in operation an inventory system known as GRIDS (Grided Resource Inventory Data System). GRIDS is designed to sample one acre sample points at ten chain intervals, using photo interpretative methods. In our ERTS investigation, we modified the ten chain grid to 100 chain grid and sample 100 acres (Figure No. 2). This modification was the result of our experience in looking at a ten acre sample on ERTS imagery. We enlarged the scale to 1:187,000 using a micro-fiche viewer which did not show anything other than shades of gray; therefore, we changed the original .02 inch diameter circle to a .20 inch diameter circle to sample 100 acres on the ERTS image.

In our test, we were comparing two areas in the Olympic Peninsula region; one in West Jefferson County adjacent to the Quinault; the other the Quinault Indian Reservation. We first reviewed the information on State lands in West Jefferson County for which we have GRIDS information on file. We interpreted 1964 high altitude photography (1:60,000), then we converted the grid design at 100 chain intervals to ERTS 1 imagery, using band 5, the red band of July 1973 and January 1973, as two negatives for interpretative work.

The data were recorded on optical character reader forms for input into an IBM Model 360-30 computer. A new configuration map was prepared to represent West Jefferson County, Figure No. 1. The Township being 41 North, Range 99 West; and the Quinault Indian Reservation, Figure No. 2, being Township 40 North, Range 99 West. We then interpreted, or completed calling, using both high altitude and ERTS imagery. We originally had attempted to identify six cover type groups which would be:

1. Recent clearcut - 1966 to present.
2. Forest reproduction - 1956 - 1965.
3. Conifer second growth - 1886 - 1956.
4. Conifer old growth - 1885 or before.
5. Hardwood - 1955 or before.
6. Conifer hardwood mixes, 1955 or before, were excluded because it was impossible to identify.

The problems associated with photo identification of high elevation and ERTS imagery are comparable to what many investigators have reported; one being that the human eye cannot detect more than 15 tones of gray. This is a major restraint along with problems of scale and the ability to locate a specific point, which is difficult if not impossible.

Other items that are useful in normal photo identification are not helpful or cannot be discerned on ERTS imagery; that of shape, form, texture, apparent size, tends to wash out when we are dealing with small forest types of specific tree identification, which we were attempting to do in this proposal. We did, and were able to, contrast the January ERTS with the July imagery, enabling us to determine in certain areas, topographic features and stream systems by comparing these images side by side; however, the early January imagery overshadowed or washed out any identifiable qualities of forest types in many of the areas because of the shadow effect of the low sun angle.

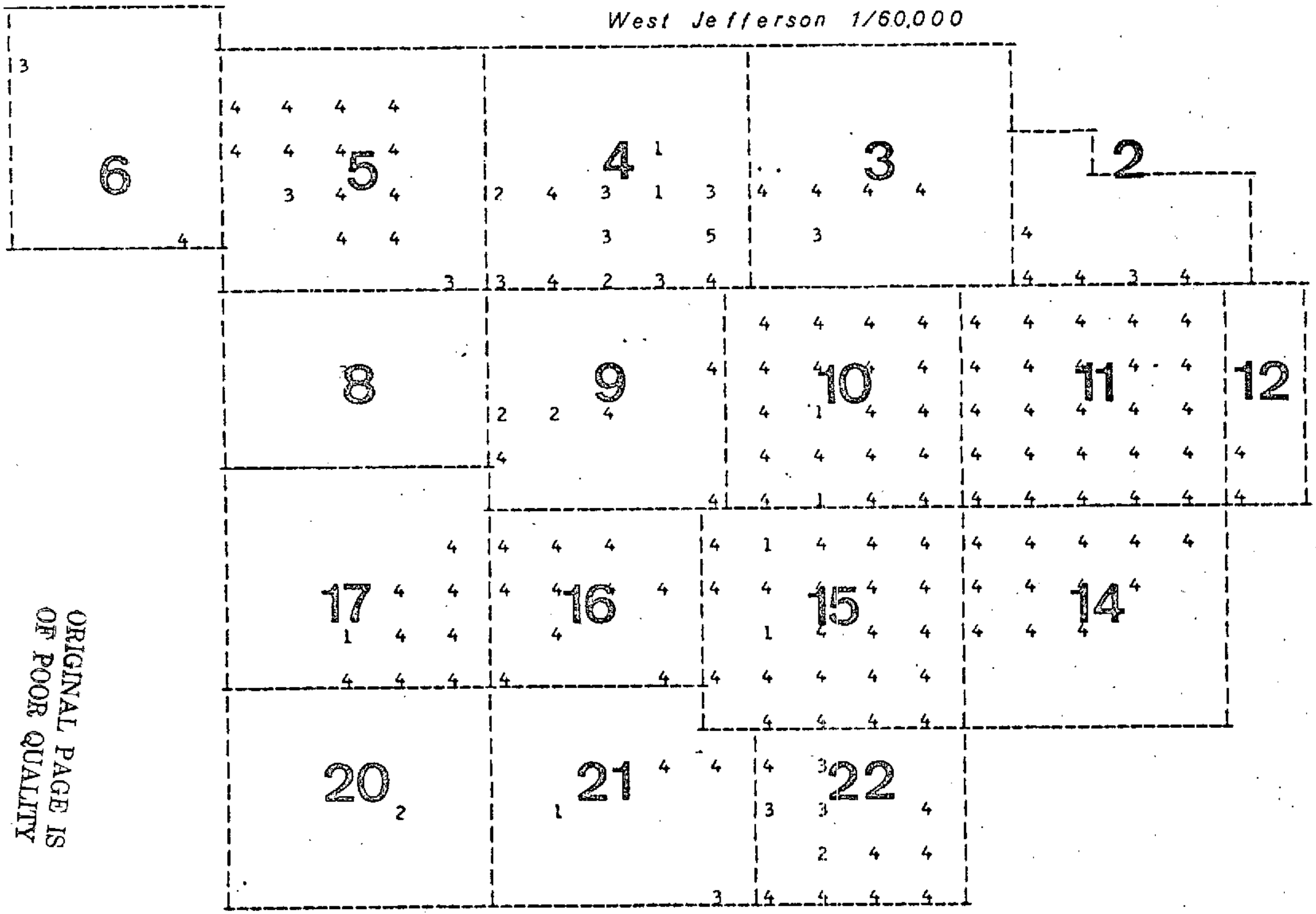
The one obvious conclusion of this investigation is that, other than telling large geographic features, major stream changes, identifiable lakes, mountains, etc., the use of ERTS imagery and the unaided human eye have rather limited application. I am sure many investigators are at the point that we are; that some computerized analysis of data is the only reasonable means of analyzing the massive data that are available from ERTS.

Table No. 1 summarized the data collected and compares the ERTS 1973 to the high altitude photos of 1974. Some trends may be inferred from the data; however, specific comparisons would not be accurate.

LISTING OF ERTS DATA FILE APR 30, 1974

LEGEND		
1 RECENT C/C	#1=	8
2 FOREST REPROD	#2=	6
3 CON SECOND GR	#3=	15
4 CON OLD GR	#4=	134
5 HARDWOOD	#5=	1
?	TOT	164

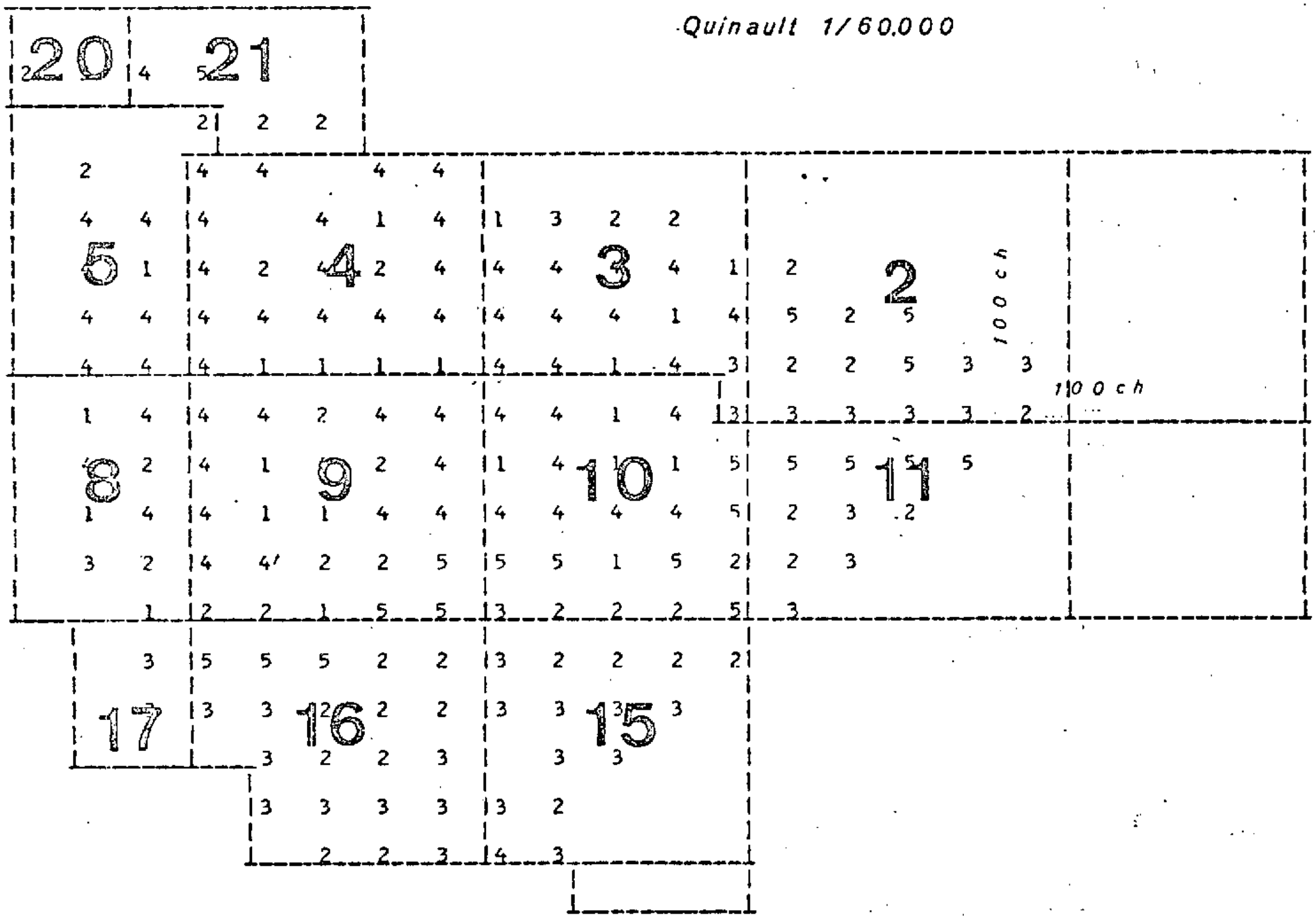
West Jefferson 1/60,000



TWP-41 RANGE-990W

FIGURE NO. 1 1964

LISTING OF ERTS DATA FILE APR 30, 1974



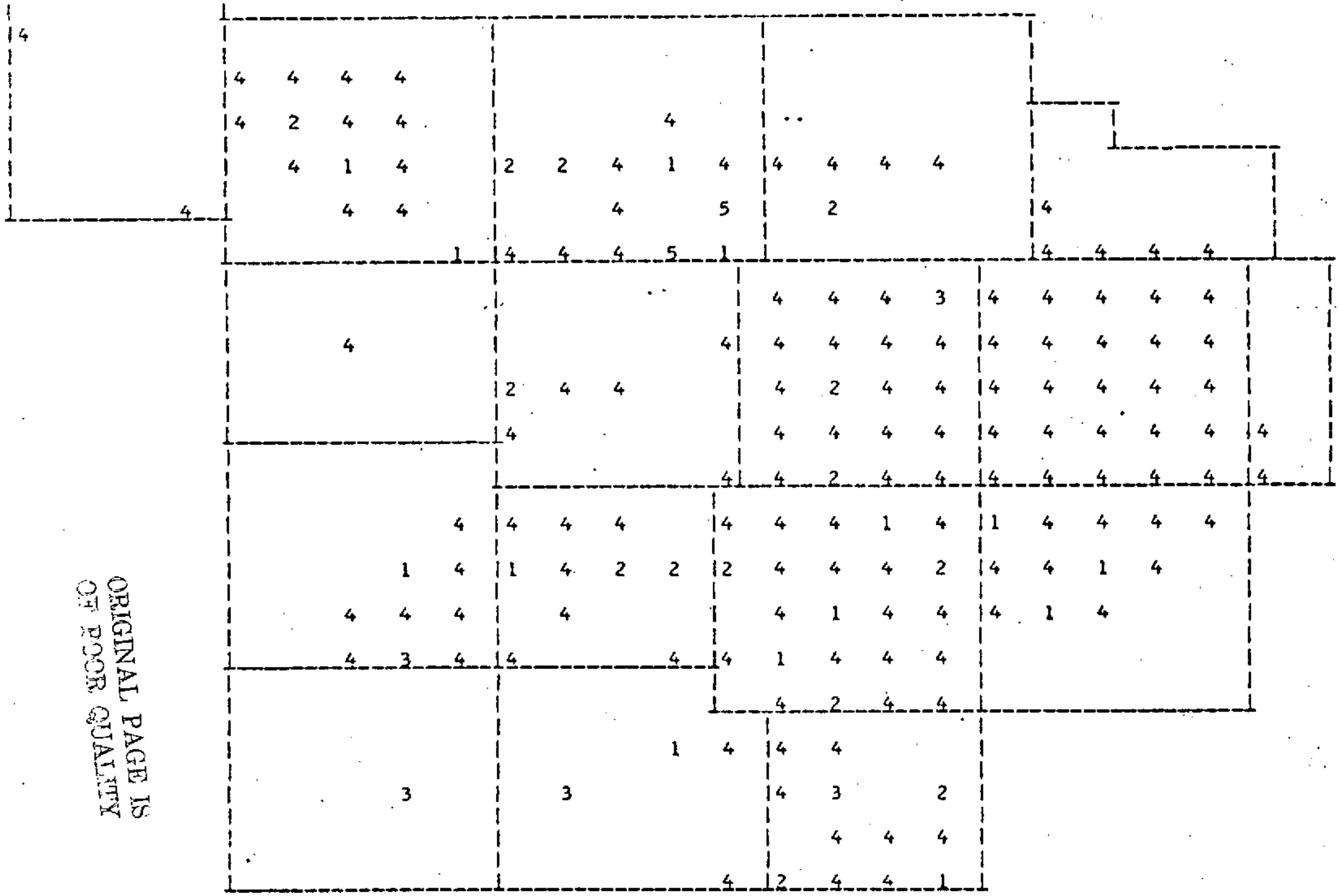
LEGEND		
1 RECENT C/C	#1=	22
2 FOREST REPROD	#2=	43
3 CON SECOND GR	#3=	35
4 CON OLD GR	#4=	59
5 HARDWOOD	#5=	20
?	TOT	179

TWP-40 RANGE-990W

FIGURE NO. 2 1964

LISTING OF ERTS DATA FILE APR 30, 1974

West Jefferson 1/1,000,000

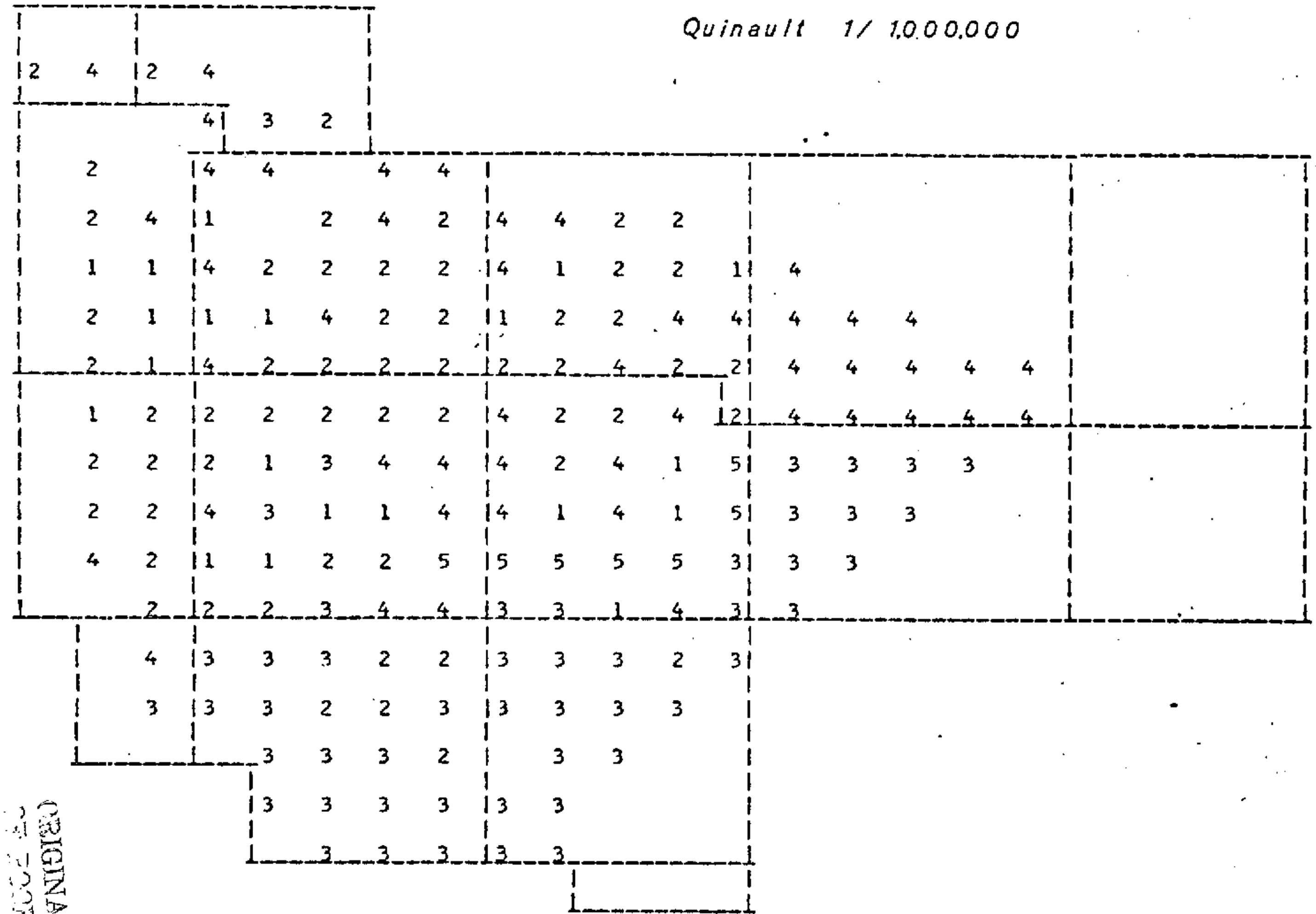


LEGEND		
1 RECENT C/C	#1=	14
2 FOREST REPROD	#2=	14
3 CON SECOND GR	#3=	5
4 CON OLD GR	#4=	129
5 HARDWOOD	#5=	2
?	TOT	164

TWP-41 RANGE-990W

FIGURE NO. 3 - ERTS 1974

LISTING OF ERTS DATA FILE APR 30, 1974



LEGEND		
1 RECENT C/C	#1=	20
2 FOREST REPROD	#2=	56
3 CON SECOND GR	#3=	49
4 CON OLD GR	#4=	47
5 HARDWOOD	#5=	7
?	TOT	179

TWP-40 RANGE-990W

FIGURE NO. 4 - ERTS 1974

July 1973

THE DEVELOPMENT OF A NATURAL RESOURCE INFORMATION SYSTEM

VOLUME I: PROGRAM SUMMARY REPORT

U. S. DEPARTMENT OF INTERIOR CONTRACT
NO. K5 1C 14200693

Performed by

RAYTHEON COMPANY
Autometric Operation
Boston Post Road
Wayland, Massachusetts 01778

TABLE OF CONTENTS

TABLES AND ILLUSTRATIONS

FOREWORD

The documentation for the Natural Resource Information System (NRIS) development program is contained in five volumes, as follows:

- I Program Summary Report
- II Hardware Components and System Configuration Study
- III Demonstration Data Base Catalog
- IV User's Guide to NRIS Processing Software
- V NRIS Processing Software Documentation

This contract was undertaken by the Autometric Operation of the Raytheon Company. The program was directed by Dr. Daniel J. DeCourcy for the Raytheon Company, and technically monitored for the government by Mr. Arthur Woll of the USDI, Bureau of Indian Affairs.

Other principal contributors to the program were Messrs. M. E. Foley L. E. Garvin, J. B. Kellom, R. F. Pascucci, M.Mendelsohn, J. Doyle and B.Heller of the Raytheon Company. Government personnel who assisted in shaping the course of the effort included G. Torbert and E. Forsee of the USDI Bureau of Land Management, and various representatives of USDI's EROS Program and the RALI Program.

PROGRAM OVERVIEW

The general concept of computer processing of map-originated data has been considered in one form or another for many years. Various approaches have been and are currently being developed in the civilian sectors of the Federal Government, as well as in state, regional and local civil jurisdictions and private industries such as utility companies. Well-known projects include the Environmental Protection Agency's STORET and AUTOMAP projects, the Department of Agriculture's GELO and COMPLOOP programs, the Census Bureau's statistical compilation approach, and several state-level schemes such as LUNR (New York), IRIS (Illinois) and LEMS (Louisiana). The Department of the Interior, through its various bureaus and services, has itself, undertaken several efforts in this general area, including the BLM's MAP MODEL in Oregon, the BSF&W's refuge planning project in Minnesota, and a BIA information system for selected reservations in the Southwest. In 1971, the USDI, through the BIA and BLM, sponsored an initial development effort to determine the feasibility of establishing a comprehensive Natural Resource Information System (NRIS) for the Country's land-related resources which are under the control of their bureaus. The effort was undertaken by the Boeing Computer Services, Inc. under Contract Number K51C14 200459. As a result of that effort, which was completed in April 1972, a competitive procurement for further development of the NRIS concept was issued by the BIA, which resulted in an award of a one-year contract to the Raytheon Company.

In general terms, the concept of using a digital computer, with appropriate input/output devices, has been shown to be feasible by virtue of the many on-going efforts cited above. However, when a closer view is taken of the various approaches, it is obvious that several fundamental considerations must be evaluated, particularly when the objective is to establish a framework within which all agencies of the USDI might be included. This brings into focus such things as the basic mission and management structure of the individual agencies; and the various report of inventory, status and policy implementation which each USDI group produces in fulfilling its individual function in managing government resources. With these considerations in mind, the further development of the NRIS concept was undertaken by Raytheon during FY 1973, yielding the results reported in this document.

PROGRAM SUMMARY

The basic objective of the NRIS development program is to provide the resource managers of USDI with a capability to manipulate and analyze large volumes of relevant map data and thereby to assist them in their planning and managing functions. This computer-based approach can be viewed as a tool to be used in cataloging, inventorying, correlating and analyzing available data in a uniform, consistent manner, at speeds and complexities not practical by conventional manual methods. The general concept is shown in Figure 1. Map and/or tabulated data is digitized into a computer format, stored in an appropriate form, and processed as desired in a central computer. The practical development of the NRIS concept involved four basic areas, two related to the philosophy of the approach, and two related to the practical implementation of an operational system.

The two tasks which addressed the general concept involved simultaneous investigations of software construction and determination of various manipulative functions which the system should provide to make it an effective tool in assisting the user in performing his planning and managing activities. The two complementary tasks which focused on the implementation considerations of the system involved the conversion of existing graphic data to computer format (i.e. digitizing of maps), and an assessment of state-of-the-art hardware components which might be used in various configurations of an operational system. The highlights of the results of each of these four tasks are presented in the succeeding pages. These are then followed by some general comments on the program itself, and a suggested next phase effort which might be pursued by USDI to further the expansion and application of the NRIS concept operationally.

ESTABLISHING USER NEEDS

It is basic to the NRIS concept that the system developed be usable by the majority of USDI agencies in conjunction with a wide variety of management and planning functions. This is a significant departure from previous map-oriented information system approaches which have been generally dedicated to limited types of data, for more or less specific operational applications.

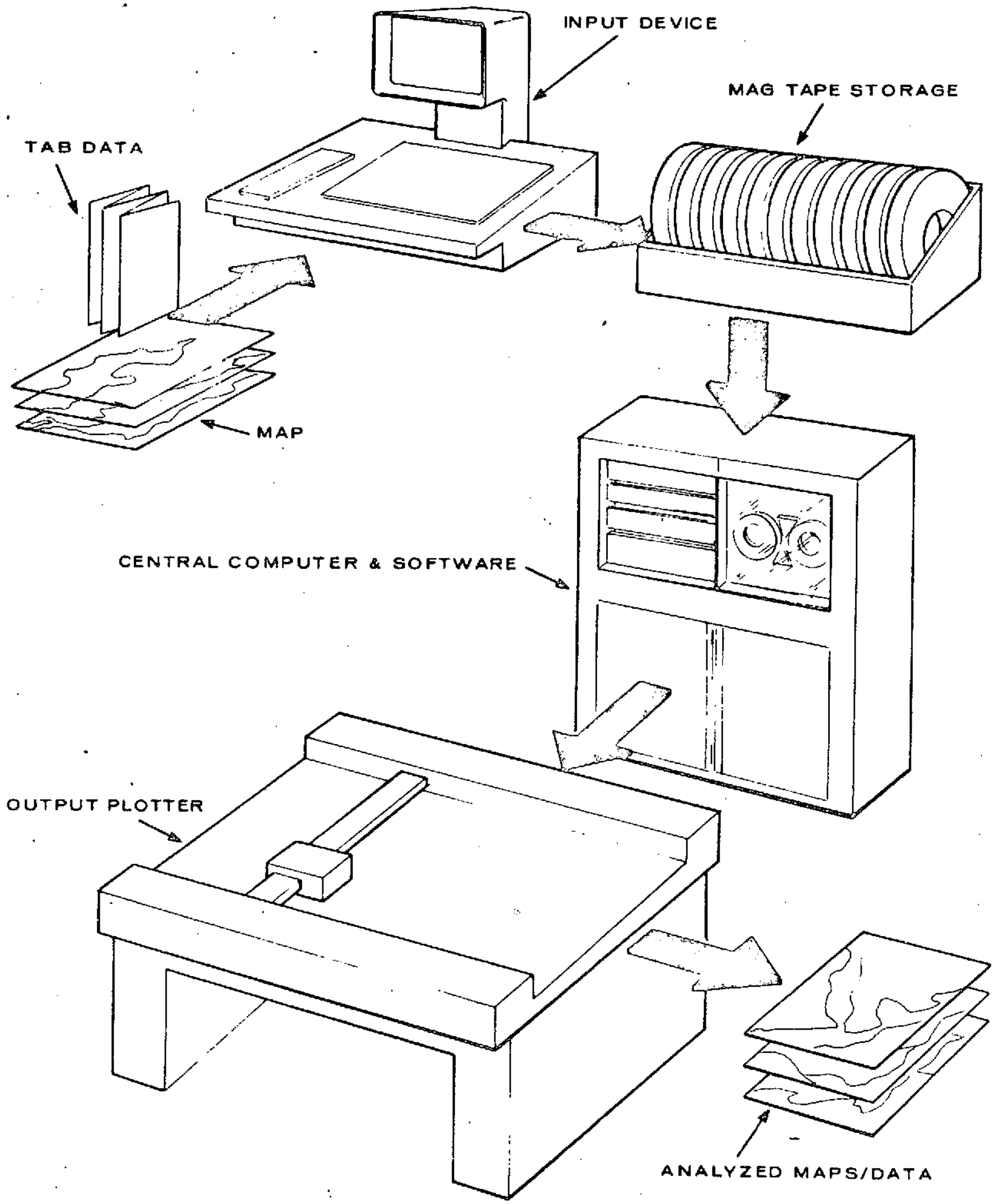


FIGURE 1 - GENERAL CONFIGURATION OF
NATURAL RESOURCE INFORMATION SYSTEM

Hence, an initial objective, in undertaking the NRIS development program, was to survey the likely users of such a system, to establish just what capabilities ought to be included in the system. To accomplish this end, it was originally intended that a questionnaire be compiled, for distribution within USDI agencies, to gather composite information of planning/management objectives, data requirements and sources, data processing needs, decisions which are customarily made based on graphic inventory data, and data output requirements. The design of this questionnaire was to reflect inputs gathered during personal interviews with selected field-level USDI managers, and the questionnaire was then to be distributed to a multiplicity of equivalent management levels to obtain a broad collection of data from which user needs might be established. After two group meetings with representative USDI personnel early in the program, it became quite apparent that the questionnaire approach was not likely to produce the desired results. A more relevent, practical scheme was needed to provide a basis for determining likely user needs. The approach selected was to identify a number of field-level personnel who were currently using multiple overlay sets of map data in "manual" form, and to discuss with each of them individually just what resource data was used for, and how it was gathered. The results were then used to determine what manipulations would be performed, if a tool were available to relieve them of the burdens of physically performing a variety of manipulative processes. To accomplish this survey of user needs, Raytheon teams of resource and computer analysts traveled throughout the country, to all bureaus and services of USDI, and conducted over ninty separate briefings to collect the appropriate information.

As a result of this extensive search for representative data users, nineteen sets of natural resource data were collected. As an example, a typical set of such overlays were supplied by the California BLM District Office at Riverside. The BLM set of data forms a more or less standard Unit Resource Analysis (URA) base of the type which BLM wishes to use widely to aid in the administration of the Planning Unit (the smallest geographic region managed by individual BLM personnel). The particular URA set supplied was for the Barstow Planning Unit of the Riverside District, and it has twelve overlays to the basic map, (township outline, hydrology, vegetative cover, soil types, land use, scenic recreation areas, visitor influence zones, wildlife habitats, mineral locations, land classification, grazing leases and lines of communication) Others of the nineteen collections included variations in area, number of overlays and complexity data sets.

The nineteen agencies, their sites, and the agency applications are shown on Table 1. A closer examination of the tabulated data shows that the selected user data sets fell into three general map scale ranges, and had series of thematic overlays which ranged from only two in two cases, to as many as 23 in one situation. The selected sets are geographically well-scattered across the country, and are current real-world representative data sets relevant to a variety of inventory, assessment, development, planning and management functions. Detailed descriptions of the collection of data, as well as full scale samples of many selected maps, are presented in Volume III, "Demonstration Data Base Catalog". These nineteen selected situations reflect a truly representative cross-section of all USDI user agencies and varying application objectives within agencies. After discussing the physical data sets with the individual agency representatives, it was possible to summarize the features to be incorporated by an NRIS approach if such a concept were to meet a realistic level of user requirements. The system requirements drawn as a result of reviewing actual data situations were actually not significantly different than what had been originally assumed from previous and parallel information system development efforts. These requirements involve routine data cataloging capabilities (selectable sheet formatting, coordinate system transformation, scale changing, symbol standardization, etc.) data maintenance (up-date, correction, augmentation, etc.) and an ability to manipulate and summarize map data. These basic manipulative requirements are shown in Figure 2. In addition to those shown in the illustration (i.e.,composite union and composite intersection, etc.) other obvious requirements include simple point inquiry (what attribute exists at a selected location?), and simple area selection (find all areas with a chosen attribute within a designated geographic region).

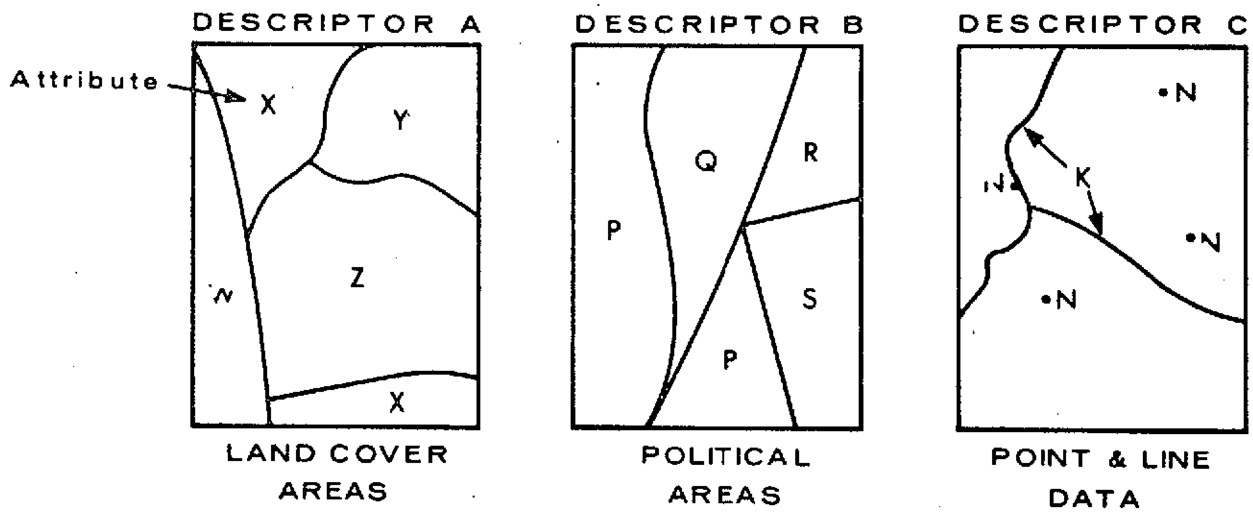
TABLE 1 - SELECTED SETS OF REPRESENTATIVE USER DATA

Agency	Site	Agency Application	Approx. Area Sq. Mi.	Approx. Scale of Base Map	Number of Themes
BSFW	Muscatatuck NWR (Ind.)	Refuge Utilization	15	1" = 600'	8
BLM	Whittaker Cr. (O&C) (Ore.)	Forest Management	40	1" = 1,000'	10
BLM	So. Calif. Desert	Ecological Assessment	500*	1" = 1,600'	2
BOR	Martha's Vineyard (Ma.)	SCORP Development	50	1" = 2,000'	2
BIA	Salt River I.R. (Ariz.)	Comprehensive Land Use Planning	100	1" = 2,000'	8
BIA	San Carlos I.R. (Ariz.)	Range Management	30	1" = 2,600'	18
NPS	Assateague Is.N.P. (Md.)	Park Development	200	1" = 6,500'	4
GS	CARETS - GAP (Va.)	Regional Planning	700	1" = 8,000'	3
BRC	Imperial Valley (Cal.)	Geothermal Power Development	100	1" = 9,000'	5
BLM	Montrose, Colo.	URA Maintenance	500	1" = 10,500'	23
BLM	No. Great Plains (Wyo.)	Mineral Development Plan	1,000	1" = 10,500'	7
BIA	Colville I.R. (Wash.)	Resource Management	2,000	1" = 10,500'	10
BLM	Barstow,Calif.	URA Maintenance	2,000	1" = 10,500'	12
NPS	Great Smoky Mtn.N.P.	Large Park Management	2,500	1" = 10,500'	14
BIA	Ft. Apache I.R. (Ariz.)	Forest Fire Management	2,600	1" = 10,500'	9
GS	Ozark Plateau (Ark.)	Regional Planning	12,000**	1" = 11,500'	4
BRC	Nebraska Mid-State	Hydrologic Site Assessment	2,000	1" = 35,000"	6
BOR	Cumberland R.Basin (Ky.Tenn.)	Interagency S&WR Area Plan	13,000	1" = 40,000	18
BOR	N.Y. State	National Recreational Inventory	50,000	1" = 40,000'	4

* DATA SET INCLUDES 10 ADJACENT SHEETS

** DATA SET INCLUDES 2 ADJACENT SHEETS

MAPS OF DIFFERENT THEMES FOR THE SAME GEOGRAPHIC AREA -



AREA RELATED OPERATIONS

1. UNION OF "X" & "P" - A MAP SHOWING ALL AREAS WHERE EITHER "X" OR "P" OCCUR.
2. INTERSECTION OF "X" & "P" - A MAP SHOWING ALL AREAS WHERE BOTH "X" AND "P" OCCUR.
3. LINE PROXIMITY OF "K" & "P" - ALL AREAS OF "P" WHICH ARE WITHIN "Δ" OF "K".
4. POINT PROXIMITY OF "N" & "P" - ALL AREAS OF "P" WITHIN "Δ" RADIUS OF "N".

COUNTING OPERATIONS

1. AREA CALCULATIONS - FIND AREAL AMOUNT OF "P" (VALUE) WITHIN A GEOGRAPHIC AREA.
2. PERIMETER CALCULATIONS - FIND THE LENGTH OF ALL LINES WHICH BOUND AREAS OF "P".
3. COUNT AND LIST - FIND ALL POINTS, "N", WITHIN A CERTAIN GEOGRAPHIC AREA.

FIGURE 2 - BASIC MANIPULATIVE REQUIREMENTS

Curiously enough, one very common requirement was identified which had not been previously considered. This system capability involves the decomposition of complex data which is compiled on a single map sheet. In several instances, the resource information on a single map was of such a complicated and highly dense character that the users simply could not physically utilize the information in any more than almost trivial analysis situations. One collection of maps had a total of 18 different themes on a single sheet. Another set has so many attribute sub-classes denoted that even the simplest of associative analysis was just too cumbersome to perform. Thus, while one very necessary capability of the NRIS should be to form multiple composite overlays, the complementary capability of sifting out and grouping existing complex data is also a very real requirement.

In summary, the NRIS user requirements established as a result of the contacts and briefings with various USDI personnel included all of the more obvious manipulative capabilities shown in Figure 2, plus several other more or less mundane capacities, such as format (centering a sub-map about a chosen point, etc.) scale and coordinate selections, and other cataloging and maintenance flexibilities. These are listed on Table 2, and have become the core requirement capabilities to which the software development was directed.

DEVELOPMENT OF SOFTWARE

The original expectation, in terms of software development, was to utilize as much as possible the previous efforts of the preceeding NRIS contractor (Boeing Computer Services, Inc.) and other known related software concepts, and thereby to extend further the software manipulative capability to include such things as coordinate system transformations, first-order rectification, and various other user-oriented simplification paths. The BSC software was to be provided by USDI to Raytheon, in an IBM-360 converted format. For reasons which are now of little consequence, the government was unable to provide this software. After several months of considering various alternatives, Raytheon made an assessment of the basic software concept, and selected a fresh approach which was deemed most appropriate to meet the basic operational system requirement. This selection is keyed to the fundamental data structuring method of digital map conversion, and is of such significance, that a discussion of the alternatives, and Raytheon's basis for the selection is warranted here.

<u>TABLE 2 - SUMMARY OF USER PROCESSING NEEDS</u>

<u>CATALOGING</u>

SCALE CHANGE	COORDINATE TRANSFORMATION
FORMAT SELECTION	EDGE MATCH CHECK
ATTRIBUTE STANDARDIZATION	RECTIFICATION OF OVERLAYS

<u>MAINTENANCE</u>

UP-DATE OF EXISTING OVERLAYS
CORRECTION TO BASE DATA
AUGMENTATION OF NEW FILES TO BASE

<u>ANALYSIS</u>

POINT QUIRY	AREAL CALCULATION
PERIMETER CALCULATION	FRONTIER SELECTION
CORRIDOR ASSESSMENT	PROXIMITY DETERMINATION
COMPOSITE FORMATION	MAP DECOMPOSITION

There are basically three data structuring methods which can be used to convert graphic data (i.e., maps) to digital computer files. Obviously, any subsequent software development by necessity is intimately tied to the original structuring selection. The three choices, as shown pictorially in Figure 3, are the CELL, POLYGON, and LINE SEGMENT approaches.

The CELL presentation, in essence, is a technique which involves the application of a uniformly structured spatial sampling filter to the original graphic, and the tagging of each cell with the predominating attribute falling within the cell. This is a relatively simple though laborous approach. Its use requires that a cell size be selected to best represent the data detail within the graphic. Furthermore, if uniformity is to be preserved all subsequent overlay themes for the same geographic area (i.e., separate resource overlays, such as soils, vegetation, timber type, administrative boundaries, hydrology, land use, etc.) must be subjected to the same spatial filtering process, regardless of each separate overlay's inherent accuracy or level of detail. In the instance where this approach has been used, the general result has been application of a compromise which in many cases has produced a data file where either significant detail was lost, or the quantity of recorded data necessary to represent the graphic was highly redundant. This approach does have several advantages, not the least of which is that the digital file is easy to produce (though typically very time consuming, at fine grid selections) and most errors in digitizing, such as a wrongly-tagged cell, have little impact on the overall logical sense of the record. In addition, since systematically known geographic cells of the map are individually annotated on a uniform basis for multiple overlays, the format is ideally suited for the point inquiry types of questions typically asked of the system. Finally, since this presentation is essentially a raster scan sampling format, it is directly convertable from processed scanned sensor data, such as the ERTS output of the EROS Program.

The second data structuring alternative is the so-called POLYGON form shown in Figure 3. The technique stores the series of X-Y coordinates which describe each individual region (polygon) of a selected attribute class, as a separate "island" of data. Because the graphic detail is directly recorded,

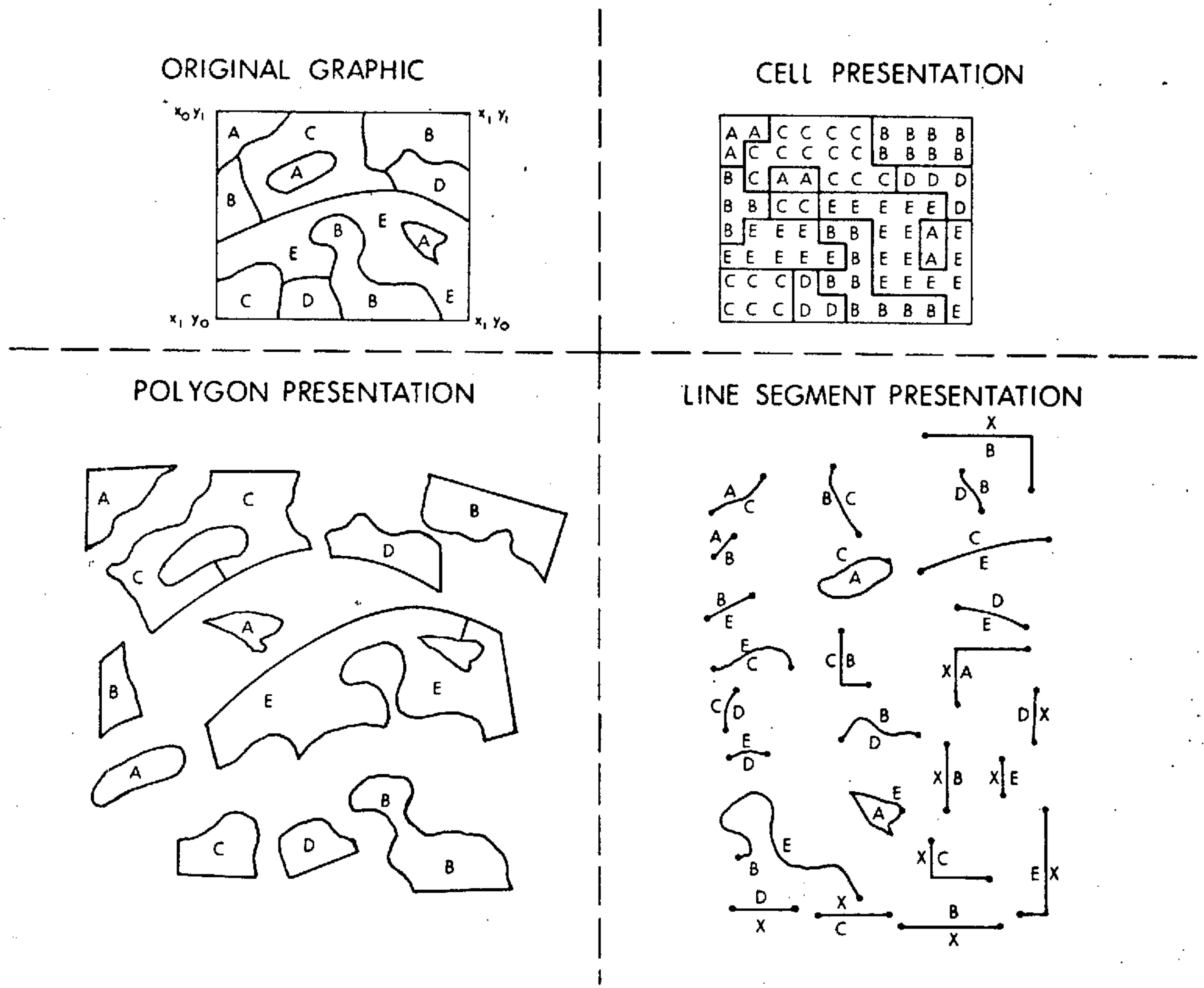


FIGURE 3 - DATA STRUCTURING ALTERNATIVES

the boundary detail can be preserved as required, within the inherent locational accuracy of maps. The largest drawback to this approach is that all line data must be digitized twice, which is costly, and introduces "slivers" of ambiguity in many cases. In addition, the requirement to circumscribe each region as one polygon can be complex at times, as example, along an estuary. Moreover, based on the experience gained from this program, it has been determined that, in many cases, a very high level of digitizer-operator judgement and care must be exercised to produce a valid polygon file. However, data in this format, i.e., individual "island" records, is ideally suited for area selection questions.

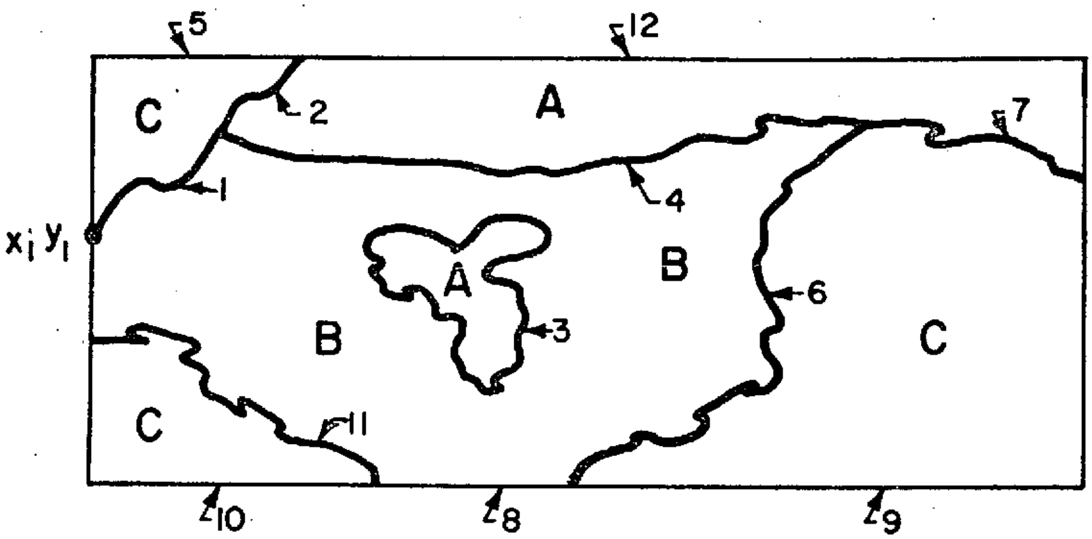
The third structure choice, also shown in Figure 3, is the LINE SEGMENT approach. This technique stores the series or "chain" of X-Y coordinates from one intersection to another which describe each boundary between two attributes. As in the case of the POLYGON approach, all graphic detail can be captured and, thus, boundary detail can be recorded to desired level of accuracy. To assure that data fidelity is achieved, this format also yields a region listing, showing which line segments group together to form a closed POLYGON. Thus, in many ways, the structuring is equivalent to the POLYGON approach, except that each line need be digitized only once, and no order need be followed. This yields a situation where maximum data capture occurs with minimum operator care and judgement. The structuring of the data as line segments, plus grouping of segments to determine bounded regions, allows most of the complex processing requirements to be met optimally with a simplified software approach. In addition, the use of this structure retains maximum detail and also guarantees that the graphic data meets all logical specifications.

The third option of LINE SEGMENT data structuring was chosen by Raytheon as the basis of the NRIS development software. All of the manipulation and analysis capabilities (see Figure 2 and Table 2) were established in software programs based on the assumption that the resource data is in the LINE SEGMENT format. This option was selected because it allows any desired level of detail to be retained at minimum digital conversion cost, and is the structure which most universally and quickly accommodates the desired processing options.

The general format of the LINE SEGMENT file is shown in Figure 4A. Each line segment is assigned an arbitrary number, depending on its storage location in the record. The chain of X-Y values which describe the line segment is the primary description of the format, supplemented by two region numbers and two attribute designators. The region numbers (R_L and R_R, for left and right sides of the line) are also arbitrarily assigned and refer to unique map areas much the same as polygons in the POLYGON format. The two attribute designators (A_L and A_R in Figure 4A) refer to the internal designation of the two attribute values which the selected line segment separates. The attribute designator, "Δ", refers to the "outside" of the map, i.e., anything beyond the border of the file. Note that there must be continuity between the end point coordinates of each line segment such that each and every end point must be listed at least two other times in the file, except for the special case of the "island" (#3 on Figure 4), where the two end points of a single segment are identical. There must also be a direct correspondence between the region numbers and the attribute designators, and, in no instance, can the left and right region numbers (or attribute designators) of a selected line segment be identical.

A series of software programs have been developed to perform the required manipulation analysis on files which are constructed in the manner shown in Figure 4A. These individual programs total about thirty in number, and the major elements are listed in Table 3. A complete description and discussion of each program is given in a separate document - (Volume IV, "User's Guide to NRIS Processing Software"). In brief, however, the major software programs listed on Table 3, used with files constituted in the format shown in Figure 4A, operate in the following manner. The "Find Attribute" program drawn on a vertical line from the user-designated coordinate and determines the number of the segment in the file which that new vertical line first intersects. The sense of the selected line segment is then determined, and the decision as to whether the left or the right attribute designator should apply is then made, and hence, the original question is answered.

If the user's question is to find all areas of specific attribute class (such as "A" in Figure 4A), then the program called "Extract on Arc File",



No.	Coordinate Chain	R_L	R_R	A_L	A_R
1	$x_1y_1, x_2y_2 \cdots\cdots x_ny_n$	101	106	C	B
2	$x_ny_n \cdots\cdots x_ry_r$	101	108	C	A
3	$x_py_p \cdots\cdots x_py_p$	106	103	B	A
4	$x_ny_n \cdots\cdots x_wy_w$	108	106	A	B
5	$x_ry_r \cdots\cdots x_1y_1$	101	100	C	Δ
.	. . . .	.	.	.	.
.	. . . .	.	.	.	.
.	. . . .	.	.	.	.
12	$x_ry_r \cdots\cdots x_my_m$	100	108	Δ	A

FIGURE 4A - LINE SEGMENT FILE FORMAT

No.	ATR	Encl. Area	Region Area	Outside Perim	List of Encl. Regs.
101	C	31.7	31.7	22.1	.
102	C	193.2	193.2	84.6	.
103	A	42.1	42.1	17.1	.
.	.	.	.	.	.
.	.	.	.	.	.
106	B	347.6	305.5	176.4	103
.	.	.	.	.	.

FIGURE 4B - REGION FILE FORMAT

TABLE 3 - MAJOR SOFTWARE PROGRAMS

(USED WITH ONE OR MORE VALID MAP FILES)

- FIND ATTRIBUTE
- EQUATE ATTRIBUTES
- EXTRACT ON ARC FILE

  - CONSTRUCT REGION FILE
  - EXTRACT ON REGION FILE

    COMPOSITE SERIES {
    - MERGE ARC FILES
    - FIND INTERSECTS (CREATE NEW ARCS)
    - STRUCTURE REGIONS
    - ASSIGN REGION NUMBERS
    - LIST GARBAGE ARCS
    - ASSIGN COMPOSITE ATTRIBUTES

      - CONSTRUCT ATTRIBUTE DEFINITIONS FILE
      - EXTRACT ON ATTRIBUTE DEFINITIONS

        - MAKE FILE FOR PLOT
        - MAKE FILE FOR LIST

(arc is a synonym for line segment) is used, and any line segment which has "A" for one of its two attribute designators, is placed in a new file and from there either plotted out (via the "Make File For Plot" program) or held for further processing. The "Equate Attributes" program is used if certain original lines are to be deleted, i.e.,if for one problem, "C" and "B" were made to be identical. Once "C" is equated to "B", all line segments containing the C and B combination would be deleted. The user then has the option to further extract the file to determine desired areas, etc.

An auxiliary file which is available in the set of programs is the Region File, which is shown pictorially as Figure 4B. This file, which is derived from the LINE SEGMENT file as required (i.e., it is not original source data), is constructed by using the "Construct Region File" program. This file can be made for either the entire LINE SEGMENT file, or with any extracted subset or combination of original files. The Region File is ordered by the region number, and lists the attribute designator for the region, the net area of the region (which is different only if there are internal "islands" in the region), the outside perimeter of the region, and a list of the included "island" region numbers, if there are any. By applying the "Construct Region File" program, the user can ask questions concerning the areal size of selected attribute areas, such as finding all areas of attribute "C" which are at least 500 acres, etc. This is done by using the "Extract on Region File" program, to determine the region number (if any) which meets the combined size and attribute requirement. The result of that operation is then used with the "Extract On Arc File" program, but this time filtering on the region number, rather than the attribute designator, to flag the line segments which constitute the desired answer.

The combining of two (or more) descriptor overlays (such as soils and ownership) is done by using the series of programs shown on Table 3 as the "Composite Series".

The necessary portions of the line segment files of each descriptor involved is acquired from the data base by using the region file or coordinates, to identify line segments of interest. Next, the selected line segment records are mixed together and reprocessed to form new composite line segments involving the two (or more) "overlaid" line groups. Next the reprocessed composite line segments are formed into composite regions, which will have composite attributes. To find the new composite attribute, it is first necessary to determine the location value at some selected position interior to each composite region. Then, using the chosen interior data point, the attribute of that point in each of the individual component descriptor sets can be determined, and each composite region can be tagged with the resulting composite attributes. Finally, a search of the composite file is made as desired and the results either plotted or tabulated.

Two other major programs involve a file called "Attribute Definition", which allows the software to handle complex attributes as if each were a simple designator. In effect, this is how composite files are structured, whether the compositing was done by the software, or the file was originally constituted as a composite attribute map. This higher degree of file handling is discussed in more detail in Volume IV.

In effect, the overall software philosophy is to utilize a selected combination of about fifteen major and twenty or so minor program functions in a modular manner in certain defined Processing Procedures. These procedures are actually, ordered sets of the program functions structured in such a manner that the system can be utilized without the need of an expert computer system analyst. These Processing Procedures, accompanied by appropriate sample applications, are presented in detail in Volume IV, "User's Guide to Processing Software".

Once software has been constructed, the remaining task is to "feed" the system by actually converting the graphic (or tabulated) data to digital form. This very practical and burdensome task of digitizing map data was explored in detail in the course of this project, and will be reported upon next.

DIGITAL CONVERSION OF MAPS

The software processing outlined above assumes that certain map data has been appropriately converted to a computer format, and then used as an input to the software to produce by manipulation the desired output. In the course of this project, many examples of representative map data were collected, each of which must be accommodated by the selected conversion process. These samples, many of which are presented in Vol. III, are typical resource inventory maps, many of which use color, alphanumerics, pictographs, codes, crosshatch and line codes to record many layers of data on single pieces of paper. These maps are made by people, for people to read. The digital computer, on the other hand, is basically just a counting machine. Therefore, to be able to store and process graphic data in a computer, the graphically portrayed information must be reduced to numbers. This translation of the existing record to a series of numerics is usually termed "digitizing".

For systems of the type being discussed here, the digitizing either involves a systematic record of binary data in sorted raster form,(to record the CELL structuring shown previously in Figure 3, for example) or the creation of piecewise linear records of the curvilinear data, to form "chains" of coordinates tied to a known local coordinate system. Since the line segment structuring alternative (shown in Figure 3) was chosen, the digitizing process required was that of establishing records with coordinate values, as shown in Figure 5. As noted on that illustration, there are several significant characteristics implicit in this digital conversion process, each of which has an impact on the proper transfering of the graphic record to the digital format. The series of discrete coordinate values, assumed to be logically connected, have features of accuracy, precision and density, each of which could govern the ultimate fidelity of data conversion. As noted, accuracy is related to the ability to select the desired sample point; precision is determined by the ability to measure the selected data point; and density is usually a controlable feature determined by the digitizer's recording rate. There are several basic types of digitizing instruments (manual, continuous, "automatic", scanning etc.), as well as several levels of capability within each type, depending on the manufacturer's basic design. These various alternatives are discussed in detail in Volume II, "Hardware Components and System Configurations Study". As described in that report, one type of digitizing instrument might emphasize accuracy, while another might compromise accuracy and precision for a high rate of data capture (i.e., density of

- DIGITIZING -

THE CONVERSION OF A CONTINUOUS FUNCTION INTO A SET OF DISCRETE VALUES.

MINIMUM CHARACTERISTICS OF DIGITALLY CONVERTED DATA

- DISCRETE DATA POINTS SUFFICIENT IN ACCURACY, PRECISION AND DENSITY TO RECORD AN ACCEPTABLE LEVEL OF GRAPHIC INFORMATION
- A LOGICAL ORDER OF RECORDING THESE POINTS, TO RETAIN CONTINUITY
- NECESSARY ATTRIBUTE DATA

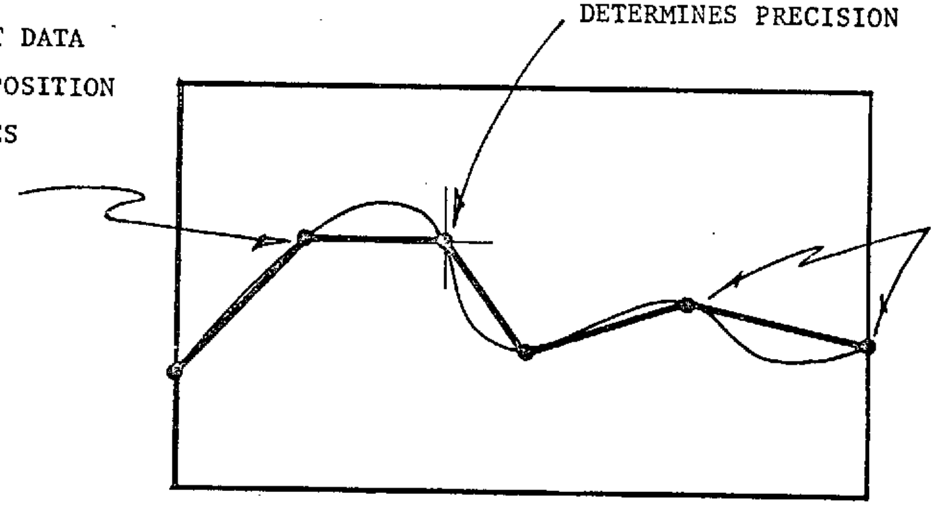


FIGURE 5 - DIGITAL CONVERSION CHARACTERISTICS

data). On the other hand, some types of digitizers are designed for a variety of purposes other than manually "translating" existing graphics to a digital form, and hence their applicability to this type of data base construction might prove to be impractically low in terms of cost effectiveness.

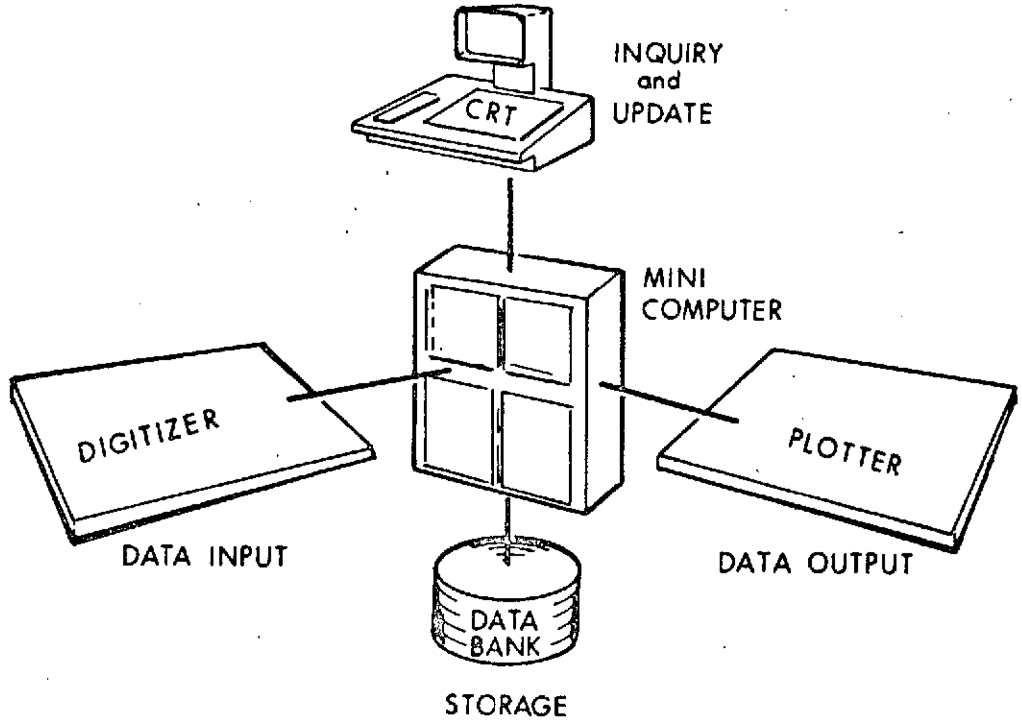
During the program, several types of instruments were used experimentally, including a conventional non-feedback point digitizer, a continuous tablet-type operating with a CRT, and a system using an on-line editing digitizer-plotter combination. Because of the nature of the almost two hundred maps used as elements of the data base, all of the digitizing was done with a trained operator in the loop. In many cases, where the map being converted was very complex, much time was required to pre-process the maps (i.e., pre-edit and mark significant features) to aid the digitizing operator in his work. Conversely, some samples were very clear and logical, but tremendously detailed. In Volume III, which catalogs all of the examples in the data base, the pre-processing, special requirements, and actual manhours of digitizing and resulting data points are documented. In terms of extremes, some samples of very straight-forward mapping required less than ten minutes to digitize, while one essentially simple map sheet required 180 manhours of digitizing to record the graphic detail.

In addition to recording the complexities of the spatial distribution of the map data, care must also be taken to sort out the map data in terms of the separate themes present. These multiple sets are usually coded (by color, line weight, line code, and possibly combinations of all three) and must be digitized as separate sub-files to retain their intended differences. Hence, what might first seem to be a rather simple map sheet, will, on closer examination, prove to be a quite complex, yet integrated, combination of related themes of data.

More specific details concerning the variety of subtle complexities encountered in the digitizing process are given in Volume III. However, the general problems included poorly reproduced maps which rendered some samples almost illegible, certain errors of commission or omission on the maps which technically made the maps illogical, various lacks in coding consistency and non-standardization in composition which made reading very difficult, and instances of base map overburdening which greatly increased the time needed to digitize and to edit the conversion process. As a result of handling this wide spectrum of field operational map data, however, it was possible to assure that a method of simple, uniform data structuring can be established, and that virtually any kind of logically correct map form can be placed in a proper format for processing. The practical conclusions are that the costs of converting such data will be directly related to the clarity and logical validity of the data, the density of the spatial information, and the accuracy and precision specifications placed on the data translation process. Ultimately, however, the individual user of the information system must bear the cost of supplying valid data files to be used in the system.

HARDWARE AND SYSTEM CONSIDERATIONS

There are basically four primary components in a graphic-based information system. As shown in Figure 6, these are the input device (a digitizer), a storage device (tape, disc, cards, etc.), a processing capability (programmed computer with data inquiry link), and the output device (a plotter). Each of these basic components can be very sophisticated, or very simple, depending on a variety of trade-off considerations. A separate report is presented as Volume II to discuss the various types of equipment available, particularly in the digitizing and plotting areas. In addition, the choices of network configurations are evaluated in terms of individual and separate application situations (an indian reservation, a national park, etc.), area applications such as the state wide BLM administrative levels, regional centralized networks such as BOR and NPS districts, and national or semi-national networks. It is obvious that some locally oriented situations might justify the expense of establishing a stand-alone network configuration, while other regional applications might best be served by using a centralized off-line processing capability with less expensive (and slower) access and output alternatives. These are considerations which ultimately must be evaluated within the constraints of mission responsibility and fiscal budget.



- LOCALIZED APPLICATION SITE
- SMALL STAND-ALONE SYSTEM IS FORERUNNER OF SATELLITE NETWORK
- SELF SUFFICIENT IN DATA BASE CREATION
- DUPLICATED IN SELECTED SITES
- USEFUL ON LOCAL PLANNING LEVEL

FIGURE 6 - BASIC NRIS CONFIGURATION

However, sufficient detail as to the hardware choices is presented in Volume II to give a proper and balanced foundation for making at least preliminary evaluations as to the appropriate network configuration for a given situation.

PRESENT CONFIGURATION AND SUGGESTED NEXT STEP

As part of the contractual effort being reported here, Raytheon developed a comprehensive series of software processing packages for use on an IBM-370/155, and converted these programs to both an IBM-360/65 and Burroughs 5500 format. These two converted forms of the software were delivered to the USGS computer center in Washington, D.C., and to the BLM Service Center in Denver, for their respective computer systems. In addition, each location will have a complete demonstration data base which represents digitally converted data on almost sixty million acres, and is approximately 250 USGS standard map sheets at the scales used, when each overlay set of data is considered separately. This very broad spectrum of data (shown previously as Table 1) is available at the two USDI computer installations, to serve as a demonstration base for studies and related analyses by USDI and others in developing and expanding the NRIS concept. The data structure which has evolved in this project, and the processing philosophy presented in other volumes of this report, go a long way toward uniting the many related previous and present efforts in a general standard which can serve as a prototype for operational development. In addition, by virtue of the very wide participation by literally hundreds of USDI field personnel in this effort, there is a greatly increased awareness within USDI of the general concept and applicability of computer-based resource information systems, and a growing information exchange on approaches and applications among the appropriate federal organizations and local and state planning groups.

Figure 7 capsulizes the overall Resource and Land Information System Development within the country at all levels of government. The ultimate objective is to provide a federally coordinated land use policy and resource management service, which would support not only the administration of federally administered public land, but also provide leadership, standards, and source data to other state and local jurisdictions. The USDI has its many data gathering and dissemination channels, notably the EROS Program and

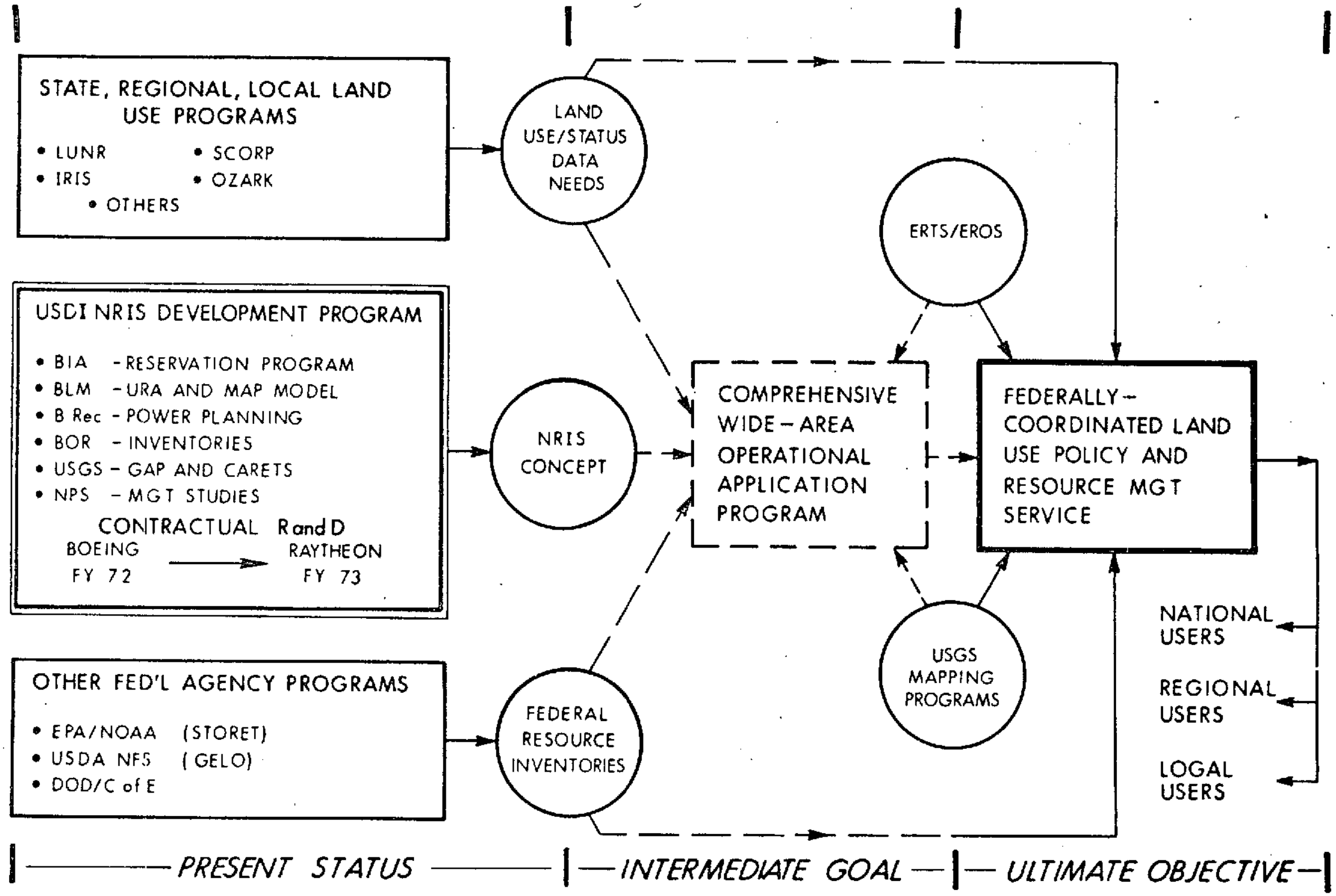


FIGURE 7 - RESOURCE AND LAND INFORMATION SYSTEM DEVELOPMENT

the related USGS mapping programs. As noted on Figure 7, by sheer weight of need, many computer-based approaches are now being developed, most of which concentrate on specific applications in specific geographic areas. The USDI's NRIS development effort over the past two fiscal years has been aimed at establishing a generalized concept and implementation mode, to meet virtually all of the diverse needs of the department's bureaus and services. It is felt that the basic foundation has been laid and the need now is to tie all of the phases together in a comprehensive wide-area operational application. One such application which is timely, appropriate and, in some respects, almost necessary, is the fulfilling of the resource and land status information needs in the State of Alaska. The recent energy resource developmental plans, coupled with the impending redistribution of virtually the entire state to conform with federal legislation, makes the challenge of system implementation most inviting, and the promises which such an application might fulfill, most rewarding to all citizens. It is therefore, the recommendation of those involved in this program, both on the contractor's side and the government's side, that full-scale system implementation be undertaken as soon as possible, with a primary application being that of assisting in the development and administration of the public lands in the State of Alaska.