Dr. Frank J. Wobber
IBM Resources Management Department
Gaithersburg, MD 20760

Remote Sensing Trends in State Resources Management *

Five cases histories record a trend towards practical problem-solving.

Abstract: *Remote sensing programs at the state level reflect many changes in remote sensing technology and particularly a trend towards practical problem-solving. Five case histories are described and analyzed to establish remote sensing trends in state resources and environmental management. Trends – including the growth of regulatory and legal applications, increased use of information systems and decision modelling, and modifications in user attitudes with respect to the scale of remote sensor records – are noted.*

Introduction

The field of remote sensing has changed in the last ten years from its primarily research and development orientation towards applications problem-solving. While industrial, university, and government sensor system development continues, there is growing institutional enthusiasm for applied remote sensing techniques.

The term "remote sensing" suggests the exploitation of the electromagnetic spectrum beyond a traditional emphasis on visible and near-infrared imaging. A decade of rapid changes in remote sensing technology is forthcoming. State agencies, some of which were traditionally conservative in the utilization of new technology, are now involved in remote sensing. Numerous local and sometimes experimental *studies* that were reported over the past decade are now being replaced by *programs* of increasing size and complexity. Additionally, applications products that solve practical management problems are being designed and used. It is from within this changing user environment that trends in the field of remote sensing at the state level must be defined.

* Invited paper, Fall Meeting of the American Society of Photogrammetry, September 10-13, 1974.

General Approach

A comprehensive analysis of trends in remote sensing must necessarily involve an integration of the experiences of many authorities in this dynamic field. This paper can but partially represent what would undoubtedly be diverse views. What is clear is that any forecast of trends must necessarily be based upon a perspective of the past, i.e., a balanced assessment of case histories. The author recognizes the element of speculation inherent in predicting remote sensing trends and the likelihood of diverse views concerning the accuracy of his interpretations.

A variety of remote sensing programs with which the author is most familiar have been examined. He judges that these are representative of the numerous state programs conducted in the past several years. Attention has been given to a variety of state resources and environmental programs which have led to solutions rather than research results.

State trends in remote sensing were established by analyzing the essential elements of state agency programs and how agency objectives were met using remote sensing techniques. This analysis centered upon the character of the remote sensing system used, the purpose of the program or user objectives in utilizing remote sensing procedures, historical user experience, and the nature of the applications products derived.

The state case histories that were studied were limited to eastern states for geographical continuity and include programs from various levels of state government. They represent a wide range of costs, i.e., from $15,000 to $2,000,000. High cost is not considered a significant trend; many beneficial state programs are being accomplished with small amounts of funding.

Resource and Environmental Applications of Remote Sensing: Selected State Case Histories

Indiana coal refuse site inventory and cost analysis

A statewide coal refuse inventory program was completed for the Indiana State Legislature under the direction of the Indiana State Geological Survey. The Indiana Coal Association and various coal companies were principal participants. The program has been summarized by Wier, Leshendok, and Wobber (1974).

The coal refuse site inventory which included coal refuse banks (gob piles) and slurry ponds was conducted to meet anticipated legislative needs of the Indiana State Legislature's Conservation Advisory Committee, and several State agencies.

Aerial color-infrared photographs at 1:120,000 scale were analyzed to locate and environmentally assess over 200 coal refuse sites. Data were also derived from *ERTS* satellite imagery. Remote sensing-derived site data served as the basis for evaluating cost of reclamation. These data were combined with coal industry and State agency statistics to compute cost of reclamation for each site.

Refuse banks from old underground mining operations were usually too small and too highly vegetated to be distinguished by using *ERTS* imagery. Data with detail provided by 1:120,000 scale color-infrared aerial photography was cost effective for this program; for approximately $2.00 per square mile, refuse sites were accurately located and a variety of data which served as a basis for cost reclamation estimates were acquired. It was judged that less comprehensive results would have been obtained using *ERTS* at a cost of at least $3.00 per square mile.

Site analysis and reclamation cost estimates were completed in less than 90 days. The estimated cost for reclaiming coal refuse sites throughout Indiana approximated 14 million dollars. This data could not have been obtained so efficiently or so rapidly by using ground survey techniques. Program results including cost of reclamation data were summarized on 1:250,000 scale Coal Refuse Inventory Maps for ease of distribution and use by the coal industry, State Legislature, and various State agencies.

New Jersey statewide wetlands mapping

The Wetlands Act of 1970 directed the Commissioner of Environmental Protection to inventory and map the State's coastal wetlands. The State examined several alternative mapping methods but finally adopted a program which combined aerial photography with systematic field investigations. The choice of remote sensing was made because State estimates proved that traditional ground survey methods would be too costly and require far more time than permitted under the Act. This (and the complementary Hackensack Meadowlands Mapping Programs) has been summarized by Deely, Anderson, and Wobber (1973); and Anderson and Wobber (1973).

Using 1:12,000 scale color and color-infrared photography for nearly 450 square miles of wetlands, an upper wetlands (inland) boundary and major species associations of wetlands vegetation were delineated. A practical biologically based methodology was applied to determine a biologically based mean-high-water line. All results were represented on 1:2,400 scale maps that are now being used for regulating wetlands county-by-county. Hearings on the maps are regularly held, and the rate at which the State's coastal wetlands are being disturbed or destroyed has been sharply reduced. The Act might have been more rapidly planned and implemented if *ERTS* imagery (*MSS* Band 7) had been available. In particular, the landward extent (upper wetlands boundary) of the wetlands could have been rapidly delineated; this would have facilitated flight planning, speedier cost analysis, and more rapid assessments of high-priority mapping areas.

New Jersey regional coastal zone management program

The New Jersey Department of Environmental Protection is a regulatory agency charged by law with protecting and enhancing the State's total environment. The Department is oriented with implementing and enforcing environmental statutes. *ERTS* remote sensing imagery (under a program funded by the National Aeronautics and Space Administration) proved useful in addressing a variety of coastal resource and environmental problems; this convinced the State to budget for continued statellite re-

mote sensing activities and computer processing of *ERTS* imagery, and to assess remote-sensing-supported information systems.

Integrated *ERTS-1* and collateral aircraft imagery were used by the State for management of New Jersey's coastal zone. Four problem areas were investigated: detection of land use changes in the coastal zone; monitoring of ocean waste disposal; strengthening the environmental basis for siting of ocean outfalls; and assessment of shore erosion/accretion for allocation of coastal zone funds.

The offshore waste disposal problem is important because of the proximity of large federally regulated offshore waste disposal sites to New Jersey's coastline. Remote sensing studies assisted the State in better understanding waste effects on coastal recreational use, fishing resources, and public health. This may support a case with the Federal Environmental Protection Agency for alternative disposal sites.

The State also is engaged in a long-term program to convert New Jersey's sewage waste disposal from numerous locally operated primary and secondary treatment plants to a smaller number of regional secondary treatment plants with long ocean outfalls. The State recognizes that ocean discharge of sewage effluent is far from a final solution to the waste problem. Remote sensing was judged to be a contributor to determine if outfall design specifications were being met and to assure that effluents had a minimal impact on nearshore waters and beaches. Problems of shore erosion and siting of ocean outfalls were most efficiently investigated using *integrated ERTS* and multilevel aircraft. *ERTS* imagery coupled with aircraft coverage proved productive and cost effective for the State.

New Jersey annually spends several million dollars of State funds for construction and maintenance of shore protection structures. The State's coastline consists of multiple coastal groins; the State has been building and repairing these structures and-or replenishing eroded areas without a complete understanding of the effectiveness of engineering control measures. A case study to determine rates of erosion accretion by using aircraft photography within two areas of the New Jersey shore was completed. The State concluded that in developed beach areas (groins, jetties, bulkheads, etc.) erosion had in fact occurred more often, was generally severe, and that the beach was slower to recover than in a natural beach setting. It is noteworthy that recently the United States Park Service decided to abandon shore protection measures on North Carolina's Outer Banks to permit beaches to return to their natural conditions.

The State, by virtue of the Coastal Area Facilities Act (1973) and Wetlands Act (1970), has the authority to control major development within the coastal area of New Jersey. Enforcement of these laws requires (a) monitoring of all authorized development projects to insure compliance with permit conditions and (b) detecting clandestine or unauthorized coastal land disturbances. The enforcement problem can be met with difficulty by using ground inspectors complemented by occasional observations from light aircraft and helicopters; however, the cost for frequent aerial coverage of the entire coastal area would be prohibitive. For these reasons the Department utilized *ERTS* as a surveillance tool for detecting coastal lands disturbances. By using *ERTS*, hundreds of changes were observed, some as small as two or three acres. A limiting factor in the operational use of the *ERTS* change-detection system were data acquisition delays; with the cooperation of the National Aeronautics and Space Administration *(NASA)*, computer compatible tapes *(CCTs)* were provided to the state to test *ERTS'* rapid-response capability. Division personnel observed changes in the status of ongoing development activities in time for inspectors to react.

The Coastal Area Facilities Act (1973) has been more speedily implemented by using satellite and aerial remote sensing data. To meet the Department's operational needs, *ERTS* data *alone* proved of greatest value for (1) change detection indicative of land disturbances within areas covered by the Coastal Facilities Act and (2) monitoring of waste dispersion within offshore waste disposal areas. Additional details concerning the program was described by Mairs *et al.* (1974).

PENNSYLVANIA ENVIRONMENTAL PLANNING PROGRAM

The State of Pennsylvania's (Appalachian Regional Commission) Project involves the application of satellite and high- and low-altitude aircraft imagery (a) to identify surface indicators of mine subsidence, (b) to locate areas of potential future subsidence, and (c) to prepare mine subsidence hazards maps within the Northern Anthracite Basin. The State of Pennsylvania's remote sensing program was part of a comprehensive program in mined land subsidence.

The utility of multilevel remote sensing

analysis to derive map products of subsided areas and for predicting zones of likely future mine subsidence was demonstrated. Map products will assist various local and State agencies in making judgments about future land development as well as zoning or insurance decisions.

Surface subsidence in areas of underground mining has created serious hazards and caused extensive damage in many of the urbanized areas of Pennsylvania. Subsidence occurs in many forms including gradual lowering of the land surface, sudden collapse, surface tilting, and the development of surface fracture networks. Damage resulting from mine subsidence may include dislocation of transportation routes (railroads and highways), rupturing and reversing of pipeline flow, structural damage to buildings, and weakening of dams. In addition, subsidence may trigger landslides, create ponds and swamps, and create avenues for mine drainage.

The imagery acquired included color, color-infrared, and black-and-white infrared photography; multispectral scanner imagery in 12 spectral bands; and dual-look radar imagery. Color, color-infrared, and multispectral imagery were used to detect fracture patterns, which control ground water movement and serve to accelerate subsidence, and surface signatures of subsidence. Thermal infrared imagery was used to discriminate mine drainage discharge points in streams and rivers. Side-looking airborne radar *(SLAR)* and *ERTS-1* satellite imagery assisted in detecting regional fracture analysis but did not prove useful for direct detection of subsidence-prone areas.

Maps at 1:24,000 scale were prepared of the Northern Anthracite Basin showing areas of mine subsidence and areas of potential subsidence and landsliding. These maps will contribute to engineering design, land-use planning, and zoning decisions for a variety of local, county, and State agencies. A fracture-lineament Map of the Northern Anthracite Basin derived from *ERTS* imagery was prepared. A Final Report documents the procedures and results of the investigation including a matrix of the utility of various remote sensors for detection of mine subsidence, groundwater flow, fracture analysis, and geological mapping.

MARYLAND LAND-USE PLANNING PROGRAM

The State of Maryland is completing two nearly simultaneous programs which apply aircraft and satellite data to the inventory, monitoring, and comprehensive planning of land use. The programs include both research and operational program applications.

A *NASA*-sponsored *ERTS-1* investigation is testing the application of data from the Earth Resources Technology Satellite *(ERTS-1)* and aircraft sensing systems with emphasis on land use, and for providing inputs to the Maryland Comprehensive Land Use Plan.

A generalized Land Use Map of Maryland was produced from *ERTS* (*MSS* Bands 5 and 7) imagery. The map is based upon *USGS* Level I land-use categories to include urban, agricultural, forest, water, wetlands, and barren land-use categories. Remotely sensed data are being used for land-use change, formulation of State land-use planning goals, review of alternative comprehensive land-use plans, and other work that is beneficial to State land-use planning programs.

A second remote sensing program in the State is a detailed land-use inventory, by counties, of the entire State to meet the needs of the Comprehensive Land Use Plan. This mapping is an outgrowth of *ERTS* land-use mapping.

NASA high-altitude aerial photography (1:120,000 scale) was of sufficient resolution and quality for 1:63,360-scale map production. Detailed land-use information was required by State and regional planners for land-use capability/suitability modelling, as well as other land-use analyses and applications. More than 50 land-use categories are being used to meet the needs of State and regional planners.

Using satellite and aircraft remote sensing, working techniques applicable to future land-use inventory and monitoring at the State and regional level were tested. While remote sensing technology did not create a land-use plan, it facilitated collection of resource information useful for plan development.

Analysis of Case Histories to Established State Trends

A summary of the analysis conducted in using these various state case histories is included in Table 1. It is concluded that the following trends will be central to remote sensing mission planning and implementation at the state level in the next several years:

- *Emphasis on Practical Results and Products.* There is an increasing focus on practical solutions and results in state governments even within the context of research investigations. Testing of remote sensing procedures by pilot projects will continue to be important; there will be increasing

TABLE 1. PRINCIPAL ELEMENTS OF RESOURCES AND ENVIRONMENTAL-RELATED REMOTE SENSING PROGRAMS

State Program	Applications Discipline	Principal Orientation	Description of Primary Remote Sensing System(s)	Purpose of the Program	User Involvement In Remote Sensing	Program Product(s)
Indiana Coal Refuse Site Inventory	Geology	Mined land inventory and reclamation	High altitude aircraft; color infrared photography at 1:120,000 scale	Legislative planning, inventory for Select Committee of State Legislature	Repeat and new users: broadened use of remote sensing to resolve State problems by State agencies	1:250,000 scale and map series and statewide cost information
New Jersey Wetlands Mapping Programs	Botany	Riparian Law; coastal zone management; wetlands management	Low altitude aircraft; color and color infrared photograpy at 1:12,000 scale	Response to wetlands Act of 1970; establish State's claim to tide-flowed lands	Repeat user: Department of Environmental Protection is involved in continuing remote sensing programs	1:2,400 scale map series and complementary map reports for all coastal wetlands
New Jersey Regional Coastal Zone Management	Coastal Oceanography	Coastal resource and environmental management	ERTS-1 imagery (MSS bands 4, 5, 6, 7); high altitude aircraft photography at 1:60,000 - 1:120,000 scale; low altitude aircraft photography at 1:12,000 scale	Environmental planning; response to Coastal Area Facilities Act (1973); enforcement of regulations; allocation of State funds	Repeat user: new user with respect to repetitive satellite imagery for coastal regulation and planning	Varied map products: State ecological map; change detection system; outfall planning maps; coastal circulation maps
Pennsylvania Environmental Planning	Geology	Mining hazards; land use planning	Low-altitude aircraft; color and color infrared (1:30,000 scale) and black and white (1:6,000 - 1:12,000 scale aerial photography; 12-band multispectral scanner imagery (1:20,000 scale) including thermal imagery; radar imagery	Regional planning by State agencies; local zoning and land use codes; insurance risk analysis	New agency user: other State agencies have used aerial photography; planning broader remote sensing role	1:12,000 - 1:24,000 scale map series; report documenting interpretative procedures/signatures for State use
Maryland Land Use Planning	Geography	Land use planning	ERTS-1; high-altitude aircraft; color and color infrared photography at 1:120,000 scale	Establish land use data base with update capacity; planning in anticipation of State land use bill; implementation of executive order for statewide land use planning	New agency user: other State agencies have used remote sensing	Pilot project reports with 1:125,000-1:250,000 scale maps. Guidance in State funding distribution and planning; information system

emphasis on products *supported* by reports rather than reports as an end in themselves.

- *Increasing Regulatory and Legal Use.* There is a growing trend to use remote sensing technology for enforcement of laws and as a response to legislation. Regulation will become an important moving force in remote sensing programs. The court system continues to emphasize direct observation, but landmark cases using remote sensing will modify this orientation. There will be an increasing number of well-established court tests using remote sensing procedures. Remote sensing for court use will continue to be dependent upon systematic supporting ground observations.
- *Increasing Number of Repeat State User Agencies.* User agencies, once introduced to successful remote sensing procedures, will broaden the application of these procedures to new problems. There will be a growing need to actively educate users rather than to encourage their passive participation in remote sensing technical meetings. The most significant number of repeat users will come from states where the "hands on" use of sensor records by state personnel has been encouraged.
- *Adoption of Special Classifications Unique to Remote Sensing.* An increasing trend for states and other users will be the adoption of classifications which meet practical needs, i.e., classifications which are scientifically rooted but not wholly acceptable to scientific purists. The user community will no longer emphasize the acquisition of the exact level of detail with remote sensing systems that traditionally has been demanded on the ground.
- *Introduction of Information Systems and Models.* The trend to present results in a map format will continue; problems now being encountered in state resource management will, however, require "dynamic maps." For example, wetlands species composition and hence the productivity of coastal marshes can be greatly modified following severe storms. Information systems will contribute to the production of "dynamic map products"; predictive models will make increasingly important contributions to resources and environmental management decision processes.
- *Changing User Attitudes in the Scale and Format of Remote Sensing Records.* Emphasis on the visible and near-infrared portion of the electromagnetic spectrum will continue; less emphasis will be placed on the use of large-scale imagery. Users will increasingly be willing to "trade" resolution for repetitive cover. The demand for high-resolution satellite remote sensing systems will increase.

Conclusions

By using selected remote sensing case histories, judgments of future trends on the utilization of remote sensing at the state level have been made.

Growth in the number and sophistication of users can be anticipated. Six specific trends have been identified. These are emphasis on practical results and products, increasing regulatory and legal use, increasing number of repeat users, adoption of special classifications unique to remote sensing, growth of information systems and models, and changing user attitudes in the scale and format of remote sensing records. The interpretation of the base data described herein will vary with the experience of the analyst. The accuracy of these specific trends will be tested by time.

References

Anderson, R. and Wobber, F. J., 1973, Wetlands Mapping in New Jersey. *Photogrammetric Engineering*, Vol. XXXIX, No. 4, pp. 353-358.

Deely, D., Anderson, R. and Wobber, F. J., 1973. Hackensack Meadowlands Mapping Program. *Technical Report prepared for New Jersey Department of Environmental Protection*, 200 pp.

Mairs, R. L. *et al.*, 1974. Application of *ERTS-1* Data to the Protection and Management of New Jersey's Coastal Environment. *Ninth Annual Remote Sensing Symposium, University of Michigan* Ann Arbor, Michigan, April, 1974.

Wier, C. E., Leshendok, T. and Wobber, F. J., 1974. A Remote Sensing Inventory and Reclamation Cost Estimate of Coal Refuse Sites in the Indiana Portion of the Eastern Interior Coal Basin. *Indiana Geological Survey Circular.* (Publication expected, November, 1975)

Nomenclature Committee

The ASP Nomenclature Committee is in the process of compiling definitions and symbols of photogrammetric and related terms for publication as a chapter in the forthcoming 4th Edition of the *Manual of Photogrammetry*. Contributions and assistance are being solicited by the Committee. If you have encountered any problems such as inconsistencies, conflicts, or omitted terms with the definitions and symbols as they now exist in the literature, please send your contributions to Professor Paul R. Wolf, Nomenclature Committee, Chairman, Civil and Environmental Engineering Department, The University of Wisconsin, Madison, Wisconsin 53706.