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# Annotated Biobliography of Remote Sensing for Highway Planning and Natural Resources, An

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# AN ANNOTATED BIBLIOGRAPHY OF REMOTE SENSING FOR HIGHWAY PLANNING AND NATURAL RESOURCES

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*Cover photograph*: Low oblique black-and-white aerial photograph of a highway and a freshwater wetland in Mansfield, Connecticut. (Civco photograph)

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# AN ANNOTATED BIBLIOGRAPHY OF REMOTE SENSING FOR HIGHWAY PLANNING AND NATURAL RESOURCES

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January 1980

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CONTENTS

# INTRODUCTION

Remote sensing is the art and science of gathering information from a distance. Through interpretation of imagery collected from aircraft or satellites, earth surface features and phenomena can be detected, identified, delineated and analyzed. These procedures have proven valuable in natural resource planning, environmental impact assessment, and engineering activities.

This annotated bibliography was prepared as part of a research effort dealing with basic and applied aspects of the use of remote sensing techniques in highway corridor selection. Since freshwater wetlands were of principal interest in that work, many of the articles chosen for abstracting deal with that subject as well as with color infrared photography -- source imagery for the research. Publications abstracted were identified through extensive manual library and computerized bibliographic searches.

The bibliography is divided into five sections:

A. Highways and Remote Sensing Applications (53 abstracts)

B. Environmental Impact of Highways and Corridor Selection Methods (23 abstracts)

C. Wetlands and Remote Sensing Applications (14 abstracts)

D. Economics of Remote Sensing (11 abstracts)

E. General Remote Sensing Applications (51 abstracts)

The complete citation is giveu for each publication abstracted together with details on the problem, approach, equipment, results, aud conclusions. The notation "(Author)" follows those few abstracts which were taken directly from the original publication. Finally, each abstract is followed by a list of keywords which indicates the subject matter of the publication.

To facilitate use of the bibliography, an author index, a keyword index, and a list of abbreviations and acronyms used are provided.

## ACKNOWLEDGMENTS

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D.L.C.
W.C.K.
M.W.L.

January 1980

Section A

# H I G H W A Y S

# A N D

# R E M O T E  S E N S I N G

# A P P L I C A T I O N S

53 Abstracts

A-1 Arnold, R. H., H. L. Furr, and J. W. Rouse, Jr. 1969. *Infrared Detection of Concrete Deterioration.* Remote Sensing Center, Texas A&M Univ., College Station, TX. 21 pp.

The preliminary results of an experiment to determine concrete deterioration by measuring thermal emissivity are presented. Surface scaling and vertical cracking are easily detected but subsurface delaminations are more difficult to detect. Acoustic techniques of detecting the type and rate of pavement deterioration have shown promise, but they do not readily lend themselves to the monitoring of extensive areas. The hypothesis tested in this study was that heat fluxes are proportional to the homogeneity of the structural material (*i.e.*, during heat transfer to the pavement, delaminated areas will heat up more quickly than solid areas. In heat transfer from the pavement, they will cool more rapidly.). Seven Portland Cement concrete specimens were used in this experiment; these were of different shape, size, and age. During the testing, the samples were subjected to varying induced meterological conditions. An infrared scanner with an indium antimonide detector was used to measure the thermal emissivity of each sample. Temperature resolution of the system was about 0.2°C. Thermographs, depicted by gray tone variations on a CRT, illustrated the relative temperature differences in the concrete specimens in areas of known fractures or homogeneity. The test results showed the existence of thermal emissivity differences related to certain types of deterioration; delaminations were observable with the infrared scanner. They were most evident during ambient cooling periods (heat transfer from the pavement). It is recommended that more detailed information be collected for the entire heat exchange phases.

thermal infrared scanner
thermal emissivity
pavement
concrete
infrared
thermograph

A-2 Barr, D. J. and W. P. Adams. 1975. *Civil Engineering Applications of Remote Sensing.* Transportation Engineering Journal 101(TE2): 279-295.

An overview of possible applications of various remote sensor systems to civil engineering practices is presented. A brief comparison is given of conventional qualitative photointerpretation (image analysis using keys, visual recognition, and/or deductive reasoning) and computer oriented, quantitative analysis (image analysis using the digital spectral characteristics of an object). It was noted that photographs provide superior geometric qualities, whereas electronic sensors (those providing the digital data) provide superior spectral qualities. Also, there is a recent trend toward ADP of nonimaged spectral data, thus increasing the repeatability of the analyses and the volume of information able to be handled. Also presented is a table cross-referencing 18 engineering terrain parameters with four remote sensing systems, with literature references given (60 in all). Examples of remote sensing as applied to environmental engineering, water resource planning, transportation

A-2 (cont'd)

engineering, and geology and soil mechanics are given. Overall, CIR photography is the best single sensor for most applications, but specific applications will dictate which sensor is most suitable. The authors state that "aerial monitoring has the potential for providing the civil engineer with a synoptic overview and a basic understanding of the natural system."

remote sensing
civil engineering
aerial photography
color photography
multispectral scanner
color infrared photography
black-and-white photography
thermal infrared
transportation

A-3 Beaumont, T. E. 1977. *Techniques for the Interpretation of Remote Sensing Imagery for Highway Engineering Purposes.* Transport and Road Research Laboratory, Dept. of the Env. and Dept. of Transport, Crowthorne, Berkshire, England. TRRL Rept. 753. 40 pp.

Traditionally, the interpretation of BW aerial photographs, supported by field investigations, has been used for site analysis and highway corridor selection. With the development of new and more sophisticated remote sensor systems, highway planners have been offered more detailed and quantitative information for use in more efficient and comprehensive route location. However, techniques for the analysis of these new imagery and data sources have not kept pace with sensor development. In this report, an overview is given of available remote sensing imagery and the state of the art techniques for its analysis. Imagery types discussed include BW, color, CIR, and multispectral photography, multispectral scanner data, and microwave radiometer imagery. Multispectral imagery was regarded as a best all-round sensor type in that the effective dynamic spectral range recorded and the overall scene contrast are increased, permitting analysis and presentations of the imagery to be tailored to the application. A discussion of the factors and limitations influencing image interpretation is presented also. Various techniques for image enhancement and analysis using computers and other specialized equipment are presented. These techniques include density slicing (both photographic and microdensitometric), contrast stretching, image masking and combination, edge enhancement, and automated data processing. It was concluded that "...Although much can be gained from applying traditional photointerpretive techniques, in order to realize the full potential of these new tools [sensor systems], the highway engineer and geologist must understand and employ some rather specialized interpretative techniques."

remote sensing
highway planning
aerial photography
multispectral scanner
radar
automated data processing
contrast stretching
edge enhancement
LANDSAT
interpretation
image analysis
density slicing

A-4 Beaumont, T. E. and P. J. Beaven. 1977. *The Use of Satellite Imagery for Highway Engineering in Overseas Countries.* Transport and Road Research Laboratory, Dept. of the Env. and Dept. of Transport, Crowthorne, Berkshire, England. Suppl. Rept. 279. 21 pp.

LANDSAT imagery was used on two road investigations in the Sudan to provide information on the four main factors that affect route location. The four major factors outlined were soil strength, earthworks, drainage and river crossings, and sources for construction materials. Interpretation techniques included the production and enhancement of false color composites in a purpose-built additive viewer which was also used for examining photographically prepared density slices of infrared Band 7 of the MSS imagery. The work in the Sudan, together with a review outlining the advantages gained by repeated observations of the earth from space, was used to define the main techniques that could be employed and to identify the major areas where satellite imagery could assist the highway engineer. It was concluded that the present generation of imagery is most suited for the planning and feasibility stages of engineering survey for road projects, such as the preparation of regional maps and inventories of terrain characteristics or reconnaissance studies involving decisions on route location. Other platforms and sensors discussed briefly include LANDSAT-C MSS and return beam vidicon (RBV); Skylab CIR photography; the Heat Capacity Mapping Mission satellite's thermal infrared scanner; and the European-built Spacelab.

highway location
highway engineering
satellite
LANDSAT
color additive viewer
multispectral scanner imagery
construction
soils
Sudan

A-5 Becker, R. E. and C. W. Lancaster. 1966. *Aerial Infrared Surveys: A Highway Research Tool.* in *Photogrammetry and Aerial Surveys.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 142:55-63.

The purpose of this paper is to present some of the basic physical attributes of thermal infrared (IR) scanner systems and their possible applications to terrain analysis. The range of the IR portion of the electromagnetic spectrum is from 0.9 to about 1000 μm; most terrestrial objects have their peak emissions in the 8.6 to 12.4 μm thermal IR band. Detected thermal IR radiation differs from visible light in that it is not reflected from an object's surface, but rather it is energy (in the form of heat) emitted from its surface. The Stefan-Boltzman Law states that the magnitude of this "spectral radiant emittance" is proportional to the fourth degree of the absolute temperature of the object and to its emissivity. Since emissivity measurements of aerial scenes are extremely difficult to make, it is assumed that all terrestrial objects have surface emissivities of unity; thus, energy flux differences can be interpreted in terms of radiation temperatures. An IR scanner is an electro-optical device in which a semiconductor detector is excited to a degree dependent on the incident energy. The electrical signal generated is amplified and converted into a visible light signal to which

A-5 (cont'd)

standard photograph film can be exposed to create an image of the thermal IR scene. Cooler objects appear darker while warmer objects appear lighter on IR imagery. In hydrologic studies, water can be delineated quite precisely because of the dramatic contrasts in emissivity between water and adjacent terrain. Also, the nature of certain subsurface features not revealed by conventional photography could be shown in thermal IR imagery. This imagery is useful in both vegetation and land use studies; different species and various land use types often possess characteristic IR radiant traits enabling their rapid identification and accurate delineation. Thermal IR imagery, in conjunction with conventional aerial photography, could provide information giving a new dimension to terrain analysis.

thermal infrared
aerial photography
infrared imagery
infrared scanner
terrain analysis
geology
visible band

A-6 Bricker, C. D. 1972. *Experiments in Aerial Remote Sensing for Highway Engineering.* in *Proc. 1st Canadian Symp. Remote Sensing,* 2:713-715. Ottawa, Ontario, Canada.

The Alberta Department of Highways and Transport evaluated various remote sensing methods for application to highway engineering with emphasis on highway route location. Remote sensing flights were made over three test areas: Edmonton-East and Devon flown in August 1970 (scale, 1:21,120) and Edson-East flown in September 1971 (scale, 1:12,000). All sites, selected to contain a diversity of cultural and natural features, were thoronghly investigated on the ground. Semi-controlled mosaics were constructed of each area. Color photography was preferred for interpretation over BW. Combinations of BW, color and CIR, although time consuming to interpret, supplied the greatest amount of information. Color infrared more clearly defined wet and dry areas and tree types over other imagery for drainage patterns and muskeg studies. Sand and gravel are more clearly defined on small scale color and, in certain instances, on CIR than on BW. Thermal infrared imagery requires more expertise in procurement and interpretation but has potential value in specific areas of highway engineering.

remote sensing
highway
highway corridor selection
aerial photography
black-and-white photography
infrared imagery
color photography
color infrared photography
thermal infrared
photomosaic
Alberta
Canada

A-7 Chaves, J. R. and R. L. Schuster. 1964. *Use of Aerial Color Photography in Materials Surveys.* in *Color Air Photos, Soil Properties and Tests.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 63:1-9.

More than 400 flight strip miles of aerial color transparencies, scale 1:6,000, were taken in the summers of 1961 and 1962 along the major road system and other selected locations in Yellowstone National Park, WY. Selected segments totaling about 100 linear mi. were taken with panchromatic BW film at the same time. A mirror stereoscope was used to examine the transparencies. Potential construction material sources delineated on the imagery were verified by ground inspection and soil samples were taken for laboratory testing. It was concluded that color photography has many advantages over BW photography for use in materials surveys. Disadvantages include higher cost, difficulty in obtaining proper film exposure and adverse effects of haze. Summaries of selected aerial color film data and characteristics, of the cost of aerial color photography and of selected aspects of color film processing and printing are given. The relationship between quality of color reproduction and photographic interpretation is given. Finally, research needed to facilitate the use of aerial color photographs for interpretive purposes is described.

aerial photography
black-and-white photography
color photography
highway
photointerpretation
Wyoming

A-8 Chaves, J. R. and R. L. Schuster. 1968. *Color Photos for Highway Engineering.* Photogrammetric Engineering, 34(4):374-379.

Results of the use of aerial color transparencies and prints in engineering materials surveys by the Federal Highway Projects Office, Region 9, U.S. Bureau of Public Roads, show that they have many advantages over BW photographs. A photograph scale of 1:6,000 seems to provide optimum results for materials surveys. Preliminary investigations of CIR photographs show that they do have some advantages over conventional color photographs for engineering interpretation and are best employed as a supplement to color film. Some of the advantages noted include: (1) CIR shows greater color contrasts among natural features or cultural objects; (2) CIR has increased ability to penetrate haze; (3) CIR enables a more positive differentiation of coniferous from deciduous trees; (4) CIR records areas of water seepage and boggy ground more positively; and (5) hydrological features such as streams and lakes can be more readily detected and delineated on CIR than with conventional color. The development of the Stereoimage Alternator system, an instrument which has the option of mapping with either BW or color aerial photographs, and technological advances made by the film industry make it possible to use color photographs for interpretation as well as for topographic mapping with double projection anagylphic plotting instruments.

A-8 (cont'd)

aerial photography
color photography
highway engineering
highway
anaglyph
color infrared photography
topographic mapping
materials survey
photogrammetry

A-9 DeLoach, W. C. 1973. *Remote Sensing Applications to Environmental Analysis.* in *Photogrammetric Analysis of Urban and Rural Environments.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 452:29-39.

To provide data to highway planners for the preparation of environmental impact statements, photointerpretation and thermal infrared scanning were used by the Florida DOT for surface water temperature and underground void detection. To study the location of I-75 east of Tampa, BW aerial photographs (scale 1:12,000) were taken of a corridor 4 mi. wide by 40 mi. long and a photomosaic map was prepared. A use classification system was devised containing 12 major divisions and 84 subsets. Of these, 51 were used in this study to prepare key features maps. Drainage and engineering soils maps of the test area also were prepared by photointerpretation. Property maps based on information extracted from tax maps of the area were delineated on the photomosaic. The remote sensing unit produced 65 map sheets in 13 weeks using 240 man-hours. In March 1971 six thermal IR scans (altitudes: 500 ft. and 1000 ft.) were made during a 24 hour period at Tallahassee, FL to study the distribution effect of the thermal effluent into the St. Marks River from an electric generating facility. Concurrent absolute temperature readings also were made along the flight lines using a radiometer. The thermal plume was identified and the maximum temperature increase in surface water was 4°C. Thermal imagery (8 - 14 μm bandwith) was taken Nov. 16, 1971 at altitude of 1,000 ft. of a portion of US-19 north of Chiefland, FL. Ground conditions associated with surface anomalies on the imagery were established by a boring program. Based on 16 borings, an apparent correlation between thermal anomalies and subsurface cavities or deep fissures was found with a reliability of 75%. It was concluded that basic photointerpretation from BW photography and thermal IR scanning contributed significant information needed in answering many environmental problems in highway planning.

remote sensing
black-and-white photography
photointerpretation
highway planning
thermal infrared
radiometer
river
sinkhole
environmental impact statement
water temperature
land use
soil mapping
drainage
soils
Florida

A-10 Edwards, R. J. G. 1973. *Some Uses of Air Photography for Road Design in the UK and Abroad.* Journal Institute of Highway Engineers, August:9-14.

The use of aerial photography by highway engineers has been generally categorized as photogrammetric studies, general interpretive studies, and specific interpretive studies. Photogrammetry is defined as "the study of the geometrical relationship between two or more points visible on a stereographic model". Of an extremely quantitative nature, photogrammetric applications involve activities such as preparation of topographic maps, development of cross sections and profiles, and the precise location of terrestrial features. Interpretation is the "objective deduction of the meaning and significance of the shape, size, pattern, color, tone, and texture of the various parts of the photographic or stereographic model image of the ground surface." General interpretive studies, commonly referred to as "terrain evaluation", use aerial photographic information to provide the highway engineer with data, usually in map form, sufficiently accurate to assess existing ground conditions, identify and analyze problem areas, and plan highway corridors. Specific interpretive studies are less objective, involving an element of subjectivity in describing problems of regional and local character and correlation of the required engineering parameters. Terrain analysis should be the methodical procedure of (1) the delineating boundaries of landscape types, (2) the identification and isolation of landforms within these landscapes and (3) the definition of the units making up the landforms. Correlation is carried out to determine the specific relationships between ground conditions and their respective photo image representation. Aside from the three aforementioned categories of aerial photo analysis, more specific applications include hydrologic studies, service line map preparation, access, land use, archeological, and pollution studies, and construction problem area assessment. Factors influencing the accuracy and precision of aerial photo analysis include the (1) scale of the photography, (2) its resolution, (3) the camera system, (4) the expertise of the interpreter/analyst and (5) imagery type.

aerial photography
highway engineering
photogrammetry
photointerpretation
terrain analysis
United Kingdom

A-11 Fedorov, V. I. 1975. *Aerial Surveys of Highway Routes and Bridge Crossings.* Izdated'stvo Transport. Moscow, Russia. 200 pp. [In Russian].

As described by the National Aeronautics and Space Administration (NASA) this is a handbook of modern techniques and equipment in aerial survey work aiding design, tracing, and siting of highways and bridge crossings. Special methods in aerial photographic surveys, photointerpretation, and computer modeling of highway corridor location are discussed. Illustrations and color plates (including stereopairs) are presented as situation examples. Topics discussed include: aerial photographic materials, stereocomparators and

A-11 (cont'd)

stereometers; terrain analysis; highway analytic layout using mathematical models; three dimensional photogrammetric applications in highway planning; aerohydrometeorology; and roadbed assessment from aerial surveys.

aerial photography
photogrammetry
highways
roads
topography
photointerpretation
highway planning
geology
hydrology
terrain analysis
regional planning
mathematical model
highway engineering
Russia

A-12 Fischer, W. A. 1969. *Examples of Remote Sensing Applications to Engineering.* in *Remote Sensing and Its Application to Highway Engineering.* National Res. Coun., Hwy. Res. Board, Spec. Rept. No. 102:13-21.

Brief discussions on three aspects of remote sensing: (1) spectral components, (2) spatial components, and (3) temporal components are presented. About one paragraph each is used to explain the following remote sensor systems: BW, color, CIR, and multispectral photography, ultraviolet, radar, and infrared imagery. A brief section on radiometry is also given. While the paper does not make direct reference to specific uses of remote sensing in engineering, the reader is provided with enough scope information to permit him to investigate the possibilities elsewhere.

remote sensing
engineering
infrared imagery
civil engineering
aerial photography
radiometer

A-13 Gamble, J. 1976. *Remote Identification of Geologic Materials by Multispectral Techniques: An Evaluation of Applicability to Highway Planning in California.* Calif. Dept. of Transp., Div. of Structures and Engrg. Serv., Transp. Lab, Research Rept., Final Rept. FHWA-CA-TL-2117-76-57. 34 pp.

This report analyzes two publications by the Environmental Research Institute of Michigan (ERIM) on the results obtained at a California test site of studies to develop techniques for automatically identifying terrain features and natural materials by remotely sensed multispectral imagery. Multispectral data were collected by ERIM over the Halloran, CA 2 by 6 mi. test site at 3000 ft. and 6000 ft. in the fall of 1972. Twelve spectral bands in the UV, visible and IR regions were recorded. A detailed geologic map to provide accurate ground truth was prepared. ERIM used three systems to process the MSS data: Euclidian distance using in-scene training sets, computer analysis

A-13 (cont'd)

based on laboratory ratio values or on in-scene training sets, and color composite photographs. Average rock classification accuracies were 37.0%, 43.9% and 77.9%, respectively. Dense vegetation was found to mask identification of rock composition. It was concluded that remotely sensed MSS data cannot, at its present stage of development, differentiate the various rock types or delineate their areas of outcrop or deposition with sufficient accuracy to enable planning and engineering personnel to make highway route selections.

highway corridor selection
highway planning
remote sensing
multispectral imagery
automated data processing
terrain analysis
geology
California

A-14 Haack, B. N. 1975. *Remote Sensing and Highway Transportation Planning: An Annotated Bibliography.* ERIM, Ann Arbor, MI. RANN Rept. 408-392. 73 pp.

This annotated bibliography contains 94 entries related to remote sensiug and highway planning. The citations and accompanying annotations are intended to provide background information for individuals in the transportation field. The abstracts are typically those prepared by the authors of the publications; most of these are followed by comments offered by Haack. The bibliography is organized into six major sections: 1. Remote Sensing in Regional Transportation Planning (17 refs.); 2. Remote Sensing in the Corridor Selection and Design of Highways (24 refs.); 3. Remote Sensing Detection of Materials Pertinent to Highway Engineering (19 refs.); 4. Remote Sensing for Environmental Impact of Highways (7 refs.); 5. Economic and Social Impacts of Highways (13 refs.); and 6. Sources (of further information, 14 refs.). An author index for the citations is provided. There is no keyword index.

bibliography
remote sensing
highway planning
environmental impact
transportation
corridor selection

A-15 Hawkes, T. W. and D. A. Brown. 1973. *Application of Aerial Mapping to Development of Highways.* in *Photogrammetric Analysis of Urban and Rural Environments.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 452:10-18.

Aerial photography can effectively be applied to the development of preliminary engineering plans, environmental analysis, community impact studies, and financial feasibility studies for limited access highways. New methodology and techniques provide an excellent tool for rapidly and inexpensively developing preliminary data required for technical and scientific investigations.

A-15 (cont'd)

The Atlanta Tollway Project is a $200 million system composed of 35 mi. of limited access highways and 10 miles of high speed rapid transit in the median. Most of the aerial mapping techniques discussed in this paper were used in the development of the financial feasibility, the environmental, and the community impact studies for that project. (Authors)

highways
aerial photography
black-and-white photography
color infrared photography
multispectral photography
environmental analysis
thermal infrared imagery
earthwork
right-of-way
highway engineering
Georgia

A-16 Henderson, F. and D. S. Simonett. 1970. *Space Photography as a Tool in Delimiting Transportation Networks.* in *Proc. American Association Geographers*, 2:71-73.

It has been suggested that photography from space may be used to update maps of transportation networks, and that photographs of the quality and resolution obtained on Gemini and Apollo missions should be tested for such purposes. This study documents the consistency of color photography with 300 ft. ground resolution to detect road networks from other transportation arteries and linear features. While 100% of the divided highways were visible on one photograph, only 30% to 35% of the complete road network was visible. In addition, a substantial number of other linear features were incorrectly identified as roads. Attempts were made to improve detection and decrease error by combining photographs and by examining only lines visible on multiple photographs. The results of each method proved the inadequacy of space photography of this resolution for road detection. Finally, a comparison between 300 and 125 ft. ground resolution color photographs was made. The results of this comparison indicate that 125 ft. is the minimum threshold ground resolution for photography from space if it is to be a viable tool in road network analysis.

transportation
highway
remote sensing
space photography
spatial resolution
road
color photography

A-17 Higgs, R. W. 1963. *Photo Interpretation in Highway Engineering.* in *Proc. Seminar on Air Photo Interpretation in the Development of Canada.* Ottawa, Ontario, Canada. 11 pp.

The Canadian Department of Public Works surveyed the ten provincial highway departments to determine their involvement with aerial photography in highway planning. It was found that eight of the ten provinces made extensive use

A-17 (cont'd)

of photointerpretation and only one used aerial photography for studies other than corridor location. BW photography had been used exclusively and analyses were commonly conducted using conventional pocket or mirror stereoscopes. Airphoto interpretation in the reconnaissance and preliminary location stages can provide the highway planner with information such as general foundation suitability, proximity of borrow areas, hazard areas, slope and curvature characteristics, and eventually cost estimates. The author noted that there are many other possible applications of aerial photo analysis other than highway route location. These include: street location (avoiding swampy areas, old drainage channels, and existing drainage patterns which may be too small or insignificant to be included on topographic maps), traffic information, property acquisition, and construction programming and monitoring.

highway
aerial photography
black-and-white photography
highway planning
highway traffic
Canada

A-18 Jordan, S. G. and T. R. West. 1975. *Highway Route Location Utilizing Remote Sensing Techniques, Fort Wayne, Indiana.* Laboratory for Applications of Remote Sensing, Purdue Univ., West Lafayette, IN. LARS Info. Note 122475. 18 pp.

In cooperation with the Indiana Highway Commission (IHC), researchers at LARS analyzed Skylab and LANDSAT multispectral scanner (MSS) data for the purpose of siting a dual lane, by pass highway around the northeast of Fort Wayne, IN. Beginning and end points for this proposed corridor were supplied by IHC. Data analyzed in this study included: Skylab IV imagery taken on Jan. 25, 1974 and LANDSAT imagery of June 8, 1973. Supportive ground truth was provided by BW aerial photographs from April 29, 1975 [scale not given], engineering soils maps, and USGS topographic quandrangles. A nonsupervised classification technique (cluster analysis) was applied to both the Skylab and LANDSAT MSS data. Because the Skylab imagery was from the winter season, and acquired during a period of heavy rains, the presence of ice obscured much of the ground surface. Therefore, results from Skylab data processing were not very useful for land analysis. The LANDSAT data, however, proved to be more suitable for the analysis. Fifteen separate classes of material were identified on the grayscale printout of the MSS data cluster analysis. These 15 categories were later classified with the aid of the BW aerial photographs. Through the examination, the growth pattern and the degree of suburban development became evident. Also, two areas of poorly drained soil suspected of having high organic matter contents were detected and delineated. The highway corridor was sited around these poorly drained areas and other salient environmental features. It was concluded that LANDSAT MSS imagery could be used in remote or underdeveloped areas where data gaps exist. It was noted that, for detailed studies for highway engineering, lower altitude aircraft MSS imagery could be used.

A-18 (cont'd)

remote sensing
highway location
multispectral scanner imagery
cluster analysis
Skylab
computed assisted classification
LANDSAT
Indiana

A-19 State Highway Commission of Kansas. 1974. *Corridor Analysis for Projects 54-8-15-038-4(28) and 77-8-25-055-2(4), Butler County.* Remote Sensing Sec., Location and Design Concepts Dept., Topeka, KS. 9 pp.

The purpose of this study was to provide preliminary data, including cultural, environmental, and natural features, that would influence the selection of an alignment for two proposed highway projects in Butler County, KS. Black-and-white aerial photos, taken on June 20, 1973 and at a scale of 1:24,000, served as the primary information and mapping base. Data were derived from the aerial photos for soil mantle types (alluvium, floodplain, residual), geologic formations (supported by geologic maps), drainage divides, utilities, and land usage (houses, forest, rangeland, cropland). Terrain was evaluated from the USGS 7 1/2" El Dorado Quandrangle map. Acetate overlays were prepared for the above features. Suggestions were made as to how the data could be used in actual corridor selection.

highway
resource mapping
black-and-white photography
soil mapping
land use
geological mapping
topography
highway corridor selection
Kansas

A-20 Kansas Department of Transportation. 1977. *Corridor Analysis for Project 59-44 F 067-3116.* Env. Support Sec., Engrg. Serv. Dept., Topeka, KS. 11 pp.

This paper reports on the identification and evaluation of cultural, environmental, and natural features that would influence the selection of an alignment for US-59 in Jefferson County, KS from US-24 near Williamstown, KS north to Oskalossa, KS. Analyses were conducted primarily using BW aerial photographs at a scale of 1:36,000 and taken on March 9, 1977. Collateral information concerning the study area was supplied by the Soils, Geology and Environmemntal Support Sections of Kansas DOT. Photointerpretation of this imagery, along with the supporting data, was used to evaluate and prepare overlays for geologic and soil conditions, land use, and cultural features. Further studies addressed archeological, air, and noise parameters. In assessing wildlife habitat, it was concluded that minimal land clearing and channelization would be required if the existing US-59 alignment were

A-20 (cont'd)

followed. Recommendations for a new route selection were made in order to maintain areas of high quality habitat. In relation to groundwater quality, ponds, undrained borrow areas, and wetlands were cited as being beneficial in removing transportation related pollutants, but their location and delineation (by means of photointerpretation) was not presented.

highway planning
geology
soils
aerial photography
black-and-white photography
wildlife
corridor selection
water quality
Kansas

A-21 Kennard, W. C., M. W. Lefor, and D. L. Civco. 1978. *False-Color Infrared Aerial Photography As an Aid in Evaluating Environmental Impacts on Inland Wetlands by Proposed Highways in Connecticut: A Feasibility Study.* Dept. of Civil Engrg., Univ. of Conn., Storrs, CT. Report JHR-78-120. 74 pp.

Using freshwater inland wetlands as an example the feasibility of using low-altitude (6,000 feet AMT) CIR aerial photography in highway planning studies was investigated. Specific objectives were to: 1) compare the applicability of available remote sensing information in evaluating highway corridor impact on freshwater inland wetlands. Sources included CIR and BW panchromatic aerial photography, and soils maps; 2) develop baseline information which will provide the basis for a benefit-cost analysis of the use of CIR aerial photography versus BW panchromatic aerial photography in site selection and impact of highway construction; 3) develop a comprehensive data bank of existing, available remote sensing imagery of the state of Connecticut; and 4) prepare an annotated bibliography of publications on remote sensing and transportation engineering, planning, and the use of remote sensing information in environmental impact assessment. The study area chosen for research consisted of the four alternate highway corridors proposed by the Connecticut Department of Transportation (ConnDOT) in 1970 between I-84 and the University of Connecticut, located in Mansfield. Existing BW and CIR aerial photographs, both at 1:12,000 scale, were interpreted and inland wetlands and surface hydrologic features were delineated. Similarly, these resources were identified and delineated on a USDA Soil Conservation Service soils map. Point samples, identifying various wetland categories, were derived from field studies. Comparisons of the three sets of wetland delineations demonstrated that CIR aerial photographs provided the highest accuracy (85% overall), followed by the SCS map (70%), and then the BW aerial photographs (68%). Additionally, fewer incorrect wetland identifications were made with CIR (3%); BW provided 13% incorrect wetland identification. Stream and surface water detail was better with CIR also. Overall, CIR was rated as an excellent tool for the identification, delineation, and classification of wetlands and surface hydrology, while BW was good, and the SCS map was fair. In studying the economics of alternate remote sensor systems, cost effectiveness (C-E)

A-21 (cont'd)

analysis was chosen over benefit-cost analysis. Twenty-seven parameters and subparameters were outlined for inclusion in a future C-E analysis. A comprehensive inventory of available remote sensing imagery products revealed that there are many sources for this imagery of Connecticut and that, previonsly, there was no single source of information documenting the coverage, characteristics, and availability of the photography. These data were compiled and organized in another publication. A standardized format for abstracting publications was adopted. At the time of this publication, the authors' annotated bibliography consisted of more than 150 publications. Also, since relevant citations were retrieved from eight different automated information storage and retrieval systems, the authors evaluated the responses. The results of this study are presented.

highways
highway planning
aerial photography
color infrared photography
black-and-white photography
inland wetlands
wetlands delineation
soils mapping
mapping accuracy
field studies
cost effectiveness
remote sensing
annotated bibliography
Connecticut

A-22 Kiefer, R. W. 1972. *Sequential Aerial Photography and Imagery for Soil Studies.* in *Remote Sensing for Highway Engineering.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 421:85-92.

Color infrared photographs [altitude not given] collected on six dates between July 1969 and June 1970 and thermal images (2000 ft. above terrain) from four times during a 19.5 hr. period are illustrated and discussed. The 0.5 by 0.67 mi. test site is west of Madison, WI. Changes related to soil type, moisture content, and vigor of vegetation occur on photographs taken on different dates. Contrast between the silty lake bed soils and a small beach ridge can be detected clearly. The optimum time of the year for aerial photography for soil studies in southern Wisconsin is about May 1 to June 15. It was concluded that thermal imagery has great potential for soils mapping but optimum times of year and of day could not be determined from these studies.

aerial photography
thermal infrared imagery
color infrared photography
remote sensing
soil mapping
soil classification
color photography
Wisconsin

A-23 Maine Department of Transportation. 1972. *Wiscasset By-Pass Corridor Location Analysis and Environmental Review U.S. Route 1.* Bureau of Hwys., Location and Surv. Div., Augusta, ME, 83 pp.

The purpose of this study was to evaluate three alternative corridors for existing US-1 in the coastal towns of Wiscasset and Edgecomb, ME. The study area comprised about 31,360 a. Black-and-white aerial photographs [scale of imagery not given] was used in coordination with soils, topographic, engineering, and geologic information to evaluate engiueering and environmental factors in siting the by pass. Photomaps presented in this report were at the scale of 1:31,680. Some of the photomaps prepared included topography, geology, soils, surface water, forested areas, non-forested areas, upland wetlands, and tidal wetlands. Upland wetlands were classified into three groups, fresh marsh and meadow, shrub swamp, and wooded swamp, and mapped from photointerpretation of BW photography. With a minimum mapping unit of two a. it was determined that there were 230 a. of wetlands in the study area. All three corridors would cross tidal wetlands, which are defined by plant species, but it is not stated whether these areas were delineated by photointerpretation or field analysis. Sixteen large scale oblique and near vertical aerial photos were taken of select areas to depict further the nature of the affected terrain; thirteen of these were of marine and tidal wetland environments. It was concluded that one alternative corridor had greater impact upon inland wetlands than the other two, both of which had equal impact. The first corridor would also require filling two-thirds of a cove which would involve displacing about 1.25 a. of highly productive marsh and filling some clam flats. Another corridor was found to have the most adverse impact upon tidal wetlands, and would result in the filling in some seven to eight acres of marsh. Area estimates of wetland loss were not given for the third corridor.

highway
environmental impact assessment
black-and-white photography
inland wetland
coastal wetland
topography
geology
soils
wildlife
Maine

A-24 Miles, R. H., H. T. Rib, and M. G. Tanguay. 1970. *Remote Sensing and Development of Annotated Aerial Photographs as Master Soil Plans for Proposed Highways.* Purdue Univ., Lafayette, IN. Joint Hwy. Res. Proj. 15, Bur. Publ. Rds. 63 pp.

Various remote sensing techniques for developing annotated aerial photographs as master soils plans for highway planning, design, and construction were investigated. Remote sensing imagery from 1965-1967 analyzed by scientists at Purdue University included BW, black-and-white IR, color and CIR aerial photographs as well as multispectral, infrared, and side-looking airborne radar imagery. Scales of some of the products ranged from 1:4,000 to 1:100,000. Automated data processing and classification were applied to the multispectral data while the other imagery was interpreted conventionally. It was found

A-24 (cont'd)

that in areas with relief of 300 ft. or less, conventional color aerial photomosaics provided an excellent base for engineering soils annotations. The advantage of conventional color over the other types is that it presents the natural color of the soil rather than in shades of gray as in BW or false-color renditions such as in CIR. However, CIR aerial photographs proved most useful in providing information on soil drainage conditions in wet or moist zones. Annotated BW aerial photomosaics did not contain as much information as color for describing the environment. Descriptions of different soils as they appear on some of the imagery types are given. Characteristics and costs of the aerial photographic films studies are also presented.

aerial photography
color photography
black-and-white photography
color infrared photography
infrared imagery
engineering soils
side-looking airborne radar
highway planning
highway design
soils
soils mapping
Indiana

A-25 Mintzer, O. W. and D. Spragg. 1978. *Mini-format Remote Sensing for Civil Engineering*. Transportation Engineering Journal, 104(TE6): 847-858.

In certain instances, mini-format system remote sensing not only can provide information rivalling that derived from more conventional aerial surveys, but also may be more cost effective. The mini-format remote sensing system described is used to gather both color and CIR photographs for site condition identification and interpretation using two hand-held 35 mm. cameras (50 mm. lenses) mounted with a mechanism to trip the camera shutters simultaneously. Photographs are taken from an open door or window of a single engine aircraft at an altitude of 500-1,000 ft. Interpretation may be accomplished by projecting the color and CIR slides, side by side, on two screens or using an 8x magnifier and viewing the slides on a light table; thus observations and analyses are made of vegetation vigor, disease or stress, drainage problems, slope, stability, landslide susceptible terrain, reclaimed land progress, locations of abandoned mines and field tile, pavement deterioration, water quality, and wetland and natural resources classifications. The cost of flight time for regular 23 cm. and 35 mm. aerial photography is nearly the same, about $30/hour (1977). However, savings in film, processing, and printing can be considerable. Calculations demonstrated that 35 mm. frames of both color and CIR film cost less than $0.75 each on the average, including flight costs. The same coverage in 23 cm. format was about $6.08, excluding flight costs. The cost of the miniformat photographs is about 12% of that of larger aerial photographs.

aerial photography
color photography
color infrared photography
small format photography
civil engineering
photointerpretation
cost effectiveness
economics

A-26 Mittlebach, F. G. and M. I. Schneider. 1970. *Remote Sensing: With Special Reference to Urban and Regional Transportation Management.* School of Architecture and Regional Planning, Univ. of Calif., Los Angeles, CA. Rept. T3. 28 pp.

Remote sensing in transportation planning and management is discussed, preceded by an overview of remote sensing and some of its general applications. The authors state that "remote sensors are apparently capable of collecting data with greater ease, more reliability and rapidly, and with less cost and manpower requirements than can conventional methods. In addition, remote sensing appears to have many practical and potential applications in transportation planning." Several examples of research applications of remote sensing to transportation planning are presented. In providing data inputs for transportation related planning activities, four major categories are identified: (1) inventory of existing transportation facilities; (2) inventory of mass transit facilities; (3) inventory of travel behavior; and (4) inventory of land use and land use capabilities In evaluating and analyzing existing transportation networks, remote sensing imagery can be used to identify, locate, and measure street widths and capacities, rights-of-way, and roadway types and their surface conditions. Further, regular, periodic remote sensing imagery can be used to monitor traffic densities and behavior-patterns which are necessary for both highway and mass transit planning and management. A key conclusion authors was that in order to justify the use of remote sensing in any phase of transportation planning the cost-effectiveness of the sensor system (acquisition, interpretation, and results) must be compared with that of alternative approaches (*e.g.*, conventional ground based studies).

transportation planning
remote sensing
cost effectiveness
mass transit

A-27 Modlin, D. G. and D. Rietschier. 1973. *A Study of the Potential of Remote Sensors in Urban Transportation Planning.* Dept. of Civil Engrg., Louisiana State Univ., Baton Rouge, LA. 158 pp.

The data requirements for comprehensive transportation studies according to the U.S. Department of Transportation (Nov. 1969) include: (1) economic factors; (2) population; (3) land use; (4) transportation facilities; (5) travel patterns; (6) terminal and transfer facilities; (7) traffic control; (8) land controls; (9) financial resources; and (10) social value factors. In interpreting aerial photographs, there are three levels of correlation between image analysis and data extraction. The first order is one in which the interpreter can make objective determinations, such as widths of rights-of-way or intersection characteristics. The second order involves gross determinations which cannot be accurately measured such as the areas of land use types. The third order of correlation includes subjective observations such as housing quality assessment. Further, data can be divided into two categories: Type I, which is acquired from aerial imagery at a single time; and Type II, which is sequential imagery that allows evaluation of changing spatial and temporal relationships. The authors concluded that remote sensing, and,

A-27 (cont'd)

in particular aerial photography, seems to be the most appropriate (cost effective, accurate, efficient) method of data collection for transportation planning. An introductory overview of the various remote sensor types and the electromagnetic spectrum is presented, as are rather detailed descriptions of mathematical models for trip generation, trip distribution, traffic assignment, and travel forecasting.

transportation planning
remote sensors
aerial photography
electromagnetic spectrum
traffic
transportation

A-28 Mollard, J. D. 1968. *The Role of Photographic Interpretation in Northern Route and Site Surveys.* in *Proc. 61st Annual Meeting Canadian Institute of Surveying.* Edmonton, Alberta, Canada. 19 pp.

The procedures for using aerial photographs in route and site surveys in northern Canada are discussed. Factors evaluated in locating corridors for roads, pipelines, and powerlines are described for various regions of Canada. These factors were designed primarily to evalaute engineering suitability. A twelve point program for siting a northern corridor from aerial photographs is suggested. Generally, it involves the (1) collection and study of existing resource information from maps and reports; (2) identification of all potential routes; (3) transfer of these possibilities to small scale aerial photographs (type not given); (4) stereoscopic interpretation of these photographs to determine most desirable route; (5) preparation of alternative cost information; (6) field checking in critical areas; (7) revision of alternate corridors and transfer to large scale aerial photography; and (8) selection of the final route. Photogrammetric practices would then be implemented to carry out the engineering design. The author notes that photointerpretation and field survey methods of obtaining terrain information should be interdependent.

road
powerline
pipeline
aerial photography
highway planning
aerial sensing
corridor selection
large scale
small scale
Canada

A-29 Noble, D. F. 1972. *Utilization of Remote Sensing in the Preliminary Aerial Survey-Highway Planning Stage in Virginia.* in *Remote Sensing for Highway Engineering.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 421:41-49.

The purpose of the study was to determine whether infrared (IR) technology could be used to delineate soils with high moisture content. Located in Augusta County, Virginia, the study area is mapped geologically, topographically, and pedologically and is heavily farmed and 80% non forested. Data

A-29 (cont'd)

were collected with a multisensor array of cameras and multispectral sensors. The spectrum was sensed from the violet through the far infrared. Ground truth in the form of radiometer and thermometer readings and color photographs was taken at the time of the flights. The 8.0 to 13.5 μm band was sensed both at day and night and was interpreted for information on moisture content. Correlation of this information with that obtained from the various types of photographs was attempted. It was concluded that nighttime thermal IR imagery in the 8.0 to 13.5 μm band was the best for the detection of surface water, and that a combination of daytime and nighttime thermal imagery can be used to detect and delineate soil areas with high soil moisture content. Coupled with aerial photographs, thermal IR imagery may provide clues to the location of subsurface cavities.

highway
remote sensing
infrared imagery
sinkhole
thermal infrared imagery
soil moisture
soils
Virginia

A-30 Ontario Ministry of Transportation and Communication. 1977. *Surveillance of the Environmental Effects of a Highway Facility by Remote Sensing: A State of the Art.* Res. and Dev. Div. Rept. RR209. 74 pp.

This report documents the state of the art remote sensing techniques as they may be applied to the detection and monitoring of changes in the environment caused by the construction and use of a highway. The report was compiled by comprehensively reviewing the most recent and relevant literature and by conducting interviews with users and researchers throughout the United States and Canada. The approaches to environmental impact assessment are reviewed as are the possible environmental effects of a highway. A discussion of remote sensing systems and the detectability of environmental phenomena by remote sensing techniques is given. The effects are categorized by the major classes of hydrology, erosion, water chemistry, vegetation, wildlife, and miscellany. The report also contains a suggested program to inventory resources, monitor construction activities, and project the long term effects of a highway. Further, a comprehensive review of the literature and an extensive bibliography are presented.

highway
remote sensing
sensor capabilities
environmental impact assessment
highway planning
highway impact
color infrared photography
hydrology
electromagnetic spectrum
camera
scanner
aerial pnotography
black-and-white photography
multiband camera
vegetation mapping
Canada
United States

A-31 Parker, D. and V. Prentice. 1969. *Progress in Remote Sensing and Its Application to Highway Engineering and Research.* in *Remote Sensing and Its Application to Highway Engineering.* National Res. Coun., Hwy. Res. Board Spec. Rept. No. 102:38-48.

A general discussion of the characteristics and uses of imaging and non-imaging, passive and active remote sensors is presented. This paper is primarily a review of state of the art remote sensing literature with little direct reference to highway engineering. In a section addressing the economics of airborne sensors, the authors point out that savings as high as 75% were possible for cases where aerial photographic surveys were used for developing plans for highway construction. Most of the savings reported by 10 state highway departments involved the photogrammetric rather than the interpretive attributes of aerial photographs. One highway department noted that it was becoming increasingly difficult to find people to conduct ground surveys and that the cost of these studies was also increasing. The authors concluded that those costs might result in more widespread use of remote sensing in highway engineering and research.

aerial photography
aircraft sensing
remote sensing
cost effectiveness
highway engineering
remote sensing history

A-32 Remeijn, J. M. 1978. *Forest Road Planning from Aerial Photographs.* ITC Journal 3:429-444.

Aerial photographs of a region to be opened up by roads contain much information about landforms, soil, land use and vegetation types. Through interpretation of medium scale (about 1:30,000) aerial photographs it is possible to indicate the most suitable locations for new roads. The actual route layout is usually planned using large scale (1:10,000 - 1:15,000) topographic maps or orthophoto maps with contours. The expensive and time-consuming technique of contour plotting can be avoided, however, by determining the terrain slopes and road gradients directly on the aerial photograph stereoscopic model through parallax measurements and radial triangulation. The mathematical principles and procedures for assessing road gradient and determining the profile of the traverse are presented.

aerial photography
road
corridor selection
earthwork
large scale
medium scale
erosion
forestry
orthophotography
photogrammetry
planning
topographic mapping

A-33 Rib, H. T. 1966. *Utilization of Photo Interpretation in the Highway Field.* in *Photogrammetry and Aerial Surveys.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 109:18-26.

The extent to which photointerpretation is being used in the highway field was determined by surveying the highway departments of the 50 states, the District of Columbia, Puerto Rico, and the Bureau of Public Roads. Prior to enactment of the Federal Aid Highway Act of 1956 only a limited number of highway organizations were using photointerpretation extensively. In 1955-56 it was determined that 33 highway organizations used photointerpretation but only 10 did so extensively. In this study it was found that 50 of the 53 organizations use photointerpretation, with 22 using it extensively. It was concluded that the greatest value of this procedure is in the early stages of highway location (highway planning, reconnaissance survey of areas, and preliminary survey of alternate routes). The application of photointerpretation to traffic surveys, construction surveys, condition and inventory surveys, and maintenance surveys is very limited. The need for more trained photointerpreters is stressed. Research underway in several states and the Bureau of Public Roads is discussed.

photointerpretation
highway planning
United States
Puerto Rico

A-34. Rib, H. T. 1968. *Remote Sensing Applications to Highway Engineering.* Public Roads, 35(2):725-733.

The state of the art of remote sensing in highway engineering is discussed. The six major stages of highway engineering include: (1) highway planning; (2) condition and inventory surveys; (3) traffic surveys; (4) highway location surveys; (5) construction surveys; and (6) maintenance surveys. Actual and possible applications of remote sensors such as BW, color, CIR, and multispectral aerial photography, and multispectral scanner and radar imagery are presented. It was concluded that while some remote sensing systems perform better than others in detecting certain features, maximum information might be acquired from aerial missions using two or more different sensor packages. In order to promote research into the use of remote sensing in highway engineering, the U.S. Bureau of Public Roads developed a research program in this area. A synopsis of some of the activities under this program is presented.

highway engineering
remote sensing
aerial photography
color photography
color ingrared photography
highway location
black-and-white photography
multispectral scanner imagery
radar imagery
highway planning
surveys

A-35 Rib, H. T. and R. D. Miles. 1969. *Multisensor Analysis for Soils Mapping.* in *Remote Sensing and Its Application to Highway Engineering.* National Res. Coun., Hwy. Res. Board Spec. Rept. No. 102:22-37.

The potential of available remote sensing systems for evaluation of soils and soil conditions was studied and an optimum combination of sensors for analyzing soils was sought. To investigate the various sensors, nine flight coverages were obtained over three controlled test sites during a 13 month period. Coverage was obtained with various aerial films (color positive, color negative, BW panchromatic, and black-and-white IR), a multiband camera (9 lens), radar sensors (K-band), infrared sensors (far infrared), and a multichannel sensor (ultraviolet through far infrared). Not all combinations were obtained in any one flight program; however, several combinations were obtained during each flight. The major conclusion was that the optimum system for delineating and mapping soils was a multichannel sensor flown simultaneously with an aerial mapping camera taking natural color photography. Of the aerial film types investigated, natural color was the most useful single film type. (Author)

highways
highway engineering
remote sensing
color photography
color infrared photography
black-and-white photography
photographic film
remote sensor system evaluation
engineering soils
thermal infrared imagery
scale
spectral signature
Indiana

A-36 Rib, H. T. 1973. *Remote Sensing Programs in the Highway Field.* in *Proc. Symp. on Management and Utilization Remote Sensing Data,* 117-129. Sioux Falls, SD.

The Federal Highway Administration (FHA) initiated a cooperative federal-contract-state research program in 1967 to investigate the application of various remote sensing systems in identifying and evaluating natural materials. Indiana, Pennsylvania, Kansas, Virginia, and California cooperated in the study. Preliminary efforts were also initiated in Maine, Massachusetts, New Hampshire, and New York, but these states did not continue their participation because in-state test sites were never chosen. In all the test sites, BW, color, and CIR aerial photographs were taken. MSS data were collected in each of the five states as well. Other sensor types used by one or more of the states included multiband aerial photography, infrared imagery, and microwave radiometer data. The Indiana study focused on determining the optimum sensor combinations for performing engineering soil mapping. This work was performed Jan. 1967 to June 1969 using a 70 mile highway project as a test site. It was concluded that 1) natural color photography was the best single sensor for engineering soil mapping, 2) MSS imagery was a supplement to color aerial photography, and 3) computer analyses of MSS data could prove to be a powerful tool in automatic terrain analysis. In Pennsylvania, both

A-36 (cont'd)

analog and digital computer processing of the MSS data for a 24 mile section of the 48 mile flight line were conducted. In identifying agricultural soil types via ADP, it was shown that "MSS imagery collected from aircraft shows promise for reducing preparation time and increasing the accuracy of soil survey maps". In Kansas, items evaluated from the remote sensing information included landform, soils, depth to bedrock, and depth to groundwater table. It was found that normal color aerial photographs at 1:10,000 were the best single source of soil information. Low altitude color (1:2,000) had a scale too large for effective soil mapping. The combined use of color aerial photos and high altitude nighttime thermal IR scanner imagery (8 to 14 μm) provided the best evidence in detecting, evaluating, and mapping engineering soils. Further, in Virginia, it was shown that nighttime thermal IR imagery (8 to 13.5 μm) was the best band for detecting water and its interface with land. Also, the combined information from photographs and night- and daytime thermal IR imagery could be used as an indicator of subsnrface cavities. The most recent of the studies, in California, had reported no significant findings at the time of this publication.

remote sensing
aerial photography
color photography
black-and-white photography
color infrared photography
multispectral scanner
highway
thermal infrared
infrared imagery
radiometer
automated data processing
automatic classification
soil classification
soil moisture
California
Indiana
Kansas
Pennsylvania
Virginia

A-37 Rib, H. T. 1977. *The Role of Remote Sensing in the Building of the Interstate Highway System.* in *Proc. 11th Symp. on Remote Sensing of Environment*, ERIM, Ann Arbor, MI. 1:379-383.

It is reported that the use of remote sensing by highway organizations has grown significantly in the past 20 years: in 1956, 33 of 53 bighway organizations reported using remote sensing, 10 extensively; by 1974, all were using remote sensing, 23 extensively. Growth in the use of remote sensing in the highway field can be attributed to: (1) the development of new film types and sensor technology; (2) acceleration of the interstate highway program; and (3) broader applications including more advanced preliminary survey techniques, environmeutal impact assessment, and computer-assisted corridor location. In the early 1960's, aerial photography was most widely used in route location, soils investigations, drainage studies, and location of construction materials. Further, during this period, strides were made in the use of remote sensor systems for planning studies, traffic surveys, condition and inventory surveys, and construction and maintenance surveys. By the late 1960's, more advanced remote sensor systems were being used in highway engineering. These included multiband photography, multispectral and

A-37 (cont'd)

infrared scanners, and microwave instruments. A significant conclusion reached in this decade was that conventional color aerial photography was the best single sensor system for highway engineering applications. With the enactment of the National Environmental Policy Act of 1969, remote sensing became an important tool in the preparation of impact statements. Dozens of such applications have been documented and included wetland and wildlife habitat description, noise impact and soil erosion potential, and detailed terrain and cultural feature analysis. In a 1974 survey of highway organizations it was found that remote sensing has shifted from the more conventional applications to ones such as traffic surveys, right-of-way appraisal, and preparation of environmental impact statements. With nearly 90% of the Interstate Highway System already completed, and almost 9% under construction or sited, the future of remote sensing in highway engineering will be primarily in condition and maintenance surveys or in photologging, a terrestrial sequential photographic process.

highway engineering
remote sensing
aerial photography

highway
interstate highway
remote sensing history

A-38 Simonett, D. S., F. M. Henderson, and D. D. Egbert. 1970. *On the Use of Space Photography for Identifying Transportation Routes: A Summary of Problems.* Dept. of Geography, Kansas State Univ., Lawrence, KS. 25 pp.

The potential of color photographs taken from space in detecting and to a lesser degree identifying existing road networks in the Dallas-Fort Worth area is discussed. Color separation plates and a 6X enlargement of an Apollo V1 photograph (April 13, 1968) were produced, and all visible roads delineated on an overlay for study. In addition, a four county sample area was selected for more detailed analysis in comparing the actual transportation network with those roads detected and other linear elements mistaken for roads. Attempts were made to discover to what degree road width, surface type, topography, land use, and linearity affect road detectability from color photographs from space. Major roads and roads under construction were the most visible while narrower roads and those in urban areas were not clearly defined in the photographs. Road width and type were found to be the major determinants in visibility, varying from 100% for divided highways to 15% for bladed earth roads. In the sample area, four percent of the linear elements delineated as roads were misclassified; this confusion occurred with other linear features such as streams, pipelines, telephone lines, field edges, railroads, lakeshores, trails, and unknown elements. It was concluded that space photographs of this resolution (300 ft.) proved to be difficult to use for accurate road delineation. Major highways in rural areas with substantial road width were completely detectable. Lower class roads were confused with other linear elements or were simply not visible. It is recommended that in order to identify and delineate all but the smallest of roads reliably, a resolution cell size of about 50 ft. should be used.

A-38 (cont'd)

remote sensing
space photography
color photography
small scale
highway detection
transportation
road
photointerpretation
Texas

A-39 Smith, W. B. R. 1977. *Colour Aerial Photography In Highway Engineering.* Remote Sensing Association of Australia Seminar, Sydney, Australia. 6 pp.

The Department of Main Roads (DMR), New South Wales, Australia, has been making increased use of color aerial photography in its highway applications. Reasons for this include the greater information of color over BW, the development of automatic color processing devices, and the diminishing cost differential between color and BW. In assessing the volume of earthwork involved in road construction, the photogrammetrist may have to contend with shadows on the aerial photos that might influence his calculations. Color prints from color negatives provide the best resolution in shadow areas and BW prints made from color negatives are better than prints from panchromatic BW aerial photo negatives. Further, pbotogrammetrists at DMR have produced more reliable contour maps from color aerial photography than from BW. In general, DMR used 1:20,000 to 1:30,000 scale photos for highway feasibility studies and preliminary location. 1:2,000 scale is used where great detail is imperative and the end product may be as large as 1:500. In rural areas, 1:5,000 scale aerial photographs are used for the final design of highway facilities or for earthwork volume assessment. For updating aerial coverage of highways, 1:8,000 scale is often used at 5 to 10 year intervals. It is the DMR philosophy that "unless the photography is to be used only for a particular purpose where color may be a disadvantage, for instance in orthophoto production, the additional dimension of 'color' has such potential value to justify the provision for production of color prints, diapositives, and enlargements."

highways
aerial photography
color photography
color film
small scale
black-and-white photography
earthwork
large scale
medium scale
New South Wales
Australia

A-40 Smith, W. B. R., P. G. Sandwith, and C. A. Woodham. 1977. *Further Progress in Photogrammetric Research and Development for Highway Purposes in New South Wales.* in *Proc. 8th Conf. Australian Road Research Board.* 9 pp.

The status of various remote sensing activities of the Department of Main Roads (DMR), New South Wales, Australia, is discussed. Aside from the increasing use of color aerial photography, new developments include: route location via computer program; use of digital photogrammetric data; cadastral surveys via photogrammetry; and the exploration of orthophoto techniques. A computer program package named OPTLOX (optimal location) uses least cost criteria, in a series of repetitive operations, in selecting the most cost effective highway route. As a result of applying this program to a specific situation, the concept of producing cost contour maps of potential routes was developod. A sophisticated interactive computer system, using Digital Ground Model data for highway location and design, was developed. This system has been employed in the past for strip triangulation and will be used in the future for earthwork volume estimates and possible cadastral survery. Traditionally, highway planning projects have been illustrated with maps, aerial photos, or models. Maps may be quite accurate but lack the detail of the aerial photograph, which, however, has inherent geometric distortion; scale models can be constructed but are usually both too large and expensive. DMR is therefore exploring the possible use of orthophotographs in highway location and design.

highways
remote sensing
aerial photography
color photography
photogrammetry
digital data
orthophotography
computer program
roads
earthwork
New South Wales
Australia

A-41 Stallard, A. H. and R. Biege, Jr. 1966. *Evaluation of Color Aerial Photography in Some Aspects of Highway Engineering.* in *Photogrammetry and Aerial Surveys.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 109:27-38.

The paper reports on the evaluation of color aerial photography in engineering applications, specifically road condition surveys and materials inventories for highway construction. The test areas for condition surveys were a strip of highway in northeast Kansas and two strips near Topeka, KS. Kodak reversal Ektachrome and Agfacolor negative aerial photography was conducted over these areas at 1:1,200 scale. Color transparencies were obtained from the Ektachrome and color prints and BW prints (matte and glossy) were obtained from the Agfacolor. It was found that color prints from Agfacolor were best adapted for identifying and evaluating initial and advanced stage pavement stains. Black-and-white glossy prints with better resolution than the matte prints sufficed for pavement sections with only advanced stains. Test areas in three Kansas counties (Ellis, Mitchell, and Brown) were selected for

A-41 (cont'd)

materials inventory studies. Various color and BW photographs at scales of 1:12,000 or 1:24,000 were evaluated for relative capabilities in detecting, mapping, and describing construction material source beds. In general, "color photography did not significantly add to the materials inventory investigation except in isolated cases. Areas where the use of color photography is most beneficial were characterized by inconsistent and erratic geology as in southeast Kansas or by thick overburden consisting of heterogeneous material as in glacial terrain in northeast Kansas."

highways
aerial photography
color photography
pavement
materials survey
geology
reconnaissance surveys
Kansas

A-42 Stallard, A. H. 1972. *Use of Remote Sensors in Highway Engineering in Kansas.* in *Remote Sensing for Highway Engineering.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 421:50-57.

Many papers have been written concerning the domestic use of various types of remote sensors; however, few describe specific applications of remote sensors to highway engineering problems. The purpose of this paper is to describe the remote sensing program conducted by the State Highway Commission of Kansas in cooperation with the Federal Highway Administration and to present the results of visual interpretation of the data collected. Descriptions are given of methods of collection and types of data, including frequency and type of ground observation data. Data collected on magnetic tape, to be reduced and analyzed by computer, are described; however, no findings are presented. Results of visual interpretation of data indicate that the combined use of color aerial photography and infrared imagery (8 to 13 μm, nighttime, high altitude) renders the most distinctive evidence for detection, evaluation, and mapping of engineering soil groups. (Author)

highways
remote sensing
highway engineering
color photography
color infrared photography
thermal infrared imagery
infrared imagery
engineering soils
Kansas

A-43 Stallard, A. H., and L. D. Meyers. 1972. *Soil Identification by Remote Sensing Techniques in Kansas: Part I.* Kansas State Hwy. Commn., Topeka, KS. 109 pp.

The Kansas State Highway Commission (SHC) engaged the services of Remote Sensing, Inc. of Houston, TX to assist in the evaluation of aerial photography and infrared imagery in detecting and mapping engineering soils groups. Remote Sensing, Inc. used the following instruments in the collection of remote sensing data over a 27 by 1 mi. test strip in Jefferson County, KS: (1) Wild RC-8 aerial camera; (2) dual channel (3-5.5 μm and 8-14 μm) thermal infrared scanner; (3) 13.3 GH scatterometer; (4) 13.7 GH microwave radiometer; and (5) a four cluster 70 mm Hasselblad camera. Several other firms and agencies participated in the data collection, reduction, and analysis, including field studies of spectral reflectance traits to prepare spectral albedo curves necessary to select proper film filter combinations. Early in 1969, BW aerial photography at 1:18,000 was collected to assist in further remote sensing missions. Later in that year, 1:1,000 and 1:2,000 scale color and CIR aerial photographic missions were conducted to assist in the initial vegetation and landform analyses. In March 1970, the major portion of the remote sensing data was collected including daytime and nighttime infrared scanner imagery acquired at altitudes of 1,000 and 5,000 ft. These missions were preceded by ground truth studies at 100 stations. Data included soil color, grain size, plasticity indices, parent material, and ground reflectance. Engineering soils maps were prepared by visual interpretation of the various imagery types and were evaluated by the use of Soil Conservation Service soils maps and the ground truth information. It was found that the combined use of color aerial photography and infrared imagery (high altitude, nighttime 8 to 14 μm) provided the most useful information for the detection, evaluation, and mapping of engineering soil groups. Color photography proved to be the best single source of information and was particularly useful in areas characterized by glacial drift and loess. Color infrared photography was not fully evaluated because of the poor quality of the photographs which resulted from improper filtering. Daytime thermal infrared imagery provided little information other than the locations of springs and wet zones. Further, low altitude remote sensing data were useful in determining detail in small target areas but was ineffective in determining the broad relationships between soils groups; analysis was more successful with the higher altitude imagery because of its wider instantaneous field of view. The techniques tested were so promising that the Kansas SHC is routinely using color and CIR aerial photographs in corridor analyses for highway location studies.

remote sensing
aerial photography
black-and-white photography
color photography
color infrared photography
ground truth
thermal infrared imagery
engineering soils
low-altitude
highway
Kansas

A-44 Stoeckler, E. G. 1968. *Use of Color Aerial Photography for Pavement Evaluation Studies in Maine.* Maine State Hwy. Comm., Materials and Res. Div., Tech. Paper 68-6R. 62 pp.

Many interlocking factors contribute to the amount of information on pavement distress features that can be gleaned from aerial photographs. Twenty-two different airphoto coverages of a short section of the Interstate near Bangor, Maine were taken over a one year period using three types of color film and two types of black and white film at photoscales varying from 1" = 100' to 1" = 1,000. Other variables to content with included the (1) appearance of pavement, (2) background of the observer, (3) sky conditions, (4) resolution characteristics of the type of paper print or transparency, and (5) the type of viewing equipment. A technique for comparing the relative amount of detail discernable on the different photo coverages was developed. Based on the comparisons of several hundred crack pattern records made by three different observers, it was concluded that the maximum amount of information on pavement distress features can be extracted from Ektachrome Infrared Aero transparencies. For extensive general pavement performance studies requiriug less detailed information, panchromatic glossy prints are adequate. The minimum photo scale requirement is contingent on (1) pavement conditions, principally whether the cracks are sealed or unsealed and (2) the type of information required for both intensive and extensive pavement evaluation studies. Generally, for reconnaissance surveys a photo scale of 1" = 500' is adequate and for more detailed studies photography having a scale of 1" = 200' or larger is suggested. For both types of studies, stereo coverage is highly recommended. (Author)

highway
aerial photography
black-and-white photography
color photography
color infrared photography
scale
pavement
Maine

A-45 Sullivan, M. C. 1975. *The Use of Remote Sensing in Transmission Line Selection.* in *Proc. 41st Annual Meeting American Society of Photogrammetry.* ASP, Falls Church, VA, 308-321.

Staff members from Gommonwealth Associates Inc. of Jackson MI used various types of remote sensing imagery and related information to select a power transmission corridor from eastern Wyoming to eastern South Dakota through northern Nebraska. Iuterpretation of ERTS (now LANDSAT) BW film positives (band not given) was conducted to delineate land use and population density. Land use classification consisted of eight categories: urban areas, forest, water, intensive agriculture, extensive agriculture, pivot irrigated agriculture, grazing, and barren land. These generalized maps were photographically adjusted to 1:1,000,000 on sepia film. These in turn were overlaid on existing maps of physiography, bedrock geology, hydrology, soils, vegetation, and designated areas (constraint areas). Using these 1:1,000,000 maps, a multidisciplinary team conducted the general study to select optimal corridors

A-45 (cont'd)

between the two termini within the 20 mile wide study area. Interactive analyses continued until several five mile wide corridors were established within this 20 mile wide strip. Detailed analysis invólved the use of 1:31,500 CIR aerial photographs which were used for detailed studies such as vegetation cover typing and vigor determination. Although the CIR photographs both were acquired in the wrong season for vegetation studies (October) and were not of the highest quality, the team found them adequate to select the transmission route. Two techniques were used: 1) location based upon land use delineations made using a modified USGS Land Use Classification System and 2) location based upon avoiding particular natural or cultural features. The latter method proved to be more useful in the western portion of the study area due to the diversity of land use. The team again narrowed the corridor and selected the optimal route. Field work was carried out to verify the determination; slight modifications in the route selected resulted from the findings of an archeologist, historic preservationist, and a paleontologist. The author concluded that while the techniques used were not new, the application was, the key aspect being that maximum use was made of remote sensing imagery during the route selection process.

remote sensing
ERTS imagery
transmission lines
route selection
microanalysis
aerial photography
color infrared photography
corridor selection
land use mapping
macroanalysis
Nebraska
South Dakota
Wyoming

A-46 Tam, L. T. H. 1971. *The Effect of Photo Interpretation on Highway Programs*. Master of Engrg. Thesis, Dept. of Civil Engrg., Univ. of Toronto, Ontario, Canada. 380 pp.

Route location, the process of siting a highway corridor between two established termini, consists of progressively more detailed, specific, and costly stages. The role of photointerpretation in highway route location is discussed as are the basic characteristics of photographic sensor systems. Ten projects in Ontario between 1965 and 1971 in which aerial photography was used to assist in solving highway related problems are documented. Each project represents one or more of the four stages of a highway program: planning, design, construction, and maintenance. The author makes liberal use of figures, line and symhol maps, and BW aerial photographs (including dual stereo plates and triplet stereo plates) in demonstrating the role of photoanalysis in highway programs. Also provided are cost data for applications aerial photography including photo acquisition, interpretation, and map preparation. It was noted that the cost of activities related to aerial photography is small compared to the overall cost of the highway program. The author also made the following observations on the cost effectiveness of photointerpretation procedures:

A-46 (cont'd)

1) the time required for a photointerpretation project is proportional to the size of the study area; 2) the time required is also a function of the characteristics of the photoanalyst; 3) labor in photointerpretation constitutes a major portion of aerial photo applications; 4) drafting and other auxillary tasks account for only a small percentage of the time and money spent on such a project; and 5) the economic feasibility of photointerpretation projects depends on the multiple use potential of the aerial photographs.

aerial photography
photointerpretation
black-and-white photography
highway
road
color infrared photography
cost effectiveness
highway corridor selection
Ontario
Canada

A-47 Tanguay, M. G. and R. D. Miles. 1970. *Multispectral Data Interpretation for Engineering Soils Mapping.* in *Application of Aerial Surveys and Photogrammetry.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 319:58-77.

The application of various remote sensing techniques to engineering soils mapping was investigated along a 70 mile section of a proposed highway from Indianapolis to Bedford, IN. The imagery collected for this site in April-May 1967 included: BW, black-and-white IR, color, CIR, and 15 channels of multispectral scanner data. Altitudes over which the aircraft conducted missions varied from 1,600 ft. to 6,700 ft. and resultant imagery scales from 1:6,000 to 1:28,800. A number of engineering soils maps were prepared from the conventional interpretation of the four types of photographs. When comparing the maps produced from BW and color photographs, differences in soil boundary location were found -- color providing more precise and accurate results. Also, a greater number of soil features such as silt mounds and exposed subsoils were distinguishable on color. The main advantage of CIR over BW and color was the accurate location of vegetation and bare soil/rock areas. Further, CIR diapositives, while seemingly more difficult to interpret because of the "false colors", provided more information on surface hydrology than did BW or color. Cost data (1967) are presented for three scales of BW prints and for one scale each of color and CIR diapositives. In general, while the film and processing for BW was less costly than for either of the other two, both the photointerpretation and field checking were more expensive, causing the total unit cost for maps made from BW to be higher than for either CIR or color. As far as the photography is concerned, the authors concluded that 1:12,000 color is the best single source of information for engineering soils mapping. The best combination of two films is CIR and color. Multispectral scanner data were analyzed by visual methods, by densitometry, and by computer assisted processing. It was found that the best method of examining MSS imagery is by automated data processing and classification.

A-47 (cont'd)

aerial photography
color photography
color infrared photography
black-and-white photography
black-and-white infrared photography
scale
computer analysis
multispectral scanner analysis
engineering soils
cost effectiveness
Indiana

A-48 Thompson, F. J. and A. N. Sellman. 1975. *Remote Sensing Impact on Corridor Selection and Placement.* in *Proc. NASA Earth Resources Survey Symp.*, I-C:1729-1745. Houston, TX.

The Environmental Research Institute of Michigan in cooperation with the Michigan Department of State Highways studied LANDSAT false color composites for land cover information to upgrade statewide highway corridor selection and placement. Highway planning in Michigan occurs in three phases: (1) reconnaissance study to determine need for a new highway and the areas it is to serve, (2) examination of each alternative and selection of a final corridor, and (3) detailed engineering study of the placement of the road within the selected corridor. Remote sensing technology can impact all three phases. LANDSAT imagery was evaluated for use in the reconnaissance planning of a hypothetical highway corridor in the Upper Peninsula of Michigan. An eight category recognition tape was prepared using the following classes: urban, open, hardwood forest, water, conifer forest -- Jack pine, marsh, conifer forest -- White pine, and managed hardwood forest. Geometrically corrected LANDSAT data were aggregated yielding a grid size of 140.8 a. for each grid cell and presented in map format. An optimal corridor location was determined using land cover classes of water and urban. The model can be used with different sets of relative weights to generate several alternative corridors. It was concluded that land cover information from LANDSAT data can be very useful in reconnaissance corridor studies.

remote sensing
LANDSAT imagery
false-color composite
highway planning
highway corridor selection
land cover
pattern recognition
reconnaissance studies
Michigan

A-49 Thomas, R. L., C. A. Whitehurst, and J. A. Monte. 1974. *Remote Sensing as an Aid to Route Evaluation for Relocated Louisiana Highway 1.* Div. Engrg. Res., Louisiana State Univ., Baton Rouge, LA. 25 pp.

NASA generated color and CIR transparencies were used to evaluate the route proposed for relocated Louisiana Highway 1 between LaRose and Golden Meadow in southern Louisiana. Limited field studies were conducted. Maps showing five major vegetation types (forest, shrub, pasture, cropland, and marsh) were prepared directly from the CIR aerial photographs. Soil conditions were analyzed using color transparencies. Three distinct old channels of Bayou Lafource were detected. Based on these limited studies it was concluded that color and CIR photographs were useful for mapping vegetation, for land use determinations, and for soil classification when supplemented by conventional soil borings. Such imagery was better for those purposes than BW photographs alone.

remote sensing
color photography
soil mapping
color infrared photography
highway planning
vegetation mapping
Louisiana

A-50 Trimble, R. C. 1974. *Highway Design from Color Photography.* in *Proc. of the 40th Annual Meeting American Society of Photogrammetry.* Falls Church, VA. pp. 573-580.

Aerial photographs were collected by the Division of Photogrammetry of the Kentucky Department of Transportation to be used in the preparation of a planimetric map, with 2 foot contours in areas in which drainage structures were planned, for the design of an 8 mile section of Highway KY 80 between Somerset and London. Initially, Kodak Plus X BW film was used at a scale of 1:3,000. However, because of the rugged terrain and the fact that the dense cover of cedar, pines, and mountain laurel obscured the center line targets used as ground control, only about 30% of the photos taken were of any use. Not wanting to resort to extensive ground surveys, the planners decided to fly the mission at a later date. The second time, smoke bombs were used to guide the pilot along the proposed highway center line. This technique worked well, but severe shadows (Feb. 19, 1972) limited the utility of the photographs. Finally, on March 8, 1972, when the sun angle was greater, a successful overflight was made using both Kodak Aerocolor Negative 2445 film and Plus X BW. It was found that the use of the color diapositives would permit photogrammetric analysis of about 90% of the study area. The remaining 10% would be covered by field surveys.

aerial photography
highway engineering
photogrammetry
color photography
black-and-white photography
Kentucky

A-51 Weeden, H. A. and J. W. Harman, Jr. 1970. *Manual of Highway-Problem-Oriented Photo Interpretation Using Panchromatic, Normal Color, and Infrared Color Air Photos.* Penn. Transp. and Traffic Safety Cntr. Rept. TTSC 7020, The Penn. State Univ., University Park, PA. 129 pp.

This comprehensive manual was prepared as a guide for the use of aerial photographs in the solution of "spot" problems in relation to highway design and construction. The various types of aerial photo films, including BW, black-and-white IR, color, and CIR, are described. The factors in planning a photographic mission, such as film choice, control and coordinated ground studies, are presented. A modified Munsell color notation system was developed by the authors to standardize color designations. Also, a table correlating image colors on CIR photos with their real world colors is shown. Part III, Current Analytical Practice, presents the prospective photoanalyst with the requirements necessary to conduct reliable interpretation in several disciplines in such broad categories as meteorology, culture, and geomorphology. Further, the methods and materials for successful photoanalysis are described. Part IV, Operational Problem Analysis for Unconsolidated Materials, describes specific applications of photointerpretation in such areas as roadway foundations, structure foundation, slopes, subgrades, and excavation. Detailed analysis of a certain parameter (*e.g.*, swamps, bogs, marshes, soils, lake bed silts) is supported with descriptions of the feature's traits of land form, drainage, erosion, vegetation, and color, tone, and texture. Film response is described with photographic examples presented in many instances. Finally, an actual sample application of red using photographic and supplemental data is presented for Erie County, Pennsylvania.

aerial photography
highway design
highway
road
highway planning
color infrared photography
field studies
regional analysis
black-and-white photography
color photography
black-and-white infrared photography
photointerpretation
photographic film
Pennsylvania

A-52 Weeden, H. A. and L. H. Lattman. 1971. *Air Photo Analysis of Infrared Color Photography.* Penn. Transp. and Traffic Safety Cntr. Rept. TTSC 7101, The Penn. State Univ., University Park, PA. 74 pp.

Analysis of aerial CIR photographs is contrasted with BW panchromatic and normal color photographs as a means for assessing the physical properties of soils and bedrock for highway design, construction, and maintenance. Two methods of mapping were explored. The first method is problem oriented and is described in a manual entitled "Manual of Highway-Problem-Oriented Photo Interpretation Using Panchromatic, Normal Color, and Infrared Color Air Photos" which supplements the report (see A-51). The second mapping method is called "reconnaissance mapping" and results in map units with a five part symbol: (1) land form, (2) soil texture, (3) surface slope, (4) water slope, (4) water table position, and (5) depth of soil to bedrock. Special symbols

A-52 (cont'd)

are added for coordinating exploratory drilling. The map is interpretive, containing information limited to a route corridor. A statistical approach was used to determine the success with which interpreters could observe and evaluate engineering and resource parameters and rank them in groups amenable to analysis. These parameters were then used to compare the capabilities of the three film types. With respect to drainage pattern delineation, CIR photography provided the most information, followed by normal color, then BW. In separating rock types, CIR and color were equally superior to BW. One disadvantage, however, of using color films was the noticeable fall off in quality away from the principal point of each photograph, hence reliable photo analysis must be done by working with the photo's effective area. Color photography (normal and CIR) costs about 50% more to procure than does BW, but savings in interpretation for mapping purposes proved to be 12% in favor of using color aerial photography. The problem oriented type of mapping was recommended. Reconnaissance mapping is successful in Pennsylvania excepting those areas of complex igneous and metamorphic rocks in the southeast.

aerial photography
photointerpretation
color photography
black-and-white photography
color infrared photography
transportation
statistical analysis
reconnaissance studies
mapping
lithology
Pennsylvania

A-53 Williamson, D. T. and B. Gilbertson. 1973. *Application of ERTS Imagery in Estimating the Environmental Impact of a Freeway Through the Knysna Area of South Africa.* in *Proc. Third ERTS-1 Symp.*, Vol. 2:1569-1573.

In April 1973 it was announced that a large freeway was to be built in the Knysa area, one of coastal South Africa's most valuable recreational resources, rich in natural lakes, lagoons, and estuaries. A study was undertaken to determine if ERTS [now called LANDSAT] MSS imagery could be used to identify natural features that could potentially be impacted by the highway, and to provide a quantitative estimate of predicted damage to the montane forest there. A false color composite of an ERTS scene was produced at the scale of 1:500,000. A Planvariograph was used to trace the planned route on the ERTS imagery. Interpretation of this imagery revealed that: 1) four estuarine features lie within the corridor; 2) two areas of indigenous forest would be crossed; and 3) dense vegetation covering coastal dunes would be traversed. The advantages of using ERTS imagery rather than maps or low altitude aerial photographs in proposed highway impact prediction were: 1) satellite imagery is a more nearly contemporaneous record of existing conditions than maps are; and 2) the volume of imagery is substantially less than with low altitude aerial photographs, thus reducing the interpretation time

A-53 (cont'd)

and making the imagery physically and conceptually easier to handle. It was concluded that ERTS imagery provided a perspective which facilitated the investigation of the type of environmental hazard inherent in the Knysna freeway development.

highway
highway impact
remote sensing
false-color composite

ERTS
LANDSAT
South Africa

Section B

# ENVIRONMENTAL IMPACT OF HIGHWAYS AND CORRIDOR SELECTION METHODS

23 Abstracts

B-1 Baker, W. W. and J. D. Gruendler. 1973. *Case Study of the Milwaukee-Green Bay Interstate Corridor Location.* in *Environmental Considerations in Planning, Design, and Construction.* National Res. Coun., Hwy. Res. Board Spec. Rept. No. 138:51-54.

In 1969, the Wisconsin Division of Highways contracted the Environmental Awareness Center of the University of Wisconsin's Department of Landscape Architecture to develop a computer program to be used in corridor analysis for a proposed highway between Milwaukee and Green Bay. The work was predicated upon a program developed by Steinitz Rodgers Associates in cooperation with Harvard University. The program is based upon a data bank of existing and future resources recorded in 1 km. sq. cells and georeferenced by the Universal Transverse Mercator projection system. Natural and cultural resource information was manually extracted from maps and aerial photographs and transformed into a computer compatible format. Nine corridor determinants were initially selected, but one, Projected Traffic Generation, was discarded because of insufficient data. Variables within these factors were weighted. The overlay of factors for each cell resulted in a corridor suitability measure for that cell and a computer-generated grey scale suitability map was produced. It was shown that in highway corridor analysis a computer-based storage and retrieval system is essential for handling the many data items involved and that the application of the computer also provides the capability of simultaneously considering many variables. The authors recommended that research be conducted into botb highway-resource interactions and efficient means of data collection via remote sensor systems.

highway
corridor selection
computer program
aerial photography
remote sensing
natural resource
cultural resource
Wisconsin

B-2 Center for Geographic Analysis. 1975. *Data Needs and Data Gathering for Areas of Critical Environmental Concern. Part 3: Executive Statement.* Inst. for Env. Studies, Univ. of Wisconsin, Madison, WI. IES Rept. 55. 23 pp.

"Areas of critical environmental concern" have been defined as those areas where natural resource values play a key role in determining the suitability and capability of various land types such as floodplains, wetlands, coastal zones, shorelands, erosion areas, scenic areas, agricultural lands, and other areas of special or scientific interest. "Suitability" means accessibility of areas to users, sensitivity or areas, development pressures, etc. The authors state that there is a need for a structured program for data gathering to meet statewide requirements for the definition and management of areas of critical environmental concern. Some of the key elements to be considered when designing such a program include: (1) blanket data and case by case data gathering using aerial, field, and other surveys; (2) critical area data extraction techniques; and (3) a georeferenced information system with the appropriate

B-2 (cont'd)

scale and resolution. A comprehensive discussion of 27 recommendations for critical area data gathering procedures is presented. Some of these are: (1) gather data to meet implementation needs; (2) involve several levels of government in data gathering; (3) make the most use of existing data before acquiring new information; (4) shift a portion of data gathering burden to the developers; (5) continue the emphasis upon map products and statistical information and computerized data banks where appropriate; and (6) increase university participation in research in order to improve criteria, techniques, and products. Finally, a four phase program for critical area data gathering and management is suggested: (1) adopt enabling legislation; (2) identify and map critical areas; (3) adopt land use control standards, and (4) enforce regulations.

environment
land use
land use planning
land value
scale
resolution
planning
management
data collection
georeferencing
critical area

B-3 Davis, P. B. and C. R. Humphrys. 1977. *Ecological Effects of Highway Construction Upon Michigan Woodlots and Wetlands: Summary of Study Findings--Phase I Report.* Agr. Exp. Sta., Mich. State Univ., East Lansing, MI. Journal Article No. 8208. 63 pp.

To determine the ecological effects of highway construction and use upon Michigan woodlots and wetlands, ten sites located along a 45 mile segment of I-75 between Roscommon and West Branch were studied. These sites were examined in respect to several natural science parameters: soils, hydrology, water quality, forestry, and wildlife. The study provided an evaluation of the environmental impact of highway construction and use on the parameters measured by each research discipline. Several models for determining optimum highway location were also evaluated including the University of Georgia Model, which was modified and tested for use by the Michigan Department of State Highways and Transportation. This summary consists of extracts of a brief and pertinent nature from the individual reports written by the investigating team for each research discipline. Methodologies utilized, site descriptions, environmental impacts, conclusions and recommendations are detailed. (Author)

highway
highway construction
environmental impact
soils
vegetation
wildlife
water quality
hydrology
Michigan

B-4 Giles, R. H., A. B. Jones, and C. W. Smart. 1976. *POWER: A Computer System for Corridor Location.* Dept. of Fisheries and Wildlife Sciences, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA. Res. Div. Bull. 117. 30 pp.

POWER is a computer program designed to assist in siting high voltage power transmission corridors. The program can also be used to aid in highway corridor planning. POWER uses geographically referenced, grid cell information and data to select the best corridor. Its operation is influenced by conditions of the study area, policies of the decision makers, and objectives of the corridor project. The cell size to be used is discussed. Input data are weighted resulting in an index of probable environmental, aesthetic, and economic impact for each cell in the study area. The computer program, written for an IBM 370, generates numerical descriptions of all possible orthogonal paths between pairs of neighboring cells. A path analysis algorithm is used to identify the best corridor, which is the one with the lowest impact. It is stated that nonorthogonal, or diagonal, path analysis would be more suitable in corridor selection. In applications in Virginia, POWER was used to analyze 41 different physical, economic and social factors to evaluate the corridor possibilities for a 70 mile wide 765 kv power transmission line.

corridor selection
transmission corridor
highway corridor
computer mapping
computer program
algorithm
environmental impact
Virginia

B-5 Gwilliam, K. M. 1972. *Economics, Transport Planning and the Environment.* International Journal of Environmental Studies, 3:187-192.

Environmental quality is recognized as a proper objective of transport planning but one which presents extremely difficult technical problems. The matter is an economic one of husbanding resources. The need to identify, measure, forecast, and evaluate environmental aspects for inclusion in a cost-benefit analysis is discussed. While there are logical and practical limitations to this approach, quantification of traffic characteristics and economic evaluations can complement design procedures.

transportation planning
highway planning
cost-benefit analysis
economics

B-6 Hausmanis, I. 1971. *Computer-aided Analysis of Alternative Route Locations within the Guelph-Dundas Test Area.* Masters Thesis, Dept. of Civil Engrg., Univ. of Toronto, Canada. 86 pp.

In response to the increased consideration of factors such as social, economic, environmental, and aesthetic requirements in the transportation planning process, this study was undertaken to (1) evaluate the possible roles of the computer in highway route selection, (2) to evaluate the applicability of readily available information as measures of route location factors, and (3) to develop numerical data banks that could be used in such a highway selection procedure. Two types of highway location factors were identified -- route independent and route dependent. The former group includes factors such as topography, soils, geology, land use, etc., while the latter involves items such as costs, aesthetics, noise, social disruption, etc. Route independent factors can be studied without reference to any preselected alternative, while route dependent factors are directly associated with specific alternatives. A discussion of and comparison between four highway planning techniques is given; these include (1) graphical route selection methods, (2) computer aided graphical methods, (3) probabilistic and statistical methods, and (4) computer aided route selection methods. The advantages of the fourth method over the others mentioned include flexibility and numerical orientation. Computer aided selection methods are discussed using the General Computer Aided Route Selection (GCARS) system, developed at Purdue University, as an example. Seven route independent factors were selected in modeling highway corridor selection for a test area in the Guelph-Dundas region of Ontario. Examples of the maps used in the preparation of these data bases are presented. Two classes of calculations, numerical surface analysis and minimum path analysis, were used to select single and multiple factor corridor alternatives.

highway
highway corridor selection
computer program
computer model
computer analysis
land use
highway location
Ontario
Canada

B-7 Howell, T. 1978. *An Automated Mapping System for Transportation Applications.* Workshop on Computer Graphics, Naval Underwater Systems Center, U.S. Dept. Navy, New London, CT. 13 pp.

The Division of Automation of the Texas State Department of Highways and Public Transportation has developed computer assisted mapping techniques, for use in transportation planning. Through digitizing, software manipulation, and interactive graphics system display, the information derived from aerial photographs or existing maps is placed into a georeferenced data management file available for use in multidisciplinary engineering, management, and environmental applications. Stereoplotter operators initially extract and encode the spatial data which is later edited by a cartographer or other professional.

B-7 (cont'd)

Maps that can be produced by the automated mapping system include planimetric, topographic, land use, and design, among others. Specialized computer routines are available for changing scale, displaying selected variables, or isolating a particular area of interest in the geographic data base. Hard copy graphics output is obtained from either a precision flatbed plotter with an optical exposure head or a faster but less precise drum plotter. Interactive graphics operations are possible with a cathode ray tube display and a data entry keyboard. The automated mapping system permits engineers and managers to access, edit, and update spatial data to be used in transportation planning.

computer mapping
transportation
geographic data base
interactive graphics
Texas

B-8 Krauskopf, T. M. and D. C. Bunde. 1972 *Evaluation of Environmental Impact Through a Computer Modelling Process.* in R. B. Ditton and T. L. Goodale, Eds., *Environmental Impact Analysis: Philosophy and Methods.* Sea Grant Publ. Office, Univ. of Wisconsin, Madison, WI. pp. 107-125.

The Regional Environmental Management Allocation Process (REMAP), developed by researchers at the Environmental Awareness Center of the University of Wisconsin, is discussed. REMAP is a computer-based environmental modeling process consisting of four phases: (1) data bank development, (2) determinant (factor) establishment, (3) alternative representation, and (4) alternative analysis and selection. Data are recorded for variables selected as being important considerations by a multidisciplinary team. These data are cell-encoded using UTM coordinates. Data are grouped into components (*e.g.*, slopes, agricultural glands, etc.) and in turn are organized into determinants (sets of factors) which influence location of the highway under study. Ten such determinants were listed in defining area suitability for highway corridor alternatives for proposed I-57 between Milwaukee and Green Bay, WI. The computer representation of a target area facilitates the combination of weighted determinants to generate corridor alternatives. Path analysis programming can be applied to these mathematical surfaces to find the routes of least cost or least adverse environmental impact. It was found that the routes suggested by the Wisconsin Division of Highways were planned primarily on the criterion of minimizing costs of right-of-way acquisition and construction.

highway
computer program
computer model
environmental impact
highway corridor selection
highway planning
Wisconsin

B-9 Kresge, D. T. and P. O. Roberts. 1971. *Systems Analysis and Simulation models.* Vol. 2 of *Techniques of Transport Planning*, John R. Meyer, Ed., The Brookings Institution, Washington, D.C. 228 pp.

A series of large scale computer macroeconomic transportation simulation models was developed and tested. The transport network of the country is conceived as an interdependent entity in which the impact of new transport projects is evaluated in relationship to the existing network and to other new projects. Attempts are made to measure the impact of new transport linkages on the growth of the national product, the division of the product between its major constituent components, the regional dispersion of economic growth, the industrial composition of growth, etc.. The models provide a systematic procedure for generating estimates by extrapolations or interpolations to fill gaps in the data. Variations of the basic model can be used for a variety of purposes ranging from general macroeconomic policy planning to specific transport planning. The models were used to evaluate alternative strategies for developing the Colombian economy and transportation system.

systems analysis
simulation model
transportation
economics
highway traffic
computer analysis
Colombia

B-10 McHarg, I. 1968. *A Comprehensive Highway Route Selection Method.* in *Roadside Development.* National Res. Coun., Hwy. Res. Board, Hwy. Res. Rec. No. 246:1-15.

Research was directed toward developing a comprehensive highway route selection method for proposed I-95 between the Delaware and Raritan Rivers in southwestern New Jersey. A balance sheet listing most of the components of benefit and cost was prepared to show alignments having the maximum social benefit at the least social cost. Transparent overlays were prepared for each of the following parameters: topography, land values, urbanization, residential quality, historic value, agricultural values, recreational values, wildlife value, water values, and susceptibility to erosion. In addition, each parameter was given three values: dark tone representing the greatest physical and engineering obstruction to highway location, light tone being an intermediate value, and fully transparent being the lowest category. When all parameters are overlaid on the base map, the maximum darkness represents the greatest aggregate, physiographic and social value obstruction. In contrast, light areas represent the least physiographic obstruction and least social value and, hence, offer prospective corridors for consideration. In addition to the 10 selected parameters, maps were prepared showing three levels of scenic values. Finally, the role of a highway as a conscious device to locate new and productive land uses is discussed. It was concluded that while this is not yet a precise method for highway route selection, it enlarges and improves existing methods. Using the criteria described, the route of least social cost and least physiographic obstruction was delineated.

B-10 (cont'd)

highways
highway corridor selection
benefit-cost analysis
social impact
physiographic impact
map overlay
New Jersey

B-11 Miller, A. H., B. J. Niemann, D. C. Bunde, T. M. Krauskopf, and B. E. Frazier. 1975. *The Application of Computer Technology to Highway Location Dynamics: Phase II.* Dept. of Landscape Arch. and the Env. Awareness Cntr., Univ. of Wisconsin, Madison, WI. 195 pp.

The work described was predicated on earlier efforts in computer aided highway corridor location (see B-14). In the more recent study, certain developments were made to improve the existing processes. The study area was decreased from 4,500 to 476 mi.$^2$, and was selected because of interest in the corridor in that area. Also, the data cell size was reduced from 1 to 1/9 km.$^2$, refining the data matrices and placing the highway within a corridor 1000 ft. wide as opposed to 3000 ft. as before. The data for natural and cultural variables were more comprehensive. Formerly, USGS topographic maps were the primary source of information. In the upgraded system, a photomosaic of prints of BW aerial photographs (1:24,000) served as the primary data base. This was supported by BW stereo aerial photo prints (1:19,200), low altitude color and CIR aerial oblique 35 mm. slides, topographic maps, and other data. A complete list of the variables and the sources of those data is given in the Appendices. The procedure of manually inputting data was replaced with an Optical Card Reader (OCR) scanner, which eliminated keypunching. The OCR scanned the raw data sheets, read the characters, and automatically punched the data. This system had the advantage of saving time and money in data input (about 1/2 of manual methods), but had the disadvantage of increased data entry errors due to the misreckoning of poorly printed characters. Additionally, a program, LINE FINDER, was developed which used dynamic programming to evaluate the effective cost of all corridors for any given plan by connecting any two adjacent candidate points and then printing the corridor of lowest effective cost. This technique used the numerical information for each cell. Formerly, corridors were manually selected by connecting the computer generated maps. Further, the manual process considered only the individual cells whereas the computer method analyzed the entire optimal route. Detailed explanations of the concepts and the operation of the programs are given.

highway
highway corridor selection
highway planning
computer analysis
computer mapping
computer program
resource variables
optical scanning
aerial photography
corridor selection
cost effectiveness
computer model
data collection
data analysis
Wisconsin

B-12 Mongan, T. R. and R. S. Nielsen. 1973. *Evaluating the Environmental Impact of Transportation Plans.* Ekistics, 35(211):356-360.

The selection of transportation alternatives based upon forecasts of environmental impacts is discussed. Types of pollution from transportation systems were identified as: air, noise, solid waste, and water. Techniques for both the estimation of the magnitudes of the impacts from pollution sources and the relative ranking of alternatives are suggested. Similar approaches are presented for social disruption factors, such as accidents, disturbance, and relocation resulting from transportation systems. It is emphasized that when assessing the detrimental effects of transportation systems, all environmental consequences must be evaluated.

transportation
environmental impact
air pollution
noise pollution
water pollution
social impact

B-13 Newkirk, R. T. 1979. *Environmental Planning for Utility Corridors.* Ann Arbor Science Publishers, Inc., Ann Arbor, MI. 199 pp.

This text is a detailed study of the theory and practice of computer assisted corridor selection. A review of existing impact assessment procedures is given. The nine major techniques reviewed include "expert committee" assessment, checklists, matrices, benefit-cost analysis, descriptive land unit analysis, input-output analysis, cartographic overlays (both manual and computer assisted), information system transformation, and mathematical surface approximation. A detailed mathematical treatment is given to quantitative methods of route determination. Least cost (least adverse environmental impact) algorithms discussed include the Transshipment Model, linear programming solutions, the Dantzig Algorithm, the Dijkstra Algorithm, and the Lee Path-Connection Algorithm. Additionally, several *ad hoc* route selection methods are described. A computer assisted corridor optimization model consisting of four phases: (1) analysis defiuition and structuring (problem description and impact and factor definition); (2) general impact evaluation; (3) composite impact evaluation; and (4) route development and analysis is given. An elaborate discussion of study area data base development is given and the techniques and rationale to impact factor weighting are documented. The author has developed a new Cascade Algorithm for formulating composite impacts to high impact ratings. Route location is actually a modified Dijkstra Algorithm applied to a "contracted dual graph" of the study area. Such a graph is simply a reduction of the number of cell vertices and edges based upon homogeneity in data composition, thus enabling more efficient path searching. A route straightening algorithm, which essentially smooths the irregularities of the computer generated solution, is also discussed. Finally, a sample application of the entire model is presented. The particular case study involved the siting of a 500 kv power transmission line in Ontario, Canada.

B-13 (cont'd)

corridor selection
utility corridors
computer-assisted selection
computer model
algorithm
mathematical model
environmental impact
spatial data analysis
impact assessment
computer mapping
Cntario
Canada

B-14 Niemann, B. J. and A. H. Miller. 1970. *The Application of Computer Technology to Highway Location Dynamics: Phase I.* Dept. of Landscape Architecture and Env. Awareness Cntr., Univ. of Wisconsin, Madison, WI. 243 pp.

A four phase process for computer processing of data related to highway corridor location was developed. Phase I involved the development of a data bank for 132 variables in the 4,500 $mi.^2$ study area between Green Bay and Milwaukee, WI. These variables included data on natural, cultural, socio-economic, and political resources. The data were derived from USGS topographic maps and 1967 aerial photographs at 1:24,000, along with other information sources and were recorded in 1 km. sq. cells. Approximately 6,200 man hours were required to encode the data for the resulting 9,304 cells. Phase II involved the identification of those factors which influence corridor siting. Ten individuals in highway planning were asked to list the factors which should determine the location of an interstate highway corridor two miles wide. Nine such factors were agreed upon. Phase III involved various combinations and differential weighting of the determinants for evaluating the effects on corridor location. Finally, Phase IV involved the analysis of several alternate corridors, using visual inspection of computer generated maps to choose the suitable corridors. Path analysis was used to select the final highway corridor.

highway
highway corridor selection
highway impact
highway planning
corridor selection
automated data processing
natural resources
cultural resources
computer mapping
computer graphics
computer program
computer analysis
data interpretation
mapping
Wisconsin

B-15 Niemann, B. J. and A. H. Miller. 1973. *EDAP: Environmental Decision Alignment Process*. Landscapes Limited, Madison, WI. 246 pp.

The Environmental Decision Alignment Process (EDAP), a computer assisted analytical procedure for determining social and environmental costs of construction activities, was developed by Landscapes Limited in coordination with the staff of Wisconsin Power & Light and Madison Gas & Electric. Designed to assist in the complicated task of planning future energy transmission corridors, EDAP uses the following seven levels of information for route selection: (1) determinants; (2) components; (3) variables; (4) data; (5) policy or corridor selection; (6) right-of-way selection; and (7) management. The use of low altitude CIR aerial photography is suggested in the right-of-way selection and management phases. EDAP was applied in the siting of four 345 kv transmission systems of approximately 110 miles employing a criterion of minimal environmental damage. The study area of 1,237,375 acres was divided into five subareas of similar physiography. This also aided machine processing of the data. These areas were further subdivided into cells of about 62 acres for which 119 data items were collected. A list of data types and the procedure for their encoding is presented. Computer analysis of the data resulted in graphic line printer grayscale printouts. These "maps", georeferenced using the Universal Transverse Mercator system, were used in the selection of the four transmission corridors.

utilities
transmission corridor
corridor selection
environmental impact
right of way
management
aerial photography
computer analysis
computer mapping
corridor determinant
data collection
planning
Wisconsin

B-16 Odum, E., G. A. Bramlett, A. Ike, J. R. Champlin, J. C. Zieman, and H. H. Shugart. 1975. *Totality Indexes for Evaluating Environmental Impacts of Highway Alternatives*. Inst. of Ecology, Univ. of Georgia, Athens, GA. 11 pp.

In 1971, the Institute of Ecology at the University of Georgia was requested by Georgia DOT to make a summary evaluation of the environmental impact assessment reports submitted by 15 federal, state, and citizen agencies for an uncompleted section of I-75 north of Atlanta. Several techniques of analysis were considered. The technique of overlaying maps graphically depicting environmental, cultural, socioeconomic, and other factors, was found to be unsatisfactory because of its insensitivity in simultaneously analyzing and selecting from several alternate corridors. Another method, the matrix approach, was not used because data were collected from a variety of sources and subjective value judgements varied. Therefore, linear vector analysis involving the linear combination of observable or consensus factors was used to develop a totality index for each of eight alternate corridors. Using 56 factors influencing highway corridor planning and selection (which could be

B-16 (cont'd)

broadly categorized as (1) economic and engineering aspects, (2) environmental and land use considerations, (3) recreational factors, and (4) social and human considerations, a mathematical index was developed to evaluate the overall impact of each alternate. Scaling and weighting of the factors was performed to normalize the data types and to place a significance value upon the factor. Also, both immediate and projected future impacts were considered. Further, a random number generator was placed in the equations to account for the possible error in attribute assessment. A computer program, written in CPS PL/1, was developed for use on an IBM 360/65. The analysis resulted in a sharp separation of the alternates into two groups of four each. The resulting indices were relative values and were used as indicators of impact magnitude. To investigate further the role of immediate vs. future impacts, the future attributes were omitted from a second analysis. The results showed a definite increase in the degree of impact as well as a reordering of some of the alternates in terms of impact rank. The recommendations generated from this study were followed by Georgia DOT in its final route selection.

highway
highway impact
highway corridor selection
environmental impact assessment
computer model
simulation model
algorithm
Georgia

B-17 Peterson, G. L., R. S. Gemmell, and J. L. Schofer. 1974. *Assessment of Environmental Impacts: Multi-disciplinary Judgements of Large-scale Projects.* Ekistics, 218(1):23-30.

A subjective technique for social and environmental impact is pressented using the evaluations of members of a multidisciplinary team to predict the magnitude of impact of various alternative projects. After identifying construction related factors, members rate these elements in terms of potential environmental impacts. The resulting environmental impact indices are used to predict possible social impacts. This process is repeated several times, redesigning and improving alternatives at teach iteration. In applying this impact assessment approach to a U.S. Army Corps of Engineers regional wastewater management project near Chicago, IL, it was found that three factors, economic activity, socioecological activity, and food production, contributed significantly to social wellbeing. The wastewater project was designed with consideration given to these three social factors.

environment
environmental impact assessment
systems evaluation
matrix
model
Illinois
Indiana

B-18 Sullivan, J. B. and P. A. Montgomery. 1972. *Surveying Highway Impact.* Environment, 14(9):12-20.

The authors surveyed 76 final environmental impact statements (required under Sec. 102 of the National Environmental Policy Act) filed by states through June 1972 for proposed highway projects within cities of more than 50,000 population. Each of the statements was checked against a list of 45 items required under terms of the legislation. Response was varied. Some statements did not mention the problem area or denied that the proposed highway would have any effect on it. Some problem areas were neglected on a significant number of statements. While each statement should be tailored to the specific highway situation, the survey uncovered the repetition of identical phrases, paragraphs, and even pages in statements for different highway impacts. Questionable assertions also were found. It was concluded that citizens, as individuals or in groups, should take action to induce transportation planners to develop the commitment necessary to supply realistic environmental analyses.

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|---|---|
| environmental impact statement | highway planning |
| National Euvironmental Policy Act | highway impact |

B-19 Turner, A. K. and I. Hausmanis. 1973. *Computer-aided Transportation Corridor Selection in the Guelph-Dundas Area of Ontario.* in *Environmental Consideration in Planning, Design, and Construction.* National Res. Coun., Hwy. Res. Board Spec. Rept. No. 138:55-70.

The purpose of this study was to apply and evaluate a computer-aided corridor selection system for the Guelph-Dundas area of Ontario. The computer program, the Generalized Computer Aided Route Selection System (GCARS) was developed at Purdue University between 1966 and 1969. It uses computer overlaying of weighted socioeconomic and/or environmental factors digitized in a matrix. The result is a numerical, three dimensional model upon which path analysis can be performed to select the route of minimal impact based upon the weighted factors, either singly or in predetermined combinations. The factors selected for the Guelph-Dundas study were earthwork costs, foundation costs, right-of-way acquisition, recreation potential, and upland bird potential. Data for these variables were collected from: topographic, geologic, and agricultural soils maps; aerial photographs [type and scale not given]; and information from the Canada Land Inventory. This information was digitized manually from 1:25,000 maps compiled for each factor. The cell size was 1/16 $mi.^2$ Path analysis was applied to both the single factor models as well as 14 multiple factor models (both two and three variable combinations). The resulting corridor selections and conclusions realized by GCARS analyses agreed closely with the manual analyses. Further, the computer approach required one quarter the time and cost about the same. Also, GCARS provided the basis for conducting more objective, quantifiable analyses. Another advantage to computer aided analysis is that the "overlays" are more easily updated as new data become available.

B-19 (cont'd)

highway
highway corridor selection
computer analysis
computer mapping
land use
computer program
resource mapping
Canada

B-20 Turner, A. K. 1978. *A Decade of Experience in Computer Aided Route Selection.* Photogrammetric Engineering and Remote Sensing. 44(12):1561-1576.

The historical development and application of GCARS (Generalized Computer Aided Route Selection), a computer assisted highway siting technique, is discussed (see B-6, B-19). The design goals of the original version of GCARS, developed in 1968, as well as the most recent version, include: (1) machine independence of the system, (2) economy of system use, (3) efficient and understandable man-machine communication, (4) flexibility, (5) sensitivity to permit various ranking techniques, and (6) general compatibility with already existing and detailed highway route design systems. GCARS-I employed an orthogonal minimum path analysis algorithm which would search for the least "cost" route based upon digital (cellular) data inputs and user supplied factor weights. Cost is not necessarily expressed in monetary units but can be expressed on a relative basis. Two teaching versions, GCARS-I1 and EASY-GCARS, developed in 1969 and 1970, respectively, are described. The development of the latest version of this computer assisted corridor selection technique began in 1973 and is named GMAPS-GCARS. This new system is actually a hybrid of a composite computer mapping technique (digital overlaying) and a more efficient minimum path analysis technique (10 to 20 times faster than earlier) and capable of searching nonorthogonally (*i.e.*, diagonally). In 1975-76, GMAPS-GCARS systems were used to aid in the environmental impact assessment of about 100 mi. of a four lane highway in extreme western New York and Pennsylvania, near Lake Erie. Information from 22 baseline maps, including a variety of environmental, cultural, engineering, and economic factors, was converted to cellular digital data having a resolution of about 7.8 a.; nearly 180,000 cells were required to cover the study area. GMAPS routines were used to produce a series of derivative (lowest level), determinant (intermediate level), and composite (highest level) models. GCARS programs were used to generate a series of corridor alternatives. The computer derived corridor was refined using more established, conventional transportation planning practices. The use of GMAPS-GCARS expedited the completion and approval of draft and final environmental impact statements for the project (between 6 an 18 months were saved). It was concluded that, while highway construction appears to be on the decline, demands for new utility lines and rights-of-way continue to rise and that systems such as GMAPS-GCARS are well suited for their siting as well.

highway
computer model
digital mapping
computer mapping
highway corridor selection
computer program
minimum path analysis
computer aided route selection
Indiana
New York
Pennsylvania

B-21 Vlasin, R. D. *et al.* 1978. *Ecological Effects of Highway Construction Upon Michigan Woodlots and Wetlands: Final Research Report--Phase II.* Agr. Exp. Sta., Mich. State Univ., East Lansing, MI, 254 pp.

Methods for objectively measuring and evaluating natural science parameters and their interrelationships as they aid in understanding environmental impacts resulting from highway activities were studied. Recent literature pertinent to this study was reviewed, resulting in an updated annotated bibliography. A method based on ecological principles for organizing information to aid in evaluating interrelationships among natural resource factors as they relate to environmental impacts resulting from highway activities was developed. An Environment-Highway Interaction Matrix was assembled to serve as a tool to identify potential impacts of 28 highway related activities on soils, water, flora, and fauna. The Michigan Land Cover/Use Classification System was modified and incorporated into an ecological approach for highway siting. A guide for highway planners, designers and decision makers was then developed to evalnate objectively environmental impacts of highways. Field examination of sensitive sites provided information which aided in constructing the model. In addition, a study was performed to determine winter use of highway rights-of-way and surrounding areas by snowshoe bare and white-tailed deer. The information in this report provides a basis for incorporating natural resource factors in the route location process. The procedures described can be used by transportation planning personnel in comparing alternative highway routes in a more analytical way prior to route construction. Also included in this report is a glossary of ecological terms and an extensive annotated bibliography of publications related to highway planning and ecological analysis.

highway
highway construction
environmental impact
soils
vegetation
wildlife
water quality
hydrology
annotated bibliography
Michigan

B-22 Yount, D. E. and D. B. Stafford. 1972. *Location of a South Carolina Highway 11 - Blue Ridge Parkway Connecting Highway.* Dept. of Civil Engrg., Clemson Univ., Clemson, SC, 66 pp.

This study examined alternate locations for a scenic connecting highway between SC 11 and a proposed extension of the Blue Ridge Parkway in North Carolina. Aerial photograph interpretation techniques were the primary tools used in selecting the route. Photographic index sheets, contact print black-and-white aerial photographs at 1:15,840 and 1:20,000 and USGS topographic maps of the study area together with Soil Conservation Service soil survey reports and various highway maps and geologic references were used to study the topography, drainage conditions, soil conditions, land use, and existing transportation facilities of the study area. From the preliminary examination of the photographic index sheets and topographic maps, two corridors were

B-22 (cont'd)

selected for study with contact prints. By examining these two corridors using the larger scale contact prints, it was determined that a combination of the two was better than either corridor alone. Using the contact BW prints a stereoscopic examination of the corridor was performed to select several possible routes for the connecting highway. This examination included extensive study of the topography of the corridor in an attempt to eliminate excessive cuts and fills and to ensure that the highway alignment blended with the existing landscape. Drainage conditions were studied to determine the location of major culverts and bridge structures. Soil conditions and land use were examined for possible problem areas. Several alternate alignments were studied and compared on the basis of how each met the basic route selection criteria. These included the most direct route between the two terminal points, the least cost route which utilizes several existing highways and the most scenic route. The alignment which best satisfied all of the study criteria was a combination of sections from the different alternates. It was found that the scale of the aerial photographs has an influence on the capability to which the location can be fitted to the existing topography. The smaller scale (1:20,000) ASCS photographs, as opposed to the 1:15,480 Forest Service photographs, are appropriate for selecting route corridors and determining adverse topographic and soil conditions. However, larger scale photographs on the order of 1:6,000 are better for making the final route selection. Another consideration in the use of aerial photographs for highway location is the time of year the photographs are taken. In this study the existing photographs were taken in either summer or winter months. Photographs taken during the winter months provide the location engineer with more information on topography and soil conditions. In heavily forested and undeveloped mountainous terrain, surface features are often obscured in aerial photographs taken during summer months.

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|---|---|
| highway | construction costs |
| highway engineering | terrain analysis |
| aerial photography | corridor selection |
| photointerpretation | North Carolina |
| black-and-white photography | South Carolina |

B-23 Zieman, J., H. H. Shugart, G. A. Bramlet, A. Ike, J. R. Champlin, and E. P. Odum. 1971. *Optimum Pathway Matrix Analysis Approach to the Environmental Decision Making Process -- Testcase: Relative Impact of Proposed Highway Alternates.* Inst. of Ecology, Univ. of Georgia, Athens, GA. 31 pp.

A technique for evaluating proposed alternate highway corridors with a "totality impact index," is discussed using uncompleted I-75, north of Atlanta, GA as the test site. The intent of the technique was to select, from among eight alternates, the route with the least environmental impact. The method involved a linear combination of values multiplied by weighting factors derived from professional attitudes. Values were scaled so that a mean impact index was calculated for each of the eight routes. A PL/1 computer program [the source code is presented in the paper] was written to calculate these

totality indices. Comparison of the relative impacts permitted the selection of the route of least adverse impact -- one that was different from the original corridor proposed by the Georgia State Highway Department.

highway
highway impact
highway corridor selection
environmental impact assessment
Georgia

Section C

# WETLANDS AND REMOTE SENSING APPLICATIONS

14 Abstracts

C-1 Anderson, R. R. and F. J. Wobber. 1972. *Wetlands Mapping in New Jersey*. Photogrammetric Engineering, 39(4):353-358.

The New Jersey Department of Environmental Protection undertook a pilot wetlands mapping project to aid in fulfilling requirements of the New Jersey Wetlands Act of 1970. A prime requirement was that map products have validity in the face of litigation. Color and CIR photographs at a scale of 1:12,000 were obtained over two sites: Mannington Meadows, a fresh to brackish marshland in Salem County, and Tuckerton, a saline marsh in Ocean County. Vegetation types were used as indicators of wetland conditions with a five acre minimum mapping unit. Image interpretation techniques are discussed. Biological techniques for high tide boundary determination of saline wetlands, for high tide boundary determination of fresh to brackish wetlands, and for upper wetlands boundary determination are described. In a 105 day period wetland maps were prepared at 1:2,400 and 1:6,000 scales showing (a) the upper wetlands boundary, (b) the line of mean high water to establish state riparian lands, and (c) delineation of major plant species associations of five acres or larger in size. The maps were found to meet national map accuracy standards of the National Ocean Survey. Based on the pilot study it was concluded that state wide wetlands mapping using biological discrimination techniques can be accomplished using aerial survey methods.

aerial photography
remote sensing
wetlands
legal aspects
color photography
color infrared photography
vegetation association
fresh-brackish wetland
water salinity
photointerpretation
wetland mapping
vegetation identification
New Jersey

C-2 Best, R. G., D. G. Moore, and W. G. Brewster. 1976. *Color Infrared Aircraft Photography to Identify and Classify Wetlands in the Lake Dakota Plain of Eastern South Dakota*. Remote Sensing Inst., SDSU, Brookings, SD. 15 pp.

A joint effort between the U.S. Fish and Wildlife Service (USFWS) and the South Dakota State University Remote Sensing Institute was conducted to define wetland types of the Lake Dakota Plain of eastern South Dakota and to document interpretation techniques using aerial photographs. Wetlands were classified according to their water regime and usefulness to waterfowl based on the Martin (USFWS, 1953) wetlands classification system. Four of the 20 types developed by Martin were found in the Lake Dakota Plain. These were seasonally flooded basins or flats (Martin Type 1), inland shallow fresh marshes (Martin Type 3), inland deep fresh marshes (Martin Type 4), and shallow prairie lakes and reservoirs (Martin Type 5). Type 1 wetlands, the most abnndant in the region, contain water only for short periods and are characterized by the presence of smartweeds (*Polygonum* spp.) and wild barley (*Hordeum jubatum*).

C-2 (cont'd)

Type 3 wetlands, the second most abundant type, are usually waterlogged during the growing season and often covered by 6 in. or more of water. They are characterized by the presence of giant bur reed (*Sparganium* sp.), spike rushes (*Eleocharis* spp.), bulrushes (*Scirpus* spp.), and other aquatics. Type 4 wetlands are difficult to differentiate from Type 3; however, there is usually a greater percentage of open water occurring in the central portion of the basin. Type 5 wetlands have standing water generally less than 3 m in depth and are characterized by emergent vegetation along the fringe. A NASA RB-57 aircraft at 18,000 m was used to collect CIR aerial photographs on June 27, 1975. The photographs used for study were at the scale of 1:8,000. Ground level photos were taken on the same day to depict the wetland types. It was found that interpretation of these CIR aerial photos could be used reliably to identify and classify the wetland types described above. Type 1 wetlands in uncultivated lands were quickly identified because of the vegetation's higher IR reflectance than that of surrounding vegetation. In fallow fields, Type 1 basins were delineated by their darker tones (low IR reflectance) and smooth texture of the standing water. Type 3 wetlands were readily identified on the photos by the presence of water and the abundance of marsh vegetation in the basin. Type 4 wetlands were distinguished from Type 3 by the greater percentage of water in the central portion of the basin. Type 5 wetlands were distinguished from both Types 3 and 4 because of their large size and the absence of emergent plants except along the wetland edges.

aerial photography
color infrared photography
oblique aerial photography
high altitude
wetland classification
aquatic vegetation
wetland
wetland delineation
inland wetland
fresh water inland wetland
South Dakota

C-3 Carter, V. and W. Stewart. 1975. *Seasonal Color-Infrared Photographs for Mapping Inland Wetlands on U.S. Geological Survey 7.5-Minute Quandrangles.* in *Proc. 5th Biennial Workshop on Color Aerial Photography in the Plant Sciences and Related Fields*, American Society of Photogrammetry, Falls Church, VA. pp. 143-161.

The United States Geological Survey (USGS) has begun research on inland wetland delineation and development of new techniques for wetland representation on 7.5-minute quadrangle maps. Presently, only superficial treatment is given to wetland delineation on these maps because of previous lack of public demand for more detailed information. However, recent environmental awareness and wetlands legislation has caused USGS to take a new approach in mapping wetlands. One of the objectives of this study was to test the feasibility of mapping and possibly classifying inland wetlands on USGS 7.5 minute quadrangles in more detail than is presently available. Using multiseasonal CIR aerial

C-3 (cont'd)

photographs, wetlands were identified, delineated, and classified using modifications of three different wetlands classification systems. Test sites included the Auburndale, Florida; Corapeake, Virginia-North Carolina; and Little Ball Club Lake, Minnesota quadrangles. Scales of the CIR imagery for these three sites ranged from 1:20,000 to 1:130,000. Conventional photointerpretation methods were used to delineate the wetlands on acetate overlays while either a stereoscopic Kelsh plotter or monoscopic transfer instrument was used for map compilation. Preliminary results indicated that to adequately map and classify all types of wetlands, data from a minimum of two seasons are required. Further, it was found that it is difficult, if not impossible, to separate wooded wetland from forest using summertime photographs. The authors also noted that ground truth surveys will be necessary to verify wetland conditions particularly if there are parameters not directly observable on the aerial photographs.

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|---|---|
| inland wetlands | quadrangle maps |
| aerial photography | Florida |
| color infrared photography | Minnesota |
| wetlands mapping | North Carolina |
| wetlands classification | Virginia |

C-4 Civco, D. L., W. C. Kennard, and M. W. Lefor. 1978. *A Technique for Evaluating Inland Wetland Photointerpretation: The Cell Analytical Method (CAM).* Photogrammetric Engineering and Remote Sensing, 44(8):1045-1052.

A procedure for objectively analyzing the inland wetland photointerpretation of several investigators is discussed. Comparisons are made between wetland photointerpretations, soils mappings, and ground truth. The technique, which permits mathematical treatments of cell encoded wetlands delineations, was developed to test inland wetland mapping methods. Using sample 1:12,000 scale CIR aerial photographs of the 45 $mi.^2$ town of Mansfield, CT scientists from several disciplines delineated inland wetlands on imagery from both September 1974 and April 1975. Digital wetland "maps" were also prepared from detailed Soil Conservation Service (SCS) maps using the legal criteria of wetlands definition by soil types. Extensive field studies were conducted of these same areas to provide the gound truth necessary for mapping accuracy determination. In applying the Cell Analytical Method to CIR photographs and the SCS mappings, at the 0.23 acre (0.09 ha) mapping level, it was found that overall the photointerpreters' delineations had an agreement with ground truth of 85.6%. The SCS map provided only a 78.6% accuracy. Based upon the background of the participants and their relative agreement with ground truth, it was noted that qualities desirable in a photointerpreter engaged in wetlands mapping should include 1) a substantial degree of experience with the remote sensing imagery type, 2) a working knowledge of the image feature relationship, and 3) some familiarity with the study area. In comparing the accuracies achieved with the imagery from the two different seasons, it was

C-4 (cont'd)

concluded that absolute wetland boundary detection should be determined from a combination of delineations made from CIR aerial photographs so that the temporal variations characterizing these wetlands and related hydrologic systems can be observed.

inland wetlands
wetland delineation
aerial photography
color infrared photography
photointerpretation
soils mapping
ground truth
computer processing
mapping accuracy
Connecticut

C-5 Eitel, D. F. 1972. *An Overview of Remote Sensing for Wetlands Investigations.* in *Remote Sensing of Earth Resources*, 1:179-192. Conf. on Earth Resourc. Observ. and Info. Analysis Syst., Univ. of Tenn. Space Inst., Tullahoma, TN.

Twenty-five publications and papers on the use of various remote sensing techniques for detecting and delineating both saline and freshwater wetlands are reviewed. It was concluded that it is improbable that an optimum sensor can be found which will record all wetland ecological variables, but three specific types (BW, color, and CIR) appear useful. Black-and-white infrared aerial photographs (scale 1:12,000) appear to be ideal for delimiting wetland boundaries due to its extreme sensitivity to moisture content variations. However, species identification requires either color or CIR (scale 1:12,000) photography. Color photographs require a strong haze filter to allow green tones to separate. Color infrared photography using a Wratten 15-G filter gives excellent results as do the Wratten 25-A, 15-G and 61 filters. Color infrared, due to its "false color" is less understandable to inexperienced analysts. Thermal infrared imagery at present is not competitive with the other types of sensing for wetlands studies. It was noted that ground truth is essential for project planning and periodic validations. In addition, rapid and accurate techniques for wetland sensing are being established: color additive viewing, density slicing, microdensitometry and color coded isodensitometry. Imagery from various satellites also should prove useful but until these systems are proven and become economically feasible, aircraft surveys must be utilized and evaluated.

remote sensing
wetland delineation
spectral signature
color photography
black-and-white photography
infrared photography
color infrared photography
thermal infrared
satellite sensing
aircraft sensing
filter

C-6 Eyre, L. A. 1971. *High-altitude Color Photos.* Photogrammetric Engineering, 37(11):1149-1153.

Preliminary studies of the then recently declassified (October 1969) high altitude (16 km) NASA RB-57 aerial photographs demonstrated the possible applications in land use change detection in South Florida. Color and CIR duplicate film positives, at 1:60,000, were examined on a rear view screen on a modified Bessler Overhead Projector. Using photographs [type and scale not given] and ground data from the 1956 USGS regional analysis of the study area, research was conducted to determine the (1) loss of southeast Florida wetlands, (2) the expansion of agriculture, and (3) the growth of urbanized areas over this 13-year period. It was found that 2600 $km.^2$ of wetlands had been drained and that 1770 $km.^2$ of these had gone into agricultural production, 41 $km.^2$ into sand and gravel quarries, 153 $km.^2$ into urban expansion, and 22 $km.^2$ into military, recreation, and utilities occupation, leaving some 614 $km.^2$ unused or unidentified. Total urban expansion in the tri-county study area over the 13 year period amounted to some 1032 $km.^2$ It was also noted that detailed analyses of the Florida Flood Control District could be conducted with CIR. Features identified from the high altitude air photos included water hyacinth infestations, excessive algal growths, and several major pollutant locations in Lake Okeechobee. Silt transportation and deposition was observed in certain locations. It was concluded that high altitude photography has advantages over that from lower platforms because it was possible to delineate and identify major patterns over extensive study areas very rapidly.

aerial photography
color infrared photography
color photography
wetland
high altitude
wetland assessment
urban analysis
agriculture
land use
Florida

C-7 Jackson, R. D., R. J. Reginato, and S. B. Idso. 1976. *Timing of Ground Truth Acquisition During Remote Assessment of Soil Water Content.* Remote Sensing of Environment, 4:249-255.

Studies were conducted in Arizona to determine diurnal, seasonal, and spatial variations in soil water content. This information is needed to evaluate microwave radiometer data used in remote sensing water content. Volumetric water content data were collected at various increments (0-0.5 cm., 0-1.0 cm., 0-2.0 cm., and 0-4.0 cm.) in an Avondale Loam (32% sand, 46% silt, and 22% clay). These data were gathered from July 1970 to March 1971 and in May, October, and December 1973. The amplitude of change in diurnal water content was found to be greatest in the upper soil layer, progressively becoming smaller as depth increased in the spring and summer; the differences among these layers was smaller in the winter. It was observed that water content maxima occurred between 0300 and 0500 hrs. and minima between 1400 and 1500 hrs. Average daily water content occurred between 1100 and 1200 hrs. This 24 hr. average can be estimated from minimum and maximum values. Maximum and minimum temperatures are well correlated with water contents, and temperature is ideally suited to radiometric remote sensing. However, data should

C-9 (cont'd)

swamp, standing water, and natural levees). SYMAP, a computer mapping program developed at Harvard University, was used to produce line printer character maps of the classes under study for each of the four filters. Visual comparison of the computer generated classification maps with SCS maps showed marked discrepancies. The best fit came from the map produced from the data using the red (WR 92) filter. The lack of precise colorimetric standards accounted for much of the error in the automated classification (between 27 and 93% of the raw data values were outside of the decision boundaries). The author concluded that, based upon this experimental design, wetland soils can not be computer mapped accurately due to the lack of calibration, the inability to correct for numerous sources of variance, and the possibilities that: (1) vegetation cannot be used as a surrogate for soil (2) color values alone are not enough for discrimination and (3) diagnostic color values do not exist in a wetland environment.

coastal wetland
color infrared photography
aerial photography
automated data processing
soil mapping
colorimetry
filter
computer analysis
densitometer
decision rule
Louisiana

C-10 Parry, J. T. and H. Turner. 1971. *Infrared Photos for Drainage Analysis.* Photogrammetric Engineering. 37(10):1031-1038.

Color infrared aerial photographs (Kodak Infrared Aerographic 542.4) were taken in the summer and fall 1962 at 1:16,868 in the Gagetown area of New Brunswick, Canada, as were 1:17,367 BW aerial photos (Kodak Plus X Aerographic 2401) in October-November 1962, for the purpose of comparing the relative ability of each imagery type in revealing drainage networks. Certain experimental design parameters placed constraints on the analyses. These included different ground resolution size (0.53 m. for the CIR and 0.43 m. for the BW), differences in illumination resulting from the asynchronous flights, and differences in ground conditions at the time of each flight. Sample areas (108 by 56 mm.) were monoscopically interpreted in the center of each of 20 photographs in both flights; caution was exercised in "registering" the areas. Details of drainage networks were marked on Herculon polyester overlays. The BW was analyzed before the CIR to eliminate bias results. Using Strahler's system of stream ordering, it was found that the CIR photos were superior in imaging drainage systems in 19 of 20 samples. The mean increase in channel lengths (1st to 4th order) of the CIR air photos over the BW was found to be 37% in the Gagetown area. Much of this difference can be attributed to the higher contrast ratio between water bodies and vegetation in the IR portion of the electromagnetic spectrum. The authors further concluded that the maximum benefit from CIR aerial photos is experienced for 2nd and 3rd order channels with progressively less advantage for

C-10 (cont'd)

larger channels. Also, CIR photos had the additional asset of revealing shallow channels and permitting the differentiation of fluvial deposits.

aerial photography
aerial sensing
photointerpretation
drainage
color infrared photography
river
black-and-white photography
terrain analysis
stream
New Brunswick
Canada

C-11 Roller, N. E. G. 1977. *Remote Sensing of Wetlands.* Env. Res. Inst. of Mich., Ann Arbor, MI. Rept. No. 193400-14-T. 156 pp.

The uses of remote sensing for wetland inventories and the related topics of inventory design and data collection are discussed. The results of studies conducted by other researchers, as well as some by the author, are presented to illustrate the usefulness of various remote sensor systems in both inland and coastal wetlands investigations. The material presented shows that conventional aerial photography is the sensor type providing the greatest amount of wetlands information. For extensive, general purpose wetland inventories, however, LANDSAT multispectral scanner imagery may be more cost effective. Data are provided on accuracy, resolution, and representative costs of remote sensing imagery acquisition and interpretation. Appendices provide information on imagery interpretation, sensor selection, film and filter combinations for specific tasks, and a brief list of organizations engaged in imagery acquisition.

remote sensing
aerial photography
black-and-white photography
color photography
color infrared photography
multispectral scanner
wetlands
scale
inland wetlands
coastal wetlands
wetland classification
classification accuracy
filter
identification
mapping

C-12 Seher, J. S. and P. T. Tueller. 1973. *Color Aerial Photos for Marshland.* Photogrammetric Engineering, 39(5):489-499.

Color and CIR aerial photographs of waterfowl habitats were studied for usefulness in evaluating marsh vegetation. Seven large scale photo transects were selected on four Nevada Marsh areas managed for wildfowl production. Detailed vegetation maps were made by field studies and compared with 1:1,000 scale and 1:10,000 scale color and CIR photographs of each transect. Sequential CIR

C-12 (cont'd)

photographs were taken during the growing season. Color and CIR photographic keys were constructed to aid photointerpreters in identifying 10 major types of marsh vegetation. It was concluded that vegetation maps from large and intermediate scale photographs were found to be accurate and time saving. Best results were obtained with a combination of color and CIR film types and field checking of vegetation communities before mapping. Most interpreters had more confidence with results from the CIR test. Interpretation tests indicated that experience level of photointerpreters did not greatly change accuracy of interpretation scores, but experienced interpreters took less time to complete the test. Field experience in the area photographed is desirable for accurate results. The larger scales (1:1,000) showed interpretation results with more accuracy than did smaller scales (1:10,000); however, coverage is limited with large scale photographs. Early morning photographs were most interpretable as reflections of the sun on the water were avoided and wave effects were not prominent. Late summer (Aug.-Sept.) was the best time to photograph marsh vegetation. Sequential photographs taken during the plant growing season added very little information to photographs taken in late summer. Data are given for costs of film and processing, for aircraft rental, and for the photographic equipment used.

remote sensing
marsh
aerial photography
color photography
color infrared photography
photointerpretation
costs
wildlife
vegetation identification
interpretation key
Nevada

C-13 Sewell, J. I. and W. H. Allen. 1973. *Visible and Infrared Remote Sensing in Soil Moisture Determination.* in *Remote Sensing of Earth Resources*, 2:689-702. Confer. on Earth Resourc. Observ. and Info. Analysis Syst., Univ. of Tenn. Space Inst., Tullahoma, TN.

Laboratory and field studies were conducted to determine the relationship between light reflectance and soil moisture content and to evaluate various remote sensors' capabilities in detecting soil moisture content. Using a spectroradiometer system, 10 samples of fine sandy loam soil with different known moisture contents, from the Knoxville, TN area were analyzed for their percent reflectance of light at six wavelengths in the visible portion of the spectrum and one in the near IR. Results from regression analyses showed that soil surface reflectance as a function of soil moisture level may he adequately described by a quadratic function. It was concluded that in order to record the entire moisture range additional information from the thermal IR wavelengths would be necessary. Three film types (BW, CIR, and black-and-white IR) and two line scanner ranges (2-5 μm and 8-14 μm) were used to acquire remote sensing data on six different dates. All sensors were not used on each flight. Film density was recorded on magnetic tape for the three film types using a x-y scanning microdensitometer. The line scanning data were

C-13 (cont'd)

correlated with field data including soil moisture levels, radiometric temperature, and incident solar radiation. Color infrared photography allowed more accurate soil moisture content predictions overall than did the BW imagery and the electronic line scanners. Further, the data from the 2-5 μm band of the scanner were more closely associated with soil moisture content than were those of the 8-14 μm range.

soil moisture
aerial photography
color infrared photography
black-and-white photography
scanner
infrared photography
thermal infrared
spectroradiometer
Tennessee

C-14 Shima, L. J., R. R. Anderson, and V. P. Carter. 1976. *The Use of Aerial Color Infrared Photography in Mapping the Vegetation of a Freshwater Marsh.* Chesapeake Science, 19(2):74-85.

Spring and fall vegetation maps were prepared for a freshwater marsh on the Patuxent River, MD. Color infrared aerial photographs taken June 20, 1968 and Sept. 12, 1968 at an altitude of 1850 m. were correlated with data obtained from extensive ground surveys made between May 12 and Sept. 19, 1972. Twelve vegetation units were recognized in the spring imagery and 14 in the fall. Vegetation units mapped refer to areas of homogeneous color on the photos; these areas represent species associations or monospecific stands which produce a distinctive tonal signature. Factors affecting photointerpretive results are discussed. Color fluctuations within an area having a distinctive tonal signature are primarily caused by a quantitative variation of plant species but also are related to the growth habit, vigor of the plant species, and environmental conditions which affect the vegetation and hence the color of the recorded image. Changes in color over the growing season reflect plant succession and vegetative decline. The general but not the absolute boundaries of areas of prominent wetland species can be determined using low altitude CIR photography. Seasonal vegetation change from spring to fall was detectable in the photographs as changes in color, saturation, and texture. Comparison of photographs made in nearby marshes demonstrated that three of the 12 spring and five of the 14 fall vegetation units can be reliably identified. Low altitude CIR photography is a valuable aid in mapping vegetation of freshwater marshes provided the following are considered: (1) the season of the year that mapping is done relative to the growth of plants, and (2) the systematic field checking of the study areas especially of species associations whose boundaries are indistinct.

remote sensing
color infrared photography
freshwater marsh
spectral signature
tonal signature
vegetation association
Maryland

Section D

# E C O N O M I C S
# O F
# R E M O T E  S E N S I N G

11 Abstracts

D-1 Craib, K. B. 1972. *The Cost-Effectiveness of Advanced Remote Sensing Systems.* in *Proc. IEEE. International Conf. on Communications,* Philadelphia, PA. 7 pp.

Accurate and precise information concerning the location and condition of natural resources is necessary for the development and implementation of effective management plans. Major problems associated with conventional ground surveys have been the relatively high cost per unit area and the limited availability of skilled field technicians. Also, budgetary limitations may result in inadequate sampling, further resulting in inaccurate resource inventories. Data from aircraft and spacecraft platforms, with their higher data acquisition speeds and larger coverage, often are more effective tools. Selection of the most suitable platform, low, high, or space, can be determined via cost effectiveness analysis. In a study comparing surveys made from 10,000 ft. and 25,000 ft. it was shown that the high altitude imagery provided exactly the same spatial resolution and four times the spectral detail at one-half the cost of the low altitude survey. Additionally, data acquisition time was less for the high altitude mission (less than one week vs. more than a month), as was time needed for photointerpretation. At higher altitudes, fewer frames are needed to cover a unit area, and there is little sacrifice in spatial detail with the smaller scale format. Not only are the costs in photoacquisition less with higher platforms, but so are those associated with processing, printing, and interpreting. The cost of the actual aircraft platform, however, increases with altitude. When all factors are included in total survey costs (acquisition, processing, interpretation), the cost effectiveness of high altitude sensor systems may be two to 10 times greater than that of comparable lower altitude surveys.

aerial photography
cost effectiveness
low altitude
high altitude
spacecraft platform
resource inventory

D-2 Craib, K. B. 1972. *The Cost Effectiveness of High Altitude Systems for Regional Resource Assessment.* in *Remote Sensing of Earth Resources,* 1:315-337. Conf. on Earth Resourc. Obs. and Info. Analysis Syst., Univ. of Tenn. Space Inst., Tullahoma, TN.

Cost and capabilities of traditional aerial photographic surveys for general geological mapping are reviewed and compared with multispectral surveys conducted at different altitudes. Interpretation time required per photograph increases directly with altitude, since more features of interest will be contained in a single frame. Interpretation time per unit of ground area, however, decreases since these same features may be examined more easily and efficiently. Higher elevations require fewer flight lines and fewer photographs to cover a given area. Also an entire area could be covered in a single day, and important consideration for areas where clear days are infrequent. It was concluded that high altitude (18,000 ft. to 60,000 ft) multiband remote sensing surveys for regional reconnaissance and mineral surveys can be much less costly and more effective by two to 10 times than traditional lower altitude methods presently in use.

D-2 (cont'd)

remote sensing
regional planning
multispectral analysis
high altitude
benefit-cost analysis
cost effectiveness
geological mapping
mineral exploration

D-3 Craib, K. B. 1977. *The Cost-effectiveness of Operational Remote Sensing Technology: A Comparative Analysis.* in *Proc. 1st Conf. Econ. of Remote Sensing Info. Syst.*, San Jose State Univ., San Jose, CA. pp. 229-244.

Cost effectiveness analysis involves the comparison of alternate methods to reach a particular goal or set of goals with the least costly, most effective approach. In contrast, cost-benefit analysis is used to determine the costs and benefits resulting from specific courses of action and, hence, the "net social benefits" from those actions. Since operational remote sensing programs have specific goals attached to them, cost effectiveness analysis is the better approach of the two in comparing alternate remote sensing methods and data gathering techniques. In August 1973, research was conducted for the U.S. Agency for International Development and the Government of Honduras to compare the relative cost, effectiveness, and efficiency of various remote sensing methods for soils and land use/cover surveys. Remote sensing data studied included BW, color, and CIR and multispectral aerial photography, and LANDSAT MSS imagery. Various film and camera combinations were used for the aerial missions. The features of interest were delineated through conventional interpretation. Study results indicated that: (1) color and CIR resulted in equally accurate soil surveys and both surpassed BW; (2) soils could be interpreted 30% more quickly with CIR than with BW, and 20% more quickly than with color; (3) land use/cover classification accuracy was highest with CIR, followed by color, then BW; (4) nearly twice the length of time was required to delineate land use/cover on BW than on CIR; and (5) the least expensive data collection program, which was BW aerial photography, resulted in the most expensive overall program and produced less accurate results than any other alternative studied. The results are described in terms of a cost effectiveness (C-E) index, which is the product of an effectiveness rating ($E_r$) and a cost rating ($C_r$). In this study, $C_r$ for the alternatives was determined as the ratio of that alternative's total costs to the BW costs.

remote sensing
black-and-white photography
color photography
color infrared photography
multispectral photography
land use mapping
multispectral scanner imagery
LANDSAT
cost effectiveness analysis
cost benefit analysis
soil mapping
Honduras

D-4 Earth Satellite Corporation. 1974. *An Analysis of Benefits and Costs in Forestry Utilizing Earth Resources Satellites or Aircraft Information.* Appendix 4 in *Earth Resources Survey Benefit-Cost Study.* Econ., Env., and Soc. Costs and Benefits of Future Earth Resources Surv. Sys. Washington, D.C. 41 pp.

A benefit-cost analysis of remote sensing of forest resources is presented. The study focused on forest inventory, protection, and management practices. Benefits from remote sensing in forestry were estimated from available information. In comparing costs of an actual photo-inventory of forests as conducted by the Bureau of Land Management with projected costs from an earth resources satellite survey, it was shown that the cost of the former (photography, interpretation, and field work) was $.1025 per acre. The projected cost of a similar survey from satellite was calculated to be between $.0217 and $.0580 per acre. It was noted that it had not yet been demonstrated, however, that an earth resources satellite survey could provide an adequate level of information, while the demonstrated technology of conventional aerial photography could.

benefit-cost analysis
economic analysis
aerial photography
ERTS
satellite
forestry
forest inventory
cost

D-5 Eastwood, L. F., T. R. Hays, R. J. Ballard, and G. G. Crnkovich. 1977. *A Comparison of Photointerpretive and Digital Production Methods for Four Key Remote Sensing-Based Information Products.* in *Proc. 1st Symp. on Econ. of Remote Sensing Info. Syst.*, San Jose State Univ., San Jose, CA. pp. 213-228.

This paper evaluates the costs of producing four information products based on remote sensing: timber volume estimate tables, land use and land cover maps, soil maps and vegetative cover maps. Two production methods for each product, one based on digital processing of satellite data, and the other on conventional photointerpretation of aircraft data were evaluated. For each, production costs (including data acquisition, ground truth, interpretation, compilation, and printing charges) and performance (as measured by accuracy and timeliness) were compared. Each of the production methods reviewed has been tested and the costs, timeliness and other performance estimates presented are based on observations made in practice. Results show that for these products, satellite based production results in significant cost and timeliness improvements at the cost of a loss in accuracy. Results of extensive literature searches show that timber volume estimates derived from satellite data were about 11% more accurate than those from aircraft platforms. However, the accuracy for the other three tasks (preparation of land use, soils, and vegetation maps) was 5-10% less accurate than possible with conventional photointerpretation techniques. Extensive cost data and man-hour estimates are presented for each system, each of the four tasks, and each cost component of the tasks.

D-5 (cont'd)

A review of these data indicates that analysis performed with the satellite based system are about 60% less costly than those prepared with conventional aircraft based system.

remote sensing
cost
classification accuracy
aerial photography
LANDSAT
timber volume
land use mapping
soil mapping
vegetation mapping
digital image processing

D-6 Enslin, W. R. and R. Hill-Rowley. 1977. *Michigan Resource Inventories: Characteristics and Costs of Selected Projects Using High-Altitude Color Infrared Imagery.* Presented at the *1st Conf. on the Econ. of Remote Sensing Info. Syst.* San Jose State Univ., San Jose, CA. pp. 194-212.

The applications of remote sensing techniques to timber management and land use mapping are discussed based upon results of the Michigan State University Remote Sensing Project. A forest inventory was conducted using 1:36,000 CIR aerial photographs [dates not given]. Categories were based upon species types, stand size classes, and stocking levels, and these delineations (photo-derived maps) were encoded at a four hectare level for computer analysis. Industrial foresters are using the maps and computer printouts on a regular basis to direct much of their fieldwork such as locating potentially productive and marketable timber stands. Three land cover/use inventories were prepared for three large tracts in Michigan in 1973. In the first, 2,590 $km.^2$ were inventoried in 18 land use classes by interpreting 1:60,000 and 1:120,000 NASA CIR aerial photographs. The second inventory involved some 5,310 $km.^2$ and 22 land use categories. Color infrared photographs at 1:31,680 were interpreted and final maps prepared at 1:63,360. And the third covering some 4,416 $km.^2$, resulted in 1:48,000 base maps reflecting some 22 categories; NASA CIR aerial photographs at 1:60,000 and 1:120,000 were used. The costs for interpretation, field checking, catography, and area calculations were \$1.39/$km.^2$, \$1.33/$km.^2$, and \$1.98/$km.^2$, respectively. Complete cost analyses for these tasks as well as for supportive ones such as photoacquisition, travel, supplies and materials, administration, and overhead, are presented. The Resource Analysis Program (RAP) of the Remote Sensing Project is a computer procedure for resource assessment that uses information derived from aerial photographs. The system was applied to Windsor Township (93 $km.^2$) to generate 11 resource factor maps. A cost analysis of this test, the details of which are presented in the paper, reveal that 212.5 man-hours and \$1,500 were required to complete the task.

D-6 (cont'd)

aerial photography
color infrared photography
photointerpretation
high altitude
small scale
resource mapping
forestry
land use classification
cost effectiveness
computer mapping
resource inventory
forest cover typing
land use mapping
land cover
Michigan

D-7 Gucovsky, M. M. 1972. *Benefit Analyses and Decision Models.* in *Proc. Intl. Workshop on Earth Resources Surv. Syst.*, 1:183-184, Ann Arbor, MI.

Two decision models are discussed briefly: type A -- choosing techniques and procedures to obtain information for investment decisions in the field of natural resources development, and type B -- improving the efficiency of managing existing natural resources. Airborne and/or spaceborne remote sensing techniques offer economies of scale and reduced time in information gathering to meet needs of a large number of complementary economic activities over a large region. Type A models can be used to develop cost functions for different systems of information gathering. Type B models, using real cost figures, can serve as a basis for comparing conventional data gathering activities with the cost of obtaining the same information using spaceborne sensors.

benefit analysis
decision models
cost effectiveness
natural resources
resource systems
spaceborne sensors

D-8 Nieuwenhuis, E. 1975. *A Discussion of the Cost, the Efficiency, and the Choice of Imagery.* ITC Journal, 1:53-69.

The selection of remote sensing imagery is discussed based upon the imagery type cost and efficiency. A project involving remote sensing applications has three components: mapping, planning, and execution. Citing data from a drainage and irrigation project, the author notes that the cost of aerial photography and interpretation is a small percentage of the total mapping cost. It might be concluded that the cost of the aerial photography is an insignificant factor; however, its suitability may affect the entire project and its cost. The relative qualities of various imagery types are discussed briefly. Scale is one of the factors affecting the cost effectiveness of aerial photo applications; as scale decreases, so does the cost per square kilometer in the photoacquisition phase. Based upon combined cost data for the period 1965-1972, it was found that aerial photographic missions at a

D-8 (cont'd)

scale of 1:10,000 cost about $4.50/km$^2$ while those at 1:90,000 cost about $.40/km$^2$. In producing soil surveys, the scale of the aerial photography plays a role in mapping efficiency. Productivity is at its maximum at about 1:70,000, hence, the relative cost of this component is at its minimum at this scale. Not only do costs vary with the scale of photography, but effectiveness in terms of information content does as well. In comparing aerial photographs at two different scales in a forest resource inventory, it was concluded that fieldwork can be reduced by as much as 10% when using 1:20,000 scale photos as contrasted to 1:40,000. The additional expenditure in the acquisition of the larger scale imagery was more than compensated for by saving field time and money. Other factors influencing the selection of a remote sensing imagery type include: (1) the required detail; (2) participating disciplines; (3) size of the area; (4) natural conditions; (5) existence of an infrastructure (*e.g.*, transportation networks); (6) demographic, political, economic pressures; (7) existing imagery coverage; (8) climatic conditions; and (9) government implementation capacities. Planners must identify the flight windows (average number of flying days per year) for each imagery type and then relate that to the size of area to be covered in order to determine if the aerial mission can be accomplished in a given time period. The optimum (or nearest to optimum when several interests are participating) remote sensing imagery type should be selected since its cost is small when compared to the cost of the entire survey project.

remote sensing
cost effectiveness
aerial photography
radar
multispectral scanner
scale
Brazil
Netherlands

D-9 Palgen, J. J. O. 1967. *Les Aspects Économiques de la Photo-interpretation.* in *Proc. 2nd Seminar on Air Photo Interpretation in the Development of Canada.* Ottawa, Ontario, Canada. 9 pp. [in French].

In December 1966, the staff of the Department of Photogrammetry at Laval University (Canada) undertook a study into the economic aspects of aerial photograph interpretation. More than 130 questionnaires were distributed to members of all the National Cartographic Services offices to survey the professionals' concepts of the role of economics in the various aerial photographic disciplines. The responses served as a basis for developing a framework for studying the economics of photointerpretation. Two possible approaches were revealed. The first involves the integration of a rationale for: (1) the empirical parameters of photointerpretation, (2) the extrapolated benefits (both to other disciplines and over time), and (3) the application of econometric principles to the model of photointerpretation and its associated costs and benefits. The second approach involves: (1) the consideration of various techniques of the analysis of natural resources using aerial

D-9 (cont'd)

photograph interpretation and photogrammetry (as well as a critical evaluation of these techniques), (3) a tabulation of the costs associated with photointerpretation from the viewpoints of the marketplace, and the planning sectors, (4) the estimation of the returns (benefits) including direct indirect, primary-secondary, and tangible-intangible, and (5) the development of statistical information (at the national level) describing the cost-benefit components of photointerpretation. Although data were not presented it was planned that such a study would be undertaken.

aerial photography
photointerpretation
photogrammetry
cost effectiveness
benefit-cost analysis
economics
Canada

D-10 Tsuchigane, R. T., and K. I. Chen. 1978. *Economics of Remote Sensing: An Alternative Approach.* in *Proc. 2nd Conf. on Econ. of Remote Sensing.* San Jose State Univ., San Jose, CA. pp. 98-108.

The authors have (1) examined the cost effectiveness (CE) of various remote sensing aircraft platforms and (2) analyzed the costs and benefits of remote sensing by LANDSAT with reference to the Large Area Crop Inventory Experiment (LACIE). The CE analysis presents the results of a study of the economics of remote sensing in terms of USDA requirements. Acquisition costs of CIR film positives from different camera aircraft combinations are presented. It was noted that the cost of low altitude (7,000 ft.) CIR imagery was the most expensive system ($3.66/mi.$^2$). For high-altitude systems, such as with a U-2 aircraft at 65,000 ft., the cost was $1.15/mi.$^2$ The least expensive platform studied was at 45,000 feet using a Sabre 60 aircraft; cost was found to be $.57/mi.$^2$ Other data for five systems are presented including resolution, aircraft operating costs, and aircraft velocities. When desired resolution is between 80-100 m., LANDSAT MSS data is the most cost effective at only about $.12/mi.$^2$ This figure does not include capital investment costs -- only film processing. A potential economic benefit from the use of LANDSAT in agricultural studies is the ready availability of timely imagery for forecasting large area crop production.

remote sensing
economics
cost effectiveness
low altitude
high altitude
LANDSAT
color infrared photography
agriculture
medium altitude
LACIE

D-11 Watkins, T. [Moderator]. 1977. *A Panel Discussion on the Economics of Remote Sensing.* in *Proc. 1st Conf. on Econ. of Remote Sensing Info. Syst.*, San Jose State Univ., San Jose, CA. pp. 356-368.

A panel discussion was held during the First Conference on the Economics of Remote Sensing Information Systems, held January 19-21, 1977 at San Jose State University. Each of the five panelists presented an opening statement on what he considered to be a major problem concerning the economics of remote sensing. This was followed by an open discussion. The published version of this presentation and discussion has been edited and abridged. Some of the key points made were: (1) in the past, as much as 80% of remote sensing needs have been satisfactorily filled, and at a relatively low cost, by conventional aircraft systems; (2) established aerial survey techniques have often provided the same information faster, more accurately, and less costly than through the use of ground studies alone; (3) satellite sensor systems are presently very experimental and do not provide the spatial resolution necessary for concentrated environmental and engineering studies; and (4) economic analyses of remote sensing programs should be quantitative rather than qualitative, and that the assumptions of the economic model should be well defined.

remote sensing economics

Section E

# G E N E R A L
# R E M O T E  S E N S I N G
# A P P L I C A T I O N S

51 Abstracts

E-1 Ahl, J. G., M. G. Boylan, D. L. Mokma, W. L. Meyers, S. W. Schar, and R. D. Vlasin. 1972. *Investigation of Land Resource Use in Southeast Michigan.* in *Proc. 8th Intl. Symp. Remote Sensing Env.* ERIM, Ann Arbor, MI. 1:23-33.

A Study was undertaken by Michigan State University, the University of Michigan Willow Run Laboratories, and the Michigan Department of State Highways to determine the potential environmental impacts of a proposed expressway extension of M-14 between Ann Arbor and Plymouth, MI. One of the problems in assessing the environmental impact of proposed highway corridors is the lack of a scientific approach for analyzing the effects of construction in an ecologically sensitive area. In this instance, however, a segment of M-14 was constructed in 1964 and could serve as a reference in environmental impact assessment for the proposed corridor. The three agencies involved produced a schedule for three major areas of inquiry: (1) analysis of vegetation; (2) analysis of soil and surface hydrology; and (3) analysis of land use characteristics. Remote sensing techniques used were aerial photography and multispectral scanning from altitudes of 2,000 and 7,000 ft. and NASA RB-57 aerial photographs from 60,000 ft. Nine-inch square high altitude CIR aerial photographs were used to analyze vegetation patterns, identify water bodies, and examine land use. Black-and-white infrared photographs taken in 1972 were also interpreted. Extensive ground truth information was collected to support the image analysis. To determine the impact that the existing section of M-14 had made on surrounding soils, land use, vegetation, and surface hydrology, aerial photographs taken in 1970 were compared with those taken in 1958 and 1963 prior to construction. Results of the analyses were projected to the proposed alternate corridors for the M-14 extention, and the extent of environmental impact was extrapolated. It was concluded that probable changes in plant communities and water levels would occur, but there would be little change in either soil or land use.

remote sensing
aerial photography
color infrared photography
black-and-white photography
multispectral scanner
surface hydrology
highway
environmental impact assessment
vegetation analysis
soil
land use
Michigan

E-2 American Society of Photogrammetry. 1975. *Manual of Remote Sensing.* R. G. Reeves, Ed., Falls Church, VA. 2144 pp. 2 vol.

This work includes the collected efforts of 242 contributors in the field of remote sensing. Volume I of the *Manual* entitled "Theory, Instruments, and Techniques" in 867 pages provides a detailed examination of both the basic and the more technical aspects of remote sensing. Volume I is organized into 13 chapters as follows: 1. Introduction; 2. History of Remote Sensing; 3. The Nature of Electromagnetic Radiation; 4. Interaction Mechanisms; 5. Interaction Mechanisms Within the Atmosphere; 6. Photographic Systems for Remote Sensing

E-2 (cont'd)

7. Electro-optical Remote Sensors with Related Optical Sensors; 8. Imaging and Nonimaging Sensors; 9. Microwave Remote Sensors; 10. Platforms for Remote Sensors; 11. Communications for Imaging Systems; 12. Remote Sensor Data Systems, Processing, and Management; and 13. Ground Investigations in Support of Remote Sensing. Volume II, "Interpretation and Applications," of 1277 pages is organized into 13 more chapters: 14. Fundamentals of Image Interpretation; 15. Cartographic Presentation of Remote Sensor Data; 16. Terrain and Minerals - Assessment and Evaluation; 17. Forest Lands - Inventory and Assessment; 18. Range Resources - Inventory, Evaluation, and Monitoring; 19. Water Resources Assessment; 20. The Marine Environment; 21. Weather and Climate - Measurement and Analysis; 22. Crops and Soils; 23. Urban Environments - Inventory and Analysis; 24. Engineering - Regional Inventories, Corridor Surveys, and Site Investigations; 25. Regional Analysis; and 26. People: Past and Present. The *Manual* provides tables, figures, and both black-and-white and color photographs. Extensive bibliographies are given as is an extensive glossary of technical terms.

remote sensing
aerial photography
image analysis
automated data processing
remote sensor systems
applications
ground truth

E-3 Anderson, J. E. 1975. *Delineation of Forest Cover Types Based On ERTS-1 Multispectral Scanner Data.* M.S. Thesis, Forest Resources Dept., Penn. State Univ., University Park, PA. 75 pp.

Two classification algorithms (DCLASS and CANAL, both developed at Penn. State Univ.) were investigated for potential application to analysis of ERTS-1 MSS data for delineating forest cover types in an 8,100 ha. study area in central Pennsylvania. Both systems generate classification maps of selected printed symbols, each representing a particular ground target category. Two sets of single season data (Oct. 25, 1973 and May 16, 1973) and data merged from these two seasons were analyzed. Ground truth was determined from the aerial photography (altitude 12,600 ft.) with color and CIR transparencies, and from timber type maps from the State Bureau of Forestry. Color infrared transparencies were more useful than those in color. It was found that DCLASS, a Euclidian classification algorithm used to analyze untransformed MSS data, was of limited value, but it might be used for areas where vegetation is fairly homogeneous. CANAL, a canonical classification algorithm using transformed MSS data, resulted in accurate classification for both single season MSS data and for merged data. The discriminatory power of this approach is much greater than single Euclidian distance classification. CANAL is recommended for use in delineating forest cover types in areas with mountainous topography and/or heterogeneous vegetation.

remote sensing
ERTS-1 data
forest cover typing
algorithms
color infrared photography
multispectral scanner
ground truth
aerial photography
color photography
Pennsylvania

E-4 Anderson, J. R., *et al.* 1976. *A Land Use and Land Cover Classification System for Use With Remote Sensor Data.* USGS Professional Paper 964, USGS, Washington, D.C. 28 pp.

The organization of a land use and cover classification system for use with remote sensing information is discussed. The system has been designed to meet the needs of State and Federal agencies, and was developed with certain criteria: (1) the minimum level of interpretation accuracy from remote sensor data should be at least 85% (2) the degree of accuracy between categories should be about equal; (3) results should be repeatable and reproducible; (4) there should be flexibility enough to allow for seasonal data as well as different platforms. The system itself is a hierarchy of four information levels according to the data type (spaceborne, high, medium, and low altitudes). Level I has been structured into nine broad land use and cover categories with Level II having 37 subcategories. Levels III and IV, representing levels of more refined, precise, and accurate identification and classification, have been left open-ended to allow the user to tailor the system to his requirements. Extensive descriptions of the land use and cover types at Levels I and II are given. Also, a color coding system using Munsell notation is suggested for Level I maps.

land use classification
remote sensing
low altitude
medium altitude
high altitude
natural resources
cultural resources
aerial photography
land use
mapping
satellite sensing
LANDSAT

E-5 Anson, A. 1965. *Comparative Photointerpretation from Panchromatic, Color, and Ektachrome IR Photography.* in *Proc. 31st Annual Meeting American Society of Photogrammetry,* 33 pp.

In 1964 a cooperative project was undertaken by the Color Photography Committee of the American Society of Photogrammetry and the U.S. Army Engineer Geodesy, Intelligence and Mapping Research and Development Agency to compare photointerpretations from BW, color, and CIR aerial photography. An RC-130 aircraft furnished by the U.S, Air Force was used as a camera vehicle over the 30 $mi.^2$ Bennettsville, SC test area. A Fairchild KC-4 camera, equipped with a Geocon color corrected lens, was used for the BW photographs. A Wild RC-8, equipped with an Aviogon color corrected lens and an anti-vignetting filter, was used for the color and CIR photography. The aerial photography was obtained over a three week period at platforms of 2,500, 10,000, 20,000 and 30,000 ft. above mean terrain (AMT). After processing by the Coast and Geodetic Survey it was found that only the 10,000 foot aerial photographs were suitable for photointerpretation. Two photointerpreters prepared maps at the 1:20,000 photo scale for each of the following: drainage, vegetation, soils, and cultural features. Further, they analyzed 42 selected photopoints for which ground truth data had been collected on vegetation (tree height, diameter, spacing, species, and general ground cover), soil type, moisture content, and surface drainage. All interpretations, mappings, and analyses were

E- 5 (cont'd)

made over a six month period using the BW prints, color and CIR transparencies in that order. It was found that CIR aerial photos revealed the greatest amount of drainage detail and afforded a more rapid and accurate means than either BW or color. The confidence level for drainage interpretation was highest using CIR photos. The vegetation maps prepared from BW and color films were nearly identical; the ones from CIR showed almost twice the detail. Further, while only two classes of cropland could be mapped from BW and color, there were four classes with CIR. While the cultural maps from each film type were comparable, the photointerpreters found working with color and CIR to be more satisfactory in speed and confidence. Numerical analysis of the information from the 42 preselected photo points showed that CIR provided 22% greater correct responses than did BW; the color aerial photos compared favorably with the CIR. Recommendations for future similar studies included considerations toward controlled sensitometry; analysis of several test areas; and employing a group of two or more photointerpreters with similar experience and capability.

aerial photography
photointerpretation
black-and-white photography
color photography
color infrared photography
vegetation mapping
drainage analysis
soils mapping
South Carolina

E-6 Anson, A. 1970. *Color Aerial Photos in the Reconnaissance of Soils and Rocks.* Photogrammetric Engineering, 37(4):343-354.

The utility of color aerial photography in geologic and pedologic applications is discussed. Several controlled tests were conducted in eastern South Carolina and western Arizona to demonstrate the usefulness of color films. In June 1964, 1:20,000 scale aerial photography was conducted using three film types: BW, color, and CIR. A group of photointerpreters was asked to analyze the imagery types without ground truth and prepare drainage, vegetation, and soils maps. They concluded the CIR photographs afforded a rapid and accurate means of mapping not only drainage, but also moist soils. Discrimination of vegetation types was better with CIR than with normal color and BW. Soils maps prepared from the color and CIR photos provided the maximum number of detailed areas. The photointerpreters were also asked to identify 42 preselected photo points (ground truth provided by Army Map Service Engineers). The correct responses using CIR photos were 22% greater than with BW; also color provided a 20% higher accuracy than BW. In a second effort, cartographic cameras (Wild RC-8 and Fairchild KC-4) were operated simultaneously at 10,000, 20,000 and 30,000 ft. using BW, color, and CIR films. Analysis of the photographs from the three platforms required 48.5 hours (225 hrs. for 30,000 ft; 13 hrs. for 20,000 ft; and 13 hrs. for 10,000 ft). Features identified and recorded were soils, vegetation, landforms, drainage patterns, land use, surface materials, geology, and cultural features. At the time of this report, work was continuing to complete a detailed analysis of the study area.

E-6 (cont'd)

aerial photography
color photography
color infrared photography
black-and-white photography
reconnaissance surveys
soils
geology
mapping
Arizona
South Carolina

E-7 Anson, A. 1976. *Applications of Color and Multispectral Techniques.* Photogrammetric Engineering and Remote Sensing, 42(4):513-523.

The requirements for Military Geographic Intelligence are as broad and varied as the disparate elements of the terrain. The type of information required cannot always be extracted from conventional aerial sensors. With color aerial photography the dimension of hue is added to those of length, width, shape, texture, and shadow. A newly fabricated aerial cartographic camera with color correction capabilities (KC-4B) and equipped with Automatic Exposure Control is described. Another method of collecting aerial color photography, through the use of BW imagery by multiband combination, is discussed. Design and fabrication of the multiband camera is complete; a viewer is under contract. A third method for extracting color information from the terrain by color coding techniques which are used to make an optical record of the spectral reflectances is also discussed; preliminary results are given. The purpose of the entire program is to optimize the collection of color aerial photography for man-machine processing with maximum resolution. (Author)

aerial photography
camera
multiband photography
black-and-white photography
color photography
color infrared photography
sensor systems
multispectral photography

E-8 Avery, T. E. 1977. *Interpretation of Aerial Photographs.* 3rd ed. Burgess Publishing Co., Minneapolis, MN. 392 pp.

This text offers a basic course in aerial photograph interpretation. Products, techniques, camera systems, and various applications are described -- some in more detail than others. The book is organized into 15 major chapters: (1) Photography, Films, and Filters; (2) Orientation and Study of Aerial Photographs; (3) Photo Scale and Stereoscopic Parallax; (4) Stereograms, Shadow Heights, and Areas; (5) Flight Planning (including technical specifications for aerial photography); (6) Planimetric and Topographic Mapping; (7) Nonphotographic Imaging Systems; (8) Land Information Systems and Land-cover Mapping; (9) Prehistoric and Historic Archeology; (10) Agriculture and Soils; (11) Forestry Applications; (12) Landforms and Physiographic Features; (13) Engineering Applications and Mining Patterns; (14) Urban Industrial Patterns; and (15) Air Intelligence and Military Target Analysis. A glossary, conversion tables,

E-8 (cont'd)

and a sample short-course outline also are provided. Black-and-white photographs (some stereograms), figures, and tables are used liberally to illustrate the applications discussed. Some color plates are included. Also, where used in the text, measurements are given in metric uuits.

aerial photography
photointerpretation
education
black-and-white photography
color photography
color infrared photography
electromagnetic spectrum
geology
photogrammetry
flight planning
land use mapping
archeology
agriculture
soils
forestry
engineering

E-9 Cheeseman, C. E., Jr. 1973. *A Performance and Cost Analysis of Aircraft and Satellites for Operational Earth Resources Systems.* in *Proc. Symp. on Management and Utilization of Remote Sensing Data,* Sioux Falls, SD. pp. 1-16.

The development of an analysis system to determine aircraft and spacecraft cost and performance for surveying Earth resources is described. Twenty variables of user requirements, ranging from length and width of target in km., to number of spectral channels required, to maximum total elapsed time for accomplishing the sensing, are listed for inclusion in the model; each is described. A description of the spatial and temporal relationships of the carriers to target requirements is given and algorithms for obtaining values of the cost elements of the system are enumerated. The model was applied to two test cases, one involving imaging the United States every 18 days at resolutions between 2 and 5 m.; the other involved sun-synchronously imaging varying numbers of small (100 $km.^2$) targets evenly distributed over the U.S. with various resolution requirements. It was concluded that satellites require a substantially higher coverage rate than aircraft to become efficient; imaging the total U.S. (or a larger area) at anything but the highest resolutions is better done by satellite. At sub-U.S. levels, or with intermittent coverage, aircraft are likely to offer the better solution. Also satellites must be capable of looking obliquely to service small high resolution targets. Coupling an oblique-look capability with tuning of the orbit to provide both long and short term cycles of target coverage is recommended as a promising technique for satellite coverage of both scattered small targets and large contiguous areas.

remote sensing
cost effectiveness
aircraft sensing
satellite sensing
used requirement
test target
algorithm

E-10 Chren, W. A. 1975. *A Comparative Evaluation of Pattern Recognition Computer Algorithms for Remote Sensing Applications at ORSER.* M.S. Thesis, Elec. Engrg. Dept., Penn. State. Univ., University Park, PA. 172 pp.

The objective of this study was to compare analytically and experimentally the various remote sensing data analysis programs developed at the Office for Remote Sensing of Earth Resources (ORSER) at the Pennsylvania State University. General discussions of pattern recognition and remote sensing are given, followed by detailed descriptions of the ORSER computer software. The actual processing strategies were tested by applying them to ERTS multispectral scanner (MSS) data. Nine land classes were determined from low altitude CIR photographs at a scale of 1:31,200. These served as a source for ground truth information. In a further study, a CIR photograph taken by SKYLAB served as ground truth for the ERTS data. All analyses were conducted with seasonally compatible data. Preprocessed MSS data resulted in the most accurate classification (91%). Other unpreprocessed classifiers resulted in accuracies of 76 to 87%, and some classifiers were more accurate than others for certain land classes.

automatic classification
pattern recognition
ERTS
color infrared photography
aerial photography
remote sensing
SKYLAB
computer program
ground truth
data analysis
Pennsylvania

E-11 Coggeshall, M. E., R. M. Hoffer, and J. S. Berkebile. 1974. *A Comparison Between Digitized Color Infrared Photography and Multispectral Scanner Data Using ADP Techniques.* The Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, IN. LARS Info. Note 033174. 13 pp.

High altitude (60,000 ft.) CIR aerial photographs were compared with MSS data using ADP techniques in correctly classifying six land use types (deciduous and coniferous forests, water, and forage, corn, and soybean crops). A NASA RB-57 aircraft was used to collect 1:120,000 aerial photographs. The MSS on the ERIM aircraft was used 22 minutes later at an altitude of 5,000 ft. The test area comprised some 6,400 a. and was about 60% forested. The CIR transparencies were subjected to a color separation process which resulted in three BW transparencies which, in turn, were digitized using a scanning microdensitometer with a 50 μm perture. The MSS used had twelve channels, but only the three approximating the wavelength sensitivities of the CIR film were used (.52 to .57 μm, .61 to .70 μm, and .72 to .92 μm). Using a computer operated image analysis system, 62 training samples were selected from the MSS digital data to develop the classification criteria as were 58 from the CIR digital data. Overall correct classification for the six land classes was 80.5% for the three MSS channels and only 47.5% for the CIR data. There was

E-11 (cont'd)

a significant amount of classification confusion with the CIR data, while there was good separation with the MSS data. Results suggested a greater potential for accurate identification of terrain features using MSS data with ADP techniques than using digitized, multiemulsion CIR aerial photography. This can be best explained largely by the greater dynamic range and higher spectral resolution of the scanning system. The authors also noted that more accurate classification results were achieved by using other combinations of the MSS channels.

color infrared photography
multispectral scanner
automated data processing
aerial photography
high altitude
spectral resolution
image analysis
digital image
algorithm
classification

E-12 Drackett, K. T., W. D. Gregg, and J. Bale. 1975. *Practical Applications of Low, Medium, and High Altitude Aircraft Remote Sensing Data to Land Use Planning.* in *Remote Sensing of Earth Resources*, 4:203-231. Tenn. Space Inst., Tullahoma, TN.

A land use inventory program should incorporate three distinct data sources to provide accurate information for planning purposes: (1) remote sensing imagery; (2) field surveys; and (3) collateral data. Remote sensing imagery can be grouped into three classes: small scale ($\leq$1:60,000) for state, regional and other broad-scale applications; medium scale (1:60,000 to 1:12,000) for county wide and moderately detailed studies; and large scale ($\geq$1:12,000) for detailed surveys or for specialized problems. Each scale offers particular advantages and disadvantages for different types of applications. Field surveys, or ground truth, provide supportive data for the land use inventory. Preliminary photointerpretation will increase familiarity with the study areas and decrease the amount of field survey time required. Field surveys also include observations made from light aircraft and helicopter. Collateral data is defined as qualitative and quantitative information extracted from previously compiled data which serve as inputs to the land use inventory. Collateral data can often be difficult to collect and manipulate and should be used selectively. Four case studies demonstrating the use of various scales and types of remote sensing imagery in land use planning are presented. In Maryland, small scale NASA U-2 CIR aerial photographs were used to generate manuscript land use maps and digital land use data. A key aspect of this study was the utility of remote sensing as a planning tool in the early stages of a state wide land use inventory strategy development. In Louisiana, small scale NASA U-2 CIR aerial photographs were used to delineate wetlands and identify significant natural and cultural features in Jefferson Parish. Multidate low and high oblique photographs were used as a decision-making aid. In San Bernadino, California, medium and large scale CIR aerial photographs were used to prepare land use maps for regional planning and for electric power demand projections. And in New Castle County, Delaware, small scale CIR and large scale BW aerial photographs were used in the provision of

E-12 (cont'd)

land cover data for the identification of non-point water pollution sources and permeability coefficients to be incorporated in the EPA Sec. 208 program for the county. From the illustrations provided in the case studies, it was concluded that aerial photography plays important roles as a primary data source by providing inventory information during initial processes of goal formation or problem identification, a source for inventory data, a graphic base for information storage, a means of displaying data for communicative purposes, and as a monitoring device.

remote sensing
aerial photography
small scale
medium scale
large scale
color infrared photography
black-and-white photography
ground truth
collateral data
land use planning
land use inventory
California
Louisiana
Maryland

E-13 Elifrits, C. D. and D. J. Barr. 1978. *A Manual for Inexpensive Methods of Analyzing and Utilizing Remote Sensor Data.* Dept. of Mining, Petroleum, and Geologic Engrg., Univ. of Missouri-Rolla, Rolla, MO. 26 pp.

This manual is intended to serve as a guide to remote sensing equipment and interpretation techniques. Brief descriptions, often including approximate cost information, are given for different stereoscopes, light tables, additive and subtractive color viewers, transfer instruments, and drafting and cartographic equipment and supplies. Also, a brief discussion of the analysis of aerial photographs and LANDSAT imagery and their application in land use mapping engineering soils studies, geologic and water resources mapping, environmental impact assessment, and agriculture is presented.

remote sensing
imagery analysis
equipment

E-14 Enslin, W. R., S. E. Tilman, R. Hill-Rowley, and R. H. Rogers. 1977. *A Procedure for Merging Land Cover/Use Data from LANDSAT, Aerial Photography, and Map Sources: Compatibility, Accuracy, and Cost.* Bendix Aerospace Syst. Div., Ann Arbor, MI. 10 pp.

Aerial photograph, map, and satellite sensor data sources: each has advantages and limitations in the development of land use/cover information for regional planning purposes. Automated data processing (ADP) of LANDSAT MSS data is a fast, low cost, method of producing general land cover maps and tabular data. Conventional interpretation of and information extraction from aerial photographs and existing resource maps is a more time consuming and expensive procedure than is ADP of MSS data, but usually provides a more detailed classification with a higher level of accuracy and reliability. An

E-14 (cont'd)

ideal Natural Resource Information System (NRIS) would involve a structured merging of information from LANDSAT, aerial photographs, and maps. A 13-task program for producing geoencoded land use/cover maps from computer processing of LANDSAT data is discussed, as is incorporating additional information derived from aerial photographs and maps. The requirements are: (1) land use classification with at least an 85% accuracy; (2) identification of additional categories or of higher accuracy not achievable with LANDSAT; and (3) evaluation of the accuracy, time and cost associated with applying the integrated inventory. Such a study is being undertaken in Michigan using the U.S. Geological Survey Land Use Classification System. The overall theme in developing land use maps by merging data sources is to identify a combination of data sources and procedures that provide a more detailed, accurate, and cost effective land cover/use inventory compared with deriving all the data from a single source.

aerial photography
LANDSAT
automated data processing
resource inventory
land use inventory
mapping
classification accuracy
efficiency
Michigan

E-15 Estes, J. E. and L. W. Senger, Eds. 1974. *Remote Sensing: Techniques for Environmental Analysis.* Hamilton Publishing Co., Santa Barbara, CA. 340 pp.

This book is a collection of papers from various disciplines of remote sensing. The text includes 12 chapters each by a different author, and addresses the state of the art of remote sensing applications. It was not organized to serve as a comprehensive text in remote sensing. The 12 sections, each preceded by a synopsis, are as follows: (1) Developing Geographical Remote Sensing; (2) Imaging with Photographic and Nonphotographic Sensor Systems; (3) Quantitative Data Extraction and Analysis of Remote Sensor Imagery; (4) Remote Sensing of Natural Resources; (5) Geomorphic-Geologic Mapping from Remote Sensors; (6) Interpretation and Mapping of Natural Vegetation; (7) Interpreting Land Use from Remote Sensor Imagery; (8) Remote Sensing of Agricultural Resources; (9) Urban Applications of Remote Sensing; (10) Remote Sensing Techniques and Urban Data Acquisition; (11) Regional Analysis and Remote Sensing; and (12) Remote Sensing and Evvironmental Quality: Problems and Potential. A brief glossary of remote sensing terms is given in the appendix as is an extensive bibliography. Also, U.S. institutions and organizations engaged in remote sensing related activities are listed.

remote sensing
environmental analysis
geography
sensor systems
natural resources
geology
computer processing
vegetation mapping
land use
agriculture
urban analysis
regional analysis
image analysis

E-16 Cold, D. P., S. S. Alexander, and R. R. Parizek. 1974. *Application of Remote Sensing to Natural Resource and Environmental Problems in Pennsylvania.* Earth and Mineral Sciences, 43(7):49-53.

Examples of geological applications of LANDSAT data in Pennsylvania are given. Specific attention was given to geologic structures, linear features, hydrogeologic and engineering studies, ore deposits, and strip and acid mine drainage. Using a LANDSAT mosaic for the state, researchers at ORSER demonstrated the capability of certain MSS channels to depict geological phenomena. Bedrock structures were well defined on midwinter scenes from band 7, while band 5 imagery at a scale of 1:250,000 depicted the contacts of some lithologic boundaries in eastern Pennsylvania to a positional accuracy of ±400 m. In combining the information derived from LANDSAT imagery, aerial photography, and field studies, six scales of linear features were recognized. Other examples and a general description of remote sensing techniques and the electromagnetic spectrum are given. In comparing the cost and manpower requirements needed to compile a statewide mosaic of imagery from various sensor platforms, it was found that LANDSAT coverage would require only 14 frames, take 1.5 man-years, and cost only $75,000; low altitude (6,000 to 10,000 ft.) aerial photography would involve 20,000 frames, 44 man-years, and $1,000,000. With a 9" by 9" frame format, the scales of each respective imagery type would be 1:1,000,000 and 1:12,000.

remote sensing
geology
cost effectiveness
LANDSAT
multispectral scanner
high altitude
aerial photography
low altitude
Office for Remote Sensing of Earth Resources
Pennsylvania

E-17 Haas, R. H. and M. C. McCaskill. 1972. *Use of Large-Scale Aerial Photography in Obtaining Vegetation Information for Urban Planning.* Remote Sensing Cntr., Texas A&M Univ., College Station, TX. Tech. Rept. RSC-39. 43 pp.

A cooperative arrangement was established between personnel of the Vegetation Systems Laboratory (VSL) at Texas A&M University and George Mitchell and Associates, Inc. in 1971 in order to perform vegetation analysis via remote sensing techniques. A key objective of the study was to perform comparative evaluations of large scale (1:6,000) BW, color, and CIR aerial photographs in forest vegetation typing. This was accomplished through the interpretation of each of the imagery types and the compilation of various vegetation maps for Woodlands-Phase 1 development area in southern Montgomery County, Texas. Color aerial photography was flown over the test area in February 1970; both BW and color contact prints were made from this film. A CIR aerial photography mission was conducted in November 1971 over eleven 0.5 a. validation sites cruised in November 1971. Overstory and understory species

E-17 (cont'd)

were catalogued. A study of these plots using all three photograph types indicated that certain land features could be distinguished equally well on all three; these features included: (1) water, (2) bare ground, (3) ground covered with litter, grasses, and forbs, and (4) overall forest vegetation. The primary weakness of BW was the poor differentiation between evergreen understory and shadow, and overstory separation was limited largely to differentiation between coniferous and deciduous types. Color imagery satisfactorily permitted shadow/vegetation differentiation and separation of overstory into similar morphological and phenotypic groups. Interpretation of CIR aerial photos provided more accurate information than did either of the other two imagery types; it further permitted species identification (especially with hardwoods); contributing factors included (1) the fact the CIR transparencies were used as opposed to BW and color prints which improved contrast and resolution, (2) CIR provides a better spectral separation, and (3) the CIR aerial photography was conducted in a season when the trees were in leaf whereas the color and BW were not. Based upon the results from the applications of BW, color, and CIR in the preliminary study areas, CIR and color were used to conduct a vegetation strata study of the Woodland-Phase 1 area (approx. 6,232 a.). The canopy and understory surveys made with CIR appeared to be more reliable than those made with color. In comparing the vegetation identifications made through interpretation of the CIR aerial photos with ground truth information, it was found that similar morphological or phenotypic groups were identified with 93% accuracy while species, a more detailed level of identification, were 77% correct.

aerial photography
black-and-white photography
color photography
color infrared photography
vegetation analysis
forest inventory
forest cover typing
Texas

E-18 Hill-Rowley, R., M. Boylan, W. Enslin, and R. Vlasin. 1975. *Improved Resource Use Decisions and Actions Through Remote Sensing.* in *Proc. NASA Earth Resources Surv. Symp.* I-C:1747-1767, Houston, TX.

Studies conducted at Michigan State University on applications of remote sensing to improve management decisions on resource uses are described. Applications are divided into two categories: (1) first generation -- direct action applications, and (2) second generation -- indirect, delayed action, multifaceted applications. Making such a distinction is crucial for justifying proposed undertakings, research design, methodology requirements, budget allocations, etc.. From activities completed in 1974-75, seven case studies are reported upon: (1) multi agency river basin planning, (2) corridor assessment for highway routing and improvement of county level planning decisions, (3) developing improved timber management practices, (4) enforcement of a recently enacted Soil Erosion and Sedimentation Control Act. (5) measures and procedures for local implementation of the new Farmland and Open Space Preservation Act, (6) appraisal standards for land value assessment, and (7) optimizing agribusiness processing plant locations. Cases 1 and 2 are

E-18 (cont'd)

second generation type, case 3 is a combination, and cases 4-7 are first generation type. Color infrared photographs at several scales from a variety of sources was used in the studies and personnel from the user agencies were included as participants. It was concluded that remote sensing provides solid, timely, relevant comparative intelligence on land, vegetation and water characteristics developed on a unified, regional basis. It will be a matter of routine to update and expand such systems. In case study 2, a dual product consisting of a general 24 category land cover inventory and a 34 group special environments classification was developed. The latter group provides information about prime agricultural lands, wetlands, steep slopes, forested areas, critical soil conditions, and areas of prominent social values including: (1) developed, commercial, residential and industrial areas, (2) scenic areas, (3) historic areas, (4) unique wildlife areas, and (5) precious wilderness areas. Inventory data were derived from 1:36,000 CIR imagery using a four hectare grid and recorded on computer coding forms especially designed so that up to six land cover and seven special environment codes could be recorded for each cell. A specific location indicator was assigned to each cell. The data were used to plan highway corridor locations with low environmental impact. The land cover inventory and particularly the special environment identifications allow a tremendous variety of corridor options to be derived and made available for effective local discussion and evaluation.

remote sensing
color infrared photography
river
water resources
highway corridor selection
highway planning
forestry
land cover
environment
statute enforcement
open space planning
tax assessment
land value
Michigan

E-19 Hootsy, J. R. 1973. *A Preprocessing and Classification System for Remotely Sensed Multispectral Scanner Data.* M.S. Thesis, Elec. Engrg. Dept., Penn. State Univ., University Park, PA. 177 pp.

Preprocessing of digital remote sensing data is discussed. Preprocessing, using statistical characteristics ascribed to the data, is described as a conversion of the raw digital data to facilitate the classification processes. Preprocessing includes functions such as data dimension reduction, noise suppression, scale corrections, radiometric corrections, etc. Various preprocessing techniques were used with four supervised ORSER classification programs. Evaluations were made using different combinations of 13 channels of MSS data from the University of Michigan scanner system. Color and CIR aerial photographs provided ground truth and information for selecting classes and training samples. It was concluded that, although generally slower, quadratic

E-19 (cont'd)

discriminant functions provided better class boundary detection than linear functions. Further, data treated by preprocessing resulted in better classification results than did data not so treated.

computer program
multispectral scanner
pattern recognition
linear discriminant
remote sensing
algorithm
aerial sensing
color photography
color infrared photography
cluster analysis

E-20 Jeter, F. P. 1975. *The Color Negative as a Multi-purpose Tool.* Photogrammetric Engineering, 41(8):1003-1004.

The Oregon State Highway Division (OSHD) has been increasing its use of color aerial photography. A prime reason for this is the fact that color film diapositives increase mapping quality and efficiency because of ease in their interpretation; with color, shadows do not appear so dense as in BW and there is more detail in the lighter areas, resulting in some increase in vertical accuracy. Color infrared film positives have been found to be a good medium for hydrological studies and in urban areas with industrial haze. However, CIR was not a good medium for contouring where tree cover exists. Experience has shown that the color negative can serve as a multipurpose tool to be used in mapping, color contact print or enlargement production, as well as for BW contact prints or enlargements. In fact, results demonstrate that color negatives can be used to generate higher quality half tone film positive enlargements than can be made from BW negatives. On the average, the total cost of color aerial negatives is about 30 to 80% higher than BW. Also, color enlargements are about \$4.25 to \$7.25/ft.$^2$, whereas BW enlargements are \$1.50/ft$^2$. The present mapping program of OSHD includes the use of color aerial photography whenever weather conditions permit; however, it is noted that the increased cost of color over BW must be justified for each mission.

aerial photography
color photography
black-and-white photography
mapping
color infrared photography
cost
Oregon

E-21 Keifer, R. W. 1971. *Effects of Date of Photography on Airphoto Interpretation.* Remote Sensing Program, Dept. of Civil Engrg., Univ. of Wisconsin, Madison, WI. Report No. 9. 24 pp.

The effects of date of photography on photointerpretation using color and CIR films are illustrated in this paper. Examples of soil studies and flooding studies have been emphasized. More than 3,000 exposures of color and CIR film on 35 mm format were taken of selected sites in southern Wisconsin during 1969 from elevations of 2,000 to 8,000 ft. above terrain. The subject matter

E-21 (cont'd)

included rural terrain (cropland, grazing land, and woodland), lakes (showing weed and algae growth), and river flood plains (showing river flooding and subsequent crop damage). Some photographs taken to study soil and floods are described. Certain intensive study sites were photographed on as many as 20 different dates during the year. The striking changes in texture, tone, and color that occur from day to day and month to month at selected sites are illustrated. Study of the original color and CIR transparencies lead the author to conclude that: (1) color film is superior to CIR film for revealing differences in soil color, especially the color of relatively dry soils with low crop cover; (2) CIR film is superior to color film for revealing soil moisture differences; (3) CIR film is superior to color film for revealing subtle differences in vegetation type and vigor that may be caused by differences in soil type or moisture content. The results of this research show that there are certain dates during the year for the procurement of best aerial photography for interpretive uses and that the date of photography may not be the same for all interpretive uses. Most of the illustrations contained in this paper are oblique aerial photographs. A critical examination of vertical stereo aerial photography taken for the purposes described should enable more precise evaluations and conclusions about the effects of data of photography on photointerpretation. The author suggests that further studies along this line include the use of vertical stereo aerial photography using color and CIR films.

aerial photography
color infrared photography
black-and-white photography
color photography
seasonal imagery
Wisconsin

E-22 Keifer, R. W. 1972. *Sequential Aerial Photography and Imagery for Soil Studies.* Remote Sensing Program, Univ. of Wisconsin, Madison, WI. Rept. No. 10. 25 pp.

A study area a few miles west of Madison, WI, was selected as a site in which to contrast the soils interpretations made from different types of aerial imagery taken on several dates. Black-and-white aerial photographs taken on June 15, 1962 and June 4, 1968 were acquired from the Agricultural Stabilization and Conservation Service (ASCS); the author conducted 30 aerial photographic missions from May 1969 through September 1971 using both 35 mm. color and CIR films. Additionally, thermal infrared (IR) imagery was collected on 8 different dates in September 1971, using a Texas Instruments RS-310 scanner. The 35 mm. photography was conducted with Minolta SRT-101 and motor driven Nikon-F cameras. The soil features of particular interest included a beach ridge, consisting of fine sandy loams underlain by sandy materials, and surrounding lakebed soils of silt loams with a seasonally high water table. The BW reproductions of the color and CIR photographs demonstrate that the beach ridge and lake bed soils are more clearly emphasized on particular dates.

E-22 (cont'd)

The author concluded that the best times of the year for conducting soil studies in southern Wisconsin via aerial photography appeared to be May 1 to June 15 and September 1 to 30. The IR imagery, along with proper radiometric ground truth, appeared to be able to depict temperature differences as small as 2°F. The apparent temperature of the beach ridge was 63°F and that of the lake bed soils about 58°F. On the imagery, the warmer sandy ridge can be clearly distinguished from the cooler, wetter, silty lake bed soils. Further, this difference was more dramatic on daytime thermal IR imagery due to the differential thermal heating by solar radiation. From these observations, the author concluded that aerial thermal IR imagery may be a better sensor than aerial photography (color or CIR) for soil type mapping and evaluation.

aerial photography
color photography
color infrared photography
thermal infrared imagery
seasonal imagery
soils
soil mapping
Wisconsin

E-23 Kiefer, R. W., S. D. Johnson, and A. W. Voss. 1975. *A Computer-based Remote Sensing Literature Cataloging System.* in *Remote Sensing of Earth Resources*, 4:675-690. Univ. of Tenn. Space Inst., Tullahoma, TN.

An inexpensive computer assisted system for the storage and retrieval of remote sensing information developed at the University of Wisconsin at Madison is discussed. At the time of this publication, approximately 1,000 articles, mostly from *Photogrammetric Engineering*, were classified in four ways, according to: (1) platform; (2) remote sensing techniques; (3) sensor type; and (4) application. There are 9 platform categories, 8 technique categories, 24 sensor categories, and 72 application categories. Each bibliographic entry in the system includes the following: (1) author and title; (2) identification number; (3) platform code (two possible); (4) technique code (two possible); (5) sensor code (three possible); and (6) application code (three possible). The user prompted computer program is primarily a sorter and lister and does not perform cross referencing in reference retrieval. The coding lists used are presented in the report.

remote sensing literature
information storage and retrieval
computer program
Wisconsin

E-24 Leupold, R. C., R. P. Herbst, J. B. Mathies, and R. J. Kohut. 1978. *Use of Color Infrared Aerial Photography for Documenting Baseline Vegetation Stress in Environmental Impact Assessemnt.* in *Proc. Symp. Remote Sensing for Vegetation Damage Assessment*, Seattle, WA. pp. 369-380.

Aerial photography is widely utilized in preparing vegetation maps for environmental impact assessments. Low altitude CIR aerial photography provides excellent species differentiation for mapping plant communities and can be effectively used for documenting preoperational vegetation stress. Analysis of CIR photos increases the efficiency of field survery attempting to document existing stress over large areas. Based on our studies in the Northeast, Midwest, and Southeastern United States, CIR photography at scales of 1:7,200 to 1:12,000 can he used to detect insect outbreaks, tree disease, frost damage, weed competition, and crop planting success. Studies have included annual monitoring to survey the development of stress. This paper discusses the resolution of CIR positive transparencies based on stereoscopic interpretation at magnification ranges of 1.5 to 9X. Classification of stress types are present in evaluating the effectiveness of remote sensing. Other environmental conditions evaluated by remote sensing, such as soils, erosion, drainage, flooding, and water turbidity aid in understanding existing stress or assessing impact. When correlated with existing and predicted air quality, CIR photos provide a data base for assessing emission impacts. (Authors)

aerail photography
color infrared photography
large scale
vegetation stress
vegetation analysis
air pollution
environmental impact
field studies
citrus crops
insects
Florida

E-25 Link, L. E., Jr. 1976. *Procedures for the Systematic Evaluation of Remote Sensor Performance and Quantitative Mission Planning.* U.S. Army Engr. Waterways Exp. Sta., Vicksburg, MS. Tech. Rept. M-76-8. 287 pp.

Techniques for quantitatively evaluating photographic and thermal IR remote sensor systems are presented. The models include considerations of the source of electromagnetic radiation, atmospheric interactions, sensor altitude, time of day and year, latitude, sensor spectral and spatial characteristics, and feature and background spectral reflectance or emittance characteristics. A detailed explanation of the theory behind the photographic and the thermal IR models is given. Each model can be implemented by using either a computer program or nomograms. The computerized version was written in Fortran IV language. A discussion of the operation of and the inputs to the program is provided. A detailed description of the nomogram construction procedure is also given. In the photographic sensor system model, BW, black-and-white IR, color, and CIR films, with various filter combinations, can be evaluated.

E-25 (cont'd)

The main output of this model is a feature/background contrast value which is a measure of how well images of features can be separated using the various film and filter combinations.

remote sensing
remote sensors
black-and-white photography
color photography
color infrared photography
thermal infrared scanner
remote sensor system evaluation
mathematical model
computer program
nomogram
electromagnetic spectrum

E-26 Mairs, J. W. 1976. *The Use of Remote Sensing Techniques to Identify Potential Natural Areas in Oregon.* Biological Conservation, 9:259-266.

In July 1974, a joint project between Oregon's Natural Area Preserves Advisory Committee and the Environmental Remote Sensing Applications Laboratory at Oregon State University was begun to provide a vegetation resource inventory of potential natural areas within state owned lands in selected Oregon counties using remote sensing techniques. The search for potential natural reserves with varied environments can be both time consuming and costly. Therefore, high altitude (20 km.) U-2 aircraft CIR aerial photographs were used to provide analysts with a synoptic view of the study areas, except for small strips in northern and western Malheur County where imagery was not available. The survey of the 208,400 ha. of state owned land was done by interpreting 1:130,000 CIR film positives on a light table with the aid of an 8X magnifying lens. Criteria used to identify or eliminate a site as a potential natural area included: degree of vegetation modification or disturbance; character of the vegetation; dominant species; and other environmental factors such as the presence of natural water features of scenic landforms. Field checks requiring 15 days were conducted to clarify uncertain photointerpretations. The survey required about 1,000 man-hours over a seven-month period. One hundred-five units having a total area of 25,700 acres were catalogued as potential natural areas. Plant communities were identified in environments ranging from moist coastal headlands to dry salt deserts. The suitability of high altitude CIR aerial photography in conducting such a survey is discussed.

aerial photography
high altitude
small scale
color infrared photography
vegetation inventory
environment
natural area
Oregon

E-27 May, G. A. 1976. *Use of LANDSAT-1 Digital Multispectral Scanner Data for Land Cover Mapping.* Ph.D. Thesis Agron. Dept., Penn. State Univ., University Park, PA. 117 pp.

Nine watersheds within the Susquehanna River Basin of southeastern Pennsylvania served as the test areas for determining the applicability of automatic data processing (ADP) of LANDSAT MSS data in regional land cover mapping. LANDSAT MSS digital data were acquired for the study areas in October and July 1973. The image processing facilities at ORSER were used to derive computer generated land cover maps which delineated major categories such as bare soil, stubbleland, hayland/grass, woodland, urban areas, disturbed lands, and water bodies. Ground truth was provided primarily by topographic quadrangles and aerial photographs. A Bausch and Lomb Zoom Transfer Scope was used to superimpose the "ground truth" on the computer classification maps. Overall, a 75% correct classification was realized by the ADP of the two -season, merged LANDSAT data. Only 68% correct classification was achieved using the October data alone. It was also shown that while mapping data sets provided better overall results, some categories were best classified by the single season characterization. The spectral group centroids in each of the four MSS bands were calculated for each land cover category to develop a spectral signature bank. The feasibility of applying signature extension (the transfer of predetermined signatures through space and time) was explored. In order to classify and map reliably and accurately, it was found that spatial and atmospheric variables must remain somewhat constant. Different types of computer generated maps were produced including line printed character maps as well as color coded maps, and at scales from 1:15,000 to 1:50,000. It was noted that the type and scale of classification map depends on the user's needs.

LANDSAT
multispectral scanner
automated data processing
digital imagery
computer mapping
computer program
spectral signature
land cover
mapping
ground truth
aerial photography
multitemporal analysis
signature analysis
Pennsylvania

E-28 McKim, H. L., C. J. Merry, S. Cooper, D. M. Anderson, and L. W. Gatto. 1975. *Applications of Remote Sensing for Corps of Engineers Programs in New England.* in *Proc. 10th Intl. Symp. Remote Sensing of Env.* ERIM, Ann Arbor, MI. 19 pp.

The utility of satellite, high altitude and low altitude aerial imagery was evaluated by the Corps of Engineers. The most significant contribution to date has been to increase confidence by more accurately estimating parameters used in models. Several new cooperative remote sensing programs addressing environmental and hydrologic problems were implemented by the Cold Regions Research and Engineering Laboratory and the New England Division of the Corps.

E-28 (cont'd)

The first objective of these programs was to determine the availability, type, scale and resolution required. The second objective was to show how remote sensing methods can be utilized to augment or update conventional procedures. For the analysis of LANDSAT data, imagery from each band was enlarged to 1:200,000 with a spatial resolution of 70 m. This imagery provided valuable information for site evaluation, definition of geologic lineaments and monitoring snow and ice accumulation and ablation. This information can influence design of new Corps facilities or on flood forecasting procedures. Skylab S190A (multiband photography), Skylab S190B (earth terrain camera), and RB-57/RC8 (high altitude aircraft) photographs were enlarged to 1:63,600 with resolutions of 25, 12.5, and 5 m. respectively. Using a modified version of the USGS land use classification system for use with remote sensing data, the CIR imagery was interpreted and land use categories delineated. The Skylab program has defined the detail of land use mapping that can be accomplished from the S190A and S190B photography. The results from the S190B imagery compared favorably with those obtained from high altitude aircraft photography. The LANDSAT S190A data products were not considered adequate for detailed land use mapping although the products were useful for rapid regional land use inventories. Low altitude aircraft photography (scale 1:33,600) was used to determine the location of materials at a potential dam construction site located on the St. John River in Aroostook County, Maine, approximately 30 mi. west of the town of Ft. Kent. A 335 ft. earthen dam will be designed primarily for hydroelectric power, with secondary use for flood control. The study showed that the material needed for construction of the earthen dam and dikes can be obtained within a six mile radius of the primary dam and four mile radius of the three dike sites. This should allow a large cost saving for transportation of material as compared to original design estimates. In another program, the effect of inundation at six New England flood control reservoirs was investigated. The effects of the 1973 summer flood were assessed from low altitude CIR photography and corroborative ground surveys. The extent and severity of tree damage was mapped and analyzed statistically. These results will be used by the Corps in the reservoir management program.

aerial photography
high altitude
low altitude
spaceborne sensors
satellites
multispectral
photointerpretation
remote sensing
LANDSAT
Skylab
land use
resolution
classification
reservoirs
flood control
New England

E-29 Merry, C. J. and H. L. McKim. 1976. *Applications of Remote Sensing in the New England Urban Studies Program.* in *Proc. of the Soc. Scientists Conf.:* 214-215. Memphis, TN.

A study was conducted to compare the accuracy and cost effectiveness of using aerial photographic techniques to derive data to be used in the STORM (storage, treatment, overflow runoff model) hydrologic model. These techniques were contrasted with the more conventional methods [not described] of the New England

E-29 (cont'd)

Division, U.S. Army Corps of Engineers in extracting information on (1) area ofwatershed, (2) land use type in watershed, (3) impervious surface area for a given land use type, and (4) curb length for a land use type. Photomosaics covering six selected 7-1/2 minute USGS topographic quadrangles in the Boston metropolitan area were prepared from NASA RB-57 RC-8 high altitude BW aerial photographs enlarged to a scale of 1:24,000. A total of six Level I, 17 Level II, and 18 Level III land use categories were delineated on the aerial photos, costing $2,890 for the six quadrangles ($0.014/a.) compared to $600 ($0.003/a.) for the conventional techniques. Watershed boundaries could not be determined from the imagery and had to be delineated and the areas measured from topographic maps. Impervious surfaces were mapped from low altitude aerial photography [1:3,500; type not given] for two selected sites. The results were comparable to those of the conventional method; a comparison of the cost effectiveness of the two methods was not possible because of insufficient data. More than 64% of all curbs in the Newton test site were identified on the low altitude photography. The cost of curb density mapping with photointerpretation was $0.899/a. compared to $1.200/a. by the conventional method of using residential density as an index. Although not always less expensive than conventional procedures, photointerpretation was recommended to derive data input for the STORM model because of (1) higher accuracy, (2) increased confidence, and (3) greater amount of detail.

| | |
|---|---|
| hydrologic modeling | cost effectiveuess |
| aerial photography | mapping accuracy |
| photointerpretation | low altitude |
| land use mapping | high altitude |
| watershed mapping | Massachusetts |

E-30 Miller, L. D., C. Tom, and K. Nualchawee. 1977. *Remote Sensing Inputs to Landscape Models Which Predict Future Spatial Land Use Patterns for Hydrologic Models.* Goddard Space Flight Center, Greenbelt, MD. NASA-X-923-77-115. 41 pp.

Landscape modeling organizes and overlays data from existing maps, analysis of remote sensing imagery, and tabular data into a computer framework. The overlays of map and image derived data provide a basis for computer simulation or modeling of the future spatial behavior of the landscape to anticipated natural events or human, activity. A typical application of such a procedure to hydrology is the prediction of future land use patterns of an urban area as input into the simulation of the urban hydrograph. The application of landscape modeling to the Denver, CO metropolitan area provides an illustration of this technique. A tropical forest area of northern Thailand provides a test case of the application of the approach in more natural surroundings. Combining the available remote sensing imagery with available map information in the landscape model provides a basis for substantial improvements in studies of land use and hydrology. Visual display of

E-30 (cont'd)

land use changes was accomplished by a cell by cell comparison of the use and cover categories as existed in 1963 and 1970. One technique discussed for the projection of future land use patterns is the Markov Trend Model, which assumes that future land use can be predicted, in the short run, by observations on recent past changes. Another method discussed is discriminant analysis, which considers the probability of land use change from one category to another on a cell by cell basis (*i.e.*, preserving spatial integrity). In the text, some attention is given to improved LANDSAT MSS image classification. Comparisons are made for classifications based (1) solely on the four MSS bands, (2) the four bands plus the six rations of these bands, and (3) inclusions of various combinations of other data planes (*e.g.*, census data, topography, freeway location, etc.).

land use modeling
hydrologic models
remote sensing
trend analysis
discriminant analysis
LANDSAT
image classification
land use classification
Colorado
Thailand

E-31 Poulton, C. E. 1972. *A Comprehensive Remote Sensing Legend System for the Ecological Characterization and Annotation of Natural and Altered Landscapes.* in *Proc. 8th Symp. Remote Sensing of Env.*, ERIM Ann Arbor, MI. 1:393-408.

An integrated legend system is presented for use in multistage earth resources inventory and land use classification. The program was developed by preparing a hierarchical classification and applying it to satellite imagery, and high and low altitude aerial photography. The broader categories are especially suitable to spaceborne and high altitude sensors, while the more detailed classes are for use with low altitude systems with their improved resolution. The detailed format for a comprehensive ecological legend includes information for: (1) gross resource and land use; (2) physiognomic type or secondary land nse; (3) specific ecosystem or detailed land use; (4) macro relief; (5) landform; (6) surficial geology; and (7) soil type or characteristics. Descriptions and symbols are presented for five of these classes. Suggestions are made as to how the other two (geology and soils) could be coded in a similar manner. A fault of the legend system, as noted by the author, is that it does not provide for direct assessment of sucb land uses (or activities) as grazing, forestry, watershed, wildlife productivity, aesthetics, or recreation.

land use
remote sensing
landscape
landform
ecology
soils
land cover
legend
resources inventory
land use classification
vegetation
geology
terrain analysis

E-32 Rambert, C. E. 1973. *Analog to Digital Conversion System for Multispectral Scanner Data.* M.S. Thesis Elec. Engrg. Dept., Penn. State Univ., University Park, PA. 104 pp.

The research described involved the design and use of a series of computer programs that would convert MSS data in its analog magnetic tape format to a computer compatible digital format (IBM/360, 9 track, 800 bpi). Eight-channel Bendix MSS data were used to create and test the programs. A hybrid computer, consisting of an EAI 680 analog computer and a DEC PDP-10 digital computer, comprised the processing system hardware. Processing the MSS data produces digital data output in ORSER format. The programs necessary to use this system are presented in appendices. The author concluded that the advantages of this hybrid conversion system over simple bulk digitizing are: (1) more precise pixel sampling; (2) variable output format; (3) no special equipment; (4) geometric corrections can be performed simultaneously with pixel sampling; and (5) preprocessing can be performed prior to signal conversion. Disadvantages cited are: (1) the hybrid system requires more hardware; and (2) better understanding of computer techniques is required than with a simple bulk digitizer.

automated data processing
computer program
analog computer
digital computer
multispectral scanner

E-33 Rinker, J. N. and R. E. Frost. 1966. *Environmental Analysis, Remote Sensing, and Education.* in *Proc. 4th Symp. on Remote Sensing Env.* Ann Arbor, MI. 2:709-711.

The criteria for efficient and accurate environmental analysis via remote sensing are discussed. Professional interest in remote sensing falls into three categories: (1) sensor systems engineering; (2) application of sensor systems for terrain analysis, delineation, target identification, etc.; and (3) environmental analysis in the broad sense. In systems engineering, a foundation in physics and mathematics, with specialization in other disciplines, is required. In the second category, emphasis must be placed on the applied natural and physical sciences. In the third category, a team effort is required with coordinated effort from individuals from the other two categories. The team approach to environmental analysis is emphasized because the various physical, natural, and cultural components of the environment are interrelated; the disciplines of geology, biology, geography, ecology, hydrology, etc., are man-made divisions of the environment. Therefore, while specialization is required to a certain extent, the ability of a remote sensing analyst to perceive the need for interacting with other disciplines is necessary.

remote sensing
education
environmental analysis

E-34 Rinker, J. N., J. Ehlen, A. E. Krusinger, T. R. Currin, A. O. Poulin, and P. B. McCracken. 1976. *Capabilities of Remote Sensors to Determine Environmental Information for Combat.* U.S. Army Engr. Topo. Lab., Res. Inst., Fort Belvoir, VA. Rept. No. ETL-0081. 242 pp.

U.S. Army Field and Technical Manuals were used to develop a list of 313 environmental information needs required by the Army to accomplish its various military tasks. Each item was evaluated against a list of remote sensing systems to determine the extent to which each system could provide the information. The systems evaluated were LANDSAT (ERTS), radar, thermal IR, low altitude oblique aerial photography, standard photo index sheets, and stereo 1:20,000 and 1:100,000 scale vertical aerial photographs. Each system was rated for its usefulness in identifying each of the environmental features. The evaluations also include the level of skill required to obtain the necessary information from the remote sensing imagery. Also, comments and discussion on the definition of factors, limitations with reference to both the factors and procedures, and possible use of other remote sensor systems are presented.

remote sensing
environmental analysis
combat
vegetation
hydrology
geology
terrain analysis
construction
utilities
agriculture
land use
urban environment
pollution
mapping
site analysis
military applications
remote sensor system evaluation
transportation

E-35 Robinove, C. J. 1972. *Remote Sensing in Geology, Hydrology, and Geography.* in *Proc. Intl. Workshop on Earth Resources Survy. Syst.* 1:55-66, Ann Arbor, MI.

Remote sensing from satellites and aircraft has many applications to the scientific disciplines of geology, hydrology, and geography. The feasibility of remote sensing for geologic purposes has been demonstrated by the discovery of significant areas for mineral exploration in the southwestern United States from space photographs, the delineation of rock structures favorable for oil and gas exploration, and the description of changes in landforms caused by geologic events such as volcanic eruptions and earthquakes. Hydrologic uses of remote sensing include the exploration for ground water in both arid and humid regions, the assessment with repetitive images of the status of perennial and intermittent lakes, the mapping of flooded areas, and the delineation of coastal and inland wetlands. Geography is both a discipline in itself and an integration of other disciplines. Geographic uses of remote sensing data include land use mapping in urban and rural areas, mapping of sequential changes in cultural features and their relation to the environment, and the

E-35 (cont'd)

synthesis of other resource information with geographic data to form information systems for management use. Basic and applied research in each discipline coupled with increasing operational use of space and aircraft collected remote sensing data in information and resource management systems will provide a future capability for better resource and euvironmental management. (Author)

remote sensing
aircraft sensing
satellite sensing
water resources
mapping
geology
hydrology
geography
mineral exploration

E-36 Rogers, R. H., J. B. Mckeon, L. E. Reed, N. F. Schmidt, and R. N. Schecter. 1975. *Computer Mapping of LANDSAT Data for Environmental Applications.* Bendix Aerospace Syst. Div., Ann Arbor, MI. 17 pp.

As part of the national effort to deal with water pollution, Sec. 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) provides regional planning agencies with the opportunity and funding to undertake regional water quality planning. A requirement of the 208 program is to predict water quality in the rivers and lakes resulting from existing and potential land use. To achieve this capability, the Triangle J Council of Governments (North Carolina) is developing deterministic models capable of predicting sediment and nutrient flow into the waterways. An essential input to these models is an accurate inventory of land cover within the watersheds of the region. Such an inventory was obtained for a 1,750 $mi.^2$ 208 study area through the computer processing of LANDSAT computer compatible tapes using the Bendix Aerospace Systems Division Multispectral Data Analysis System. Ten land cover categories were interpreted for the study area at a resolution of 1.1 a. These included three urban density categories, four forest types, agricultural-managed lands, bare soil construction sites, and water. The resulting products included color coded overlays for each of the 10 categories for a 1:96,000 scale base map (photographically enlarged from 1:576,000 computer-generaged film negatives), a color composite map of the same categories and scale, and a computer tape containing 54 quadrangles (7 1/2 minute) where each 50 m. grid cell was coded as to the 10 land cover types. The overall classification accuracy was estimated to be better than 90%. These taped data were aggregated into 10 a. grid cells and merged with soils and slope data to compute sediment and nutrient flows in the drainage areas. The complete inventory was accomplished within a period of 60 days at a cost of less than one cent per acre, a significant improvement in dollars and time over conventional photointerpretation and mapping techniques.

E-36 (cont'd)

LANDSAT
automated data processing
multispectral scanner data
computer program
computer
data analysis
land use inventory
water quality
Section 208
geometric processing
ground truth
North Carolina

E-37 Rogers, R. H. and S. E. Tilman. 1976. *A Strategy for Land Use/Cover Data File and Map Preparation.* Bendix Aerospace Sys. Div. Rept. BSR 4239. Ann Arbor, MI. 21 pp.

A conceptual framework for producing digital land use/cover files and maps is discussed. Developed to be used in coordination with studies associated with Sec. 208 of the 1972 Water Quality Act, the program suggests a plan for combining the results of ADP of LANDSAT data and manual interpretation of aerial photographs and maps. Designed to be used on a regional planning level, the system combines information form 14 land use and cover categories in matrices of 10-acre geocoded cells. Of those 14 types, 10 of the more homogeneous ones, such as rangelands, woodlands, water, and wetlands, would be delineated from LANDSAT information. The other categories requiring improved spatial/spectral resolution, such as commercial services, industries, transportation, communication, utility corridors, and tree and bush fruits, would be delineated by aerial photograph interpretation. A system for geocoding these data is presented. A series of 11 tasks, from ground truth acquisition to final color-coded map generation (at 1:125,000) and file creation is recommended.

land use
natural resources
resource inventory
aerial photography
digital image
LANDSAT
automated data processing
mapping
photointerpretation
georeferencing

E-38 Sellman, B. 1972. *High Altitude Aerial Photography as an Information Source for Urban Landscape Analysis.* in *Remote Sensing of Earth Resources*, 1:206-218. Conf. on Earth Resourc. Obs. and Info. Analysis Syst., Univ. of Tenn. Space Inst., Tullahoma, TN.

Photographic imagery (BW, color, and CIR) of a seven county region (4000 $mi.^2$) in southeastern Michigan collected from a NASA RB-57 aircraft at 60,000 ft. was evaluated for use in urhan landscape analysis. Photomosaics were prepared from the three kinds of imagery. Color rendition was not uniform across a full frame even though an anti-vignetting filter was used. Using just the central portion of a frame is recommended as in the use of band pass filters to separate color film positives into discrete monochromatic images. Wratten 61 (green) and 29 (red) filters were used to enhance images of residential development and vegetation detection, respectively. The broad coverage of high altitude photographs permits studies of the spatial setting of

E-38 (cont'd)

land use features. Some of the more important changes in urban structure can be detected readily. The quantity and quality of information in the imagery can be increased through color interpretations and the use of special processing techniques. The possibility of using filtered monochromatic negatives produced from a CIR film positive to determine approximate populations is discussed.

remote sensing
high altitude
color photography
urban environment
filter
black-and-white photography
color infrared photography

E-39 Shamburger, J. H. and H. K. Woods. 1975. *Application of Remote Sensors to Army Facility Management. Appendix B: Validation of Environmental Maps Produced Through Air-Photo Interpretation.* Mobility and Env. Sys. Lab., U.S. Army Engr. Waterways Exp. Sta., Vicksburg, MS. Tech. Rept. M-74-2. 40 pp.

Field studies were conducted to determine the accuracy of environmental maps produced through interpretation of BW aerial photographs [scale not given] taken in the Fort Belvoir, VA area in 1972. Data on vegetation type, height, and density, wildlife habitat, soil type, and six other factors were collected in 36 sample sites. In the analysis phase, the values on the single factor maps prepared using aerial photograph interpretation were compared with the overlays reflecting the field studies. Subjective evaluations showed that the original photomaps were fairly accurate but required a few minor alterations in line shifting, factor class change, and the addition of new areas. Factor maps are presented for all the features investigated. Generally, accuracies derived via photointerpretation were greater than 90%. In studying the relative expenses associated with gathering remote sensing data, it was found that panchromatic black-and-white IR aerial photographs, at 1:30,000 to 1:40,000, were the most cost effective ($2.00 to $4.50/mi.$^2$) of those investigated. Multispectral camera imagery acquired from 16,000 ft. was the most expensive ($30.00/mi.$^2$). It was noted, however, that data acquisition is only one component of the successful use and application of remote sensing methods. Other considerations include the type of probelm to be analyzed, the cost of ground control data, data manipulation, and information extraction and presentation.

environment
environmental assessment
remote sensing
aerial photography
natural resources
photointerpretation
black-and-white photography
vegetation
wildlife
mapping
cost effectiveness
Virginia

E-40 Sherz, J. P. 1972. *Final Report on Infrared Photography Applied Research Program.* Inst. for Env. Studies, Remote Sensing Prog., Univ. of Wisconsin, Madison, Wl. Rept. No. 12. 62 pp.

The feasibility of using special aerial photographic films for water pollution monitoring of the outfall from the U.S. Steel Mill at Calumet, IL was studied. Both color and CIR films were used. Laboratory tests were made on water samples taken at various points on both sides of a breakwater, on one side of which the waters received the steel mill outfall. Total solids, iron and phenol concentrations were measured. Reflectance analysis of these water samples was conducted with a spectrophotometer. The laboratory study indicated that there were apparent correlations between various concentration levels of total solids, iron, and phenols and the percent reflectance of the water samples. The films were tested with a microdensitometer. White styrofoam panels were compared with barium sulfate standards in terms of percent reflectance throughout the 0.4 μm to 0.73 μm range of the electromagnetic spectrum. There was a high degree of correlation; styrofoam was then adopted as the reference standard (100% reflectivity). Two methods were used to correlate water quality with photographic image reflectances: (1) absolute reflectance vs. pollution concentration and (2) ration of two wavelength reflectances vs. pollution concentration. It was concluded that the wavelength ratio method correlates well with pollution concentration. Two other areas investigated were (1) effects caused by lens falloff and angle of incidence and (2) depth penetration of various films. Differences in tone on either side of the U.S. Steel breakwater appeared more pronounced on color aerial photographs than on CIR. This was verified by the microdensitometric analyses. It was concluded that this was the case because color has more water "penetration power" than does CIR (*i.e.*, CIR film did not record tonal differences due to iron presence on either side of breakwater because the iron solids were up to 15 feet below the water surface). Another conclusion was that corrections must be made to raw microdensitometric data because of the effects of lens falloff and changes of angle of incidence with the water. An array of calibration panels throughout the sampling area would provide localized reference standards, however.

remote sensing
color photography
color infrared photography
reflectance standards
microdensitomer
depth penetration
water quality
reflectance curves
band ratioing
Illinois
Wisconsin

E-41 Smedes, H. W., A. K. Turner, and J. C. Reed, Jr. 1976. *Oblique Airphotos for Mapping, Educating Users, and Enhancing Public Participation in Environmental Planning.* in *Photogrammetry, Water Quality, Safety Appurtenances, and Shoulder Design.* National Res. Coun., Transp. Res. Board, Transp. Res. Rec. No. 594:1-5.

The utility of oblique color aerial photographs in various environmental planning procedures is discussed. In a study in Jefferson County, CO it was demonstrated that low altitude oblique aerial photographs could bridge the gap

E-41 (cont'd)

between on site observations and map representations. A citizens action group was organized to assist in the development of an open space program. User groups, consisting of citizens, were formed to play an integral role in the decision making processes. It was realized early in the study, however, that map and point information for natural and cultural parameters was not easily communicated to those laymen participating in the plan's development; maps and vertical aerial photographs used by professionals were found to be unfamiliar to users. Therefore, oblique aerial photographs were used to train the citizens in map comprehension by illustrating the relationship between real world phenomena and map content. After this initial bridge was crossed, the participants were introduced to computer mapping techniques; they agreed that the oblique aerial photographs contributed significantly to their understanding of maps of natural resources. Further, oblique color aerial photos were used to assist in environmental analyses and scenic evaluations. The cost of acquiring about 100 oblique color aerial photographs was $59.

oblique aerial photography
open space planning
mapping
education
public participation
cost effectiveness
Colorado

E-42 Simpson, R. B., R. S. Yuill, and D. T. Lindgren. 1972. *Urban-Field Land Use From RB-57 Photography: The Boston and New Haven Areas.* Proj. in Remote Sensing, Dept. of Geography, Dartmouth College, Hanover, NH. 84 pp.

This study reports on work undertaken between June 1971 and June 1972 on the use of high altitude RB-57 CIR aerial photography in the preparation of land use maps and computer data bases of the Boston and New Haven metropolitan areas. A prime purpose was to compare information derived from the aerial photographs with U.S. Census information. The photography used was primarily NASA RB-57 high altitude (50,000 to 60,000 ft.) CIR positive transparencies (1:100,000) acquired with a Wild RC-8 camera. The imagery was viewed over a light table with a stereoscope; however, frames were interpreted monoscopically. The land use classification scheme was taken from the EROS Atlas of Urban and Regional Change and included 12 different categories. Aerial photointerpretation of the New Haven area (nine topographic sheet equivalents) required seven man-weeks. Interpretations were coded at the 1/25 km.$^2$ cell level and put onto computer cards. Various computer graphic techniques were used to generate land use maps (water areas, multifamily and mixed residential, single family residential, industrial, commercial, transportation and utilities, institutional, recreational, agriculture, forest and vacant) in the Boston and New Haven areas. Comparisons were made between this digital data base and others from the northeastern United States. Studies correlating percentage of urban land use (5 km.$^2$ cell size) and transportation network

E-42 (cont'd)

characteristics in the Boston metropolitan area resulted in a regression model utilizing three transportation variables; the model had a correlation coefficient of 0.76 at the 0.01 confidence level.

land use
aerial photography
transportation
color infrared photography
high altitude
Connecticut
Massachusetts

E-43 Stephens, P. R. 1976. *Comparison of Color, Color Infrared and Panchromatic Aerial Photography.* Photogrammetric Engineering and Remote Sensing, 42(10):1273-1277.

This paper compares the ease of interpretation and the amount of information content of three types of aerial photography. Using a 35mm. Asahi Pentax Spotmatic Camera, the investigator [located in New Zealand] acquired panchromatic BW (Ilford F P4), color (Kodachrome X), and CIR (Kodak Ektachrome Infrared) aerial photography, all at 1:18,000. The film positives of these imagery types were assessed for ease of recognizing and identifying selected terrain features such as alignments, fault plug zones and seepage areas, eroded surfaces, erosion types and processes, vegetation types and condition, and drainage patterns. The BW photography was interpreted first, followed by the color, then the CIR; further, a one week lapse was allowed before moving from one imagery type to the next so that they could be evaluated as objectively as possible. CIR aerial photography was ranked highest; overall, color was second, and BW was rated third. In one instance, however, the analysis of drainage patterns, BW was equal or superior to either color or CIR. This was due primarily to the greater detail shown in shaded or partially obscured gronnd areas. It was concluded that, based upon costs and information contents, a combination of CIR and BW aerial photography provided best photointerpretive results with CIR being the best single sensor.

aerial photography
color infrared photography
color photography
black-and-white photography
vegetation stress
erosion
New Zealand

E-44 Tanner, C. E. 1977. *Guide to Preselection of Training Samples and Ground Truth Collection.* Env. Monitoring and Support Lab., Env. Protection Agency, Las Vegas, NV. EPA-600/7-77-100. 32 pp.

Automated data processing (ADP) of digital remote sensing imagery can be a cost effective method for image classification. However, to ensure accurate processing via pattern recognition techniques, training samples must be properly selected and adequate ground truth must be provided. Schemes are

E-44 (cont'd)

presented for the selection of training samples for both LANDSAT and aircraft multispectral scanner (MSS) data. In general, it was recommended that 36 training samples per class be chosen for each LANDSAT scene. A theoretical situation is presented for an aircraft MSS scene. Two criteria of training samples are that they be homogeneous and uniformly distributed. These samples should be selected initially from color, CIR, or BW aerial photographs. Field investigations of the training samples to be used in the ADP of the MSS data should be conducted to determine how well a preselected site actually typifies the class of interest. It was noted that such field verification may result in as much as a 20% attrition rate. Whether conducting conventional image analyses (*i.e.*, photointerpretation) or ADP image analyses, field studies are necessary to provide the analyst with the valid ground cover classification. Ground truth operations, although highly necessary, are usually expensive and are rarely performed properly. Techniques are outlined and a sample ground truth form is presented that permits collecting necessary field information efficiently and accurately.

aerial photography
multispectral scanner
automated data processing
training sample
classification
computer processing
ground truth
field studies
Northern Great Plains

E-45 Thompson, W. T. 1971. *Earth Survey Bibliography: A KWIC Index of Remote Sensing Information.* Transportation Systems Center, Cambridge, MA. Rept. No. DOT-TSC-NASA-70-1. 265 pp.

This bibliography contains 1,650 literature citations on remote sensing of earth resources. The bibliography is divided into three parts: (1) a listing of the bibliographic citations by an accession number; (2) a keyword-in-context (KWIC) index; and (3) an alphabetized author index. The KWIC index is a permuted title index generated through computer manipulation of citation titles. Keywords are extracted from the titles and an index is prepared automatically. A alphabetical keyword listing is generated with much of the title (or context) surrounding the keyword field. Information is provided on how documents can be acquired.

remote sensing
earth resources
bibliography
keywords

E-46 Valentine, K. W. G. and J. F. Hawkins. 1975. *A Quantitative Comparison of Color Photography and LANDSAT Imagery for a Small Scale Land Resource Map of Northern British Columbia.* in *Proc. 3rd Canadian Symp. on Remote Sensing*, 1:489-494. Edmonton, Alberta, Canada.

Thirteen soil surveyors produced a terrain map of an 800 mi.$^2$ area just east of Telegraph Creek in northern British Columbia. The mapping was done on three adjacent color photographs and a LANDSAT image for comparison. The percentage agreement with ground truth maps was measured and the time and cost calculated to estimate how accurately a small scale resource map of northern British Columbia could be made, how much it would cost, and how long it would take. There was nearly 60% agreement with ground truth on the photographs and about 50% on the LANDSAT image (using a simplified legend). Sources of bias in the results may mean that these figures are lower than absolute levels of accuracy attainable. The results were satisfactorily consistent between individuals on each image. Using photography (costing approx. $442,000) a 1:1 million resource map of northern British Columbia would take 4 1/2 years to produce. Using LANDSAT imagery enlarged to 1:500,000 (costing about $2,000) with a simplified legend, a map could be produced in six months. The latter alternative is recommended. (Author)

aerial photography
color photography
LANDSAT
ground truth
color composite
terrain analysis
cost effectiveness
British Columbia
Canada

E-47 VanGenderen, J. L., B. F. Lock, and P. A. Voss. 1977. *Testing the Accuracy of Remote Sensing Land Use Maps.* in *Proc. 11th Symp. Remote Sensing of Env.* ERIM, Ann Arbor, MI. 1:615-623.

A technique for ground truth sampling and data analysis is discussed for testing the accuracy of land use and cover maps prepared from remote sensing imagery. The main aspects considered in designing the remote sensing sampling procedure included: (1) the frequency that any one land use type is erroneously classified into another category; (2) the frequency that the wrong land use is erroneously included in any one class; (3) the proportion of all land incorrectly classified; and (4) the determination of whether or not classification errors are random. A stratified sampling technique was selected over a strictly random sampling procedure so that smaller areas and infrequently occurring land use types would be adequately sampled. The major difference between the two approaches is that stratified sampling considers each land use category, or stratum, as an independent subsample in which random sampling is employed. Purely random sampling of an entire study area does not break the area into separate groups. Within each stratum, random sampling points are selected on the basis of a random number generator and some corresponding grid referencing system. Probability statistics show that in order to achieve an 85% overall accuracy in the land use and cover classification

E-47 (cont'd)

map, at least 20 sample points per category are required. For a 90% level, at least 30 such points are needed, and better than 60 for a 95% accuracy. Contrasting ground checked land use of sampling points with the categories derived from remote sensing will permit an estimation of: (1) the correct and incorrect classification (matrix) of individual categories (2) the overall correctness of the entire land use map and (3) trends in the misclassification of certain land use and cover types.

remote sensing
land use mapping
classification accuracy

E-48 Way, D. S. 1973. *Terrain Analysis: A Guide to Site Selection Using Aerial Photographic Interpretation.* Dowden, Hutchinson, and Ross, Inc., Stroudsburg, PA. 392 pp.

Terrain analysis is defined as the identification and interpretation of landforms resulting from geological processes. A sytematic approach to terrain analysis is presented for use by planners in analyzing natural systems and making decisions. The approach is interdisciplinary with discussions of general geology, soils, rock types, glacial, fluvial, and aeolian landforms. Numerous graphic examples are giveu by use of figures, maps, and BW aerial photograph stereo models. Specific issues of site development, including sewage disposal, excavation and grading, soil compaction, highway construction, and other areas, are discussed briefly. Also, various remote sensor systems are described and sources for aerial photographic information are given.

terrain analysis
photointerpretation
aerial photography
resource mapping
glacial landforms
identification
geology
soils
land cover
remote sensing
fluvial landforms
interpretation

E-49 Weeden, H. A. and N. B. Bolling. 1975. *Reconnaissance Mapping from Aerial Photographs.* ORSER/SSEL, Penn. State Univ., University Park, PA. Tech. Rept. 17-75. 18 pp.

A technique for reconnaissance mapping as opposed to "spot problem" mapping of rock and soil is presented. Five terrain parameters were used to describe the mapping units and fully describe the three basic situations of rock dominated, soil dominated, and intergrade landscapes. These five include: soil texture, slope, water table position, depth to bedrock, and special features (strike and dip, landslide areas etc.). It was concluded that: (1) aerial photo analysis to determine soil texture is not feasible because of

E-49 (con't)

the fine grading system and requires field and/or laboratory analysis; (2) degree of slope can be derived directly from an aerial photograph stereo model; however, refinement and accuracy is a function of the photo analysis equipment used as well as the experience of the photointérpreter and mappings should be checked against existing topographic maps; and (3) determination of depth to bedrock using aerial photo analysis is an estimation at best and is usually accomplished by utilizing the landform information present in the stereo model. A technique for doing this is given. After identifying and mapping similar landform units, each was assigned a set of five symbols describing each of the landform elements. In applying this procedure to a USDA BW aerial photograph (1:20,000 and covering some 5,000 a.) taken on May 25, 1957, the photointerpreter took six hours to map the units. However, 16 hours of background study were needed to prepare the area study guide (keys). It was noted that greater speeds and higher accuracy could be obtained from color transparencies studied on a light table, and that CIR would reveal the most information with regard to soil moisture. In regards to evaluating certain criteria used in highway location studies, including depth to bedrock, depth to water table and design objectives, the aerial photographic elements of landform, drainage, erosion, tone or color, land use, and vegetation were identified as being useful indicators. It was also concluded that the success of the results depends on individual background and skill and is influenced by the availability of multiscale and color photography.

photointerpretation
aerial photography
reconnaissance studies
landform
mapping
soils
bedrock
highway location
interpretation key
Pennsylvania

E-50 Weekelic, G. E., J. C. Stephan, H. E. Smail, and T. F. Ebbert. 1977. *A Survey of Users of Earth Resources Remote Sensing Data.* in *Proc. 11th Intl. Symp. Remote Sensing of Env.*, ERIM, Ann Arbor, MI. 3:1067-1076.

Battelle Columbus Laboratories conducted a survey to assess Earth Resources Survey (ERS) data use. The survey was intended to determine the use of LANDSAT (or other satellite) and high altitude (> 60,000 ft.) aircraft imagery and data. The first phase of the study involved identifying, obtaining, and reviewing information on ERS data and users from direct sources such as (1) the three ERS centers, (2) structured and unstructured personal and telephone conversations, (3) tailored and comprehensive questionnaires, and (4) selected ERS presentations and publications. The second phase involved the aggregation and analysis of data user responses from five user categories: (1) industry; (2) state, regional, and local governments; (3) federal government; (4) academic institutions; and (5) non-U.S. users. Three different types of surveys were conducted: (1) questionnaires submitted to participants in the 1975 ERS symposium held in Houston, TX (373 responses); (2) telephone and personal

E-50 (cont'd)

interviews from July 1975 and March 1976 (about 400 interviews); and (3) mail surveys of remote sensing users (389 responses). Care was taken that respondents (1161 in all) were not included in more than one of the three surveys. It was found that geologically related and land use applications represented the largest class of data use. Other high use areas included agriculture and forestry. Industry was the largest user of ERS data (particularly LANDSAT) primarily for mineral and fossil fuel exploration. State and local governments were the group least frequently using LANDSAT data. Academic institutions used LANDSAT for a variety of research applications. It was concluded that the use of satellite acquired data would increase as future LANDSAT systems capabilities improved, particularly in terms of greater spatial resolution, more spectral coverage, more regular repetitive coverage, better data turn around, and more technical and financial assistance to potential LANDSAT data users. With respect to greater spatial resolution, most users commonly recommended 20-40 or 10-20 m. while some, especially at the state and local levels, suggested 1-10 m. spatial resolution. Also, another important recommendation was that more high altitude aircraft imagery be required to supplement LANDSAT imagery.

remote sensing
LANDSAT
high altitude
data users
user requirements

E-51 Wilson, J. E. 1969. *Sensor Detection Capabilities Study*. USGS Circ. 616. 25 pp.

Ten remote sensor systems were evaluated for their relative capabilities in representing each of 98 classes of both man-made and natural features. The ten sensor imagery types were : (1) BW photography, (2) color photography, (3) CIR photography, (4) black-and-white IR photography, (5) 2 to 14 μm thermal IR imagery, (7) side-looking airborne radar, (8) imaging microwave radiometer, (9) electro-optical (television) imagery, and (10) nonimaging scatterometer. Based upon the current state of the art in sensor technology, each system was subjectively rated from 1 to 8 in its effectiveness in characterizing each of the 98 features. Such comparisons were made for day and night low altitude (1,000 to 5,000 ft.) and day high altitude (10 to 100 miles) conditions. Where no evaluation was given, it was assumed that no detection of that particular target was possible with that system given the specified conditions. The ratings, which were based upon studies of imagery (or data) from the various sensors and/or reviews of pertinent literature, are relative and do not indicate the degree of accuracy or precision with which a feature could be detected, identified, and characterized. It was concluded that photographic remote sensor systems hold the greatest promise for 89 of the 98 features studied.

E-51 (cont'd)

remote sensing
aerial photography
black-and-white photography
color photography
color infrared photography
microwave imagery
scatterometer
remote sensor system evaluation
electro-optical sensors
thermal infrared imagery
side-looking airborne radar imagery
high altitude
low altitude
identification

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| a. | acre(s) |
| ADP | automatic data processing |
| agron. | agronomy |
| Am. | American |
| arch. | architecture |
| ASCS | Agricultural Stabilization and Conservation Service |
| ASP | American Society of Photogrammetry |
| assoc. | association |
| bpi | bits per inch |
| bur. | bureau |
| BW | black-and-white |
| Can. | Canada |
| Canad. | Canadian |
| CIR | color infrared (see also FCIR) |
| cntr. | center |
| cm. | centimeter(s) |
| comm. | commission |
| conf. | conference |
| coun. | council |
| CRT | cathode ray tube |
| DEC | Digital Equipment Corporation |
| dept. | department |
| div. | division |
| DOT | Department of Transportation |
| econ. | economics |
| ed. | edition |
| Ed(s). | editor(s) |
| elec. | electric(al) |
| engr(s). | engineer(s) |
| engrg. | engineering |
| env. | environment(al) |
| ERIM | Environmental Research Institute of Michigan (see also WRL) |
| EROS | Earth Resources Observation System |
| ERTS | Earth Resources Technology Satellite (see also LANDSAT) |
| FCC | false-color composite |
| FCIR | false-color infrared (see also CIR) |
| FHA | Federal Highway Administration |
| ft. | foot, feet |
| GE | General Electric Company |
| ha. | hectare |
| hr. | hour |
| hwy(s). | highway(s) |
| info. | information |
| inst. | institute |
| intl. | international |
| IR | infrared |
| journ. | journal |
| km. | kilometer |
| LARS | Laboratory for Applications of Remote Sensing |
| m. | meter(s) |
| mi. | mile(s) |
| mm. | millimeter(s) |
| μm | micrometer |

## LIST OF ABBREVIATIONS AND ACRONYMS (cont'd)

| | |
|---|---|
| MSS | multispectral scanner |
| NASA | National Aeronautics and Space Administration |
| no. | number |
| obs. | observation(s) |
| ORSER | Office for Remote Sensing of Earth Resources |
| pixel | picture element |
| pp. | pages |
| proc. | proceedings |
| proj. | project |
| publ. | public |
| rd(s). | road(s) |
| rec. | record |
| ref(s). | reference(s) |
| rept. | report |
| res. | research |
| sec. | section |
| serv. | service(s) |
| soc. | social |
| sp., spp. | species |
| SSEL | Space Science Engineering Laboratory |
| suppl. | supplemental |
| surv. | survey(s) |
| symp. | symposium |
| syst. | system(s) |
| topo. | topographic |
| transp. | transportation |
| UK | United Kingdom |
| UN | United Nations |
| univ. | university |
| USDA | United States Department of Agriculture |
| USGS | United States Geological Survey |
| UV | ultraviolet |
| WR | Wratten |
| WRL | Willow Run Laboratories (see also ERIM) |