IMAGE ANALYSIS FOR FACILITY SITING: A COMPARISON OF LOW- AND HIGH-ALTITUDE IMAGE INTERPRETABILITY FOR LAND USE/LAND COVER MAPPING

H.M. Borella
EG&G, Santa Barbara Operations

J.E. Estes, C.E. Ezra,
J. Scepan, and L.R. Tinney
University of California, Santa Barbara

ABSTRACT

For two test sites in Pennsylvania the interpretability of commercially acquired low-altitude and existing high-altitude aerial photography are documented in terms of time, costs, and accuracy for Anderson Level II land use/land cover mapping. Information extracted from the imagery is to be used in the evaluation process for siting energy facilities. Land use/land cover maps were drawn at 1:24,000 scale using commercially flown color infrared photography obtained from the United States Geological Surveys' EROS Data Center. Detailed accuracy assessment of the maps generated by manual image analysis was accomplished employing a stratified unaligned adequate class representation. Both "area-weighted" and "by-class" accuracies were documented and field-verified. A discrepancy map was also drawn to illustrate differences in classifications between the two map scales. Results show that the 1:24,000 scale map set was more accurate (99% to 94% area-weighted) than the 1:62,500 scale set, especially when sampled by class (96% to 66%). The 1:24,000 scale maps were also more time-consuming and costly to produce, due mainly to higher image acquisition costs.

INTRODUCTION

As technology has advanced to date so too has consumption of energy, an important economic asset in a modern society. The United States and Canada currently consume some one third of the world's total energy production. The need for facilities increases to satisfy new energy demands and shifts in the spatial location of those demands. Mapping of land use/land cover for site potential analysis is an important application of remotely sensed data. The project documented in this paper was designed to analyze the applicability of: 1) aerial photography, 2) appropriate ground supporting data, and 3) site specific scientific literature for use in analysis and interpretation to meet NRC requirements for facilities siting and transmission line corridor selection (Borella, et. al., 1982). The interpretability of commercially obtained low-altitude and existing high-altitude imagery were compared in terms of time, cost, and accuracy with respect to the preparation of Anderson Level II land use/land cover categories (Anderson, et. al., 1976).

Specific objectives of the research reported herein included:

- Acquisition by commercial means of low-altitude color and color infrared aerial photographs of an area ten miles in radius around two test sites located in Pennsylvania;

- Using these photographs, produce an Anderson Level II land use/land cover map for the ten mile radius area at a scale of 1:24,000;

- Acquisition of the latest available, existing, high-altitude aerial photography through the United States Geological Survey's EROS Data Center and National Cartographic Information Center and map land use/land cover using the Anderson Level II classification scheme;

- Documentation of the time involved in each operation along with the cost associated with each task;

- Conduct of field verification efforts for the two test sites;

- Assessment of the accuracy of the land use/land cover maps generated at each scale;

- Production of a set of map overlays which illustrate the differences between the two scales of maps; and,

- Comparison of the relative time, costs, and accuracies associated with the generation of land use/land cover mapping from the two sets of imagery.

Following a brief discussion of the background of this project, this paper includes sections on: the test sites used for this analysis; the rocedures used in data acquisition; the mapping effort; and information on the statistical approach used in the accuracy assessment. Time, cost, and accuracy figures are then compared which contrast the potential of both commercial and existing photography to provide Anderson Level II land use/land cover information. This is followed by a brief section which includes the conclusions arising from findings of this research effort.

BACKGROUND

The National Environmental Protection Act (NEPA) has been interpreted to require terrestrial and aquatic resource inventories and descriptions of preferred facility sites and transmission corridors before an assessment can be completed and a construction permit issued. NRC Regulatory Guides 4.2 and 4.7 outline information needs and siting considerations in a general way, but leave considerable area for interpretation of specific needs to applicants and their consultants. Because of applicants' uncertainty as to specific detailed information requirements, their response over a period of years has been to generally increase the volume of information submitted in successive environmental reports in the hope of gaining comprehensive coverage. The effect has been and is now to saturate the assessment process with information leading co excessive staff time for review and in some cases to an unitentional obfuscation of issues rather than clarification.

The Council of Environmental Quality (CEQ) has cautioned agencies on this problem in the preparation of Environmental Impact Statements (EIS), and has recommended that these documents should be limited to the essential information needed for rational decision-making. Following the same reasoning, it is believed that the continual growth of environmental reports should be limited by better specificatin of information requirements or by formats which would satisfy regulatory staff needs for assessment and decision-making, even though the reports are reduced in volume.

Unfortunately, specification of detailed information needs on a point-by-point basis has proven to be a relatively intractable problem because of the site-specific nature of environmental assessment. It has usually been necessary to trade off detailed instructions for general guidance which is applicable on a nation-wide basis. An alternative to detailed descriptive guidance is to specify an informational format which would show certain relevant details about a site. Remote sensing is such a format.

Adoption of remote sensing techniques for regulatory environmental guidance may have the advantage to NRC of enabling agency personnel to specify comprehensive information gathering techniques which are not site-specific but which would, in all probability, yield a substantial portion of the information needed for licensing assessment on any site likely to be considered.

Although development of remote sensing techniques for facilities siting appears desirable, uncertainties exist with respect to the potential of adapting them to regulatory needs. The scope of this work deals specifically with aerial photography, the main uncertainties of which at present relate to the following:

1. The extent to which existing regulatory siting guidance can be met using these methods.

2. Fine tuning of the interplay between aerial photography and ground truthing needed to meet licensing requirements.

3. Quantification of presumed cost advantages of these methods.

4. Relative information return from the technology.

Image acquisition (commercial low-altitude and existing) coupled with field visits were carried out to determine the information return from remote sensing technology in relation to selected regulatory siting requirements, namely land use/land cover. The results presented herein should provide NRC a documentary basis for evaluating these techniques for acquiring information relative to resource evaluation for inclusion in environmental reports and for revising existing guidance for making environmental surveys.

TEST SITES

The two circular test sites with a radius of 10 miles selected for acquisition, analysis, and comparison of the commercially acquired and existing high- altitude, remotely sensed data are located in east central Pennsylvania (see Figure 1). The northernmost site is centered on the Susquehanna power plant site near the town of Berwick, Pennsylvania, Latitude 41 5' 30"N Longitude 76 8' 0"W.

The Berwick site is located in a folded ridge and valley section of the Appalachian Mountain System. This area land cover is predominantly forest with heavy strip-mining activities. Both urban (nearly 7%) and agricultural activities (about 21%) are less dominant in areal extent here than at the Lancaster site. Agriculture areas are mostly in corn and pasture, while both active and abandoned strip mines attest to coal mining in the area.

The second site is Lancaster and its environs, which is located in south-central Pennsylvania and centered at latitude 40 2' 15"N; longitude 76 18' 20"W (Figure 1). Land use/land cover in the Lancaster site exhibits more of a mixture of cover types. The dominant land use patterns are related to agriculture and related activities (approximately 60% of the total area) and to large urban areas (nearly 22% of the total area). Dominant agricultural activities revolve around corn, oats, hay, alfalfa, tobacco, and some truck crops.

DATA ACQUISITION

Commercial low-altitude (1:24,000) color and color infrared aerial photography was flown over the two test sites on 25 September 1981 by Photo Science, Inc. (PSI), based in Gaithersburg, Maryland.

It was agreed that mapping land use/land cover in Pennsylvania would best be accomplished after full leaf maturity in the spring and before leaves start to fall in autumn: this image acquisition mission was coordinated by EG&G and University of California, Santa Barbara (UCSB) personnel. EG&G/UCSB developed detailed specifications for the image acquisition mission and coordinated the contract with PSI through Pacific Western Aerial Surveys of Santa Barbara, California. (In the commercial aerial image acquisition field, it is not unusual for individuals needing imagery of a distant area to work through a local firm that in turn contracts with a firm near the area of interest to actually fly the image acquisition mission.)

The camera systems flown by PSI were Wild Heerbrugg RC8's, which exposed color and color infrared films simultaneously. Flight lines followed by PSI were jointly planned by personnel from Pacific Western Aerial Surveys and UCSB, such that sufficient overlap (60%) for stereoscopic coverage was obtained. Sidelap was designated at 20% to ensure that no gaps or misses would occur through lack of coverage from line-to-line or through crab or yaw of the aircraft in flight.

After PSI flew the image acquisition mission, the film was sent to Dayton, Ohio for processing, returned to PSI for quality assurance and assessment, and shipped to Pacific Western Aerial Surveys in Santa Barbara, which received the 1:24,000 scale color and color infrared aerial imagery in late October. These materials arrived in the format of 9x9-inch color infrared (CIR) positive transparencies and color negatives from which positive prints were produced.

When received, the processed low-altitude aerial imagery was thoroughly checked with respect to mission specifications in the contract. Specifically, the film quality was assessed, degree of vignetting examined, color balance and processing checked, actual flight lines plotted against the flight-line maps provided, photograph centers plotted, overlap and sidelap computed, and correctness of scale verified. Though the color infrared (infrared ektachrome) imagery was of totally acceptable quality, the color color film was acceptable but not of high quality; basically the latter appeared to be overexposed and had a somewhat "washed out" appearance. Although bothersome, the degree of loss of contrast was not sufficient to reject the imagery (part ofthe UCSB Central Library has computer links to data centers and imagery coverage catalogues). All other characteristics and parameters of the imagery flown by PSI met contract specifications and the data were accepted. Figure 2 is an example of the color infrared aerial photography acquired for this project.

High-altitude aerial photography has been taken by various Federal Government agencies for research and applications-oriented purposes. Information concerning this coverage can be obtained from a number of Federal data banks (e.g., the U.S. Department of the Interior's United States Geological Survey, EROS Data Center, Sioux Falls, South Dakota). A thorough search of the coverage acquired by all Federal Agencies and other sources was conducted through the UCSB Map and Imagery Collections Library (part of the UCSB Central Library has computer links to data centers and imagery coverage catalogues) to determine the availability of post-1974, existing, high-altitude coverage for the two test sites. This imagery search yielded the following results:

1. Black and white high-altitude imagery flown by the United States Geological Survey (USGS) on 10/12/76 at a scale of 1:78,000 for the 10-mile radius around both test sites. This imagery was obtained from EROS Data Center in early November 1981.

2. Color infrared high-altitude imagery flown by the National Aeronautics and Space Administration (NASA) dated 7/21/74 data scale of 1:126,000 of the Berwick site appeared to be available, and this imagery was also obtained from EROS in early November 1981. Examination of the example (Figure 3) shows early construction activity at the Susquehanna power plant. This imagery was judged to be of very good quality by the analysts.

3. Color infrared high-altitude imagery for the Lancaster site flown by NASA on 2/5/74 at a scale of 1:128,000

also appeared to be available. This imagery was also ordered, but only partial coverage of the Lancaster site was available.

Although statements regarding image quality, extent of coverage, degree of cover, etc., are included in the catalog material concerning the high-altitude photography, once this imagery was received it was thoroughly examined for its potential to meet project requirements. Color balance, ground resolved distances (GRD), acutance, scale, overlap and sidelap were all checked to determine not only the degree of site coverage but also the quality of coverage as related to Anderson Level II land use/land cover mapping requirements. Based on evaluation of these data, it was found that:

1. While the USGS black and white image coverage was complete for the two sites, the graininess of the film and its poor contrast made it of very poor quality for land cover mapping. That is, the Principal Investigator and image analysts involved in this project determined that acceptable Anderson Level II land use/land cover mapping accuracies could not be achieved using these data.

2. The NASA color infrared imagery coverage of the Berwick site was indeed complete and, as previously indicated, the analysts deemed the quality of this imagery as appropriate for Anderson Level II land use/land cover mapping.

3. Complete coverage of the Lancaster site was found not to be available, and the poor color balance of that portion of imagery which did cover the site rendered the data unacceptable for detailed land use/land cover mapping.

COLLATERAL DATA

No two areas of this country are exactly alike physically, socially, or culturally. All areas have a certain degree of uniqueness in their land use/land cover patterns. It is axiomatic that the more familiar an image interpreter is with the region and/or phenomena he/she is asked to analyze, the more accurate the analysis will be. As such, on-site field verification visits are often important in any image analysis project, particularly in those which the analysts interpret data acquired in areas about which they have limited knowledge. As the image analysts in this project could not visit the sites prior to the data analysis phase of this project they were, in essence dependent upon collateral data for site-specific background information. These collateral data included:

1. U.S. Geological Survey generated Land Use and Land Cover (LUDA) 1:250,000 maps for the two test sites. The Lancaster test site is located on the 1972 Harrisburg quadrangle, and the Berwick (Susquehanna) site is found on the 1972 Williamsport quadrangle.

2. U.S. Geological Survey 1:24,000 scale (7.5') and 1:62,500 scale (15') topographic quadrangles.

3. Vegetation maps and related articles.

MAPPING

Areas within a radius of 10 miles of the Lancaster and Berwick test sites were mapped at Anderson Level II using the commercially acquired color infrared transparencies. (Figure 4 shows indices of the 1:24,000 scale 7.5' USGS topographic quadrangles relevant to the Berwick study area.)

Land use/land cover mapping was accomplished using manual photo interpretation procedures. The color infrared transparency imagery was solely employed in the interpretation; these data were deemed of superior quality for Anderson Level II mapping purposes compared to the color print data. To aid in location and area referencing during the land use/land cover mapping, mylar overlays with roads and stable features copied from 1:24,000 USGS topographic quadrangle maps were used as a mapping base; i.e., the mylar overlays to be used directly with the aerial image were annotated with roads and other stable features to make the interpreters' information transfer task more efficient.

Trained imaged analysts interpreted the imagery and transferred the interpreted land use/land cover classes to the base map thereby producing pencil-line working copy maps. The interpreters who analyzed the low-altitude imagery at one site did not work on the high-altitude imagery of the same site, which eliminated potential bias which might have been generated by interpreters becoming familiar with a site through experience gained at one scale, and transferring this in their analysis of another scale.

MAPPING FROM EXISTING DATA

Due to lack of comprehensive coverage of the total area of both test sites by either of the two sets of available color infrared imagery (making statistically significant comparisons with the low-altitude data more tenuous), a decision was made to use the black-and-white (B&W) data to map both sites.

The data were receivd in a B&W positive transparency format (1:78,000 scale). Pacific Western Aerial Surveys made and printed inter-negatives to the scale of 1:62,500. Overlays of 15' topographic quadrangle maps were generated and used as the base maps. Interpretations were made from the original B&W positive transparencies. The prints were used for locating and mapping features.

After considerable analysis it was determined that Anderson Level II criteria could not be met employing these data. As such, Anderson Level I criteria were used. Problems have mainly related to image quality, interpretability, consistency of category identification, and labeling, which rendered uniform applications of Level II criteria difficult, if not impossible; that is, it was determined, to the author's satisfaction, that Anderson accuracy criteria could not be met at Level II.

A Level II classification was accomplished for the Berwick site using the color infrared high altitude imagery, which was examined, evaluated, and deemed of acceptable quality to meet Anderson Level II accuracy requirements. Analysis of these data was accomplished employing techniques similar to those described above.

Once pencil line "working copy" maps had been employed in the field verification and accuracy assessment process, final "archive copy" maps were generated from them. Land use/land cover polygons were transferred from the pencil line working copy maps to final archive maps. It should be emphasized that no corrections to the working copies were made as a result of field verification.

An example of a final map product at (1:24,000 scale) is shown in Figure 5.

MAPPING PROBLEMS

Local relief distortion inherent in the low-altitude aerial photography acquired from PSI sometimes caused slight mislocation of smaller features on the map. This localized "scale error" required that the image analysts essentially manually "rubber sheet" the base map overlays to the imagery in order to accurately map photo-derived information to their correct planimetric positions.

Up-to-date 1:62,500 scale USGS topographic maps for the two Pennsylvania sites were not available. The most recent map was updated in 1955; the earliest in 1981.

The 1:62,500 scale black-and-white (B&W) imagery was of poor quality. As previously stated, this B&W imagery exhibited very low contrast, which reduces texture in some features making them less interpretable, and also tends to blur the edges of features. This loss of acuteness makes object identification more difficult, particulary when dealing with small area polygons at Anderson Level II.

Lack of available color imagery increased difficulty of mapping vegetated versus non-vegetated areas in transitional regions. Scale-relief distortion was also found in the existing imagery.

Given the low contrast, the scale of this imagery was generally too small to permit Level II mapping consistency throughout the study area and to meet minimum mapping unit standards.

Finally, there was also some difficulty caused by having to map with opaque prints (with back-lighting) as opposed to transparencies (although all interpretation was done by viewing the original B&W positive transparencies and transferring information to the mylar overlays).

Complete Lancaster site coverage was not available, and the existing coverage (eastern portion of study area) was determined to be of very poor quality (poor color saturation, contrast, and extensive vignetting).

Lack of consecutive coverage of both sites with acceptable quality color infrared imagery also makes satistical comparison with maps generated from 1:24,000 scale data less than satisfactory. Therefore, Anderson Level II accuracies achieved in this project can only be compared for the Berwick site.

Along with the 1:24,000 scale and 1:62,500 scale Level II classification maps, an additional map was created for the Berwick site. This overlay was produced to locate, identify, and analyze classification discrepancies between the land cover maps at the two mapping scales.

The comparative difference overlay was produced as follows: each of the twelve 1:24,000 scale archive classification maps were photographically reduced onto a clear film medium at 1:62,500 scale. The separate reduced maps were then overlain on top of the archive copies of the 1:62,500 scale classification maps. Areas exhibiting differing classifications between the 1:24,000 and 1:62,500 scales were then traced onto a separate sheet of frosted mylar. A minimum mapping unit of 0.5 inch (0.25 cm) was used, and special care was taken to insure accurate registration of the two maps (see Figure 6).

The final map product of this effort is a single, frosted mylar sheet showing the areas which were found to exhibit classification discrepancies between the 1:24,000 scale Anderson Level II mapped classes and the 1:62,500 Anderson Level II mapped classes for the Berwick site.

An examination of this 'difference' map shows that the Anderson Level II classes which appear most frequently are residential, cropland and pasture, other agricultural land, and deciduous forest. Reviewing each class in turn, it is possible to speculate why these differences might occur.

That the mapping was done by different photo interpreters using imagery flown almost six years apart is the most obvious cause of differences in classifications between the two map series. Although errors caused by some difficult-to-document land use changes are bound to come into the spatial errors on the discrepancy map, overall accuracies for both scale maps were quite high within this project. This discussion and documented errors are not statistically significant in the total context of the mapping effort.

Class Residential, a category often found surrounding other types of land uses (i.e., commercial and mixed urban classes), is also scattered throughout the agricultural and forested areas of the Berwick study area in the form of a single unit residences (often with smaller detached structures). In addition, identifying residential land uses and structures sometimes requires considerable use of "collateral data".

Category Cropland and Pasture would seem to be a distinct and fairly easy classification to map, but in fact, the Anderson scheme leaves room for subjective interpretation. Also, some of the agricultural practices (e.g., small field, diverse crop farming, etc.) peculiar to this study area can make identification of cropland and pastureland difficult.

Because Class Other Agricultural Land is a very broadly defined category in the Anderson scheme, the photo interpreter must make certain basic decisions at the beginning and follow them throughout the mapping effort in a systematic way. Elements of this category (perhaps more than any other) can be placed legitimately in other classes within the Anderson scheme.

Different image analysts, unless they have worked together or have decided on specific guidelines prior to the interpretation task, can often have difficulties in consistently labeling this category.

The Deciduous Forest Category, the most widespread land cover type present in the Berwick site, is a constant target for change as forested areas are given over to agricultural and urban/suburban land uses.

STATISTICAL PROCEDURES FOR ACCURACY ASSESSMENT

The statistical basis of the accuracy assessment procedures are basically those presented in detail in "Sampling for Thematic Map Accuracy Testing," an article by Rosenfeld, et. al., (1982), in the January issue of Photogrammetric Engineering and Remote Sensing, which describes a stratified systematic unaligned sampling technique. Sample points taken from the map as a whole, with additional random samples for under-represented thematic categories, are used to estimate the thematic accuracy of all mapped categories.

Prior to selection of sample points to be verified, the minimum sample size needed to validate the accuracy for each category within specified confidence limits was estimated using a cumulative binomial distribution. The binomial distribution is proper in this case as verified points can be either "correct" or "incorrect". Anderson, et. al., (1976) state, "the minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent".

After preliminary evaluation of the commercial color infrared photography and the existing high-altitude color infrared imagery of the Berwick site and a review of the Anderson Level II classification scheme, all interpreters felt confident that the 85% accuracy level from these data could be attained. Based on a detailed analysis, it was also determined that Anderson Level II accuracy criteria could not be met using the existing B&W high-altitude photography. However, Level I Criteria could be met. Anderson Level I maps of both sites were generated, but do not relate to the discussion of map accuracy presented herein.

Using the binomial distribution and imposing a 95% confidence requirement as described by Rosenfeld, et. al., (1982), it was calculated that a minimum sample size of 19 points per thematic category per site was needed to verify Anderson Level II classifications at 85% accuracy, with an allowable error of 10%.

Once the desired minimum sample size per category was determined, the sample selection procedure was implemented as follows:

1. Each site was stratified using a 5-km grid network based upon Universal Tranverse-Mercator (UTM) coordinates. These 5-km square "strata" provided the basis for subsequent sampling.

2. A systematic sample grid overlay was made for each scale of strata used (1:62,500 and 1:24,000 scale maps were used). The overlay was partitioned into a 500-m sample grid covering the 5-km strata, thus resulting in a 10 by 10 sample grid of 100 sample points per strata coded by number as shown in Figure 7.

3. A computer program was used to randomly order the 100 potential sample points within each strata. A separate random sample was provided for each strata thereby resulting in an unaligned sample design since not all samples were used.

Two sets of points were generated for each map to provide both area-weighted and category-specific estimates of accuracy. (An area-weighted accuracy assessment tests accuracy of the map as a whole. This technique yields an overall accuracy figure for the entire map without regard format accuracies within individual classes. A "by class" sampling technique provides accuracy figures for each thematic category within the map.) An initial set of points was selected for verification by taking the first five random points within each 5-km strata, and marking their locations on the working map copies (see Figure 9) in the generation of approximately 175 points per site to be used in an area-weighted accuracy estimate. After tabulating the land use/land cover category of each point, a second set was generated in an iterative manner thereby subsequent groups of five points per strata were examined for all strata, and points for any under-represented categories were added to the list to be verified and flagged as such on the working copy map overlays. This dual approach provides both an accurate area-weighted sample and an efficient set of additional points needed for category-specific accuracy assessments. In some instances, however, it was not possible to adequately represent some classes due to their relative rarity, even after exhausting all 100 potential sample points per strata.

Following Rosenfeld's procedure, initial verification of mapping accuracy was done by an expert photointerpreter who hadn't participated in the original mapping effort. Any point he was unsure of was designated for subsequent field verification; obvious agreements and outright errors were directly photo-verified and tabulated. This procedure is, of course, constrained by the level of expertise of the expert photo interpreter. Subsequent field verification efforts basically validated this approach, but the lack of local area familiarity did result in one important category verification error involving Deciduous and Mixed Forest classes in the Berwick site. The impact of this problem, which was limited to the one site, is discussed next.

In the field, it was estimated that approximately 10-15% of the Berwick site is actually Mixed Forest and not Deciduous Forest as mapped and photo-verified. Since neither the photointerpreters nor expert verifier were very familiar with the area, this is somewhat understandable. With only single dates of imagery available at scales where the resolution of individual tree crowns is difficult, such errors can and do occur. This Mixed Forest category is a problem to USGS land use/land cover mappers as well. In this study, interpreters made logical conservative decisions based on their experiences. Had they been provided with both summer and winter images of these areas, classification errors would have been reduced.

Field verification involved approximately 20 specified samples per site with an additional 10 "correct" points added to test the expert photo-interpreter's verification accuracy. All "correct" points did agree in the field.

Accuracy results are presented in Tables 1 through 6. In each instance an area-weighted accuracy estimate table is provided first, followed by per class accuracy estimates. The range of numbers for each table of estimate represents the range corresponding to a 95% confidence level. Given the results found for the specified sample size, we can expect the true estimate to fall within this range 95 out of a 100 times.

Because the Deciduous and Mixed Forest Classes in the Berwick site are not adequately distinguishable using the available imagery, we can only estimate the mix of those classes. Examining the USGS LUDA maps we find that 69.3% of the forested area is mapped as Deciduous Forest and 30.7% is classed as Mixed Forest. Assuming this relationship is correct, we can estimate that 19.4% of our 1:24,000 scale map is in error where Mixed Forest areas have been mapped as Deciduous Forest.

TIME AND COST FACTORS

Table 7 is a summary of time involved in creating base map overlays and photo-interpretation. Time factors were broadly similar between sites, with slightly more time involved for the Lancaster site than for the Berwick site. Analysts considered this increased time to be due primarily to the greater amount of urban and agricultural land use in the Lancaster site. Interpretation and mapping time were generally related to the amount of map area involved; the increased time required to complete the 1:24,000 scale maps, as compared to the 1:62,500 scale maps, is basically the same factor (about 2.5x) as the map area differences involved.

The time and cost factors are relevant only in that they give an estimate of the overlay and interpretation time by the analysts. It does not cover all the hours of technological supervision provided by the Principal Investigator. Table 7 basically summarizes costs for a first effort, not idealized because of lack of area visitation, knowledge of the area, etc.

Subsequent activities could be more economical, but may not be because the sites of interest may be unique in their topographic, demographic, and sociological parameters.

While it appears that the cost of the 1:24,000 imagery for the two sites has a cost/site of approximately $6300, this reflects only the contract for the flying, some planning, acceptance, etc. It does not include the many overview hours by the Principal Investigator and others in a cooperative effort in flight line planning, outlining photographic specifications and then, after the film is returned, the overlap, sidelap, altitude, etc., checking and acceptance. The cost of approximately $6300 should be viewed as the image acquisition cost only.

CONCLUSIONS

Based on an overall assessment of time, costs, and accuracies in the study of two sites in Pennsylvania, it is believed that commercially acquired 1:24,000 scale low-altitude aerial photography is preferable for use in Anderson Level II mapping projects of this type. Although more expensive in terms of cost (especially in respect to actual data acquisition), the 1:24,000 scale imagery is definitely more interpretable and accurate, especially if category accuracy is important. For the siting task of interest to NRC, the higher accuracy of the low-altitude image based mapping may also have important legal implications. The uncertainty of availability of current, high-quality, high-altitude photography of a chosen area is another reason for choosing the 1:24,000 scale imagery.

In addition, using available high-altitude imagery as a base may necessitate mapping at scales smaller than appropriate for the given siting tasks. That is, the use of smaller scales in mapping implies using a larger minimum mapping unit and a subsequent loss of information in some categories throughout the map set.

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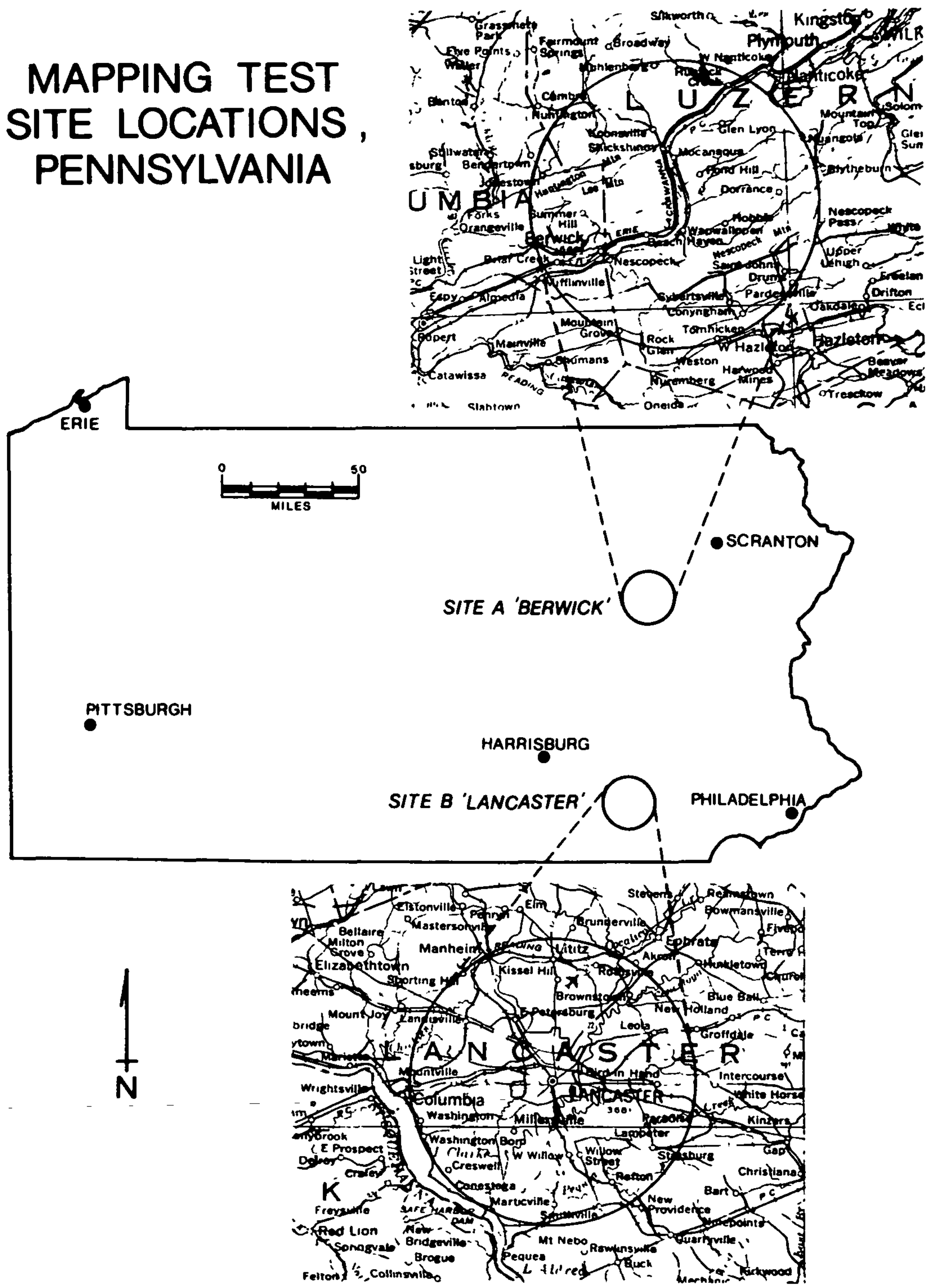

Figure 1. Diagram of mapping test site locations, Pennsylvania.

Figure 2. Sample of a portion of color infrared photography acquired 9/25/81, scale 1:24,000, Frame 4270, Area A, showing the extremely high quality and fine detail of CIR photography acquired for mapping effort. Susquehanna power station and surrounding area are shown.

Figure 3. Example of a portion of 1:126,000 scale color infrared photography (7/21/74) acquired for project (also from USGS EROS).

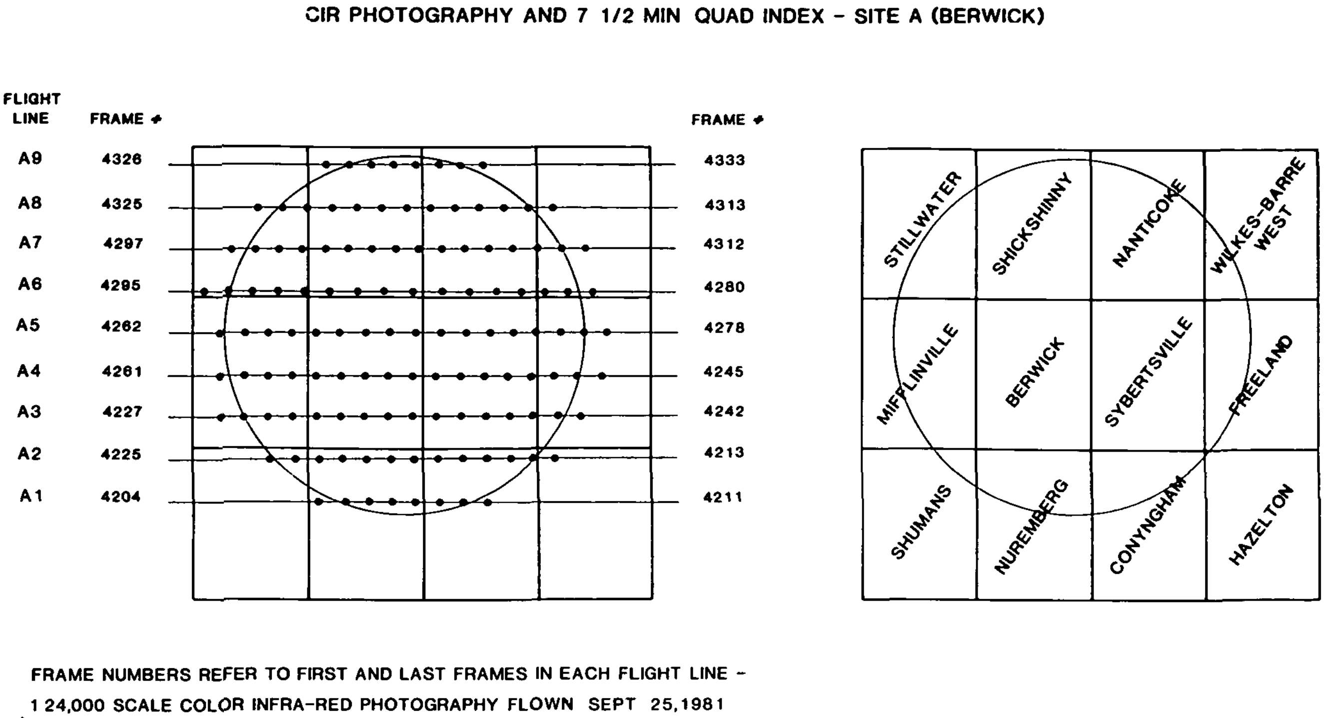

Figure 4. Flight line/topo map locator: Area A

Figure 5. A portion of 1:24,000 scale 'archive copy' finished map. Anderson Level II classification. Figure shown is not at 1:24,000 scale.

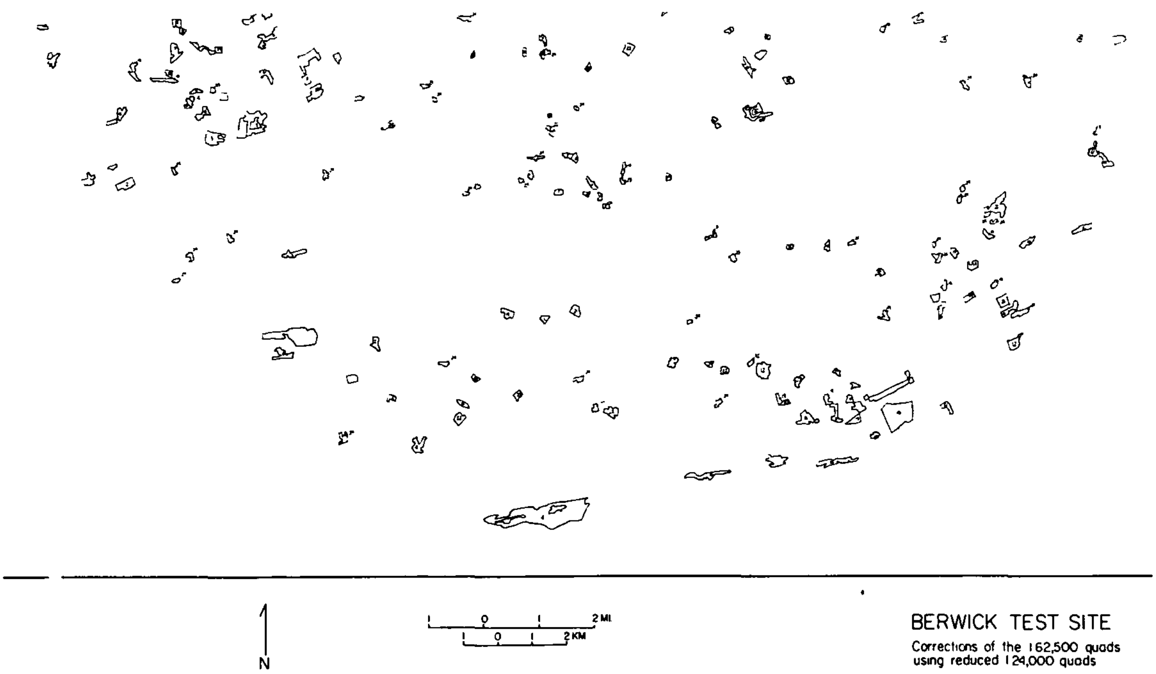

Figure 6. Portion of Comparative Difference Map.

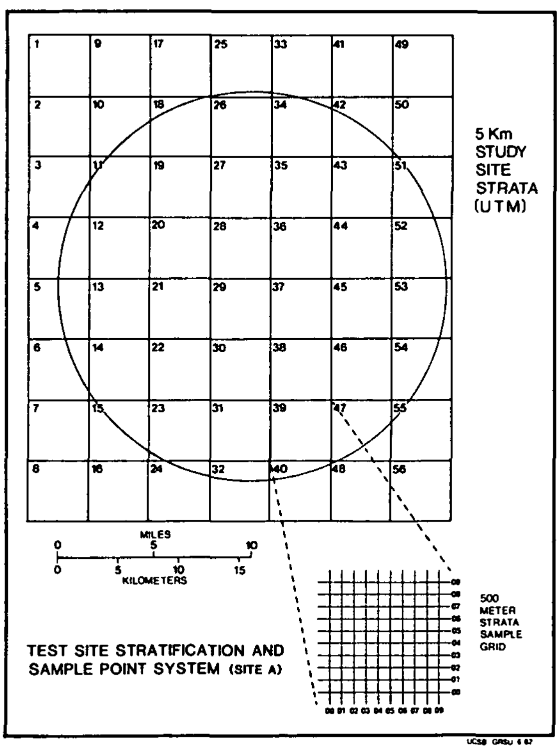

Figure 7. Systematic sample grid overlay employed during the accuracy assessment phase of the project.

MAPPED CLASS

VERIFIED CLASS	11	12	13	14	15	16	17	21	22	23	24	41	51	52	53	61	62	72	75	76
11	7							1												
12		1																		
13			0																	
14				3																
15					0															
16						0														
17							1													
21								35												
22									0											
23										0										
24											1									
41												109								
51													2							
52														2						
53															0					
61															1	0				
62																	0			
72																		0		
75																			1	
76																				8

OVERALL CLASSIFICATION ACCURACY 170/172 = 99% *

95% CONFIDENCE INTERVAL 96 - 100% *

*does not include correction for coniferous or mixed forest lands problem discussed in text

Table 1. Berwick low altitude mapping (1:24,000 scale) accuracy. Area weighted sampling. USGS Anderson Level II classification.

MAPPED CLASS

VERIFIED CLASS	11	12	13	14	15	16	17	21	22	23	24	41	51	52	53	61	62	72	75	76	CLASS ACCURACY	95% CONFIDENCE INTERVAL
11	35																				100%	90-100%
12		22																			100%	84-100%
13			20																		100%	83-100%
14				19																	100%	83-100%
15					0																*	*
16						22															100%	84-100%
17							22				1										96%	78-100%
21	1						1	33	1											2	87%	70-95%
22									23												100%	85-100%
23										14											100%	77-100%
24									1	1	23										92%	73-99%
41												115								1	99%	95-100%
51													21	1							96%	77-100%
52													1	23	1						92%	74-99%
53															27						100%	87-100%
61															1	5					83%	*
62																1	20			1	91%	71-99%
72																		0			*	*
75																			16		100%	79-100%
76											1			1					1	40	93%	80-99%

96%** AVERAGE CLASS ACCURACY

*inadequate sample for meaningful assessment

**does not include correction for coniferous or mixed forest lands problem discussed in text

Table 2. Berwick low altitude mapping (1:24,000 scale) accuracy. Sampling by classes. USGS Anderson Level II classification.

MAPPED CLASS

VERIFIED CLASS	11	12	13	14	15	16	17	21	22	23	24	41	51	52	53	61	62	72	75	76
11	7																			
12	1	0																		
13			0																	
14				2																
15					0															
16						0														
17							1													
21	1							35												
22									0											
23										0										
24											0									
41								2				109								2
51													1							
52														2						
53															0					
61												1				0				
62																	0			
72																		0		
75								3				1							1	
76																				4

OVEPALL CLASSIFICATION ACCURACY 162/173 = 94% *

95% CONFIDENCE INTERVAL 89 - 96% *

* does not include correction for coniferous or mixed forest lands problem discussed in text

Table 3. Berwick high altitude mapping (1:62,500 scale) accuracy. Area weighted sampling. USGS Anderson Level II classification.

MAPPED CLASS

VERIFIED CLASS	11	12	13	14	15	16	17	21	22	23	24	41	51	52	53	61	62	72	75	76	CLASS ACCURACY	95% CONFIDENCE INTERVAL
11	50							2				1									94%	84-99%
12	6	4	1			1		2													29%	8-57%
13	4	1	6			2		1													43%	15-69%
14				18																	100%	82-100%
15					0																*	*
16	5					6		1													50%	21-79%
17	7					1	8	1				1									44%	21-70%
21	1							94													99%	95-100%
22	1							1	4											1	57%	*
23	1							1		0											*	*
24	3										0										*	*
41								2				131								2	97%	92-99%
51												1	17								94%	73-100%
52								1				1	1	11	5						58%	35-80%
53								1							19						95%	75-100%
61								1				2				0				1	*	*
62								1					5				3			4	23%	4-50%
72																		0			*	*
75								4				1			1				10	2	56%	40-91%
76	3	1						11				3							1	16	46%	29-65%

66%** AVERAGE CLASS ACCURACY

*inadequate sample for meaningful assessment

**does not include correction for coniferous or mixed forest lands problem as discussed in text

Table 4. Berwick high altitude mapping (1:62,500 scale) accuracy. Sampling by classes. USGS Anderson Level II classification.

MAPPED CLASS

VERIFIED CLASS	11	12	13	14	15	16	17	21	22	23	24	41	51	52	53	61	62	72	75	76
11	29																			
12		5																		
13			1																	
14				1																
15					0															
16						1														
17							1													
21								90		1	1									
22									2											
23										7										
24											2									
41												22								
51													9							
52														0						
53															0					
61																0				
62																	0			
72																		0		
75																			0	
76																				3

OVERALL CLASSIFICATION ACCURACY 173/176 = 98%
95% CONFIDENCE INTERVAL 95 - 99%

Table 5. Lancaster low altitude mapping (1:24,000 scale) accuracy. Area weighted sampling. Anderson Level II classification.

MAPPED CLASS

VERIFIED CLASS	11	12	13	14	15	16	17	21	22	23	24	41	51	52	53	61	62	72	75	76	CLASS ACCURACY	95% CONFIDENCE INTERVAL
11	51																				100%	93-100%
12		24																			100%	85-100%
13		1	20																		95%	76-100%
14				20																	100%	83-100%
15					1																*	*
16						17															100%	81-100%
17		1	1				14														88%	61-98%
21		1		1			1	101			1						1		1	1	94%	88-98%
22									20												100%	83-100%
23			1							26											96%	86-100%
24											25										100%	86-100%
41												40									100%	91-100%
51													26								100%	86-100%
52														1							*	*
53															20						100%	83-100%
61																0					*	*
62																	6				100%	*
72																		0			*	*
75																			8		100%	*
76																			2	19	86%	63-98%

97% AVERAGE CLASS ACCURACY

*inadequate sample for meaningful assessment

Table 6. Lancaster low altitude mapping (1:24,000 scale) accuracy. Sampling by classes. USGS Anderson Level II classification.

TIME AND COST FACTOR COMPARISONS FOR LEVEL II MAPPING

	1:24,000 SCALE				1:62,500 SCALE			
	OVERLAYS		INTERPRETATION		OVERLAYS		INTERPRETATION	
	TIME (HRS)	COST ($)	TIME	COST	TIME	COST	TIME	COST
BERWICK	16	384.00	70 1/2	1692.00	6	144.00	20 (I) 31(II)	480.00 744.00
LANCASTER	25 1/4	606.00	78	1872.00	7 1/2	180.00	24	576.00

(I) ANDERSON LEVEL I MAPPING

(II) ANDERSON LEVEL II MAPPING

FIGURES REPRESENT COSTS OF WORK PERFORMED AT
UC SANTA BARBARA BY REMOTE SENSING UNIT STAFF

Table 7. Time and cost factors comparisons for Level II mapping.

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