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# Aerial Photographic Assessment of Transmission Line Structure Impact on Agricultural Crop Production

**Low-Altitude 35-mm vertical aerial photography provided a cost-effective method of acquiring information regarding crop type, crop pattern, orientation of the structure to the cropping pattern, area lost to production, and structure dimensions, location, and type.**

Abstract: *Vertical 35-mm true color negative type aerial photography provided an acceptable data base for describing electrical transmission line structure impact upon agricultural land in the Midwest. Information provided included crop type, cropping patterns, orientation of structure to cropping patterns, production area loss, and structure dimensions and characteristics. A 1:5,000 nominal film scale exposure was obtained of each of 2,668 structures on 17 pre-selected transmission line segments in six states by means of a floor-mounted 35-mm motordrive camera in a small aircraft. Each negative was production-enlarged to a 8.9 by 12.7 cm (3½ by 5 in.) print and analyzed with a pocket comparator with measuring reticle and a special area grid.*

## Introduction

Because of increasing concern nationally over possible significant loss of productive agricultural lands to such other uses as electrical transmission lines, techniques of assessment are required which are economically feasible, timely, accurate, and credible. To determine the situation in their operational area, the Mid-Continent Area Power Pool (MAPP)—a consortium of Upper Midwest power companies in Minnesota, North Dakota and South Dakota, Iowa, Nebraska, Wisconsin, and Montana—requested assistance in the development of a suitable transmission line structure impact survey technique.

Existing photography of the subject areas was unsuitable or unavailable for one or more of the following reasons: (a) inadequate scale, (b) age, (c) the film/filter/time of photography did not permit accurate land-use and crop-type identification, and/or (d) the time and cost required to locate, purchase, and assemble suitable existing photographic coverage was prohibitive. Consequently, it was determined that low-altitude 35-mm vertical aerial photography would afford a cost-effective method of acquiring the necessary data base: crop type, crop pattern, orientation of the structure to the cropping pattern, area lost to production, and structure dimensions, location, and type.

## Test Flight Design and Results

On 29 June 1978 approximately 16.1 km of transmission lines in Minnesota was flown repeatedly to provide a basis for selection of an optimum photo scale and format orientation, and to

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assess operational practicability under typical overflight conditions.

These tests, and ultimately the project, were accomplished with a Cessna 206 aircraft having a 40.6-cm diameter floor camera port, an A-11 ring camera mount, and a 35-mm Nikon F2 motordrive camera with 250-exposure film back, 135-mm lens, and an HF-3 haze filter. The following photography and flight parameters were selected as most suitable:

- Film—EK Vericolor II Professional 5025 Type S. Although slightly more expensive than black and white, color was more suitable for crop type identification.
- Film Scale—1:5,000. Scales of 1:7,200 and 1:10,000 were tested and rejected.
- Final Photo Product—8.9 by 12.7 cm (3½ by 5 in.) color print enlargements. Assuming an average film scale of 1:5,000, this produced a final working print with a scale of approximately 1:1,400. These color enlargements were commercially-produced at high speed in a continuous strip of prints at a cost of less than $0.40 per frame.
- Format Orientation—long axis perpendicular to the line of flight to facilitate visual tracking and realignment above transmission lines when the aircraft was forced out of position due to turns, corners, unstable air, or drift.
- Photo Coverage—one frame per structure.

Although forward visibility through the camera port around the camera was usually adequate, alignment with some of the less-visible types of powerlines was facilitated by the presence of a small window in the aircraft floor near the rudder pedals. A common feature of many transmission lines is the presence of many small-angle corners (less than 25°). Flat turns with little or no banking of the aircraft were found possible on most of these corners, which reduced the amount of backlooping and attending costs.

## Project Area Location and Description

A total of 17 electric transmission line segments totaling approximately 805 km were flown, which provided a broad sample of line sizes (voltages), structure types, and geographic locations on representative agricultural lands in Minnesota, the Dakotas, Nebraska, Iowa, and Wisconsin as shown in Figure 1 and listed in Table 1. Local relief varied from the relatively flat land in western and southern Minnesota, northern Iowa, eastern Nebraska, and the eastern Dakotas to the rolling landscape of western Nebraska and southeast Iowa. Structural configurations were either wood H/K frame types, single pole, or metal four-cornered Lattice tower structures. Transmission lines were characterized by voltages of 100-161 KV, 230 KV, and 345 KV.

## Project Overflight Results

Crop types and agricultural practices associated with the selected line segments varied considerably and consisted of tame pasture, rangeland, row crops, and cereal crops, irrigated and non-irrigated. A sample of the photography obtained is shown in Plate 1. On lengthy segments where no crop production occurred beneath the transmission lines—as in the Nebraska and Dakota range areas—no exposures were made so as to conserve film. A drawback of this procedure was the difficulty of matching structures with their corresponding photographs. Other than tallying the number of structures not photographed, no time exists for the photographer to determine an exact location and to record a description of where photographic gaps occur in a line. Recording such information would require either backlooping to give time for recording location or having a third person aboard to record. A related problem occurs when the planned flight line is ended. Considerable time is spent describing the location of the flight point but, even then, uncertainty exists as to exact location. For further applications this problem could be alleviated by predetermining line segment end points as was done with starting points during this project.


Fig. 1. Approximate location of the 17 transmission lines within the MAPP Region (shaded area).

Consideration of a particular pilot's ability to fly aerial photography should be made prior to any application of this technique. A major contributing factor to the successful completion of aerial photo operations during this project was the skill with which the pilot navigated the aircraft under difficult, non-conventional flying conditions. Not all pilots are capable of consistently holding an aircraft in a vertical position above a fixed line while maintaining proper aircraft altitude and ground speed, crabbing correctly into side winds and minimizing tip and tilt through turns and unpredictable winds while simultaneously keeping watch over the instruments.

This project photography was complicated by variability in structure/line visibility in that some structure designs hindered sighting efforts. H/K frame structures, in particular, offer only a single

Table 1. Project Flight Summary

| Flight Date | State | Segment No. | Approx. Line Coverage | Line Voltage | No. Line Miles | No. Towers | Average Datum | ASL | f/stop | Shutter Speed | Flight Time | Weather |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (KV) | | | (ft) | (ft) | | (sec) | (hrs) | |
| 6-29-78 | Minn. | 1 (TEST) | Plato west ca. 10 mi. | 230 | 10 | TEST | 1050 | 3265/ 4239/ 5479 | 5.6 | 1/500 | 1.9 | 3500 scat. 10 brok. 7 mi. vis. |
| 7-27-78 | Nebr. | 9 | Twin Church to near Wayne | 230 | 29 | 203 | 1350 | 3565 | 4/5.6 | 1/500 | | clear, lt. haze |
| | Nebr. | 10 | Loup River to Grand Is. | 345 | 30 | 125 | 1810 | 4025 | 5.6 | 1/500 | | clear, mod. haze |
| | Nebr. | 11 | Riverdale west to range | 230 | 15 | 103 | 2387 | 4602 | 5.6 | 1/500 | 7.6 | clear, mod. haze |
| | Nebr. | 12 | McCool to Crete | 345 | 48 | 248 | 1542 | 3750 | 5.6 | 1/500 | | clear, mod. haze |
| | Nebr. | 13 | Blair to Decater | 345 | 38 | 243 | 1010 | 3225 | 5.6 | 1/500 | | 5000 scat. 25,000 scat. mod. haze |
| 8-05-78 | Minn. | 2 | Morris to Ottertail R. | 230 | 32 | 136 | 1025 | 3240 | 5.6 | 1/500 | | clear, lt. haze |
| | No. Dak. | 3 | Wahpeton to Horace | 230 | 18 | 119 | 930 | 3145 | 5.6 | 1/500 | | 25,000 scat. lt. haze |
| | No. Dak. | 4 | Forman west to range | 230 | 15 | 91 | 1290 | 3505 | 5.6 | 1/500 | 5.2 | 25,000 scat. lt. haze |
| | So. Dak. | 5 | Westport to Groton | 345 | 38 | 155 | 1300 | 3515 | 5.6 | 1/500 | | 25,000 thin scat.,lt.haze |
| | So. Dak./Minn. | 6 | Watertown to Canby | 230 | 33 | 133 | 1730 | 3945 | 5.6 | 1/500 | | 5000 scat., lt. haze |
| 8-14-78 | MN/Iowa/Wis. | —aborted | —aborted due to poor visibility— | | | | | | | | 1.8 | |
| 8-16-78 | Minn. | 7 | Trimont to Lakefield | 345 | 21 | 126 | 985 | 3200 | 4 | 1/500 | | clear, vis. ∞ |
| | Iowa | 8 | Spencer to Peterson | 100-161 | 14 | 112 | 1000 | 3215 | 4 | 1/500 | | clear, vis. ∞ |
| | Iowa | 14 | Avoca to Anita | 100-161 | 34 | 243 | 1000 | 3215 | 4 | 1/500 | 6.8 | clear, vis. ∞ |
| | Iowa | 16 | Oskaloosa to Poweshiek | 100-161 | 19 | 133 | 1000 | 3215 | 5.6 | 1/500 | | clear, vis. ∞ |
| | Iowa | 15 | Millersburg to Hills | 345 | 28 | 206 | 1000 | 3215 | 5.6 | 1/500 | | clear, lt. haze |
| | Wis. | 17 | Bell Center to Hillsboro | 100-161 | 33 | 138 | 950 | 3165 | 5.6 | 1/500 | | 5000 scat. lt. haze |
| 9-04-78 | Minn. | 1 | Plato to Bird Island | 230 | 37 | 154 | 1050 | 1850 (50 mm lens) | 2.8 | 1/500 | 2.0 | 13,000 scat. mod. haze |
| | | | | | 492 | 2668 | | | | | 25.3 | |

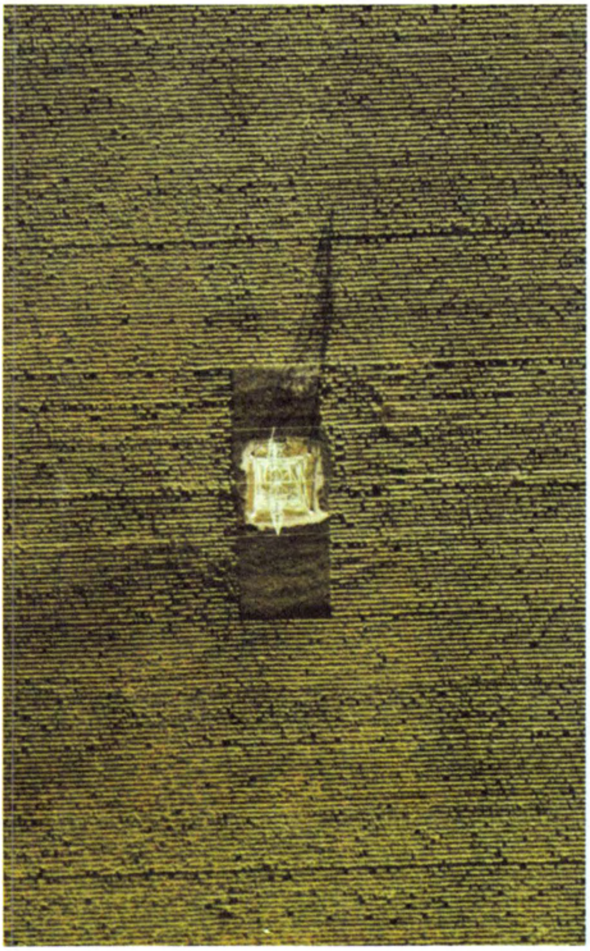

PLATE 1. Cornfield with four-cornered lattice structure.

narrow dimension to the eye when viewed from directly overhead, causing delay or added strain in accomplishing recognition. Also, row crops paralleling transmission lines or structures occasionally tended to obscure the lines and structures but, in such instances, structure shadows often aided sighting efforts. No sighting problems were encountered over four-cornered lattice structures.

## PHOTO SCALE DETERMINATION

Following processing, the 35-mm color negatives were production-printed in continuous strips (enlarged) to an 8.9 by 12.7 cm format. Because the actual distances between the outside conductors on the structure crossarms were known in each case, they were used to establish the scale of the color prints. Linear photo measurements were made between the line conductors located on the opposite ends of the structure crossarm with a six-power pocket comparator equipped with a reticle graduated in 0.1524 mm (0.0005 ft) intervals. It will be noted that the photo scale distance measured was not at ground level where the actual measurement is ultimately made. However, since the 650 m aircraft height above the crossarms was very large as compared to the 18 to 24 m of crossarm height above the ground, no adjustment was deemed necessary.

## AREA MEASUREMENT

Since a nominal scale of 1:1,400 was being approximated with the finished photography, a 1:1,400 scale dot grid was developed wherein each dot represented a ground equivalent of 0.00024 hectares (0.0006 acres). Following photo scale determination on a line segment, a dot count was made of the impacted area on each photograph. Where the photo scale was determined to be 1:1,400, each dot was multiplied by 0.00024 hectares. When the photo scale was not 1:1,400 (the usual case), an area correction factor (ACF) was determined (ACF = Photo Scale Reciprocal$^2$ ÷ Grid Scale Reciprocal$^2$) and applied to the grid dot count on each structure (ACF × #dots × 0.00024 hec).

A potential for three types of error existed in this area measurement technique: (a) a positive systematic error of up to 3.7 percent due to the method of calculating the photo scale, (b) a random error of up to ±1.6 percent due to errors in measuring the photo distance between outside conductors, and (c) errors in dot grid counts. To evaluate the latter, dot grid counts of seven figures of known area and differing shapes comparable to those encountered in the study were performed by nine persons experienced in dot grid use. Evaluation of their comparative area measurement results indicated that errors under 6.5 percent were to be expected for the dot grid area measurements. In summary, it was concluded that the errors to be anticipated in the area measurements would fall within acceptable limits.

## RESULTS

In addition to the land area removed from crop production, considerable supplemental data were made available through visual analysis of the 8.9 by 12.7 cm color prints: i.e., structure type, presence or absence of guy wires, land-use types and percentages, structure orientation to cropping pattern, structure field location relative to field boundaries and farming patterns, angle of conductors from boundaries and farming patterns, angle of conductors from boundaries, structure distance from boundaries, farming operations through (or under) structures, crop type, structure base and span dimensions, and presence or absence of irrigation.

These variables, in combination with the area estimates, provided much of the data base from which relationships between transmission line structures and nearby crop production—such as

TABLE 2. AERIAL PHOTOGRAPHY AND PHOTO INTERPRETATION COSTS

| | | |
|---|---|---|
| *Operational and Photographic Expenses* | | $2,819.25 |
| Aircraft and pilot (25.3 hrs @ $70/hr) | $1771.00 | |
| Film (369 ft @ $.30/ft) | 110.70 | |
| Processing (369 ft @ $.25/ft) | 92.25 | |
| Printing (2,668 frames @ $.30/frame) | 800.40 | |
| P.I. Equipment (dot grid, comparator) | 44.90 | |
| *Personnel* | | 199 hours |
| Aerial Photography (Planning, Flight) | 54.0 hrs | |
| Film/Print Handling, Inspection | 12.0 hrs | |
| Photo Measurement/Data Extraction | 133.4 hrs | |
| *Aerial Photography/Interpretation Expenditures per Structure* | | |
| Operational and Photographic Expenses | | $1.06 |
| Personnel | | 4.5 minutes |

the following examples—were established (Gustafson *et al.*, 1978):

- As the structure size increased, the land lost also increased with H/K frame type structures;
- For Lattice structures, the land lost reached a peak for a tower of 25 to 29 feet in width and then decreased slightly due to farmers being able to pass through with their equipment;
- Comparison of results for modified H/K frames and tangent H/K frame structures confirms that guy wire presence significantly increases land lost to production; and
- In many cases, structure presence had considerable influence upon row crop field operating patterns.

## COST ANALYSIS

The project expenditures summarized in Table 2 include only the operational expenses incurred relative to the overflights, required photographic materials, and personnel time for flight planning, aerial photography, photography handling, and photo data extraction. Not included are costs for preliminary project planning, data processing, test flight, photography equipment depreciation, and project overhead. A projected estimate of around $6.00 to $7.00 per structure (which includes *all* cost factors, including overhead) would not be unrealistic. The same survey undertaken with traditional ground methods, both in terms of time and financial requirements, would have far exceeded the outlay necessary for this aerial photography-based method.

## CONCLUSION

Low altitude 35-mm vertical color aerial photography proved to be a cost-effective tool for gathering and analyzing baseline data relative to the impact of transmission line structures upon agricultural crop production. In addition to its low financial and operational time requirements, the photography also provided a valuable visual record which, in addition to its value for assessing current conditions, provided a basis for possible future change analysis.

## ACKNOWLEDGMENTS

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## REFERENCE

Gustafson, R., R. Morey, V. Eidman, and M. Meyer, 1978. *An investigation of electric power transmission and agriculture compatability in the MAPP Region.* Misc. Pub. 1713, U. Minn. Agr. Expt. Sta., St. Paul, MN; 287 pages.

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# Erratum

In the May 1982 issue of the Journal, in the article, "Dot-Grid Area Measurement on Panoramic Photographs," by William Befort and Joseph J. Ulliman, a line was left out. The words—and photo missions should be laid out with this—should be inserted between the next to last and last lines in the left column of page 758.