1: male plug, plus 110 volt wire
1: Vent-hole cover
1: piece of $\frac{1}{4}$ inch, white opaque Plexiglass, $1\frac{1}{4} \times 18''$
2: pieces of $\frac{1}{8}$ inch, white opaque Plexiglass, $2\frac{3}{8} \times 2\frac{3}{8}''$

Wood used was $\frac{1}{4}''$ white oak plywood:

1: piece $2\frac{3}{8} \times 18''$ (outside diameter) for top of lamp housing
1: piece $2\frac{3}{8} \times 18''$ (outside diameter) for side of lamp housing
3: pieces $2\frac{3}{8} \times 4\frac{5}{8}''$ (outside d ameter) for side of rheostat housing
1: piece $4\frac{3}{8} \times 4\frac{5}{8}''$ (outside diameter) for top of rheostat housing

All connecting edges of wood are mitered at a 45° angle. The inside of the reflector is painted with white enamel. The lamp is attached to the top of the reflector. The wiring is simple series hookup.

THE AIRPHOTO-INTERPRETATION PROGRAM OF RESEARCH AND INSTRUCTION AT PURDUE UNIVERSITY*

Robert E. Frost, Research Engineer, Purdue University Engineering Experiment Station, Lafayette, Indiana

ABSTRACT

A report on the cooperative program conducted by the Joint Highway Research Project of the Indiana State Highway Commission and the School of Civil Engineering of Purdue University.

Full-time airphoto-interpretation research projects were performed for the State Highway Commission, The Civil Aeronautics Administration, and the Corps of Engineers. Miscellaneous part-time projects were conducted for such organizations as the Indiana Aeronautics Commission and the University of Indiana.

The State Highway Commission projects included soils mapping and pattern development, drainage mapping and pattern development, highway strip mapping and pattern development, material surveys, and the application of strip photography to road improvement and location problems. Procedures were developed employing the simplest of equipment requiring a minimum expenditure of time and money. Airphoto-interpretation of soils and permafrost in arctic and subarctic regions, and soils trafficability, constitute the studies conducted for the Corps of Engineers. Part time projects for the State of Indiana included the preparation of engineering-soil maps for use in site selection and materials surveys.

To promote effective utilization of the results obtained from the various research projects, dissemination is made through training programs and various publications of professional organizations, the Civil Aeronautics Administration, and Purdue University Bulletins.

The instruction portion of the airphoto program at Purdue includes both undergraduate and graduate courses. The teaching schedule covers lectures, laboratories, special problems, field trips, and examinations. A thesis is required for both civilian and military students majoring in photo-interpretation. Military students from the Corps of Engineers and the U. S. Air Force receive the same instruction; however, Air Force personnel who are studying for a Masters Degree in Civil Engineering take additional university courses. The University also sponsors a Reserve Military Intelligence Unit for officer and enlisted personnel.

JACK W. GARDNER

* Paper read at Eighteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 9 to 11, 1952.

Introduction

THE primary function of a University is teaching. The secondary function is the production of research. For many years Purdue University has been engaged in photo-interpretation research and instruction. This program is one of the functions of the Joint Highway Research Project and the School of Civil Engineering.

The Joint Highway Research Project is a cooperative endeavor between the State Highway Commission of Indiana and the Engineering Experiment Station of the University. Its functions are† (1, 3): to conduct basic research of highway materials and methods which will facilitate economical design, construction, and maintenance; to provide instruction in the fundamentals of highway engineering; and to provide practical experience in the various highway functions. The several major fields of research include aggregates, bituminous materials, portland cement concrete, base courses, soil studies, traffic, economics, administration, traffic paints, and airphoto-interpretation. Research in these fields is performed in five laboratories, chemistry and bituminous concrete and aggregates, soils, traffic and transportation, and airphoto-interpretation, each under the supervision of a full time research engineer.

In conjunction with the research program is a graduate program which offers both theoretical and practical laboratory and field activity. Graduate students are employed by the research project in the capacity of Graduate Assistant or Research Assistant and they apply their research toward graduate credit. The degree most commonly obtained is Master of Science in Civil Engineering; however, degrees are offered in other fields.

The program of research in airphoto-interpretation at Purdue was started in 1942 with a purpose of developing techniques of identification and interpretation of soils for highway use (2). The airphoto laboratory now contains six full-time research engineers and five graduate assistants. The staff is assisted by seven full-time assistants and several part-time student assistants.

Since its inception the scope of activities of the airphoto program has been broadened considerably through contract activities between the University and other agencies. In addition to conducting research on soils patterns in Indiana, considerable information has been accumulated about the soil patterns of parent materials of the United States and of portions of the Canadian and Alaskan Arctic and Subarctic. A listing of the reports, theses, papers, and manuals covering results of some of the airphoto projects is given in the bibliography accompanying this paper. In addition, there are many unpublished reports covering various phases of photo research performed for the State Highway Commission of Indiana, Corps of Engineers, Civil Aeronautics Administration and other agencies.

In this paper, a brief review will be given of the purpose, scope, and some of the results of the major programs of research and instruction in the field of airphoto-interpretation at Purdue. The techniques of soil analysis and interpretation for engineering use have been discussed on other occasions and will not be repeated here. The reader is referred to the bibliography for reference material covering this phase. Those most readily available are listed under papers and magazine articles.

Airphoto Research Projects

The airphoto-interpretation research is divided into research performed for the State Highway Commission, the Civil Aeronautics Administration, the Corps of Engineers, and in connection with miscellaneous projects.

† Numbers in parenthesis refer to bibliography.

STATE HIGHWAY COMMISSION

The program being conducted for the State Highway Commission of Indiana includes five major areas of study; these consist of soils mapping and pattern development, drainage mapping and pattern development, highway strip mapping and pattern development, material surveys, and the application of continuous strip photography.

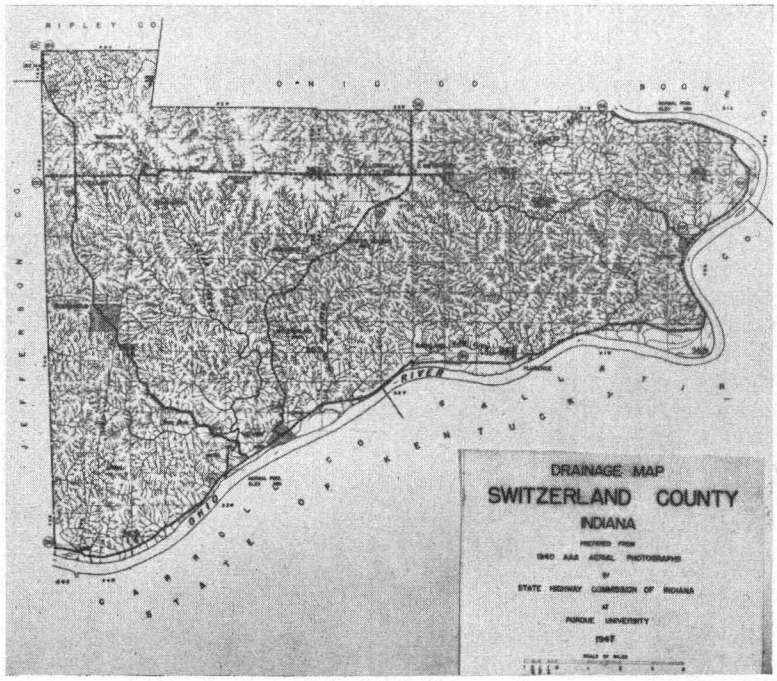

FIG. 1. Typical county drainage map made from airphotos.

Drainage Mapping and Pattern Development

This program provides for the development of a drainage map of the State and for the development of techniques for correlating drainage patterns with surface and subsurface conditions as obtained from aerial photographs (48).

One of the early studies included the development of the use of airphotos for drainage mapping for highway purposes. Procedures for preparing county drainage maps to a scale of one inch equals one mile were developed in a relatively short period of time at a low cost. Figure 1 is a photo copy of a county drainage map. To prepare a map of this type requires about 500 man hours total, including original layout, study, transfer, drafting, and supervision, or about one and one half man hours per square mile. Such maps are of great value to the State Highway Commission in location studies where information concerning a watershed must be obtained.

Simple equipment such as a pocket stereocope, home-made transfer device and ordinary drafting equipment provide the necessary equipment. Figs. 2 and 3 show the transfer device used in reducing and transferring information directly from the marked airphotos at three inches to the mile to work sheets at one inch to the mile, by projection. It uses an ordinary classroom delineascope and

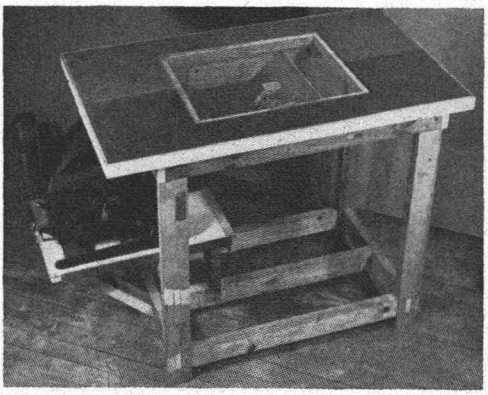

FIG. 2. Device used for transferring information from airphotos to the work sheets by direct projection and reduction.

prism. Since the program was started in 1945 drainage maps for 53 out of 92 counties have been completed.

Considerable study is being performed to develop the techniques of interpretation of drainage patterns and to determine their engineering significance in fields other than highways (51). Drainage patterns are being studied for many of the major soil-parent materials of the United States. Figure 4 is typical of studies in which drainage patterns are correlated with soils and rocks. Some of this research has been reported in PHOTOGRAMMETRIC ENGINEERING (75).

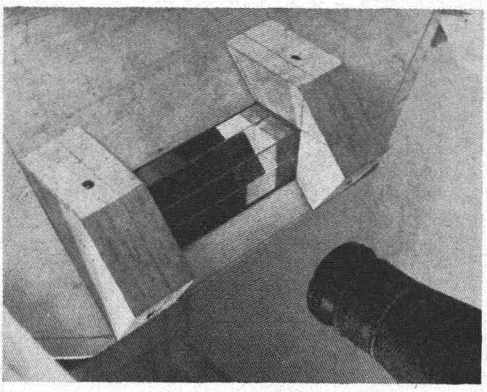

FIG. 3. Details of transfer device.

Soils Mapping and Pattern Development

This program consists of developing techniques for photo interpretation and identification of the airphoto patterns of the soil parent materials and their variations as occur in the State of Indiana (31, 59, 63). Indiana contains five major bedrock types, has been partially covered by two glacial invasions, and has had its face lifted by wind and water activity. This provides an excellent field for development of airphoto-interpretation techniques because a variety of surface materials and their reflected airphoto patterns exist. Many of these patterns are complex; they are the result of the combined agents of deposition and destruction in the shaping of the surface features. This program provides material for many graduate theses, the resulting data of which contribute not only to a general soils map of the state but to the photo-interpretation profes-

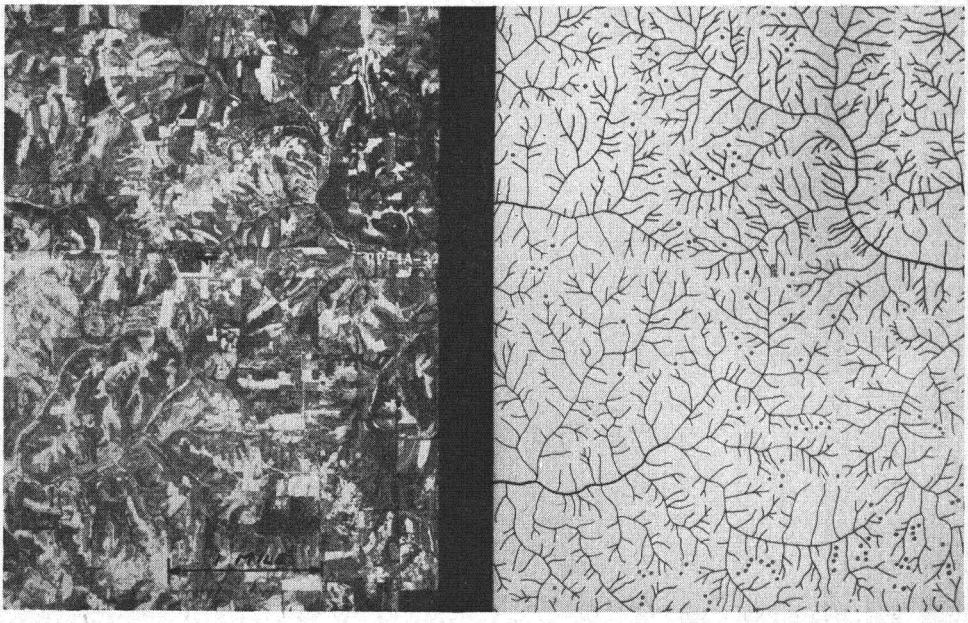

FIG. 4. Airphoto and corresponding drainage map.

sion as well. A detailed description of the soils mapping program at Purdue is given in the paper by Mr. Montano printed elsewhere in the proceedings of the 18th Annual Meeting.*

Strip Mapping Program

This project has as its objective the development of techniques for the preparation of strip maps for use in new road location and improvement of existing road locations (70). Figure 5 is an engineering strip map prepared from airphotos for purposes of relocation of a highway. The strip map is designed to provide soils and drainage information on an area a little over a mile on either side of a road location for the length of the particular job. The strip maps show soils grouped on a parent material—land form basis. Such maps are a great aid in conducting a detailed soil survey program where it is necessary to obtain physical test data for use in design. Areas for field sampling can be located in advance of field operations. In the case of highway improvement they also assist in material location.

Continuous Strip Photography Program

One of the new developments in aerial photography—the Sonne or continuous strip method—has considerable application in the field of highway and airport engineering (43). Figure 6 illustrates one application of this type of photography to the field of highway engineering—that of making performance surveys. The conducting of performance surveys provides an index of the service life of a road, runway, or the road bed of a railroad. Distress of a pavement whether from heavy loads, poor subgrade, pumping action, frost action, bad aggregate or some other cause is reflected in discoloration and crack patterns. Each type failure has a particular crack pattern and discoloration. Instead of conducting field performance surveys by walking and observing countless indications of distress,

* See page 719.

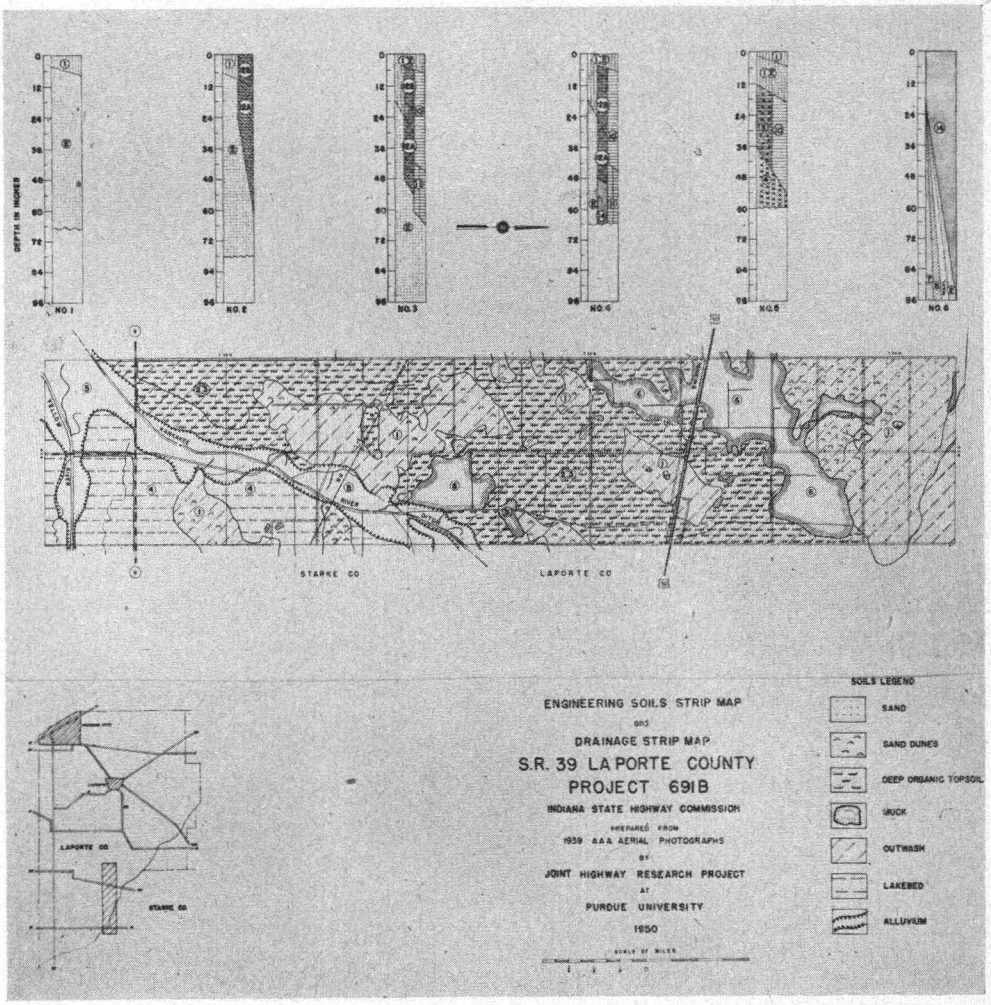

FIG. 5. Strip map made from aerial photographs.

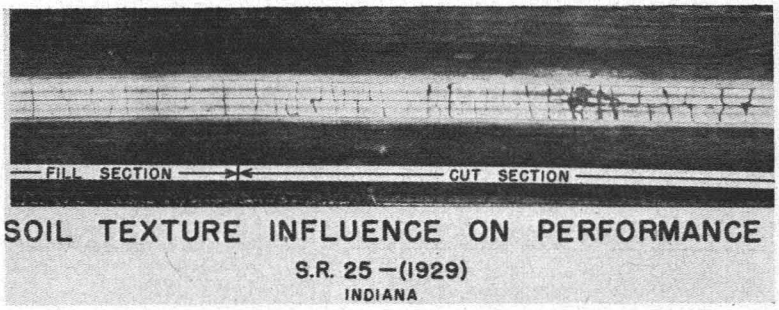

FIG. 6. Sonne strip photo showing the application to the field of performance surveys.

the maintenance engineer now has access to the photographic record. Performance surveys can be made of many miles of road at any time of year in a short period of time. The photograph provides a record which can be analyzed at the convenience of the maintenance staff. In addition it provides a means of comparison between roads when the repair of several is being considered and maintenance budgets are cut. This method makes possible the recording of progressive destruction of the pavement throughout its life cycle.

CIVIL AERONAUTICS ADMINISTRATION

Another major program in the use of airphotos was conducted for the Civil Aeronautics Administration during the war. Part of the purpose of this contract work was to study the origin, distribution, engineering characteristics and airphoto patterns of soils of the Continental United States. The results of the work were published as CAA Technical Development Report No. 52 (79) and later supplemented by a report on western United States soils (80). The program in photo-interpretation involved development of a method of using airphotos for airfield site selection. The identification features were summarized and shown graphically in the form of a series of three guide charts or guide keys based on parent materials as illustrated in Figure 7. In using the method, the engineer used a soils parent material map, which accompanies the report, to determine parent material. This gives the starting point from which detailed features of the pattern are obtained. Use of the guide charts and the procedures outlined makes it possible to obtain considerable information from the airphotos.

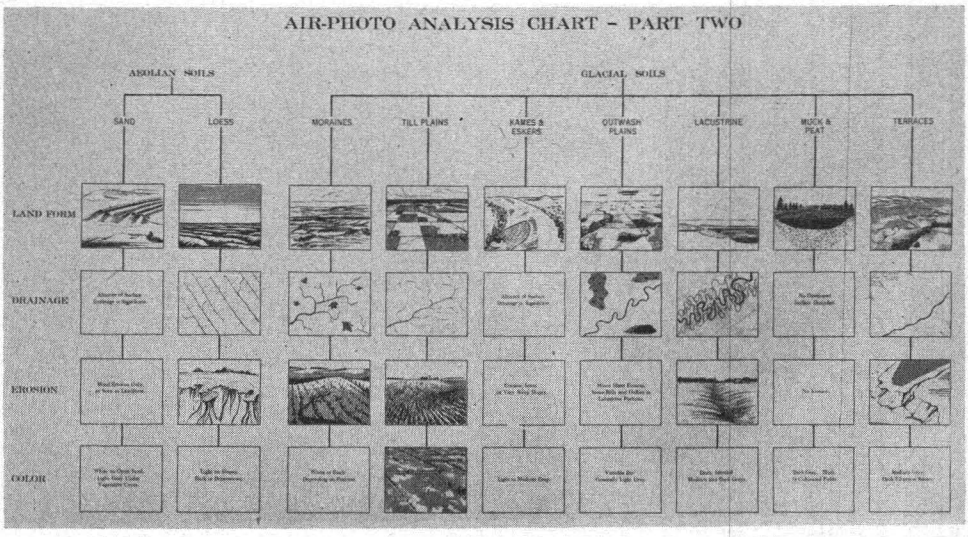

FIG. 7. Sample guide chart developed for glacial soils.

Another part of the program of research and development consisted of making soil surveys from airphotos of 36 airports in the United States in connection with a program for new location and improvement of airfields. Figure 8 is an airphoto mosaic of one of the site studies. Figure 9 is the engineering soils map of one of the site study areas made from airphotos. Such maps provided a basis for the grouping of areas so that the suitability for airfields from the standpoint of soils, drainage and expected problems could be determined and studied for new locations. Sources of materials for use in improving areas were shown on the maps.

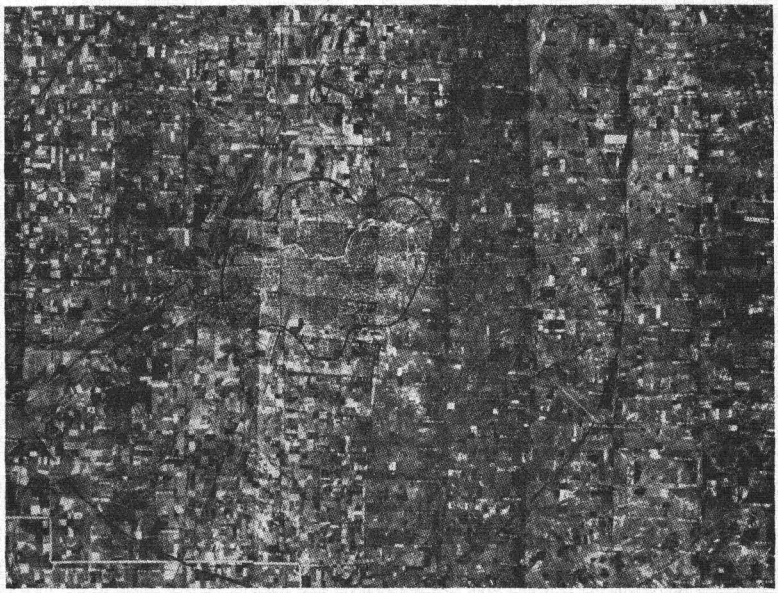

FIG. 8. Mosaic of airfield site selection study area.

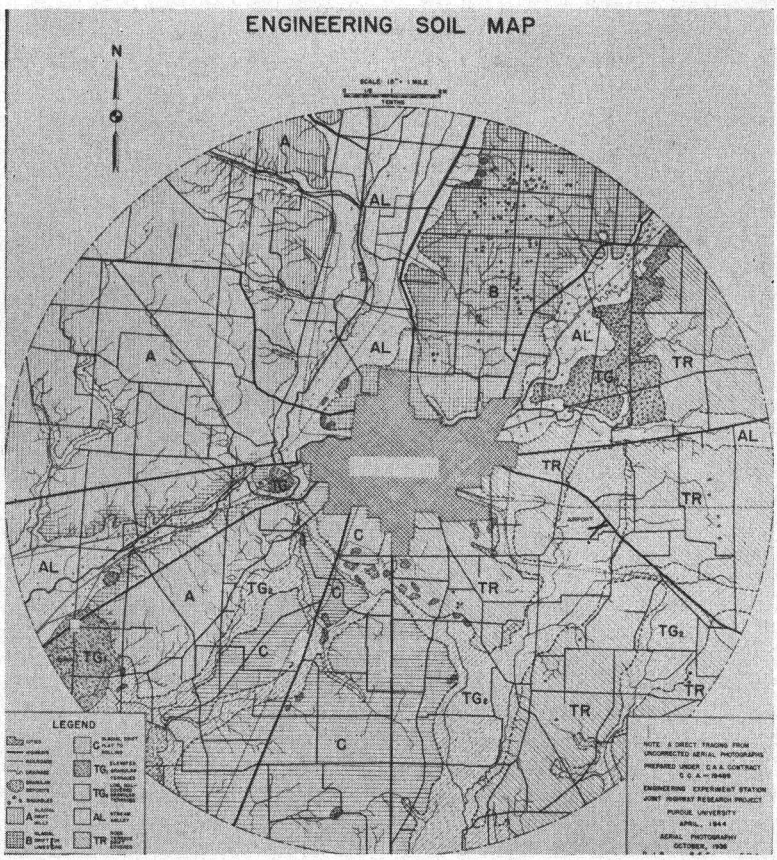

FIG. 9. Engineering soils parent material map of one site selection study area.

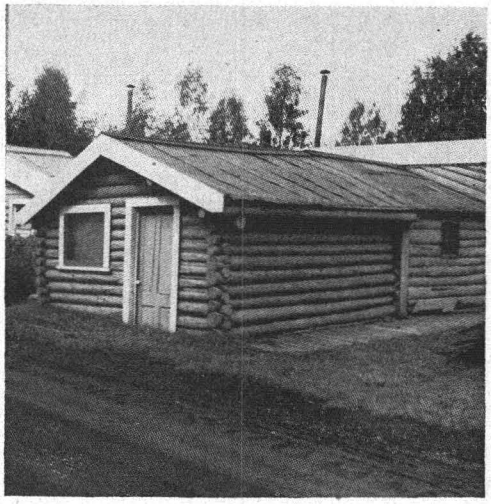

FIG. 10. Settlement of a house resulting from thawing permafrost in a silty soil area.

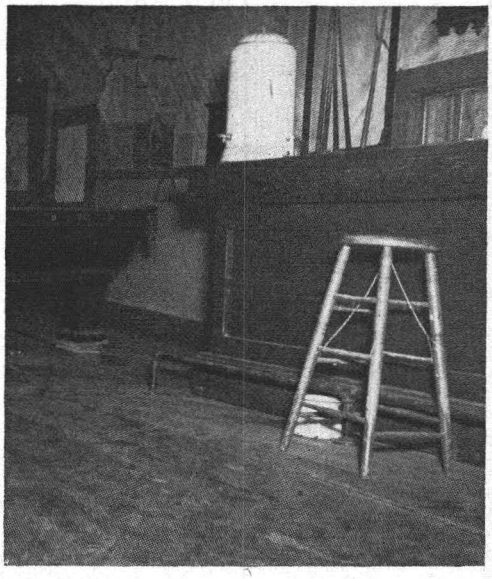

FIG. 11. Severe damage to a floor in a heated structure resulting from thawing permafrost.

CORPS OF ENGINEERS

Two major programs constitute the airphoto studies for the Corps of Engineers. These are airphoto-interpretation of soils and permafrost in arctic and subarctic regions, and prediction of soils trafficability from airphotos.

Permafrost Study

In 1945 the Engineering Experiment Station entered into a contract with the Corps of Engineers under the immediate supervision of the St. Paul District to develop techniques for interpreting soils and permafrost conditions from airphotos for use in airfield site selection. The techniques of airphoto-interpreta-

tion as developed in temperate climates were extended to include the application of the principles to the Arctic and the Subarctic (67, 71, 74, 78).

In permafrost regions, engineering problems associated directly with permafrost result from an upset in the thermal balance in the situations where fine-textured soils exist. Figures 10 and 11 are typical of problems in permafrost areas. One of the causes for such activity is the large amount of ice in the frozen

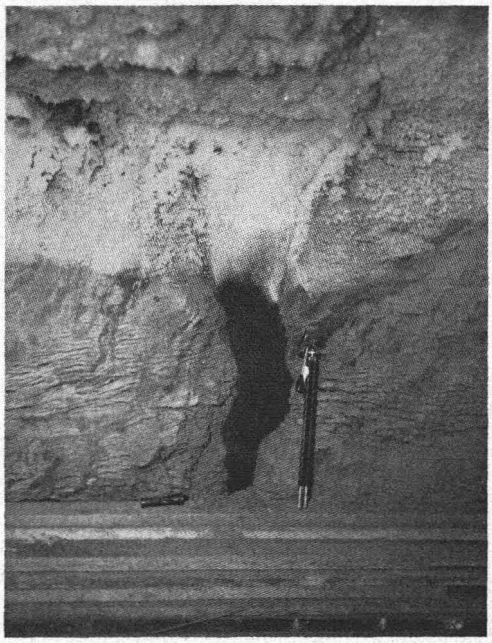

FIG. 12. One type of ice-soil relationship. This shows an ice wedge.

soil which thaws when the surface of the soil is disturbed. Figures 12 and 13 show two types of ice-soil relationships. Many of the adverse permafrost conditions can be identified with ease as in the case of soil polygons. One type of soil polygons is contained in the oblique photo in Figure 14. These are geometric configurations which contain a continuous wedge of ice beneath the outlining perimeter. Figure 15 is an airphoto of an arctic area containing many identifying permafrost features.*

There are two basic methods of using airphotos for obtaining information about soils and permafrost—the recognition method and the interpretation method. The recognition method involves the comparison of certain of the more outstanding soils and permafrost features, as recorded on photos, with typical photo-pattern features, as contained in a photo-guide manual or a photo-guide key. This type of photo study can be accomplished by anyone who has been briefed on the proper use of the key and who is cognizant of the limitations. Analysis follows identification and the success of the analysis lies entirely within the province of the analyst. Analysis results in the presentation of data. Interpretation of data whether based on fact or inference is the final step, and is based on the "end point," the "desired result," or the "field in which the information is to be used." The airphoto-interpretation method is based on application of

* This photo was cleared for publication in connection with a paper for the American Society of Civil Engineers. See reference No. 78.

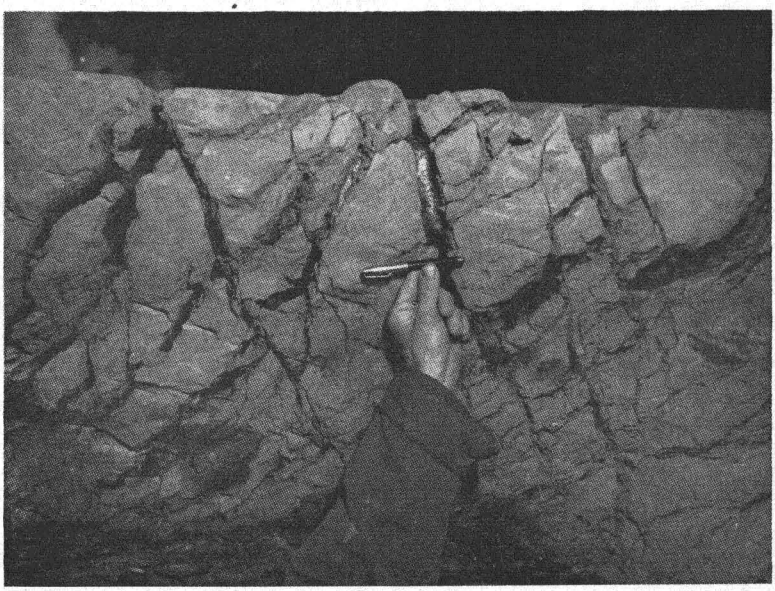

FIG. 13. This shows lenses of ice in frozen fine sand with silt.

processes of logic and deductive reasoning in performing a detailed analysis of the natural and physical environmental features of an area which collectively are responsible for the creation of a photo pattern. This type of analysis requires some engineering background, as well as some background in such natural sciences as geology, physiography, and pedology.

In a relatively undeveloped region, such as the Territory of Alaska, aerial photography can be used to great advantage—particularly because the Terri-

FIG. 14. Oblique photo of polygons in a permafrost area.

tory is not adequately mapped—for military or civilian use in locating airports, highways, railroads, bases, etc. When it is known that some engineering structure is to be built in a particular region, the airphotos should be studied; in a few hours time, a general engineering soils map can be produced which will show the good, poor, and intermediate soil areas evaluated on the basis of anticipated performance of engineering structures. Thus, the poor soil areas can be eliminated almost entirely by study of the aerial photographs, and the field investigation can be concentrated on those areas best suited to engineering construction.

With the completion of the airphoto-interpretation program in Alaska, the

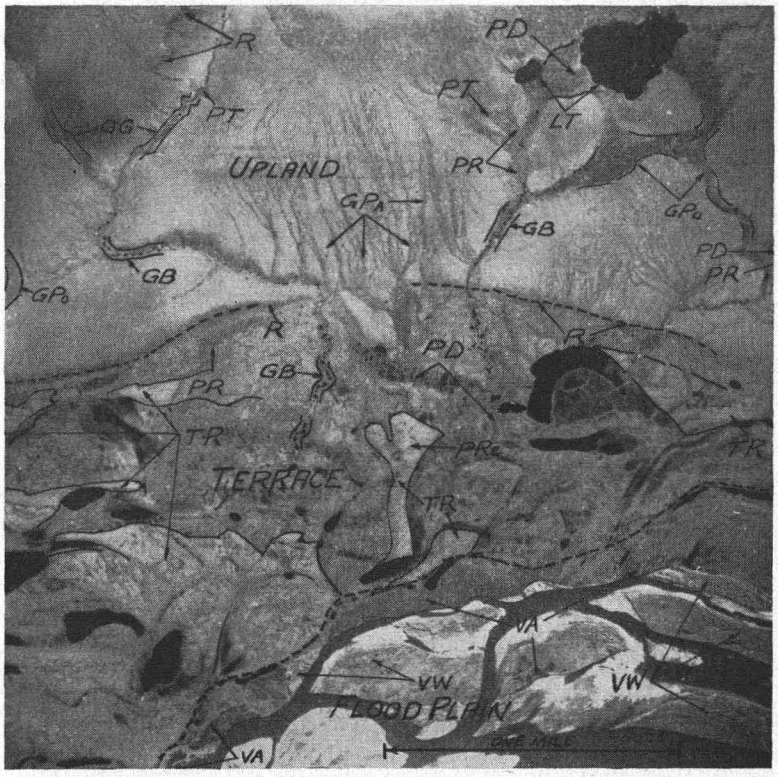

FIG. 15. Outstanding permafrost identifying features are marked on this arctic photo.

the Corps of Engineers expanded the program to permit conducting a similar study in arctic and subarctic Canada. During the past summer, several Purdue staff members conducted a field investigation in Canada correlating field data with the airphotos, by sampling the soils of some of the major parent materials.

Trafficability Study

Another important project in progress over two years for the Corps of Engineers is that pertaining to a prediction of trafficability conditions of soils, from aerial photographs. As a special application of the method, one of the graduate students, an engineer officer pursuing an advanced degree at the University, was given the problem of preparing a terrain and trafficability analysis of an arctic area. This thesis had important significance because the officer involved had not been to the arctic and had just completed the basic course

in photo-interpretation. This survey was later field checked and, in general, was found to be a fairly accurate presentation of conditions in the areas selected. The trafficability program is continuing under the supervision of the Waterways Experiment Station at Vicksburg, Mississippi.

SPECIAL PROJECTS

From time to time the airphoto laboratory is called on to perform an interpretation and analysis of soil conditions which fall outside the regular scope of full-time activity. One study consisted of preparing engineering soil maps for use in site selection and materials survey for several county airfields in Indiana, for the Indiana Aeronautics Commission. Figure 16 is an uncontrolled mosaic of a portion of an Indiana county in which several airfield sites were under consideration. The area is divided into the soil parent material areas. Detailed study of the airphotos made possible rating the several sites on a priority basis in order of engineering suitability from a soils standpoint.

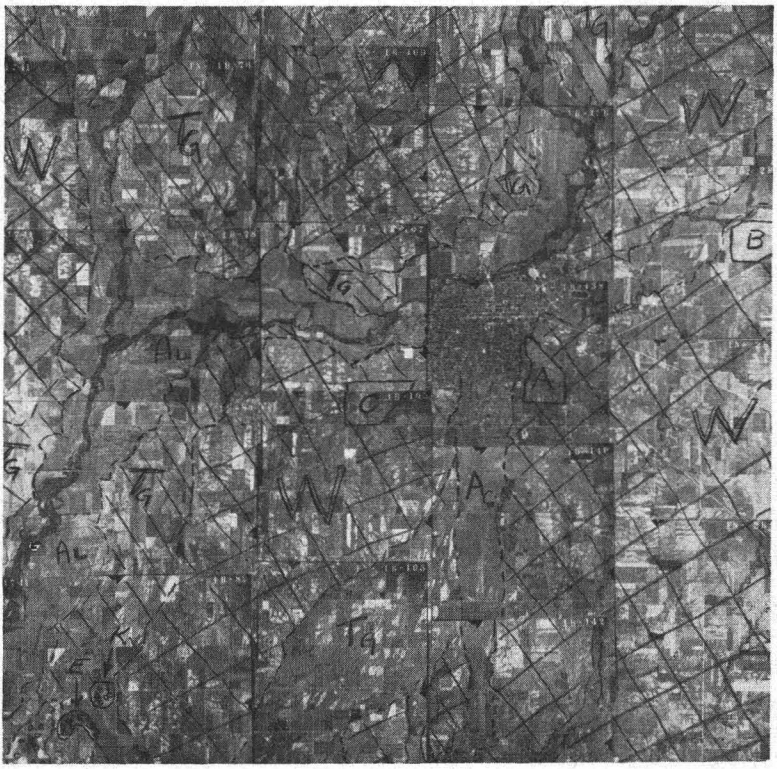

FIG. 16. County airfield site selection.

On another occasion photos were used to evaluate several sites in the Hammond-Gary area for the purpose of locating a building to house one of the University Extension Centers. Information concerning engineering soil characteristics and general engineering suitability saved considerable field exploration in a heavily industrialized area.

DISSEMINATION OF RESEARCH INFORMATION

For the findings of research to be effective they must be made available and must be utilized.

There are many outlet sources for the findings of the various research programs. All work conducted for the State of Indiana passes through an Advisory Board composed of representatives of the Experiment Station and the Highway Commission, for incorporation in various highway functions of the State. Many research findings are published by the University in bulletin form and are available for public distribution. Some of these findings are made public through publications of professional organizations such as American Society of Civil Engineers, Highway Research Board, American Society of Testing Materials, Society of Military Engineers, Society of Professional Engineers, and American Society of Photogrammetry. The University purchases reprints of the papers and makes them available for free distribution. The results of the government research are made available to the government through progress reports, interim reports, and final reports. Considerable information has been released on permafrost, and several papers have been presented on this subject. The reports prepared through contract research for the Civil Aeronautics Administration are available from the Superintendent of Documents. The best means of disseminating research information has been through the training programs.

Instruction and Training

The other major function of the airphoto program at Purdue is to provide instruction in the field of airphoto-interpretation as a part of the regular university curriculum in Civil Engineering.

University Instruction

Instruction is offered on undergraduate and graduate levels. Course work covers such items as: types of aerial photography, their use and limitations; difference between map reading, photogrammetry, photo reading, photo recognition, photo analysis, and photo-interpretation; and basic principles, limitations, degree of expected reliability, and procedures for each of the above. The student is taught the application of logic and deductive reasoning to the identification and evaluation of natural and physical environment of an area as reflected in airphotos. Some time is spent in discussion of keys, their significance, use, and their limitations as aids in photo recognition or photo reading. Lectures, laboratory periods, special problems, field trips and examinations make up a sixteen week semester. A special problem course is offered in which a student can obtain credit by conducting a research project on some phase of photo-interpretation.

Graduate Thesis

Students, either military or civilian, majoring in photo-interpretation are required to prepare a thesis on some phase of the photo program. The officers are given subjects in connection with one of the government programs as it is believed that they will derive the most benefit from these programs. The civilian students usually conduct a thesis in some phase of the Indiana State Highway Program. The civilian students conducting a thesis in airphoto-interpretation have all been employees of the University, either as graduate assistants or as research assistants.

Military Instruction

Part of the students are officers of the Corps of Engineers sent to Purdue as special students. Because the special students do not receive academic credit, it is not necessary that the officer have a degree in civil engineering. In the past, engineer officers taking the course work represented the following major fields

of experience: civil engineering, geology, geography, and military science and engineering. One officer had no college training. In addition to the Engineer Officers, there is a group of Air Force Officers who are taking the regular graduate program on a two year basis, through the U. S. Air Force Institute of Technology. Both groups receive the same instruction in the airphoto field; however, the Air Force personnel, who are pursuing a master's degree in Civil Engineering take other courses in the regular University program. For the military personnel, a special problem-seminar is added which is designed to cover the military significance of photo-interpretation.

RESERVE UNIT—MILITARY INTELLIGENCE

The University sponsors an affiliated type reserve unit in Military Intelligence. This consists of a parent group known as 477th SIRA (Strategic Intelligence Research and Analysis) and four PI cells (photo-interpretation). This program has been in operation for over two years. The officer personnel of both the parent unit and the cells are university staff members, and the enlisted men are university students. Most of the personnel, both officers and enlisted men, are in some way connected with the airphoto-interpretation laboratory either as full time staff members or as part time student assistants.

SUMMARY

In concluding this discussion a few remarks about the future are offered. The surface has hardly been scratched. Considerable research needs to be done in the fields of photo reading, analysis, and photo-interpretation to make this relatively new tool more readily available to the users, whether military or civilian. Detailed study coupled with field inspection is a *must* in any program of research, development, and training. In this field, research is urgently needed to point out the limitations of Recognition, Analysis, and Interpretation for study of both cultural and natural patterns. The question of how much factual information and how much inferred information can be obtained from each method must be determined and made known if the techniques are to be used with continued success. The benefits of the training program are not immediately measurable. It remains for students of photo-interpretation to continue in this profession. One way is for them to establish research and training programs and to continue to study so that definite contribution can be made to the profession through their findings—whether military or civil.

We at Purdue realize the great significance of all studies relating to aerial photography, particularly during such an emergency as at present. We are proud that in some small way we can be of service to our country by passing on the "Fruits of Research" to its military and civilian personnel through our research and training program.

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ENGINEERING SOILS MAPPING OF INDIANA FROM AIRPHOTOS*

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ABSTRACT

This paper is in two main sections: Background and procedure, the first; and a Photo Interpretation key to major soil areas of Indiana, the second.

Until recent years, engineering soils mapping has been dependent on topographic, geologic and pedologic information. In Indiana, topographic mapping and geologic mapping, by the U. S. Geological Survey, have given limited coverage. Agricultural soils mapping has made considerably greater progress. Engineering soils mapping, however, lacks adequate data from these sources. In recent years, airphoto-interpretation of engineering soils materials has been most encouraging in filling the need for engineering soils information.

A program of engineering soils mapping of Indiana from air photos was started at Purdue University in 1946. Studies of air photo patterns of soils and engineering significance of such patterns have been made and the principles and limitations governing air photo-interpretation of engineering properties of soils have been studied. The major work has been done by graduate students on a county unit basis, under supervision of a staff member of the Joint Highway Research Project of Purdue University, with thesis work on a regional unit basis.

The student's work in an area is divided into laboratory research and field investigation. Laboratory work consists of: (1) assembly of background material, (2) assembly of the area mosaic, (3) delineations of geologic parent materials on the mosaic, (4) detailed stereoscopic study of mosaic materials. Field investigations, the next step, is for verification of the delineations marked on the mosaic, and to obtain soil samples of the various delineations for testing in the laboratory. Returning to the laboratory, the student transfers the data from the mosaic to one inch to a mile base maps, using classroom delineascope. The final map is then prepared by tracing from the base map according to a system of symbols set up at Purdue University. The staff member then takes over the incorporation of the final maps into the state engineering soils map at a scale of one inch equal to four miles.

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* Paper read at Eighteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D.C., January 9 to 11, 1952.