

# Cadastral Surveys by Photogrammetry

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•THE U. S. Forest Service, an Agency of the Department of Agriculture, administers some 186 million acres of National Forest and National Grasslands located in 44 states and Puerto Rico. These lands generally fall into the following three categories: (a) National Forest lands reserved from the public domain—159 million acres located mostly in the West; (b) National Forest lands acquired primarily under Weeks Law—23 million acres located mostly in the East; and (c) the National Grasslands—4 million acres located mostly in the western plains states, but also scattered elsewhere throughout the United States. These lands are called the National Forest System.

The Forest Service has more than 281,000 miles of property lines between lands in the National Forest System and lands owned or administered by others. More than 1,132,000 land survey corners are required to control these property lines.

The National Forest System lands are not grouped together in solid blocks of government ownership, but are often intermingled in a complex pattern with lands owned or administered by others. Because of the age of many of our land surveys, the complex ownership patterns, and the miles of property lines involved, the Forest Service has some complicated property line problems. The following conditions contribute to these problems:

1. Federal regulations contain no provision for the maintenance and perpetuation of the surveyed lines and corner monuments of public land surveys.

2. Even though Government survey markers are protected under Federal law, corners are frequently destroyed either intentionally or by accident. Attempts to prosecute violators are seldom successful and therefore not often undertaken.

3. Due to man's destructiveness and to time and the elements, many surveyed lines and corners have now completely disappeared.

4. In the rectangular survey system there is a common but shortsighted practice of granting title to rural parcels of land by aliquot parts of section descriptions, without requiring an official subdivision-of-section survey to mark the property lines and corners on the ground. We therefore have many miles of property lines that have never been surveyed, in addition to the miles which were once surveyed but for which the lines and corners have been obliterated and lost.

5. Cadastral surveys conducted under State authority have the same built-in decay factors and same rate of corner destruction through ignorance, carelessness, or malice.

6. For land surveys in rural areas in many States there are no regulations concerning survey accuracy or standards for property corner monumentation, no prescribed format for survey notes or plats, and no provision for filing survey records as public documents or for making the records available on request to those who need them.

Fortunately, most official U. S. Government surveys have excellent records in the form of survey notes and plats. Copies are readily available on request from the Bureau of Land Management. During ground search for survey evidence, these notes and plats enable the searcher to know what to look for, to verify evidence that is found, or to definitely establish that all evidence has disappeared.

Notes and plats of land surveys done under State authority, however, are often difficult or impossible to find. Sometimes they are not much help if found. Corner monumentation also often leaves much to be desired. Valuable time is often spent searching in vain for the written records of survey evidence discovered on the ground, and also in searching on the ground for evidence of survey work indicated in the records to have been done.

We would certainly welcome the day when each State, in collaboration with the State Land Surveyor Societies and Boards of Professional Registration, would not only regulate the registration of licensed land surveyors, but would also:

1. Establish an Office of State Land Surveyor;
2. Prescribe land surveying accuracies (which are commensurate with specific needs);
3. Set standards for land survey corner monumentation;
4. Prescribe a format for land survey notes and plats;
5. Prescribe a format for records of corner remonumentation work;
6. Provide for a centralized official repository for the required filing of official land survey notes and plats (and corner remonumentation records) as public documents;
7. Provide for public inspection of cadastral survey records and for furnishing copies for a nominal fee on request; and
8. Provide effective protection under law for land survey monuments and accessories on the ground and for the preservation of official land survey records in a centralized office.

#### SURVEY AUTHORITY

National Forest System lands fall into two main categories as far as authority to do official land surveying is concerned. These are:

1. Land reserved from the public domain. These lands have never been in private ownership. Authority to conduct official land surveys on these lands is vested in the Bureau of Land Management, an Agency of the Department of the Interior.
2. Acquired lands. These lands have at one time been in private ownership. When land originally passes from U. S. Government ownership to private ownership, Federal land survey authority ends. The land becomes subject to the applicable land surveying laws of the State. Even though the U. S. Government reacquires title to these lands, the survey authority remains with the State.

Generally, either the Bureau of Land Management or the State-authorized land surveyor has authority to survey property lines between these two categories of land. The foregoing is, of course, an oversimplification of this subject. There are various exceptions, grey areas, and overlaps in these matters.

#### MANAGEMENT POLICY

National Forest System lands are managed under the principle of multiple-use sustained yield. This means (a) managing all the various renewable surface resources so that they are used in the combination which will best meet the needs of the people consistent with the capability of the land; (b) achieving and maintaining a continuing high-level annual or regular periodic output of these resources; and (c) accomplishing this without impairing the productivity of the land.

The manner of managing these publicly owned lands and their resources directly affects the well-being and economy of nearby communities and people. Directly or indirectly it may affect all the American people.

One of the first requirements for effective land management is to know the correct location of land ownership lines on the ground. (There are certain rather obvious advantages to managing the right areas.)

## LAND LINE LOCATION PROGRAM

Public demand for increasingly intensive use of National Forest System lands and resources creates urgent needs for accurate well-marked property boundaries. Because of this need, the Forest Service in 1958 set up a special Land Line Location Branch in the Division of Engineering specifically to do cadastral work.

The purpose of the program is to locate accurately and mark adequately the property boundaries of National Forest System lands. Activities of this program fall logically into three main parts:

1. Recovering what remains of each controlling corner of each property boundary and preserving its location with an enduring corner monument;
2. Obtaining the official cadastral surveys required to reestablish the property lines and corners that are lost and to establish the needed new lines and corners; and
3. Marking these property lines so their location is apparent on the ground and setting up a continuing maintenance program to insure that the lines and corners will not be obliterated.

## CADASTRAL SURVEYS BY PHOTOGRAMMETRY

### Forest Service Tests

Because of its pioneering in, and successful use of, aerial photographs and photogrammetry for such important work as mapping, timber management, range inventory, fire control, pest detection and control work, road reconnaissance and location, and ground search for land survey evidence, it was probably inevitable that the Forest Service would also investigate using photogrammetry for cadastral surveying. Initial Forest Service tests, using second-order stereoscopic plotting instruments and graphic methods for distance and angle determination, did not provide the accuracy sought. Further tests, using precision optical train photogrammetric instruments, high-precision aerial cameras, special photography, pre-targeted ground points, and computational rather than graphic methods, did produce accuracy satisfactory for most Forest Service cadastral survey needs.

Of those official cadastral surveys accomplished photogrammetrically by the Forest Service, the following two projects are of special interest. One was on National Forest land reserved from the public domain. It was a dependent resurvey in T. 18 N., R. 8 E., Mount Diablo meridian, California, in the Tahoe National Forest. By this survey, the original lines and corners were reestablished. The work was done in cooperation with the Bureau of Land Management, the photogrammetric work being planned and executed by the Forest Service. This survey has been approved by the Director, Bureau of Land Management. The official plat and survey notes are on file in that Agency, from whom copies can be obtained on request. A description of this project by J. E. King (U. S. Forest Service, Retired) was published in the June 1957 issue of Photogrammetric Engineering.

The other project was on acquired National Forest land. This was a resurvey of T. 36 N., R. 9 W., fifth principal meridian, Missouri, in the Mark Twain National Forest. It was done in cooperation with Dr. Clair V. Mann, County Surveyor of Phelps County, Missouri. Photogrammetric work was planned and executed by the Forest Service. It is an official land survey under Missouri State authority. Official records of the survey are on file in the county office, and are available on request. A description of this project, prepared by Dr. Mann and titled "The Case for Adoption of Photogrammetric Methods in Land Surveying," was published in Photogrammetric Engineering, Vol. 29, No. 5, pages 556-860. A complete account of the project has also been prepared by Ray F. Fassett, Chief of the Surveys and Maps Branch of the Division of Engineering in the Forest Service Regional Office, Milwaukee, Wisconsin. Individual copies of the report may be obtained by writing to that office.

### Present Application

**Corner Search**—Much of our present use of photogrammetry for cadastral work is for "search and rescue" operations to recover on the ground the remaining evidence of the survey corners that control our property lines so we can perpetuate them before all evidence is gone. We find that to reestablish a corner by cadastral survey after all acceptable evidence has disappeared is approximately ten times more expensive than to recover and remonument the corner before it is completely obliterated and lost. Because of the age of a large percentage of the surveys in our areas of interest, survey evidence is rapidly disappearing. There is an urgent need to complete this corner search and rehabilitation work.

For corner search we use relatively simple but effective photogrammetric methods to plot up existing surveys on a good map base and then to transfer these plotted corner point locations to suitable aerial photography coverage of the area. Photos containing these plotted corner locations are then used to select the best route to the corner and a search is made in the immediate vicinity of the point shown on the photo as the approximate corner location. These photos, together with complete copies of the survey notes and plats, suitable maps, and a few simple tools, enable a trained and experienced corner search party to operate with minimum lost motion and to attain maximum recovery of survey evidence.

When corner search has been completed in an area we know what additional cadastral survey work must be done. We also have the information needed for selecting the most suitable method for doing the surveying. Corners with acceptable remaining evidence are remonumented and official records prepared. Corner remonumentation must be done under proper survey authority. The remonumentation party, therefore, must include either a Bureau of Land Management surveyor or a State-licensed, registered land surveyor, depending on the status of the land involved.

When the surveyor is a Bureau of Land Management employee, that Bureau supplies its official corner monument. Also, the remonumentation notes become a part of the agency's official survey records. When the services of a registered land surveyor are used, the Forest Service furnishes a blank, brass-cap monument. The surveyor's name and registration number are stamped on the cap along with the corner designating letters and numbers at the time the monument is set. Due to the present inadequacy of State laws governing the official preparation and filing of survey records for work of this type in rural areas, the Forest Service must also provide the forms to be used to record the work and safeguard this record until arrangements can be made for its official filing. This is generally in the courthouse of the county where the land is located.

In this program, the Forest Service fully recognizes that it shares the ownership boundaries with the adjoining landowner. It respects the rights of these neighbors. It is anxious to obtain their cooperation and support in locating accurately and marking these common property lines.

**Surveys**—The Forest Service continues to use photogrammetric methods in other cadastral survey work when applicable. Procedures used are generally as follows:

1. Existing aerial photographs and photographic identification of the remaining corners (recovered by the procedures previously described) are used to construct an accurate large-scale plat showing previously surveyed land lines and, by protraction, the required new lines.
2. The locations of missing corners, and new corners to be established, are projected to the aerial photographs. Then the photographs are used to locate the approximate position of each corner on the ground.
3. All existing usable horizontal and vertical control is recovered and any required additional control is monumented and accurately surveyed. The surveyed position of each control point is converted to State plane coordinates.
4. A photographic target is placed on the ground at each point to be used for horizontal and vertical control and at each recovered property corner, and also at the approximate location of each property corner which has been lost and at each new corner which is to be established.

5. After the ground targets are in place, the area is photographed with a precise aerial camera.

6. The aerial photographs are used in a precision optical train photogrammetric instrument to bridge between horizontal control points and to obtain instrument coordinates for each targeted property corner. Bridge adjustments and State plane coordinates, when applicable, are then computed by electronic data processing methods.

7. Using the coordinates thus obtained for each targeted and known corner point, plus the original survey notes, the plane coordinate position is computed for each of the corners not recovered on the ground, then for each corner of the new subdivision of section corners to be established.

8. Having the photogrammetrically measured coordinate positions of the lost corner points, of the new corner points that are to be established, and of the ground targets set near them in the field, the distance and direction are computed from the target to its respective corner point location.

9. The distance and direction from the target to the corner point are measured on the ground and suitable corner monuments and accessories are set.

10. Official notes and plats are prepared.

Rights-of-Way—Photogrammetry is a useful tool in rights-of-way acquisition work. During the last five years the Forest Service has processed an average of 1500 rights-of-way cases each year. When applicable, photogrammetric methods are used in cadastral surveying needed for rights-of-way acquisition.

When photogrammetry is used in making surveys for road location and design, it is often advantageous to plan and accomplish required cadastral work along with the photogrammetric work done in connection with the road location. For discussion purpose, this cadastral work could be considered to be in two categories:

1. Unofficial measurements needed to show the right-of-way location in relation to existing land ownership lines and corners, but which do not change or add to any actual existing official land surveys on the ground, and

2. Official cadastral surveys needed to establish new lines and/or corners, or to reestablish old ones. This would involve altering or adding to existing land surveys on the ground.

In the first case, the right-of-way plat and deed description would suffice for the record. In the second case, in addition to required right-of-way plats and deed descriptions, official cadastral survey plats and notes must be prepared, certified by proper authority, and filed as public records of official land surveys.

Mineral Claims—There are many complex property lines on National Forest System land reserved from the public domain because of patented mineral claims. The method of laying out these claims results in claims crisscrossing and overlapping in some areas and leaving gaps in others. This creates many irregular property lines and isolated parcels of Government land of various shapes and sizes.

Most of these claims were surveyed many years ago. Most of the corners and lines are now difficult to find on the ground. Many others are completely lost. Our photogrammetric corner search methods are especially helpful in untangling the ownership patterns in these areas. Cadastral surveys to relocate our property lines and the corner markers which control them are frequently best accomplished by photogrammetric methods.

## CONCLUSION

The Forest Service uses photogrammetric methods for cadastral surveying when this method is deemed best suited for the job at hand. Official land surveying, regardless of the system, the methods or the equipment used, must be conducted under the responsible charge of capable professional land surveyors who are duly authorized under State or Federal law to perform this service.

Sometimes the question is asked, "Is it legal to use photogrammetric methods to make cadastral surveys?" We respectfully suggest that it is the responsibility of the authorized land surveyor who is in charge of the work to design the survey and to select the methods and the equipment that will be used. His certification of the finished survey, under proper State or Federal authority, determines the legality of the survey, not the methods and procedures used to do the work.