PHOTOGRAMMETRY AND ITS USE IN SURVEYING

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We, in the Legal Surveys and Aeronautical Charts Division of the federal government, have given a good deal of thought about the use of photogrammetry on legal or cadastral surveys. For some years now, we have been using rudimentary photogrammetric methods in plotting water boundaries on our plans. This has reduced considerably the labour formerly spent in arduous shoreline traverses and offsets and has also given a more accurate representation of the boundary. The specifications have been set out in an appendix to the 1961 Manual of Instructions for the Survey of Canada Lands. We have also used air photographs to describe islands for purposes of sale or lease.

It is only recently, however, that we have tried to use more sophisticated photogrammetric methods to supplant field measurements between actual boundary monuments. Our first experiment along these lines was made in 1958 in collaboration with the Photogrammetric Research Section of the National Research Council on the complete resurvey of Alnwick Indian Reserve near Peterborough, Ontario. In addition to the resurvey of the existing subdivision, the project included the survey of subdivisions of some of the lots. The aims of the experiment were:

(a) to determine the accuracies attainable using photogrammetry, and

(b) to compare the costs of a photogrammetric survey with those of a conventional survey.

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The whole survey was done by conventional methods and roughly half was repeated by photogrammetric methods.

The following conclusions from this experiment were drawn:

(a) The accuracies achieved by photogrammetry were, from a practical viewpoint, adequate for this type of survey. On short lines random accidental errors of photogrammetric positions sometimes resulted in a relative error between the ends of a line that exceeded our usual tolerance of 1 in 2500, but the actual size of the error was not significant in relation to either the value of the land involved on the capability of precisely positioning a fence or other boundary marker. The mean square error of distance determination of some 35 short lines of less than 80 feet, for example, was ±2 inches. In the accuracy of absolute positions, however, the photogrammetric survey was appreciably better than the conventional traverse work.

(b) As far as costs go, this particular photogrammetric survey did not compare favourably with the conventional survey. This, in part, was due to encountering unforseen difficulties in the field, which, if we had been aware of them soon enough, might have motivated us to

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take a different approach.

Even though the costs of this survey seemed to indicate that the photogrammetric method was not competitive with conventional surveys, the accuracies were in my opinion sufficient for the purpose. In addition there were indications that a far greater area and number of lots could have been surveyed with a relatively small increase in the photogrammetric and field survey costs. We also came to the conclusion that, although increased travel costs may be involved, the introduction of a second phase of field work after the completion of the photogrammetric work would be more economical because, by such an approach, we could eliminate many more field measurements.

We decided then that further tests should be made on the application of the method to our work. Believing that the results of the survey should be technically acceptable, I felt we could eliminate the conventional survey and concentrate on refining our field and photogrammetric procedures in the interests of economy.

Our second test, conducted in 1961, was the resurvey and subdivision of about 40 per cent of the existing lots in Cornwall Island Indian Reserve. The area covered by this survey was smaller than that of the Alnwick survey but involved establishing nearly twice as many lots. The island was reasonably free of bush, so fence lines and other evidence of occupation showed quite prominently on existing photos. All in all this seemed to be a good test area. One regret from the

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economic viewpoint was that only 40 per cent of the island was to be surveyed but, since this type of project is not uncommon, we felt we should try it anyway.

With the help of the Topographical Survey Division, we began by laying out a network of geodimeter control traverses over the whole island providing a minimum of five properly spaced control points for each stereo-model that would be used.

We then found all the monuments we could and either targeted them directly or placed targets on pairs of hubs suitably placed to form a strong triangle with each monument. Where the two hub targeting was done, each side of the triangle was measured at this time. Where a monument could not be found or where a new monument was to be placed later at newly subdivided corners, a pair of targeted hubs was placed to form a strong triangle with the estimated position of the monument, and the distance between the two hubs was measured. After completion of the targeting the photography was taken.

The next step in the project was the photogrammetric work. From this, we got plane rectangular co-ordinates of every target hub or targeted monument that appeared on the photographs. To these co-ordinated values we applied our field measurements to calculate positions for all the monuments that we had not targeted directly. In addition, we were now able to calculate, from the old plan dimensions, the theoretic positions of the many monuments that we had been unable to find in our first search.

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This brings us to the second phase of the field work. Armed with co-ordinate positions of the unfound monuments and their associated target hubs, we returned to the field to complete our search for the monuments. But now, instead of simply searching in a general area, we could restrict ourselves to the immediate vicinity of the theoretic position determined on the ground by measurement from the two nearby hubs. In this way a thorough search was made for every monument on the basis of both occupational evidence and plan dimensions, and where a monument was still not found, we were able now to replace it with reasonable confidence wherever the weight of evidence indicated that it should be.

Following the restoration of the existing lot framework, we were now able to calculate the positions of all new subdivision corners on the lot lines. Again, nearby each of these, we had a pair of co-ordinated target hubs so the survey posts were set by short measurement from these hubs. This completed the field work.

The results of this survey confirmed our previous findings regarding accuracy, the mean square error of short distance determinations being about ±0.2 foot. In addition, however, this test revealed a further feature of the photogrammetric process that was not apparent in the first test. In comparing the old plan dimensions with those determined from the photogrammetric co-ordinates, we found a number of significant differences. When these were investigated, they proved to be errors or blunders in the conventional survey work, whereas the photogrammetric work was free from such errors.

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When we examine closely the photogrammetric routines that were used on this job we find that, barring misidentification of targets on the photographs, it is virtually impossible for a gross error in position to occur in the photogrammetric result if an automatic co-ordinate printer is used. This "correctness" of mathematical data resulting from a photogrammetric survey is a feature whose value will be better appreciated in later years when retracements or resurveys are needed.

Another feature of the photogrammetric survey that will be of great help in later surveys is the photographic record of ground detail. It is probably safe to say that enough ground detail will always remain to relate the original photographs to existing features. With such conclusive evidence as dated and publicly recorded photographs available, who will be able to dispute later the existence or positions of fences or other evidence of possession that might show on the photographs?

The cost of this survey was compared with costs of roughly similar conventional surveys done in the past. It was more costly than some and less costly than others, and it is interesting to note that it was less costly on a unit basis than two quite recent but smaller surveys done in the same reserve. In making these comparisons we have ignored all the additional valuable information available from the photogrammetric method and have simply considered only the legal survey requirement. Perhaps the most significant cost feature is the fact that it was more economical than our first test -

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in other words the experience we gained on the first test paid off in economies on the second. Even if we did not bring the cost down to the point where we can say conclusively that we now have a more economical way of attacking large scale re-surveys, we have at least moved in the right direction. In fact, we have come down into the normal cost range that we would expect to encounter in the conventional approach to this type of work. As I said before less than half of the lots on the island were surveyed. All lots, however, could have been surveyed with virtually no increase in actual photogrammetric costs.

Once again our experiences on this project showed where our methods could be improved to effect further economies. It is significant that most of these improvements relate to field work for it is here that economies must be made. In this particular project, for example, the field costs accounted for more than nine tenths of the total cost of the survey.

All in all the Cornwall Island test has proved encouraging; so much so, that we are even now in the middle of a third and yet larger test project. This is the complete resurvey of all the lots in Caradoc I.R., near London, Ontario, together with a subdivision of nearly all of the lots. I have called this a test project but it is really more of a production job in which some operations are experimental. From past experience I feel that photogrammetry will do the job for us. What we are now trying to determine are the best routines and procedures to use on this work.

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The Caradoc survey covers about 18 square miles or about 12 times the area surveyed in Cornwall Island. In this area we are surveying some 1,000 corners, which is about twice the number surveyed in Cornwall Island. Again we have divided the field work into two phases, one before and the other after the photography and photogrammetry. So far we have completed the first phase of the field work and the photography. In this first phase we have already made very substantial improvements in economy over the Cornwall Island survey in that we have targeted twice the number of corners spread over a much larger area in considerably less than twice the time. The second phase of the field work will not be done until next spring and here too we expect to make substantial savings in cost.

I would now like to explain a few of the more important changes that we have incorporated in our work at Caradoc.

1. The first change introduced relates to the ground control. In the Cornwall Island test we provided rigid control for each stereo-model used. This meant that we had to fix at least 5 points at suitable locations in each overlap used so that with 10 models we had to fix and target 35 control points. In Caradoc we are relying on perimeter control around the whole reserve with an interior block adjustment by a photogrammetric bridging process to provide minor control for individual models. Using this method we have only had to provide about 45 control points involving some

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50 miles of careful traversing. Had we provided ground control for each individual model, this would have involved some 200 control points and 200 miles of traversing.

2. The next change we made was to try to reduce the time spent in the second phase of field work in searching for missing monuments. I explained earlier how, in the Cornwall Island survey, we had returned to every corner where a monument had not been found and made a further search for the monument using the co-ordinated position calculated from plan dimensions to indicate where to search. In the Caradoc survey we have tried to avoid much of this by anticipating in the first phase of field work where we would place a monument on the basis of physical evidence such as fences if the original monument could not be found. We have therefore placed provisional monuments at fence intersections whenever an exhaustive search failed to uncover the old monument. Later, after the photogrammetric work has been done, we will calculate the theoretic position of the corner from the old plan data and, if this falls within the area that we have already searched thoroughly, we will not return there but will simply adopt the provisional monument as marking the corner. We have estimated that, in our Cornwall Island survey, we could have avoided returning to some one hundred corners had we adopted this procedure. On the present survey the benefit of this will not be known until the second phase of the field work is completed.

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3. Another change we have introduced may sound rather trifling but its effect has already proved significant in reducing field costs. In the Cornwall Island survey we had made rather elaborate sketches in the field to show the relationship of each corner to its surrounding detail and targeted hub or hubs to ensure that the photogrammetric operator could positively identify the targets on the photographs, and that the surveyor could find the hubs during the second phase of the field work. While it might not seem to be much of a job to make a field sketch, we must remember that the time taken to make sketches of 1,000 corners and their surroundings could probably add up to several days. In the present survey we have used sketches only as a last resort and have generally relied on photo-interpretation in the field to mark target positions directly on enlargements of existing photographs.

4. Lastly we have avoided whenever possible the use of two targets to fix one corner. In the past we had felt that the use of two targets provided a valuable partial check on the work of the photogrammetric operator for it gave a direct distance check between the target co-ordinates. However, the consistent reliability of the photogrammetric results led us to question the value of this procedure. We decided that here too we could make a significant saving by targeting a corner directly when possible, for this would eliminate the measuring and recording of three distances for each corner, not to mention the carrying and placing of so many extra targets.

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It would be rash to predict now the outcome of this latest project but certainly to date the indications are most encouraging. I am personally convinced that, as we become more adept in its use, photogrammetry will gradually assume an increasing importance in legal surveying wherever there is a need for extensive surveys. In particular its long term effect in preserving a photographic record of all ground detail in relation to property lines is, to my mind, a very strong arguement in its favour.

When we start looking at other benefits that photogrammetry might bring to the community at large, however, I think we have an overwhelming case for its use. In the fields of planning, whether for engineering, agriculture, forestry, or conservation, or for community, town or region, the photogrammetric survey provides virtually all the raw materials that the planner needs and, perhaps most significantly, it can show all detail in relation to those most important of features, the property boundaries - features that are often overlooked by planners and that have often upset the best thought-out plans. Even in our own field of property boundaries it is not hard to imagine how easily boundary disputes could be settled when boundaries can be portrayed not only in relation to survey monuments but also to all topographical and cultural features that a person can see on the ground.

When one considers that, as time goes on, there will be improvements in cameras, lenses, aircraft, photographic materials photogrammetric equipment, as well as development of new methods

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and techniques in carrying out legal and other surveys, I think it is entirely reasonable to expect that, in the future, photogrammetric methods will be utilized more and more to make measurements on the earth's surface and that this will include measurements required for legal or cadastral surveys.