CHAPTER 18

TECHNIQUES OF CADASTRAL SURVEY

1 Prefatory

1.1 In Chapter 8 we discussed at length the role played by boundaries and maps in land registration. We saw how surveys and maps in some form or other are indispensable, and it is obviously worthwhile to consider in some detail how they are made, what their limitations are, and how they can be improved or modified the better to meet the requirements of land registration. We therefore now propose to identify the essential features of cadastral survey and to examine the factors which influence the choice of techniques to be adopted to meet the needs of the registrar, though of course the chapter is not intended to be a treatise on the detailed mechanics of surveying.

1.2 First, let us make clear exactly what we mean by surveying in this context, for 'survey' is yet another of these words which have more than one meaning. It can mean "to view comprehensively and extensively" or it can mean "to obtain by measurements data for mapping".[1] It is in the latter narrower sense that we use it in this chapter. In our context, surveying is the measurement of land for a purpose. It is an economic activity in which the variables of capital, labour, and skill, as they exist at any one time and place, are combined in such proportions as to achieve the required purpose with the maximum economy and in the shortest possible time consistent with the accuracy desired.

1.3 When a survey is being planned, clearly the purpose for which it is intended will always be the factor that must be considered first. It is of prime importance. The other factors – capital, labour, and skill – change in relative importance from time to time and from place to place, but nevertheless may dictate the way in which the survey is actually done: thus there is no standard method of effecting a survey.

1.4 In considering the use of land surveying in connection with land ownership we must therefore be sure to have a very clear picture of what its purpose is. The work is done to describe the shape, size, and relative position of each landholding with an accuracy that may vary according to the purpose for which the survey is actually required. The land occupier wants to know where his boundaries are and, although a map of them is a useful adjunct, it interests him much more to be able to see them on the ground and thus know how far he can cultivate or how close he is to his boundary when putting up new buildings. To him it is really of little importance that he should know his exact acreage, though he may want this when arranging a transaction if prices are fixed by area, and area also may be required by the State (not the landowner) for assessing taxes or controlling subdivision.

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[1] Chambers

1.5 In Chapter 8 we differentiated two methods of parcel definition: (1) by officially emplaced and mathematically co-ordinated monuments, and (2) by topographical detail.[1] The former obviously requires a different order of survey from that which will suffice for the production of the topographical map which is used to illustrate the latter. Thus two distinct patterns have evolved for registration purposes. These are often referred to as

(a) general boundaries (i.e. the 'English' pattern) and

(b) fixed boundaries (i.e. the 'Colonial' or 'Torrens' pattern).

1.6 In Chapter 7 we described how the British Ordnance Survey map, a purely topographical map depicting the visible physical features of the countryside, was prepared originally for military reasons; it then came to satisfy numerous general purposes and was ultimately used to illustrate the register of title, a practice made possible only by the 'general boundaries' rule and the fact that boundaries in Britain are usually demarcated in length by permanent physical features.[2] Then we described a quite different sort of map, the cadastral map like that prepared in France and Germany expressly for the purpose of assessing land tax; boundaries shown on the map were often unmarked on the ground and boundary marks were not put in; the survey itself was not of a very high order. Though such maps were used for the purpose of identifying properties on a deeds register, they were considered inadequate to support a registered title, and we explained how, in Germany, for that purpose, exact boundary marking was insisted on and precisely surveyed.[3] Crown grants in Australia were similarly demarcated and surveyed, and so naturally this system of identifying parcels was adopted when Torrens introduced registration of title in I858.[4]

1.7 Before we can decide on a suitable survey technique we need to know the nature of the boundaries to be surveyed, that is, whether they consist of visible physical features or are demarcated by substantial boundary marks or merely by temporary pegs. It should be particularly noted (since it is often forgotten) that conditions and practices can vary very widely within the same country or even within the same district, as, for example, between urban and rural property. We must also know the accuracy required (a vital but confusing matter discussed at length below) as this largely determines the cost of the service. This cost may be paid by the taxpayers as a whole, as in the English system, or by the individual landowners, as in the Australian system, or by some combination of the two. Finally, we need to know in what form the survey data must be presented to meet the registry requirements, whether by registry index maps, filed plans, co-ordinate lists, punched cards, or any other method.

1.8 It is evident that the basic data required to determine what will be a suitable survey technique vary from place to place and from time to time, so that all we can really do in a general chapter is to isolate the common principles of any survey

[1] See 8.8
[2] See 7.5
[3] See 7.6.9
[4] See 8.4.3

system and indicate how the variable factors will influence the choice of survey techniques. Perhaps ‘common principles’ is too restrictive a heading; nor does ‘essential features’ or ‘basic requirements’ exactly cover all the general matters we wish to discuss. We have therefore chosen as a heading ‘Considerations affecting cadastral survey techniques’ and have inserted subheadings to indicate what these considerations are.

2 Considerations affecting cadastral survey techniques

(1) The Integration of Surveys

2.1 Any viable cadastral survey system must comply with the basic principle of land surveying, which is to work from the whole to the part. The whole may be a registration block, a complete town or a complete country but the principle is always the same. Surveys of the parts (i.e. individual properties) cannot with certainty be fitted together to form a map, even with the most precise measuring systems available to surveyors, unless the size and shape of the area into which they must fit are known.

2.2 Clearly the larger the area chosen as the whole the less likely are problems to arise when individual property units arc fitted together; for example this will be necessary if subsequent mutations change the boundaries of initial registration blocks which have been independently surveyed. Undoubtedly, the best method is to adjust all cadastral surveys to a national framework of control stations, permanently marked on the ground by survey monuments, protected by law, and the positions of which, relative to one another, have been accurately established by the national survey organization.

2.3 It is usual, in a country of any size, for control points in the national framework to be classified into first, second, third and often fourth order and it is important to remember that this is a surveyor’s classification which refers to the techniques and order in which the points were established and does not affect the overall accuracy of the framework. To the layman the only difference between first-order points and fourth-order points is that the former are perhaps 40 to 50 km apart whilst the latter may be spaced at intervals of 1 to 2 km throughout the more developed areas of the countryside.

2.4 The establishment of national framework surveys is, however, a costly and time-consuming business involving surveying techniques of the highest order of precision for measurement of angles and distances. After making due allowance for the shape of the earth the measurements are combined through triangulation, trilateration or traverse methods to produce a homogeneous network of co-ordinated points with which any other survey of lower order, and for whatever purpose, may be integrated.

2.5 Thus it is evident that the establishment of a national survey framework is a counsel of perfection which cannot always be achieved in practice. Countries where extensive new lands were being developed for the first time could seldom afford the cost or time involved, with the result that land registration, in common with

other forms of development in these countries, has tended to precede rather than to follow the provision of adequate overall survey control. In the early days in Australia "the country had to be opened up for settlement quickly and even today the pace of the registration of new holdings outstrips the development of a national framework…In N.S.W. it was virtually a necessity to proceed with the normal uncontrolled boundary survey."[1]

2.6 Various expedients have been used to alleviate the control problem. The most usual is to reduce the 'whole' referred to in paragraph 2.1 above to a more manageable size consistent with immediate requirements. For example, a town may be treated as an independent unit and in some cases even adjacent properties are surveyed separately as isolated units. The important point to realize is that although such surveys may be consistent in themselves, they are extremely unlikely to be mutually consistent and cannot therefore be readily assembled into a general map.

2.7 It can be argued that provided the control units chosen are large enough to form convenient registration blocks the overall control problem can be deferred indefinitely so far as the registrar is concerned. High-order survey control, it may be said, is a luxury rather than a necessity. If it can be provided *ab initio* at no great expense, all well and good. But no registration scheme should be delayed or made prohibitively expensive solely because of demands for geodetic control. Registration is a means to an end, as we emphasized in the second paragraph of this book, and so survey is a means to a means to an end, the end being greater security of tenure, more efficient operation of the land market, cheaper credit facilities, more effective implementation of land reform policies, and better land administration. When viewed in this perspective, survey precision and the fitting together of registration blocks will be seen to be a long way down the order of priority.

2.8 Stewart-Wallace indeed, having pointed out that to consider the part before the whole infringes the first principles of geodetic surveying, remarked: "Land registration, on the other hand, works from the part to the whole; it is concerned with particular properties only. Provided such a plan (or for that matter verbal description) is provided as enables any particular registered property to be identified on the site, land registration is indifferent whether or not the plans of particular properties fit in with scientific accuracy on geodetic maps of the whole country."[2]

2.9 This attitude, however, may be short-sighted. Administrative boundaries are never fixed and immutable; at some stage it will almost always be necessary to attempt a reconciliation of conflicting records and this may well cost more than the initial saving. Any country contemplating the introduction of systematic land registration would be well advised to attend to the control requirements first since failure to do so will make future embarrassment inevitable, quite often in the shorter rather than the longer term. It is significant to note that countries like Australia and Canada are now turning to integrated surveys to help resolve in the future problems in relocation of properties should their boundary marks disappear.

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[1] Information provided in February 1974 by Mr K J Whitehcad, Supervising Surveyor of the Registrar-General's Department in New South Wales.
[2] Stewart-Wallace Land Registration 62

(2) BOUNDARY DEMARCATION

2.10 Surveyors can only survey and record the position of property boundaries if these are pointed out to them at the time of the survey. If the boundaries coincide with physical features natural or artificial, survey is not likely to be of particular significance so far as parcel definition is concerned and it oilers no great problem. No matter how imprecise the measurements, the features will still be there next week or next year. The danger from total destruction of boundary evidence is minimal and the map becomes of secondary importance.

2.11 The situation is very different, however, when we are dealing with the invisible boundaries of Chapter 8.[3] Two courses of action are open to the surveyor:

(a) He can survey and record the position of pegs or other corner marks shown to him as delimiting the property; in which case, if these subsequently disappear, the possibility of their being re-established correctly depends entirely on the accuracy of his survey and on the control on which the survey was based. The survey is crucial.

(b) Alternatively, he can replace, or cause the landowners to replace, the pegs or local marks by 'permanent' monuments prior to survey. In this case the burden of responsibility is shared. In the event of the destruction of a monument the survey evidence no longer stands alone, for it is unlikely that all the boundary monuments in an area will disappear at the same time. As a safety precaution, however, it is advisable, and usual, to make statutory provision for the protection of boundary monuments against wilful destruction.

2.12 An interesting and relevant comment on this subsection is that "in N.S.W., at least, any policing of the destruction of survey monuments is well nigh impossible. Many survey marks are removed during the course of construction work and never replaced. The Department of Main Roads is one body which does however exert some supervision over the recovery and replacement of survey marks disturbed during construction work".[4]

(3) ACCURACY AND TOLERANCES[5]

2.13 We referred above to the 'accuracy' required in the survey, and it is in regard to 'accuracy' that there has always been much misunderstanding when 'fixed' and 'general' boundaries have been under consideration. There is a common supposition in some quarters that wherever general boundaries are adopted, registration is defective and inadequate, whereas if a plan is prepared under 'fixed boundary' legislation, the register is perfect. As we explained in Chapter 8, a physical feature such as a hedge or fence is not (like the Euclidean line) something which has no thickness, and therefore a certain indefiniteness is introduced into a general boundaries description. The lack of precise definition, however, is due

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[3] See 8.1.2

[4] K J Whitehead (sec para 2.5 above)

[5] Much of this is based on a paper written in 1966 by Mr A D Hamilton as an adjunct to his lectures on cadastral survey at the School of Military Survey, Newbury.

rather to the nature of the boundary itself than to any inaccuracy in the cadastral plan. We can only repeat that it is a different system of boundary definition, which has evident merits where there is in fact adequate boundary marking in length on the ground.

2.14 We must also dispel a fallacy which is widely held. It has frequently been argued that, since valuable land can afford accurate (and so expensive) survey, then the more valuable the land the more accurate the survey should be. We hope that we have made it abundantly clear that, so far as boundary definition is concerned, the criterion is the permanence (or impermanence) of the demarcation on the ground, and in fact the more valuable the land the more likely it is to be demarcated by solid features. Built-up city centres are an obvious example with, in Great Britain, unfenced moorland at the other end of the scale. Thus, paradoxically, the need for survey in connection with boundary definition may well increase in inverse ratio to the value of the land. The less intensively land is developed, the less likely is its owner to maintain any boundary fencing or even marking, and the more reliance must be placed on survey with ultimately, perhaps, the *reductio ad absurdum* of the survey costing more than the value of the land.[6]

2.15 In any case, however, there cannot be absolute accuracy even under a fixed-boundary system. As every surveyor knows, it is quite impossible to measure an angle or a length exactly; there will always be some small residual error. But while no surveyor will obtain the identical measurements of his predecessor, he can obtain a measure within certain 'tolerances' (i.e. within a permissible range of variation) depending upon the type of equipment used and his methods of survey. To what accuracy therefore must he work to satisfy the landowner and the administration? Can he or the administration give a guarantee of accuracy to the landowner which is meaningful and useful? Technically there is a requirement that his work shall be such that he or his successors can replace a lost beacon or line within certain tolerances, but what are these tolerances? Is a guarantee really necessary if the physical marks remain in position, or sufficient of them remain to enable a missing one to be replaced with little difficulty?

2.16 What indeed is a 'guarantee' in this connection? The survey laws are generally quite distinct from the registration laws, and are often administered by different authorities; but it is possible in some circumstances for the two legal enactments taken together to offer the landowner not only a guarantee of title to his property but also, in large measure, a guarantee of the accuracy in the recording of

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[6] There is strong support for this general proposition in a letter from no less an authority than Professor Ir van der Weel, Rector of the International Institute for Aerial Survey and Earth Sciences (ITC). He refutes the contention that the value of a parcel is determined by multiplying its area by a fixed amount per square metre, and shows that, instead, the price per square metre is calculated by dividing the value of the parcel by its area. He concludes: "Summarizing and generalizing I am convinced that, if there exists a relation between the value of the land and the accuracy with which its boundaries have to be measurcd, this relation can only be rather vague and will certainly not be valid for extreme cases where the land value is very high or very low. Overlooking this fact may lead and has led to unrealistic accuracy requirements for cadastral (and other) surveys, thus obliging the surveyor to use time consuming and expensive procedures" (XXII Survey Review 171 (January 1974) 234).

the position of his boundaries relative to those of his neighbour. It is this situation, evident in many countries operating Torrens type registration statutes coupled with rigorously supervised survey systems, that has led to the common but erroneous belief that these statutes guarantee boundaries. We discussed this point at length in Chapter 8.[7] Any survey system which provides an implicit guarantee of the positional accuracy of property boundaries – whether used in conjunction with a register of title or not – is of real practical value to a landowner whose property demarcation has not been maintained, or to an administrative officer who is faced with boundary relocation problems. But the term 'guaranteed boundary' has meaning only in the sense that the reconstruction of the boundaries from survey data may be guaranteed by the State. It cannot mean that the boundaries are 'insured' so that the State will accept some pecuniary liability if demarcation or survey are later shown to be faulty.

2.17 The question of accuracy can be fiercely debated, and it is a field into which the layman hesitates to venture, though instinctively he may feel that expertise is running riot when, for example, measurements are recorded to a hundredth part of a link. A link is 7.92 inches; a hundredth part of it is about 2 mm, an accuracy which not only seems unnecessary but is difficult to believe possible. Accuracy has in fact tended to become a fetish amongst the Torrens '0.01' surveyors, 'the uttermost last inchers' as they have been called by those who doubt whether the expense and delay caused by demands for such accuracy are really justified. This accuracy may produce a once-and-for-all 'final survey', capable of minute subdivision should the occasion arise, but how often does the occasion arise? And if it does, is it not then possible to effect the survey which only then actually becomes necessary?

2.18 Nevertheless any cadastral survey system must make provision for defining and maintaining acceptable standards of accuracy. In general two cases arise. If all surveys for land registration purposes are carried out exclusively by a government agency it is evident that the necessary control can be exercised by the agency itself[8], in much the same way as a manufacturer exercises quality control over his own product. If, however, land surveys are carried out exclusively by surveyors in the private sector or, as is more usual, by both government and private surveyors, more formal arrangements are necessary, and it is usual to make legal provision for the official supervision of any survey to be used in a land transaction. This then brings us to the consideration of survey law.

(4) Survey Law

2.19 The first requirement in survey law is provision for duly authorized surveyors and their assistants to have a right of access to private property for the purpose of conducting a survey, and of course provision must be made at the same time for the assessment and payment of compensation for crops necessarily destroyed or any other damage done during survey operations. This law will also

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[7] See 8.6

[8] The British Ordnance Survey is in this category. Private surveyors play no part in the maintenance of the registry maps.

include penalties for the wilful destruction of official survey monuments, to which we referred above. (These provisions may be included in statutes providing for systematic adjudication.)[9]

2.20 In those countries where surveyors in private practice are authorized to carry out 'official' surveys, the normal arrangement is for the survey law to provide, *inter alia*, for the examination, licensing, and discipline of practising surveyors (i.e. for the control of the quality of the surveyors permitted to practise), and for the issue of a set of survey regulations defining the standards to be achieved and the method of presentation of survey data to the controlling authority (i.e. control over the quality of the surveys themselves). Most survey authorities do not stop at the promulgation of regulations but check in considerable detail that the surveys submitted to them do in fact conform with the standards set.

(5) Methods Of Book-Keeping

2.21 A basic requirement of any cadastral mapping system which is intended to be kept up to date is an effective method of book-keeping. The survey records office can be looked upon as the survey counterpart of the land registry[10]. Its function is to classify and record approved survey data relating to all properties on the register in order to keep surveys continuously in step with registerable transactions. It is thus the repository of survey data needed for effecting mutations in those systems which require them to be effected officially. The exact nature of the survey data recorded and the methods of book-keeping used will naturally vary with the particular requirement of the system of registration. It is clear for example that data needed to support the maintenance of registry index maps in a 'general boundaries' system will differ from that needed to support a fully numerical cadastre.[11] In the former case the essential records are the mutation forms by which the registrar authorizes and describes the nature of each mutation and the surveyor's field sheets, duly checked, which support the changes subsequently made to the registry index map. In the latter case the authority to survey is accompanied by the surveyor's original field books recording the measurements actually made during his survey together with a volume of computations show in the control data used and the results obtained and a plan which illustrates graphically the effect of the boundary mutation. In both cases it is desirable to ensure that the indexing of survey data bears as direct a relationship as possible to that used to identify properties on the land register.

2.22 Throughout our discussions so far we have stressed the need for official supervision in one form or another for the effective operation of a cadastral survey system. At this point it may be worth emphasizing that we are not merely advocating bureaucracy; any widespread survey activity requires discipline if it is

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[9] See 23

[10] For example, the records of alienated lands and the Land Register have been successfully maintained as virtually one register in New South Wales under the control of the Registrar-General. Under this method the survey plan is part of the register and both are available for public inspection at the same office.

[11] See subsection 3(2) below

to be welded into a consistent whole and, if it is to allow one surveyor confidently to use another's work, there must be a controlling authority. It need not necessarily be a Government department but could be a professional association; more usually it is a combination of the two.

2.23 We may expect therefore that the overall need for supervision will extend to the handling of survey records. This is in fact the general situation in survey records offices set up in support of land registration systems. The essential features are that records of all surveys relating to registrable transactions or extensions to available survey control, whether carried out by government or private licensed surveyors, become public property once they are checked and approved. Nevertheless since much of the survey data can be used for many other purposes it would be inequitable to make it too freely available to persons who have not contributed to its cost. Accordingly a filter system is introduced to separate out those plans and records (such as registry index plans and general plans) which can be made available to any member of the public merely on payment of a copying fee. These must be distinguished from detailed plans of particular properties, copies of which can be supplied to the landowner concerned on application, and also from the numerical data (analogous in many ways to a doctor's clinical notes) which may only be supplied to other practising surveyors. Most authorities supply all essential data to licensed surveyors free of cost, or on payment of a nominal copying fee, but data supplied to engineers and surveyors engaged on non-title work are charged for at a rate which reflects part of the cost of survey. Funds collected in this way help to finance extensions to the national control framework.

3 Types of survey system

3.1 Before considering particular techniques of cadastral survey in more detail it is convenient to divide the possibilities into systems which are essentially graphical or pictorial and those which are essentially mathematical or numerical. There is some blurring of the dividing line between these two basic alternatives; for example, so far as the registrar and the public arc concerned, a numerical system can be made to appear purely graphical merely by omitting all measurements from the plan, but the distinction is nevertheless sufficiently clear for us to make some valid comparisons.

(1) Graphical Systems

3.2 The main distinguishing feature of this broad group of systems is that they are designed to illustrate the pattern of land holdings on the register in a pictorial manner to a degree of precision commensurate with the scale of illustration chosen. A graphical system is particularly suitable for situations where the majority of properties are clearly defined on the ground by visible features and the principal function of the map in the land registration system is that of an index. Apart from overall consistency (even an index needs to be free from gaps and overlaps) there are few survey constraints provided that the function remains solely that of an index. Outstanding examples of this use of a graphical system are to be found in Britain where Ordnance Survey maps are adapted for the purpose and in some registration

areas of Kenya where properties are identified and indexed on enlarged aerial photographs.

3.3 In most developing countries, however, and indeed in many developed countries this kind of situation is exceptional. Moreover, there are complicating factors, as boundary features in many areas are often scarce or transitory, and so the survey must be not merely an index but also capable of providing the registrar with evidence for the resolution of disputes over missing boundaries; it may possibly also be necessary to calculate areas. These factors have an effect on the choice of survey methods as we shall presently see.

(2) NUMERICAL SYSTEMS

3.4 In this group of systems the boundary data may also be presented to the registrar in map form either with or without the addition of dimensions, but it could equally well be presented in the form of printed lists of coordinates, bearings and distances between boundary monuments, or alternatively as punched cards or magnetic tape. The essential difference between maps produced by graphical systems and those produced through numerical systems is that in the latter case, since boundary data have been recorded in numerical form to the standard of measurement accuracy specified for the system they are quite independent of the map scale. Thus, as there is no need for dimensions to be obtained by scaling, the maps can be drawn at any scale which is administratively convenient.

3.5 Clearly the inherent qualities of numerical systems go well beyond the limited requirements of a simple registry index map and we may therefore expect to find them being used in situations where the additional benefits to the landowner or the community at large are of great importance – perhaps even more important than supporting a register of land rights. For example in countries such as Singapore, where it is customary to demarcate and sell land by area, in addition to supporting the land register the survey system may (1) provide data for planning a suitable layout of plots, (2) physically translate the plan to the ground, (3) locate and record the positions of municipal services, and (4) provide the areas of individual plots.

3.6 In New South Wales the numerical cadastral survey has been used since the early days of the Colony but of course with gradually improving orders of accuracy. It has worked well in a country where undeveloped or unimproved land was the general rule and boundaries had to be laid out and monumented in such a way that their position could be relocated at a future date. These conditions still persist – in fact many boundaries are created by design in plan form and then transferred to their position on the ground by numerical cadastral survey.

4 Survey methods

4.1 We will now briefly describe some of the more common survey methods which have been used for cadastral purposes and attempt to demonstrate in what circumstances they can be considered to satisfy the conditions we mentioned at the beginning of this chapter.

(1) Annotation Of Existing Topographical Maps Or Aerial Photographs

4.2 The principal advantage of this procedure, from the standpoint of the registry, is that the basic need to control scale and consistency has already been met and paid for. Provided that properties can be identified unambiguously from the plotted or photographic detail and the record is required only as an index to the register this method can be regarded as highly satisfactory, but as difficulties of identification increase the value of the method rapidly diminishes. So rapidly in fact that all confidence is soon lost. It is fundamental to all land survey activities that all measurements and identifications should be capable of independent verification within certain allowable tolerances. Observations which do not comply with this rule are merely unsubstantiated opinions, not matters of fact, and a surveyor's opinion is probably no better than that of anyone else!

(2) Graphical Survey By Plane Table

4.3 In a situation where there are no suitable topographical maps or aerial photographs but where it is customary to demarcate property boundaries either in length or by visible monuments at the corners, it should be possible to build up an index map by direct observation in the field. In this case, however, the system must itself provide the necessary control of scale and consistency from its own resources.

4.4 Once control for a particular area such as a registration block has been established, one method of constructing an index map is by use of a survey technique known as plane-tabling. The procedure is as follows. Positions of all control points in the area are plotted at the desired map scale on gridded paper. This blank map is then divided up into a series of squares of a size convenient to fit on plane-tables, which are merely drawing boards mounted on portable tripods which can be adjusted to a convenient height. The index map is then built up graphically by field surveyors who erect (and level) their plane-tables successively over the monuments marking the control points and, with the aid of sight rules, or alidades, first establish the correct orientation of the board by aligning it on the nearest control point, and then draw pencil lines to all other salient points of boundary detail they wish to record. As the work proceeds the intersections of the radiating lines mark the relative positions of each of the features sighted, at a uniform map scale. Additional boundary detail between these fixed positions is then sketched in.

4.5 Even from this brief description it will be evident that the method, though simple and effective, is rather tedious and slow. The output of a single surveyor will not be high, so for such a system to be effective large numbers of plane-tablers must be employed, and this introduces further problems of organization and management. Nevertheless when wage rates are low and there is a social need to provide maximum employment opportunities such a system can be viable. It is still the method used almost exclusively in cadastral systems on the Indian subcontinent, and in the Nile Valley, but it has been largely superseded elsewhere. The method is limited in its effectiveness to those areas where physical boundary features are the rule rather than the exception and where individual properties are relatively small in size. It is of course possible, as in parts of the Nile valley, to use plane-tabling to

map properties demarcated only by temporary marks, but it will be realized that this adaptation of an essentially one-man technique increases the labour requirements, for, unless boundary turning-points are visible to the planetabler, assistants are needed to indicate their positions.

(3) Graphical Survey By Compass And Chain[12]

4.6 In areas where conditions such as tree cover or lack of physical boundary features preclude the economical use of the plane-table, a graphical representation of parcel boundaries can be built up by direct measurement between boundary marks or monuments. In the simplest situation (i.e. where the ground is relatively flat) the necessary bearings and distances can be measured by compass and chain. Once again it is necessary to treat the work systematically ensuring that the main traverses fit between the control points previously established, before building up the network of individual property boundaries. The plotting can be carried out directly by protractor and scale on gridded map sheets like those used in plane-tabling or, alternatively, the field records of bearings and distances can be converted to rectangular co-ordinates (northings and eastings) by simple trigonometry prior to plotting. Although the method is labour-intensive in respect of field-work the coordinate method of handling the field data readily lends itself to automation in the office.

4.7 Unlike the plane-table method the compass and chain method is sensitive to uneven terrain. The registry map is two-dimensional and the distances needed to plot boundaries on it must be reduced to the plane of the map. If the terrain is flat, or nearly flat, distances measured on the ground differ only in scale from the distances shown on the map but, as ground slopes increase, the variation between the ground and the map becomes more and more significant. Provision must therefore be made to measure and record not only distances but also angles of slope or variations in height in order to reduce measured ground distances to the horizontal plane. Various expedients are used to overcome this problem but all suffer from the twin drawbacks of being time-consuming and prone to mistakes thus limiting the general usefulness of the method.

(4) Graphical Survey By Tacheometer

4.8 This method is really a logical development of the last method, the difference being that an instrument called a tacheometer is used in conjunction with a levelling staff to measure distances by optical means. The same instrument is usually, but not always, used for the measurement of angles which are substituted for compass bearings. The instrument can be so constructed that the distances measured are true horizontal distances regardless of the slope of the ground, and this is an additional advantage. Although these instruments are fairly expensive and require more skill to use than is needed for compass and chain surveying, the total volume of labour

[12] The term ‘chain’ in survey literature is not confined to the Gunter’s chain of 66 ft but includes the engineer’s chain of 100 ft and also linen and steel measuring tapes or bands of various lengths.

required is less since the output per man is much greater, particularly in hilly country. Plotting can also be easily automated.

(5) Rigorous Ground Survey Methods

4.9 So far we have described methods whose main purpose is to produce a registry index map and provide for its maintenance; but the methods we shall now describe, because of their inherent measuring accuracy, are capable of supplying more precise detail than is needed for purely index purposes. Whether or not the registrar can make use of this detail, it does have added value for the landowner and the Community, and this must be taken into account in any cost-benefit study of cadastral survey methods. It should also be emphasized that, whilst it is generally true that the more accurate the survey the more it costs, the relationship is not a simple one, at least at the lower end of the scale where labour costs tend to swamp all other factors in the cost equation.

4.10 For the purposes of this chapter we can group together all the more rigorous ground survey methods, since they are essentially the same in concept and differ only in the type of equipment used to measure angles and distances. Angles are universally measured by theodolites of various patterns. Those reading directly to one second of arc are the most common for cadastral surveys of the highest precision. Distances may be measured by steel tapes, often suspended in catenary (i.e. hanging freely between supports clear of the ground) and corrected for the effects of thermal expansion, slope, sag and height above sea level. Alternatively it is becoming increasingly common for distances to be measured by electronically timing the passage of modulated electromagnetic or light waves between the line terminals. These distance measuring techniques may be grouped under the name electronic distance measurement (EDM).

4.11 Common to all these methods which depend on accurate measurements is the need for precise boundary marking. The methods are therefore only applicable to situations where corners of property boundaries are marked by survey monuments.

4.12 Another feature of cadastral survey methods where data are collected in numerical form is the facility with which the data may be handled by automated data processing (ADP). In one such system being developed in Sabah, Malaysia, the surveyors' field measurements are recorded on computer data cards. The cards are subsequently scanned automatically, the survey is computed, adjusted for consistency and automatically presented as a filed plan in a standard format complete with boundary data and areas.

4.13 For a modest capital outlay on the purchase of suitable processing equipment it is evident that great savings in labour costs can be made without loss of quality. For example the checking of surveys, which is a great drain on skilled manpower in many cadastral survey agencies, is virtually eliminated in the Sabah system.

(6) AIR SURVEY METHODS

4.14 All the survey methods described so far, whether graphical or numerical, rely on survey data measured and recorded in the field. Some indication has been given of ways in which economies can be made in the use of labour, but it will have been noticed that the main potential for saving is almost always to be found in the phase of the system following the collection of data. It is therefore clearly worth considering whether survey methods are available which would reduce the dependence on physical measurements in the field. The most obvious choice lies amongst those mapping methods which make use of vertical aerial photographs and which largely replace measurements on the ground (field surveys) by measurements on photographs (photogrammetry).

4.15 There are three points to note. *First*, no photogrammetric method can entirely eliminate the need for ground measurements. We still have the survey control problem and also the need to establish the scale relationship between the real earth and the model earth represented by the air photographs. *Secondly*, the camera is no better than the field surveyor at recording invisible boundaries. Like him it can only record what has been made visible to it, but unlike him it cannot ask for clarification during the course of its survey. This is possibly the greatest single factor limiting the choice of air survey methods for cadastral purposes, for in effect they are only suited to areas where 'air visible physical boundaries are the rule or alternatively where it is economically practicable to make boundary corner monuments 'air-visible'. *Thirdly*, the viability of most air survey methods depends on the economics of large scale operations. The taking of aerial photographs is expensive and so is the equipment required for extracting data from them. This expense may be justified for the initial construction of maps to support a land registration system, but it is doubtful if expenditure on this scale could be justified merely for the maintenance of an established system.

4.16 It is not intended here to describe particular photogrammetric methods in detail; it is sufficient for our purpose to state that, as with ground methods, the range of choice is sufficiently extensive to cover the whole range of accuracy requirements and methods of presentation which are likely to be met with in the registration of rights in land. The limitations on their use, as we have pointed out, are set by the environment and are not inherent in the methods themselves.

(7) HYBRID SYSTEMS

4.17 Before ending this brief review of survey methods it is perhaps worthwhile to reiterate a statement that we made at the beginning. There is no standard way of carrying out a survey. It follows therefore that a single cadastral survey system may, and often does, encompass more than one of the methods we have described. To quote but one example, the system being used in the British Virgin Islands for the preparation of registry index maps combines photogrammetric plotting of physical boundary detail, adjusted to a rigorous ground survey, and tacheometric survey of boundaries which are not visible on aerial photographs but which can be pointed out to field surveyors. A wide range of combinations of this sort may be employed

and such hybrid systems appear to offer the maximum scope for achieving the most economical solution of the cost equation in nearly all circumstances.

5 The administrative organization

5.1 In our consideration of the basic requirements of any cadastral survey system mention was made of the need for an authority to exercise administrative control over the system. We stated briefly that the controlling authority could be a Government department, a professional association, or more commonly a combination of the two. Let us now examine this proposition in more detail.

5.2 Since support of the land register (whether of deeds or title) is the main function of a cadastral survey system it can be argued that the Registrar himself is the best person to maintain administrative control. On the other hand, the administrative problems associated with a survey system are unlikely to be the same as those associated with the preparation and maintenance of a land register, except perhaps at the book-keeping stage, and it is obvious that technical survey matters and the maintenance of accuracy standards can be most efficiently controlled by an organization distinct from the registry. Where registration of title is concerned, however, the map which is actually used for illustrating the register, since it is an integral part of it, must be under the control of the Registrar to the extent that it cannot be altered in any way without his consent.[13] Hence the system of mutation forms which is necessary where the map is kept by an organization outside the registry[14]. Such a system is not needed if the registry keeps its own copy of the map, or if each parcel has its own filed plan.

5.3 A professional association of surveyors could in theory effectively control the survey practitioners and maintain the required accuracy standards but it would be less easy, and probably highly undesirable, for such an unofficial body to be the sole custodian of survey records which, like the land registers themselves, are essentially public property.

5.4 For these reasons we consider that the arrangement, already widely adopted, of having cadastral survey managed by a Government department in co-operation with a land surveyors board representing the private sector of the profession to be the most satisfactory administrative arrangement when both sides contribute directly to the maintenance of the registry map. As we pointed out in paragraph 2.18 however, where maintenance of the map is carried out exclusively by a single agency with its own staff, as is the case in Britain, there is no need for such an arrangement since the private sector has no responsibility in the matter. The Government department can be purely a survey department responsible for all survey matters including of course topographical mapping and geodetic surveys or

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[13] Mr J A Griffith, Senior Deputy Registrar of New South Wales, comments: "Personally I am unable to accept the concept of a system which would purport to give the Registrar responsibility for title under a guaranteed title system, without responsibility for identification of and definition of the parcel."

[14] See 17.3.6

alternatively it may be a branch of a larger department dealing with wider aspects of land administration.

5.5 Arguments can be adduced in favour of either alternative but we do not consider these issues to be of major importance provided that whatever arrangement is decided upon, the actual technique of cadastral survey is seen to be distinct and independent from registration matters. The Registrar decides what picture is required to support the register but how it is drawn and the actual drawing of it are best left to the surveyors.

6 Conclusion

6.1 We have tried to indicate in the foregoing paragraphs the essential features of a cadastral survey and to show that there is no tailor-made solution applicable to all circumstances, when a new system is being set up.

6.2 Anyone charged with such a task would be well advised to make a study of existing systems in countries where conditions are broadly similar to his own. Such a study may not, in many cases, provide an immediate solution to the problem but, by comparing the relative efficiency of survey methods in real conditions, it is possible to narrow the range of choice and to identify places where improvement can be made.

6.3 It must always be remembered that a cadastral survey system, once started, is a continuing commitment and the importance of proper long-range planning for its maintenance in changing circumstances cannot be emphasized too strongly. This is the lesson to be learnt from the Napoleonic cadastre in France.[15]

6.4 It has also been pointed out that all cadastral surveys are expensive, although in some systems the true costs are not immediately apparent; nevertheless it is important to resist the temptation to sacrifice long-term needs for the sake of short-term savings. This is often difficult when dealing with politicians, treasury officials, and some administrators; but the kind of study we have just advocated will amply demonstrate the problems that have arisen in many countries through substituting expediency for proper planning.

6.5 A resolution adopted at the UN Regional Cartographic Conference for Asia and the Far East held in India in 1955 stated: "The precision of a cadastral survey should not be more than necessary for the fulfilment of practical requirements. The system, the method of production, and the legal basis should be adapted to local circumstances both social and physical."[16]

6.6 This statement summarizes our thesis and the only reservation we would make is that when 'practical requirements' are being assessed, vision should not be confined to the present but future needs must also be taken into account, subject always, of course, to current administrative feasibility. Above all it must be remembered that, although the immediate requirements of the Registrar must take

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[15] SeeA.2.4

[16] Report of UN Regional Cartographic Conference for Asia and the Far Last (1955) I ll

priority, a sound cadastral survey system can be made to serve many other needs of the community at little or no extra cost. In fact efficient land administration may be able to make do without registration of title; it cannot dispense with cadastral survey.