Fit for Purpose Parcel Mapping Methodologies for a Seamless Cadastre Database

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Fit for Purpose, Cadastral Mapping

SUMMARY

The joint FIG/World Bank Publication states that Fit-for-purpose means that the land administration systems – and especially the underlying spatial framework of large scale mapping – should be designed for the purpose of managing current land issues within a specific country or region – rather than simply following more advanced technical standards. The Fit-for-purpose approach is participatory and inclusive – it is fundamentally a human rights approach. Benefits relate to the opportunity of building appropriate land administration systems within a relatively short time and for relatively low and affordable costs.

LAND ADMINISTRATION VISIONARIES

Few would dispute (though some surely do) that Torrens and De Soto are two pioneering visionaries in the land administration field. Torrens was responsible for the establishment of the Land Registry of England and Wales in 1862 and de Soto, in large part through the publication of his ground breaking book, *The Mystery of Capital*, alerted us to the mountain of dead capital that exists within the developing countries of the world.

SIR ROBERT RICHARD TORRENS

Born in 1814 in Cork, Ireland, Torrens travelled to South Australia with his wife in 1840. He became collector of customs and quickly gained a reputation for unorthodox practices: in his first year he was censured for reducing wharfage rates without authority, carelessness with pay lists, unauthorised absences and not supporting some of Governor Sir George Grey's policies. Despite his cavalier political and business practices during his appointment as colonial treasurer and registrar-general, he was a nominated member of the Legislative Council between 1851 and 1857 and member of the Executive Council in 1855. In 1856, the *South Australian Register* published the first report and outline of a Torrens bill. Although he claimed authorship of the system, it's clear that it had been an evolutionary process and was not his achievement alone.

HERNANDO DE SOTO

Peruvian economist Hernando de Soto's message to the developing countries of the world and their donors is a simple one: Enable poor people to register their property so that they can borrow against it to build businesses, buy farming equipment, seed and fertilizer and for other purposes. Millions of citizens of developing countries do not have formal title to their land and De Soto believes that this is a key source of rural and urban poverty. According to de Soto, the value of un-registered land in developing countries totals over US$9 trillion. As a result of not registering their land, their most under-utilized and prized possession, they cannot convert their asset into collateral for loans.

DE SOTO AND THE IMPORTANCE OF SECURE LAND TENURE

Between half and three quarters of a country's wealth can be comprised of land and buildings. Securing land tenure through creation of a property title can significantly increase property values and subsequent investments. de Soto's book *The Mystery of Capital* attempts to explain why capitalism has triumphed in the west and failed everywhere else. The following extracts from that book offer powerful arguments to support his theories.

The major stumbling block that keeps the rest of the world from benefiting from capitalism is its inability to produce capital. Capital is the force that raises the productivity of labor and creates the wealth of nations and it is the one thing that the poor countries of the world cannot produce for themselves.

Even in the poorest countries, people save and accumulate wealth. In Egypt, for instance, the wealth that the poor have accumulated is worth fifty-five times as much as the sum of all direct foreign investment ever recorded there, including the Suez Canal and the Aswan Dam. But the poor hold their resources in defective forms: houses built on land whose ownership rights are not adequately recorded, unincorporated businesses with undefined liability and industries located where financiers and investors cannot see them. Because the rights of these possessions are not adequately documented, these assets cannot readily be turned into capital, traded or used as collateral for a loan.

The formal property system is where capital is born. Once the focus is on the title to a house and not on the house itself, it is possible to go beyond viewing the house as mere shelter (a dead asset) and to see it as live capital.

In the West, by contrast, every parcel of land, every building, every piece of equipment or store of inventories is represented in a property document that is the visible sign of a vast hidden process that connects all these assets to the rest of the economy. These assets can be used as collateral for credit. The single most important source of funds for new business in the United States is a mortgage on the entrepreneur's house. These assets also provide a link to the owner's credit history, an accountable address (Author note: universally available from what3words.com, 2015) for the collection of debts and taxes, the basis for the creation of reliable and universal public utilities and a foundation for the creation of securities (like mortgage backed bonds) that can then be rediscounted and sold in secondary markets. By this process the West injects life into assets and makes them generate capital. Americans and Europeans established widespread formal property law and invented the conversion process in that law that allowed them to create capital. (de Soto, 2000)

BEFORE THE TORRENS SYSTEM

Before the Torrens system was introduced in 1862, a General Law title system operated that consisted of a chain of title deeds all of which had to be in place to enable a property to be transferred. Title deeds are documents that show ownership, as well as rights, obligations, or mortgages on a property. A General Law title could have many deeds, many of which were handwritten, not always legibly. Torrens created a central registry where all transfers of land are recorded in the register, thereby producing a single title with a unique number (or folio) that also records easements, mortgages and discharges of mortgage.

WHAT IS THE TORRENS TITLE SYSTEM?

The Torrens title system is a secure and reliable method of recording and registering land ownership and interests. Established in South Australia in 1858, the then revolutionary and efficient land titling system was adopted throughout Australia and New Zealand. Countries now using the system include, among others, England and Wales, Ireland, Trinidad and Tobago, Malaysia, Singapore, Iran, Canada and Madagascar.

The Torrens title system works on three principles:

1. The land titles Register accurately and completely reflects the current ownership and interests about a person's land.
2. Because the land titles Register contains all the information about the person's land, it means that ownership and other interests do not have to be proved by long complicated documents, such as title deeds.
3. Government guarantee provides for compensation to a person who suffers loss of land or a registered interest. (Victoria State, 2012)

UK LAND REGISTER RULES (LTR 1898) - MAPS AND VERBAL DESCRIPTIONS OF LAND (FIXED BOUNDARY AND GENERAL BOUNDARY SURVEYING)

It appears that in 1898 the UK Land Registry was not about to become entangled in a discussion of the pros and cons of general boundary versus fixed boundary surveying methodologies. Rather, their focus seemed to be squarely on getting properties into the revenue-generating register as quickly and affordably as possible by either method. As might be expected, revenue was the driving force in the establishment of the Land Registry.

Rule 209. The ordnance map, on the largest scale published, shall be the basis of all registered descriptions of land.
Author note: The UK Ordnance Survey national coverage map series consists of 1:1,250 (urban), 1:2,500 peri-urban) and 1:10,000 mapping (rural). In the past, 1:10,560 (6 inches to I mile) scale mapping was also used.

Rule 210. The notes on the plan, if sufficiently exhaustive, will in many cases render a verbal description of the land on the register unnecessary, but a schedule in the case of large estates should at any rate be added.

Rule 211. If it is desired to indicate on the filed plan, or otherwise to define in the register, the precise position of the boundaries of the land or any parts thereof notice shall be given to the owners and occupiers of the adjoining lands, in each instance, of the intention to ascertain and fix the boundary, with such plan, or tracing, or extract from the proposed verbal description of the land as may be necessary, to show clearly the fixed boundary proposed to be registered; and any question of doubt or dispute arising therefrom shall be dealt with as provided by these Rules.

Rule 212. When the position and description of the boundaries of the land have been thus ascertained and determined, the necessary particulars shall be added to the filed plan, which shall be the Property Register.

Rule 213. Except in cases in which the fixed boundary of the land has been thus ascertained the map shall be deemed to indicate the general boundaries only. In such cases the exact line of the boundary will be left undetermined (as for instance whether it runs along the centre of a wall or fence, or its inner or outer or how far it runs within or beyond it; or whether or not the land registered extends to the centre of an adjoining road or stream). When a general boundary only is desired to be entered in the register, notice to the owners of the adjoining lands need not be given. The result of this Rule is that, where the boundary is left undetermined, no indemnity will be given if the dispute is confined to the general boundary line.

Rule 214. Where, and so far as, physical boundaries or boundary marks do not exist, the fullest available particulars of the boundaries shall be added to the plan. This Rule appears to be applicable whether a precise boundary is fixed or not. (Benjamin, Marigold, 1899)

Author note: The UK Land Registry system, and its exclusive use of 1:1,250, 1:2,500 and 1:10,000 national map coverage for creation of the cadastre, is worthy of consideration of adoption by developing countries as a Fit-for-purpose parcel mapping model for creation of a seamless cadastre database. It was obvious to the pioneering UK Land Registry, even in 1862, that accurate topographic mapping in conjunction with a hybrid of general boundary and fixed boundary surveying methodologies, was eminently Fit-for-purpose.

CONVERTING DIRT TO GOLD: HOW TO CREATE CAPITAL FOR MILLIONS OF PEOPLE IN DEVELOPING COUNTRIES

Millions of the world's poor have assets in the form of houses, crops and businesses, yet they cannot create capital from them. One reason they are not able to leverage their assets is due to the lack of a formal property system. Or, on the other hand, there is a formal property system that operates under corruption-ridden, complex, expensive and pro-wealthy rules. Too much land is in the hands of too few people in developing countries and by some estimates, putting land measuring as little as one tenth of an urban acre, or one or two rural acres, in the hands of the poor in developing countries is sufficient to break the cycle of poverty.

Citizens of developing countries can begin to generate wealth in the form of land that they own or occupy. The first step in converting their land from an asset to capital is providing a solution to the problem of achieving secure land tenure. Debates have been taking place regarding the lack of secure land tenure in developing countries for many decades. If nothing is done to implement a workable program for establishing secure, pro-poor and pro-women land tenure in the very near future it is safe to assume that the same debates will continue for many more decades. A global approach to helping people secure land tenure must be implemented as soon as possible.

The real estate market is the proven catalyst for generating capital movement in markets worldwide. The power of the real estate market is the asset (land and structures). Knowing "**where**" this property is located, and "**who**" owns it is the basic foundation for real estate transactions. The ability to access the "where" and "who" information is critical for the rapid exchange of properties in the marketplace. If a comprehensive, accurate and transparent land records system is in place, the speed with which such property transactions can transpire is significantly increased. The faster property contracts move, the more capital there is in motion in the marketplace. The more capital that is available in the marketplace, the greater the investment and development that results.

Many developing countries deny women the right to own property. A report by ActionAid International, *Cultivating Women's Rights for Access to Land 2005*, states that, although it has been proven that empowering women socially and economically leads to positive effects on household food security levels, women experience unacceptable statutory and customary discrimination.

Geospatial mapping and GIS foundations are the means by which the door to the property title insurance market is opened. Once the issue of who owns what property is settled, this provides the assurance needed for financial institutions to provide primary and secondary mortgage financing. The concept revolves around the reality in developing countries that the citizens, when they acquire title or a certificate of occupancy to the property they own (or occupy) can obtain secured loans, backed by the property title or certificate of occupancy, for the purpose of improving their property or for buying new property.

The US model is the basis for establishment of the primary and secondary mortgage markets in developing countries. The effect on the economies of those countries is substantial. This is not surprising when it is realized that 12% or more of the US economy is driven by the primary and secondary mortgage and real estate markets. When people buy a home they start to take better care of it. They buy paint, lumber and plumbing supplies. They employ builders to construct additions to their property. They buy a second home. They employ landscapers, plumbers, electricians, and painters. The economic conditions within countries that enable their citizens to own property improves dramatically.

The happy citizens are then persuaded that paying property taxes and getting permits to build or improve a home are necessary functions of society and of benefit to everyone. Taxes pay for improvements in city infrastructure, construction of schools, hospitals and parks. They learn that capitalism can be a good thing. So they register their property and pay taxes on equitably assessed property values. A modern land records management system is created and all the property ownership and mapping information is used to feed a GIS, in addition to a variety of land records management software modules for land registry records keeping, cadastral mapping and tax revenue calculation.

The databases are kept current and the NSDI compliant information becomes available for use by both the public and private sectors. As a result, a reliable and transparent revenue stream is established to enable local and national governments to provide greatly improved services to the citizens, attract investment and provide funding mechanisms for property and industrial development. (McKenna, 2006, 2016)

WHO OWNS THE WORLD

A recently published book, *Who Owns the World* by author Kevin Cahill, asserts that the main cause of most remaining poverty in the world is an excess of land ownership in too few hands. What the book also asserts is that private ownership of a very small amount of land – one tenth of an urban acre or an acre or two of rural land, granted to every person on the planet has the potential to, and Cahill believes will, begin the ending of poverty on a global basis.

In some countries people have obtained the land they need, the acreage for a private dwelling, and obtained a form of ownership for that acreage. In many cases, what they have is not ownership but feudal tenure, sometimes called 'freehold'.

The very touchstone of what freedom really is, though, in the here and now, is clear. It is the right and ability of individuals, men and women, to actually own land. With ownership comes security of shelter, and a vital means to the right to life. But, as the 15% of the planet who have obtained relative ownership of their homes show, ownership is also the first step to prosperity and the solvent that destroys poverty.

More than 50% of the world's 197 countries and 66 territories have either no land registry at all, or one that covers less than 10% of the land of the country. Ask why so few proper land registries exist anywhere in the world. Then look at those who scream the loudest about the sanctity of private land ownership rights, those not named in any land registry, but who really do own most of the land of the earth.

Of the earth's 6,500 million inhabitants, few, perhaps just 15%, own anything at all, and most are pitifully poor. The distinguishing feature of universal poverty is landlessness. Yet, there is no great movement to get land to the impoverished masses. Aid, yes. Land, no. (Cahill, 2006)

THE SEAMLESS CADASTRE DATABASE

There are several compelling reasons for surveying a property parcel that will become part of a comprehensive fiscal cadastre:

- Problems with inadequate cadastres, lax and inequitable tax policies and practices hinder the revitalization and maintenance of neighborhoods and prevent local governments from collecting revenue needed to support public services.
- Provide documentation in the form of a parcel survey to help citizens achieve secure land tenure
- A property owner desires to know as accurately as possible the value of his or her asset when selling a property or seeking a mortgage on it, and;

- A taxing agency needs to know the area of a parcel in order to apply the correct property tax rate to it

Parcel corners locate parcels on the surface of the earth, to one level of accuracy or another, resulting in a coordinate-based cadastral mapping system that is improved and updated as new parcels are surveyed or mapped over time. An important role that is played by parcel corners is the ability to calculate the area of a parcel based on the parcel corner coordinates. Therefore, the more accurate the parcel corner coordinates, the more accurate is the resulting parcel area calculation. Regardless of the methodology employed for the location of parcel corners on the earth's surface, it is impossible to calculate any parcel area with 100% precision.

There are two primary technologies employed today in the task of locating parcels on the earth's surface.

1) Land surveying: Land surveyors use a total station (a tripod mounted optical instrument that measures angles and distances between parcel corners along a parcel boundary) and GPS receivers that locate a position on the ground based on time and distance measurements to satellites that are in orbit above the earth. When parcel corners are surveyed using either total station or GPS technology, the resulting fixed boundary accuracy of parcel corners can be calculated to within a few centimeters of their true position. A two man field survey crew can survey fixed boundary parcels at the rate of 3 to 10 a day, depending on the complexity of the parcel boundaries.
2) Aerial surveying: Aerial surveying, or photogrammetry, is widely employed throughout the world to create general map boundary databases over very large portions of the earth's surface. When parcel corners are surveyed using photogrammetric technology, their resulting accuracy can be calculated to within 5 centimeters to three meters, depending on the level of accuracy of the underlying photogrammetric map that has been created. Individual mapping technicians (using inexpensive office-based workstations) can survey general boundary parcels at the rate of 40 to 50 per day, depending on the complexity of the parcel boundaries.

The major differences between land and photogrammetrically surveyed parcel corners are the accuracy, cost and time required to create the parcel corner coordinates. (McKenna, 2016)

DEFERRED MONUMENTATION – GOOD IDEA OR BAD IDEA?

In his excellent, informative and mostly pragmatic paper, "*Deferred Monumentation and the Shakedown Factor*", D. Goodwin discusses how surveyors and legislators, in their efforts to define land unambiguously, have had to consider a number of models including the general boundary system, even though the physical boundary features such as fences and walls sometimes disturb or destroy boundary marks when they are erected. Additionally, they usually are not erected exactly on the legal boundaries, either to avoid disturbing boundary marks or else in ignorance of their position. In another widespread model, the fixed boundary system, corner boundary marks are the norm. Goodwin raises two questions. First, whether it would be better for surveyors to place boundary marks after the erection of physical boundaries, roads and services, and second, whether it is necessary to place boundary marks at all, or whether these should be placed only to resolve conflict where this arises.

Goodwin discusses his Case Study 1: High Density Developed Townships in Zimbabwe. HDDTs, which make up a significant percentage of dwellings in Zimbabwean urban centres, typically cater to lower income residents. The townships were originally set out by the Department of Physical Planning to non-title specifications, and core houses were built, amounting to approximately half of the final residential unit. Non-title pegs that were placed were necessary for the orderly building of roads and houses, and guiding the erection of physical boundaries. Despite having no legal weight, these pegs also assisted from time to time in arbitrating disputes.

The following are thought to be the most significant questions asked of residents in Goodwin's research:

Question: How long does it take right holders to enclose their properties with some form of physical boundary?

- About 20% of physical boundaries are built in the first year of occupation
- Approximately 50% of the properties are enclosed by about four years
- Approximately 66% of the properties are enclosed after about seven years
- After 17 years, 90% of properties are enclosed by physical occupation lines.

Question: What form is the physical boundary?

- Fence 63%
- Hedge 16%
- Concrete wall 9%
- Brick wall 3%
- Other 3%
- No physical boundary 6%

Question: Is there any dissention with neighbours over the common boundaries?

- Ninety-eight per cent of respondents had achieved amicable consensus over the common boundaries, even where these departed from the pegs originally placed.

According to Goodwin, the gains accruing from deferring boundary monumentation are seldom justifiable, and boundary marks should have well defined centre-marks and be surveyed to accuracies comparable with survey control marks in order to densify control and to act as witness marks. Goodwin suggests that, although right-holders generally regard physical boundaries as the primary boundary evidence, departures with legal boundaries are seldom a threat to secure title. Wherever there is doubt, dispute or disaster, it is important that a dense network of surveyed points exists, whether control marks or boundary marks, that can be used in arbitration and re-instatement. All compromise is based on give and take, but there can be no give and take on fundamentals. Goodwin draws the conclusion that any compromise on mere fundamentals is a surrender. He states that physical boundaries erected by abutting right holders exhibit a degree of give-and-take, and

> right-holders tend to regard these positionally-flawed physical boundaries as the primary source of boundary evidence, but the underlying fundamentals of well-defined marks, both control marks and well defined boundary marks, should not lightly be surrendered. (Goodwin, 2013)

Author note: In a world where time and money are not a consideration, Goodwin's conclusions are beyond reproach. Like Goodwin, the author of this paper has densified control networks through the use of accurately surveyed permanent parcel boundary marks (all photo identifiable for use within aerial triangulation block adjustments) for inclusion in the national network. However, the cost to install parcel corner boundary markers that will then be surveyed in the field is simply prohibitive to most national and local governments in developing countries. The urban area around, for example, Nairobi, contains approximately 1.5 million parcels. How long would it take and how much would it cost to install and survey boundary marks to each of those parcels? Maybe $50, more likely $100 per parcel, and very likely more than that. This is too much time and money for government agencies who urgently desire to have a functioning and affordable revenue-generating fiscal cadastre as soon as possible. Digital orthophotography will provide the means to create as many as 75% of those parcels at a fraction of the cost ($10 approximately) required for general boundary parcels compared to the cost of fixed boundary parcels. Well-defined boundary marks can be installed and surveyed for those parcels that cannot be mapped using general boundary mapping techniques. Likewise, any general boundary surveyed parcels whose ownership is transferred can have well defined boundary marks installed and surveyed (at the seller's expense) with a subsequent upgrade of its status within the cadastre to a fixed boundary parcel. The unfortunate reality is that monumentation of all parcel corners will result in deferred revenue collection.

Goodwin did not mention the shortcomings of the physical flaws involved with the recovering of fixed boundary markers: namely the "Pincushion Effect". The "pincushion corner" (Fig. 4) is a term coined by surveyor and author Jeff Lucas to describe the phenomena of multiple boundary markers being set by land surveyors when only one boundary corner exists under the law. It is common knowledge that no two surveyors can agree on the location of any given property corner. The pin cushion is physical proof of that notion. Is the pin cushion also physical proof that the entire 2cm accuracy fixed boundary claim is a tad over rated?

Fig. 4 The 'Pin Cushion' Corner (Dietz Surveying, Maryland, USA)

Area Calculation Comparisons of a Fixed Boundary and a General Boundary Surveyed Parcel
The diagrams below (Figs. 1, 2 and 3) show how the area of a hypothetical 2 Ha parcel is calculated using fixed boundary survey coordinates values (theoretical 100% precision) and using general boundary coordinate values (a 3 meter off-set to reflect the maximum error obtained from a 1:5,000 digital orthophoto). The maximum coordinate off-set (outward or inward) results in an area calculation for the parcel that is within 8% of the actual parcel area. It should be noted that a coordinate error of 3 meters is associated with mapping accuracy that is inferior to Class 2 accuracy as defined in the ASPRS Map Accuracy Table shown in **Table 1.** Class 2 accuracy should be the minimum accuracy level applied to cadastre creation.

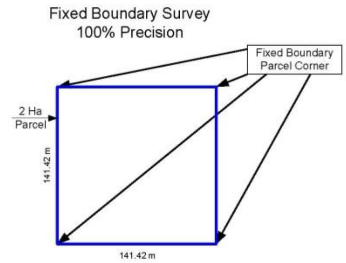

Fig. 1. Fixed Boundary Survey Parcel. This 2 ha parcel has been surveyed to a theoretical 100% accuracy

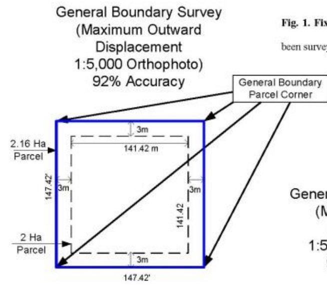

Fig. 2. This graphic shows a general boundary 2 ha parcel (located on a 1:5,000 scale orthophoto) with the maximum outward displacement of 3 meters applied to the parcel corners. As a result, the parcel area calculation of 2.16 Ha is off by 8% approximately.

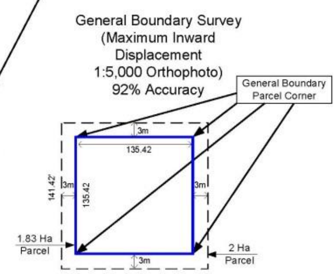

Fig. 3. This graphic shows a general boundary 2 ha parcel (located on a 1:5,000 scale orthophoto) with the maximum inward displacement of 3 meters applied to the parcel corners. As a result, the parcel area calculation of 1.83 Ha is off by 8% approximately.

WHAT IS A CADASTRE?

A Cadastre is a public record that contains a delineation of individual parcel boundaries, attributes for ownership information and the rights associated with each parcel that is used to confirm ownership and as a basis of property taxation. When all ownership information is accumulated a modern land administration system is developed which is used to feed a GIS (in addition to a variety of land records management software such as modules for land registry, cadastre and valuation records keeping), maintain cadastral mapping databases and enable property tax revenue calculation.

Most countries that use modern GIS, total station, GPS and photogrammetric mapping techniques to create a contiguous parcel database (cadastre) for the calculation of property taxes primarily use the general boundary survey methodology to create a database of calculated parcel areas based on general boundary parcel corner coordinates. Because of the reality that the resulting calculated areas are in error from 3% to 8% for ASPRS Class I or Class 2 mapping at a scale of 1:5,000 (Class 3 mapping is rarely used due to the higher errors achieved) the billing area for each parcel could be reduced by 10%. That is, if the parcel area calculated from a general boundary survey is, for example, 2.39 Ha, then the area billed by the tax office could be 2.39 Ha less 0.24 Ha, or 2.15 Ha. This 10% buffer ensures that owners have confidence that they are not being over-billed for the taxes associated with their property. In the event that the owner needs to determine his property area with greater accuracy, for example when applying for a mortgage or selling the property, then a 2cm accuracy fixed boundary survey can be carried out at the owner's expense.

The following table (**Table 1**) shows the level of accuracy that is achieved utilizing photogrammetric mapping techniques that are based on internationally accepted mapping standards. American Society for Photogrammetry and Remote Sensing (ASPRS) mapping accuracy is reported as ***Class 1, Class 2, or Class 3***. Class 1 accuracy for horizontal and vertical components is shown below. Class 2 accuracy applies to maps compiled within limiting RMSE's twice those allowed for Class 1 maps. Similarly, Class 3 accuracy applies to Federal Geographic maps compiled within limiting RMSE's three times those allowed for Class 1 maps.

ASPRS Accuracy Standards for Large-Scale Maps evaluates positional accuracy for the x-component and the y-component individually. Positional accuracy is reported at ground scale.

ASPRS Map Accuracy

Map Scale (Metric)	Class 1 Planimetric Accuracy limiting RMSE (cm)	Class 2 Planimetric Accuracy limiting RMSE (cm)	Class 3 Planimetric Accuracy limiting RMSE (cm)
1:1,200	30	60	90
1:2,000	50	100	150
1:2,400	61	122	183
1:4,800	122	244	366
1:5,000	127	254	381

Table 1

The table below (**Table 2**) shows the accuracy obtained for general boundary parcel calculation for parcels of varying areas, depending on which accuracy class and map scale has been used for the digital orthophoto production.

Note: Parcel calculation accuracy increases when the map scale is smaller and the parcel area is larger. Areas below were calculated based on ASPRS accuracies shown in Table 1.

Map Scale	Class 1	Class 2	Class 3	Map Type
1:5,000	99%	98%	97%	(20 Ha parcel)
1:5,000	98%	96%	93%	(5 Ha parcel)

1:5,000	97%	93%	90%	(2 Ha parcel)
1:2,000	97%	95%	92%	(0.5 Ha parcel)
1:2,000	94%	88%	83%	(0.1 Ha parcel)
1:1,250	88%			(0.1 Ha parcel)

Table 2

Note: Whatever the level of accuracy that is achieved using general boundary survey methodology, it is important to note that the cost of creating a general boundary parcel is typically 5% to 10% of the cost of creating a parcel using fixed boundary survey methodology. Parcels measuring 0.1 Ha or less could be placed in a uniform category for taxation purposes.

LARGE ADMINISTRATIVE AREA PARCEL DATABASES

When parcel corner coordinates are acquired for a large number of parcels, for example for a village, a city or an entire country, a cadastral geodatabase is created. A cadastral database represents and contains ownership data for a continuous surface of connected parcels.

If a parcel split occurs, two new parcels are added to the cadastral database and the original parcel database is maintained as part of the historical record. In a geodatabase, the parcel-based topology of the database determines how parcels, boundary lines, corner points and other features share coincident geometry. Parcel polygons are defined by a series of boundary lines which can store recorded dimensions as attributes in a lines data table. Specific topological conditions support multiple survey records for adjacent parcel boundaries whose dimensions are specific for each parcel, even when the boundaries are shared. Topology is a branch of geometrical mathematics which is concerned with order, contiguity and relative position, rather than actual linear dimensions.

For a parcel survey that is being submitted in support of an application for a mortgage loan, marked parcel corners can be very accurately located using total station or GPS surveying equipment. The resulting survey of parcel corners in this manner is known as a “Fixed Boundary” survey. Often, even though the parcel is surveyed with great precision, the parcel corner coordinates are not produced on the national grid, but are created with parcel corner coordinates that are on a local grid specific to that parcel only. This is a major drawback when the parcel information is required to become part of a national cadastre.

The parcel corner coordinates are not intended to provide the true legal representation of a cadastral parcel. They are merely a part of the methodology developed to represent all the historical and legal record information available within a land administration system. Some GIS software packages (such as Esri’s Parcel Fabric) support a coordinate-based cadastre with the goal to continually refine and establish digital representation of coordinates at the corners of parcels.

For many years cadastral boundary networks were created with no accurate reference to real-world coordinate locations as surveyors did not tie into the national grid. With the advent of high accuracy total station and GPS surveying equipment it has become significantly easier to use coordinates to geographically define parcel locations. Traditional survey methods used for relocating property boundary corners may be interpreted in different ways. When different surveyors use different positioning data to re-establish the location of a boundary, boundary location disputes often arise. A coordinate provides a unique and unambiguous record of a point and can be quickly and accurately relocated with the use of total stations and GPS receivers.

To gain maximum benefit from the use of coordinates, a system needs to be in place within the cadastre that provides a measure of the reliability, consistency and accuracy of coordinates in a parcel boundary network. Traditional parcel data management has focused on entry of individual parcel and subdivision plans that use coordinate geometry (COGO) to enter high accuracy metes (bearings and distances) and bounds (neighboring lands) descriptions. The following is a typical metes and bounds example: “Commencing at the point of beginning then North 44°35’16” East 100.26 meters, then Northwest 26° 14’58” 195.37 meters". Using such a workflow, individual parcels or subdivision plans are entered independently of all other survey plans. While such a workflow is adequate for management of individual parcels, a contiguous parcel database across an entire jurisdiction is difficult to assemble in this manner.

The best-fit-to-ortho mapping technique involves use of geo-referenced digital orthophotos that have been created for a given jurisdiction (for example a municipality). Using this mapping technique, cadastral maps are completed to the same level of accuracy as the digital orthophotos based on the visual fit of the parcel boundaries to photo identifiable features that appear in the digital orthophoto image.

The following steps are taken in the cadastral mapping workflow:

- Analyze the location of roads, tracks and trails that appear on the digital orthophotos and use those features as guidelines for the placement of road Rights-of-Way (ROW) and road centerlines.
- Analyze ground evidence on the digital orthophotos pertaining to structures, fences, walls, hedges, hydrographic features, vegetation lines and agricultural lines and use these features as guidelines for the placement of parcels.
- Place the pertinent data for parcels on a block-by-block or small-cluster basis.
- Create a unique parcel identification number (PIN) for each parcel.
- Place Errata Notes for areas of conflict that will require adjudication.
- It is important to take note of the fact that when fixed boundary parcel surveying techniques are used to create individual survey plans with *survey precision*, that precision is lost when the parcels are re-created as a contiguous parcel database using topographic maps or digital orthophotos as a backdrop. The resulting contiguous parcel cadastre acquires *map accuracy*

and results in the creation of a “General Boundary” survey based cadastral database. (McKenna, 2016

CONCLUSION

Parcel mapping that ensures secure land tenure for a large percentage of a nation’s citizens can be produced at an acceptable and Fit-for-purpose level of accuracy using general boundary survey techniques that are a small fraction of the cost of parcel mapping created using fixed boundary survey techniques. Most modern cadastres, including most of the 3,000 American county cadastres, are mapped according to internationally recognized mapping standards for map scales of 1:1,250 (urban), 1:2,500 (peri-urban), 1:5,000 (rural) and 1:10,000 (rural).

Note US map scales are typically 1:1,200 (urban), 1:2,400 (peri-urban) and 1:4,800 (rural).

As a result of the reality that there is a choice of utilization of two different survey techniques (fixed boundary and general boundary) for the creation of cadastral maps, it is essential for users of a cadastre to be aware of the fact that parcel corner coordinates can be provided in two options:

1) Fixed Boundary Parcel Corner Coordinates
2) General Boundary Parcel Corner Coordinates

A map accurate contiguous general boundary cadastral database is cheaper, faster to produce and considerably more efficient to manage topologically than an individual parcel, fixed boundary, based cadastral database. As stated above, it is important to note that individual parcels created using fixed boundary survey techniques eventually need to be reassembled into a contiguous parcel database that inevitably involves use of a digital orthophoto or topographic map database that relegates them to general boundary status.

Cadastral databases must have a continuous parcel network that can be managed and referenced to real-world coordinates using a comprehensive geospatial framework. The feature geometry of many GIS data layers is required to fit onto, and be coincident with, the cadastral database. The result is a highly accurate GIS database that meets the goals of surveyors, registry and cadastre offices, tax offices, multiple government agencies and GIS professionals and supports multiple GIS applications that must have geospatially accurate data layer representations.

It has been demonstrated above that a general boundary parcel corner accuracy of 3 m (1:5,000) or better (easily attainable using even satellite imagery) is capable of parcel area calculation that is within 92% of the parcel’s actual area. Digital orthophotos can be created that enable general boundary parcel mapping that is accurate to 30 cm. Such accuracy produces digital orthophotos to 1:1,250 map accuracy standards, an accuracy that has been, and still is, internationally regarded as a very acceptable accuracy for topographic and parcel mapping.

Many so called “fixed boundary” parcels are surveyed by less than competent surveyors (for sure the pin cushion practitioners!) using inferior optical equipment for angle measurement and less than adequate distance measurement techniques (e.g. un-calibrated measuring tapes) that are fortunate to achieve survey traverse closures of 1:5,000. Using modern optical survey equipment there is no reason why 1:25,000 should not be the minimum standard for a traverse closure for a parcel survey.

Even the poorest of countries sometimes insist on creation of a fixed boundary cadastre that has been surveyed to an accuracy of 1 or 2 cm. When does a fixed boundary survey become a "real" fixed boundary survey? Is it when parcel corners are surveyed to 1 cm accuracy? Or 2 cm accuracy? Or 10 cm accuracy? There are those who are of the opinion that even at 1 cm parcel corner accuracy, the parcel is still a general boundary survey. If a homeowner or bank must have a 1 cm accurate survey plan then that homeowner, not the other citizens, can pay to have that survey completed at a cost, depending on the country, of between $200 and $1,500. Compared to the approximate $10 per parcel cost for general boundary parcel mapping. And besides, the fixed boundary parcel is no more efficient at being the repository for all parcel attributes (rights, owner name, valuation, etc.) than a general boundary parcel. The reality is that a general boundary parcel is a really good location for "parking" the scanned image of a fixed boundary survey plan of the same parcel. It is a simple matter to attach that scanned fixed boundary survey plan as an attribute to a general boundary centroid, click on the centroid and display and print the survey plan.

General boundary surveys using satellite and aerial imagery and best fit to ortho mapping techniques can result in cost and time savings of as much as 90%. The question must be asked: "Is the relatively exorbitant cost and huge increase in time required to create a fixed boundary cadastre a technologically, financially and politically prudent direction to take?" This paper demonstrates that general boundary parcels are created with Fit-for-purpose accuracy, quicker and cheaper per the FIG and World Bank Fit-for-purpose objectives. Realistically, the cost for cadastre creation should be a hybrid of both surveying methodologies: general boundary parcels using photogrammetric data (topographic mapping or digital orthophotography) and fixed boundary for the parcels that cannot be derived by any means other than field surveying. It is time to stop thinking of parcel corner accuracy in terms of centimeter accuracy for creation of most fiscal cadastres and create affordable revenue-generating cadastre databases, based on the UK Land Registry model. The UK model complies with the accuracies of time-honoured and NSDI compliant map scales of 1:1,250, 1:2,500, 1:5,000 and 1:10,000. The resulting cost savings can be put to better use on other aspects of land administration activity.

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BIOGRAPHICAL NOTES

Mr. Jack McKenna's career began with the British Ordnance Survey with training in photogrammetry and surveying (RICS Standards) and further training at Wild in Heerbrugg, Switzerland. He collaborated with the Organization of American States (OAS) on development of the MuNet Cadastre Modernization Project for implementation in Latin America and the Caribbean (LAC). The development of MuNET involved onsite visits to many Spanish and English speaking countries in LAC. The objective of the MuNet cadastre modernization initiative is to help municipalities improve their economies (through increased revenue generation), strengthen their infrastructures and improve their land tenure security. He is Director of Business Development in Africa and the Caribbean with Trimble Land Administration Solutions.

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