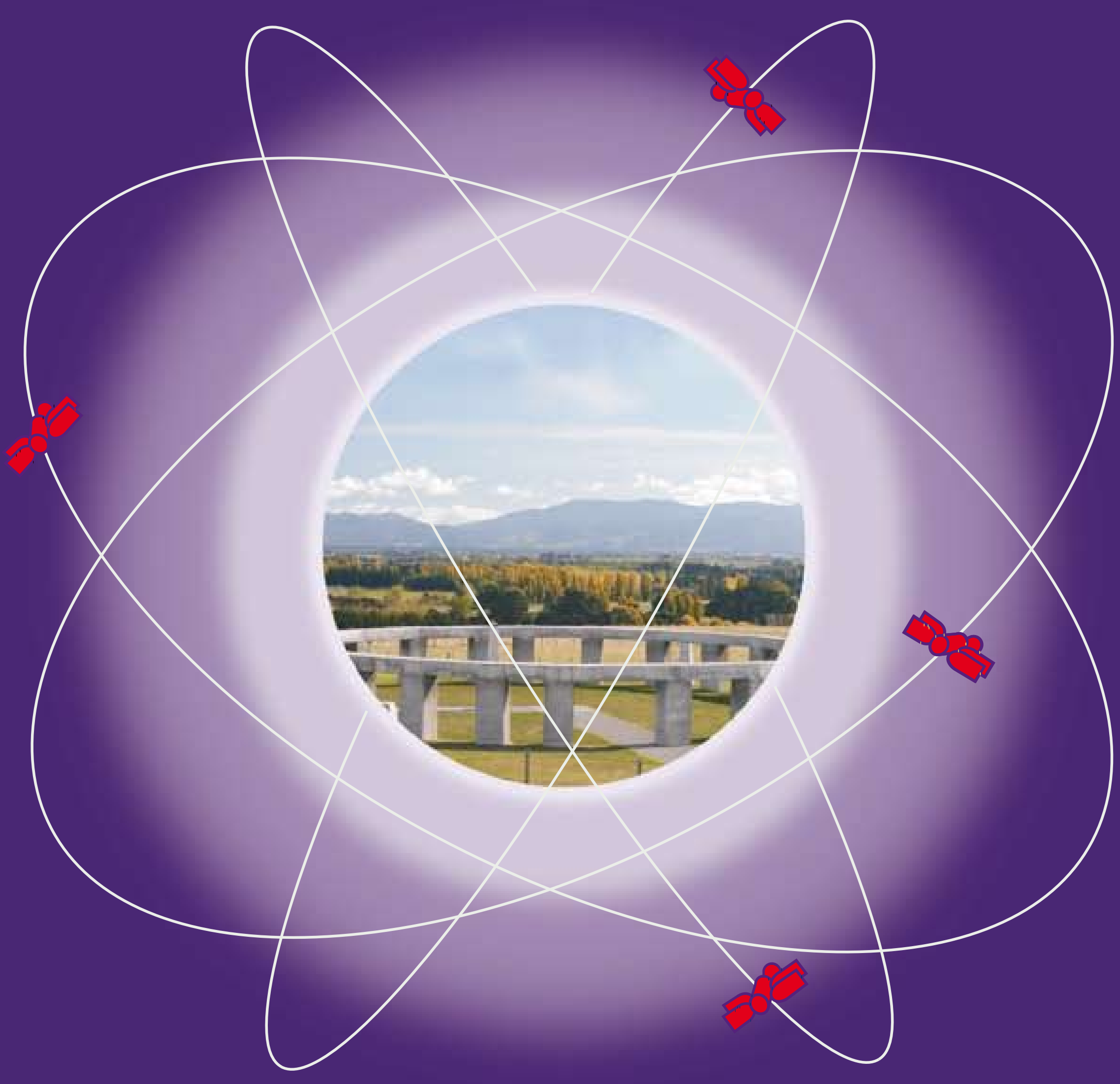
NEW ZEALAND SURVEYOR

Journal of the New Zealand Institute of Surveyors No. 299 2009



- Climate change, local government and the survey profession
- Intensity calibration method for 3D laser scanners
- Lines on the land
- Water level measurement and tidal datum transfer using high rate GPS buoys
- Access to landlocked Maori land

NEW ZEALAND INSTITUTE OF SURVEYORS

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NEW ZEALAND INSTITUTE OF SURVEYORS
Te Rōpū Kairūri o Aotearoa

New Zealand Surveyor
A Journal of the New Zealand Institute of Surveyors Inc.
Issue No. 299 2009
ISSN 0048-0150
www.surveyors.org.nz

Phone: (04) 471 1774
Fax: (04) 471 1907
Email: editor@surveyors.org.nz

Correspondence relating to literary items in New Zealand Surveyor may be addressed to the editor. Papers, articles and letters to the editor, suitable for publication, are welcome.
All correspondence relating to business aspects, including subscriptions and advertising, should be addressed to:
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New Zealand Institute of Surveyors Inc.
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Wellington
NEW ZEALAND

Phone: (04) 471 1774
Fax: (04) 471 1907
Email: nzis@surveyors.org.nz
Distributed free to all members of the Institute.
Subscription rates available from the National Manager.
Published annually by the New Zealand Institute of Surveyors – 121th year of publication.

Designed and typeset by
Bateson Publishing Limited
PO Box 2002
Wellington
Phone: (04) 385 9705
Email: bateson.publish@xtra.co.nz

New Zealand Surveyor

The views expressed are those of the authors and are not necessarily those of the New Zealand Institute of Surveyors.

COVER PICTURE

Stonehenge Aotearoa symbolises the long history of surveying and astronomy to which modern surveyors are heir. It is a working structure designed for its Wairarapa location, and was built by Phoenix Astronomical Society members with support of the Royal Society of NZ.
Photograph: Chris Picking

EDITORIAL

BRUCE MCFADGEN
Editor

New Zealand has a distinctive landscape that reflects its location across the boundary between two major tectonic plates; the Australian Plate to the west, and the Pacific Plate to the east. Tectonic processes, operating over tens of millions of years, have uplifted the mountain ranges that today form the spectacular backbone of both main islands, and produced the volcanoes that now dominate parts of the country. 'Lines on the Land' (Mick Strack, this volume), comments that early surveyors frequently remarked on the contrast of the mountainous areas with the lowland country – untamed nature on the one hand and the landscape of production on the other – that made New Zealand the alluring mix that attracted settlers here.

'Lines on the Land' highlights the dual role played by early surveyors. On the one hand they described the physical land; its topography, vegetation, geology, resources, and suitability for settlement. On the other hand, they were expected to divide that land into parcels for people to occupy, develop, and exploit. Problems arose, however, because while the surveyor might have had the knowledge of the ground, he had little say on how that ground was to actually be divided. The surveyor was the acknowledged expert in measurement, which he carried out according to the wishes of other people. What could have been sensible subdivision, based on intimate knowledge of the land, became a tyranny of straight lines and right angles planned from afar; a subdivision of land that often bore little relationship to what was actually present on the ground.

Today we live with some of the outcomes of this duality. Those of us who live in Wellington will be familiar with the steep streets that disregard the contour of the land, and which frequently end in, or are divided by, a zigzag. The dislocation of field knowledge and planning, however, extended beyond the physical landscape. Maori cultural and land use practices were frequently disregarded, with the result that many blocks of Maori land after subdivision were effectively unusable, and some blocks still remain so. The question today is whether or not, as a profession, we have learnt anything from the past; to what extent are modern surveyors in control of what they do, or like the surveyors of old, do they dance to someone else's tune?

The issues facing land subdivision today are somewhat different from the past. First, the recent understanding of the tectonic origins of New Zealand clearly identifies the hazardous nature of the New Zealand landscape, and the need to incorporate into future planning the probability of severe and damaging earthquakes, volcanic eruptions, and tsunamis. Second, the Earth and its inhabitants are facing the most rapid and severe bout of global warming experienced for more than 6,000 years. 'Climate Change, Local Government and the Survey Profession' (Alan Milne, this volume) discusses the warming and some of its implications. Of particular concern is the predicted rise in sea level, now estimated to be about 1.6 m by 2100 AD, which will have far-reaching effects, for example, on coastal settlements, largely through coastal erosion and flooding. Herein lies the problem.

There is now some awareness of the damaging effects of earthquakes, but rather less understanding of the dangers of tsunamis. The 1855 AD Wairarapa earthquake, which raised Wellington harbour between one and two metres, and almost razed the fledgling settlement of Wellington, triggered a tsunami that swept across the Rongotai isthmus from Lyall Bay to Evans Bay. In 1947 two waves struck the East Coast, an area that was, thankfully, only sparsely populated at the time. The waves, about 10 m and 6 m high, were local events, one in March and one in May, probably caused by small earthquakes. Being surrounded by sea, New Zealand is at risk not only from local events, but also from tsunami generated thousands of kilometres away, as happened following large earthquakes in South America in 1868 and 1960, and in Samoa in September this year. The risk of tsunamis is only now beginning to be fully appreciated, as is the effect of global warming on sea level. That rising sea levels might possibly trigger earthquakes and tsunamis, recently reported at a conference about the effect of global warming on geological hazards, is a matter of some concern for New Zealand. Yet the popularity of the coast has never been greater – another manifestation of the allure of the natural environment.

The move to living on the coast over the last few decades has been extraordinary. Environment Waikato, for example, reports that more than 70 per cent of Coromandel beaches are now built on, and most beaches are less than 50 metres wide, with only a single fore dune between the houses and the sea. Sand dunes protect against storm waves and tsunamis, and provide a buffer against coastal erosion. Yet in some parts of the coast the dunes have been flattened in the interests of building houses, and the fore dune is little more than an apology for a sand ridge, if it still exists. It is not as if our beaches are even stable, yet we build on sand that is less than 150 years old, or on shorelines where the long term trend is erosion. Add into the mix a sea level rising at an increasing rate, storms of increasing intensity, and an increased exposure to tsunamis, and the prognosis is one of pending disaster.

Surveyors today are in a situation not dissimilar to that of colonial times. Having mapped the shoreline for more than 150 years, our profession is aware of its hazards. Yet fully aware of the potential for inundation, erosion and loss of property, our profession also subdivides the land along the shoreline. The question is, does our profession speak up about hazards and do something about them, or will our reply to the future be that we were only following the wishes of our clients?

ALAN MILNE

Registered Surveyor and Past Mayor, Kapiti Coast, New Zealand

Climate change, local government and the survey profession

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INTRODUCTION

This paper owes its impetus to the 9th South-East Asia Survey Congress in Christchurch in 2007, which I saw as something of a watershed, and an awakening for the profession. The sustainable development theme was perhaps akin to talk of the environment thirty or forty years ago.

It owes its genesis, however, to my abrupt and somewhat traumatic change of career just eight years ago when I became Mayor of the Kapiti Coast District during the NZIS Conference in Wellington, a council with management and staff highly tuned to sustainability and fully aware of national and international trends. It probably took me three years to understand the relevance of sustainable development for councils and to realise the relevance to the survey profession; and then I was introduced to climate change! Early in 2005 I attended a conference in Melbourne with big business leaders, scientists, traders, federal, state and local government as the main participants. I was very surprised that there was no debate about the probability of climate change; it was all mitigation, adaptation and carbon trading.

The Kapiti Coast where I live, and have worked since 1963, is a low lying west facing coastal plain of sand and peat with much of its housing, retail and commerce below the ten metre contour. It has had water supply issues, and has experienced flooding and ponding, and coastal erosion. Like many New Zealand coastal communities, consideration needs to be given to the possible impacts of climate change and sea level rise.

I am satisfied that climate change is occurring; that local government will become more climate change conscious in its planning zoning and rules and hearing decisions; and that this will impact upon our survey professionals.

Be clear that climate change will not be the only issue facing us this century – it might not even be the most significant. Any or some of climate change, patterns of resource use, resource shortages (oil, water, minerals, land), food supply imbalances, disease, pollution, strife/war, population growth or even issues which we may not have thought too much about, such as the move away from our western style economy, could seriously impact civilisation over the next century.

Climate change

Just as it is nonsense to say that the world is getting warmer because today is hotter than yesterday, it is nonsense to rely on even a ten year trend. It is the trend over hundreds of years and the evidence of thousands of years, which must be considered. I have become convinced that climate change is happening and I am strongly influenced by the trends as reported by many scientists in reputable publications. I acknowledge that there is an opposing view, but much of that debate is about causes or predicted effects rather than whether or not it is occurring.

There is no doubt that climate change does happen due to natural causes, I have just read a Council commissioned report (KCDC 2008) which advised that the land under the proposed Kapiti Western Link Road (currently averaging about 10 metres above sea level) was under the sea 5,000 years ago and was probably around 120 metres above the sea at the last ice age – all with no anthropological contribution. Climate change comes with natural cycles as the earth oscillates and moves relative to the sun, and has also been further influenced by volcanic activity and meteorites entering the earth's atmosphere (National Academy of Sciences 2009).

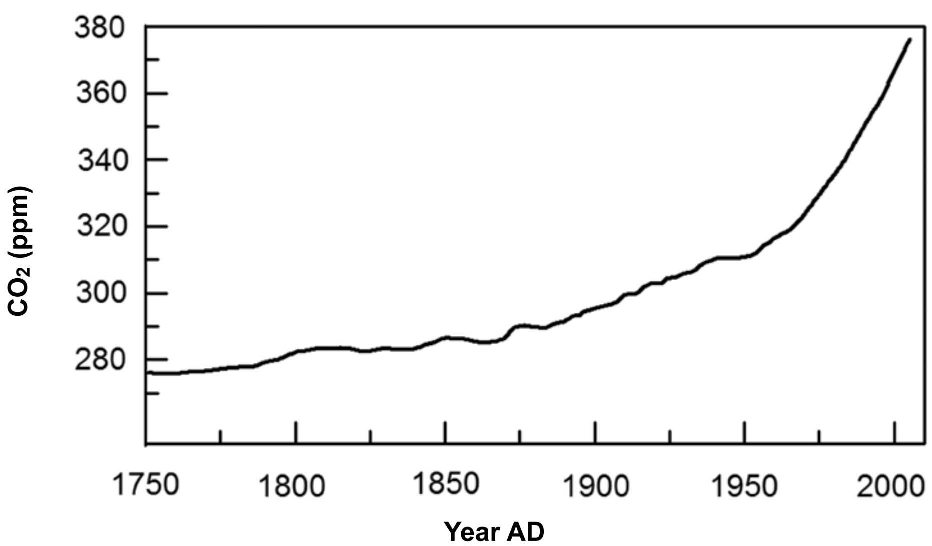
However, there is also evidence that human activity, particularly in the last three hundred years, is contributing to climate change, and at an accelerating rate. The invention of the steam engine and the ensuing industrial revolution, the internal combustion engine, the population shift to cities (50% of the world's population, and 87% of our population in New Zealand, now live in cities) and highly developed farming practices in countries like New Zealand (49% of our carbon dioxide equivalent (CO_2e) emissions come from animals and fertiliser), all add to the emissions retained in the atmosphere (MfE 2007).

Recognising the cause of global warming is important if we are to attempt mitigation measures to reduce emissions and change our lifestyle habits, whether they are at home, in our office, on our farms or in our industrial processes or our means of transport. On the other hand, if we are to ignore mitigation and only consider adaptation, the cause is less relevant and estimating the impact and effects becomes much more critical.

Way back in time it just did not matter, towns and communities could just go with the flow, pack up their homes and move to a more appropriate location usually close to water. Civilisation is now set in concrete with infrastructure, buildings, services and structures, again generally close to water, but all of which must be protected because they cannot be moved.

I find the 'hockey stick' graph of CO_2e in the atmosphere (Figure 1) incontrovertible and, as an accelerating curve, genuinely concerning. After thousands of years of little change it is now trending upwards at an accelerating rate. From analysis of particles in minute air bubbles in Antarctic ice, it has been determined that there were consistently about 285 parts per million CO_2e in the atmosphere for thousands of years. From 1780 this has changed, today it is about 385 ppm and the question is when will it reach 500 ppm (and what will the impacts then be?). This same general trend is evident in most of the indicators, be it CO_2e, nitrous oxide, methane, or sulphate aerosols (IPCC 2007).

Figure 1. Graph of CO_2 in air recovered from ice-cores in the Antarctic and in air over Tasmania. Measurements on which graph is based were carried out by the CSIRO. (Graph constructed from data kindly provided by Dr David Etheridge, CSIRO).



Carbon dioxide is principally a product of industry, transport, and city population concentrations. Nitrous oxide in New Zealand is from farm fertilisers, and methane from the breath of ruminant farm animals. Sulphates significantly emanate from aerosols.

What happens to these emissions? They accumulate in the atmosphere effectively creating a blanket that restricts the escape of some radiation thereby gradually increasing the temperature of the earth. This is commonly known as the green house effect.

A world average temperature drop of 5 degrees would put us back in the ice age (NIWA 2008). The effects of a possible increase of only 2 degrees (corresponding to 500 ppm CO_2e) is uncertain, a fear is that an average increase of 5 degrees would destroy civilisation as we know it.

The graph of temperature changes between 1850 and 2000, at best a wobbly hockey stick, none the less still trends in an upward direction with an increase over the period of just less than a degree (IPCC 2001, Fig. 2.3). With a base line of the average temperatures over the period 1960 to 1990, prior to 1938 every year was colder and since 1978 every year has been warmer. Of particular interest are the short term variations shown in the annual graph which show up to 0.4 degree annual variations and even the ten year smoothed line shows both upward and downward movement trends. However, the total graph demonstrates a similar accelerating curve as in the hockey stick.

Anticipated impacts include increases in air and sea temperatures (although a possible outcome could be a significantly colder Europe but with a disproportionally warmer Arctic), changes in current flows, the melting of sea ice and land based ice sheets (Greenland and Antarctica), sea level rise, salinity change, acidity change, increased rainfall intensity, floods, droughts, crop change, disease drift and more extreme weather events more often. Tundra thawing could have dual adverse effects with less frozen days (impact on access) and the significant release of methane from within the peat.

Given our current atmospheric and sea current patterns and the volume of sea which surrounds us, the average impact on New Zealand is likely to be close to the world average. However, New Zealand will experience more rain (and flooding) along the western coasts and less rain (and more droughts) along the eastern coasts, both particularly in winter and spring. NIWA projections are for a sea level rise of about 0.5 metres (with a recommended assessment of the consequences of a rise of 0.8 metres) and an average temperature increase in the range of 1.1 to 6.4 degrees with a mid range of 1.7 to 4.4 degrees, by 2100 (MfE 2008b). We can all expect more extreme weather events more often, but water supplies may be at risk. Transport links may be challenged. Traditional crops will tend southwards and there may well be less snow. Even a modest sea level rise could result in a significant intrusion of the coast line and loss of housing and infrastructure.

Local government

The direct impacts on Councils in New Zealand will vary with location, altitude, proximity to the coast and sea level, water supplies and farming practices. Most communities will experience some change.

Local government will variously respond by showing leadership and embarking on community education, consulting with its ratepayers, recording measurements and exploring mitigation opportunities, considering changes to its policies, planning for adaptation and working towards carbon neutrality in its operations. Climate change will impact on Councils' policy documents, annual plans and long term council community plans, city and district plans, coastal plans, flood levels, storm water, infrastructure and asset protection and cost sharing options.

The first mitigation opportunities for Councils will be with energy use (plant, pumps, transport and lighting) and water supply and treatment. Councils will already be considering performance and adaptation of storm water and other at risk infrastructure, and climate change will increasingly feature in decisions on coastal protection and flood management.

Council decision making is often a rather complex process. While the Local Government Act and the Resource Management Act are the most prominent pieces of legislation, councils are controlled and empowered by about twenty different Acts. Elected members make their decisions based on staff recommendations and reports, knowledge of the issues, understanding of community aspirations, reaction to special interest group pressures, gut feeling, personal principles, election promises, cost and consequent rating impact, and the requirements of the law. These are often conflicting and making a decision often requires compromise. The principles of any local government decision making include being open, transparent, accountable, effective and efficient, and showing recognition of community views, involvement of Maori, co-operation with other bodies, and demonstrating sound business practice, prudent stewardship and a sustainable development approach. All decisions must comply with the law.

A sustainable development approach is often led by the policies of the Ministry for the Environment (MfE) as shown in publications specifically aiming to help local governments identify and quantify the opportunities and hazards that climate change poses for their functions, responsibilities and infrastructure. In 2008, these included 'Preparing for Climate Change', 'Climate Change Effects and Impacts Assessment', 'Coastal Hazards and Climate Change' and 'Climate Change Adaptation and Second Generation RMA plans'. To quote, 'Long term planning functions need to embrace expected long term shifts and changes in climate extremes….'. 'The concept of a precautionary/cautious approach is implied in the RMA', and 'Local government can be financially liable for decisions that are shown to have been made in the face of information that should have led to a different conclusion'. (MfE 2008a, 2008b) The very clear messages within these documents are that climate change is happening, there will be effects, the risk will lie with local authorities, and that climate change must be integrated into council decision making.

Today's councillors can and do make decisions ignoring climate change. However as staff direction becomes stronger, community pressures grow and directives from MfE become absorbed, councillors will show increased recognition of climate change impacts. Tomorrows decisions will be different and will be apparent in many 2009 - 2019 Long Term Council Community Plans.

Survey profession

Climate change will bring with it both opportunities and threats for the survey profession. There will be changes in what we do and how we do it. It will be appropriate and more professional to be proactive rather than reactive.

Already some surveyors will be involved in major mitigation type projects including wind farms, thermal generation, public transport or forestry while also giving consideration in the office to more efficient vehicles and practices. Alternative energy sources, walkways, carbon capture projects and energy aspects of buildings are all potential consultancy opportunities.

Councils are and will be considering adaptation, infrastructure protection and relocation, more detailed coastal and flood impact surveys, improved storm water control for higher intensities, public transport routes and generally more sustainable developments, all in response to anticipated greater storm intensities and sea level change. This will be good for the survey profession.

The threats to the traditional activities of surveyors will include changes to councils' district plans particularly zoning, policies, standards and rules, and a different attitude to the hazard assessment of developments (and requiring a greater degree of proof that the project is not a risk?). Clients will become more conscious of the impact of climate change risk on their projects, and that their prospective purchasers will be seeking greater security in their investment. Sea level change may become a more significant design and approval factor in coastal developments and air temperature increases may impact on ski field developments. The current rapid expansion of dairy farms may slow when farm carbon emissions become a factor in 2012. Reliability of urban and rural water supplies may also effect approvals.

In summary, climate change will become a significant factor in professional activities, mitigation and adaptation will bring new opportunities, our use of energy will change, council decisions will affect our activities, both clients and purchasers will look for greener, environmentally friendly, carbon neutral and no risk developments. The community and local government may well remain ahead of professional understanding and that is perhaps a significant challenge for our profession.

A very negative view of the future is provided by James Kunstler's book *The Long Emergency* (Kunstler 2005). It gives a clear message that only a limited number of American (religious) communities will be sustainable given his anticipated impacts of climate change. *Collapse – How Societies Choose to Fail or Survive* by Jared Diamond (Diamond 2005), shows how it has been possible for past societies to let themselves succumb to environmental change, and by inference how our civilisation could let it happen to us. The 2007 Australian of the Year, Tim Flannery has written *The Weather Makers* (Flannery 2005), which is a very comprehensive and useful explanation of the causes, the processes and impacts of climate change with the clear message that we are the weather makers.

The proceedings of the 9th South-East Asia Survey Congress as printed in the *New Zealand Surveyor*, No 297, December 2007, gives a comprehensive overview of both climate change and sustainable development.

To gain a better insight into climate change and central and local government thinking, the MfE publications referred to previously, and accessible at www.mfe.govt.nz, and also the Adapting and Adaptation series at www.climatechange.govt.nz are essential reading.

CONCLUSIONS

I have stated it before, I am satisfied that climate change is occurring, that local government will become more climate conscious in its planning, zoning and rules and its hearing decisions, and that this will impact on the survey profession.

Four years ago my personal challenge was to get local government members thinking about climate change, to get our communities debating the issues, to seriously consider the opportunities for mitigation and adaptation and, most importantly, to assess the risk to our own cities and districts and to determine the appropriate responses.

My challenge to the profession, albeit four years later and with climate change now an everyday news item and even a dinner party topic, is not dissimilar. How should our profession be responding to climate change? Are we even thinking about climate change or are many of us denying it? Are we debating the issues with our clients and in our communities? Are we considering the opportunities and the risks?

Will our profession, our practices and our projects, survive climate change?

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Intensity calibration method for 3D laser scanners

ABSTRACT

A calibration method for intensity values from a 3D laser scanner (Leica HDS 3000) is presented in this paper. Different influences on the returning laser beam by objects were inspected by using different measurement setups whereby subsequent established variances were compensated. In order to assess the quality of the determined design models for the return laser beam of a laser scanner, a practical dataset was corrected by using a developed programme. In addition, a comparison has been made by segmenting an uncorrected and a corrected dataset.

KEYWORDS

3D-Laserscanning, calibration, segmentation, intensity

INTRODUCTION

Terrestrial 3D laser scanning (TLS) has been utilised in various applications where geometric information needs to be captured with high spatial density such as built structures, archaeology, cultural heritage, mining and reverse engineering (Boehler et al 2004, Bae et al 2007, Gordon 2005). 3D laser scanners are capable of capturing geometric and colour information (RGB) for objects, and also the strength of the returned laser beam. Among the information captured from TLS, the usefulness of the intensity value is mainly for target detection as well as for visualising a measured point cloud (Lichti 2002). However, the raw intensity return of laser scanners needs to be calibrated (Pfeifer et al 2007)

The scientific focus in TLS has been mainly directed at the determination and investigation of the accuracy as well as the extraction of geometric features from point clouds (Belton, 2008). Few research projects have investigated the intensity values of laser scanners. For example, Hoefle and Pfeifer (2007) utilised a model-driven approach to correct the influences of topographic and atmospheric effects on the intensity value of airborne laser scanners (ALS). In addition, Kaasalainen et al (2007) developed a rigorous approach to classify the surface of glaciers by using the point cloud information including calibrated ALS intensity values. Lichti (2002) analysed the effects of reflecting surface material and investigated the relationship between intensity and distance in order to classify 3D point clouds with the correctly calibrated intensity. Hancock et al (1998) used terrestrial laser scanners' intensity for the detection of obstacles for highway environments to control mobile robots. Lichti (2005) used near infrared intensity in combination with colour information to filter and classify terrestrial laser scanner point clouds. Wang et al (2009) described the potential of intensity data for planar surface segmentation.

This paper presents a calibration method for the intensity values from 3D laser scanners. First, four experiments with a laser scanner (Leica HDS 3000), a camera (Nikon D2Xs), and a monochromator (LOT Oriel Lambda 500), were conducted in order to investigate the relationships between the returned laser beam and the incidence angle of the laser, the distance between a laser scanner and objects, and the radiometric properties of the objects. Using these instruments, a calibration model for the laser scanner is presented. Second, in order to demonstrate the effectiveness of this approach, a segmentation method is used to compare an uncorrected and a corrected point cloud.

EXPERIMENTS

Basically, laser scanners can be conceived as a fast total station (Gordon 2005), which can measure millions of points within minutes. Two major reasons for the incorrect intensity values from a laser scanner can be summarised as:

- Distance and Incidence angles of the laser beam to objects
- Radiometric properties of objects.

In order to investigate the mathematical relationship between the above factors and the returning laser scanner intensity, the following experiments were conducted and a final correction model for the laser intensity values was developed.

PRELIMINARY EXPERIMENT WITH A LEICA HDS 3000 AND A PHOTOGRAMMETRIC CAMERA

To find the relationship between laser spot size and the distance between the scanner and objects where the focus of a photogrammetric camera is fixed, the following experiment was conducted. The experimental setup consisted of a 100 m long test track with marked positions 10 m apart. A white sheet of paper attached to the bottom of a plastic box was used as a projection screen. A scale (a simple ruler) was mounted on the bottom of the box. (Note that the scale should be attached at right angles to the projection direction of the scanner). At each position, the scanner was used to capture the bottom of the box. While the scanning was in progress, 2D images were taken of the scale and the projected laser beam. Because of the high speed the laser spot moved across the object's surface, the laser spot is difficult to capture. The highest picture rate on the Photogrammetric camera (Nikon D2Xs), eight frames a second, was therefore used. Once all positions and images were captured, the diameter of the laser spot was found by comparing the length of the scale with the laser spot. Although this experiment isn't accurate enough to determine the exact spot size, it is good enough to show how spot size changes with increasing distance between scanner and target (Figure 1). This does not influence the measured intensity value within the accuracy of the spot size provided by the manufacturer.

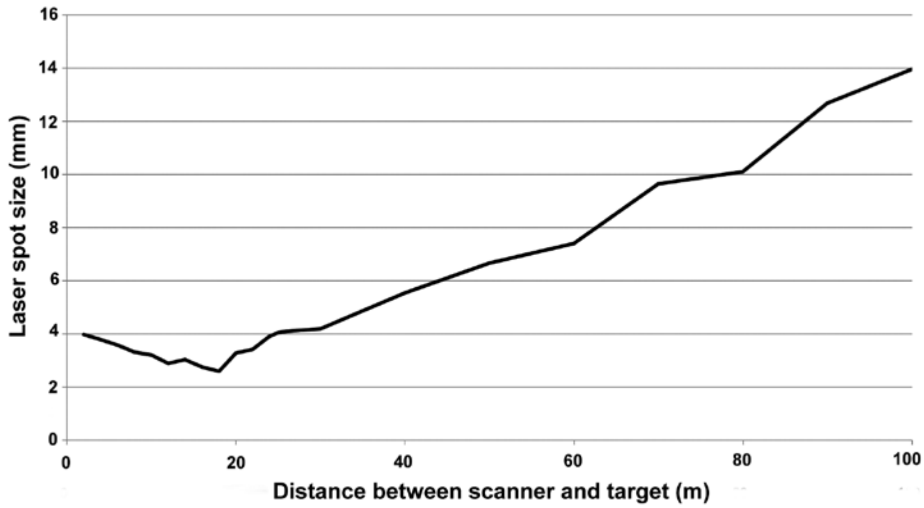


Figure 1: Variation of laser spot size with increasing distance between scanner and target.

Table 1: Statistical comparison between measured and estimated values.

	Standard deviation [%]	Maximum difference [%]
Measured values	2.6	7.8
Modelled values	0.5	1.4

Experiment I (Distance vs Intensity)

The purpose of this experiment was to model how a changing distance affects measured laser intensity values. Using a 200m long test track with 10m increments, a planar test object was vertically set on every position. The intensity value at 10m distance is taken as the reference (= $I_{reference}$), and is assumed to be without error. From the measured intensity at the other points (= $I_{measured}$), an intensity correction for distance is given as:

$$CORRECTION_{distance}=I_{reference}-I_{measured} \quad (1)$$

Least-squares method with a polynomial function (Jaeger et al 2005) shows that:

$$CORRECTION_{distance}\sim 5.7426x10^{-9}xd^3 -3.5915x10^{-6}xd^2+9.5578x10^{-4}xd-1.4424x10^{-2} \quad (2)$$

where d is the distance between the scanner and the test target in metres. Table 1 shows the results of the approximated as well as the measured values.

Experiment II (Incidence angle vs Intensity)

To investigate the relationship between the incidence angle and the returned intensity from an object, a flat object was irradiated and the incidence angle of the laser beam varied from zero (vertical setup) to approximately 76°. The distance between the flat object and the scanner, and their horizontal orientation, were kept constant. Individual scan lines were extracted out of the 3D point cloud in order to evaluate the difference to the surface normal direction for each point, which resulted in values between

Figure 2: Measured intensity vs modelled intensity.

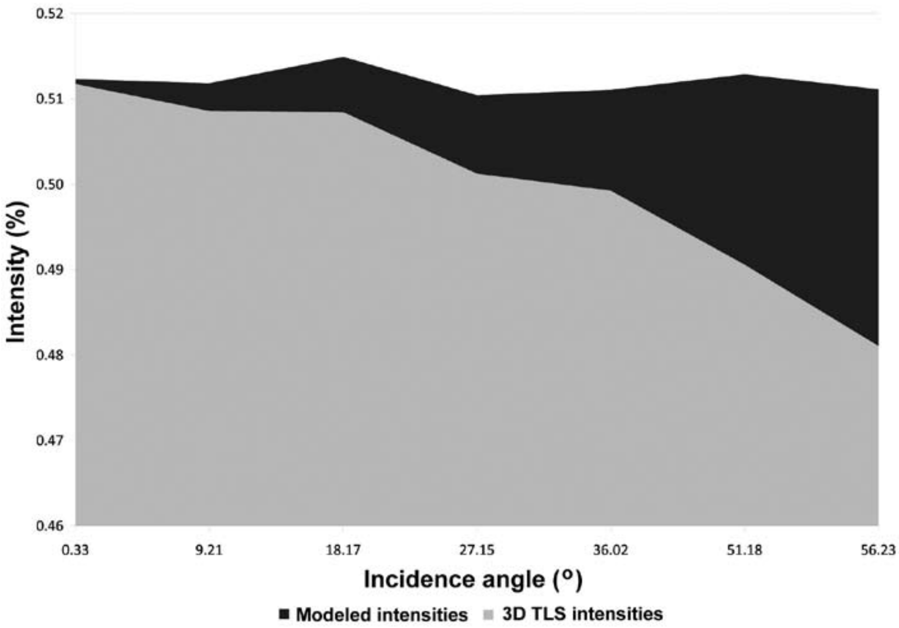


Table 2: Comparison between the results of the measured and uncorrected intensities.

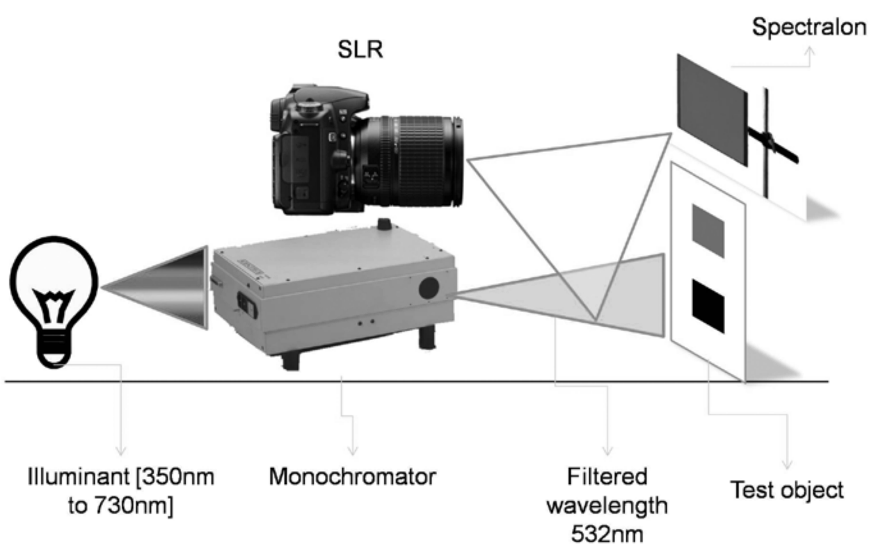
	Standard deviation [%]	Mean intensity [%]
Measured values	1.1	50.01
Modelled values	0.15	51.20

0.3° and 57.5°. Similar to the modelling approach in the previous section, a reference intensity value was used, which showed the smallest angular deviation compared to a normal projection. The differences between this reference value and all other measured intensities were calculated. Finally these figures were approximated with a polynomial approach (Jaeger et al 2005). Given that the resulting function uses an angle as input parameter a solution had to be found to determine the incident angle for each point. To estimate the incident angle (α) for each laser beam, the point cloud surface was locally approximated with a 3 by 3 filter mask in order to determine the surface normal (Drixler 1993). In a similar manner to Section 2.2, using the least-squares method, the correction term for the effect by the incidence angle (named $CORRECTION_{surface}$) is formulated:

$$CORRECTION_{surface} \sim 1.147x10^{-8}x\alpha^4 - 1.254x10^{-6}x\alpha^3 + 4.497x10^{-5}x\alpha^2 - 2.345x10^{-4}x\alpha + 4.695x10^{-4} \quad (3)$$

where α is the incidence angle of the laser beam to the surface of the object. Figure 2 shows the effect of this influence compared to corrected intensity values. The incidence angle α has to be inserted into this equation in the unit of 'gon'. Note that 'gon' can be converted to angles by multiplying by ~0.9048. The statistical results of the two datasets to assess the quality of the modulation are presented in Table 2, where the reference intensity was 51.17%.

Figure 3: Schematic description of the experimental setup.



Experiment III (Radiometric property v. intensity) and the proposed intensity model

When observing intensity values of practical datasets it is quite obvious that the behaviour of these values is not linear. The aims of this experiment were to discover the radiometric characteristics of the scanner, and to describe a model that transforms intensity values into pseudo quotients of reflexion. To determine the quotients of reflexion on a test object, a camera and a monochromator has been used. This optical instrument uses optical grids to filter certain wavelengths out of a given light source. As the 3D laser scanner used a wavelength of 532nm, the projection of the scanner onto the test object was simulated by the monochromator. A planar wooden board has been used as a test object. To capture a wide radiometric range of output from the instrument, squares were painted on the board that gradually ranged from black to white in different tones of grey. A spectralon panel with a known quotient of reflexion for the used wavelength was used as a reference value. Spectralon is a thermoplastic resin that reacts highly lambertian and reflects more than 99% of incoming radiance (Labsphere 2009).

The spectralon panel, as well as every square on the test object, was irradiated with the monochromator. During each projection of the light beam the irradiated surface was captured with a digital single lens reflex camera. The shutter speed was fixed during the experiment to receive consistent results. Measurement of the grey scale values of the light spot on each square were compared with the value for the spectralon, in order to derive comparative values for the squares. Figure 3 shows the set up of the experiment.

The surface of the test object was then scanned with the 3D laser scanner. Recorded intensity values of the scanner, however, only ranged from roughly 40% to 65%. According to the manufacturer, these values are because of the decoder used. By using the two datasets (quotients of reflexion and measured intensities), a calibration function was modelled that transforms intensity values into pseudo coefficients of reflexion. Figure 4 compares the results from the monochromator and the laser scanner for seven measurements.

The estimated polynomial equation (Jaeger et al 2005) is able to handle uncorrected or corrected intensities (*i*) in percent for values between 43.75% and 51.6% and follows:

$$f(i) \sim -82711.8531xi^4+158892xi^3-114213.1379xi^2+36418.0765xi-4247.0431 \quad \textbf{(4)}$$

SOFTWARE FOR INTENSITY CORRECTION AND CALIBRATION

In order to apply the cognitions that were mentioned in the previous sections, a software was developed to calibrate and correct a given point cloud. The programme delivers a modified point cloud and at least one image matrix by interpreting the projection matrix of the scanner as an image by using the intensity values as schematically presented in Figure 5.

If the scanner possesses a camera, a second image can be written with the greyscale values. The basis of this function, as well as for approximating the point cloud surface, is *Leica's* ptx-format. It consists of blocks with geometry, intensity and colour information listed in the order the point cloud was measured. If a distance measurement wasn't successful, the structure of the matrix can nevertheless be found by using default values.

Figure 5: Dataflow in the developed programme.

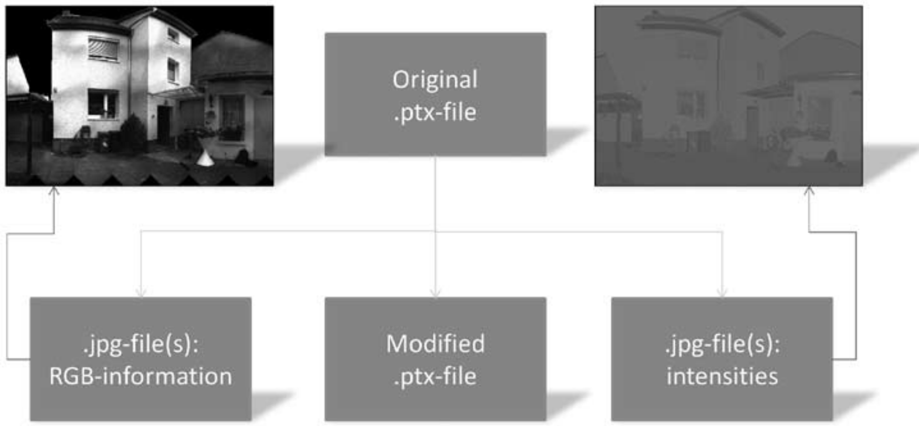


Figure 6: Calibration of the given dataset.

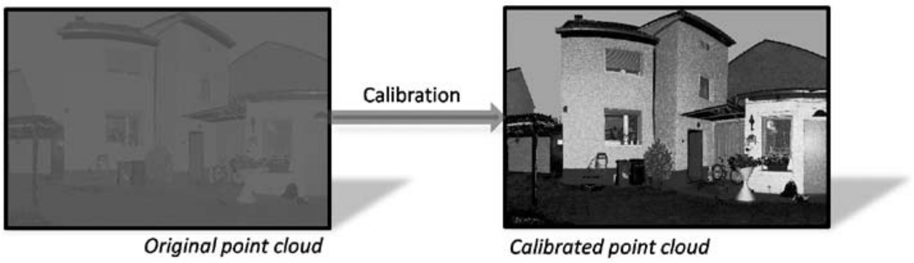


Figure 7: Correction of a calibrated pointcloud.

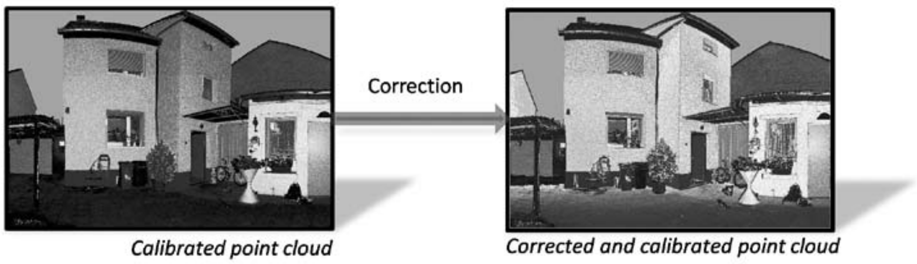
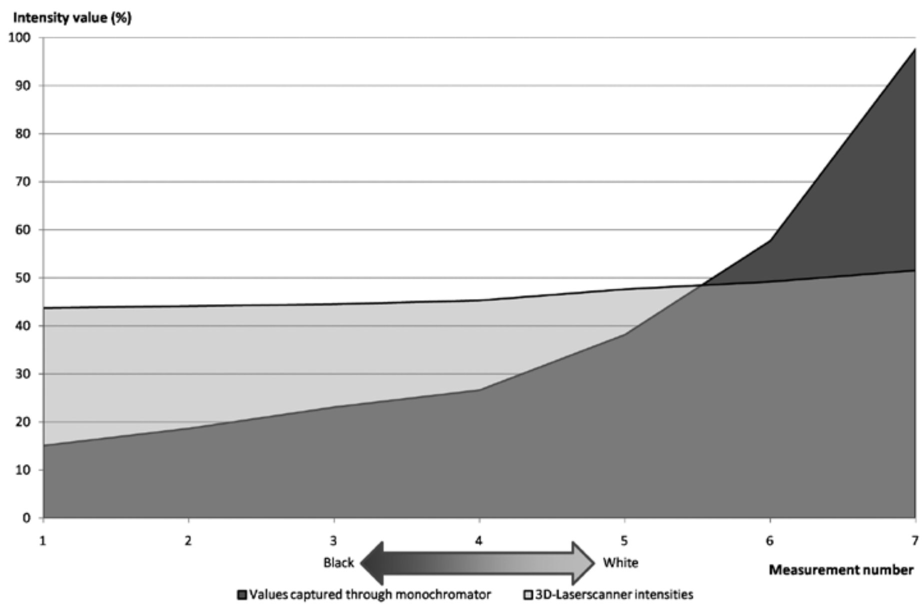


Figure 4: Measured quotient of reflexion and intensities for seven measurements.



For every scan that captures information, a new block is added to the file. The header of each block contains the dimensions of the scanned matrix.

CALIBRATION AND CORRECTION OF A POINT CLOUD

To test the software, a dataset was obtained by scanning a house. The distance between the scanner and the house was about 5m. This distance allowed awkward angles of impact for the upper areas of the building to be included. The scene was scanned with a resolution of about 2cm by 2cm on the house surface, which resulted roughly 210000 points. Figure 6 shows the results of the process that transforms the measured intensities into values of the pseudo quotient of reflexion.

The calibration process causes a visual effect that is similar to stretching, i.e. the contrast increases. As the horizontal distance between the scanner and the object was only about 5m, no damping effects on the intensity due to distance were expected. For this example, only the effect of the incident angle was corrected. Figure 7 shows the result of the calibration and correction process.

The effect of the correction can clearly be seen in the right image of Figure 7. The most important change is the correction of the small side part of the cladding in the middle of the house. After processing, the front looks quite homogeneous. Also important is the correction of the gable in the left part of the image, which had characteristics that were similar to the cladding of the building.

Figure 8: Segmentation of the calibrated point cloud [left] and the calibrated and corrected dataset [right].

SEGMENTATION OF POINT CLOUDS

The pictures shown in Figure 8 were processed with a segmentation algorithm, which uses the statistical ISODATA method (Ball et al 1965). This algorithm is mostly used in image processing to divide the content into different groups. The cladding was divided into three classes: one for bright claddings (light grey); one for the dark gable in the right image part (dark grey); and one for values in between (grey).

After correction, the front of the house falls mostly within the light grey class. The gable in the left part of the picture was classed as grey before correction, and as light grey after correction (as expected). The dark gable in the right image appears "noisy" after correction, which can be attributed to its rough surface. The transition between the grey and the dark grey classes on the courtyard after correction are a result of incident angles that are beyond the valid values.

VERIFICATION OF ACCURACY

After considering all influences on the final intensity values separately, a clearer idea of the accuracy achieved can be obtained by presenting the errors in a summarised version. Two summarising variances are calculated: one without any compensation of the mentioned influences, and one that used all modelled correction values. Gaussian errors are used to determine this variable:

$$dY = \frac{\partial \varphi}{\partial X_1} \cdot dX_1 + \frac{\partial \varphi}{\partial X_2} \cdot dX_2 + \cdots + \frac{\partial \varphi}{\partial X_m} \cdot dX_m . \quad (5)$$

The parameter dY describes the standard deviation that results from the functional connectivity between the particular parameters X_m.

Distance effects have a standard deviation of 2.6% (for an analysed object distance between 10m and 200m). This was reduced to 0.5% by using the correction values from the estimated polynomial function Equation (2). The deviation from the normal incidence angle has a standard deviation of 1.1% (for angles between 0° and 56.7°). After using the

Table 3: Summary of the standard deviations.

	Standard deviation of intensity [%]	Measured standard deviation [%]	Standard deviation after correction [%]	Resulting, measured standard deviation [%]	Resulting, corrected standard deviation [%]
Influence through the measured distance	0.2	2.6	0.5	2.61	0.53
Influence through the incidence angle	0.2	1.1	0.15	1.12	0.25
Influence of measured distance and incidence angle	0.2	2.6 + 1.1	0.5 + 0.15	2.83	0.56

correction value Equation (3), the standard deviation was narrowed to 0.15%. Because they are statistical errors, instead of Equation (5), the standard deviations are combined using the expression:

$$\Delta z = \sqrt{(\Delta x)^2 + (\Delta y)^2} \qquad \textbf{(6)}$$

Eq. (6) can be used for additive functions with arbitrary many terms; Δz describes the resulting standard deviation that was calculated by using the given standard deviations, here represented by Δx and Δy. Because no details about the standard deviation of the intensity value are published, it was estimated as 0.2%.

From Table 3, it appears that the effect of distance is larger than that of the incidence angle. In practice this circumstance is reversed because arbitrary surfaces can be found in the real world. Edges and holes can cause large correction values that falsify the intensity and raise the standard deviation of a homogenous surface.

SUMMARY

It has been shown that the intensity value supplies an alternative information source that could be used for segmentation or general visualisation purposes. Modelling with the aid of polynomial functions showed no noteworthy variations. With the help of implemented software, a tool is now available that can compensate for the effects of distance between the scanner and target, as well as the variation of the incidence angle. The intensities can also be transformed into pseudo quotients of reflexion by using the proposed calibration function. All introduced functions are only suitable for the analysed instrument.

The method was primarily developed to offer distinguishable features that can be used for segmentation or classification purposes. Practical application fields can, for example, be found in mining, architecture, robotics or in preservation of historical monuments. Follow up research will try to use corrected intensity values for tracking of objects when using a 3D time of flight camera. Also the combined use of geometric and radiometric information in knowledge bases for detection purposes will be analysed.

An influencing factor on intensity not mentioned is humidity. Research into multispectral scanning systems (Hemmleb 2006) suggest that future developments could combine this technique with conventional 3D-Laserscanners to capture more information about the irradiated material. This data could then be used to compensate the influence through humidity.

ACKNOWLEDGEMENTS

The author would like to express his gratitude to Dr. Kwang-Ho Bae, Dr. David Belton and Kwanthar Lim in the Department of Spatial Sciences at Curtin University of Technology, Australia, for their comments and assistance on this manuscript.

i3mainz, University of Applied Sciences Mainz, Germany: Furthermore I have to thank my former colleagues M.Eng. Uwe Huxhagen and M.Eng. Andreas Marbs for heaps of help over the past years. M.Sc. Rainer Schütze and M.Sc. Burkhard Tietz showed me lots of helpful material when I was programming on this project. Also I have to thank Prof. Dr.-Ing. Frank Boochs, M.Eng. Guido Heinz, Prof. Dr.-Ing. Fredie Kern and Prof. Dr.-Ing. Jörg Klonowski for sharing their knowledge with me.

Dr. Sebastian Schmidt (University of Colorado, USA) and Prof. Dr. Manfred Wendisch (University of Leipzig, Germany) helped me out with instruments that I've used for radiometric experiments and gave me much theoretic input. Thanks a lot for that.

I'd like to thank Markus Mettenleiter at Zoller + Fröhlich, Germany for giving me helpful hardware hints. Katja Bartolomae, Marion Grosse-Elshoff and Ulf Karnagel at Leica Europe gave me details about some of the Leica formats that I have used while programming.

Special thanks go to Michaela Plein for her patience with me over the years.

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Lines on the land

ABSTRACT

The actions of surveyors in dividing New Zealand into property have had a dramatic effect on land use and on the physical nature of the landscape. The landscape of production and the landscape of untamed nature are both highly representative of New Zealand culture, and the tensions between the two continue to shape how the land is valued. This paper takes an historic view of the role of surveyors in portraying, measuring and shaping the land.

INTRODUCTION

There has always been, and there remains in New Zealand, an ambiguous role for surveyors. On the one hand they have been charged with exploring, describing, and mapping the land for multiple purposes – describing the topography, vegetation, geological form, and illustrating the location of resources, people and communications routes between them. On the other hand they have been required to carve up and define this space into property – to establish boundaries with reference to lineal dimensions, but with little reference to the pre-existing, indigenous natural environment and landforms, or to the indigenous people and their relationship with place. Cadastral mapping has brought order, control, and uniformity over the infinite diversity of both the indigenous people and place, and has therefore served the colonial agenda well, but much has been lost in the process. This paper discusses some aspects of this loss.

Landscapes are highly modified by settlement and production patterns, and underlying this modification is the cadastral framework that comprises the legal boundaries superimposed on the land. The design and creation of these boundaries is performed by surveyors who have expertise in landform, land use and production patterns (both urban and rural), but who are generally constrained by historically ingrained thinking in straight lines and two dimensions. Consequently, the typical productive landscape is a grid-like pattern of boundaries that clearly differentiates the extent of individual legal rights, but which bears little relation to the holistic and integrated ecosystems of 'natural' landscapes. There are, however, some landscapes where the cadastral pattern and the allocation of individual rights have been ignored because they are inappropriate for their owners; such boundaries have become a barrier to production off the land, and to the maintenance of any ongoing relationship of people with the land.

A case study of such land, the former Taieri Native Reserve alongside the lower Taieri River gorge, illustrates how cultural attitudes and relationships towards land are affected by the way the cadastral framework is imposed on landscape. In summary, the legal process of boundary survey and parcel allocation was always inappropriate for this piece of communally owned Maori land, and as a consequence, the land has been abandoned, and the cadastral pattern has been overgrown and become an invisible element of the landscape. At the same time, the cadastral pattern on adjoining land owned by non-Maori has dominated the landscape.

LANDSCAPE

Images and descriptions of the New Zealand landscape abound in the country's art, histories, and archives to such an extent that much of the Kiwi identity is based on the picturesque nature of the natural environment. Tourism promotion carries on the great tradition of portraying the alpine and forested environment as unique, dramatic, and wild, but it also recognises the beauty and scenic appeal of the middle landscapes of well-ordered, rural productive farmland. Much has been made of New Zealand's wilderness and picturesque landscapes – "a central part of [which] requires us to retreat from the scene and stand outside it" and present it as a "pure" icon of nature (Steel 2008:36-37). And while the Kiwi psyche illustrates great affection for such landscapes, there is also the desire to see that land is not wasted; that it should be used for optimum production and should not be left to wild nature.[1] The colonial surveyors often painted, and always described and mapped these two versions of the land, and in doing so succeeded in attracting settlers to New Zealand – it was an alluring mix; satisfying the aesthetic desire for the dramatically picturesque (the majority of the settlers having come from rather plain and bland, but peaceful, rural England), as well as the promise of access to and ownership of productive farmland. The fact that the development of farmland required the destruction of so much of the picturesque bush seemed not to matter.

Landscape consists of significant cultural features on the land; structures showing heritage, marking human achievements, and defining the place of people in the land. Landscapes are "the carriers of culture, ordering our world, giving us common symbols, integrating us as individuals into a visible and meaningful environment." (J. Nivala quoted in Fisher 2005:4-5). And as Byrnes (2001:11) describes: "A landscape is a cultural construction: it is a particular perspective *on* or *of* the land. Perspective determines the ways in which people mentally or geographically orient themselves – and in this case, how they proceed through space." Surveyors are major contributors to this perspective; illustrating the spatial relationships, the connectivities, and the rights asserted over these spaces. Occupation of the land is determined by plans on paper, and on the marking of boundaries on the ground by surveyors. The two dimensional plan or map is as much a vital component of how land is interpreted and understood, as the artist's impression of the landscape is, or tourism's photographic scenes.

MAORI SEEING THE LAND

Europeans are so used to visualising their world on a two dimensional map, that they often forget that there are other ways to view the world. Maori certainly perceived their world quite differently – they not only had a completely different relationship with the land and environment, but their mental image of their whole world was not visual – they did not create pictorial maps to explain where they stood on this land. Instead of being perceived through the sense of sight, the land was perceived and absorbed into consciousness by the telling of and listening to stories.[2]

The making of maps presupposes a system of cartography, possession of a written record, and some means of accurate measurement over long distances. Maori had none of these and instead relied on mental images of their land. The oral narrative (see for example Pomare & Cowan 1987) of Maui and his brothers out fishing in their waka and hooking the great fish – Te Ika a Maui – is especially significant because it establishes a mental map of the land – the waka, the fish, the anchor stone, the dissected landforms caused by Maui's brothers hacking at their fish, and the brothers turned into stone on the upturned waka. Today, the land Aotearoa is visualised and portrayed on Cartesian maps as three main islands, and with a little imagination, it is possible to construct a fish shape out of Te Ika a Maui (the North Island), a solid long boat shape out of Te Waipounamu or Te Waka o Maui, and a smaller blob at the end that could be the anchor stone, Te Puka o Te Waka o Maui (Garven et al 1997). It is not hard to visualise all of this in the accurately charted maps of New Zealand, but these shapes also seem to have been inherent in the Maori perception as well. Cowan records how "The ancient Maori conceived a wonderfully accurate idea of the general outline of these islands." (Pomare and Cowan 1987:41). It seems remarkable to Pakeha today that an ancient Maori story can produce an image of Aotearoa that so clearly matches the mapped image; that shapes and spatial relationships can be perceived so clearly other than by visual means.

Once Maori were exposed to European maps that represented the land visually, they too were able to produce maps that were at least as good as any lay person might be expected to produce of the land around them. Maps created by Maori for early settlers illustrate a keen sense of land form. An early Maori map of the South Island[3] is far from dimensionally correct, and yet it illustrates a particular perspective on land – not of scientific dimensionality, but of regular occupation, use, and a sense of belonging. This map emphasises the scale of those areas with which the map maker was familiar and those that had special significance for use, occupation, or history, and diminishes the scale of areas remote and less known.

Accurate scale maps are the norm, and are the expected product of most state agencies in illustrating, describing and defining land parcels. The shapes and lines drawn thus have become so familiar that the more abstract mind maps of people unfamiliar with such a medium now appear quaint. Yet the mind maps present a similarly valid perception of landscape for those people used to reading the land in this way.

Maori mapped their lands in stories; recording the places they needed to visit to gather various resources (see Davis 1990) and such oral history maps served them well. Maori also had stories about how the local landforms were created. Stories of gods and ancestors maintain the relationships that Maori have with their land. "Beginning in the half light of history where Gods became ancestors and ancestors take on the attributes of Gods, the land was shaped by culture-heroes" (Anderson 1998:13). Stories tell of the Taieri taniwha, Matamata, who wound his way through the hills from central Otago, creating the upper Taieri gorge, settling down for a while, creating the Taieri plain depression, wriggling through the lower Taieri gorge (Te Rua-Taniwha – the monster's lair) and haunting that area before returning inland and forming the coastal hills around Saddle Hill (Bray et al 1998:15).

Maori had a clearly developed land tenure regime: "No mistake could be greater than the notion that the Maoris were without law in their relations with one another, or that there was any looseness in their notions of the tenure of land. On the contrary, they had very stringent laws that were not at all unsuited to their condition and the stage of social development they had reached …" (George Clarke Jr. Protector of Aborigines 1844 as quoted in Jones 1999). Their close relationship with their land was reflected in the process of naming it. The mind map was a series of interconnected names – descriptions of forms, locations of resources, sites of historic events, paths of their ancestors, recollecting whakapapa.[4] Maori-named features "form a cultural grid over the land which provides meaning, order and stability to human existence. Without the fixed grid of named features we would be total strangers on the land – lost souls with nowhere to attach ourselves," (Mead as quoted in Pitts 1992:92).

But this Maori way of seeing the land was not the 'seeing' of the European gaze in 1840. The relationship formed for Maori by these stories and this naming was easily dismissed by the European settler and surveyor who had a different view of the land and most certainly a different agenda for its use and possession. "It was the oral nature of Maori mapping of Aotearoa that rendered that map invisible to the European. I would argue that the erasure of this Maori construct was due less to an inability than to a refusal to read this narrative mapping. A refusal that was part of a deliberate censoring of Maori culture into silence, of its significant 'relegation' to Nature. European geographers, explorers, and surveyors understood, only too well, the power of naming." (Pitts 1992:92).

COLONIAL SURVEYORS SEEING THE LAND

If landscapes are defined as places "belonging to and shaped by a people" (Fisher 2005:3) then the role of the surveyor in shaping landscapes can be immediately recognised. A very significant role of the cadastral surveyor is to define on the land the extent of what is owned. This creates the cadastral framework – the pattern of boundaries – that is the dominant feature of productive landscapes.

Surveyors were the first colonial human modifiers of 'natural' landscapes. As explorers of the new lands only recently discovered by Europeans, surveyors mapped the routes into and through the new lands; they were at the forefront of land exploration and exploitation. They left their marks in this mapping process; clearing land for access and for their measuring operations. While the fundamental training of surveyors is in measurement science and particularly the measurement and subdivision of land parcels into saleable allotments, they also have the experience to observe and evaluate the land for human purposes – primarily for settlement and production. This was especially so for the colonial surveyors whose specific commission was to explore and describe the land, and to identify its suitability for resource exploitation, for communications routes, and for future towns and cities.

The new landscapes were often painted and reported on by early colonial surveyors for their employers (land developers) or for colonial authorities. These paintings and descriptive writings remain a record of how the European mind visualised the land – either as the picturesque, wild, and dramatic (Pound 1983), or as tameable, eminently productive, but empty and therefore available for settlement and for being converted into property. "Pakeha also believed that ownership somehow improved the character of the owner and enriched in a moral and spiritual sense all those who lived off the land. The great majority of immigrants wanted to own some land, not only to raise their standard of living … but to return to a more organic relationship with nature and community which they imagined had been disrupted by the industrial and urban revolutions." (Brooking 1996:141-2).[5] This suggests the rural idyll; the honest toil of the yeoman farmer. And indeed this was the impression blatantly put before the potential English immigrant.

The early surveyors also portrayed the alternate images of this land - the wild remote mountains, forests, lakes and wild rivers that were spectacular to gaze upon but not at all suitable for living within. The appreciation of such places and images was thought to be exclusively the sphere of civilised culture – yet another construct from which to exclude Maori – "It was indeed a majestic scene: sublime in its grandeur; and I wished there had been other than savages to have gazed with me on its glories." (George Angas as quoted in Pound 1983:12). The emphasis is, of course, on the framed scene of raw nature from which humankind is excluded – Maori had a quite different relationship with such places, being a part of the environment, rather than a viewer of a scene.

Once the settlers had settled the land, cleared it, modified it, and created a new landscape in the productive mould, and effectively alienated most of the land from Maori, a realisation slowly dawned on them that much was being lost and in fact much may disappear if no protective action was taken. By the 1890s it was recognised that the indigenous population was in rapid decline and may soon die off,[6] and that indigenous landscapes were similarly declining under the pressure of land development. Action towards the preservation of indigenous landscapes was enacted in the scenery protection provisions of the 1892 Land Act. The Chief Surveyor Stevenson Percy Smith was at the forefront of this action. He was a surveyor, an artist, an ethnographer, an advocate for Maori, and "was a key figure behind New Zealand having the particular pattern of indigenous nature in its landscapes that it does" (Park 2003:70 and see also Nightingale & Dingwall 2003). The land reforms of the 1890s were effective in dividing New Zealand into two kinds of country: that part dedicated to progressing human activity, and that part from which human activity was excluded; "we have had not much cause to learn to live with and inhabit indigenous nature" (Park 2003:70).

Thus in early art and description (as in modern tourism advertising), New Zealand was seen to, and indeed still appears to present, the best of both worlds – safe, secure, and productive living spaces, as well as awe inspiring, wild places to visit.

THE COLONIAL PROJECT

The primary goal of British colonisation was to provide a space for the expansion of a civilised population into a new land along with the civilising influence of British culture, law, administration and religion over the existing indigenous people.

"Christian ideology provided (through the obligation to spread the Gospel) a justification for colonising the newly 'discovered' territories. Because of the then territorial nature of Christendom, 'Christian mission … was inconceivable except as colonialism …', so that 'to evangelise was to colonise' and vice versa. Closely related to the duty to spread the Christian Gospel was the duty to civilise, and these, together with the moral right to appropriate under-used land, provided the fuller ideology that inspired and sustained the developing imperialism and creation of empires on into the 19th century." (Brookfield 1999:59-60).

The role of the colonial surveyor was significantly different from the role of the surveyor in England. "The modes of survey adopted in a Parent State must differ from those adopted in a Colony; the object of the former being to map a country long peopled and divided by well known artificial boundaries; the object of the latter being to prepare a waste of undivided country for an inflowing people" (J T Thomson as quoted in Gough 1969:11).[7] In Britain, the cadastral pattern existed by long established occupation and use and the surveyor was involved with measuring and mapping the existing more organic patterns. Land ownership was settled and the land market was inactive. There was also a satisfactory record of ownership and a compliant population of landowners to satisfy administrative record keepers and tax gatherers. In the colonies, surveyors had quite a different agenda. They were involved in establishing a new cadastral framework over the land. The framework allowed for new boundaries and new parcels to be created to serve a newly arriving population of land buyers, keen to start production off the land and to participate in an active land market (where land is regarded as a commodity) from which to create wealth either from production or from speculative sale and purchase.

The civilising mission necessarily sought to bring order to the wild and chaotic state of indigenous ecosystems and indigenous people; to transform the physical and cultural landscape. In this scheme there was little scope for recognition of pre-existing indigenous land rights, just as there was little interest in recognising the physical diversity of land.

Several tree species were valued for fine timber and the bush ecosystem was seen as interestingly picturesque, but for the most part the bush was seen as a barrier to progress. Open grasslands were the desired productive land cover. The duty of all settlers was to clear the bush as quickly as possible, and significant government funding assistance was provided for this mission. Similarly, Maori occupation of the land was a very real barrier to this settler mission. Government land purchase agents were very active in the takiwa of Ngai Tahu, and almost the whole of the South Island was purchased from Maori by the 1860s (Waitangi Tribunal 1991).

Maori customary tenure was simply not understood. Although many early surveyors, missionaries and administrators made an attempt to understand Maori and their relationship with the land, it was not taken seriously as a system – it was either too complicated, or too irregular, or too arbitrary to be considered as an appropriate system to retain. It was much better for Maori to adopt a civilised system of land tenure; why retain inferior and inappropriate systems of tenure? As Scott (1998:36) has described: "The fiscal or administrative goal towards which all modern states aspire is to measure, codify, and simplify land tenure … accommodating the luxuriant variety of customary land tenure was simply inconceivable".

Surveying the land and creating the cadastral map was the tool used to achieve these changes on the landscape and the people. The creation of cadastral boundaries allowed for the individualised and privatised ownership of land parcels. Common instructions to surveyors were to establish town sections of one quarter acre, suburban allotments of 10 acres and rural lots of 50 acres. It was a given that these parcels could and should always be set out in regular adjoining quadrilaterals of known dimensions. This was also clearly the best way to ensure that no parts of the land were missed and excluded by this new cadastral record. It also ensured some uniformity when the parcels were to be fairly allocated to the incoming settlers.

The cadastral map was prepared with almost no regard for either indigenous landforms, land cover, or customary land use – it was like a blank canvas on which the western perception of land patterns could be drawn in disregard of what was actually there on the ground, in much the same way as the artist starts with a blank canvas and creates what is desired. The cadastral map shows only the dimensions of the land; boundary distances and areas, so the dimensions assume primary importance rather than what is actually on the land. This suited the orderly disposal and allocation of land parcels into separate ownership and thereby advanced the colonial agenda:

"The cadastral map is an instrument of control which both reflects and consolidates the power of those who commission it … The cadastral map is partisan: where knowledge is power, it provides comprehensive information to be used to the advantage of some and the detriment of others … Finally, the cadastral map is active: in portraying one reality … it helps obliterate the old." (Kain and Baigent as quoted in Scott 1998:47).

The surveyor was also involved in naming the newly surveyed lands.[8] This [re]naming process acted specifically to undermine what was there before; previous connections with the land. "The task of the colonial land surveyors was to effect this transformation: theirs was the responsibility of reining in the wilderness, taming and claiming the land, transforming an 'unbounded' space into a known and named place." (Byrnes 2001:122). Pitts (1992:92) expresses the same concept: "Renaming writes out history and writes it anew, and with the arrival of the white man, the physical geography of this land was made into a palimpsest, upon which a new text could be inscribed."

While the settlers cleared the land physically, the surveyors cleared the land symbolically; creating bounded but empty spaces upon which new land-uses could be initiated, new relationships forged (supported by the state authorised cadastre), and new perceptions of order imposed. The surveyed boundaries are straight lines; parallel and perpendicular; creating an ordered dimensioned grid, where value can be easily assigned, parcels easily illustrated, and transactions easily conveyed.[9] Such little regard was paid to topography and landform that the grid layout could be drawn up from a distance with virtually no local knowledge.

To a very significant degree, the mathematics of defining the land is performed on a two dimensional plane. The detail of the topography is ignored, and a neat allocation of correctly sized parcels with parallel straight-line boundaries is created and superimposed over that topography, with little or no consideration of how that topography might vary. At least that is the evidence of colonial surveying history.[10]

SURVEYORS AND STRAIGHT LINES

The artistic, creative, and diverse geographical knowledge that surveyors have in the land was usually set aside to ensure that the mathematical and scientific technicalities of their profession were satisfied; getting the bearings and distances to close, and having regular straight-line boundaries fit together. The surveyor illustrated "a contradiction exhibited by so many land measurers that it is almost a defining characteristic - a passion for exact definition and for untamed wilderness." (Linklater 2002:203). So while these land professionals are intimately concerned with land detail, of the diversity of ecosystems affected by topography, geology, vegetation, and climate for their mapping duties, they tended to abandon that knowledge when creating land parcel boundaries for the cadastral record.

The fictional narrative that Maurice Shadbolt (1990) writes of in his novel *Monday's Warriors*, illustrates the cultural gap between the surveyor establishing boundaries on the land and Maori being part of the land:

"Booth asked Titoko to observe where a splendidly straight line had been drawn. This line by its nature, failed to notice the curves of the Waingongoro; it leapt through them. Here and there shading reached north of the river.

Titoko tipped the map right and left and shook it a little, as if hoping something might fall out. Then he rolled it up briskly and returned it to Booth. He cleared his throat. 'When I ride beside the Waingongoro I see no line,' he announced. 'I see tree, rock and water.'

'Nonetheless,' Booth said.

'Or should I look heavenward?' Titoko asked. 'Is that where this magical line lives?'

'It has been placed according to the best information available,'

'By men who see nothing of tree, rock and water?'

'It is not incumbent upon those who draw maps to have personal knowledge of the terrain. They are intimate with government requirements in respect of confiscation. They know the cost of war must be met by sale of land. Further, they have surveyors' reports.'

'You tell me this line is the work of blind men?'

'In a sense,' Booth had to agree.

'Send men with sight,' Titoko suggested.

'Maps cannot be redrawn frivolously."

'They are holy scripture?'

'For present purposes perhaps.' Booth said.

'Are surveyors as priests of this religion? Their pegs as the cross of Christ?'

'You overstate the case,' Booth argued. 'The fact is that the health of this colony depends on the drawing of lines.'

'Men who draw lines,' Booth explained patiently, 'provide for the requisite acreage, not whims of alpine water.'

'Alas, Mr. Booth.'

'Must we feud on that account?'

'Men feud better for a bend of river than for a line none can see.'

'Settlement north of the river can be left for later debate,' Booth said. 'It is to the point that the river must be bridged, and a road provided.'

'For what?'

'Progress,' Booth said."

The straight line boundaries and the grid pattern of property created by the surveyor are both simple and convenient but they are not so innocent. The lines are drawn to obliterate what lies beneath – they serve to turn land and nature into a commodity, to remove customary connections with land, to create an ordered landscape, and to impose colonial mastery over the land (Pawson 2002:203).[11] It would seem that in all these things, they have been spectacularly successful.

THE TAIERI NATIVE RESERVE

Surveyors were directly involved in selecting sites for new settlements, exploring those lands and then establishing their cadastral boundaries over that land. Frederick Tuckett was appointed by the NZ Company in 1844 as Chief Surveyor to scout out a location for the proposed new settlement of New Edinburgh. Tuckett chose Otago Harbour as his base. To initiate the purchase of the lands required for a full agricultural settlement – township, small-holdings and moderate sized farms – Tuckett and his party with his Maori guides trekked overland to define the limits of the Otakou Purchase – the first major land purchase in the South Island (Evison 2006:48).

The party was impressed with the Otago Harbour but was somewhat intimidated and delayed by the swampy nature of the Taieri plain. Part of Tuckett's responsibility was to report to the New Zealand Company about the suitability of the land for settlement and agriculture,[12] and these descriptions of the landscapes encountered also express the European cultural aesthetic – the picturesque nature of the land. Dr Monro, accompanying the party, on first viewing the Taieri plain, painted this narrative picture:

"We looked down upon a plain stretching away to the southward for at least 20 miles, with an average breadth of five or six, bounded on all sides by naked hills of rounded outline. This plain we learnt from the natives, was called the Tairii. Its general colour was a brownish yellow, broken only by the black hue of one or two patches of wood … To the westward we saw a great extent of country of an upland but not mountainous character. Its general level is not very high, but its surface is singularly broken lying in rollers, or like the sea in a heavy swell. The appearance and colour of this tract of country indicated that it was partly though not purely grassy. … The soil at the upper part of the valley appears exceedingly rich, covered with a dense succulent-looking vegetation of course grass, sow-thistle, ti-ti, etc. This rich soil is, however, of very limited extent." (Monro (1884) as quoted in Davis (1973:223)).

As well as a careful documentation of the overland travel, this account from the exploration party assessed the resources available to the incoming settlers:

"Along the edges, however, of this basin-shaped valley, much valuable land will be found; and the surrounding hills are, generally speaking, well grassed, with a fair sprinkling of anise, but there is a great want of wood in the district." (Monro 1884 as quoted in Davis (1973:223)).

The surveyor Barnicoat (1884) also adds his interpretation of the picturesque landscape through the lower Taieri gorge:

"This proved a most romantic little voyage. The River is confined by bold, lofty, rugged & wooded hills, which barely give its water room to pass. The scenery is most picturesque & romantic. On our way down I observed a native garden on the side of one of the hills overhanging the river in which the earth was prevented from sliding to the bottom by means of trunks of small trees laid along the side of the hill & fixed by pegs driven in the ground."

In his exploration of coastal Otago, Tuckett (1844) "found what I had despaired of in New Zealand, an extensive field for colonisation as I expected to find when I left England, and scarcely inferior in respect of natural advantages."

One of the parcels of land excluded from the Otago purchase was a 2300ha block on the north bank of the lower Taieri gorge. This was designated the Taieri Native Reserve and for a time it remained unalienated Maori customary land. The purpose of this land reserved from sale, was to accommodate a small settlement of Maori at a kaik at Maitapapa. The whole of the Taieri plain was a rich resource gathering area supplying duck, weka, ti kouka, and tuna in abundance, and many other native fish species proliferating in these productive wetlands. Unfortunately, the land reserved was defined as the adjoining hill country, which, although recognised as worthless for agriculture, was at least seen by the surveyors as better than the swampy wastelands. Maori expected continued access to these wetlands even though their actual occupation (their physical presence on the land) was evidenced only by the kaik. It was clear that the main and very valuable resource area was the river, the swamp and the lake lands of the Taieri plains.

Surveyors soon arrived to carve up this newly available land as if it was a blank canvas. A grid was drawn over the Taieri plain and surveying proceeded. The Native Reserve was officially bounded by one straight line from coast to river bend.

Within a decade or two, when Maori were able to see the effects of the land becoming property, their reserve provided little benefit to them. Maori were excluded from gathering their food from the adjoining private property, and their connections to that place were disintegrating. Maori were effectively forced to individualise their reserve, (see Strack 2006) and in 1868, at a sitting of the Native Land Court, surveyors presented a plan of subdivision of the reserve. Like many Land Court partitions, the subdivision consisted of a series of parallel strips allocated to most Maori with any connection to the Otakou purchase with no consideration of actual occupation. The surveyors ensured that local Maori assisted in establishing and agreeing to these boundaries,[13] but the boundaries conformed to the regularised, parallel, straight lines of the surveyor; unrelated to any sensible use of the land, and no acknowledgement of landscape.

There may, however, have been some consideration of Maori systems of land and resource management. Considerable effort was made to ensure that the majority of parcels had frontage onto the river, and also shared parts of the rough hill country. This often resulted in either somewhat disjointed boundaries, or many long thin sections extending from the river to the hills. This distribution of land with all members of the community sharing access to all the resources is illustrative of wakawaka (Anderson 1998:114).[14] But these strips were never used, and the boundaries were never fenced; the land, which was in unusable parcels, was abandoned. The cadastral pattern has since been obliterated by reversion to a weedy, wild vegetative cover, and it is now looked upon as wasteland. The colonial aesthetic of establishing a neat, ordered and controlled landscape in this instance has failed. Furthermore, the attempt to incorporate Maori tenure into the colonial pattern has similarly failed. Most of the strips of land are still registered in Maori ownership, but many parcels have not been dealt with since the 1860s and there is no Maori occupation. Some of the land has been gazetted as scenic reserve, some is in pine plantation, some cleared for grazing leases, but most is covered in thick gorse.

The swamp land of the Taieri plain, however, was subdivided, purchased by settlers, drained, and in spite of continued intermittent flooding, has become productive farmland. The productive landscape is symbolised by neat and regular boundary fences and shelterbelts enclosing clear pastures. The original swampy landscape has been converted to an ordered controlled landscape of productive property. The cadastral pattern is obvious, and the familiar checkerboard pattern of fenced grasslands is the dominating feature of the landscape.

The effect of the loss of ownership and control of the land and rivers by Maori has resulted in great loss to Maori culture and ways of life. But the European attitudes to rivers as a resource to be used (and then usually by being convenient drains) have resulted in great environmental loss also. As Sharp (2001:47) summarises:

"Great tupuna awa (ancestor rivers), the sacred and indivisible sources of life for the people who regarded themselves as their children, have been dammed, diverted and polluted. Shingle has been extracted from their beds; native fish have been exterminated, the eel population decimated, the bush stripped from their banks. The taniwha (god-like water monsters) have retreated from the rivers and lakes, or died. Waters and reefs have been made receptacles of sewage and industrial waste. Mahinga kai, food sources in swamps and estuaries, have been drained, fenced and farmed; or they have been dredged and their waters confined for ports. The land has been stripped, fenced, ploughed by others, and built upon. The old villages are deserted and all that is left are ghosts and memories."

This is nowhere more true than at the Taieri.

SURVEYED LANDSCAPES

New Zealanders place a high value on mountain, bush, river and coastal landscapes – those wild unoccupied spaces of their landscape art, postcards, and tourism brochures. But they also demand increased access to these landscapes. On the other hand, unless land is set aside specifically for various conservation purposes, they like to see the rest of the land in neat orderly production. High value is placed on property ownership, and an implicit responsibility of ownership is to optimise production off the land. Abandoned and unutilised land is seen as wasteland and it seems to offend sensibilities to see land in such a condition. Different values are expressed by these statements, but as a group, New Zealanders seem able to compartmentalise the different images of their ideal landscapes. Many tourist images, for example, are of neatly ordered arable lands, such as seen when flying over Canterbury, or well fenced open pasture. The boundary fence is just as much part of the beauty of the image as the productive land within it.

It is easy to focus on a work of art or a tourist poster to illustrate the ideal landscapes, but the map or plan is used at least as much to help visualise the landscape. Topographic maps can relay to even the superficially educated user a wealth of land information. Cadastral maps display information about property rights in both the legal and spatial extent. Maps, more than anything else, are accessed to show where the reader stands in the world. The bird's eye views of the land; the map, the aerial photograph, Google Earth, are images beyond the normal view, but they are easily accepted as appropriate representations of the land, despite the loss of the senses of smell, hearing, texture, feeling and belonging (see Goodwin 2007). Surveyors observe these additional components of landscape, but have no tools to represent them to others. The landscape is portrayed in two dimensions, thus bringing simplicity and order to the land.

"Landscapes are manufactured they simply cannot exist without human contemplation, and furthermore the utilisation of a specific style of contemplation that reflects a learned way of viewing the world." (Steel 2008:36). Surveyors have created those varied landscapes now so highly valued. They have identified where the picturesque exists and assisted in protecting those places, and they have overlaid most other landscapes with a cadastral pattern that emphasises ownership and efficiency of production. They have undermined customary tenures by establishing new property regimes, and renamed places to obliterate the memories of the past. Much has been gained in the utilisation of the land, but much of the indigenous has been lost.

In summary, there are fundamental conflicting attitudes to the land that arise, in part, from the attitudes that prevailed when the colonial system of land subdivision and tenure was first established. There is a demand for the excluding power of ownership, and a contrary demand for more access to conservation lands. Maori customary property rights are rejected, while the right of all citizens to own private property is defended. There is an insistence on pure wilderness, yet an expectation of fully productive land-use. Biodiversity in nature is valued, while at the same time, monocultural farming methods persist.

The colonising project of surveying the land continues, as does the constant attention to maintain order and simplicity lest wild nature reclaims her space. Human control over landscape is almost absolute, in complete disregard that humans are part of the landscape, not separate from it; "landscape is the forgotten yet still functioning tool of the colonial legacy, representing the successful conquest of a European worldview over an alternative understanding that is denigrated so completely that it's only in its overlooking that it is found." (Steel 2008:37). Yet, in the face of changing environmental conditions, and differing cultural attitudes, a more environmentally sensitive and culturally inclusive approach to land subdivision and management practices might, in future, provide for a more sustaining relationship between people and the land.

GLOSSARY

Kaik – Kai Tahu dialect version of kainga (village)

Hapu – tribal group

Mana – authority

Takiwa – tribal region

Taniwha – god-like water monster

Tapu – sacred

Ti kouka – cabbage tree

Tuna – eels

Wakawaka – division of land to allow for the allocation of use rights

Whakapapa – genealogical record

ENDNOTES

1 It is observable in New Zealand, that if we give up on production off the land, the first stage of reversion to 'nature' is an infestation of weed and pest species – not the 'pristine nature' that our sensibilities appreciate.

2 Lucas (2003:145) describes landscape as "the stories in the land", and she certainly recognises that there is more than the sense of sight involved, but the stories of Maori are understood much more literally than the personal and individual stories to which she is referring.

3 Sketched by Edmund Halswell c1840 from an unidentified Ngai Tahu source. Reproduced in *Map New Zealand: 100 Magnificent Maps*. Alexander Turnbull Library. 2006. and further reproduced in my review of that book in *Survey Quarterly* 2007 (49):31.

4 "The function of whakapapa was to anchor claimants into known landscapes, and to establish the ongoing basis from which tribal and hapu mana, identity, and activity in the present could be validated by the past." (Keenan 2002:260).

5 Porteous (1996:79) suggests that the colonial desire for a well structured productive landscape was almost universal in the Anglophone world. In the Americas "Jefferson wanted a nation of innocent, happy, bucolic yeoman farmers with little industry and only small towns."

6 This had been predicted well before this time - "A barbarous and coloured race must inevitably die out by mere contact with the civilised white: our business therefore, and all we can do, is to smooth the pillow of the dying Maori race" Dr Isaac Featherston, surgeon and politician 1846, and this is matched in the USA in Chief Seattle's 1854 Oration: "It matters little where we pass the remnant of our days. They will not be many. … A few more moons, a few more winters, and not one of the descendents of the mighty hosts that once moved over this broad land or lived in happy homes, protected by the Great Spirit, will remain to mourn over the graves of a people once more powerful and hopeful than yours."

7 Scott (1998;51) carries this idea further: "Where the colony was a thinly populated settler-colony, as in North America or Australia, the obstacles to a thorough, uniform cadastral grid were minimal. There it was a question less of mapping preexisting patterns of land use than of surveying parcels of land that would be given or sold to new arrivals from Europe and of ignoring indigenous peoples and their common-property regimes."

8 "Through their inscriptive efforts – inhabiting, naming and textualising the place – surveyors described an existing landscape. By imposing their frame on the land, by direct implication, they denied the validity of what has been called the 'oral mapping' of Maori. Maori already employed mnemonic devices in their construction of mental maps; they contextualised a geographical reference framework into which topographical features could be fitted into each other." (Byrnes 2001: 44).

9 Scott (1998:58) states it clearly: "… the grid creates regular lots and blocks that are ideal for buying and selling. Precisely because they are abstract units detached from any ecological or topographical reality, they resemble a kind of currency which is endlessly amenable to aggregation and fragmentation. This feature of the grid plan suits equally the surveyor, the planner, and the real-estate speculator. Bureaucratic and commercial logic, in this instance, go hand in hand. As Mumford notes, "The beauty of the mechanical pattern, from the commercial standpoint, should be plain. This plan offers the engineer none of those special problems that irregular parcels and curved boundary lines present. An office boy could figure out the number of square feet involved in a street opening or in a sale of land; even a lawyer's clerk could write a description of the necessary deed of sale, merely by filling in with the proper dimensions the standard document. With a T-square and a triangle, finally, the municipal engineer could, without the slightest training as either an architect or a sociologist, 'plan' a metropolis, with its standard lots, its standard blocks, its standard width streets … the very absence of more specific adaptation to landscape or to human purpose only increased by its very indefiniteness, *its general usefulness for exchange*."

10 It is interesting to note that the Queen's instructions to Governor Hobson in 1840 suggested that NZ should be surveyed according to a very regular rectangular grid (such as was later implemented in the prairie provinces of Canada, where the topography was rather more monotonously flat than NZ!).

11 "The grid was one of the 'civilising' influences of capitalist colonisation. It was the most straightforward way of delineating private property rights in land, of commodifying nature for those asserting a stake in it. It was the most efficient means of accommodating capital in space, providing a stage from which that capital could be used in the

conversion of nature into resources." … "The desire for order was part of it, but more commonly explanations have focused on its simplicity for the surveyor, and that it was evidence of mastery over nature, or at least the need for it." (Pawson 2002:203).

12 They were also expected, in consideration of the Treaty of Waitangi protections of te tino rangatiratanga, to ensure Maori interests were recorded: Shortland (1851:287-8 Letter to JJ Symonds Esq. 'Precautions to be adopted in purchasing lands from Natives.' and quoted in Evison 2006:46) issued instructions to the party: "Before completing any purchase of land from the natives, it appears to be essential to obtain first the native name of every place within the district proposed to be purchased, with the names of the persons who have individual rights in each place 'I a ratau te turuturu o te kainga' the general rights of principal chiefs and others being more easily dealt with. For whereas several may have joint right to those parts, which have never been resided on, or made 'tapu' to any particular person, individuals and families will be found to have a peculiar claim to those parts which are in occupation of, or have at any former time been in possession of, or made 'tapu' to an ancestor. The next step should be to desire the natives to decide which places they wish to sell, and what to reserve for themselves. For it will seldom happen that they will readily part with a large district without reservation unless it is wholly unsuited to their methods of cultivation – and even then there would probably be some favourite eel-fisheries, to them of great moment, with which they would not part."

13 – "I accordingly got them all out on the ground and made them put in all their pegs and cut their lines as shewn on the maps". (D. McLeod 1868 quoted in Strack 2008:145).

14 The concept of such allocations of strips is not unique - a similar distribution and allocation of strips of land in a range of ecological zones is described by Scott (1998:39) in a Russian village.

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Water level measurement and tidal datum transfer using high rate GPS buoys

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SUMMARY

The transfer of tidal datums using high rate GPS buoys offers advantages over traditional techniques, which may be limited by their practicality, efficiency and cost. This paper describes an experiment where two GPS buoys were deployed simultaneously near two tide gauges within Otago Harbour, New Zealand. The tide gauge records were used to verify, first, that GPS buoys can measure water levels, and second, test the accuracy to which a tidal datum can be transferred based on water levels estimated by the buoy. It was found that a datum could be transferred with a similar accuracy to previous experiments using conventional techniques, concluding that GPS buoys are a viable means of tidal datum transfer.

With rising sea levels and an increasing demand for coastal properties, cadastral surveyors and engineers need to be able to readily define cadastral boundaries along the sea shore both reliably and accurately. The use of GPS buoys has the following advantages for tidal datum transfer:

- Efficient datum connections between the GPS buoy and benchmark.
- Expedient and relatively easy data collection.
- Existing GPS equipment can be used.
- GPS buoys can be deployed in close proximity to the shore, and do not have to be rigidly attached to a structure, as with traditional tide gauge instruments.

KEYWORDS

GPS buoys, tidal datum transfer, cadastral boundaries.

INTRODUCTION

Tidal datums are used for a number of important purposes. They provide reference surfaces for navigational charts (e.g. chart datum, Chang and Sun (2004)); height datums (e.g. mean sea level, Hannah (1989)); as an indicator of climate change (Pugh 2004) and as the basis for defining various coastal cadastral jurisdictional boundaries (Baker and Watkins 1991). For some applications, a tidal datum must be transferred between locations and to do this, tide gauges have typically been used in the past. However, GPS buoy technology, now capable of measuring (ellipsoidal) heights at the low centimetre level, provides a viable alternative method. A GPS buoy is essentially a GPS antenna mounted on a floating platform.

Traditional methods and techniques have limitations in practicality, efficiency, cost and accuracy (Goring 2007). Dewar and Hannah (2005) discussed two general methods for transferring tidal datums using levelling (either spirit or GPS levelling) and tidal datum transfer techniques. Firstly, levelling can be undertaken using an established gauge as a starting point. Unfortunately today, terrestrial (or spirit) levelling is a time consuming, expensive and typically requires extensive logistics, such as traffic management planning. Alternatively, GPS levelling, which measures ellipsoidal height differences, can overcome many of the problems associated with terrestrial levelling, but does require a high quality geoidal undulation model. Both levelling techniques ignore local sea surface effects. Secondly, tidal datum transfer methods can be used, where a temporary tide gauge is set up at a remote site and the datum transferred by comparing tidal observations at both the temporary and a nearby permanent gauge. Traditionally in cadastral surveying, a simple tide staff is used at the remote site, which is inefficient and has a low level of accuracy due to the manual observations required. More generally, tide gauges may be difficult to install at many locations where it is difficult to rigidly fix them.

Using a GPS buoy to measure water levels offers many advantages over traditional techniques with its ability to determine heights relative to an absolute reference frame. While large scale GPS buoys have been used for long-term datum determination (e.g. Arroyo-Saurez et al 2005), there has been little research involving light-weight designs for short-term tidal datum transfers. However, Abidin (1999) suggests that small systems using GPS show potential for this type of application. The purpose of this paper is to demonstrate the viability of GPS buoy technology in transferring tidal datums. In particular, we verify the ability of a high rate GPS buoy to measure sea level by determining its precision and accuracy relative to tide gauge observations, and demonstrate the accuracy with which a tidal datum can be transferred using sea levels estimated by a GPS buoy.

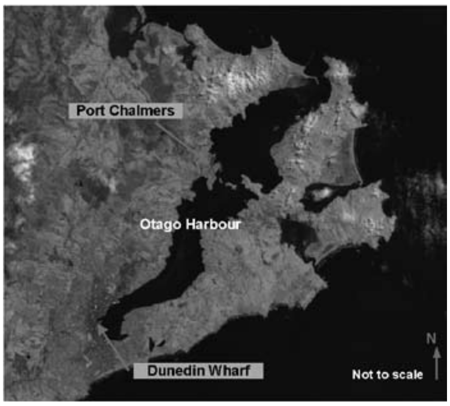


Figure 1: The Otago Harbour tide gauge deployment locations.

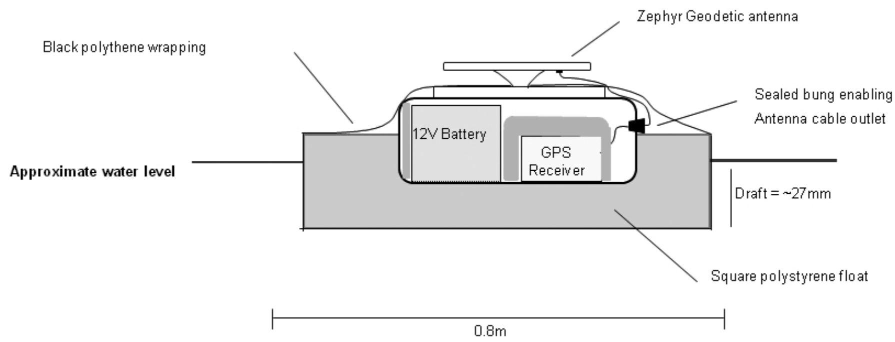


Figure 2: Sectional view of the GPS Buoy.

The experiment was undertaken in Otago Harbour – a 22 km long tidal inlet that is located on the eastern coast of the South Island of New Zealand. Existing tide gauges, located approximately 10 km apart at two port facilities, Port Chalmers and the Dunedin Wharf (Figure 1), were used to provide a means of calibration and comparison.

WATER LEVEL MEASUREMENT USING GPS BUOYS

Since early designs in the late 1980's (e.g. Kelecy et al 1994) GPS buoy technology has rapidly progressed in both design and applications. This has been largely driven by the use of buoys for absolute calibration of satellite altimeters (Schone 2001), with applications ranging from tsunami monitoring (Kato et al 2001) to river level monitoring (Moore et al 2000). Research has typically involved three types of design:

1. Lightweight wave rider, which must be tethered and operated from a boat.
2. Autonomous lightweight wave rider, housing all the necessary equipment within the buoy.
3. Autonomous, large scale buoy for use in long-term rugged environments.

The advantages, disadvantages, and applications of these designs are summarised in Table 1.

METHODOLOGY

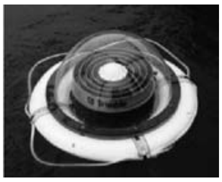
GPS buoy design

The GPS buoy used in this study was of the wave rider style and designed to operate autonomously. It consisted of a simple square block of polystyrene with the GPS box inserted into its centre. This box contained the GPS receiver (Trimble 5700) and battery, with the antenna (Trimble Zephyr Geodetic) fixed on top (Figure 2). Both the tether and shape of the buoy were key design considerations as they have the potential to influence the buoy's dynamics and therefore the mean vertical position above the water surface. In order to reduce any effects on the buoy's vertical position due to the movement of the anchor system, the buoy was connected to a secondary float before being attached to either an anchor or pile.

Antenna height offset

Determining the height of the antenna above the mean water surface is a fundamental part of measuring absolute sea surface heights. In this experiment a spirit level and lightweight measuring rod were used to measure the height difference between the centre point on the top of the antenna and a bench mark that the water level had been raised to. This was carried out in a controlled environment using a temporary tank filled with fresh water with the buoy in its full deployment state.

Table 1: Advantages, disadvantages and applications of the three major GPS buoy designs. Table layout from Watson (2005).

GPS Buoy Design	Description	Advantages	Disadvantages	Application Examples
Lightweight wave rider (antenna only)  e.g. (Key et al 1998), (Cheng 2005)	• A light-weight buoy usually using a life preserver as the floatation source • The buoy can be operated from a boat and only houses the GPS antenna • The antenna offset from the mean water level is small, typically positioned 50–250 mm above it	• Economical and simple to construct, with low cost materials that are readily available • Easily portable because of their small size • No need to monitor and correct for the buoy's tilt • Low centre of mass	• Logistical support is required throughout the entire deployment (personnel and boats) • Lack of versatility with the tether required • Deployment restricted in rough sea conditions • Suitable for short duration deployments only (Watson 2005)	• Absolute altimeter calibration • Tidal Datum Transfer • Orthometric height transfer over water (measuring geoidal slope) • River and lake level monitoring • High frequency wave analysis • Mapping the sea surface
Autonomous lightweight wave rider   e.g. (Parker 2007)	• A light-weight buoy as above, except it houses the GPS receiver, antenna and battery • Can operate autonomously, either: anchored, drifting or tethered	• As above • Reduced logistical support required, with autonomous operation of up to 5 days	• As above • Logistical support still required, although reduced • Deployment time is still limited to short to medium terms	• As above • Verifying and calibrating tide gauges • Applications requiring autonomous (stand alone) operation for periods <1week
Autonomous, large scale  e.g. (Kato et al 2001), (Arroyo-Saurez et al 2005)	• A large, rugged buoy that houses the GPS system in addition to power storage and generation and data communications • Can operate autonomously for significant durations • The antenna reference point is typically 5-7 m above the mean water level (Watson 2005)	• Can operate for long time periods and in rough sea conditions • Additional sensors can be integrated into the buoy, such as meteorological instruments (Watson. 2005)	• High Cost • Not easily portable • Can be difficult to measure and correct for buoy's tilt influencing the antenna's position above the water level. • Reliability issues with power and communications (Watson, 2005)	• Tsunami monitoring • Tidal Datum Determination • Absolute altimeter calibration • Long term tidal monitoring

A correction for ocean salinity was made to the height difference between the antenna reference point (ARP) and mean water surface. The estimated antenna offsets for the buoys were ~ 0.264 m ± 0.002 m.

Deployment

Two GPS buoys were deployed simultaneously at Port Chalmers and Dunedin Wharf (Figure 1) within close proximity to existing tide gauges. Observations were made every 5 seconds over a period of four days. Higher rates, such as 1 Hz, are frequently used for GPS buoy data collection (Watson 2005), however a comparison of both the precision and mean of the height difference between the tide gauge and GPS buoy was less than 1 mm between the 1 and 5 second epoch data rates. Because of the difficulties in processing and managing the increased data, 5-second epoch observations were made. A minimum of 3 days of tidal observations is required for successful use of the range ratio method of tidal datum transfer (Grant and O'Reilly 1986). The four days of tidal observations observed for this experiment satisfies this requirement as well as providing sufficient data to verify the GPS buoy's ability compared to the tide gauges. These observations were post-processed using GPS reference stations co-located with the gauges. Outliers were a common feature of the processed GPS heights and were identified by the clear jumps in the heights compared to the tidal pattern. These were possibly caused by the carrier phase ambiguities being incorrectly resolved and were removed. Figure 3 shows the GPS buoy being deployed at Port Chalmers.

To directly compare the sea level observations from the tide gauge (relative to chart datum) and the GPS buoy (relative to the GRS80 ellipsoid), the observed heights need to be reduced to the same reference surface (see Figure 4). In this situation the height difference between the ellipsoid and

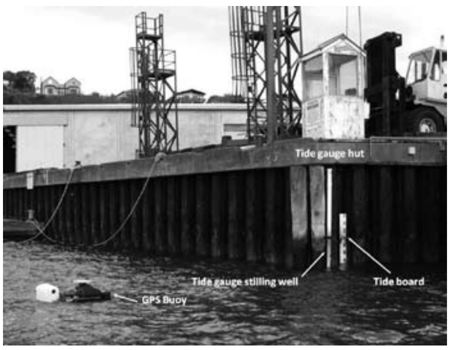


Figure 3: GPS Buoy deployment at the Port Chalmers tide gauge site.

orthometric height datum at the reference station, ($h_{REF} - H_{REF}$), was used in combination with the geoidal undulation between this position and that of the buoy, $\Delta N_{REF-Buoy}$), to determine ellipsoidal-orthometric separation at the buoy ($\sim N_{Buoy}$). The calculated offset to chart datum, (CD_{Offset}), was then applied to reduce the GPS buoy heights to chart datum ($GPSBuoy_{SSH}$).

The buoy should preferably be positioned within 200 m of the tide gauge being used for verification and the reference station (Watson 2005). This both simplifies the GPS processing, as some errors in the GPS observables will be correlated between the two sites, as well as minimising the effects of geoidal undulation and dynamic sea surface topography (Figure 4). Sea surface topography is the difference in the mean sea surface due to the effects of wind, temperature, salinity and current between two locations. For most tidal datum transfer situations, there is often no orthometric height control close to the subordinate station and therefore the tidal observations and datum transfer must be made relative to another datum. A tide gauge is often referenced arbitrarily to a nearby benchmark; and so when GPS buoys are used to transfer a datum, the reference height can be relative to the ellipsoid at the GPS base station benchmark. Alternatively a geoid-ellipsoid separation model can be used to reduce the ellipsoidal height to an orthometric height surface.

Verification

In order to verify the GPS buoy's ability to measure sea surface heights, filtered GPS heights were directly compared to those from the existing tide gauge at the location. The difference ($Difference_{TG-GPSBuoy}$) between the tide gauge and GPS buoy measured heights was computed as:

$$Difference_{TG\text{-}GPSBuoy} = TG_{SSH} - GPSBuoy_{FilteredSSH}$$

where TG_{SSH} is the tide gauge sea surface height (relative to chart datum) and $GPSBuoy_{FilteredSHH}$ is the GPS buoy filtered sea surface height. The GPS buoy heights required filtering to take into account the effect of the tide gauge's stilling well and different observation sampling rates, with the tide gauge taking the mean of every 30 seconds prior to the tenth minute. Upon analysis, a 3 minute sampling period was selected and any outliers removed. This enabled both the precision as well as absolute and systematic biases between the two systems to be determined from these differences.

Tidal datum transfer

The range ratio method was used to transfer the tidal datum MHWS between Port Chalmers and Dunedin Wharf and vice versa. Three days of simultaneous GPS buoy observations were used. The high and low points required for this technique were determined by fitting polynomial curves to the extremities of the data (typically over a two hour period). The range ratio method assumes that the ratio of the vertical distances from the respective datum planes to mean high water springs (MHWS) at the reference and subordinate sites (i.e. MHWS/mhws) is equal to the ratio of the observed mean tidal range at the same two sites (i.e. MR/mr). Thus, the ratio is given as:

$$\frac{MHW}{mhws} = \frac{MR}{mr}$$

Marshall (2007) gives the full details of the tidal datum transfer procedures used. This method was chosen because of its proven accuracy, and because it enables a direct comparison to previous research undertaken by Dewar and Hannah (2005). However, other methods may be better suited to other sites depending on their physical and tidal characteristics. For example, in some locations only part of the tidal range can be observed because of the influence of mud flats. In this case the modified height difference method (Dewar and Hannah 2005) could be used. The least squares method (Grant and O'Reilly 1986) may be particularly suited to the high rate GPS buoy data, but this requires further investigation.

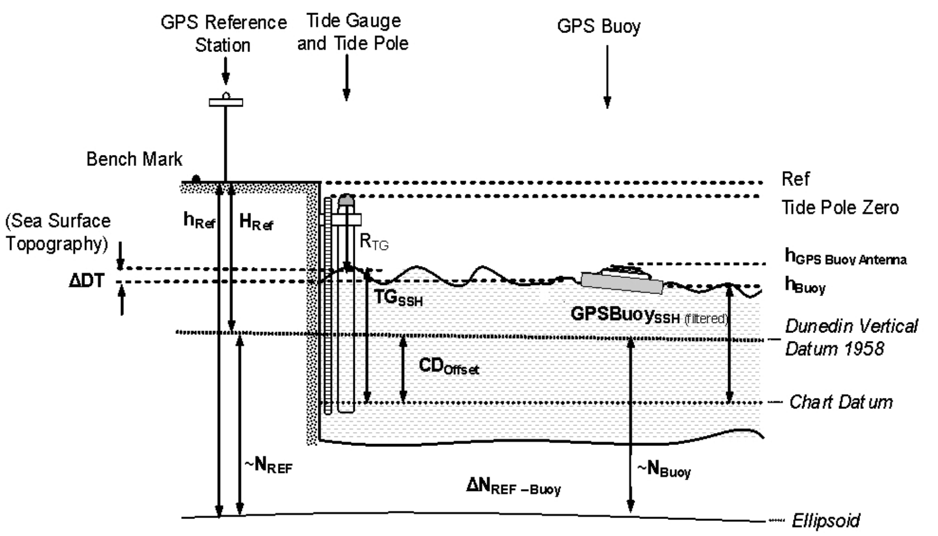


Figure 4: Datum connections and methodology for verification of the GPS buoy with the tide gauge.

RESULTS AND ANALYSIS

GPS buoy verification

Differences between the tide gauge and GPS buoy sea surface heights were used to verify the ability of the GPS buoy to measure sea surface heights in the manner described in the preceding section on ***Verification*** above. Table 2 summarises the precision achieved for two deployments. The first deployment (Initial Dunedin Wharf Test), logged data at 1 second to test the prototype, while the second deployment used two GPS buoys observing data simultaneously at Dunedin Wharf and Port Chalmers.

The three deployments demonstrated standard deviations at the ~±2 cm level. This precision was ~1 cm poorer than the majority of recent research involving this type of design. The reason for this is unknown, although a rougher sea state may have been a factor.

Table 2: Summary of precisions of the height difference between the GPS buoy-tide gauge for three deployments.

	Deployment	Sampling Rate	Observation Period	1 σ (mm)	95% (mm)
1	Initial Dunedin Wharf Test	1 sec	~ 24 hours	±17	±33
2	Dunedin Wharf	5 sec	~ 4 days	±23	±43
3	Port Chalmers	5 sec	~ 3.75 days	±24	±47

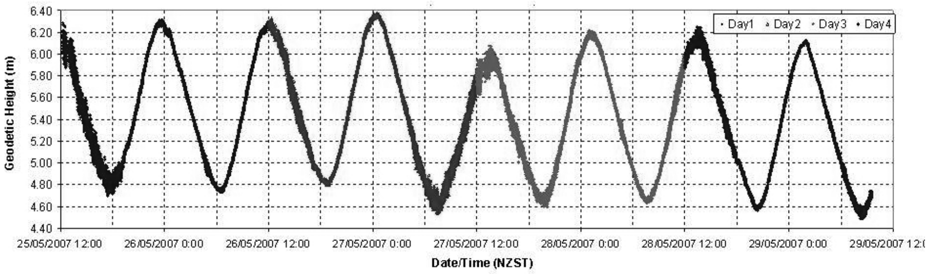


Figure 5: Dunedin wharf deployment sea surface height estimates from the unfiltered GPS buoy data.

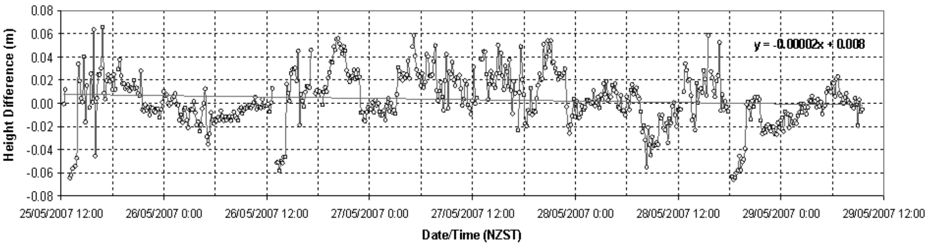


Figure 6: Dunedin wharf deployment residual differences between the filtered GPS buoy data and the tide gauge.

Table 3: Comparison of geodetic to chart datum offsets.

Deployment		Initial Dunedin Wharf Test	Dunedin Wharf	Port Chalmers
Chart datum to ellipsoid offsets	Measured Datum Offsets (m)	4.322	4.322	4.450
	Mean $Difference_{TG-GPSBuoy}$ (m)	4.309	4.319	4.443
Absolute bias between TG and filtered GPS buoy SSH (reduced to CD)	Mean $Difference_{TG-GPSBuoy}$ (m)	+0.013	+0.003	+0.007

Figure 5 is an example of the unfiltered sea surface heights graph of the tidal variation over the four days, while Figure 6 graphs the difference between the tide gauge height and GPS buoy (filtered) height.

Table 3 compares the mean difference between the tide gauge measurements relative to chart datum and those of the GPS buoy reduced to chart datum using the measured datum connections. The mean bias between the two systems is small, being less than 7 mm for both simultaneous deployments. When considering the potential error budget, this appears to be insignificant.

Tidal datum transfer

The mean high water springs datum was transferred between Dunedin and Port Chalmers and vice versa using the process described previously. Residuals between the datum transferred and the long-term datum established were below 10 mm (Table 4).

Similar results were obtained by Dewar and Hannah (2005) who transferred the MHW datum using tide gauge data from the same locations as this project. Using the range ratio method and a similar two-day period of observations, a mean difference of ~10±21 mm was demonstrated, suggesting a similar level of accuracy. Although only two comparisons were obtained, the results do indicate that the GPS buoy is a viable data collection tool for tidal datum transfer.

DISCUSSION

Increasing demand for coastal properties, increasing land values, and rising sea levels has heightened the need for reliable and accurate tidal datums to be defined for use by cadastral surveyors and engineers. Both the lines of MHWS and MHW are used to define coastal cadastral boundaries in New Zealand.

In some circumstances a mathematical approach, such as a tidal datum transfer, is not required. This is the case when the shore-line is steep and stable or the land value is low compared to the area that may be affected. In this case the tidal boundary can be defined using previous surveys or a re-survey of physical evidence, such as the face of a cliff, or edge of vegetation or driftwood. However, in other areas where a high value is placed on the ownership of the land the seaward cadastral boundary must be defined with more accuracy and therefore a suitable tidal datum transfer procedure must also be used (Baker and Watkins 1991). Figure 7 demonstrates the relationship between a coastal datum and the physical beach profile.

Typically a tide pole has been used by surveyors as part of the process to determine

Table 4: Comparison of the MHWS datum transferred to that already established at Port Chalmers and Dunedin Wharf.

Control to Subordinate Stations	Dunedin to Port Chalmers (m)	Port Chalmers to Dunedin (m)
MHWS datum transferred (above CD) [Reduced using measured datum connections]	2.149	2.174
Long-term MHWS datum (above CD) (LINZ 2007)	2.14	2.18
Difference (m)	-0.009	+0.006

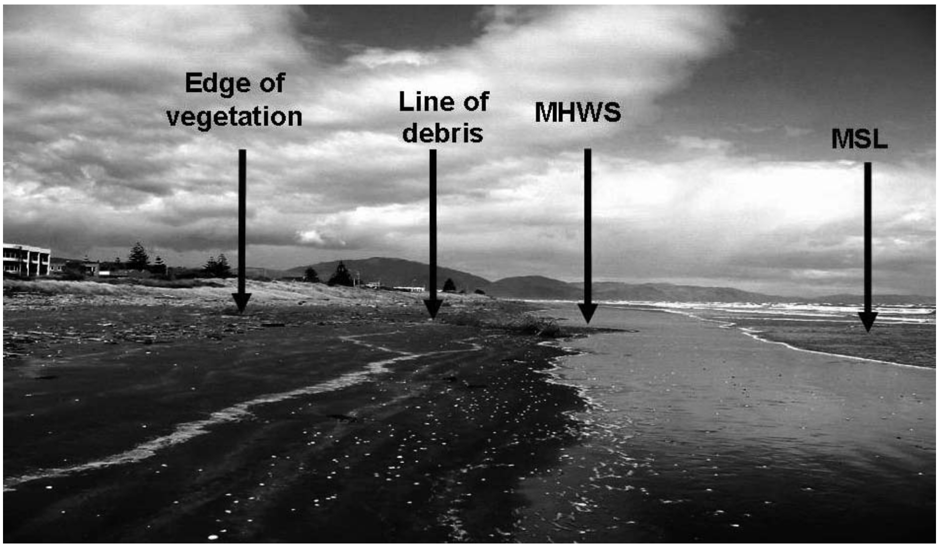


Figure 7: Image showing cadastral boundary lines on the coast. (Source: LINZ 2005).

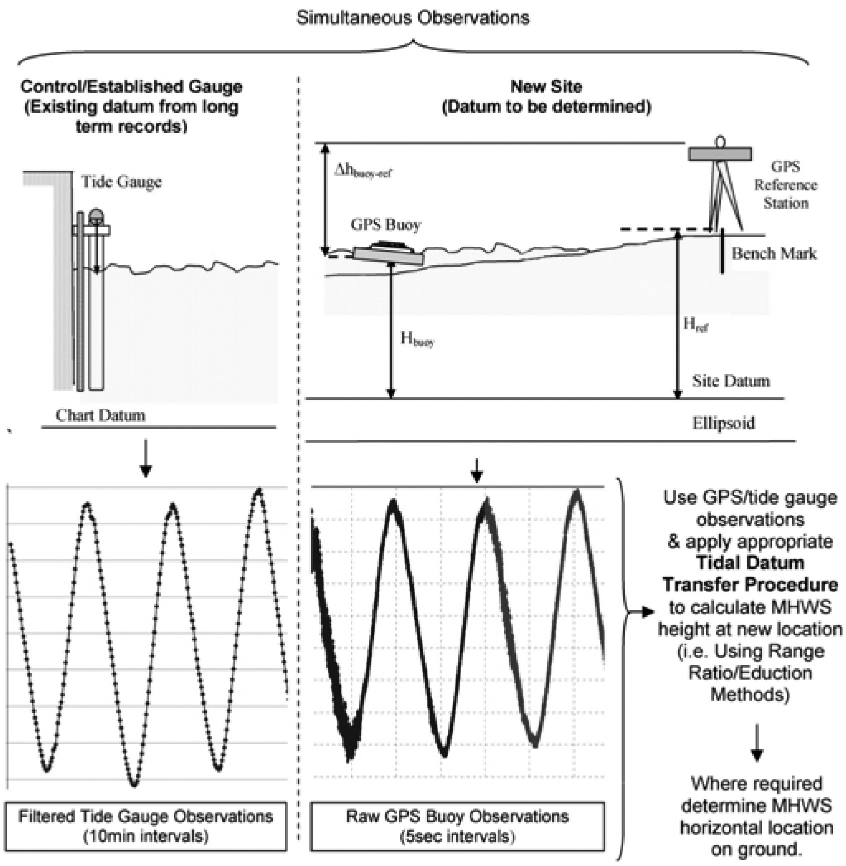


Figure 8: Example of the process for transferring a tidal datum using a GPS buoy.

this coastal boundary at the subordinate site, with these observations then combined with those sourced from the permanent (control) tide gauge. However, the use of GPS buoys may have advantages in many situations. A particular environment where it may be particularly useful is in estuarine areas involving high value land, where there is little wave action and a flat gradient. The vertical error therefore has a large effect on the horizontal position of the boundary because of the slope of the foreshore, and in sheltered environments especially, the GPS buoy has small errors. It should be noted that for best results a GPS buoy would need to be deployed at both locations to ensure the lower frequency observations from the control tide gauge does not degrade the quality of the transferred datum. However, typically a cadastral surveyor is expected to use a sole buoy at the subordinate station. Figure 8 summarises an example of the process that could be used to transfer a tidal datum using a GPS buoy.

The perceived advantages of the GPS buoy are:

- Efficient datum connections between the GPS buoy and benchmark eliminates the need for levelling to the tide gauge/staff and errors associated with this. This is probably one of the biggest advantages of high rate GPS buoys.
- Efficiency and time saved in data collection, with no manual observations required. This saves time, money and inconvenience.
- Existing GPS equipment as owned by a typical surveying firm can be used in combination with cheap readily available materials for buoy construction.
- Potential for increased accuracy in the datum transferred because of higher frequency observations. This is maximised by deploying a GPS buoy at both control and subordinate locations.
- They can also be deployed in close proximity to the shore, while not being required to be rigidly fixed as

with traditional tide gauge instruments (Watson et al 2007)

GPS buoys should also prove useful for hydrographic survey applications in areas where the installation of a tide gauge is difficult, such as establishing chart datum to be used as a reference point for the survey.

CONCLUSION

GPS buoy technology was successfully verified and applied to transferring a tidal datum within Otago Harbour. Increasing coastal development and sea level rise has highlighted the need for accurate tidal datums; however, existing methods of tidal datum transfer often have limitations. Although GPS buoy technology has been increasingly applied to many situations there has been little research investigating the use of light-weight designs for transferring tidal datums.

GPS buoys were deployed simultaneously at Port Chalmers and Dunedin Wharf tide gauges for four days allowing the observations to be compared against those of the gauges. Possibly because of rough sea conditions, these differences were less precise than expected, with a standard deviation at the ±2 cm level but with no significant bias between the two systems. The tidal datum MHWS was transferred and compared to that established from long-term tidal observations, with residuals at the 10 mm level.

It can be concluded that GPS buoys are a viable means of transferring tidal datums. The buoys were demonstrated as being simple and cheap to construct, while also being able to utilise typical GPS surveying equipment. It is therefore considered to have real potential for use in tidal data collection in many situations.

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ACKNOWLEDGEMENTS

This research was gratefully supported by a specialist processing unit research bursary from Land Information New Zealand. Assistance was provided by the School of Surveying's technical officers, Alastair Neaves and Mike Denham.

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Access to landlocked Maori land

INTRODUCTION

Maori land is more likely to be landlocked than general land because of the way Maori freehold land has been created and dealt with in the past. The current Maori land legislation (Te Ture Whenua Maori Act 1993 –TTWMA) and the guiding principles of the Maori Land Court are directed at facilitating the occupation, development and utilisation of Maori land, and therefore, providing physical access to landlocked Maori land is a matter of some importance. The Property Law Act 1952[1] (and more recently, PLA 2007) makes provision for the High Court to investigate landlocked land and to provide reasonable physical access. That prescribed process has provided a satisfactory remedy for general land. But the particular problems with Maori land, including multiple owners, fragmented title and parcels, and difficulties with occupation, have meant that the PLA has not been useful for providing a remedy for Maori land. Recent amendment of TTWMA[2] makes special provision for the MLC to investigate landlocked Maori land and provides a more suitable course of action for Maori seeking to remedy the problem of landlocked Maori land.

SUBDIVISIONS OF GENERAL LAND

The New Zealand surveyor performed a fundamental role in the colonial project by surveying the land and creating land parcels for purchase, settlement and production. The object of the early surveys was "to prepare a waste of undivided country for an inflowing people." (J T Thomson, cited by Gough 1969:11).

Communication links and access onto land were fundamental requirements, so land parcels surveyed out of any newly purchased Crown land for the issue of a Crown grant were provided with some sort of legal road frontage even if the parcels were defined well before the roads were actually built. The assumption continues that newly surveyed parcels were provided with legal frontage, even if some strips of land were never dedicated as legal roads.[3]

Many early statutes established regulation for the laying out of roads and streets. The legislative requirement to provide legal access to all new allotments was introduced in the Public Works Amendment Act 1900. Since then numerous other statutes have continued to require all land parcels to have frontage to a legal road or some other form of physical and legal access. The Local Government Act 1974 s321[4] required all land to have frontage to a legal road to provide for vehicular access, although there were some exceptions allowed for. Access could be allowed by the sea, lake or navigable river, or over a right of way easement over adjoining land. The Resource Manangement Act now ensures that all roads shown on survey plans will be appropriately legalised (s238) and the subdivision process requires local authority consent and compliance with District Plan rules.[5]

Some land parcels could still become landlocked by some historical discrepancy. Often access tracks have been used over strips of land that were mistakenly assumed to be on legal roads or right of way easements. In other situations, land parcels have been exchanged between adjoining owners that have resulted in those parcels being isolated from previous legal access or frontage. Sometimes errors in title records or transfers have inadvertently separated parcels from their previous access. In all these situations the PLA has been used to apply for a remedy, and has provided much-needed valuable access. Toomey investigated the use of these PLA landlocked land provisions, identifying 20 cases that have been brought to the High Court (Toomey 2003). Her critique of these cases suggests that the protection of proprietary rights (indefeasibility) is a fundamental principle that should not unnecessarily be overridden in favour of granting one owner access over another's land. The court should only grant relief if the case for the applicant is particularly strong. The better utilisation of land is recognised as an important principle but care should be taken in overriding indefeasibility of title as protected under the Land Transfer Act. She was particularly critical of the possibility that a land developer may be able to use the provisions of the Act to achieve some windfall profits from obtaining reasonable/ vehicular access to land when the purchase price may have been based on restricted or non-existent access.

The case analysis shows that the courts are generally cautious about overriding property rights, although there is continuing debate about the validity of reading down the ability to provide access when the Act is remedial in effect and therefore should be used fully to remedy the problem of landlocked land.[6]

PARTITIONS OF MAORI LAND AT THE NATIVE LAND COURT

Maori freehold land is a creature of the Native Land Court process. The Native Land Court was established by the Native Lands Act 1863 with the explicit purpose to investigate the ownership of Maori customary land and to convert that ownership into a freehold, individualised form of tenure recognised in a Certificate of Title recorded by the Registrar of the NLC. The actual process of creating such a title, being a conversion from a pre-existing customary title,[7] meant that there was no consideration for the requirements for access – the land always belonged to Maori and this process was just a different way of recording that ownership. Maori owned the land; they applied for a NLC derived freehold title to that land, there was no development planning, so road planning or other access concerns were not part of the process. There was however, always the power to take up to 5 per cent of land from any Maori title to lay out a road for public purposes.

Subsequently, a significant part of the activity of the NLC was in determining succession to Maori land titles. Because Maori freehold titles are assumed to be held as tenants in common, the succession determinations meant that the number of registered owners on each title increased rapidly. There was less direct connection with, use of, or occupation on the land parcels by the registered owners. This created a need to have a process to separate out these title shares to counteract the problems of multiple ownership. The court, therefore, developed a process of making partition orders to separate out individual shares from the parent title. These partitions by the NLC were often office exercises of drawing lines on the plans to create strips of land representing defined proportions of land that supposedly matched the defined share holdings. Again, this land was often seen in isolation from other orderly settlement patterns and there was little consideration for requirements for access. Reports about Maori land have identified these issues as problems uniquely affecting Maori land and in need of remedial action. In 2000, the registrar of the Maori Land Court (Grant 2000) reported that almost half of the Maori freehold land titles are unsurveyed, and well over half are not registered under the Land Transfer Act and up to one-third are likely to be landlocked.

ROADWAYS

TTWMA has given the Maori Land Court the authority to create roadways to provide access to Maori land.[8] This roadway provision is unrelated to any legal argument about whether land is landlocked – it merely allows for providing additional or improved access. Roadways can be created over general land, Crown land and other Maori land with the consent of the relevant land owner, and for connections to State highways or other public roads, with the consent of Transit NZ or the territorial authority. Such roadways do not affect the ownership of the land over which they are created, but they do affect subsequent use, so they are a very real restriction on the subject title. It is certainly not the normal situation in New Zealand that what appears to be a public road may be owned by an underlying owner. This is contrasted to the situation in the United Kingdom where the common law doctrine of *ad medium filum*[9] may apply to some public roads.

Roadways laid out by the court may subsequently be proclaimed as public roads or streets subject to certain conditions and consents, in which case the land encompassed by the roadway defined by a survey, will be vested in the territorial authority. This stage clearly transfers the title of the land away from the subject owner, and more accurately represents the physical status of the land.

The roadway provision in TTWMA is not particularly helpful for Maori seeking access to their land. The fact that access can only be granted this way with the consent of the affected adjoining owner is a considerable barrier to use of this provision to improve access.

LANDLOCKED LAND

Part 14 Title Reconstruction and Improvements and *Part 16 Surveys of Maori Land* of TTWMA 1993 include details on partition, amalgamation, aggregation, exchange orders, easements, roadways and landlocked land to enable the better utilisation of Maori land. Sections 315-326 deal with easements, roadways and landlocked land. Sections 326A-D were inserted into the Act in 2002, with the essence of the amended sections being to provide a remedy for landlocked land.

These sections are similar to the landlocked land provisions of the Property Law Act, but the fact that the process and issues can now be dealt with by the MLC has opened up the scope of remedies available to Maori. Firstly, there is a philosophical bias and a legislative imperative to promote the better utilisation of Maori land by providing access to landlocked Maori land, with less emphasis on the indefeasibility protections of title. Secondly, the alternative approach to the law that is illustrated by the MLC proceedings is clearly more accessible to Maori and even encourages Maori to seek remedies this way.

The MLC is a court of record and has authority to make legally binding orders, but its process is very significantly different from the adversarial model of the High Court. The adversarial model requires an applicant and a respondent[10] with their legal counsel and all parties advocating for the protection or extension of their property rights. The MLC responds to an application for access, but requires all affected parties to be joined in the application. This immediately avoids the confrontational adversarial method, and allows for negotiation with mediation provided by the court. The benefits of the informal MLC process when dealing with landlocked land applications can be seen in the forum it provides owners. The requirement to bring all affected parties together to present the case forces a good level of discussion, negotiation and compromise that is lacking in a High Court action, notwithstanding the consideration the court may take of "the conduct of the parties, including any attempts they have made to negotiate reasonable access to landlocked land." (Property Law Act 2007: s329(c)).

The landlocked land provisions in TTWMA offers new opportunities to Maori and their communities to gain access to their landlocked parcels allowing for utilisation and retention. It is intended that the MLC allows for applicants to bring their cases directly to the court without the need for legal counsel, so that the facts can be heard and a reasonable resolution may be arrived at, rather than depending on well argued law and precedent. However, when the MLC is dealing with the complex issue of landlocked land, lawyers can make the process easier.[11]

MAORI LAND COURT PROCESS

Not all cases have to be solved with a court hearing and orders being granted. The MLC offers judicial and telephone conferences if they are better suited to the application. The MLC uses its discretion and applies it differently to each case. Under the landlocked land provisions of TTWMA for an application to the Maori Land Court (MLC), Maori land owners should firstly gather consent from all beneficial owners or trustees to consider applying for access to their lands. The next step should involve consultation with adjoining and affected land owners. If a suitable resolution between parties is unlikely, an application to the MLC seeking relief may be considered. At the MLC, careful preparation is required – investigating how land became landlocked, what negotiations have occurred, what hardships are suffered by all parties, and how land may be better utilised. The application fee of $61 to the MLC is a token charge that should be no barrier to seeking a MLC resolution. The application requires the owners of the land adjoining the landlocked block to be part of the application. Every person that may have an interest in the landlocked land or other affected lands may be heard in relation to the application. A copy of the application must be sent to the local authority concerned. The Court may also require the applicant to give notice to other affected people. The Court then must have regard to seven conditions. These conditions cover the nature and quality of the access, the circumstances in which the land became landlocked, the conduct of all parties, hardship caused, Part 3B of the Conservation Act 1987, public safety affecting railway lines and other such relevant matters. After taking into consideration these matters, the Court may make an order. This order can vest in fee simple any other piece of land to the legal estate of the landlocked land or can make and attach an easement over any other piece of land in order to provide access to Maori land.

Most applications attempt to have negotiations with adjoining and affected parties. However, very few parties can get a productive result, and often the case ends up in the MLC. The setting of the court creates a degree of formality and allows for everyone to express their views and concerns. Most applications are adjourned for further information to be obtained before continuing through the application process. Often the information required involves waiting for valuation reports, site visits, completion of surveys, and an estimate of the number of times access will be used. Parties involved may need to negotiate between themselves for the final conditions and elements to be included in the order.[12] The flexibility of the court allows it to hold off on a decision until all conditions are satisfied.

At the conclusion of a hearing, when the judge is satisfied that access needs to be provided, an order needs to be made granting access. The order for access can be made conditional upon final documentation, such as a valuer's report or council consent.[13]

The flexibility of the court process, however, contributes to significant delays or even the stalling of the applications. This can be seen in a Waikouaiti case where it is taking several years to even get past the discussion stage among trustees and affected parties.[14] Of the several applications brought to the court only one has resulted in the issue of an order for an easement to provide access.[15] In other cases, however, the MLC has been able to satisfy applicants' access requirements by making a temporary order[16] or by providing a forum for negotiated agreement without a court order.[17]

MAORI LAND RECORDS

It is apparent that Maori freehold land has been left behind in the development of the digital cadastre. Typically, survey costs have been too high for the owners of Maori freehold land to formalise parcel boundaries. Discrepancies between Landonline and Maori Land Court records have inhibited registration of Maori freehold land titles (Ministry of Justice 2005:6). There are approximately 15,000 unregistered partition orders (Land Information New Zealand

2006:5), so it is unsurprising that establishing legal access to the partitioned parcels is problematic. Current initiatives including a Land Tenure Review[18] and the Maori Freehold Land Registration Project[19] will review and improve the many issues affecting Maori freehold land titles.

Reconciliation of Maori freehold land titles with records held under the Land Transfer Act 1952 and TTWMA 1993 is long overdue (Grant 2000:18). Historically, Maori land records have not been consistently recorded, although since the passing of TTWMA 1993, all orders made by the Maori Land Court must be registered with LINZ[20] and the Maori Land Court continues to retain all court records, allowing for Maori land records to be searched either with Landonline or in the Maori Land Court (Land Information New Zealand 2008). Land Information New Zealand (LINZ) and the Ministry of Justice have instigated the Maori Freehold Land Registration Project whose aim is to identify and accurately register all Maori freehold land in New Zealand. The project addresses the problem of inadequate and incomplete Maori freehold land records and will allow for efficient electronic searches of all Maori freehold land titles and surveys. All Maori freehold land titles and ongoing records will be incorporated into Landonline and they may also be obtained through electronic searches in the MLC database (*Maori Land Online)* or Te Puni Kokiri's *Maori Land Information Base*.[21]

This project brings huge benefits to all those involved in Maori freehold land. Maori landowners will be able to receive the same rights as general landowners under the Land Transfer Act 1952 (Ministry of Justice 2005:3-6). All Maori freehold parcels in the future will be recorded and placed spatially among other land parcels in Landonline. It will become easier to identify landlocked Maori land and therefore will contribute to unlocking access to these landlocked parcels.

The project aims to provide Maori landowners with a provisional or fully registered computer freehold title. The title may be a Computer Interest Register (CIR), which will be allocated to parcels with no underlying survey work (Ministry of Justice 2005:3-6). Prior to Landonline, the CIR record was recorded in the Provisional Register. These titles are similar to general land 'Limited as to Parcels' where measurements or dimensions do not define boundaries. The CIR title will give increased authority to the boundary position relative to other land parcels (Ministry of Justice 2005:4). In comparison, the Computer Freehold Register (CFR) title is required to have a full field survey of the concerned land parcel.[22] A CFR of Maori freehold land allows the same rights as those CFR of general land. Obtaining finances for development of Maori freehold land has often been difficult because of the complexities of Maori freehold land ownership (Harris 1997: 132-152), and uncertainty or inconsistency of title records. Having a CFR or CIR title to Maori freehold land will improve title security and facilitate financial assistance from banks and lending providers (Hutchings 2006: 22-27). The Maori Freehold Land Registration Project will allow for easier identification and future development of Maori freehold land parcels.

DISCUSSION

A comparison between Maori land laws and the general governing legislation including the Property Law Act 2007 (PLA), show that general land laws are not effective in providing access to landlocked Maori land. The landlocked land provisions within TTWMA provide a more satisfactory avenue for Maori seeking access to their land and this legislation will emerge as an effective key to unlock landlocked Maori land. The defining difference is that in the PLA, notice must be served on affected and adjoining owners, who then must defend their rights. In TTWMA, all adjoining and affected parties must be joined as a party to the application. This immediately sets all parties in a different position with respect to each other and requires all parties at the MLC to seek to settle a mutually acceptable solution to access.

The significant benefit to Maori of the landlocked land provisions now incorporated into TTWMA and under the jurisdiction of the MLC is that the MLC is a court with special jurisdiction to deal with Maori land issues from an underlying philosophical base of the two principles – retention and better utilisation. The court also has the freedom to apply a mediated approach rather than the adversarial approach and to adjourn proceedings in order to get a better outcome for Maori. Furthermore, and not at all insignificantly, is the affordable claim lodgement fee of $61 and that there is no particular encouragement or even advantage to employing lawyers for the hearing.

The MLC will actively seek to draw all affected parties together, for them to actively negotiate their own resolution and draft their own conditions. The result is not so much a resolution imposed by a court on a question of law, but a cooperative negotiated agreement about the most acceptable outcome for all concerned. The court, however, retains the power to impose an order if necessary.

After six years of implementation, the MLC has only processed eight applications under TTWMA section 326B. The MLC has been effective in resolving several access issues, and has done so without always implementing court orders. The process advances and encourages negotiations towards better access and facilitates access to landlocked lands.

The Maori Freehold Registration Project ensures that Maori land titles will be available in a form that is consistent with New Zealand's cadastre. The titles may be researched like all general land titles, and this will facilitate surveyors and lawyers searching Maori land documents. Maori will be in a better position to remedy other title and boundary deficiencies. Access to the titles will greatly benefit all Maori land owners and those seeking to assist them in the better utilisation of and access to their lands. The negotiation process at the MLC, the updated recording system and increased knowledge of MLC staff will enhance the support that can be offered to those affected by landlocked

Maori land and advance the purposes of Te Ture Whenua Maori Act.

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Kawerau A5A- Access to landlocked land. Maori Land Court, Waiariki District, 6 September 2005, Savage J.

Motukahakaha & Mangonui East 86A. Maori Land Court, Taitokerau District, 12 March 2003, Spencer J.

Re Oparau No1 Block. Maori Land Court, Waikato Maniapoto District, 5 November 2004, Milroy J.

Christchurch City Plan

Waitaki District Plan

ENDNOTES

1 S129B inserted by the Property Law Amendment Act 1975. Now ss326-331 Property Law Act 2007. The new Act replicates the old with slightly different structure and wording but with similar effect.

2 ss326A-D inserted by TTWM Amendment Act 2002.

3 See for example, discussion in *Burke v MacLeod* 2006 High Court Dunedin CIV-2004-412-375. unreported.

4 Since repealed by the RMA Amendment 2003.

5 So now, for example the Christchurch City Plan policy 10.4.2 states "To require safe and effective vehicular access where practicable, to properties in subdivisional and /or land use developments." and the Waitaki District Plan states at 14.4.2.3 "Property Access: Every allotment shall have a frontage to an existing road or to a new road and vehicular access to the road."

6 See for example *Roberts v Cleveland* at the High Court: "The legislation is plainly remedial and should be given a fair, large and liberal construction and interpretation." (1990) 1 NZConvC 190,452.

7 Maori customary possession of all New Zealand was confirmed and guaranteed in Article 2 of the Treaty of Waitangi

8 TTWMA section 316 "Court may lay out roadways".

9 That adjoining owners own 'to the middle thread' of the road. All public roads in New Zealand are assumed to be vested in the Crown or the territorial authority.

10 s129B (3)(a) required all adjoining owners to be joined as a defendant to the application.

11 As Maori Land Court Judge Spencer commented on in the case *Motukahakaha & Mangonui East 86A.*

12 See *Motukahakaha & Mangonui East 86A*.

13 See *Re Oparau No 1 Block*.

14 Pers Comms at the Ngai Tahu Maori Law Centre.

15 *Te Kawa A6.* Maori Land Court, Waikato Maniapoto District, 4 July 2005, Milroy J.

16 *Hongoeka 4A-Reasonable access to landlocked land*. Maori Land Court, Aotea District, 6 October 2006, Harvey J.

17 *Kawerau A5A- Access to landlocked land*. Maori Land Court, Waiariki District, 6 September 2005, Savage J.

18 Hui Taumata Action Taskforce. *Maori Land Tenure Review 2006.* Wellington.

19 Ministry of Justice Website, http://www.justice.govt.nz/maorilandcourt/registration-project.htm accessed 18 May 2008.

20 Te Ture Whenua Maori Act 1993, s123(2)

s123 Orders affecting title to Maori freehold land to be registered

(2) For the purpose of registration, the order shall be transmitted by the Registrar of the Court to the District Land Registrar or (as the case may require) the Registrar of Deeds; and the District Land Registrar of Deeds shall, except as otherwise provided in this Act, register the same accordingly.

21 The website address for the mentioned search engines:

Maori Land Online: http://www.Maorilandonline.govt.nz/mlol/searchmlis.jsp

Maori Land Information Base: http://www.tpk.govt.nz/en/services/land/mlib/

22 Surveyor-General's Rules for Cadastral Survey 2002/02.

Result of enquiry

On 15 May 2009 the Council of the New Zealand Institute of Surveyors conducted an enquiry to consider whether the actions of Mr P H Pirie of Palmerston North, a member of the New Zealand Institute of Surveyors, had placed him in breach of the rules of the Institute in terms of rule 21.2 relating to public practice and rule 21.3 relating to good business practice, in servicing his client.

The complaint concerned Mr Pirie's handling of a subdivision undertaken at Fielding during the course of 2007 and alleged that the standard of service provided by him was unsatisfactory, unacceptable, and had involved the following:

(i) Poor communication and in some circumstances, a failure to communicate.
(ii) Failure to discuss the amalgamation proposal and all of its implications.
(iii) Timeframes given to survey the subdivision and get titles were misleading.
(iv) Delays and error with survey of the subdivision.
(v) Delay and errors with subdivision documentation submitted to Manawatu District Council.
(vi) Errors and delay with documentation submitted to LINZ.
(vii) Lack of supervision and oversight of non-registered surveyor(s).

The complaint was initially investigated by the Complaints Sub-Committee of the Institute which found that:

(a) In the matter of poor communication a prima facie case for a breach of Rule 21.3.2 in respect of Good Business Practice had been established.
(b) In the matter of whether the timeframes given to survey the subdivision and get titles issued were misleading, a prima facie case for a breach of Rules 21.2 and 21.3 in respect of Good Business Practice and Public Practice had been established.
(c) In the matter of supervision and oversight of an employee a prima facie case for a breach of rules 21.2 and 21.3 in respect of Good Business Practice and Public Practice had been established.
(d) In the matters of:
  - Failure to discuss the amalgamation and all of its implications
  - Delays and error with survey of the subdivision
  - Delays and errors with subdivision documentation submitted to Manawatu District Council
  - Errors and delays with documentation submitted to LINZ

  that there was no case to answer.

Matters identified for enquiry

In relation to the alleged complaints the actions of Mr Pirie identified for enquiry were:

<u>Rule 21.3.2 Communication</u>

(a) The adequacy of Mr Pirie's communications with the complainant and its solicitors.

<u>Rules 21.2 Public Practice and 21.3 Good Business Practice</u>

(b) The adequacy of the timeframes given by Mr Pirie to complete both the Resource consent application and the subsequent Land Transfer Survey. Were these timeframes misleading as to be possibly in breach of the Rules? Had Mr Pirie failed to meet his professional obligation to his clients?

<u>Rules 21.2 Public Practice and 21.3 Good Business Practice</u>

(c) The adequacy of Mr Pirie's supervision of his professional staff. Had there been adequate supervision of staff members employed by Mr Pirie?

The Council found that:

- In terms of communications, Mr Pirie was in breach of Rule 21.3.2 in that he failed to assume responsibility for client communication once it became apparent that there were difficulties between the company's Fielding office and the client and furthermore that he failed to continue to keep his client adequately informed on a regular basis, as required by the Rules.
- In terms of timeframes, the timeframe given by Mr Pirie in respect of the Resource Consent Application had been largely addressed and was not in breach of the Rules.
- In terms of the Land Transfer Survey, that the accumulated delays in the performance of the survey, despite repeated assurances, caused his client to be misled as to when the services would be completed.
- In terms of staff supervision, that Mr Pirie failed to employ adequate supervision of staff, adequate management to support a second office, and placed an over-reliance of trust and expectation on new staff which was not justified.

The Council resolved:

(i) That in accordance with Rule 24.1.1(c) that the Registered Professional Surveyor status of Mr Pirie be withdrawn forthwith and application for this Distinction may not be made for a minimum period of two years ending 1 July 2011. It is noted that should he wish to re-apply for this Distinction at a future date that he be required to complete the requirements as if this was a first application.
(ii) That in accordance with Rule 24.1.1(d) that a fine of $8,000.00 be imposed on Mr Pirie to be remitted to $3,000.00 on the condition that he complete and undertake a 12-month programme of business improvement. This programme is to be submitted to Council for approval with quarterly reporting detailing progress with the programme and a summary of activities completed. The business improvement programme shall include the identification of a business mentor, mentor to be approved by Council, and include a summary of expected activities to be completed with this mentor.
(iii) That in accordance with Rule 24.2.4 that Mr Pirie be required to pay the costs incurred by Council in investigating and hearing the matter in the sum of $1367.91 incl GST.
(iv) That the decision be published in *The New Zealand Surveyor*.

Result of enquiry

On 3 October 2008, following the receipt of a complaint, the Council of the New Zealand Institute of Surveyors conducted an enquiry to consider whether the actions of Mr D M Thompson, Tauranga, a Member of the New Zealand Institute of Surveyors had placed him in breach of the rules of the Institute in terms of rule 21 relating to good business practice and/or public practice.

The complainant alleged that Mr D M Thompson having been engaged to obtain a separate title containing the dwelling occupied by her on her parent's land, did not perform this task but instead engaged in unnecessary and inappropriate activities involving neighbouring property owners and followed the directions of the Western Bay of Plenty Council, rather than her instructions.

In addition, the complainant alleged that Mr Thompson invoiced her for a total of $21,141.84 some $7,304.34 in excess of the estimated fees, of which she paid $13,302.95, and that some eight months after accepting the commission no application for resource consent had been filed with the Council.

It was alleged by the complainant that in relation to the above matters Mr Thompson had shown misconduct and negligence in violation of the Institute Rules of Ethics, Professional Conduct and Public Practice.

The letter of complaint from the complainant, together with a written explanation from Mr Thompson, were examined by the Complaints Sub-Committee of the Institute. The Complaints Sub-Committee found that:

(a) In the matter of excessive fees, this was always a matter between RPC Ltd and the complainant, and by order of the Disputes Tribunal that matter was disposed of.

(b) In the matter of the non-performance of the agreed services within a reasonable time frame, a significant contributory factor was the failure by Mr Thompson to make or obtain a sufficient, independent assessment of Proposed Plan Change 68 and its consequences for the subdivision required by the complainant and that failure established a prima facie case for unprofessional conduct.

(c) In offering services to others in relation to similar matters that he was advancing for his client without obtaining her prior consent, established a prima facie case for a breach of Rule 21 in respect of Good Business Practice and/or Public Practice.

(d) In the matter of the suggestion of collusion with the Council to the detriment of his client's interests, there was no case to answer.

In relation to these alleged complaints the actions of Mr Thompson identified for enquiry were:

(a) Was Mr Thompson justified in relying initially on the advice of Council officers as to the status of the proposed application for resource consent and that the proposed subdivision conformed to the Council's rules, or should he have carried out his own independent assessment of the District Plan provisions and the implications for the proposed subdivision, including an assessment of District Plan Change 68?

(b) Was the delay and/or non-performance in respect of the contracted task of submitting the application for resource consent justified or extenuated by the circumstances?

(c) Did Mr Thompson have a professional obligation to provide his client with a revised completion timetable for the contracted work once he was advised by the Council that the proposed subdivision did not comply with the District Plan or Proposed District Plan Change 68 and, if he had such an obligation, was his apparent failure to provide the information a breach of the Institute's code of ethics?

(d) In offering services to other property owners in the vicinity of the complainant's land in respect of similar matters that he was advancing for the complainant without, apparently, obtaining her prior consent, did Mr Thompson breach the Institute's code of ethics and/or fail to meet his professional obligation to his client?

As a result of the enquiry Council found that:

(i) Whilst Mr Thompson had acted with good intent on behalf of his client, by offering professional services to neighbouring property owners had placed himself in a conflict of interest situation and was therefore in breach of Rule 21.3.3 (Conflict of Interest).

(ii) That in the process of providing planning services to his client Mr Thompson had failed to meet the standards of professional conduct as set out in Rule 20.2.1 (d) in that he failed to recognise his own professional and technical limitations.

(iii) Mr Thompson was found in breach of Rule 21.3.2 (Communications) with respect to:

(a) Failed to communicate delays with respect to meeting timeframes agreed in the original term of engagement; and

(b) Failed to communicate variations related to tasks and consequential timeframes.

Council resolved:

(i) That the Registered Professional Surveyor status of Mr Thompson be removed with effect from 4 October 2008 and that he not be permitted to reapply for the status for a period of two years and that if applying for the status in future would be required to provide evidence of further training and practice experience in resource management and planning if he wished to practise in those areas.

(ii) That in accordance with Rule 24.2.4 Mr Thompson be fined the sum of $2,000 and be required to pay 50% of the fixed costs incurred by Council in investigating and hearing the matter in the sum of $1,744.50.

(iii) That the decision be published in the *New Zealand Surveyor*.