NEW ZEALAND SURVEYOR

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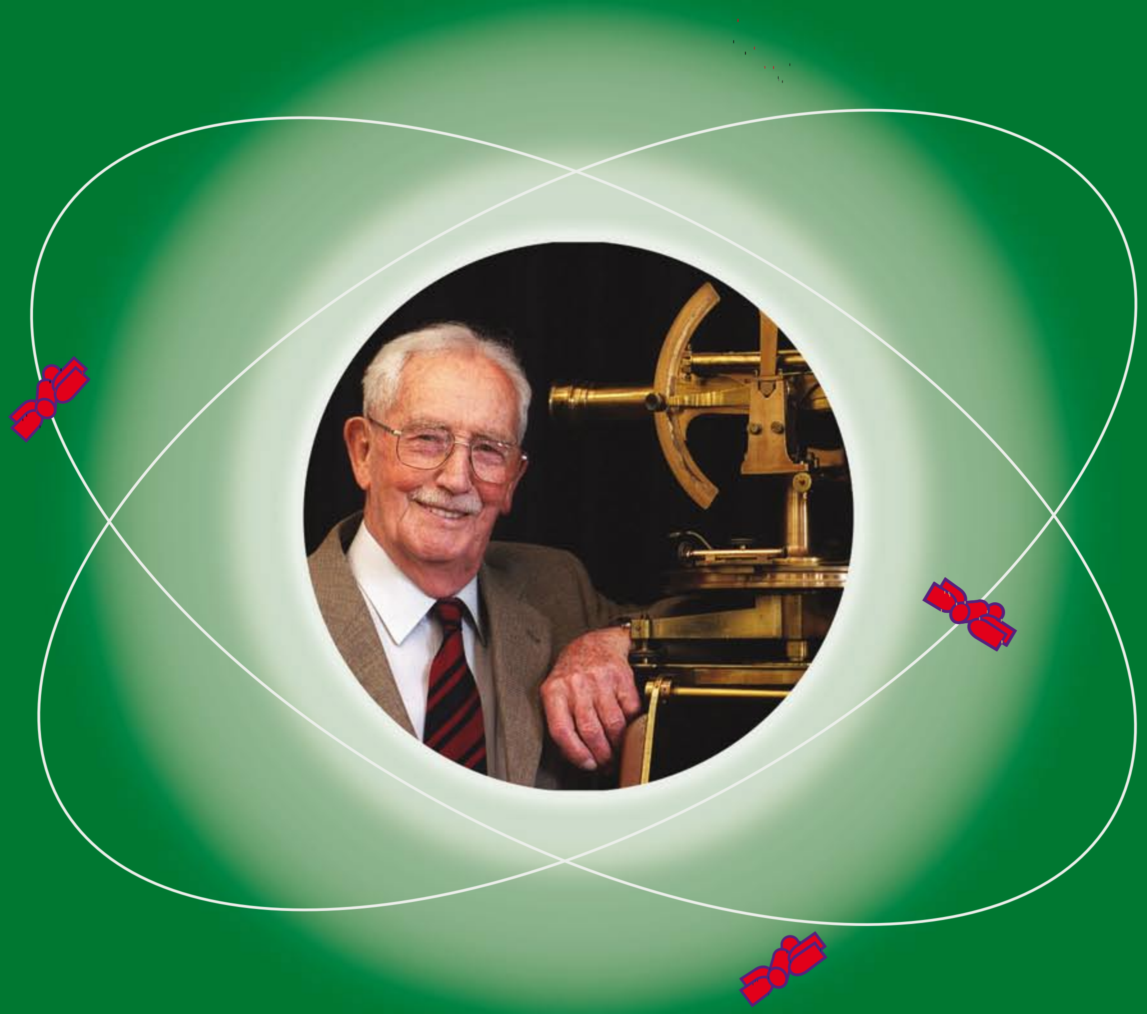

- New Zealand Vertical Datum 2009
- Professional conduct of cadastral surveyors in New Zealand
- Letters to the Editor
- An alternative cadastral survey dataset for New Zealand
- Beyond the Horizon: Making way for offshore resource management in New Zealand

NEW ZEALAND INSTITUTE OF SURVEYORS

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COVER PICTURE

Cover photograph: Emeritus Professor John B Mackie.
Photograph courtesy of the Otago Daily Times.

EDITORIAL

BRUCE MCFADGEN
Editor

Emeritus Professor John Bullamore Mackie – surveyor

This issue of the NZ Surveyor *marks the 100th birthday of John Mackie, Emeritus Professor of Surveying at the University of Otago. The following tribute is abridged from the introductory chapter, written by Allan Blaikie, FNZIS, for the Festschrift presented to John Mackie by his former students and colleagues in September 2010.*

John Mackie's initial interest in surveying, astronomy in particular, arose from his association with Professor James Park at the University of Otago. John was a student studying for a BE Mining from 1929 to 1934, and Park was Dean of the School of Mines. Park was also the author of several textbooks, including *A Handbook on Theodolite Surveying and Levelling*, which was widely used by student surveyors and mining students.

John was appointed a lecturer at the Otago School of Mines in 1947, and from then until 1962, was responsible for the surveying content of the course, which included mine surveying and astronomy. This appears to have kindled a broader interest in surveying, including geodesy and cadastral surveying. At that time, the only way to register as a cadastral surveyor was to become articled to a registered surveyor for four years, and to complete a series of examinations set jointly by the Survey Boards of New Zealand and six Australian states.

Shortly after starting at the School of Mines, John realised his credibility as a 'real' surveyor was being questioned by some local registered surveyors, who were members of the New Zealand Institute of Surveyors (NZIS). He quickly concluded that the only way to remedy this was to complete the requirements, as determined by the Survey Board of New Zealand, and become registered.

To do this while fulfilling his duties as a university lecturer posed a problem. Fortunately, the Survey Board responded to John's enquiry as to how he could become a registered surveyor by offering him exemption from five of the 12 subjects they examined. Further exemption from two of the usual four years of a cadetship was also offered, and as a further concession, he was allowed to work his cadetship in broken periods during university summer vacations. So in 1949, he was indentured to Mr Neville Russell, registered surveyor, of the firm of E R Garden and Associates of Dunedin, a move that laid the foundation for the contribution he was to make to surveying over the following years. He completed the requirements for registration in 1956 at the age of 46. As his autobiography, *Captain Jack* records, he had "become a 'real' surveyor at last", and could add MNZIS to the letters after his name. Without this achievement, the NZIS and the profession would be distinctly poorer.

ELEMENTS OF ASTRONOMY

John recognised early in his career at the School of Mines that the textbook prescribed for Astronomy, *The Elements of Astronomy for Surveyors* by Sir Robert William Chapman (1866-1942) and first published in 1919, had become obsolete. Chapman, Professor of Mathematics and Mechanics at the University of Adelaide, had revised the publication three times but subsequent changes to surveying instruments, optical theodolites in particular, meant somewhat different techniques were now available. John therefore set about revising the text, and in 1953 the fifth edition of the book was published under the joint authorship of Chapman and Mackie. This revision was welcomed by John's mining students, and also by survey cadets in Australasia who were studying for their examinations. It also received international recognition, as have the four further editions between 1953 and 1985. Each is under the sole authorship of J B Mackie, and it has also been published in languages other than English. The final edition was published when he was 84 years old. The textbook was the first of many significant contributions to surveying, one that has endured, and will continue to do so for years to come.

SURVEYING DEPARTMENT AT OTAGO UNIVERSITY

For many years, the NZIS, founded in 1888, had envisaged a university course with an appropriate degree being the pre-requisite for registration as a surveyor. Serious attempts were made at the beginning of the 20th century to establish a suitable course, and several proposals were presented. For a full account see J A McRae's *New Zealand Institute of Surveyors 1888 – 1988* (NZIS 1989).

The matter was raised again in 1957, the year following John's registration. At the NZIS annual conference later that year, he presented a paper entitled 'The Education and Training of the Land Surveyor in New Zealand'. In the subsequent discussion, a motion was carried to recommend to the Council of the NZIS to set up a committee to investigate commencing a University Diploma course in surveying.

The resulting committee included four very senior and highly respected members of the survey profession: Archie Bogle CBE, of Wellington; Russell Dick ISO (Surveyor General), also of Wellington; Charles Grierson OBE, of Auckland; and Henry Paterson Kt St J, of Dunedin. Also appointed were: Professor Gordon Williams, Dean of the Mining School at the University of Otago; and John as convenor and secretary. Co-opted members were Professor N A Mowbray, Dean of Engineering at Auckland University; Professor Harry Hopkins DFC, Dean of Engineering at Canterbury University; and Dr Frederick Soper CBE, Vice-Chancellor of the University of Otago who, at John's suggestion, was offered the chairmanship.

The committee deliberated on the length of the course (two, three or four years), whether it should be a degree or diploma, and where it could be offered. In the end a motion was carried, and later approved by the NZIS, to institute a three-year course in surveying, the first year of which could be taken at any of the four university centres. Initially, the course should be a diploma, devised so that it could later be converted into a degree course.

The next major decision was the location of the new course. The Auckland branch of the NZIS supported Auckland, which had the largest population and the most practising surveyors. Attachment to the engineering faculty at the University of Auckland was seen as an advantage. Canterbury also saw their engineering faculty as an appropriate home for surveying. John, however, felt that surveying could become a 'poor sister' within an engineering faculty, as had occurred in some overseas universities, and was not swayed by the arguments. He considered the existing links with surveying at the Otago School of Mines a better proposition. His view was vindicated 25 years later when the Department of Mineral Technology (the successor to the School of Mines) was moved from Otago to engineering at Auckland, only to fade into oblivion a few years later. In the end, the Academic Board of the University of New Zealand decided on the University of Otago as the appropriate location, even if this did not meet with universal approval.

The go-ahead was given in the early 1960s to establish the course at Otago. It would initially be a diploma (DipSurv), with a degree course to follow in the near future. The Survey Board decided to end the existing system of articled cadets at the end of 1963. All this was due in no small measure to the wisdom and tenacity of John Mackie.

John, now an Associate Professor, was committed to the establishment of the new Department of Surveying, sharing premises with the Department of Mineral Technology. From 1960 to 1963 he continued his normal teaching and research. At the same time he was involved in designing alterations for new teaching facilities, establishing a field camp at Taieri airport, ordering and setting up new equipment, designing lectures and practical work timetables, and recruiting staff. His success in these endeavours was no small achievement.

The first professional year of the course began in 1963. But only two candidates had successfully completed their intermediate examination in 1962. The Otago Vice-Chancellor was horrified. The explanation given was that many employers had recruited additional cadets just before the cadetship system ended, to avoid the uncertainties of the new course. Thus the pool of aspiring surveyors largely flowed into the 'old' system. It was to be two or three years before the expected intake of about 25 candidates materialised.

In 1968 a BSc degree in surveying was offered alongside the diploma. The degree required two mathematics papers in addition to the diploma papers. While this was a useful option and a considerable number of candidates enrolled for the degree, some reverted to the diploma when the reality of the additional papers became apparent. Therefore only a minority of candidates graduated with the BSc degree.

John was now into the last decade of his career as retirement was compulsory at 65 years. Fittingly and deservedly he was given a Personal Chair as Professor of Surveying in 1969. A four-year Bachelor of Surveying (BSurv) degree was approved in 1974, and the intermediate first year began in 1975.

John retired from the university early in 1976. His greatest successes were achieved in the previous twenty years when he realised the dream, shared with many others in the profession, of a university degree for surveyors. Establishing the course at Otago is John Mackie's greatest single contribution to surveying.

THE NEW ZEALAND INSTITUTE OF SURVEYORS, 1947 TO 2010

John's first significant contribution to the affairs of the NZIS was in 1953, when he submitted to the NZIS council a well-prepared paper on the subject of university education for surveyors. It was unsuccessful, possibly because John was not yet registered, and some councillors may have questioned his credibility. The situation, however, was rectified with his subsequent report in 1957.

In 1957, John was elected to a two-year term as chairman of the Otago Branch of the NZIS, followed in 1958 by his election to the NZIS council. He was a councillor from 1958 to1965, and a vice-president from 1965 to 1973. In 1969 he was elected a Fellow of the NZIS.

The most prestigious award the NZIS may make to members is the Fulton Medallion. John received the Class A2 award for his 1957 paper and the Class A1 award in 1973 for outstanding service to the NZIS. This honour is rarely bestowed by the NZIS, and only 21 awards have been made in the 122-year history of the Institute.

John and Sue retired to Nelson in 1976. Although his connection with the council of the NZIS had ceased in 1973, John was elected president from 1977 to 1979. He served as immediate past president from 1979 to 1981, thus completing 19 years of service on the

NZIS council – an outstanding contribution. Also in 'retirement' John served for seven years on the Survey Board of New Zealand. As well as interviewing candidates for registration, the board also scrutinises the various projects candidates are required to submit; astronomy was John's responsibility.

John was a pioneer, both in New Zealand and internationally, for his work in determining the deformation of the earth's crust near fault lines. Early in his career the idea of such a phenomenon was not part of scientific considerations, but as the hypothesis of plate tectonics gained credibility, the need to measure relative movements became apparent. A strong motivation was the possibility of earthquake predictions being an outcome. In the mid-1960s, John established a pattern of ground marks on Molesworth Station in Marlborough, including across the Awatere fault, aimed at determining the extent of any horizontal or vertical movement taking place over time. Staff and students in the first years of the Department of Surveying were involved in this work. He also worked with others on similar projects in the USA and Japan. Instrumentation at the time required painstaking observations, often at night, and calculations in the pre-computer era. It is now much easier with GPS.

In 1995 John received the OBE for services to surveying and the community, and in December 2000, the University of Otago gave its ultimate seal of approval of John Mackie's efforts and achievements by conferring on him an Honorary Doctorate of Science.

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New Zealand Vertical Datum 2009

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ABSTRACT

Until the recent implementation of the New Zealand Vertical Datum 2009 (NZVD2009), heights in New Zealand (NZ) were referenced to one of 13 disparate local vertical datums. The local datums were based on tide-gauge based estimates of mean sea level (MSL) that were transferred by precise levelling along the major roads. The local datums have limited spatial coverage due to the steep NZ topography. The heights of the benchmarks have generally not been verified since they were established 30 to 50 years ago. The regional and fragmented nature of the local datums means that they do not integrate well with ellipsoidal heights from Global Navigation Satellite Systems (GNSS) or the New Zealand Geodetic Datum 2000 (NZGD2000). NZVD2009 has therefore been developed as a national vertical datum for NZ and its continental shelf. It uses the normal-orthometric height system because gravity observations are not available at many benchmarks and a gravimetric quasigeoid as its reference surface rather than a tide-gauge determined MSL. This provides a height system that can be accessed at all locations within NZ and is compatible with both GNSS and NZGD2000.

INTRODUCTION

To enable heights to be consistently referenced among different datasets, they either need to be held in terms of a common datum, or the relationship between the different datums needs to be known. Until recently in New Zealand (NZ), heights were typically referred to one of 13 local vertical datums (LVDs) that were based on local estimates of mean sea level (MSL) determined at different times between 1926 and 1977. The LVDs were known to be offset from each other, but the magnitude of the offset was often uncertain. With the increased use of Global Navigation Satellite System (GNSS) positioning and the need for consistency with the New Zealand Geodetic Datum 2000 (NZGD2000), the use of 13 separate LVDs is undesirable, and the establishment of a new vertical datum for NZ is warranted.

A vertical datum can be defined by the selection of a height system and a reference surface. This paper presents the major types of height system and reference surface that could be used for a new NZ vertical datum. From this theoretical context, the existing LVDs and their limitations are investigated and used as a basis for selecting the new datum, New Zealand Vertical Datum 2009 (NZVD2009).

HEIGHT SYSTEMS AND VERTICAL DATUMS

Contrary to common perception, the concept of 'height' is not straightforward. For example, there are several different height systems that can be defined. Most (but not all) relate to the Earth's gravity field, or an approximation of it (e.g. Featherstone and Kuhn, 2006). Gravity-based systems give heights that can predict or approximate the flow of fluids (i.e. so that fluids flow from a higher point to a lower one). Other height systems can be defined that are independent of the Earth's gravity field, and can give the appearance of fluids flowing 'uphill'. This section compares the major height systems that have been proposed over the years.

Geopotential Numbers

Strictly, all natural or physical height systems must be based on geopotential numbers, C. A geopotential number is the difference in potential from a reference equipotential surface, W_0, (usually the geoid) to the potential at the point of interest, W_P (Heiskanen and Moritz, 1967), such that:

$$C = W_0 - W_P \qquad \textbf{Equation 1}$$

Geopotential numbers are measured in geopotential units (GPU), where 1 GPU = 10 m^2s^{-2}. Because they do not have units of length, geopotential numbers are less intuitive to non-technical users. They accurately predict the flow of water (water will flow from a higher geopotential number to a lower one), and they exhibit the property of holonomity (Sanso and Vaníček, 2006). Holonomic height systems provide a theoretical zero misclosure regardless of the levelling route taken. Conversely, non-holonomic height systems will give a levelling misclose, even if the levelling were errorless, as a result of the approximations made when modelling the gravity field. Furthermore, geopotential numbers cannot be directly observed as there is no instrument that can measure gravity potential. Instead they are practically determined using geopotential differences that are derived from precise levelling and gravity observations (e.g. Torge, 2001).

Dynamic Heights

To overcome the intuitive problem with geopotential numbers not being expressed in units of length, the dynamic height, H^{dyn}, was proposed by Helmert (1884). This is obtained by dividing the geopotential number by a constant gravity value, g_0, often chosen to be the value of normal gravity at 45°N/S. The dynamic height is given by:

$$H^{dyn} = \frac{C}{g_0} \qquad \textbf{Equation 2}$$

Dynamic heights are very simple to compute (if the geopotential number is known), and because they retain the attributes of the geopotential number, they predict the flow of fluids correctly and give a holonomic zero levelling loop closure. The unit of length changes depending on the gravity constant that is used, so it is generally not the same as an international standard (SI) metre. The dynamic height does not have a geometrical meaning because it is purely a physical quantity (Jekeli, 2000). These heights are typically obtained by applying a dynamic correction to precisely levelled height differences. These corrections can be very large if g_0 is not representative of the region concerned.

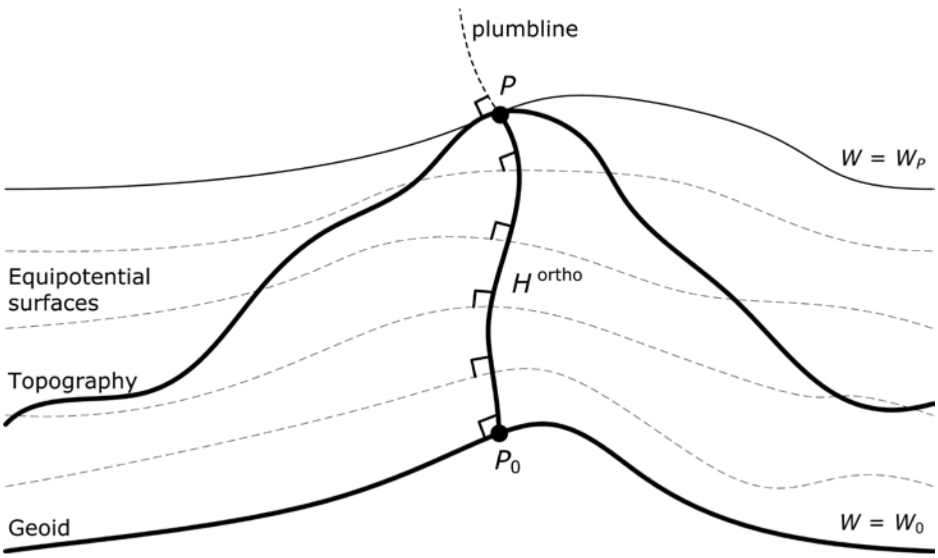

Figure 1. The orthometric height (adapted from Featherstone and Kuhn, 2006).

Orthometric heights

The most common type of height that is claimed to be used is orthometric height, H^{ortho}. The orthometric height is defined as the length of the curved plumbline from a point P, to its intersection with the geoid at P_0, as shown in Figure 1 and is given by:

$$H^{ortho} = \frac{C}{\bar{g}} \qquad \textbf{Equation 3}$$

where $\bar{g}$ is the integral mean value of gravity along the plumbline (Figure 1). It should, however, be noted that the term "orthometric" is often applied to a range of height definitions, but although these are related to the Earth's gravity field, they do not have the strict definition given here. As such, many height systems that purport to be orthometric do not actually provide true orthometric heights.

To correctly determine $\bar{g}$, the exact path of the plumbline through the Earth and the gravitational acceleration at all points along that plumbline need to be known. This requires knowledge of gravity variations (cf Strange, 1982) or the mass-density distribution (cf. Allister and Featherstone, 2001) through the topography. Because this information is not available, it is not possible to observe or compute a true orthometric height.

Approximate orthometric heights

To overcome the problem of not being able to determine $\bar{g}$ exactly, a number of approaches have been developed to approximate it. Each approximation results in a different kind of orthometric height which is normally named after its proponent.

The approximation of Helmert (1890) is based on the Poincaré-Prey relationship for integral mean gravity (Heiskanen and Moritz, 1967) and the Bouguer shell gravity expression that accounts for the topographic mass above the geoid but neglects the terrain effects. The Bouguer shell accounts for the effect of the terrain by approximating it as a shell at a constant height. The terrain effects are a result of the difference between the actual topography and the shell, and are modelled by a terrain correction.

Helmert-orthometric heights are computed either from a geopotential number or by the application of an orthometric correction to precise levelling observations. Both methods require surface gravity observations at the points of interest. These heights can be quite different from their *true* orthometric counterparts due to the large corrections to precise levelling observations that are necessary (Featherstone and Kuhn, 2006). Nevertheless Helmert-orthometric heights are probably the most common type of 'orthometric' height in actual use; for example in Belgium, Denmark, Finland, Italy and Switzerland (EUREF, 2006).

Other approximations such as Neithammer (1932) and Mader (1954) include corrections for the terrain effect and as such give a closer approximation of the true orthometric height than Helmert heights. However their computational complexity has seen them used less frequently in practice. More recent approaches (e.g. Tenzer et al, 2005) give a close agreement to true orthometric heights, but as a result of their recent development have not yet been implemented in practice.

Normal Heights

The normal gravity field is the gravity field defined by an Earth-fitting ellipsoid that contains the total mass of the Earth (including its atmosphere), and rotates at a constant angular velocity more or less equivalent to that of the Earth (Moritz, 1980). The normal gravity field can be used to define a height that avoids assumptions about the shape and density of the topographic masses needed to compute $\bar{g}$.

The normal height, H^{N}, was proposed in 1954 by Molodensky (cited in Molodensky et al 1962). It replaces $\bar{g}$ in Equation 3 (which was measured along the plumbline) with normal gravity, $\bar{\gamma}$, measured along the curved ellipsoidal normal (of the reference ellipsoid) hence (Jekeli, 2000):

$$H^{N} = \frac{C}{\bar{\gamma}} \qquad \textbf{\textit{Equation 4}}$$

The change from a physical to a geometrical gravity field also means that H^{N} is measured between the ellipsoid, Q_0^{N}, and a surface called the telluroid, Q (Figure 2), not between the geoid, P_0 , and the topographic surface, P , used for orthometric heights (Figure 1). The telluroid is a surface whose normal potential at every point Q is equal to the actual potential to every corresponding point P . The distance from the telluroid to the topographic surface is the height anomaly, ζ .

Because normal heights have no physical meaning (being defined by a gravity model), they are not as applicable to the real Earth as the orthometric (and Helmert-orthometric) height (Featherstone and Kuhn, 2006). Additionally, while they cannot predict fluid flows universally, they nevertheless give a reasonable approximation in many situations. Like the other heights described above, normal heights can be computed by applying a correction to spirit levelled height differences if there are suitably dense gravity measurements along the levelling route.

It is common to illustrate the H^{N} relation in Figure 2 in reverse so that the height anomaly, ζ , also becomes the distance between the quasigeoid and the topographic surface (shown in Figure 2 as $H^{N\text{-}O}$). Note that the height anomaly, ζ , and quasigeoid height, ζ , are the same, but different terminology is used to reflect the different conceptualisations (Featherstone and Kuhn, 2006). This means that H^{N} and normal-orthometric heights, $H^{N\text{-}O}$, (see section below) are geometrically the same. As such both can be compatible with GNSS ellipsoidal heights when they are derived from the quasigeoid.

Normal-orthometric heights

Many countries, NZ included, do not have gravity observations along all the precise levelling routes, so the computation of the geopotential numbers necessary for (approximate) orthometric or normal heights is not strictly possible. To overcome this limitation, the normal-orthometric height, $H^{N\text{-}O}$, was developed (e.g. Rapp, 1961; Heck, 2003). In this system the geopotential number, C , is replaced with the spheropotential number, C' , which is wholly derived from the normal gravity

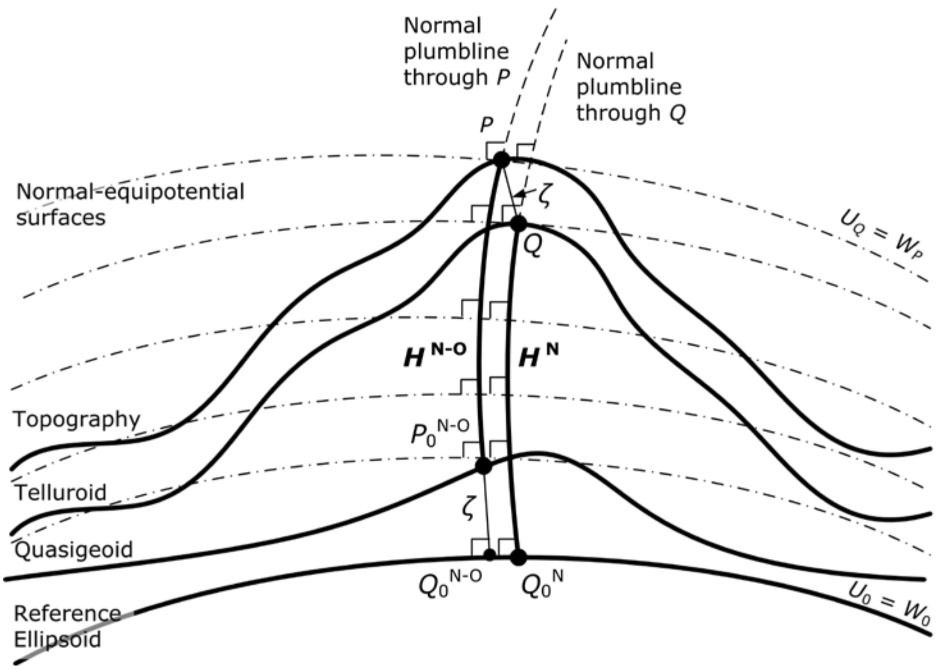

Figure 2. The normal and normal-orthometric heights (from Featherstone and Kuhn, 2006).

field. The normal-orthometric height is defined as the distance from the quasigeoid to the surface of the Earth along the curved ellipsoidal normal (Figure 2) and is given by:

$$H^{N\text{-}O} = \frac{C'}{\bar{\gamma}}$$ ***Equation 5***

The consequence of not using surface gravity observations is that while normal-orthometric heights are easy to compute, they are even less likely to predict fluid flows correctly than normal heights. In practice, normal-orthometric heights are obtained by applying a normal-orthometric correction (NOC) to precisely levelled height differences (e.g. Heck 2003).

The quasigeoid is a surface that results from the approximations and assumptions about the structure and composition of the Earth that are made under Molodensky's theory. The quasigeoid is identical to the geoid over the oceans and is typically within a few decimetres of it over most land areas, but the difference can reach nearly 3 m in extreme cases (Flury and Rummel, 2009). The maximum difference in NZ is approximately 0.5 m at Aoraki/Mt Cook (Amos and Featherstone, 2003). At heights less than 250 m, where most NZ settlements are located, the difference is less than 3 cm.

Ellipsoidal heights

The ellipsoidal height, h, is the distance from the reference ellipsoid to the Earth's surface along the ellipsoidal surface normal as shown in Figure 3. Unlike the heights discussed in the sections above, it is defined independently of the Earth's gravity field, i.e. it is a purely geometric quantity. Consequently, ellipsoidal heights are generally poor at predicting fluid flows. They are however relatively easy to define mathematically and as such are the type of height obtained from GNSS receivers.

Relationships between Height Systems

The different types of height described above can be related using the reference surfaces that are consistent between them. These relationships are summarised in Figure 4. Algebraically, ellipsoidal heights are related to orthometric heights by the geoid height, N:

$$H^{ortho} = h - N$$ ***Equation 6***

and, normal-orthometric heights by the quasigeoid height, ζ:

$$H^{N\text{-}O} = h - \zeta$$ ***Equation 7***

Vertical datum definition

To realise a vertical datum, it is necessary to select a type of height system and a compatible reference surface. Once these choices have been made, and the observed height differences corrected for systematic errors affecting their observation (e.g. Vaníček et al., 1980), a vertical datum can be realised point-wise by performing a least-squares adjustment of the corrected height differences to minimise the impact of random errors, and to account for the impact of random and systematic errors in the levelling loops (e.g. Sansò and Vaníček, 2006).

The type of height system chosen normally depends on the data that was available to the agency responsible at the time of datum definition (or the system can be chosen and the necessary data then acquired). For example, if gravity observations are unavailable, then only the normal-orthometric or ellipsoidal height systems can be used. The choice of reference surface is guided by the choice of height system, i.e. orthometric heights use the geoid; normal-orthometric heights the quasigeoid and ellipsoidal heights the ellipsoid. In gravimetric systems the reference surface is normally defined so that it approximates MSL and therefore provides heights that are broadly consistent with it.

If a vertical datum is defined by fixing MSL at a single tide-gauge point it can result in the 'zero height' departing from MSL at other locations in the datum – because MSL is not a truly level surface. An alternative practice that has been adopted in a number of countries (e.g., Australian Height Datum, AHD, [Roelse et al., 1975]; Canada CGVD28 [Kingdon et al., 2005]) is to constrain multiple tide-gauge MSL values

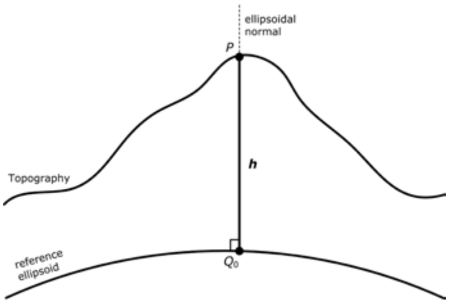

Figure 3. The ellipsoidal height.

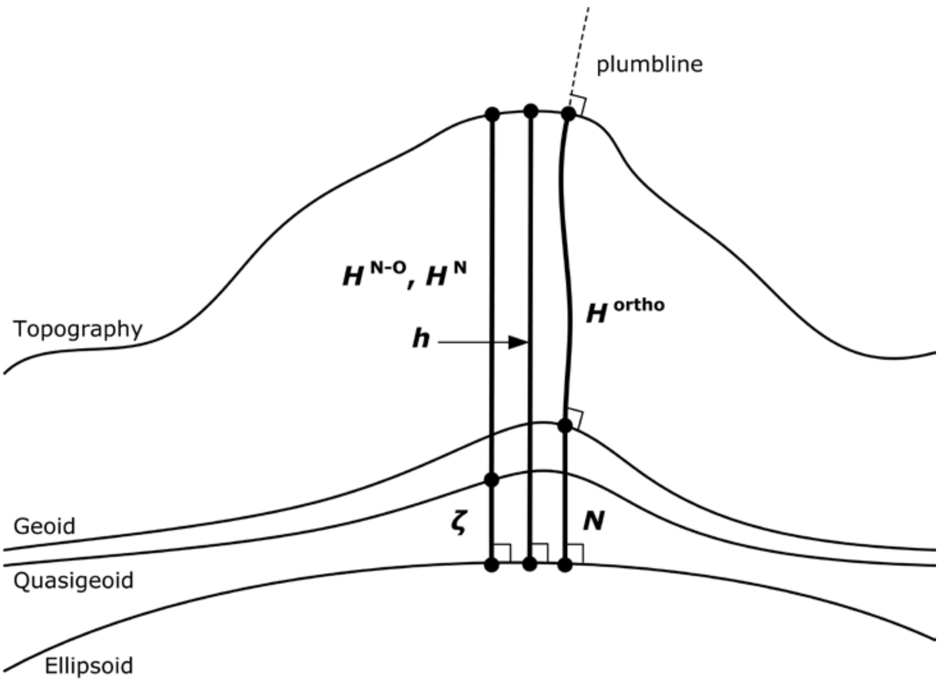

Figure 4. Summary of the relationship between orthometric, normal, normal-orthometric and ellipsoidal heights.

to zero in the precise levelling adjustments. This approach gives a vertical datum with a "zero level" that is close to the observed MSL at all locations, but it does not represent an equipotential or "level" surface. For example, the Australian AHD adjustment fixes 30 tide-gauges to "absorb" the effect of a 70 cm sea level "slope" around the Australian coast (Featherstone and Kuhn, 2006). If a vertical datum is not defined in relation to an equipotential surface, it is more difficult to determine its relationship to other vertical datums.

NEW ZEALAND'S HEIGHT SYSTEMS

Local vertical datums

Until recently a nationally consistent gravimetric vertical datum was not available for heighting in NZ. Instead, heights were typically referenced to one of 13 major local vertical datums (LVDs; Table 1). Each of the NZ LVDs is based on a determination of MSL at different tide-gauges over a range of time intervals (normally at least three years) and epochs (primarily 1920 – 1970).

LVD heights are in terms of the normal-orthometric height system. These have been incorrectly referred to as orthometric heights in the LINZ geodetic database, and in many publications (e.g. Gilliland, 1987; DoSLI, 1989; Reilly, 1990).

Many smaller or special-purpose datums have also been defined over the years. A significant number of these (e.g. Tekapo, Karapiro and Maraetai) were defined with respect to other existing datums for specific hydro-electric power projects. Others (e.g. Deep Cove, Tikinui, and Chatham Island) were defined from short periods (e.g. several months) of tidal data and are only used for local purposes.

Tide gauges

Historically, the tide gauges used in NZ have been established in harbours and rivers by local port authorities for use in the prediction and verification of tide tables. Data from these gauges was analysed by Land Information NZ (LINZ) and its predecessor agencies (Department of Survey and Land Information – DoSLI; Department of Lands and Survey – L&S) to determine MSL at each site. This MSL value was then used as the zero height for the LVD to which a local levelling network was referenced.

The NZ tide gauges are generally in locations that are less-than-optimal for vertical datum definition purposes (Figures 5 and 6). They are frequently situated in harbours or rivers (within a few kilometres of the coast), whereas the ideal locations are either offshore or on the open coast to minimise the non-linear tidal effects that occur near the coast (e.g., Pugh, 2004). This means that the observed MSL will not necessarily be representative of the region that the datum is expected to cover (e.g., Hipkin, 2000; Cross et al., 1987; Merry and Vaníček, 1983).

The Dunedin-Bluff 1960 datum is a notable anomaly in Table 1. Unlike the other LVDs, it was defined by fixing the height of a benchmark in Balclutha in terms of the Dunedin 1958 datum, and a

Table 1. Major levelling datum origins and periods of MSL observation used to define them.

Local vertical datum	Observation period	Duration
One Tree Point 1964	1960 – 1963	3 years
Auckland 1946	1909 - 1923	14 years
Moturiki 1953	1949 - 1952	3 years
Gisborne 1926	1926	1 year
Napier 1962	*Unknown*	*Unknown*
Taranaki 1970	1918 - 1921	3 years
Wellington 1953	1909 - 1946	37 years
Nelson 1955	1939 - 1942	3 years
Lyttelton 1937	1918 - 1933	15 years
Dunedin 1958	1918 - 1937	19 years
Dunedin-Bluff 1960	*None*	-
Bluff 1955	1918 - 1934	16 years
Stewart Island 1977	1976 - 1977	3-5 tides

Figure 5. NZ North Island precise levelling networks, tide gauges and LVD junction points

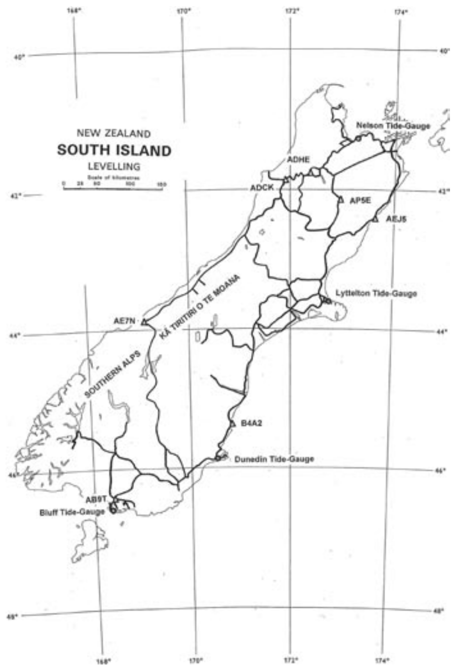

Figure 6. NZ South Island precise levelling networks, tide gauges and LVD junction points.

benchmark in Invercargill in terms of the Bluff 1955 datum. The Stewart Island 1977 datum is not defined by a 'long-term' tide gauge derived estimate of MSL. Rather, it has a 'zero' based on a value of MSL determined from three temporary tide gauges established around Stewart Island/ Rakiura using observations over three to five successive (but not simultaneous) tides. The Stewart Island approach, furthermore, was based on trigonometric heights that could be in error by 0.2-0.3 metres. Consequently, the resulting MSL could be in error by 0.5 metres from the long-term trend.

Precise levelling networks

First-order precise levelling in NZ (accuracy standard of $\pm 2\,\mathrm{mm}\sqrt{k}$, where k is the levelled distance in km) has historically been the method for precise height transfer in NZ. Reciprocal trigonometric (±0.1-0.2 m) and barometric levelling (±15 m) has also been used to increase the density of the precise levelling networks. However, due to their lower accuracy, trigonometric and barometric levelling are not generally considered part of the NZ precise height network.

There currently exists more than 16,000 km of two-way first-order precise levelling that has been observed since the 1960s to give the coverage shown in Figures 5 and 6 (e.g., Gilliland, 1987). These networks were observed in a piece-meal fashion and the large loop around the South Island (Figure 6) was only completed in the late 1980s. Each local vertical datum (LVD) has been defined using a least-squares adjustment to give heights for its constituent marks.

It can be seen from Figures 5 and 6 that the levelling coverage is not uniform over NZ. Some areas, such as the central North Island (Figure 5) in the vicinity of the Moturiki tide gauge, have a very strong network configuration, but other areas, notably the south-west of the South Island (Figure 6), are particularly sparse.

The irregular coverage has a great deal to do with the topography over which the levelling runs traverse and the lack of roads in the sparser areas along which precise levelling lines are placed for stability and access reasons. The South Island levelling lines that transect the Southern Alps/Kā Tiritiri o te Moana (Figure 6) are limited to the three mountain passes over them. It is not practicable (or in some cases possible) to obtain a denser precise levelling network in these remote areas due to the steep and rugged topography.

New Zealand geodetic datum 2000

The current official geodetic datum for NZ is NZGD2000. It is a three-dimensional geocentric datum that uses the GRS80 ellipsoid (Moritz, 1980) and is aligned to the ITRF96 (Boucher et al., 1998) global reference frame. To incorporate the effects of tectonic deformation, NZGD2000 uses a horizontal deformation and velocity model to 'correct' observations for the effects of deformation from the time of acquisition to the datum's reference epoch (1 January 2000). No vertical deformation model is used in NZGD2000. NZGD2000 uses ellipsoidal heights in terms of the GRS80 ellipsoid (LINZ, 2007). The use of ellipsoidal heights is becoming increasingly popular amongst users of the survey control system, even though they do not refer to the Earth's gravity field.

PROBLEMS WITH THE CURRENT DATUMS

Sea level variability

Sea level observed at tide gauges can vary on annual, inter-annual and inter-decadal cycles, hence the particular epoch of data used will affect the determined level of MSL (Bell et al., 2000). Ideally sea level observations would be analysed from a full 18.6 year metonic cycle, however for the NZ LVDs this has seldom been achieved (Table 1).

Analysis of sea level observations by LINZ (Rowe, 2006, pers. comm.) has shown that variations in the observed MSL can differ from the long-term average by 10 cm over a three-year period. Figure 7 shows the monthly sea level trends for the Wellington tide gauge (Rowe, 2006, pers. comm.). Given that a number of vertical datums have been defined by only three years of sea level observations (cf. Table 1), it is very likely that they refer to a MSL that is not representative of the long-term average. For example if MSL was defined from data indicated by either of the horizontal lines in Figure 7 rather than the full set, the resulting MSL could be offset from the long-term average by over 50 mm. Based on the very limited data available (e.g., Figure 7), an offset of 5-10 cm could readily be attributed to the choice of epoch for the shorter duration definitions (e.g., One Tree Point 1946, Moturiki 1953, Gisborne 1926, Napier 1962, Taranaki 1970, Nelson 1955, Stewart Island 1977; cf. Table 1).

Local vertical datum offsets

Due to the factors described above, the 13 LVDs are offset from each other. Where two or more vertical datums abut or overlap, it is possible to estimate the offset that exists between the datums at that point. This offset will be affected by systematic observation and reduction errors along the route of the precise levelling and any deformation that has occurred since the levelling was carried out. The consequence of this is that when vertical datums join at multiple places, the observed offsets will also differ.

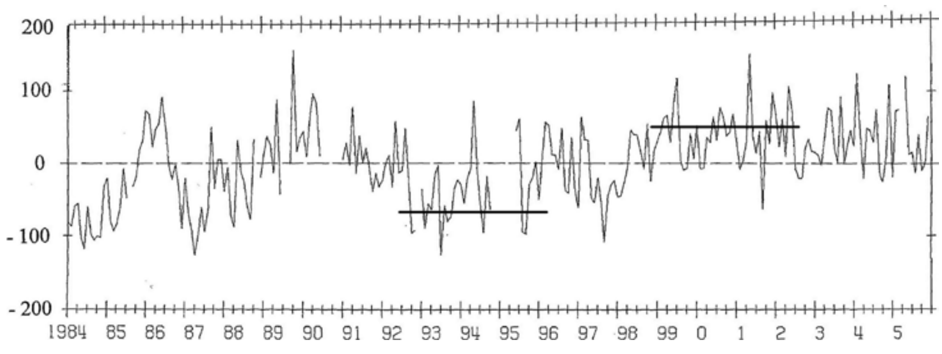

Figure 7. Monthly sea level observations for Wellington tide-gauge from LINZ records, 1984 – 2006 (mm).

Observed (post-adjustment) NZ LVD offsets have been obtained from the LINZ geodetic database by comparing the heights of marks that are located at the junction points of the adjacent datums. The offsets are shown in Table 2; the junction points are shown on Figures 5 and 6. The Taranaki-Moturiki offset observed at AHBB (-0.455 m) is abnormally large compared to the other offsets. This is probably due to mark movement between the observations of the respective levelling lines, however it was not possible to confirm or disprove this hypothesis from analysis of the precise levelling records.

Vertical deformation

The Earth's surface in the NZ region experiences relative movements that deform its shape (e.g., earthquakes). The horizontal movements are reasonably well known (e.g. Beavan and Haines, 1997; Beavan, 1998; Walcott, 1984), but the vertical movements are not. Regional studies show that areas within the Taupo Volcanic Zone are subsiding by up to 10 mm/yr (Otway et al., 2002). Local subsidence of up to 8.5 m has been reported from the Wairakei area (38° 37' S, 176° 06' E) due to geothermal energy draw-off for electricity generation (Bevin et al., 1984).

Uplift rates of the Southern Alps/Ka Tiritiri o te Moana (cf. Figure 5) are in the order of 10 mm/year due to the interaction of the Pacific and Australian tectonic plates along the Alpine Fault (e.g., Beavan et al., 2004; Walcott, 1984; Wellman, 1979). These subsidence and uplift rates have a slow but continuous effect on the heights of stations.

Earthquakes and associated co-seismic, post-seismic and inter-seismic deformation often have the largest short-term effect on heights. Important NZ examples include: subsidence of up to 2 m from the Edgecumbe earthquake of 1987 (Beanland et al., 1990); uplift of 2.7 m from the Inangahua earthquake of 1968 (Lensen and Otway, 1971); uplift of 2.4 m and subsidence of 0.9 m from the Napier earthquake of 1931 (Henderson, 1933); and uplift of 1.3 – 2.1 m in Wellington Harbour and up to 6.4 m near Turakirae Head from the 1855 Wairarapa earthquake (Begg and McSaveney, 2005).

Although the evidence for uplift is not conclusive everywhere, and some areas will have undergone subsidence, it is still useful to evaluate its potential effect. Given that most of the NZ LVDs were defined about 50 years ago, and assuming an average linear uplift rate of 0.2 mm/year, this could mean that the heights of some benchmarks and datum origins may have risen by up to 10 cm between then and 2010.

Table 2. Offsets determined from height differences at junction points of LVDs (metres).

Mark	Vertical datum 1	Vertical datum 2	Offset
ABHL	One Tree Point 1964	Auckland 1946	+0.206
AGD8	Auckland 1946	Moturiki 1953	-0.069
ABTE	Auckland 1946	Moturiki 1953	-0.075
ABV5	Auckland 1946	Moturiki 1953	-0.067
ABX2	Gisborne 1926	Moturiki 1953	-0.075
AD2J	Napier 1962	Gisborne 1926	+0.166
AEVR	Napier 1962	Moturiki 1953	+0.099
AE54	Napier 1962	Taranaki 1970	+0.046
AE54	Taranaki 1970	Wellington 1953	+0.191
AE54	Napier 1962	Wellington 1953	+0.237
AHBB	Taranaki 1970	Moturiki 1953	-0.455
B48K	Taranaki 1970	Moturiki 1953	-0.014
AEXF	Taranaki 1970	Moturiki 1953	-0.019
AEXF	Taranaki 1970	Wellington 1953	+0.102
AEXF	Moturiki 1953	Wellington 1953	+0.121
AEJ5	Nelson 1955	Lyttelton 1937	+0.014
AP5E	Nelson 1955	Lyttelton 1937	+0.039
ADHE	Nelson 1955	Lyttelton 1937	-0.086
ADCK	Nelson 1955	Lyttelton 1937	-0.076
B4A2	Lyttelton 1937	Dunedin 1958	-0.054
AE7N	Lyttelton 1937	Dunedin 1958	-0.087
ADP2	Dunedin-Bluff 1960	Dunedin 1958	-0.019
AB9T	Dunedin-Bluff 1960	Bluff	-0.001

Inconsistent with GNSS/NZGD2000

Over the past 10 years, LINZ has physically surveyed many control marks to determine their coordinates and ellipsoidal heights in terms of the NZGD2000 geodetic datum. Because no official relationship between NZGD2000 and the LVDs has been defined, it has been difficult for users to consistently integrate GNSS observations with LVD-based heights.

Common approaches to integrate heights have been to use a global gravity model (GGM) such as EGM96 (Lemoine et al. 1998) or EGM2008 (Pavlis et al. 2008) as a transformation surface, or to observe a GNSS height on a LVD benchmark. The GGM approach is based on two assumptions: that the LVD origins are coincident with the GGM/geoid; and that the GGM accurately models the Earth's gravity field in the area of interest. GGMs model the geoid globally with a relatively coarse spatial resolution. EGM96 has a resolution of approximately 39 km in NZ (Amos 2007), and EGM2008 13 km, therefore the actual geoid (or MSL) variations in the geoid at smaller scales to this will not be detectable from the models. The accuracy (1σ) of EGM96 over NZ has been estimated from GPS-levelling as 0.6 metres (Amos 2007) and 0.1 metres for EGM2008. When assessing the suitability of using a GGM to transform heights, the accuracy of the GGM in relation to the local gravity field (as well as the accuracy of the input heights) needs to be considered. This method will not give heights in terms of a LVD. The resultant heights will be in relation to the average level of the sea as defined by the GGM.

To convert a GNSS (ellipsoidal) height to a LVD normal-orthometric height, the common approach has been to physically survey a benchmark with a LVD height using GNSS, and therefore geometrically determine the difference between NZGD2000 and the LVD. This offset can then be used to transform heights in the vicinity of the benchmark. Because this approach utilises a single offset to model the geoid surface, the accuracy of the transformation degrades with increasing distance from the benchmark. If a number of marks are surveyed over a small area (generally up to 5 km x 5 km), then an inclined plane can be used to model the offset and thereby extend the coverage of the transformation. The primary limitation of this approach is that it is attempting to model an irregular surface with a point or plane. Larger regions can be better modelled if additional regression coefficients are used to define a non-planar surface.

No single reference system for large applications

The existing LVDs work suitably for tasks that are wholly contained within a single LVD where there is ready access to the benchmarks. Where LVDs abut or overlap, benchmarks may have heights in relation to more than one datum. This can introduce user confusion where the difference between two or more heights is not understood or user error where the difference between datums is not noted. The LVDs are not suitable for applications that span more than one datum and which require all heights to be consistently recorded.

This confusion is exacerbated when each of the datums purports to depict mean sea level. Where the offset between datums is small (or the user does not recognise that the heights are in terms of different datums) it is likely that the datum relating to a particular height could be mistaken. Having height data in a number of datums also makes the integration of different datasets difficult, especially over large areas. To avoid these problems a national datum needs to be defined so that all heights can be referred to it.

Unsuitability of levelling-based datum

Internationally, the most common method of establishing a vertical datum has been to determine MSL at a tide gauge and then transfer the level to benchmarks in the hinterland by precise levelling. Precise levelling is a labour intensive and expensive method of transferring heights that only provides heighted benchmarks along the levelling routes. Since NZ does not have an extensive road network over many parts of the country (cf. Figures 5 and 6) it is not possible to efficiently implement a national vertical datum based on precise levelling alone.

One approach to modernise the LVDs would be to determine updated estimates of MSL at the original tide-gauges and re-adjust the existing precise levelling observations in terms of the 13 LVDs. Alternatively, the precise levelling observations could be readjusted to form single networks in the North, South and Stewart Islands. In both cases the levelling observations that would be readjusted are typically 30 to 50 years old. Without physically re-observing large parts of the height network (an untenable task due to its high cost) the 'new' heights would typically move at the decimetre level and thereby cause more confusion by doubling the number of datums in an area. The resultant heights would not be any more accurate or reliable than the existing LVD heights so it is expected that their uptake by users would be low.

NEW ZEALAND VERTICAL DATUM 2009

The New Zealand Vertical Datum 2009 (NZVD2009) was officially released in September 2009 and is formally defined in the standard: LINZS25004 (LINZ, 2009). It is the first time that a single vertical datum has been implemented across NZ and its continental shelf. The notable feature of NZVD2009 is that it uses a gravimetric geoid as its reference surface rather than the conventional tide-gauge estimate of MSL.

NZVD2009 is a world first implementation of a geoid-based national vertical datum. The concept of using a geoid as the reference surface in NZ's vertical datum was initially proposed in 2001 (Grant and Blick, 2001). Since 2001, the approach has gained in popularity and it is being proposed as the basis for a number of modernised vertical datums (e.g. United States [Childers et al, 2009], Canada [Véronneau et al, 2006]).

The key parameters for NZVD2009 are:

Table 3. NZVD2009 parameters.

Attribute	Value
Height system	Normal-orthometric
Reference surface	New Zealand Quasigeoid 2009
Normal gravity field	GRS80
Reference ellipsoid	GRS80

The New Zealand Quasigeoid 2005 (NZGeoid05; Amos 2007) was published by LINZ in 2005 together with a set of offsets that could be used to transform NZGD2000 ellipsoidal heights to the 13 LVDs. NZGeoid05 was intended for use as a transformation surface not as a datum in its own right, and heights should not be referred to as being in terms of 'NZGeoid05'.

Height system

NZVD2009 retains the normal-orthometric height system based on the GRS80 normal gravity field (LINZ, 2009). This choice was made because of the lack of gravity observations on NZ's precise levelling marks. The use of the GRS80 normal gravity field makes NZVD2009 consistent with NZGD2000 which also uses the GRS80 reference system (LINZ, 2007). This differs from the LVD normal-orthometric height system which referred to the GRS67 normal gravity field.

Where NZVD2009 heights are determined by precise levelling from an existing benchmark, the normal orthometric correction (NOC) as defined in Equation 8 should strictly be applied to the height differences.

$$\mathrm{NOC} = -\frac{f^*}{R} H_{avg} \sin 2\phi \cos\alpha \,\delta s$$

Equation 8

Where: f^* GRS80 normal gravity flattening constant (0.005 302 440 112)

R GRS80 mean Earth radius (6,371,000 m)

H_{avg} average normal-orthometric height of benchmarks (m)

ϕ mid-latitude latitude of benchmarks

α azimuth between benchmarks

δs horizontal distance between benchmarks (m)

The magnitude of the NOC is 0.83 mm when evaluated over 1 km at 1000 m altitude (45° S, 1 km north-south levelling line with 20 change points 50 m apart). At a more typical average height of 200 m the NOC is 0.17 mm. This means that application of the NOC should take into account the length of the levelling line and the accuracy of the resulting NZVD2009 heights.

New Zealand quasigeoid 2009

NZGeoid2009 (Figure 8) is a regional gravimetric quasigeoid computed over the extent of NZ's continental shelf (160°E – 170°W, 60°S – 25°S). Although NZGeoid2009 is technically a quasigeoid, the more common term 'geoid' and symbology (*N*) is used to avoid confusion when describing it in relation to NZVD2009.

The NZGeoid2009 was computed by the Western Australian Centre for Geodesy (Claessens et al, 2010) following the same general procedure that was used for its predecessor NZGeoid05 (Amos, 2007; Amos and Featherstone, 2009). It is based on the EGM2008 global gravity model up to degree and order 2160 and has been enhanced with 40,737 terrestrial gravity observations across NZ, marine anomalies from the DNSC08 global model (Andersen et al, 2008), and a 1.8" grid (~56 m) digital elevation model to correct for the effect of the topography on the gravity field.

The model was computed using a remove-compute-restore approach using Stokes integration with a deterministically modified integration kernel (Featherstone et al, 1998) with L = 40 and ψ_0 = 2.5° (L is the spherical harmonic degrees removed from the kernel and ψ_0 the integration cap radius). A detailed description of the computation process for NZGeoid2009 is provided in Claessens et al (2010).

Across the NZ mainland the "height" of NZGeoid2009 above the GRS80 ellipsoid varies from 0 m at the south of Rakiura/Stewart Island to approximately 40 m at the north of the North Island. This change is generally in a north-south direction, with some local variations around topographic and geological features. It is published (and was computed) on a 1' x 1' grid (~1.9 km in NZ) which means that localised variations in the geoid that are smaller than this will not be represented in the model.

Datum offsets

The accuracy of NZGeoid2009 in relation to the LVDs was estimated by comparisons with geometrically determined geoid values at control marks where both ellipsoidal and normal-orthometric heights had previously been observed. In NZ there are 1,422 suitable GPS-levelling points that are unequally spread among the 13 LVDs (Figure 9, Table 4). The spatial coverage of the GPS-levelling points is not uniform, and large gaps exist in some areas, notably the south-west of the South Island, north-west Nelson and East Cape. Furthermore, many of the points are located in topographically flat terrain rather than the mountains where the geoid surface is expected to be more variable.

The results of the GPS-levelling comparisons on a datum-by-datum basis are shown in Table 4 (LINZ 2009). All of the offsets are significantly non-zero, and in most cases they agree (within statistical limits) with the offsets observed at the LVD junction points

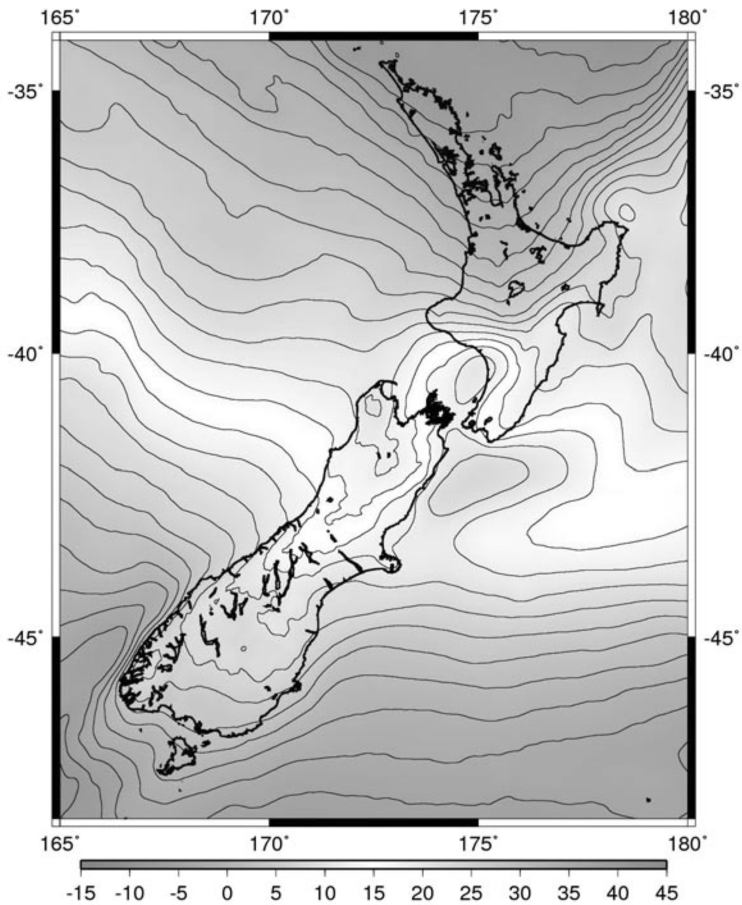

Figure 8. New Zealand Quasigeoid 2009 (NZGeoid2009) relative to the GRS80 ellipsoid (two metre contours).

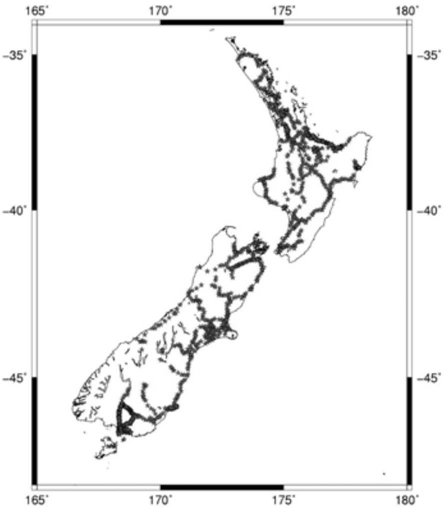

Figure 9. 1422 GPS-levelling points.

(Table 2). The standard deviation of the Stewart Island 1977 datum is larger than the others because it has been determined from five relatively low accuracy GPS-levelling points. The Lyttelton 1937 offset is probably higher due to the very long levelling lines that were used to establish the initial normal-orthometric heights (e.g. Lyttelton to Haast via Arthurs Pass). All of the offsets are positive as a matter of coincidence rather than planning. This shows that the NZGeoid2009 is consistently 'higher' than the LVDs.

An estimate of the overall accuracy of the NZGeoid2009 can be found from the standard deviations at all 1422 GPS-levelling points once their respective offset biases have been removed. This gives an overall standard deviation for NZVD2009 of 0.062 m.

Transformations

Heights can be transformed between NZVD2009, NZGD2000 and the NZ LVDs using Equations 9 to 12 (LINZ, 2009). The relationship between the heights is shown schematically by Figure 10.

To determine the value of the NZGeoid2009 at a point, the geoid grid needs to be bi-linearly interpolated at the NZGD2000 (latitude/longitude) position of the height being transformed. The transformations to/from the LVDs do not take into account the change in the normal gravity field from GRS67 to GRS80 because its effect is typically sub-millimetre (Amos, 2007). The sign convention in Equations 9 to 12 was chosen to ensure that the LVD offsets were positive and therefore increase the likelihood that they would be implemented correctly.

The nominal accuracy of the transformations is a combination of the offset/NZGeoid2009 accuracy (from Table 4) and the accuracy of the original height. Care needs to be taken when combining heights that have been derived from different sources, such as transformed ellipsoidal heights and precisely levelled NZVD2009 heights. In this scenario it is possible that the heights may not be in terms of each other and additional checks should be made to verify the relationship.

NZGD2000 to NZVD2009:

$$H_{NZVD2009} = h_{NZGD2000} - N$$

Equation 9

LVD to NZVD2009:

$$H_{NZVD2009} = H_A - o_A$$ ***Equation 10***

Between LVDs:

$$H_B = H_A - o_A + o_B$$ ***Equation 11***

LVD to NZGD2000:

$$h_{NZGD2000} = H_A + N - o_A$$

Equation 12

Where: $H_{NZVD2009}$ NZVD2009 normal-orthometric height

H_A, H_B LVD A and B normal-orthometric heights

$h_{NZGD2000}$ NZGD2000 ellipsoidal height

N NZ Geoid2009 value at the NZGD2000 position of h

o_A, o_B Offsets of LVDs A and B from Table 3

Use of NZVD2009

NZVD2009 provides, for the first time in NZ, a national height reference system that can be used to consistently integrate geospatial datasets. Although it is the official national vertical datum, it will not formally replace the existing LVDs in the near future.

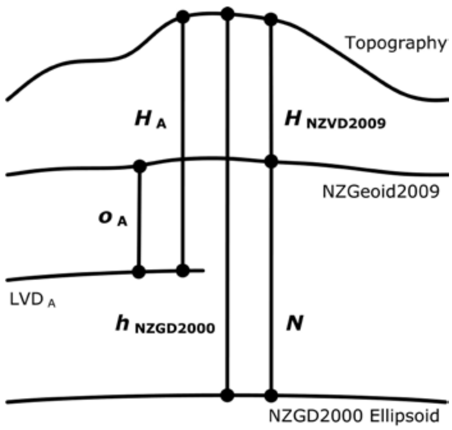

Figure 10. Schematic relationships between NZVD2009, NZGD2000 and LVD heights.

Table 4. Offsets from NZVD2009 to the 13 LVDs and their standard deviations (metres).

Local vertical datum	Number of points	Offset from NZVD2009	Standard deviation
One Tree Point 1964	51	0.06	0.03
Auckland 1946	137	0.34	0.05
Moturiki 1953	258	0.24	0.06
Gisborne 1926	61	0.34	0.02
Napier 1962	54	0.20	0.05
Taranaki 1970	70	0.32	0.05
Wellington 1953	78	0.44	0.04
Nelson 1955	111	0.29	0.07
Lyttelton 1937	251	0.47	0.09
Dunedin 1958	73	0.49	0.07
Dunedin-Bluff 1960	181	0.38	0.04
Bluff 1955	92	0.36	0.05
Stewart Island 1977	5	0.39	0.15

Instead, it will co-exist with them, so that existing datasets that cover distinct areas can continue to use a LVD as their height system, and also take advantage of the NZGD2000/GNSS height transformations that are provided with NZVD2009.

Unlike the LVDs, NZVD2009 is not explicitly tied to local MSL. The 'zero level' of the NZGeoid2009 surface is defined by the EGM2008 GGM that was used in its computation, and as such, NZVD2009 heights do not attempt to represent local MSL, although they typically occur within 0.5 metres of it. This means that, if the relationship between a NZVD2009 height and local sea level is required, then this will need to be quantified by physical inspection at the site in question. This requirement is actually no different for the LVDs since the MSL value for these heights is only applicable in the vicinity of the origin tide-gauges, and perhaps also only during the time period of the tide gauge observations (Table 1).

The new NZVD2009 heights for control marks that currently have ellipsoidal or normal-orthometric LVD heights will be obtainable from the LINZ geodetic database. In the first instance, however, these will be determined by transformation. This means that a mark that has a LVD height that was precisely levelled in 1973 will be assigned a NZVD2009 height derived from the 1973 height. Therefore, although the NZVD2009 height will be computed in 2010, it will in effect be a height from 1973 that in many cases has not been recently verified. As such, like with any survey mark, the published heights or coordinates should be verified in the field to ensure that they are reliable before they are used.

The NZVD2009 will not be a panacea for all height applications in NZ. The datum has been designed as a national datum for the consistent representation of geospatial and surveying data rather than for high-accuracy engineering projects. Where a particular application demands very precise heights, or where gradients/outfall levels are critical, it may be appropriate to use an application-specific datum that may also be related to NZVD2009.

SUMMARY

NZVD2009 provides for the first time a consistent height reference system that can be accessed across NZ and its offshore islands. Because gravity observations are not available at many of the control marks in NZ, the normal-orthometric height system has been retained. NZVD2009 is based on the NZGeoid2009 quasigeoid surface. Unlike most datums it is not directly connected to MSL at a tide gauge but it is generally within 0.5 metres of it.

The NZGeoid2009 is based on the EGM2008 GGM and is defined in relation to the GRS80 ellipsoid, therefore NZVD2009 normal-orthometric and NZGD2000 ellipsoidal heights can be efficiently transformed between the two systems. This relationship also allows GNSS derived ellipsoidal heights to be consistently related to NZVD2009.

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REFERENCES

Allister, N.A. and Featherstone, W.E. 2001. Estimation of Helmert orthometric heights using digital barcode levelling, observed gravity and topographic mass-density data over part of the Darling Scarp, Western Australia. *Geomatics Research Australasia*, 75: 25-52.

Amos, M.J. 2007. Quasigeoid modelling in New Zealand to unify multiple local vertical datums. Unpublished PhD thesis, Curtin University of Technology, Perth, Australia.

Amos, M.J. and Featherstone, W.E. 2003. Preparations for a new gravimetric geoid model of New Zealand, and some preliminary results. *New Zealand Surveyor*, 293: 3-14.

Amos, M.J. and Featherstone, W.E. 2009. Unification of New Zealand's local vertical datums: iterative gravimetric quasigeoid computations. *Journal of Geodesy*, 83(1): 57-68, doi: 10.1007/s00190-008-0232-y.

Anderson, O.B., Knudsen, P., Berry, P. and Kenyon, S. 2008. The DNSC08 ocean wide altimetry derived gravity field. *Paper presented at the 2008 General Assembly of the European Geosciences Union*. Vienna, Austria, April 13-18, 2008.

Beanland, S., Blick, G.H. and Darby, D.J. 1990. Normal faulting in a back-arc basin: geological and geodetic characteristics of the 1987 Edgecumbe earthquake. *New Zealand, Journal of Geophysical Research*. 95(B4): 4693-4707.

Beavan, R.J. 1998. Revised horizontal velocity model for the New Zealand geodetic datum. Client Report 43865B, Institute of Geological and Nuclear Sciences, Lower Hutt.

Beavan, R.J. and Haines, A.J. 1997. Velocity map of New Zealand for provisional 1997/98 dynamic datum. Client Report 42793D.10, Institute of Geological and Nuclear Sciences, Lower Hutt.

Beavan, R.J., Matheson, D.W., Denys, P., Denham, M., Herring, T., Hager, B. and Molnar, P. 2004. A vertical deformation profile across the Southern Alps, New Zealand, from 3.5 years of continuous GPS data. In: van Dam, T., and Francis, O. (Eds.). *Proceedings of the Cahiers du Centre Européen de Géodynamique et de Séismologie workshop: The State of GPS Vertical Positioning Precision: Separation of Earth Processes by Space Geodesy*, Luxembourg, 23: 111-123.

Begg, J.G. and McSaveney, M.J. 2005. Wairarapa fault rupture – vertical deformation in 1855 and a history of similar events from Turakirae Head. In: Langridge, R., Townend, J. and Jones, A. (Eds.). The 1855 Wairarapa Earthquake Symposium Proceedings, Greater Wellington Regional Council, Wellington, pp. 21-30.

Bell, R.G., Goring, D.G. and de Lange, W.P. 2000. Sea-level change and storm surges in the context of climate change. *IPENZ Transactions*. 27(1): 1-10.

Bevin, A.J., Otway, P.M. and Wood, P.R. 1984. Geodetic monitoring of crustal deformation in New Zealand. In: Walcott, R.I. (Ed.). An Introduction to the Recent Crustal Movements of New Zealand. *Royal Society Miscellaneous Series 7*, The Royal Society of New Zealand, Wellington, pp. 13-60.

Boucher, C., Altamimi, Z. and Sillard, P. 1998. Results and analysis of the ITRF96. *IERS Technical Note 24*. Observatoire de Paris, Paris, France.

Childers, V.A., Smith, D.A., Roman, D.R. and Diehl, T.M. 2009. GRAV-D: The NGS "Gravity for the re-definition of the American vertical datum" project. Presentation to International Association of Geodesy General Assembly, Buenos Aires, Argentina, 31 August – 4 September 2009.

Classens, S., Hirt, C., Amos, M.J., Featherstone, W.E. and Kirby, J.F. 2010. NZGeoid09 quasigeoid model of New Zealand. *Survey Review*, in press.

Cross, P.A., Hannah, J., Hradilek, L., Kelm, R., Mäkinen, J., Merry, C.L., Sjöberg, L.E., Steeves, R.R., Vaníček, P. and Zolkoski, D.B. 1987. Four-dimensional geodetic positioning. *Manuscripta Geodaetica*, 12(3): 147-222.

DoSLI, 1989, Geodetic Survey Branch Manual of Instruction, Department of Survey and Land Information, Wellington.

EUREF, 2006. European Vertical Reference System, EUREF website, URL: www.euref-iag.net, accessed 18/03/2010.

Featherstone, W.E., Evans, J.D. and Olliver, J.G. 1998. A Meissl-modified Vanicek and Kleusberg kernel to reduce the truncation error in gravimetric geoid computations. *Journal of Geodesy*, 72(3): 154-160, doi: 10.1007/s001900050157.

Featherstone, W.E. and Kuhn, M. 2006. Height systems and vertical datums: a review in the Australian context. *Journal of Spatial Science*, 51(1): 21-41.

Flury, J. and Rummel, R. 2009. On the geoid-quasigeoid separation in mountain areas. *Journal of Geodesy*, 83(9): 829-847, doi: 10.1007/s0019000903029.

Gilliland, J.R. 1987. A review of the levelling networks of New Zealand. *New Zealand Surveyor*, 271: 7-15.

Grant, D.B. and Blick, G.H. 2001. A National Vertical Datum Independent of Mean Sea Level, Presentation to International Association of Geodesy Scientific Assembly, Budapest, Hungary, 2-7 September 2001.

Heck, B. 2003. *Rechenverfahren und Auswertemodelle der Landesvermessung*, 3rd edition, Wichman, Karlsruhe, Germany.

Heiskanen, W.A. and Moritz, H. 1967. *Physical Geodesy.* W.H. Freeman and Company, San Francisco, USA.

Helmert, F.R. 1884. Die mathematischen und physikalischen Theorieen der höheren Geodäsie. Vol. 2, B.G. Teubner, Leipzig, Germany.

Helmert, F.R. 1890. Die Schwerkraft im Hochgebirge insbesondere in den Tyroler Alpen. In geodätischer und geologischer Beziehung, Veröffentlichung Königliche Preussiche, Geodätischen Institutes und Centralbureaus der Internationalen Erdmessung, No. 1, Berlin, Germany.

Henderson, J. 1933. The geological aspects of the Hawkes Bay earthquakes. *New Zealand Journal of Science and Technology*, 15(1): 38-75.

Hipkin, R.G. 2000. Modelling the geoid and sea surface topography in coastal areas. *Physics and Chemistry of the Earth*, 25(1): 9-16, doi: 10.1016/s146418950000003.

Jekeli, C. 2000. Heights, the geopotential, and vertical datums. Report 459, Department of Civil and Environmental Engineering and Geodetic Science, Ohio State University, Columbus, Ohio, USA.

Kingdon, R., Vaníček, P., Santos, M., Ellmann, A. and Tenzer, R. 2005. Toward an improved height system for Canada. *Geomatica*, 59(3): 241-249.

Lemoine, F.G., Kenyon, S.C., Factor, R.G., Trimmer, R.G., Pavlis, N.K., Chinn, D.S., Cox, C.M., Klosko, S.M., Luthcke, S.B., Torrence, M.H., Wang, Y.M., Williamson, R.G., Pavlis, E.C., Rapp, R.H. and Olson, T.R. (1998) The development of the joint NASA GSFC and the National Imagery and Mapping Agency (NIMA) geopotential model EGM96, *NASA/TP-1998-206861*, Goddard Space Flight Center, Greenbelt, USA.

Lensen, G.J. and Otway, P.M. 1971. Earthshift and post earthshift deformation associated with the May 1968 Inangahua earthquake, New Zealand. *The Royal Society of New Zealand Bulletin*, 9(1): 107-167.

LINZ, 2007. Standard for New Zealand Geodetic Datum 2000, LINZS25000. Land Information New Zealand, Wellington. Available at: http://www.linz.govt.nz/geodetic/standards-publications/standards/index.aspx.

LINZ, 2009. Standard for the New Zealand Vertical Datum 2009, LINZS25004. Land Information New Zealand, Wellington. Available at: http://www.linz.govt.nz/geodetic/standards-publications/standards/index.aspx.

Mader, K. 1954. Die orthometrische Schwerekorrektion des Präzisions-Nivellements in den Hohen Tauren (The orthometric weight correction of precision levelling in high terrain), Österreichische Zeitschrift für Vermessungswesen, Sonderheft 15, Vienna.

Merry, C. and Vaníček, P. 1983. Investigation of local variations of sea surface topography. *Marine Geodesy*, 7(2): 101-126.

Molodensky, M.S., Eremeev, V.F. and Yurkina, M.I. 1962. Methods for the study of the external gravitational field and figure of the Earth. Israeli Programme for the Translation of Scientific Publications, Jerusalem, Israel.

Moritz, H. 1980. Geodetic Reference System 1980. *Bulletin Géodésique*, 54(3): 395-405, doi:10.1007/bf02521480.

Niethammer, T. 1932. Nivellement und Schwere als Mittel zur Berechnung wahrer Meereshöhen (Levelling and weight as means for the computation of true sea level heights). Schweizersche Geodätische Kommission, Berne, Switzerland.

Otway, P.M., Blick, G.H. and Scott, B.J. 2002. Vertical deformation at Lake Taupo, New Zealand, from lake levelling surveys. *New Zealand Journal of Geology and Geophysics*, 45(1): 121-132.

Pavlis, N.K., Holmes, S.A., Kenyon, S.C. and Factor, J.K. 2008. An Earth gravitational model to degree 2160: EGM2008. Paper presented at the 2008 General Assembly of the European Geosciences Union, Vienna, Austria, April 13-18, 2008.

Pugh, D. 2004. *Changing sea levels: effects of tides, weather and climate*. Cambridge University Press, Cambridge, United Kingdom.

Rapp, R.H. 1961. The orthometric height. Unpublished Master of Science Thesis, Department of Geodetic Science, Ohio State University, Columbus, USA.

Reilly, W.I. 1990. The geoid and the needs of the GPS user. *New Zealand Surveyor*, 33(277): 35-41.

Roelse, A., Granger, H.W. and Graham, J.W. 1975. The adjustment of the Australian levelling survey 1970-71. Report 12, Division of National Mapping, Canberra, Australia, second edition.

Sansò, F. and Vaníček, P. 2006. The orthometric height and the holonomity problem. *Journal of Geodesy*, 80(5): 225-232, doi: 10.1007/s0019000500157.

Strange, W.E. 1982. An evaluation of orthometric heights accuracy using borehole gravimetry. *Bulletin Géodésique*, 56(4): 300-311, doi: 10.1007/bf02525730.

Tenzer, R., Vaníček, P., Santos, M., Featherstone, W.E. and Kuhn, M. 2005. The rigorous determination of orthometric heights. *Journal of Geodesy*, 78(1-3): 82-92, doi: 10.1007/s0019000504452.

Torge, W. 2001. *Geodesy*. 3rd edition, Walter de Gruyter, Berlin, Germany.

Vaníček, P., Castle, R.O. and Balazs, E.I. 1980. Geodetic levelling and its applications. *Reviews of Geophysics and Space Physics*, 18(2): 505-524.

Véronneau, M., Duval, R. and Huang, J. 2006. A gravimetric geoid model as a vertical datum in Canada. *Geomatica*, 60(2): 165-172.

Walcott, R.I. 1984. The kinematics of the Plate Boundary Zone through New Zealand: a comparison of short- and long-term deformations. *Geophysical Journal of the Royal Astronomical Society*, 79(2): 613-633.

Wellman, H.W. 1979. An uplift map for the South Island of New Zealand, and a model for uplift of the Southern Alps. In: Walcott, R.I. and Cresswell, M.M. (Eds.). The Origin of the Southern Alps. *The Royal Society of New Zealand Bulletin*, 18, Wellington, New Zealand, pp. 13-20.

TECHNICAL REFERENCE INFORMATION

The following information is not strictly a part of this paper, but is included here for those readers who wish to obtain further information.

LINZS25004 Standard for New Zealand Vertical Datum 2009: http://www.linz.govt.nz/geodetic/standards-publications/standards/index.aspx.

LINZG25705 NZVD2009 Factsheet: http://www.linz.govt.nz/geodetic/standards-publications/standards/index.aspx.

LINZ Geodetic Database: http://www.linz.govt.nz/gdb

Coordinate Conversion on the LINZ website: http://www.linz.govt.nz/coordinateconversion

Further information about NZVD2009 and NZGeoid2009: http://www.linz.govt.nz/nzvd

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Professional conduct of cadastral surveyors in New Zealand

SUMMARY

The integrity of the national cadastre in New Zealand depends, at least in part, on the competency and the honesty of the surveyors who are authorised to contribute data to it. While trust must be placed in those who are licensed or were registered, or in some other respect permitted to provide such data, checks and audits are required to ensure that standards are maintained.

The Cadastral Survey Act 2002 (the Act) requires surveyors contributing to the cadastre to obtain and renew annually a licence issued by the Cadastral Surveyors Licensing Board of New Zealand (CSLB). The Board issues and monitors standards that licence holders must meet, and their surveys are validated by Land Information New Zealand (LINZ) before being accepted into the cadastral record. Where discrepancies are found they are investigated and reported on. The Surveyor General then considers the magnitude and significance of any errors found, and may bring the licensed surveyor before the CSLB by way of a complaint. After consideration of the notification by the Surveyor General, the CSLB decides whether to accept the complaint. If accepted, the Act requires that a hearing be held. Anyone else may also bring complaints to the Board relating to 'professional misconduct' as defined in the Act. As this definition relates mostly to technical matters, complaints from the public are rare.

This paper describes the disciplinary process that has been put in place, the principles that have affected its development and the remedial measures open to the CSLB. By using specific examples, the nature of errors made in recent cases is discussed, their generic causes are identified, and penalties the Board can impose are described. The paper comments on the pressures that surveyors have been under over the last decade, principally due to changes to the cadastral record system, and also to the extraordinarily high demand for services. The paper comments on how these have translated into the professional conduct of New Zealand surveyors with respect to the cadastre.

KEYWORDS

professional practice; discipline; ethics; professional pressures

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INTRODUCTION

In the late 1990s there was a government drive in New Zealand to minimise regulation of business and reduce controls on the free operation of market forces. Many areas of the economy were deregulated and the Government of the day sought to remove restrictions on the entry into and control over professions. This was exacerbated by several high profile cases of fraud or inappropriate ethical behavior by respected medical, legal and accounting professions. Enthusiasm for this general policy waned following the failure of some trades-people to provide adequate levels of work, notably in the house building area where many 'leaky buildings' were supplied to the market. Had the review of the Survey Act 1986 taken place 12 months later, and with the failure of the free market in the building industry, the outcome for surveying may have been different.

The New Zealand Institute of Surveyors (NZIS), the principal body representing professional surveyors, was created as body of statute in 1900, having previously existed as a private incorporation since 1888. During the 1990s it lobbied for changes to some of its powers under the then current legislation (the Survey Act 1986) in order to be more responsive to change and to increase its disciplinary powers. It was therefore a willing, if not eager, participant with the Government in reviewing the regulation of the surveying profession. The result of this review was that the NZIS was removed from statute and became an Incorporated Society, and as such is able to amend its own constitution, and the Survey Board of New Zealand (SBNZ) was replaced by the Cadastral Surveyors Licensing Board of New Zealand (CSLB) with a narrowed focus. A more detailed explanation of these events may be found in Coutts and Grant, 2009.

This paper describes and assesses the outcome of these regulatory and administrative changes, specifically: the new complaints and disciplinary process that has been put in place; the principles that have affected the development of the process; the disciplinary powers available to the Board; and the definition of professional misconduct. The paper discusses the nature of errors and actions that have resulted in cases of professional misconduct, indicates their generic causes, and describes the disciplinary powers and penalties that are available to the Board. The paper comments on the pressures that surveyors have been under during the last decade, principally due to changes to the cadastral record system, and to an extraordinarily high demand for services. The paper comments on how these have translated into the professional conduct of New Zealand surveyors with respect to the cadastre.

HISTORY OF SHARED RESPONSIBILITY

Since the passage of the first legislation setting up the institutional arrangements for land surveying in New Zealand, the New Zealand Institute of Surveyors and Board of Examiners Act 1900, the competency standard setting and disciplining of professional surveyors in New Zealand has been shared between three bodies namely:

- A department of state, variously known as the Department of Lands and Survey, the Department of Survey and Land Information, and now the Department of Land Information New Zealand (LINZ);
- An examining and registration board known as the Survey Board of New Zealand, (SBNZ)
- The professional surveyors' association, the NZIS.

LINZ is the repository of the survey and title record, and the Crown guarantees, for ownership and dimensions (within limits), the titles that it issues. While not guaranteeing individual surveys or land parcels, LINZ is dependent on the integrity of the cadastre that underpins the issue and guarantee of titles to land. It therefore requires that only suitably qualified surveyors undertake boundary location and demarcation (cadastral) surveys. While 'authorization' of surveyors to do this work was first undertaken by government local officials, the 1900 legislation established a separate body, the SBNZ, to carry out the 'registration' function, albeit chaired by the Surveyor-General and with members appointed by the Minister of Lands.

These components were put in place after 1900, but problems were still perceived with issues such as the charges surveyors made for surveys, unauthorized personnel carrying out work, and too many titles in use (such as 'authorised', 'registered' and 'licensed'). Further legislation, in the form of the Surveyors Registration Act 1928 and the Surveyors Act 1938, required all Registered Surveyors (those who had passed the requisite tests of the SBNZ) to be members of the NZIS. Both the SBNZ and the NZIS were empowered to discipline Registered Surveyors, but only the SBNZ could remove their registration.

Between 1938 and 1966, the tests for registration as a surveyor had grown to include not only topographical and control surveys, land title definition and land law, but also municipal engineering and urban and rural planning as they related to the subdivision and development of land. The NZIS accepted those who passed the registration test as full members without further examination, but only after an enquiry as to their 'good character'. While there was no public concern regarding this issue, and the NZIS considered that these additional areas were relevant to the general practice of professional surveying in the New Zealand context, officials were of the view that this was not only unnecessary, but beyond the scope that the original legislation had intended.

In 2002, after considerable debate, new legislation in the form of the Cadastral Survey Act 2002 (henceforth referred to as the Act) was passed. One of the objectives of officials at this time was to disentangle the close and complicated relationships that had grown up between LINZ, the NZIS, and the SBNZ. While there was no evidence that this was in any way detrimental to the system, it lacked separation, but more importantly, transparency. The principal effects of the changes, for the purposes of this paper, were that the SBNZ was disestablished and replaced by the CSLB, and the NZIS was removed from the statute. In addition, the standards required in order to gain a cadastral licence were restricted to cadastral competencies only, with only minor recognition of the wider issues of land subdivision. For further explanation of the structure, role and functioning of the CSLB in matters related to cadastral surveyors in New Zealand see Coutts (2008).

Under this regime, discipline by the CSLB is restricted to matters related to cadastre, and any other disciplinary issues are left to the relevant professional bodies to deal with, should the offender be a member of such a body. Beyond this, other matters of unprofessional conduct were therefore left for the market to deal with. In order to assist the CSLB with discipline, 'professional misconduct' is defined in a Schedule to the Act (see Appendix 1).

It is not the function of the CSLB to deal with boundary disputes. While these do occur from time to time, the appropriate place for such disputes is the Court system.

NEW DISCIPLINARY PROCESS

Part 4 of the Act, which includes sections 34 to 46, introduces professional misconduct, outlines the broad procedures the CSLB must follow and defines its powers and rights and those of anyone involved with disciplinary proceedings. Section 35 states that any person may make a complaint against a Licensed Cadastral Surveyor (LCS), and may include a member of the CSLB or a person acting on behalf of the Crown. In this latter case, it is in the name of the Surveyor-General that complaints are usually made. The Surveyor-General may learn of errors in surveys from a number of sources including: his own audits; the validation process; or surveyors unable to rationalise earlier work over which they are working. The procedure for processing complaints under the new system is described in the following sections.

Statutory procedure

The process begins when the CSLB is notified of a complaint which, as noted above, may come from anyone. The Board meets at approximately two-monthly intervals and does not delegate any part of the process. The first requirement on receiving a complaint is that the CSLB must inform the surveyor concerned and may proceed to investigate its validity. In the notification the surveyor is invited to respond to the allegations made. In addition, the Surveyor-General is required by s.35(4) to provide any information that he has that may be relevant to the complaint.

Complaints are received by the Secretary of the Board, and placed on the agenda for the next meeting. Having received the information, the CSLB must decide whether to 'accept' or 'decline' the complaint. The Board does not take lightly the decision to accept or decline complaints. It is usual that all members have read the full files of correspondence and technical information supplied, and the decision typically follows a robust debate on the issues raised. In order to proceed, the CSLB must be convinced that there is a case to answer, and if so convinced, it will resolve to 'accept' the complaint.

The majority of the complaints that have been accepted to date have come from the Surveyor-General. In his submissions, the Surveyor-General provided files showing that very thorough investigation had already taken place, which obviated the need for further investigation by the CSLB before a decision about whether or not to accept was made. The CSLB is empowered to not receive or investigate a complaint if it considers that it is vexatious or trivial (s.36).

When the Board decides to accept a complaint, it is required to immediately inform the cadastral surveyor concerned. In so doing, there is a requirement to:

State that the CSLB has one or more reasons to believe that a case exists for exercising its disciplinary powers over 'professional misconduct';

- To supply the cadastral surveyor with the particulars supporting that belief, and
- To set a date for a hearing into the complaint to be held that is not less than 28 days from the time of the notification.

Complaint hearings are not open to the public although the Board has the ability to over-ride this general principle in any specific case. To date this has not happened. The Surveyor-General, who for all other purposes is a member of the Board, is not a member for disciplinary purposes, and any Board member who has laid the complaint or who has a conflict of interest in the case, is disqualified from sitting as a member of a hearing panel. The CSLB makes its decision by simple majority, is required explicitly by the Act to observe rules of natural justice, and permits the Board to receive evidence even though it may not comply with the rules of evidence in a general court of law.

Following the making of a decision to uphold a complaint, the Board may make an 'order' in writing. The order must contain the reasons for the decision and include detail of the surveyor's rights of appeal. The order takes effect from the date it is served on the surveyor in question, unless the Board specifies that this should occur from a later date. The CSLB may then decide to publish its order, including naming the individual concerned. This may happen through the *NZ Gazette* (the official organ of the New Zealand Government) or by paid advertisements in professional journals. It could also be made available to the news media.

Any LCS found guilty of professional misconduct has the right of appeal against the judgment. Appeals are heard in the District Court, the 'lowest' tier in the hierarchy of the New Zealand judicial system. In hearing such an appeal the Court will call on the complainant and the respondent to participate, and will not call the CSLB to defend its judgment. The District Court's decisions are final.

Board policy procedure

To date the CSLB has received complaints from the Surveyor-General, from members of the public, and most recently from another Licensed Cadastral Surveyor. Those lodged by the Surveyor-General have been accompanied by a file documenting the originating problem and the detailed communications between his office and the surveyor in question. None of these complaints have generated further investigation by the Board prior to holding a hearing (in those instances when the complaint was accepted).

Most of the complaints generated by the public have been 'not accepted' as they were outside the jurisdiction of the CSLB. In the one case that was accepted, unreported as the surveyor was found not guilty of professional misconduct, the Board's investigation was conducted by a senior private practitioner residing in the same region who provided two reports on the circumstances of the survey, answered specific questions specified in his brief, and expressed some opinions.

On the receipt of all complaints from the public, particular care is taken to identify the issue or issues raised to determine whether or not they fall within the ambit of the Act. In most of these cases, which have not been accepted, the issues have related to misunderstanding of the constraints of the definition of 'professional misconduct' and have usually been related to the quality of the communication between the surveyor and the client.

As the five members of the CSLB who are involved are distributed through the length of the country, the cost of a special meeting would be significant. Having accepted a complaint, and in order to optimise the time of the members and minimise the costs, it has so far been the Board's practice to schedule hearings to coincide with the next regular Board meeting. The Board conducts its hearings in an inquisitorial manner with all of the members of the CSLB present (but excluding the Surveyor-General), the Board's legal advisor, the complainant, and the LCS who has been complained against. The CSLB secretary is also in attendance. The participants may bring people to support them, or be represented by counsel.

Following introductions the complainant is invited to present his or her case. Apart from points of clarification, the complainant has the right to do this without interruption. The Board members may then ask questions of the complainant. While cross-examination is not permitted, with the consent of the Chair of the Board, the defendant may be permitted to ask questions of the complainant. However, this is a privilege rather than a right. When this presentation has been completed, the LCS is then invited to present his or her defence. Again, they have the right to present their case without interruption followed by a period of questioning, as before. The complainant is then given the opportunity to respond to or comment on any matters raised by the surveyor's submissions. When all of these steps are complete the hearing is over. The Chair reserves the Board's decision and adjourns the hearing.

The Board, following a brief break during which the parties depart, debates the question of whether the complaint has been substantiated. If it finds that the complaint has not been proven then there is little more to discuss. Where the complaint is upheld, the Board must then decide what Order it will make as a consequence. The nature of the Order is given to the Board Secretary, who will then prepare a draft Order with the assistance of the Board's counsel. After comment by the members of the Board, the Order is then signed by the Chair and dispatched to the LCS. A copy is sent to the complainant.

During a hearing, a full record of the proceedings is taken and minutes produced. The hearing is recorded on tape, though will only be transcribed on request (which has not yet been necessary). Following circulation amongst the members in draft form for comment, the final minutes are confirmed at the next CSLB meeting. These form part of the Board's official records.

Principles to be applied

Related to the procedural steps above, the Act requires that in the exercise of its disciplinary functions, the Board must observe the rules of natural justice. While these are few in number they are critical to achieving a fair and just outcome from the process. As noted earlier, the Board's judicial functions are fundamentally 'inquisitorial' rather than 'adversarial'. That is, it is the function of the CSLB to gather all the facts relevant to the issues presented, and not merely to adjudicate on the evidence that the parties place before it. In this way the Board is at liberty to carry out its own investigations and gather whatever information it considers necessary in order to reach an appropriate conclusion.

Complainant: Any LCS complained about is entitled to know who it is that has lodged the complaint, and is given adequate facility to defend him or herself against any accusations made. The Board does not deal with anonymous complaints, but cannot compel either the complainant or the respondent to appear before it if they do not wish to do so. While to date it has not been presented with a case where neither has appeared, the Board has dealt with cases where the respondent has not appeared but only supplied written statements.

Evidence: The respondent LCS must be given all the information that is available to the CSLB and all documentation that is held by the Surveyor-General. This information should ideally be available in reasonable time before the hearing so that suitable advice and adequate responses can be prepared. In practice, detailed statements and some information (by both parties) is only supplied at the hearing itself.

Peer evaluation: The LCS is entitled to be judged by an impartial panel of his or her peers. For this purpose the Board is made up of former or current LCSs, with the addition of a lay member to add the dimension of the interests of the general public. Since New Zealand is a small country, and the surveying community a restricted number within it, it is inevitable that there will be many instances where the accused LCS is known to one or more of the Board members. While there have been instances where CSLB members have found it necessary to declare relationships with defending LCSs, none has yet deemed it necessary to disqualify themselves from a hearing. Additionally, having been invited, no complainant or respondent has objected to the continuance of any member to hear a case.

Disciplinary powers of the Board

The fundamental purpose of the Cadastral Survey Act 2002 is "…to promote and maintain the accuracy of the cadastre …" (s.3(a)). It is not intended in this Act, specifically, to punish people whose actions threaten that accuracy. It does, however, have some powers to enforce standards for cadastral surveyors and indirectly, cadastral surveys.

In particular, the CSLB has only three avenues for its Orders in dealing with a proven case of professional misconduct. Specifically it can:

- Cancel a licence;
- Suspend a licence; or
- Permit, for a period up to three years, a LCS to continue to practice but only under conditions of employment, supervision, relevant training or education, or other specified conditions.

In addition, the Board may require a guilty party to pay any costs and expenses of, and incidental to, the hearing or the investigations into the complaint.

Clearly, these requirements can have a punitive effect on a cadastral surveyor who is found to be guilty of professional misconduct as they may restrict the ability to earn a livelihood from cadastral survey practice. However, the prime purpose of these actions is to protect the cadastre from loss of integrity rather than to extract any form of retribution from the cadastral surveyors concerned. It is appropriate now to consider what constitutes professional misconduct in this context of cadastral surveying.

Professional misconduct defined

The 2nd Schedule of the Act (see Appendix 1) is quite explicit, through twelve clauses, in describing the nature of professional misconduct with respect to cadastral surveys. The first clause in the list (1(a)), not surprisingly, is negligence in the conduct of a survey. Negligence can be generally interpreted as not doing something that a competent surveyor would do in undertaking a cadastral survey.

The following three clauses relate to personal knowledge of a survey that they have certified as being correct. The first (1(b)) refers to not having personally carried out or directed a cadastral survey (including the related field work); the second (1(c)) to certifying a cadastral survey without having carried out sufficient checks to ensure its accuracy, including calculations, working plans and other records; the third (1(d)) refers to certifying a cadastral survey without complying with the standards set by the Surveyor-General.

The next three clauses relate to dishonesty directly relating to surveys. These include, knowing of deficiencies (1(e)), fabricating field notes or knowingly supplying erroneous information (1(f)); all of which are identified as forms of professional misconduct. This is followed by items of a similar nature with respect to being found guilty of giving incorrect information to the CSLB and to misuse of a cadastral surveying licence (1(g)). The remaining clauses (1(h) to 1(l)) relate to cadastral surveyors not carrying out specific and lawful requirements of the Court, or the Surveyor-General, or having used an authority to enter onto property in an inappropriate manner.

In exercising its disciplinary powers on the matters of general negligence, incompetence, dishonesty or noncompliance, the CSLB considers all of the evidence supplied in support of a complaint. The focus is on how these may have affected the accuracy of the cadastre, as specified as the prime function of the Act, and by implication, the Board.

There are other matters outside this definition that are likely to be the cause of complaints by cadastral surveyor's clients. It is usually instances of these other forms of behaviour that generate complaints that are not accepted by the CSLB, being outside its statutorily mandated powers. Such other 'offences' are generally termed 'unprofessional behaviour' in the New Zealand system. Unprofessional behaviour may be dealt with through the complaint mechanisms of professional bodies, in particular the NZIS. Surveyors who do not belong to a professional body, however, escape discipline for breaches of the broader aspects of professional conduct. Unprofessional behaviour under these circumstances may include ethical issues, dubious business practice, disagreements with the professional judgements of other surveyors, deficiencies in business communication, and disputes over fees. In some instances the latter are disguised as complaints about the former aspects of professional activities.

PROFESSIONAL MISCONDUCT – LESSONS LEARNT

In the six years since the inception of the new Board, there have been 26 complaints received by the Board, of which only 10 have been 'accepted'. With such a small number it is not possible to do a comparative analysis, and the time period is not long enough to consider the development of any trends that might lead to predictions. The CSLB has published a news sheet (CSLB, 2008) for the information of practitioners analysing in some detail the complaints that have been upheld up to April 2008 to explain the nature of misconduct detected and prosecuted so far, and is preparing a second publication.

In the first three years none were accepted, but since then a steady though small trickle has grown, especially from the Surveyor-General. Having developed from nothing there now seems to be a regular supply from the Surveyor-General. While not all of the Surveyor-General's complaints have been accepted, it can be noted that the investigatory work that proceeds the lodging of a complaint, combined with the technical and professional competence of the staff of the office of the Surveyor-General (OSG), tends to minimise the chance that the complaint will be declined.

Members of the public, while not appreciating the subtlety of the distinction between

Table 1. Complaints received by the CSLB 2002-08.

	2002	2003	2004	2005	2006	2007	2008	Total
Accepted	0	0	1	2	3	1	3	10
Declined	0	1	0	7	2	2	4	16
Total	0	1	1	9	5	3	7	26

professional misconduct and unprofessional behaviour, usually do not have the knowledge or resources to prepare a substantive case. The Board nevertheless treats all complaints seriously, and if considered appropriate and relevant, it will refer a complainant to the professional body.

Representation

Within the context of the hearing, respondents are permitted to be represented by counsel, or to have someone else speak for them. The Board has so far refrained from actively encouraging the presence of lawyers, consistent with its inquisitorial rather than adversarial procedures. In the cases so far, the CSLB has only twice had legal counsel for the respondent present. In both cases they were defending complaints laid by the Surveyor-General. In neither case did the Surveyor-General engage counsel, but presented the complaint with the assistance of one of his Senior Advisors.

The experience of legal representation so far has been equivocal. In the first instance the lawyer added little to the defence, and had his representations been critical, would not have benefited his client. In the second case the lawyer had a better understanding of the needs of the survey profession and did an adequate job in representation. In both cases it was beneficial to the complainant that the CSLB's approach is inquisitorial, and that the Board is comprised of qualified and experienced surveyors. The nature of complaints is such that much technical evidence is introduced that requires technical surveying knowledge to understand, as well as an appreciation of the practical conditions under which a surveyor works. There are seldom purely legal issues at stake, and it is of benefit to surveyors appearing before a CSLB disciplinary hearing that those called upon to judge the case can fully appreciate the practical issues facing surveyors in the field and in the office, rather than merely testing facts and opinions presented against a legal test.

It has been noticed by the Board that most LCSs, and probably most people, are not their own best advocates. While not actively encouraging the participation of lawyers specifically, respondents are encouraged to bring people to speak for them, or at least give them support. Other surveyors, who understand the technicalities as well as the realities of practice, make the best advocates or supporters for respondent cadastral surveyors. In the one case where a private citizen has had a complaint accepted by the CSLB and brought before it in a hearing, a lay spokesperson for the complainant did a good job of keeping the complainant on track and relevant to the professional issues, despite the fact that the complaint was not upheld.

Causes of errors

Cases dealt with by the Board are individually reported in the NZIS *Survey Quarterly*, but are also discussed in general terms in an annual publication of the CSLB known as the *Bulletin*. The cases heard by the CSLB that have been upheld have pointed out some particular lessons. The single most common issue has been the relationship between LCSs and their technical staff. In some cases the field staff have been incompetent or dishonest, making false entries in field notes, not placing ground marks in the way they have indicated in plans and data sets, or calculating 'closing' observations or measurements. The particular concern for the Board, in most cases, is that the LCS was not sufficiently close to the detail of the survey to recognise these defects.

This has emphasised the importance of the relationship between the 'signing surveyor and any field staff being used. The element of trust cannot be over-emphasised, as whoever is in the field, it is the licence of the LCS that is at stake, and there can be no delegation of the responsibility for the correctness of the work. Before delegating the field portion or the creation of data sets to another party, LCSs must have absolute faith in the competence and integrity of their staff. They must also diligently carry out both office and field checks with sufficient thoroughness as to attest to the accuracy and integrity of the work for which they are taking responsibility. Supervision and direction become critical professional issues under these circumstances.

In two cases (Bulletin, 2008; Bulletin 2009), the general competence of the LCS was called into question. In one of those cases the cadastral surveyor had returned to the country after a number of years overseas practising in areas of surveying other than cadastral, and in the other case the LCS was a sole practitioner working in an isolated professional environment. In these cases the Board is forced to consider the general current competence of the practitioner. In the former case the licence was cancelled, and in the latter case, after a second appearance before the CSLB on disciplinary issues, the surveyor did not renew his licence when it expired.

Admissions

In some cases, when LCSs have been confronted with complaints, they have tended to admit to or accept culpability without legal advice and before facing a hearing. This has not always been in their best interests, and in some cases, when a complaint has been lodged, has worked against their ability to mount any credible defence to the complaint. While this is commendable in its openness and honesty, it has not always been prudent or, in some cases, desirable.

It is never wise to be the judge in one's own case. Simple admission of guilt can obscure the cause or causes of failure, obstruct the understanding of the case by the Board, and potentially limit any learning outcomes that may be desirable for the individual or for the system. Given that the CSLB is a body to protect the cadastre rather than a punitive one for errant surveyors, it is important that it understand the contributing factors when serious errors are discovered. It can also disguise or protect any other parties that may have contributed to the problem. While not suggesting subterfuge on the part of guilty parties, self-judgement in such cases is unlikely to be impartial.

Stress

In a number of cases the contributing factors (some of which could be construed as extenuating circumstances), have been related to work-place stress. There are cases where the pressure to turn around work has come from clients, especially with smaller firms, but on other occasions pressure has been from internal demands to complete particular surveys by close deadlines. Other forms of stress include having under-estimated the cost of work in the first instance, the lack of convenient survey control for the standard of cadastral survey required, not being able to deal with over-zealous junior staff, and the absence of a paternal attitude by the government department such as that which many senior surveyors grew up with and that now no longer exists in the electronic environment.

PROFESSIONAL CONDUCT AND THE CADASTRE

Professional misconduct under the new definition, and therefore applicable to complaints to the CSLB, is focused mainly on technical matters. Matters of personal and professional integrity are referred to in the requirements to not knowingly provide erroneous or fabricated information to the cadastre (personified by the Surveyor-General). Unethical behaviour by individuals in this context can be quite difficult to detect, and its control therefore relies heavily on the personal standards of the individual LCS. It may be noted that the Cadastral Survey Act 2002 removed the need for any character checks before the issue of a licence. A licence may be removed, however, if an LCS is convicted of certain nominated crimes under the Crimes Act 1961 (too numerous to discuss here but include theft, burglary, robbery, blackmail, deceit, access to computers for dishonesty and forgery). The system is therefore more reliant than before on ethical standards inculcated through the social, educational and training regimes of the surveying profession and the nation.

In New Zealand, nearly all of the present LCSs are graduates of the School of Surveying at the University of Otago, and the majority of LCSs are members of NZIS. When a CSLB order is published, therefore, the conviction becomes widely known and impacts directly and immediately on a surveyor's reputation. This in itself should act as a considerable deterrent to misconduct.

New Zealand is not alone in the stress that development trends have placed on all professional surveyors, planners, engineers and architects. The shortage of staff to carry out the over-supply of work that has been accepted by survey practices has placed a considerable load on practitioners. It is suggested that this has encouraged LCSs to place an unwarranted level of trust in technician support staff, and to give graduate surveyors greater responsibility than their current post-graduation training merits. The demands on these people, in turn, have forced them to take shortcuts in order to complete work on time for their employers and their employer's clients. In some cases, the para-professional staff were not adequately trained to the level of the work that they were expected to undertake, and the supervising surveyors have been overly busy, resulting in a lack of sufficient checking, supervision and/or direction. In many cases it is only the prosecution before the CSLB that has led to the adoption of appropriate quality assurance procedures.

The Board has already been made aware of two survey companies who, by their own internal checking systems have identified para-professional staff who have been dishonest in their cadastral work. These firms are being put to considerable time and expense to check the extent to which the integrity of the cadastre has been threatened, and the degree to which they are exposed to disciplinary action by the CSLB, as well as correcting such work that they have found to be in error.

This situation has been further exacerbated by the change from paper plans to a digital environment. The lodging and processing of paper plans had a considerable human input, and was de-centralised through 12 local offices around the country, many of which had their own 'local customs' when it came to the acceptability of plans. The new digital lodgement system is through Landonline, with all 'cadastral survey datasets' (CSD) passing through a single consistent process. This means that there are fewer people involved, adding to the consistent but unforgiving nature of the national system. Many of the acceptance criteria are also automated, so that if there are any items in the CSD that do not fit the criteria, the plan is rejected. This brings the CSD to the attention of the Surveyor-General's staff and initiates closer scrutiny. This is likely to explain why the number of LCSs coming before the CSLB as a result of complaints from the OSG has increased.

Continuing change to the operating environment for licensed surveyors, in particular as technology develops, will maintain the need for continuing professional education amongst practitioners for them to continue to meet the required competencies. While the operating environment may be constantly changing, the standards of competency must be maintained, and the process of dealing with those who do not meet those competency standards must be consistent, transparent and just.

As noted above, when professional surveyors are confronted with workplace stresses that cause resources to be spread thinly across a practice, unanticipated and unfortunate outcomes can result. In such contexts systematic problems should quickly be identified and remedial measures reported to the profession through the professional bodies. Unfortunately these measures do not prevent instances of incompetence or unprofessional behaviour from sullying the reputation of individuals who have been brought before the Board and found wanting in their performance. In these circumstances the surveying profession, as well as the community in general, are considerably better off as a result of the presence, functions and work of the CSLB than it would be in its absence.

REFERENCES

Cadastral Survey Act 2002.

Cadastral Surveyors Licensing Board of NZ Bulletin, April 2008. CSLB, Wellington.

Cadastral Surveyors Licensing Board of NZ Bulletin, April 2009. CSLB, Wellington.

Coutts, B. J. and Grant D. B. (2009). The New Zealand Surveyor in the 21st Century. *Journal of Spatial Science.* 54:49-62.

Coutts, B. J. (2008). The Cadastral Surveyors Licensing Board. *Survey Quarterly*, 54: 9-11.

New Zealand Institute of Surveyors and Board of Examiners Act 1900.

Surveyors Registration Act 1928.

Surveyors Act 1938.

Survey Act 1986.

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APPENDIX 1

The Cadastral Survey Act 2002. Schedule 2: Professional misconduct.

1. A licensed cadastral surveyor is guilty of professional misconduct if the cadastral surveyor is found in any proceedings or appeal under Part 4 -

(a) to have been negligent in the conduct of, or failure to conduct, any cadastral survey:

(b) to have certified to the accuracy of any cadastral survey or cadastral survey dataset without having personally carried out or directed the cadastral survey and the related field operations:

(c) to have certified to the accuracy of any cadastral survey or cadastral survey dataset without having carried out sufficient checks to ensure the accuracy of the entries in any field book and the accuracy of all calculations, working plans, and other cadastral survey records that may have been made by any person employed by him or her in relation to the cadastral survey:

(d) to have certified to the accuracy of any cadastral survey carried out by the cadastral surveyor or under his or her personal direction if the operation of pegging and ground marking, and all other requirements of the cadastral survey, have not been carried out in accordance with standards set under Part 5:

(e) to have certified to the accuracy of any cadastral survey or cadastral survey dataset, knowing it to be defective:

(f) to have made any entry in any field book or other record that purports to have been derived from actual observation or measurement in the field, if in fact it has not been so derived:

(g) to have supplied to the Surveyor-General or the chief executive any erroneous information in relation to any cadastral survey, cadastral survey mark, or boundary, knowing the information to be erroneous in any material particular:

(h) to have been convicted of any offence against section 31 or section 58(b) or (c):

(i) to have failed to comply with any conditions imposed by the Board under section 39(2)(c) or (7) or the High Court on any appeal against an order under section 39:

(j) to have failed to comply with any requirement imposed under section 52:

(k) to have persistently exercised the powers of entry conferred by section 53 in an unreasonable manner:

(l) to have failed, without reasonable cause, to perform any duty imposed on licensed cadastral surveyors by standards set by rules made under section 49.

2. For the purposes of determining whether or not a licensed cadastral surveyor is guilty of professional misconduct, the fact that a cadastral survey or cadastral survey dataset may have been approved by or on behalf of the Surveyor-General or the subject of a determination by the chief executive that it complies with standards specified in rules made under section 49 is not relevant.

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Beyond the Horizon: Making way for offshore resource management in New Zealand

ABSTRACT

The growth of New Zealand's offshore oil, gas and minerals sector, together with a growing awareness of the need for environmental regulation beyond the Territorial Sea of New Zealand, has resulted in the promise of a new regulatory regime. This new framework for administering offshore resources, will establish an information system based on offshore environmental data that will resemble the concept of seabed cadastre long anticipated by the academic surveying community. A proposed EEZ Consents Act will require environmental impact assessment of certain activities, and make provision for decision making and administration in the management of offshore mineral resources. The *Deepwater Horizon* drilling disaster in the Gulf of Mexico serves as an example of how a well-developed regulatory system can fail, and draws attention to the need for marine planning to accompany offshore development. Surveyors in New Zealand are encouraged to consider their roles in environmental management at the levels of policy and planning, and also at the level of provision of information for environmental impact assessment.

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INTRODUCTION

In 1998, a paper published in the *New Zealand Surveyor* advocated the creation of a marine cadastre for New Zealand (Hoogsteden and Robertson, 1998). The theme of marine cadastre was taken up the following year at the New Zealand Institute of Surveyors & Fédération International de Géomètres Commission VII Conferences at Pahia. Surveyors play a crucial role in the administration of the most important onshore resources, and it seemed reasonable to propose an extended role for the nation's cadastral administration as economic activity extended further offshore. It was suggested that the seabed cadastre might evolve as a seamless extension of the land cadastre, guided by the same principles of organization and administration (e.g. accuracy; priority of registration) that have proved so valuable and necessary to the land tenure system onshore.

Despite the passage of over a decade, it would appear that there has been no move by government toward a marine cadastre per se. There have, however, been a series of developments in a variety of sectors which contribute toward a classification and inventory of New Zealand's marine domain (MfE 2005c). The Ministry for the Environment; the Ministry of Fisheries, and the Department of Conservation have all worked with the National Institute of Water and Atmospheric Research to develop a system of environmental classification that, in some ways, resembles the broader objectives of a marine cadastre.

> *"[T]he Marine Environment Classification provides a useful broad-scale classification*

of biotic and physical patterns in New Zealand's marine environments … [it will be used] as a spatial framework for analysis and management of marine conservation and resource management issues." (MfE 2005c).

The NZ Marine Environment Classification system fits neatly with the literature, which wholeheartedly endorses environmental and resource management aspects of a cadastre (Fowler and Treml 2001; Barry et al. 2003; Ng'ang'a et al. 2004; Ng'ang'a 2006; Strain et al. 2006; Komjathy 2007). This work suggests that a seabed cadastre will demonstrate its worth as a multi-level planning and management tool, rather than a narrower administrative tool for tenure and exchange (see also Nichols et al. 2000; Sutherland and Nichols 2004).

Following the research, one is led to an understanding of the concept of the marine cadastre as a means of managing information – increasingly environmental information – pertinent to the administration of offshore property rights. This paper therefore suggests opportunities for professional surveyors as information providers, and as information managers in the context of the offshore cadastre. In the twenty-first century, it is environmental law that provides an important part of the structure from which property rights are developed, and it is environmental regulation that holds the key to the administrative role that surveyors might undertake.

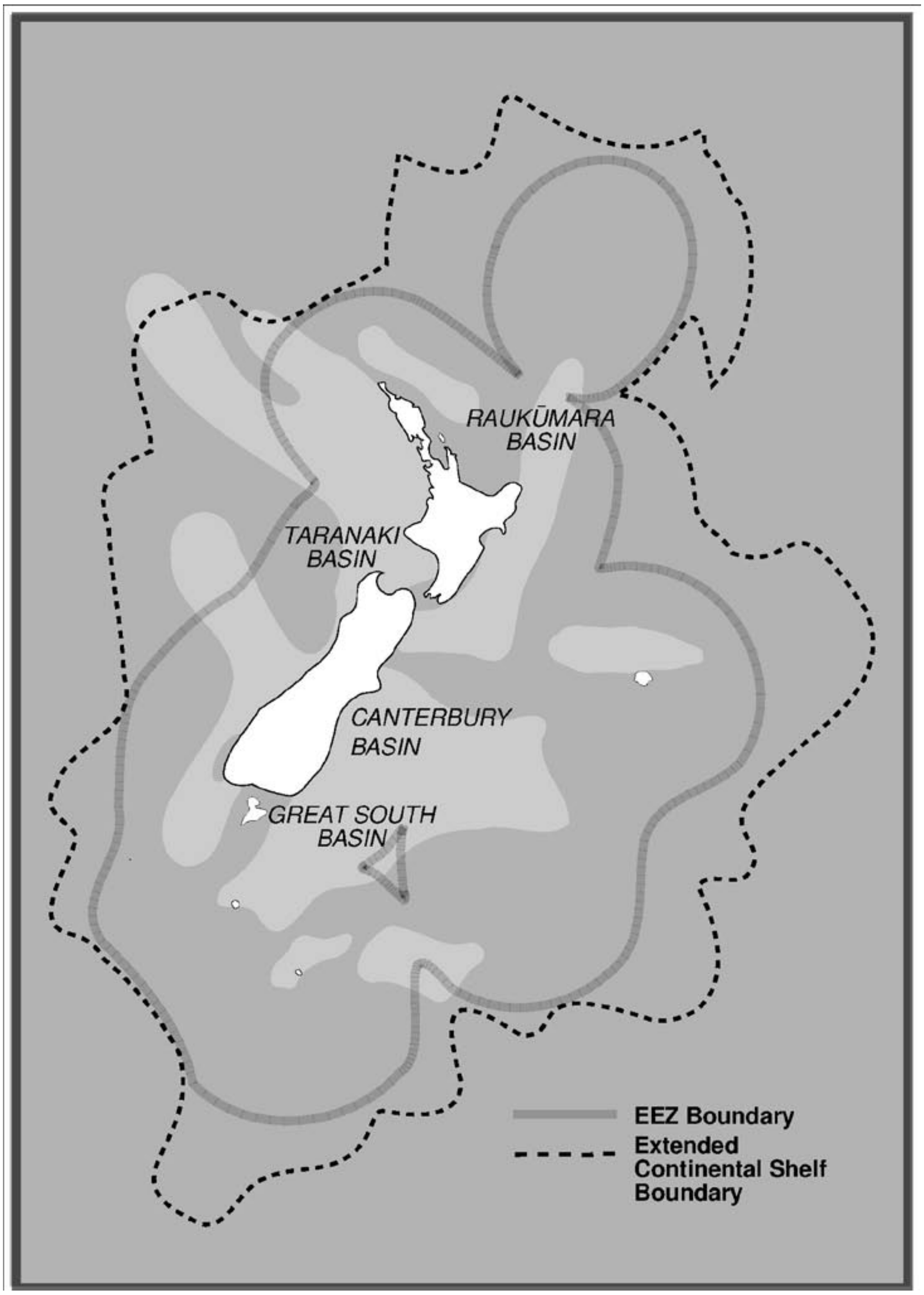

Figure 1: Zones and basins.

The first subject explored in this paper is the legal framework for offshore environmental management in New Zealand. This is a developing area that has received considerable attention over the past ten years, resulting in the proposal of an act to govern resource exploitation in the Exclusive Economic Zone (EEZ). A striking feature of the proposed legislation is the creation of the office of EEZ Commissioner whose duties will include information management. Does this signal the arrival of the long-awaited offshore cadastre?

In April 2010, a blown-out well began gushing oil into the Gulf of Mexico in what was to become America's worst ever environmental disaster. The event exemplifies the themes of this paper, because it highlights the need for New Zealand to institute a robust legal system for offshore environmental management. It is also an event from which lessons can be drawn in terms of how the regulatory system should operate. What regulatory problems contributed to the *Deepwater* disaster? And of what relevance are the lessons learnt to the administration of offshore resources in New Zealand?

The marine cadastre is a broad concept of which some features are beginning to materialise in a distributed way within New Zealand (MfE 2005c). In order to find a point of practical application in the larger effort of management and administration of offshore resources, this paper concludes with a discussion of environmental impact assessment (EIA) – also occasionally referred to as assessment of environmental effects (AEE). Along with a professional approach to information management, the surveyor brings knowledge of how the physical environment of the oceans can be described and mapped, and the levels of accuracy and quality that can be achieved. His/her work might then become the descriptive basis of the legal instrument – the EIA – that secures the rights of the offshore developer. Finally it is suggested that the information requirements for EIA might best be resolved within a marine planning infrastructure that incorporates the principles of informed participation and open access to information.

ENVIRONMENTAL REGULATION OF THE NEW ZEALAND EEZ

The following description of New Zealand's offshore regulatory regime focuses on the oil, gas and minerals (OG&M) sector. Hydrocarbon prospects are located throughout New Zealand's EEZ, with the Taranaki; Canterbury; Great South and, most recently, Raukumara Basins having received attention as locations for development (Figure 1).

New Zealand's Resource Management Act 1991 establishes a legal regime for environmental management onshore, out to the limits of the Territorial Sea. However, there is no legal regime in New Zealand that supports environmental management of the EEZ.[1] Oil pollution in the EEZ is addressed by the Maritime Transport Act 1994, and the Fisheries Act 1996 goes some way toward managing the environmental effects of fishing, but nowhere is there a legal requirement for offshore mining companies to manage the overall effects of their activities on the marine environment beyond the limit of the Territorial Sea (MfE 2005a; 2005b). The NZ Government and mining companies are concerned, and actively working together to manage the situation using best practise guidelines, but as the Prime Minister John Key has recently acknowledged, a set of legal rules to govern the industry is required in the near-term (NZPA 2010).

Concern with, and planning toward a legal environmental regime for the offshore environment, has been several years in the making in New Zealand. In 1998 the Parliamentary Commissioner for the Environment published an influential report, which led to attempts to formulate an oceans policy for New Zealand (PCE 1999). Early hopes that an oceans policy might produce a means by which to rationalize and integrate the plethora of New Zealand maritime legislation using modern environmental principles, were abandoned after the difficult passage of the Foreshore and Seabed Act 2004, which appeared to exhaust the Government's will for such a comprehensive undertaking (Taylor 2010; Vince and Haward 2009). The Government nevertheless proceeded with research and consultation, eventually favouring an act for the EEZ that would fill the gaps in existing legislation, while looking to create further integration across sectors in the future (MfE 2007a; 2007b; 2008).

The proposed EEZ legislation is described in a cabinet paper entitled, Proposal for Exclusive Economic Zone Environmental Effects Legislation (MfE 2008), and although the bill has not yet been formally drafted, is hereafter referred to as the EEZ Consents Bill. For the purpose of these discussions, the EEZ Consents Bill contains two salient proposals: The first is to create the position of EEZ Commissioner who will take overall responsibility for managing information and issuing consents to the OG&M Sector for offshore activities.[2] The second objective of the bill is to make environmental impact assessment (EIA) a legal requirement for projects that reach a certain size and scale (Brown 2008); the nature and requirements of such assessments are treated in more detail below. Although the government maintains that consents for activities in the EEZ do not constitute property rights, this is something of a moot point as an EEZ Consent will confer certain rights, call for certain duties, and will possess value.

It is tempting to draw a cadastral analogy in which the EEZ Commissioner is the corollary of the Surveyor General, and the EIA is the equivalent of the boundary survey, the instrument that allows the parcel (here understood as a bundle of rights attaching to a certain place) to be created. However there is an important distinction between the procedural law that requires an EIA to be performed, and substantive law that requires a certain specific outcome such as the creation of a land parcel. A parcel of land cannot be registered until it is legally defined, and the surveyor accomplishes this through a survey and plan. There is something neat and final about the process; a rule is followed and a particular outcome assured (i.e. a registered legal description of a land parcel henceforth exists). An EIA, on the other hand is not highly prescribed in content (at least not to the extent of a survey plan), and does not force a particular outcome. An EIA is provided for the information it contains, which helps in the making of an informed decision. The nature of that information is critical only in a general sense, and the decision maker is in no way bound by it (Holder 2006). This leads to some interesting and relevant questions: On what basis will the EEZ Commissioner make decisions to grant or withhold consent? What are the requirements pertaining to accuracy and completeness of the information that is presented in the EIA? Presumably, as is the case with the land cadastre, the information that the EEZ Commissioner manages will be made available as a public record, but this aspect remains to be elaborated. If the analogy with the land cadastre is pursued, it might be asked whether an official role for a qualified offshore surveyor might exist in the process.

Some further aspects of the EEZ Consents Bill are raised later in this paper. Before doing so, a bird's eye view of environmental management is provided through discussion of the 2010 oil spill in the Gulf of Mexico. The intention is to frame a discussion of principals and objectives from which policy and rules might be expected to follow. This is a conscious attempt to operate at more than one level, and to take responsibility not only for understanding and executing duties within the regime, but for helping design the regime itself.

Deepwater Horizon

America's worst-ever environmental disaster occurred as a result of the blow-out of an exploration well in BP's Macondo Prospect in the Mississippi Canyon, offshore from the State of Louisiana. The resulting explosion on the *Deepwater Horizon* drilling rig claimed the lives of 11 people. In the 88 days between 20 April 2010 and 18 July 2010, more than four million barrels of crude oil spilled into the sea from the damaged well on the sea floor. Hundreds of kilometres of the coastlines of Louisiana, Alabama, and Florida, were contaminated, and more than 6,000 vessels and 40,000 people have been involved in combating the effects of the spill (Wray 2010). The amount of oil suspended in the water column —dubbed 'submerged clouds' by scientists—and spread over the surface of the Gulf, may approach the magnitude of the largest oil spill in history. [3] This earlier, 'intentional' event resulted from the destruction of oil wells in Kuwait during the First Gulf War in 1991 (BBC 2010).

As the disaster unfolded, BP's stock market value declined by one half. One of the largest multinational oil companies in the world, BP was forced by the Obama Government to set up a $US20bn fund to pay claims for damages, and by the end of July 2010 BP had spent $US3bn on containing and cleaning up the spill. Analysts with the firm of Goldman Sachs have estimated that the total bill for the disaster could reach $US70bn (Wood 2010). It was not only the companies involved in the incident that had to carry the burden of the unfolding crisis: the former Minerals Management Service (MMS), a division of the Department of the Interior of the United States Government, and the Government's regulator of the offshore oil and gas sector, faced harsh criticism of its apparently inadequate supervision of the industry. A six-month moratorium was placed on all further deep-water drilling in the Gulf of Mexico. Drilling in Arctic waters was stopped, the Director of the former MMS was removed, and the agency renamed The Bureau of Ocean Energy Management Regulation and Enforcement.

Though the immediate causes of the Macondo blow out were technical and concerned drilling technology and techniques, it soon became apparent that there were cultural and systemic problems with the way in which the offshore industry is regulated. The Washington Post reported that:

> *"The federal agency responsible for regulating U.S. offshore oil drilling repeatedly ignored warnings from government scientists about environmental risks in its push to approve energy exploration activities quickly, according to numerous documents and interviews." (Eilperin 2010a).*

The main concerns regarding the way in which the MMS regulated the offshore drilling industry, included, "… accelerating permit approvals and incorporating industry practices in the regulations." (Eilperin and O'Keefe 2010). The MMS was described as having a 'scandalously close' relationship with, and having been corrupted by, the offshore oil industry (Goldenberg 2010). A flow of personnel between government and industry blurred the interests of regulators and the regulated (Fahrenthold 2010). In the case of the Macondo blow out, critics questioned why BP was granted an exemption from providing a site specific environmental assessment, and why neither BP's Initial Exploration Plan for the site, nor the overall Environmental Impact Statement covering the Western and Central Gulf of Mexico considered the eventuality of a catastrophic oil spill (Eilperin 2010b; MMS 2007; BP 2009; CBD 2010).

Montara

One theme emerging from commentary on the *Deepwater Horizon* incident is that deepwater drilling is particularly risky as it pushes the boundaries of technology, knowledge and experience. However, Australia's recent experience with the Montara blow-out in the Timor Sea shows that catastrophic pollution can also result from drilling in shallow water. The Montara well was drilled by the *West Atlas* jack-up rig under contract to PTTEP Australia. The well (250 km north-west of Truscott in Western Australia) flowed uncontrolled into the sea for 74 days between 21 August 2009, and 3 November 2009. Estimates for the total amount of oil released into the environment vary, and a report from an enquiry into the disaster is currently still being withheld by the Government of Australia. However, it is likely that the amount spilled will be in the same range of magnitude as that of the *Exxon Valdez* grounding in Alaska in 1989 which, prior to *Deepwater Horizon*, was the largest spill in US history (Wikipedia 2010).

Beyond the Horizon *in New Zealand*

The Key Government has announced itself as: '… pro-active and pro-development of petroleum resources' (MED 2009). Several important international OG&M companies, as well as New Zealand companies, are currently exploring New Zealand's EEZ under permits from the Crown Minerals division of the Ministry of Economic Development (NZEE 2010).[4] Under pressure as a result of the *Deepwater Horizon* spill, the Government has announced that it: "… is determined to ensure NZ's marine environment is properly protected as we expand petroleum exploration and development in the EEZ." Part of this effort has been to assign a new Environmental Protection Authority with responsibility for regulating the EEZ.[5] The Government is also now awaiting a report, expected in September 2010, from Environmental Resources Management (ERM), a global provider of environmental, health and safety, risk, and social consulting services, on the environmental protection that would be required in the EEZ. The report should contribute to the development of the EEZ Consents Bill which Minister Smith expects to present to Parliament before Christmas this year.[6]

The proposed EEZ Consents Bill is enabling legislation, rather than being a law primarily aimed at conservation and protection of the marine environment (MfE 2008). The bill aims at responsible development, a crucial aspect of which is managing the tension between economic growth and environmental protection (Taylor 2010). The rules eventually established under the legislation will become important tools in achieving sustainable development. However the social and political context within which laws operate is also important. Environmental protection is not simply an objective scientific activity in which certain 'acceptable' threshold levels of pollutants are set and monitored, or certain eco-systems described and protected in an holistic manner (though these are certainly necessary and desirable activities). In the case of *Deepwater,* environmental rules were in place and the letter of the regulatory law was followed. But this was not enough to prevent an environmental disaster.

Environmental protection has to respond to the economic and social context within which development activities take place. It is often the public that voices the social and economic context, and that contributes in a powerful way to governance. *Deepwater* resulted in enormous public outrage which is leading to changes in the way the offshore OG&M sector is regulated. Due to public pressure, site specific EIAs will in future be required in the Gulf of Mexico (Werner 2010). The importance of societal contribution is well recognized in Europe, finding form in the Aarhus Convention, and the EC Directive on access to information, public participation in decision making, and access to justice in environmental matters (UNECE 1998; EC 2003). As a result of the open attitude of the European Community, the author was able to access EIAs for offshore oil and gas development from a UK Government website, and to learn that public consultation is a well-established feature of environmental impact assessment in the European context.[7]

Looking abroad, the picture of offshore governance that emerges from Europe, Canada, and Australia is that of extending the discipline of spatial planning, long practised on land, to coastal and offshore areas. Emphasis is on wide consultation and participation. The international model is centred around the creation of Large Ocean Management Areas (LOMAs) which provide a spatial framework for integrated, ecosystem based management (Foster et al. 2005; Walmsley et al. 2007; Douvere 2008). In the case of Canada and Australia, enabling legislation and policy has created the political will and practical facilitation for the process to move forward.[8]

Though New Zealand has relinquished for the moment, the idea of creating an all-embracing re-writing of its oceans legislation, opportunities still exist for addressing the problems described by the Parliamentary Commissioner for the Environment in 1999, and for which the Oceans Policy process was initiated (PCE 1999). The proposed EEZ Consents legislation will be guided and informed by a Policy Statement which will set out objectives and principles (MfE 2008, para 9 and 12). This is one mechanism by which regulation can be set into context. The Policy Statement is also the mechanism by which regulation can best be informed and continue to grow in much the same fashion as the 'adaptive' development undertaken by resource developments in unexplored environments. Following the overseas example, a government science agency might be provided with legislated responsibilities in the marine planning area; hence providing the continuity, resourcing and facilitation required of such a process.

INFORMATION REQUIREMENTS FOR EIA

Central to the EEZ Consents Bill, is the requirement for an environmental impact assessment (MfE 2008, para 190). An EIA is a report detailing the likely effects of a development on the environment, and how these might be managed.

> *"[The] environmental impact report is a written statement describing the ways of meeting a certain objective or objectives and the environmental consequences of so doing. The statement is to be an objective evaluation setting out clearly and precisely, with appropriate documentation, the environmental consequences of a proposed action and of the alternatives to that action, and ways of avoiding or ameliorating any harmful environmental consequences." (Commission for the Environment 1973, p.4)*

The EIA will, no doubt, refer to a variety of geographic, geologic, biological and other environmental data, and might contain plans, images, and other spatial information. It is not difficult to imagine a surveyor's plan becoming a subsidiary requirement of an EIA. However, this is where the difficulty begins. Surveying is a profession that is used to a very high degree of specification, and highly standardized products. Legislation governing surveys prescribe exactly what is required and when. It may be difficult for the surveyor to come to terms with the much less regulated nature of the information requirements of an EIA. Furthermore, EIAs are scaled to the size and importance of the projects to which they refer, meaning that different levels of detail, and perhaps different technology and techniques, will be employed in different situations. How is the surveyor to achieve any comfort or certainty operating within such a wide-open, non-prescribed system?

Earlier in this paper it was noted that the OG&M sector in New Zealand is operating within a voluntary framework of best practice aided by Guidelines from the Ministry for the Environment (i.e. MfE 2006). A starting point for the surveyor is therefore to look at surveying and information practices associated with EIA within the industry, and across various jurisdictions. To this should be added a review of all available information types and sources. One important source will be the engineering side of the offshore profession which often utilizes very advanced techniques and technology to achieve detailed site surveys as part of the exploration process. Most importantly, questions should be raised regarding the purpose of the EIA, for this more than anything should determine the types and levels of information needed. It is at this point that the importance of marine planning reasserts itself. The question of the purpose of the EIA, and therefore of what information requirements will need to be served, could emerge from a forum of concerned parties working together within an oceans planning framework.

A detailed examination of industry practice, review of possible information sources, and development of guiding purposes with respect to the supply of hydrographic information for EIA, is beyond the scope of this paper. Examining these factors will be the necessary next step in developing a position from which surveyors might inform government during the drafting of legislation and associated regulations. For this purpose, access to information is important, and it is hoped that government and industry will be open to sharing their experiences and activities.

RELEVANCE OF THE DISCUSSION TO COASTAL AREAS AND TO THE PROFESSION OF SURVEYING

This paper focuses attention on the EEZ and the offshore areas in which the OG&M sector is operating. There may not be many surveyors in New Zealand that feel they have the capability of operating in the offshore environment, or have links with the OG&M sector. Much of the argument is, however, relevant to coastal areas and to other industries. Activities that fall under the Resource Management Act (RMA), such as port expansions and the establishment of Aquaculture Management Areas, are required to provide environmental assessments. The information needs for EIAs under the RMA will be similar to those envisioned for the offshore environment under the EEZ Consents Bill. Furthermore, trans-boundary effects are explicitly noted in the EEZ Consents Bill, which means that any industry operating anywhere near the jurisdictional area of the RMA will have to consult with regional authorities. After *Deepwater*, any OG&M activity in the EEZ might be seen as relevant to coastal areas. As information standards are developed for the offshore they will be applicable to coastal situations. Similarly, many of the lessons learned through working with the RMA in coastal areas and onshore may be relevant to the consenting process offshore.

It has been suggested to me in discussion, that the term 'surveyor' used in the context of the arguments presented in this paper may be overly generic, and that the words 'hydrographic surveyor' might be a better substitute. This is certainly true of the information gathering aspects of the seabed cadastre, but less true of the administrative aspects of the seabed cadastre, and of the managerial opportunities open to all surveyors engaging in resource management both onshore and offshore. This paper is intended as a general introduction, and one of its intentions is to raise interest in these issues on the part of land surveyors. It is up to land surveyors to take some ownership of the offshore issues, just as it is correct for hydrographic surveyors to be aware of the cadastral, and resource management aspects of their usually more narrowly prescribed operations.[9] This paper stops short of outlining precise roles for the surveying community in offshore development, and suggests that this should be the object of ongoing study. Nevertheless, it is certainly envisioned that the involvement of surveyors will go beyond the provision and managing of hydrographic information, to providing a facilitating role in the compilation of EIAs, and in marine planning more generally. In making use of existing resource management networks within the regions, there would appear to be room for the uptake of offshore issues by the surveying profession generally.

CONCLUSIONS

The legal requirements of the EIA under NZ's proposed legislation, and the professional way this information will be managed, have certain key characteristics of a cadastral nature. In the cadastral analogy the environmental impact assessment (EIA) has a similar function to that of the surveyor's plan. When EIAs are submitted to the office of the EEZ Commissioner, a spatial database will evolve made up of data that the applicant will have compiled as part of the application. Once approved, an EIA would create a precedent from which to judge new applications. A cadastre very much like a registry system of land rights would thus be created, in which each new instrument is the result of carefully consulting previously registered instruments. Regulations under the act would provide operating procedures and standards, but the detail and spirit of integrated environmental management would draw on the accumulation of environmental wisdom contained in the continually incrementing offshore cadastral database.

Deepwater has highlighted how enormous consequences for society have, in part, resulted from decisions made by only a few with a relatively narrow agenda. In the case of the Macondo Prospect in the Gulf of Mexico a reasonably good regulatory structure existed, and the letter, if not the spirit of the laws were observed. In the case of *Deepwater*, the government service has been criticized for the way in which the rules were applied, and for the lack of separation between the interests of industry and government. Good regulation, therefore, has to be more than a set of rules and the ability to monitor and enforce them. The way in which the regulation takes place is important. *Deepwater*, and Montara, demonstrate that the potential for catastrophe is ever present. [10] The risks are so immense they need to be widely shared among the population rather than being shouldered by either the industry or regulators. This is something that might best be done through an inclusive planning process. Having to negotiate with a spectrum of different approaches to development and the environment might appear a set-back for industry, but the sobering results of *Deepwater* should allow for a more tolerant perspective. Through its Oceans Policy process, New Zealand has demonstrated exemplary commitment to consultation and inclusion, and this process, though unsuccessful in its original intent of integrating all marine management under a single governance regime, can and should be seen as a prototype effort in marine planning. A similar process needs to be applied to the creative and scientific efforts demonstrated by the many organizations that participated in the NZ Oceans Classification (MfE 2005c). Applying such a process, and making provision for ongoing planning support in the policy statement that will accompany the new EEZ legislation, would establish New Zealand as an important innovator in marine governance.

REFERENCES

Barry, M., Elema, I. and Molen, P. V. D. 2003. Ocean Governance and the Marine Cadastre: The Netherlands North Sea. *Geomatica,* 57: 10.

BBC 2010. www.bbc.com/oilspill. Accessed June 15, 2010.

BP 2009. Initial Exploration Plan, Mississippi Canyon Block 252, OCS-G 32306.

Brown, D. 2008. Managing the environmental effects of activities in New Zealand's EEZ. *Resource Management Journal*, November 2008, 23-27.

CBD 2010. http://www.biologicaldiversity.org/index.html. Centre for Biological Diversity Accessed August 2, 2010.

Chevron 2010. Lagavulin Exploration Well Environmental Statement, March 2010, Chevron, Document No. CUE SA 705-005, DECC No. W/4062/2009.

Commission for the Environment 1973. Environmental Protection and Environmental Enhancement Procedures, 1981 Edition, first published 1973 in Review (Tussock Grasslands and Mountain Lands Institute) ; 27.

Douvere, F. 2008. The importance of marine spatial planning in advancing ecosystem-based sea use management. *Marine Policy,* 32: 762-771.

EC 2003. Directive of the European Parliament and the Council on public access to environmental information, 2003/4/EC.

Eilperin, J. 2010a. U.S. Oil drilling regulator ignored experts' red flags on environmental risks. *Washington Post,* May 25, 2010, Washington DC.

— 2010b. Administration may have more time to review oil-drilling proposals than it says. *Washington Post,* June 2, 2010, Washington DC.

Eilperin, J. and O'Keefe, E. 2010. Offshore drilling agency to undergo radical overhaul, Salazar announces. *Washington Post,* May 12, 2010, Washington DC.

Fahrenthold, D. A. 2010. Report shows close ties between rig inspectors, oil industry. *The Guardian,* May 26, 2010, London.

Foster, E., Haward, M. and Coffen-Smout, S. 2005. Implementing integrated oceans management: Australia's south east regional marine plan (SERMP) and Canada's eastern Scotian shelf integrated management (ESSIM) initiative. *Marine Policy,* 29: 391-405.

Fowler, C. and Treml, E. 2001. Building a marine cadastral information system for the United States – a case study. *Computers, Environment and Urban Systems,* 25: 493-507.

Goldenberg, S. 2010. Barack Obama orders six-month freeze on offshore drilling and expansion, President admits he was wrong to believe oil companies were prepared to deal with catastrophic spill. *The Guardian,* May 28, 2010, London.

Holder, J. 2006. *Environmental Assessment- The Regulation of Decision Making.* Oxford University Press.

Holmes, C. 1999. The Relevance of Multibeam Data in the Coastal Cadastre. Proceedings, NZIS/FIG Comission VII, Bay of Islands Conference, The Coastal Cadastre—Onland, Offshore, 9-15 Oct 1999, pp.45-52.

Hoogsteden, C. C. and Robertson, W. A. 1998. On land – off shore: strategic issues in building a seamless cadastre for New Zealand. *New Zealand Surveyor,* No. 288: 22-29.

Kerr, R.A. 2010. A Lot of Oil on the Loose, Not So Much to Be Found. *Science*: 329 (5993): 734-735.

Knight, P. D. 2000. The Legal Framework for Administering Offshore Petroleum Interests in New Zealand. *The New Zealand Surveyor,* No.290: 3-9.

Komjathy, K. 2007. A Systems Engineering Approach to Designing an Ocean and Coastal Information Management Strategy. Unpublished M.Sc.E Thesis, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, New Brunswick, Canada.

MacAskill, E. 2010. Oil rig fire triggers new pollution fear in Gulf of Mexico Thirteen workers flee drilling platform but oil company denies spill. *The Guardian.*September 3, 2010, London.

MMS 2007. Gulf of Mexico OCS Oil and Gas Lease Sales: 2007-2012 Western Planning Area Sales 204, 207, 210, 215, and 218. Central Planning Area Sales 205, 206, 208, 213, 216, and 222. Final Environmental Impact Statement. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region.

MED 2009. NZ Ministry for Economic Development, Petroleum Action Plan, http://www.med.govt.nz/templates/Page 42260.aspx. Accessed September 3, 2010.

MfE 2005a. Getting Our Priorities Right: The role of information in setting priorities for management of New Zealand's ocean. *Ministry for the Environment Publication* ME602. New Zealand Government.

— 2005b. Offshore Options Managing Environmental Effects in New Zealand's Exclusive Economic Zone. *Ministry for the Environment Publication* ME603. New Zealand Government.

— 2005c. The New Zealand Marine Environment Classification. *Ministry for the Environment Publication* ME594. New Zealand Government.

2006. Environmental Best Practice Guidelines for the Offshore Petroleum Industry. *Ministry for the Environment Publication* ME718. New Zealand Government.

2007a. Improving Regulation of Environmental Effects in New Zealand's Exclusive Economic Zone, Discussion Paper. *Ministry for the Environment Publication* ME824. New Zealand Government.

2007b. Improving Regulation of Environmental Effects in New Zealand's Exclusive Economic Zone, Summary of Submissions. *Ministry for the Environment Publication* ME846. New Zealand Government.

2008. Cabinet Paper: Proposal for Exclusive Economic Zone Environmental Effects Legislation. Cab 07-C-0751, Office of the Minister for the Environment, Cabinet Policy Committee. New Zealand Government. Available from: http://www.mfe.govt.nz/issues/oceans/current-work/cabinet-paper-eez-effects-legislation.html. Accessed September 6th. 2010.

NZEE 2010, Exploration: Petrobras a big score for Brownlee, New Zealand Energy and Environment. *Business Week*, June 15, 2010. http://nzenergy-environment.co.nz/home/free-articles/exploration-petrobras-a-big-score-for-brownlee.html. Accessed July 29, 2010.

NZPA 2010. Rules will be in place before oil drilling: PM. *New Zealand Herald*, June 29, 2010.

Ng'ang'a, S. 2006. Extending Land Management Approaches to Coastal and Oceans Management: A Framework for Evaluating the Role of Tenure Information in Canadian Marine Protected Areas. Technical Report No. 243, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, New Brunswick, Canada.

Ng'ang'a, S., Sutherland, M., Cockburn, S. and Nichols, S. 2004. Toward a 3D marine cadastre in support of good ocean governance: a review of the technical framework requirements. *Computers, Environment and Urban Systems,* 28: 443-470.

Nichols, S., Sutherland, M. and Monahan, D. 2000. Good governance of Canada's offshore and coastal zone: Towards an understanding of the marine boundary issues. *Geomatica,* 54: 415-424.

PCE 1999. Setting Course for a Sustainable Future. Wellington, Parliamentary Commissioner for the Environment.

Strain, L., Rajabifard, A. and Williamson, I. 2006. Marine administration and spatial data infrastructure. *Marine Policy,* 30: 431-441.

Sutherland, M. and Nichols, S. 2004. The Evolving Role of Hydrography in Ocean Governance and the Concept of a Marine Cadastre. *The Hydrographic Journal,* 111: 4.

Taylor, P. 2010. Toward a National Ocean Policy in New Zealand. In: Cicin-Sain, B., Vanderzwaag, D. and Balgos, M. C. (Eds.) *Integrated National and Regional Ocean Policies Comparative Practices and Future Prospects.* UN University Press, Tokyo. In Press.

UNECE 1998. The Aarhus Convention, United Nations Economic Commission for Europe, Arts. 6 and 7. Full document available at: http://www.unece.org/env/pp/documents/cep43e.pdf. Accessed September 3, 2010.

Vince, J. and Haward, M. 2009. New Zealand oceans governance: Calming turbulent waters? *Marine*

Policy, 33: 412-418.

Walmsley, J., Coffen-Smout, S., Hall, T. and Herbert, G. 2007. Development of a Human Use Objectives Framework for Integrated Management of the Eastern Scotian Shelf. *Coastal Management,* 35: 23 - 50.

Wikipedia 2010. http://en.wikipedia.org/wiki/Montara_oil_spill. Accessed July 29, 2010.

Werner, E. 2010. US is toughening scrutiny of deepwater drilling. *The Washington Post,* August 16, 2010, Washington DC.

Wood, Z. 2010. BP Faces ExxonMobil Takeover Bid Speculation. *The Guardian,* July 11, 2010, London.

Wray, R. 2010. BP makes record loss as Tony Hayward quits. *The Guardian,* July 28, 2010, London.

ENDNOTES

1 Section 9 of the Territorial Sea, Contiguous Zone, and Exclusive Economic Zone Act 1977 defines the boundaries of the EEZ

(1) The exclusive economic zone of New Zealand comprises those areas of the sea, seabed, and subsoil that are beyond and adjacent to the territorial sea of New Zealand, having as their outer limits a line measured seaward from the baseline described in sections 5 and 6 and 6A of this Act, every point of which line is distant 200 nautical miles from the nearest point of the baseline.

The Territorial Sea limit is 12 nautical miles from the normal and straight baselines described in the Act (either the Line of Low Water or the Straight Baselines respectively depending on which are relevant). There are areas of the Extended Continental Shelf (ECS) lying beyond the EEZ boundary to which New Zealand has rights to the seafloor and subsoil. For the purpose of regulating the Oil, Gas and Minerals Sector (OG&M), provisions of prospective legislation apply identically to both the EEZ and the ECS. For a description of the existing legal framework for the administration of offshore property rights in the OG&M sector see: Knight (2000).

2 On August 11th 2010, National Radio broadcast a statement by the Environment Minister Nick Smith suggesting that the new regulatory system for the OG&M Sector might not be limited to the EEZ, but might also take in the Territorial Sea. Minister Smith also stated that new legislation would be before Parliament by Christmas 2010.

3 Estimates of the amount of oil spilled (and the amount of oil remaining in the sea, and hence posing an environmental risk) are continually being revised. For a review of figures see Kerr 2010.

4 E.g. Exxon Mobil; Petrobras; Anadarko; OMV; Origin. New Zealand Oil and Gas.

5 Press release June 3rd 2010: http://beehive.govt.nz/release/new+environmental+protection+authority+announced.

6 See Note 2 above.

7 See https://www.og.decc.gov.uk/environment/index.htm, accessed August 25th, 2010. EIAs that accompany applications for permits are made available upon request from the Environment Management Team, Department of Energy and Climate Change, or from the offshore operators themselves. Offers for consultation for a deepwater offshore well were extended to a local council, environmental groups and a national wildlife conservation advocate. See: Chevron (2010).

8 Canada: *Oceans Act 1996*; Australia: *Australia's Ocean Policy 1998.*

9 In this context see Holmes (1999).

10 Offshore oil and gas development has a history of major accidents that unfortunately seem inherent in the industry: *Piper Alpha*, North Sea, 1988, 167 deaths; Petrobras, *Enchova Central,* Platform, 1984 (42 deaths) & 1988 (no loss of life); ODECO, *Ocean Ranger* Semi-Submersible, 1982 (84 deaths). Six months after the Deepwater Horizon disaster, yet another oil rig has caught fire in the Gulf of Mexico (MacAskill 2010).

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An alternative cadastral survey dataset for New Zealand

ABSTRACT

This paper assesses New Zealand's system of electronic record-keeping (Landonline) in the light of recent technologies and data-processing capabilities. A prototype cadastral survey dataset is put forward for the purpose of discussion, and its implications are discussed for future surveys in New Zealand. It is concluded that, although a monument-based cadastre should be retained, there are compelling reasons for expressing observations in terms of coordinates rather than vectors.

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INTRODUCTION

International debate about boundary monumentation (beaconing) and record keeping has continued for decades (e.g. Hadfield 1966; Toms et al. 1986; Johnstone et al. 1989; Goodwin and Regedzai 1997; Ballantyne and Rogers 2010). In particular, there has been discussion about whether boundary marks are still necessary. This has been debated both in New Zealand (e.g. LINZ 2007:12), where it was suggested that boundaries only needed to be marked where there is "conflict"), and internationally (e.g. Karlsson 2005; Jarroush 2009; Williamson 1991; Government of South Australia, Section 5). This paper considers the specific case of monumentation and record keeping in New Zealand, where the system of electronic record-keeping (Landonline) is based on bearing and distance vectors rather than coordinates.

The paper was motivated by a number of issues facing cadastral surveyors in New Zealand today:

i. the volume of records accompanying e-surveys retrieved from Landonline, sometimes running to scores of pages;

ii. clutter on some plans, especially plans of GPS surveys, caused by large numbers of bearings and distances;

iii. multiple determinations of point positions, especially with GPS technology, which raises the question of whether there is still merit in keeping all observations, or whether the time has arrived for surveyors to provide results as weighted and adjusted positions carrying greater probability than component observations;

iv. the powerful COGO (Coordinate Geometry) capabilities of GPS receivers and Total Stations. Survey/CAD/GIS packages work with data in the form of coordinates with associated topology, and NZGD2000 coordinates (latitude and longitude) are available via Landonline and readily transformed to any projection. Collectively these suggest that survey data archived and retrievable in coordinate form (as opposed to bearing and distance vectors) would be more useful to surveyors today than vector data.

The paper begins by looking at broad theoretical considerations underpinning cadastres, and at important criteria for Cadastral Survey Datasets (CSD). A prototype CSD is then put forward for the purpose of discussion, and its implications discussed for future surveys in New Zealand. It is concluded that, although a monument-based cadastre should be retained (i.e. we consider survey marks to be superior to coordinates), there are compelling reasons for expressing observations in terms of coordinates rather than vectors in future.

CLARIFICATION OF TERMS

Before comparison and reasoned discussion are possible on the topic of cadastral survey datasets, it is essential to gain clarity on three fundamental issues, namely:

- Monument-based cadastres
- Coordinates
- Survey systems and the influence of history

Monument-based cadastres

This paper confines itself to cadastres that are 'monument-based', which is the case in New Zealand. An essential feature of monument-based cadastres is that boundary marks on the ground, if undisturbed, provide the best evidence of land rights. The underlying rationale is that marked boundaries (either in the form of marked corners connected by straight-line boundaries, or else in the form of boundaries with a physical existence such as rivers or walls), are the visible, tangible substance of what is agreed to between buyer and seller, grantor and grantee. Boundary marking is important for land because, even though we speak of a 'land parcel', land has no separate existence – it is continuous with abutting parcels. Boundary marks (also known as monuments or beacons) or boundary features (e.g. walls in a unit title survey) are usually viewed by right-holders as what delimit land parcels, separate them from contiguous parcels, and govern the extent of land rights.

A potential legal difficulty is avoided by regarding the evidence of undisturbed boundary marks as superior to the measurement or description of those marks. This is because if dimensions are guaranteed they need to be perfect, which fails to recognise that all measurement is subject to error. If land within marked boundaries is conveyed, however, then dimensions are secondary. A frequently quoted analogy (Simpson 1976: 132,133) is that of a fishmonger selling salmon. The point is made that it makes a difference if the fishmonger offers a certain piece of fish, as displayed, for a stated price (in which case the weight is not critical: what customers see is what they get) or whether fish is sold by the kilogram, in which case fishmongers' measures have to be correct or else they are culpable if the fish sold is underweight. Furthermore, in the context of cadastral surveying, a third party (the surveyor doing a subdivision) measures up the dimensions of an agreed parcel of land, emphasising that its dimensions are secondary. In summary, in a monument-based cadastre it is recognised that (a) surveys of monuments may be imperfect and burdened with error, (b) written descriptions have limitations and may be flawed and, (c) as accuracies of equipment improve, measurements may change over the years without material change in the position of marks.

In a monument-based cadastre, as well as physical evidence on the ground (supplemented by written description and sometimes even oral evidence), mathematical evidence is the principal tool used by surveyors to ascertain whether boundary marks still occupy substantially the same position as when they were first placed and to replace disturbed marks or place new marks in sympathy with the old. In the course of most surveys, a check is made for disturbance of survey marks by comparing the relationship between marks on a former system with their relationship today. It does not matter if past and present survey systems are different; a bearing swing and/or scale change between the systems will be consistent between all marks provided that they still occupy substantially their original position. In quantifying bearing swing and scale change, an important principle borne in mind by surveyors is that small disturbances of marks result in large errors in orientation and scale over short distances. For this reason, swing and scale are generally calculated from accepted marks as widely distributed as possible. Thereafter, since bearing swing and scale change will never be perfect, replacement positions are calculated from accepted marks as nearby as possible in order to minimise the effect of errors.

The following questions may assist in teasing out some of the subtleties of monument-based cadastres:

Q: What happens if no direct measurement was made from the closest undisturbed mark in the previous survey?

A: Given the cadastral-rated equipment used by surveyors for at least a century, swing and scale can equally well be applied to indirectly measured lines from nearby marks as to directly measured lines. In either case, good relativity, the hallmark of a monument-based cadastre, will be preserved.

Q: Since surveyors need to use data from widely distributed marks for comparison, how is this arrived at if only short lines are observed and measured?

A: If previous survey data is in the form of bearing and distance vectors for a series of short lines, bearing swing and scale change for longer lines are calculated via a series of consecutive bearing and distance vectors (usually named 'missing line' calculations, 'data-traverses' or 'ray-trace' traverses) or else by generating pseudo-coordinates from bearings and distances, followed by joins (inverses). It will be noted that if previous survey data is already expressed in the form of coordinates, time will be saved because joins can immediately be taken out between coordinates without first having to calculate missing lines or run data-traverses. In particular, transformation is possible.

Q: Does it make any difference if the previous and current surveys are on different survey systems (e.g. if previous survey coordinates were on a local system and the present survey on the projection, or if the previous survey coordinates were in different units, e.g. links)?

A: It does not matter. Provided that any bearing swing and scale change are accounted for, relativity will not be compromised.

Coordinates

The second issue on which clarity needs to be gained, is the use of the term "coordinates". Strictly, vector bearings and distances are also coordinates (i.e. polar coordinates) but in this paper the term 'coordinates' will be used in the sense of grid coordinates: x,y or E,N. The word coordinates holds a number of different associations for users and, for NZ cadastral surveyors, includes at least the following four types:

i. National survey control coordinates on the NZGD2000 datum. This datum is semi-dynamic, in other words coordinates are given for a certain epoch but underpinned by a national deformation model (see Blick 2003:15, 19). In practice, NZGD2000 stops short of being fully dynamic (i.e. four dimensional, where continuously changing coordinates of marks would account for the effect of crustal deformation), because this was thought to be too disruptive for users.

ii. Digitized cadastral data captured from record sheets into the digital cadastral database (DCDB) which, owing to errors in the digitisation process, could conceivably be fifteen or more metres in error compared with surveyed positions.

iii. Coordinates in the survey-accurate digital cadastre (SDC), where distances and bearings for a number of surveys have been subjected to a block least squares adjustment, with a few ties across roads and to control marks (Rowe 2003), thereby producing a result sufficiently good for searching purposes (e.g. via a LandXML file) but generally inferior to the original survey data (e.g. McKinnon 2003).

iv. Coordinates on traverse sheets, derived from vector measurements of bearing and distance.

Clearly, different strategies need to be adopted when working with the different coordinate types listed above and, just as clearly, original measurements will be superior to joins between inaccurate or approximate coordinates. Where coordinates are unreliable (e.g. in (ii) above) surveyors do not have to be told that surveys will have better internal consistency if loop traverses are used, and tied to a single point rather than distorted to fit the unsatisfactory control. But it is important to note that good survey observations expressed in the form of coordinates should not be branded with the stigma of less accurate coordinate types. With this in mind, in this paper a fifth coordinate type is added to the above list, namely "observation coordinates". This term will be used to denote coordinates derived directly from observations, either vectors (e.g. from a Total Station) or from GPS.[1] Such observation coordinates are defined as being:

i. derived from observations that are reduced (e.g., for a total station, curvature and refraction and instrument and prism errors);

ii. adjusted (either traverse bearings 'closed' and a Bowditch adjustment, or else a least squares network adjustment) to fit in with national survey control coordinates, or else with confirmed marks on a previously approved survey which is on the national system;

iii. calculated on the official projection in use;

iv. independently checked. For GPS, this would either have taken the form of two observations a minimum of 30 minutes apart with acceptable differences between the two fixes, or else of a network adjustment with sufficient redundancy and acceptable residual errors. For Total Stations (or EDM and optical theodolite) a check will ideally be a "double tie" (i.e. two independent fixes from different setups).[2] In either case it is assumed that a mean will have been taken to arrive at a position carrying greater probability than that determined by any of the component observations.

The following questions may suggest themselves:

Q: Would observation coordinates be the same as 'legal coordinates' (as used in cadastral systems where coordinates take precedence over ground marks)? In other words, could boundary marks ever be replaced on observation coordinate values alone, with no reference to other marks?

A: The answer is no. Coordinates of marks may change over time, for example if a readjustment was made of the national survey control system. When this happens, replacing on a coordinate value will not preserve relativity between marks. What should not change, however, is the joins between observation coordinate pairs. Thus, if observation coordinates were determined today between a control mark and a boundary mark, then in thirty years' time the joins between the observation coordinates could be applied to the new (e.g. readjusted) coordinates of the control mark, and a coordinate calculated for the boundary mark on the current system. The observation coordinate of the boundary mark would be numerically different, but the joins between it and the control mark would be the same, and relativity would have been preserved.

Q: Why not just preserve relativity by using the original bearing and distance observations themselves, as is done with adoptions in current NZ practice? Why go to the trouble of turning vectors into coordinates?

A: The answer is threefold. First, especially where two or more determinations are made of the same point (e.g. two GPS observations), storing vector data for all fixing rays for a point is less efficient than storing a mean position in digital form.

Second, observation coordinates would make use of all observations, and so yield more probable positions than if only single fixes were used. Third, where coordinates are stored, joins can be done between any coordinated points whereas, if vector data are stored, ray-trace calculations are needed between all non-contiguous points and this is work that may have to be repeated for every subsequent survey. In particular, coordinates enable the powerful tool of transformation.

Survey systems and the influence of history

The final area in which clarity needs to be gained is that of survey systems used historically, and decisions made in historical times that still influence survey practice today. New Zealand currently enjoys a comprehensive national survey control system, but in earlier times surveys were sometimes done in isolation (in other words, 'island surveys', independent of other surveys) or on meridional circuits (initially not for all districts) in which bearings but not distances were carried out from origin marks to geodesic stations. There were obvious drawbacks to many early surveys, including difficulties inherent in relating surveys to one another, and the possibility of gaps and overlaps, hence the Palmer Report of 1875, which recommended a unified national control system of coordinates[3] and culminated in the NZGD2000 national survey system we enjoy today. However, along the road leading to the national geodetic system, specific details of surveys vary from case to case depending on the type of equipment used and on any local survey system/s specified, and this needs to be factored in by today's surveyors. For example:

- In a survey system of circa 1865 one would expect poor distances (e.g. if a surveying chain was used) with superior angular measurements.
- In a survey done by base extension, any inaccuracies in the measured base line would likely be manifested as a constant scale change between surveyed marks.[4]
- For surveys in the past few years, with a total station or an EDM and optical theodolite, comparable accuracies are expected between bearings and distances, and there is generally no scale change. However, a constant bearing swing is not uncommon between surveys owing to differences in the origins used for bearings.

Available materials, rate and patterns of settlement, and decisions made by early surveyor administrators about such things as accuracies, data structures and required checks, all influenced the way in which surveys were carried out in any era. Knowledge of historical circumstances, therefore, is frequently important when considering old survey marks and survey records. In particular, although details are beyond the scope of this paper, the reasons why Landonline data is held in its present form are important. Briefly, a policy decision was taken to capture observations, which at that point in time meant archiving bearing and distance vectors. Other significant policy decisions were as follows:

- Bearings (submitted to Landonline and on survey and title diagrams) are adjusted ('closed');
- Distances are not adjusted (i.e. even if a Bowditch or least squares adjustment is done for a traverse, Landonline requires ellipsoidal distances prior to adjustment);
- Bearings are on a meridional circuit projection;
- Distances are reduced to the ellipsoid but are not on a projection;
- Traverse sheet coordinates, on the other hand, are adjusted, reduced to the ellipsoid and on the projection.

Clearly there is no right or wrong to any of the above. Policies were based on the best data available, and the resulting observations form an extremely valuable data set of which New Zealand surveyors can justifiably be proud. However, having said this, survey hardware and software have advanced in directions that could not have been predicted a hundred years ago. Two advances are of special significance, first, the measurement and processing of coordinate geometry has become much easier (e.g. coordinate transformations), and second, especially in the case of GPS, it is increasingly common for several determinations to be made of point positions not just a single determination.

AN ALTERNATIVE CADASTRAL SURVEY DATASET

This section discusses an alternative cadastral survey dataset (CSD) for a survey near Dunedin, at Purakanui. The CSD includes three main elements, which are considered below and illustrated in the Appendix.

Observation Coordinate File (OCF) (Appendix Table A.1)

This subsection considers desirable criteria for an observation coordinate file (OCF) containing the most likely positions of points in a survey, with the smallest associated error ellipses and greatest confidence achievable. In concept, this file would be retrievable in digital form from Landonline for all surveys after a specified epoch (i.e. existing surveys would be approached in the same manner but surveys after a certain date might be required in a different format).

The following criteria were used to create the OCF:

i. The form should be that of an Excel spreadsheet (or equivalent), easily portable (e.g. comma separated, CSV file) to CAD/survey software and to data controllers used by GPS and Total Stations, and also capable of printout in an acceptable format;

ii. Only independently checked coordinates should be listed in the OCF (unless for an acceptable reason and clearly marked as unchecked or incompletely checked);

iii. Tolerances for acceptable differences between fixes would need to be prescribed, perhaps using the current rules for cadastral survey as a starting point (e.g. LINZ 2010; s3.1(a));

iv. A single (unchecked) survey determination would normally only be permissible where a survey was already based on the national survey control system and acceptable agreement was obtained with coordinates from a previously approved survey also on the national system. In other words, an approved survey on NZGD2000 plus visual evidence plus a single fix could provide a check on coordinates established in the current survey if also on NZGD2000;

v. The CSV file of observation coordinates should specify the datum and projection used, where instruments have been set up (Total Station and/or GPS base station), and should contain the name of each mark using letters and numbers but no Roman numerals (except referring to previously approved surveys), a concise description, and whether found (i.e. a found survey mark, placed and coordinated in a previously approved survey), placed (i.e. a mark newly coordinated in the current survey), adopted or calculated;

vi. Adopted marks should quote the description of the mark exactly as given in the previous survey, and should give the date of that survey (to signal the age of the description). For example, 'Iron tube buried 0.2m (Dec. 1945)'. Surveyors are aware that adopted points carry an unwritten caveat: they have been neither visited nor surveyed, only calculated according to data from an approved dataset that is unchanged apart from any justifiable bearing swing. However, it is argued that useful work may have been done bringing such points onto the current survey system (e.g. by calculating ray-trace/data-traverses) and their inclusion in the OCF is warranted, if only for searching purposes by future surveyors;

vii. Observation coordinates should, wherever possible, be on an official NZ projection, to permit easy comparison with Landonline SDC coordinates and for easy searching using GPS. It is noted that a LandXML file is already obtainable from Landonline, but (a) this step could be avoided for surveys with OCFs and (b) the LandXML coordinates are in some instances still inferior to actual observations. This means that, for data comparison purposes, ray-trace calculations still need to be done using vector observations;

viii. If there are no national survey control network marks within a reasonable distance, it should sometimes be possible to base a new survey on the cadastral survey network by basing it on an approved survey which is itself based on the national survey control system. In this case, more stringent tolerances should apply than if a survey was based directly on national survey control marks. These tolerances would need to be specified in the Cadastral Survey Rules;

ix. In order to be on the NZGD2000 survey system, observations used to compute observation coordinates would need to be reduced (for instrument, atmospheric and geometric errors) and projected into a plane system. Also bearing and distance misclosures in traverses would need to be adjusted, local transformations or network adjustments done where appropriate, and weighted means taken. A guiding precept in this process should be to preserve acceptable relativity between marks;

x. For a monument-based cadastre, when ascertaining whether survey marks have moved or not, the more well-defined marks there are to choose from, the better. Although it is generally recognised that boundary marks are more susceptible to movement than control marks,[5] in the case study the view has been taken that if boundary marks are (a) sufficiently well defined (e.g. an iron spikes, tubes, lead plugs, masonry nails in concrete footings or wooden boundary pegs tacked with copper nail, (b) surveyed to the same precision as witness, traverse and reference marks, and (c) checked with a double tie or equivalent, there should be no reason not to assign these equal weight as evidence in data comparisons. The best judge of whether (a), (b) and (c) apply is naturally the surveyor doing the work, and one way of making future surveyors aware of the decision taken would be for the surveyor to flag marks as suitable for comparison. In the sample records in Appendix B, compliance with (a) and (b) is signalled by assigning a 'monument/mark comparison status' (MCS) code, noted in the last column of the OCF;

xi. Finally, the assumption is made, given the accuracy of all cadastral rated equipment today, that inferred vectors (i.e. joins) between MCS coordinates are no less accurate than vectors derived from direct measurement.

Survey diagram: (Appendix Figures A.1 and A.2)

Assuming the existence of an Observation Coordinate File for every survey after an agreed inception date would affect specifications of both the survey and title diagrams. The following points are noted about the survey diagram in the case study:

i. The survey diagram should continue to show all marks surveyed, adopted or coordinated in a survey, with appropriate symbology for new and old marks etc.;

ii. The legal appellation, DP number, north arrow and survey system should continue to be shown;

iii. As well as scale, a scale bar should be considered, although this is seen as more critical for the title diagram, which is used by lay persons.

iv. Given the ease with which joins/inverses can be calculated by a variety of means today, and the possibilities offered by GPS for survey of non-intervisible marks, this paper tests the idea of omitting bearings and distances from survey diagrams where they are accompanied by an OCF;

v. The idea is also considered of whether significantly less CAD work will result from omitting bearings and distances, and whether clutter on survey diagrams would be avoided (especially in the case of GPS surveys). However, diagrams become harder to "read" and one idea is for a minimalist survey diagram to be accompanied by a copy marked up with representative measured lines (without bearing and distance values) added either by CAD or manually and then scanned.

vi. One disadvantage of the proposed survey diagram is that, for a simple confirmation of an origin with a total station, two joins would be necessary[6] whereas the bearings and distances can now be read directly from the survey diagram. However, join calculations are not onerous today and more flexible options would result for establishing origins between any two found and confirmed marks of suitable status.

Title diagram: (Appendix Figure A.3)

A title diagram should ideally provide the maximum benefit to right-holders and legal practitioners, and the following points are noted for the title diagram in this case study:

i. Title diagrams should continue to show bearings, distances and areas. However, it is suggested that a tabular form will often be less cluttered than where bearings and distances are written along boundaries;

ii. It is suggested that providing a multiplicative constant on the title diagram would permit a user with a hand calculator to compute distances on the topographical surface of the earth from the distances given. At present this would involve a factor for converting ellipsoidal distances to ground level in an area, but if projection distances are used a slightly different scale change would be given;[7]

iii. In the example, a simple alphabetical labelling is given for convenience in legal description. In addition to such legal labelling, given names and description of boundary marks are also provided in the tables[8] with the rationale that these could aid positive identification by right-holders, especially where names are inscribed on boundary marks by surveyors;

iv. A scale bar is given for ease of use by lay persons.

DISCUSSION

An obvious question is, how would future surveys differ as a result of the amended CSD described in this paper? Let us consider a survey done in the vicinity of the sample survey at Purakanui. A future surveyor would have to retrieve not only records for the sample Purakanui survey but also a number of older surveys. A first point of difference is that the Purakanui dataset would be more compact than the older surveys. It should be noted that, for the older surveys, the definition process would remain unchanged from current NZ practice. In other words, the benefits of alternative CSDs would only apply to surveys after an agreed epoch; older surveys would continue to be approached as they always had been. For the Purakanui survey, a second difference would be that coordinates of all marks could be downloaded in digital form into survey software and data controllers, thus avoiding input errors from entering data again. A third point of difference is that any missing-line and ray-trace calculations done by the surveyor in the Purakanui survey would not have to be repeated; joins could now be done between any two points, saving duplication of work. A fourth point of difference would be that, in addition to the traverse marks and witness marks formerly available for checking disturbance, four new plastic boundary pegs in the Purakanui survey have been assigned monument comparison status (MCS) on the grounds that they are well-defined, surveyed with precision comparable to traverse stations and witness marks etc, and are independently checked. A study in Canada showed that monuments established at the time of survey (prior to servicing and construction) are reliable about 60% of the time (Ballantyne 2010:256), and the MCS marks in the Purakanui survey, placed after servicing and construction, are likely to have an even higher chance of surviving and thus of providing a greater pool of survey marks for future surveyors to draw on for use in the data comparison process. Briefly, the future surveyor would find sufficient well-distributed, MCS marks to carry out a transformation to determine whether any marks had been disturbed. Disturbance would be easily and clearly shown by transformation residuals. If, for any reason, the previous survey was on a different survey system (e.g. a local system) a useful by-product of the transformation would also be an average bearing swing and scale change. Once transformation parameters had been calculated between the two survey systems, computations, replacements and placing new pegs would be very simply achieved, without any need for adoptions yet without compromising relativity between marks.

A further point for discussion is the trade-off between on one hand the undeniable advantages of knowing which lines were actually observed versus, on the other, the amount of CAD work involved and the resulting clutter when lines are shown on a survey diagram. Figures A.1 and A.2 show two possible alternatives for survey diagrams, the first without and the second with broken lines showing observed rays. A further variation would be for the CAD observations shown in Figure A.2 to be added by hand to the minimalist diagram in Figure A.1, and submitted as an accompanying scan.

With reference to the issue of whether or not surveys should be properly constrained to three or more control marks on the LINZ geodetic database or just a single mark, one downside of the former option is the variable amount of additional work necessary. However, weighed against this is the fact that there is merit in having an increasing number of surveys rigorously based on the national survey control system. Another downside is that constraining a survey to the national trig system would be questionable in instances where LINZ control was inconsistent. Looking first at the far more common scenario of consistent control, adjusting/constraining traverses and GPS networks to the national system would in no way compromise relativity between marks. In the small minority of cases where control was inconsistent, misclosures and residual errors should always alert surveyors to the presence of unacceptable control and it would then be better to tie surveys to a single point. In these cases, digital OCFs could be clearly signalled as being relative to a single point (preferably that point should be on trig in order to aid searching), and future surveyors could very simply transform these surveys into improved LINZ control or into their own survey systems. Similarly, if for any other reason a future survey was based on a different survey system (e.g. a local system or a different projection), any bearing swing and/or scale change introduced in constraining coordinates to LINZ control would be accounted for when marks were checked for disturbance in the future.

Even if any or all of the core components of the prototype CSD offered in this paper were to be accepted in concept, fine-tuning would be needed by specialists at LINZ in consultation with members of the surveying profession, and further work would be needed spelling out specific changes to the 2010 Surveyor General's Rules, but it is hoped that even in their present form these sample records may provide a helpful basis for discussion.

CONCLUSIONS

It was felt that a modified Cadastral Survey Dataset as piloted in the case study:

- Offers possibilities for smaller and more portable datasets for surveys submitted to and retrieved from Landonline in the future;
- Could save work presently spent in computing missing lines or generating coordinates from sequential bearing/ distance vectors;
- Would add functionality to data retrieved from Landonline and used with current data processing software and with technologies such as GPS and Total Stations. Time savings should be possible for a variety of operations if past surveys could be uploaded into CAD/survey packages and/or Total Station or GPS data controllers;
- Would have gains especially in the data comparison process, enabling multiple comparisons to be made in a single operation when checking for disturbance of marks, calculating a bearing swing etc. In particular, coordinate transformations would be easier, by means of which many points in a past and current survey could be compared in one operation to check for disturbance. Points with high residuals could easily be rejected, and the transformation run again until small residuals are obtained for suitably configured marks. At that point, a reliable least squares bearing swing (and if necessary, scale change) could be calculated;
- Would remove one possible source of error (manual data entry) if data from an approved Cadastral survey could be automatically transferred and uploaded;
- Would produce less cluttered survey diagrams, especially for GPS surveys;
- Would produce more 'lay-person friendly' title diagrams;
- Would in no way increase opportunities for surveyors to use poor survey practice because, 'at the end of the day it is up to individual surveyors to undertake sufficient QA checks to certify their work as accurate' (Nikkel 2010);
- In areas of high crustal movement, Observation Coordinate Files would facilitate transformation if it was ever deemed necessary to apply the national deformation model to transform NZGD2000 coordinates from a previously approved survey into a current survey;
- Perhaps most importantly, survey data submitted to Landonline, stored and retrieved would be in the form of meaned and adjusted quasi-observations (in the form of coordinates) with smaller error ellipses of probability than those of the original component observations and therefore capable of producing a better survey result than is usual for current practice.

In summary, it is concluded that New Zealand's monument-based cadastre should not be supplanted by a system of legal coordinates. In other words, marks should not be replaced or parcel mutations computed on coordinate values alone. However, a number of features of New Zealand's cadastral system fail to take advantage of technology and computing methods available today, particularly the possibilities afforded by coordinate transformation. The existing system of submission and retrieval of vectors is inefficient and falls needlessly short of an optimal survey result in that generally not all of the survey data is used to calculate and archive positions with the least uncertainty. It is therefore concluded that an observation coordinate file in digital form should be archived for every survey after an agreed inception date, with Survey and Title diagrams being altered accordingly, and that in future joins between archived observation coordinates should be used for replacement from the nearest ground marks verified as undisturbed.

REFERENCES

Ballantyne, B. and Rogers, S. 2010. Nothing But Blind, Pitiless Indifference: Boundary Monuments, Deferral and the Public Interest. *Survey Review* 42(317): 256-269.

Blick, G. 2003. Implementation and Development of NZGD2000. *New Zealand Surveyor*, 293: 15-19.

Cadastral Survey Act, 2002 [12/2002] reprinted 27th March 2008, Government of New Zealand.

Goodwin, D. P. and Regedzai, F. 1997. The 'Shakedown factor' in Surveying for Title. CONSAS proceedings. Durban, South Africa.

Government of South Australia. Section 5 of the Cadastral Survey Guidelines: The Coordinated Cadastre. Land Services, South Australia. http://www.landservices.sa.gov.au/5Publications/Surveying-Drafting_Manuals_and_Guidelines/Cadastral_Survey_Guidelines/0default.asp. Accessed 12th August, 2010.

Hadfield, C. D. 1966. The Relationship of Legal Surveys to Coordinate Systems. *The Canadian Surveyor* 20(2): 97-106.

Jarroush, J. 2009. Technical Aspects of Converting Analogical Cadastral System to Digital System - A Case Study in Israel. FIG Working Week 2009. Eilat, Israel, 3-8 May 2009.

Johnstone, T. M. and Toms, K.N. 1989. Review of Adoption of Legal Parcel Coordinates in the Australian Capital Territory.

Karlsson, K. 2005. A Future Legal Coordinated Cadastre for Sweden? International Symposium & Exhibition on Geoinformation 2005, Penang, Malaysia, 27-29 September, 2005.

Lee, L. P. and Adam, R.S. 1997. *A History of the New Zealand Survey System*. New Zealand Institute of Surveyors.

McKinnon, D. 2003. Using Landonline coordinates and GPS RTK surveying. *Survey Quarterly* (34): 32,33.

Nikkel, Tony. 2010. Personal correspondence with the authors, e-mails 21/04/2010, 9:09 a.m and 11:11 a.m.

Rowe, G. 2003. The Survey Conversion Project – making a survey-accurate digital cadastre for New Zealand a reality. *New Zealand Surveyor*, 293 June 2003: 31-38.

LINZ, 2007. Review of the Rules for Cadastral Survey (15th October, 2007).

LINZ, 2010. Rules for Cadastral Survey 2010, LINZ 65000. New Zealand Government (24 May, 2010).

Simpson, S. R. 1976. *Land Law and Registration*. Surveyors Publications, London.

Toms, K. N., Grant, D.M. and Williamson, I.P. 1986. The Development of a Co-ordinated Cadastre for South Australia. *The Australian Surveyor* 33(3): 214-229.

Williamson, I. P. (1991). Cadastral Reform - An Australian Vision for the 1990s. *In*: Kadaster in Perspectief, Dienst van het Kadaster en de Openbare Registers. Apeldoorn, Holland: 175-191.

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APPENDIX

A modified cadastral survey dataset

Table A.1. Printout of an Observation Coordinate File (OCF).

SO 123456						
Section 1 Block II Town of Purakanui and Proposed Road Stopping				**Otago Land District**		
FIELD BOOK	NZGD2000 North Taieri Circuit, False Origin 800000.00mN 400000.00mE		NAME OF MARK	DESCRIPTION	F/P/ A/C	MCS
	N metres	E metres		[F: Found, P: Placed A: Adoped, C : Calc]		
				[MCS = Monument Comparison Status]		
	811678.37	427475.60	Trig 16421(A238)	Brass Plaque set in conc pillar.	-	-
	812728.90	427544.09	Trig Z (A237)	Bayonet set in conc.	-	-
	810168.74	425322.33	Trig Mopanui (A22G)	12mm stainless steel pin set in conc.	-	-
	811885.64	427082.18	OIT XXII DP 6000	Iron tube set in conc. (0.2m deep)	F	MCS
	812343.65	427291.65	OIT II DP 8775	Iron Tube (0.2m deep)	F	MCS
	812395.37	427314.24	OIS VIII DP 16092	Iron Spike (0.2m deep)	F	MCS
	812643.17	427081.09	OIT IV DP 8111	Iron Tube (0.2m deep in road)	F	MCS
	812661.50	427059.82	OIT V DP 8111	Iron Tube (0.1m deep)	F	MCS
	812643.17	427081.09	OIT IV DP 8111	Iron Tube	F	MCS
	812724.74	427216.80	OIT XIII DP 8111	Iron Tube	F	MCS
	812556.84	427185.80	IT 1	Iron Tube (0.1m deep in road)	P	MCS
3rd setup	812516.05	427183.46	IT 2	Iron Tube (0.1m deep in road)	P	MCS
4th setup	812503.34	427194.72	IT 3	Iron Tube (0.1m deep)	P	MCS
GPS Base	811688.46	427471.31	IS 4	Iron spike (0.1m deep)	P	MCS
1st setup	812643.21	427069.50	IT 5	Iron Tube (0.15m deep)	P	MCS
2nd setup	812554.25	427184.70	IT 6	Iron Tube (0.15m deep)	P	MCS
5th setup	812504.69	427230.94	IT 7	Iron Tube (0.2m deep)	P	MCS
6th setup	812550.07	427241.79	IT 8	Iron Tube (0.2m deep)	P	MCS
	812636.19	427151.20	IT I DP 8111	Iron Tube (Aug. 1954)	A	
	812654.17	427112.66	IS III DP 8111	Iron spike (Aug. 1954)	A	
	812642.96	427141.61	IS II DP 8111	Iron spike (Aug. 1954)	A	
	812669.10	427175.58	Bdy adpt DP 8111	Wooden peg (Aug. 1954)	A	
	812358.79	427271.74	III DP 8775	Iron spike (1956)	A	
	812384.31	427276.02	IV DP 8775	Iron spike (1956)	A	
	812402.98	427279.15	V DP 8775	Iron spike (1956)	A	
	812398.50	427295.34	VI DP 8775	Iron spike (1956)	A	
	812602.91	427185.85	28R29 SO14822	Wooden peg (1875)	A	
	812598.58	427190.35	28R SO14822	Wooden peg (1875)	A	
	812566.71	427195.74	27R28 SO14822	Wooden peg (1875)	A	
	812539.92	427200.26	27R SO14822	Wooden peg (1875)	A	
	812517.67	427204.02	Peg 1/R	Plastic peg	P	MCS
	812503.20	427235.00	Peg 1R2	Plastic peg	P	MCS
	812499.75	427242.39	2R9 SO14821	Wooden peg (1875)	A	
	812489.20	427264.99	9R10 SO14821	Wooden peg (1875)	A	
	812470.18	427271.56	10R11 SO14821	Wooden peg (1875)	A	
	812451.15	427278.14	11R12 SO14821	Wooden peg (1875)	A	
	812437.11	427276.99	12R13 SO14821	Wooden peg (1875)	A	
	812543.36	427238.73	1R3 SO14821	Plastic peg	P	MCS
	812536.68	427250.62	1-2 SO 14821	Plastic peg	P	MCS
	812608.31	427135.25	Peg VIII SO 14822	Wooden peg (1875)	A	
	812481.40	427168.17	IS VII SO 14822	Iron spike (1875)	A	
	812461.45	427246.36	Peg VI SO 14822	Wooden peg (1875)	A	
	812341.30	427100.68	A SO14821	Wooden peg (1875)	A	
	812278.53	427239.14	V SO14821	Wooden peg (1875)	A	

Figure A.1. Purakanui survey diagram (broken lines not shown).

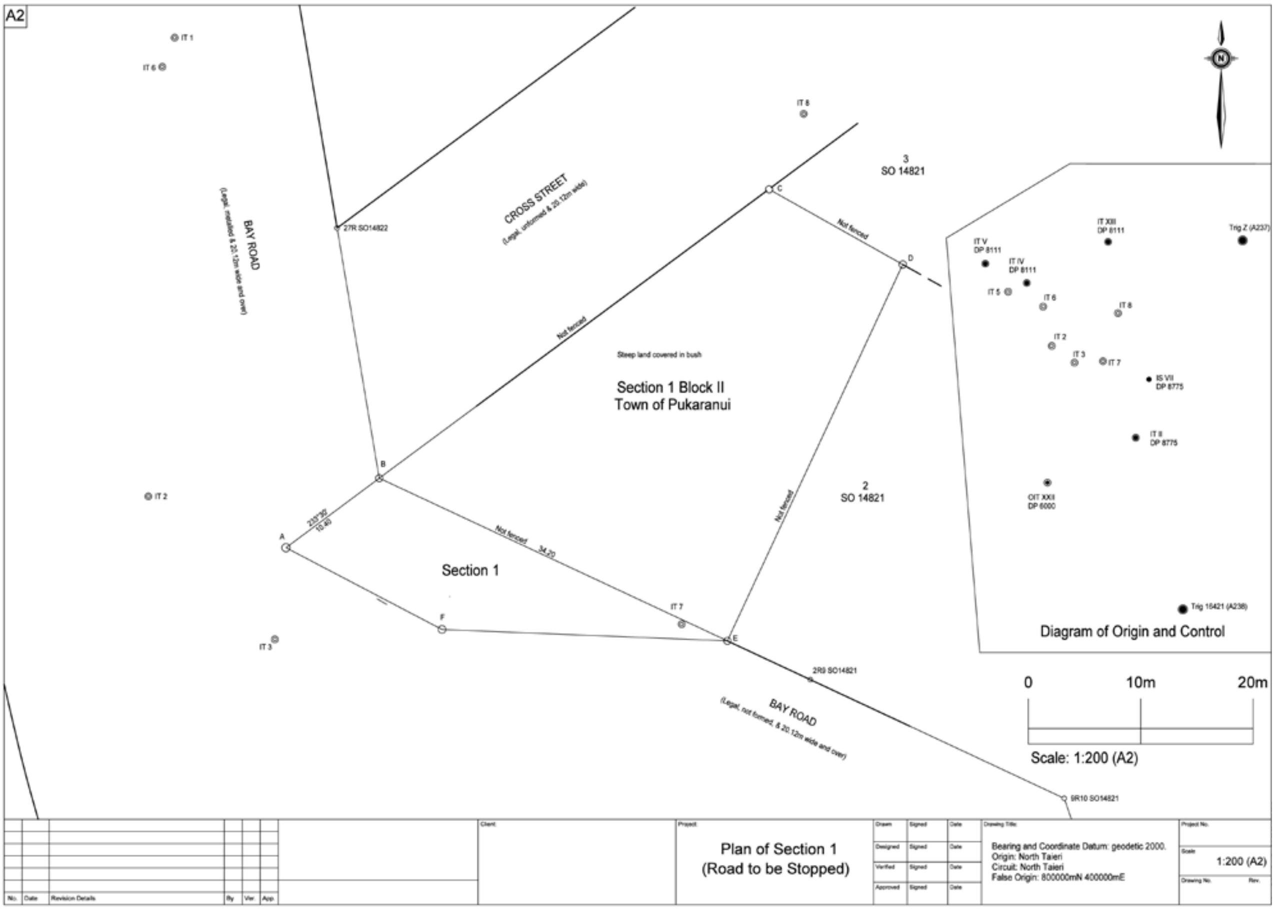


Figure A.2. Purakanui survey diagram (broken lines show observations but generally without giving bearings and distances).

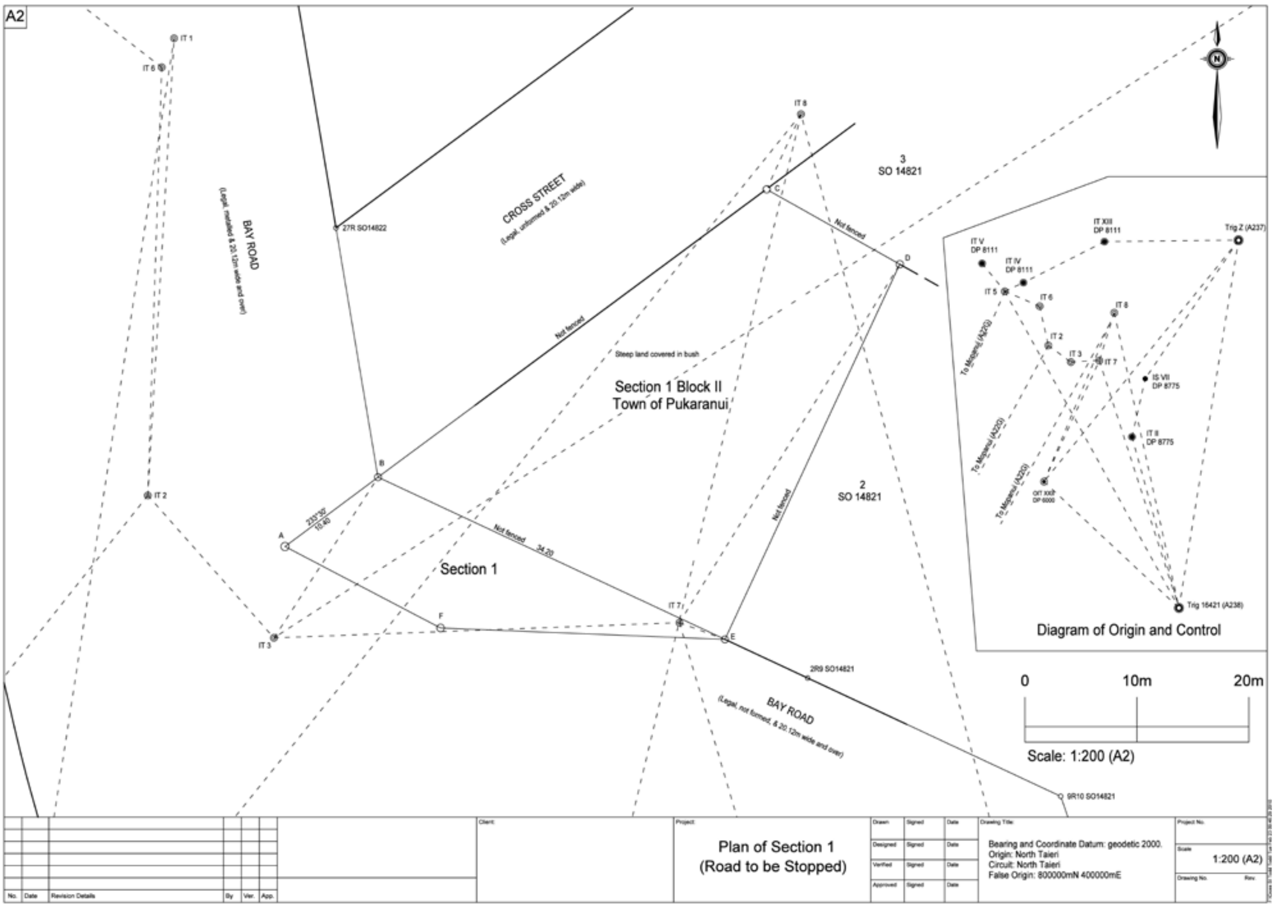
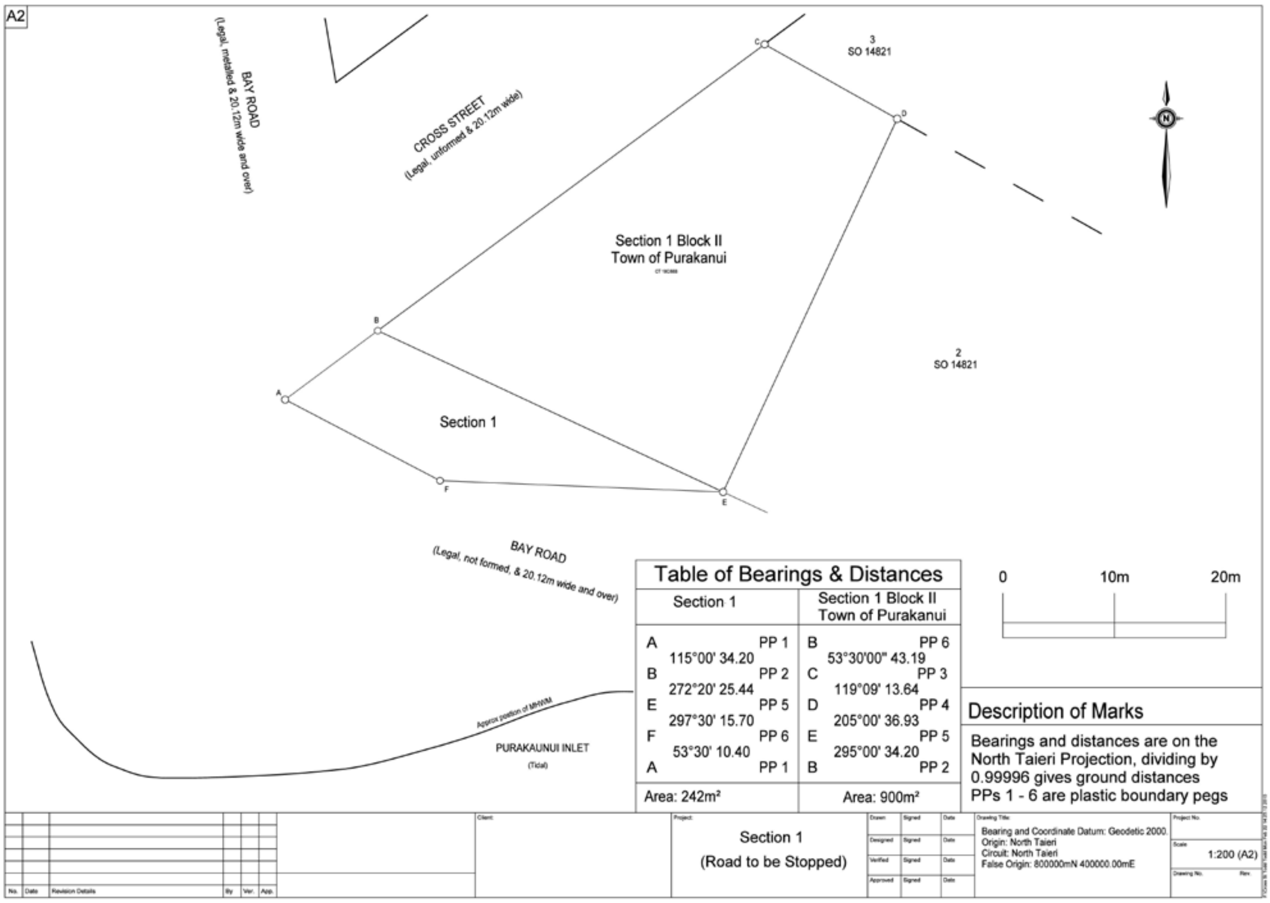


Figure A.3. Purakanui title diagram.



ENDNOTES

1 Observations for GPS surveys are in the form of baselines on the WGS84 datum, but these are usually conveniently viewed by users as coordinates in a wide variety of forms including geodetic coordinates (latitude and longitude) and coordinates on a wide variety of projections (including New Zealand's meridional circuit projections).

2 "Double ties" are considered preferable to a second fix from the same setup using different units and a different circle setting. For the latter, mis-plumbing and/or zero constant and prism errors are more likely to go unnoticed. In the 2010 Rules for Cadastral Survey, s 8.1(e) calls for "a minimum of two vectors for each boundary point and each new survey mark".

3 New Zealand's first unified survey control system was NZGD1949, followed by NZGD2000 (a semi-dynamic datum). Before NZGD1949 meridional circuits and old cadastral datums (OCDs) were independent from one another.

4 When J.T. Thomson introduced the first meridional circuits in the mid nineteenth century, a large number of small triangulations were observed as and when required (Lee and Adam 1997:7).

5 A Canadian study shows that monuments established before servicing and construction are reliable only 60% of the time [Ballantyne and Rogers 2010]. After a "shakedown" period, it may be possible to survey to lower accuracy without compromising tenure security [Goodwin and Regedzai 1997].

6 Joins might be done with COGO tools in a Total station or GPS data controller, or on a laptop computer or hand calculator

7 To give an idea of magnitudes, an ellipsoidal distance for a 2km boundary at Twizel (~465m above MSL) would be 0.15m less than a ground distance), and the projection correction for a 2km boundary on the Central Meridian on the North Taieri Meridional circuit would be -0.08m, decreasing away from the central meridian to zero (at about 57km from the CM), then increasing again.

8 In current NZ practice, boundary positions common to survey and title diagrams ought to have the same descriptor.

Letters to the Editor

17 December 2009

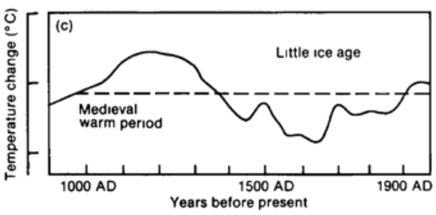
The Editor

Dear Sir,

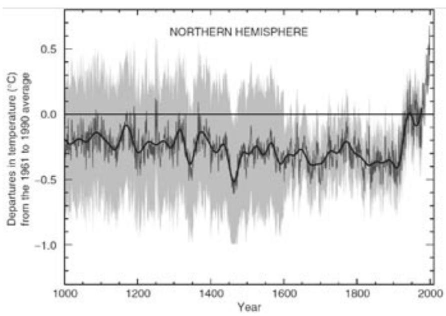
NZ Surveyor No. 299, Article 'Climate change, local government and the survey profession'

The author of this article, Mr A Milne, is a protagonist for the views that climate change is due to man-made causes, that the earth will continue to warm, sea level will rise, more extreme weather events will occur, crops will trend southwards, and threats to surveyors will include changes to district plans and hazard assessments. He also has many maybes: water supplies maybe at risk; transport links maybe challenged; sea level change may become more significant in design in coastal development; air temperature increases may impact on ski field development; dairy farm development may slow.

All of this is based on the supposed 'man-made-ness' of the (unproven) possibility that the temperature of the earth will continue to increase. This he says is shown by the incontrovertible 'hockey stick' graph of CO_2 in the atmosphere. Well, as Mr Milne hints at ('… it is madness to rely on even a 10 year trend.'), the temperature of the earth has been decreasing for ten years. There is no proven link that an increase in atmospheric CO_2 causes global warming, in fact the increases in recorded CO_2 lag years behind the increase in temperature, so CO_2 is possibly an indicator of what has happened to the temperature, but it is not a cause of it happening. There are many scientific papers by highly qualified climate scientists who have examined the data and methods used by Dr Michael Mann in producing his hockey stick graph for the IPCC, for example, *The Scientific Proposition: Global Warming*, by Dr.Willem de Lange of the University of Waikato.



IPCC Graph 1990



'Hockey stick' graph

Dr de Lange demonstrates that the hockey stick graph fails to show the known medieval warm period, which was warmer than today's world, and it fails to show the little ice age. The few temperature records the hockey stick was based on are unrepresentative, and better historic temperature data are well documented. The hockey stick is plain, bad science.

The other IPCC graph above, published in 1990, shows the medieval warm period and little ice age, so for them to adopt the hockey stick only a few years later is a blatant disregard of facts they were well aware of, and a denial of known scientific evidence. Far from being incontrovertible, the hockey stick graph has been shown by many scientists to be a complete scientific falsity. The IPCC has acknowledged this by withdrawing it from their website. This removes the basis for the IPCC concern for catastrophic global warming and much of the basis for Mr Milne's article.

It is well documented that there has been (slight) global cooling for ten years now. Warming has not been happening for over ten years, it may not happen, and the supposed urgency for mitigation measures has disappeared. The climate-gate scandal that is just starting, reveals IPCC members colluding to suppress evidence that greatly weakens their case. This is yet another of the factors that show the bias of the IPCC towards promoting the 'global warming is all bad' message when the balance of good scientific evidence is contrary to their case.

I am aware that to a degree, climate change is happening, and any changes, for warmer or for cooler, will affect society and also our profession. There is nothing new in this, as climate change has been happening for thousands of years, since long before humans were using large quantities of fossil fuels. Our profession is changing to cope with or, better still, be ahead of, various changes, which could include climate change. Whether climate change is happening or not or whether climate change is due to human causes or not, our society and cities are changing, they will continue to change, and we will do well to be ready for it. Councils will change their district plans, assessment methods will change as better methods are developed, water supplies may be at risk, dairy farm development will almost certainly slow, but all of these will most likely happen for reasons other than climate change. One change that we should prepare for, a 'maybe' that Mr Milne omitted but one that is as likely as some that he did mention, is that of the continuance of global cooling. There are a number of scientists including Dr de Lange predicting this possibility, but not predicting it as an extreme or 'tipping point' or coming apocalypse. If the IPCC message is correct (that warming is due to burning fossil fuels), then if cooling occurs should we burn fossil fuels to counteract this? This would be a nonsense to me, and it is contrary to the principle of conserving non-renewable resources (which I support). But the contrary nonsense helps expose the present IPCC view as a nonsense, or worse.

There is an 1896 photograph in the Kurow museum of the mighty Waitaki River, frozen from bank to bank and the local policeman walking across on the ice. If the current cooling trend continues this event could happen again. But in New Zealand we are still close enough to our pioneer heritage to be resourceful and adaptable, to be able to well recover from disasters, and to be ready to respond to new opportunities as they arise. My estimate is that surveyors are still near the top of those who are resourceful, adaptable, and hard working, and dare I say it, highly questioning of people who promote unproven assertions.

Yours etc.

Alan Radcliffe,
MNZIS, Licensed Cadastral Surveyor.

22 March 2010

The Editor

Dear Sir,

Comment upon Alan Radcliffe's letter re: 'Climate change, local government and the survey profession'

In answer to your request to comment upon Mr Radcliffe's letter. Firstly, Mr Radcliffe is quite correct to point out that there is controversy surrounding the issue of whether climate change, as has been observed in the last 100 to 150 years, is being forced by human activities. There are some who would hold that these changes do not have human causes, but rather are a function of other (natural) causes. Changes in the solar forcing are sometimes cited as one such cause. In support of this case, reference is often made to past (warmer) periods on Earth when it appears that global CO_2 levels were far lower than they are today. It is important to note, however, that the fact that the Earth has seen warmer periods under much lower CO_2 conditions does not invalidate the proposition that CO_2 is a significant culprit in current global warming – it merely indicates that there are, indeed, other factors in the natural system that can produce such warming. If, for example, the factors that drove the medieval period of warming were to work in sympathy with the present increase in greenhouse gases, it suggests not just a potential for the Earth to get somewhat warmer, but actually to fry! Unfortunately, many critics ignore this possibility.

Secondly, Mr Radcliffe appeals to an article by Dr Willem de Lange of the University of Waikato for support. It is important to note that Dr Lange's article was published by the *Gauntlet* magazine and not in a peer reviewed scientific journal of international standing. In other words, it would appear not to have been subject to the level of scrutiny that the very IPCC reports that Mr Radcliffe criticises are subject to. I note, for example, that Dr de Lange speaks of New Zealand sea levels having fallen by 0.03 m so far this century despite the increased levels of atmospheric CO_2. However, the existence of decadal level signals in mean sea levels have been well known for many years. It is for this reason the calculation of long term sea level trends, if they are to be robust estimates, should not be determined from data records of anything less than 50 to 60 years in length. Thus Dr de Lange's comment is not really relevant to the debate – a good peer reviewer would have flagged this issue. Having said this, and from a broader perspective, Dr de Lange's article has considerable merit and should help stimulate reasoned debate.

Thirdly, and solely on the basis of arguing against the 'hockey stick' graph, Mr Radcliffe argues that this removes the basis for IPCC concern for catastrophic global warming. It does not! He speaks of a 'Climate-gate scandal' in which IPCC members collude to suppress evidence that greatly weakens their cause. He further suggests that the present IPCC view is a 'nonsense or worse'. The reality is that the IPCC reports not only deal with issues far broader than temperatures alone, but also draw upon the best scientific knowledge available. The reports are not the product of one person, but the product of a multiplicity of experts from around the world. Moreover, they are thoroughly peer reviewed. Is it possible that in approximately 1000 pages of data and detailed analysis, there may have been an incorrect conclusion? Yes! Is it possible that the reports that constitute the IPCC document are largely rubbish? Absolutely not!

On a personal level and as a contributor to the IPCC report (at least as it relates to sea level change), I can assure Mr Radcliffe that for us there was no suppression of evidence. Indeed, I would be very happy to release all my data to Mr Radcliffe for his personal assessment. I could also add to this a time series of the raw annual mean temperatures at the four major cities in New Zealand that support clearly a warming of more than 1°C since 1900. Every scientist I know personally, who is involved in the IPCC analysis, calls the evidence as they see it. While a very few may have been tempted to argue beyond the boundary of that which the evidence can reasonably support, the vast majority are concerned only about the facts and a correct interpretation of those facts. Indeed, in a recent survey by the American Geophysical Union of over 10,000 Earth scientists from which over 3,000 responses were received, 90% were of the view that when compared with pre-1800s levels, mean global temperatures had generally risen and 82% were of the view that human activity was a significant contributing factor to this change.

Stepping back to the bigger issue at stake, it might be useful to summarise some of the elements of climate change equation that are widely accepted. These include the following –

1. Global temperatures have risen significantly (on average by about 0.6°C) over the last century. As mentioned earlier a larger increase than this is visible in the New Zealand data.
2. Global sea levels have risen at approximately 1.8 mm/yr over the same time frame. This is also visible in the New Zealand data.
3. On-shore glaciers (particularly in the mid latitude regions) have retreated dramatically.
4. Changes are occurring, both to the Greenland ice-sheet and the Arctic ice sheets, that have not before been seen in the lifetime of those presently living on Earth.
5. Long term climate change should be assessed over periods of decades rather than over a period of a few years. Over relatively short time-frames natural variability in the data tends to overwhelm any long-term signal that might be present.
6. Atmospheric CO_2 levels, along with other greenhouse gases have much higher concentrations now than at any time in the recent past.

To this I would add the observation that the human race has a history of poor management of its physical resources. Human greed and self-interest tend to outweigh other alternatives until the consequences (or unintended consequences) of such greed become unsustainable. In other words, it is consistent with human folly that we deny that we are doing unsustainable damage to the environment until the consequences become blindingly obvious.

At a macro level, then, the present debate hinges around three questions –

(a) Are humans the cause of the present increase in atmospheric greenhouse gases?

(b) Is the present warming in global temperatures (and sea level rise, etc) a consequence of this?

(c) If the answer to (b) is, “yes” what are the longer term consequences?

In answer to the first question, and while other arguments can be advanced, I would suggest that the weight of evidence presently available suggests 'yes'. As regards the second question, I appeal to the survey of earth scientists mentioned earlier. Certainly, and at least as regards sea level change, I can see no other reasonable alternative. As regards the last question, it is here that I see the greatest uncertainty. While our best analyses suggest a high likelihood of severe consequences, it is possible that the consequences may not be as predicted. In 1988 in Wellington at the NZIS Annual Conference, and in the face of the first claims of likely coastal catastrophe, I published my personal predictions for global sea level change. These were subsequently formalised in a peer-reviewed paper in the journal *Marine Geodesy*. To quote, 'Taking approximate midpoints between the high and low figures, it is suggested that a reasonable range within which to expect a eustatic sea level rise is 10–17 cm by 2025 AD and 18–35 cm by 2050 AD.' Contrary to many others who have had their more catastrophic predictions revised downwards over the intervening years, I continue to stand by these figures. As for the longer term, I also stand by the figures most recently published by the IPCC, namely for a rise in global sea levels, relative to 1990 of between 19 cm and 59 cm.

In summary, and in my view, Mr Radcliffe's letter raises questions that need to be asked. The fact that his arguments have some significant deficiencies should not detract from the debate over how our profession should respond to climate change. Nor should they detract from the wider issue of the unsustainability of our use of many natural resources. Climate change is happening and I suggest that it will continue to do so. As surveyors our response needs to be one of a careful assessment of the evidence, followed by a thoughtful, pragmatic, and measured series of actions. In doing so, let us not bury our heads in the sand by denigrating the integrity of the global scientific community through assertions of global conspiracies that in my experience just do not exist!

Yours etc.

John Hannah,
School of Surveying,
University of Otago.

22 March 2010

The Editor

Dear Sir,

NZ Surveyor No. 299, article 'Climate change, local government and the survey profession'

I am delighted that my paper has provoked such a professional response and I have the hope that it will lead to much more debate amongst our members over ensuing years.

My own views largely evolved over the period 2004 to 2007, and were based on my reading, discussions with other Mayors and Councillors (particularly about long term trends, which were actually impacting their own communities around the world), hearing visiting speakers, and attendance at a number of conferences devoted to the subject (Melbourne, Wellington and Montreal).

My observation at the time of the 2007 conference in Christchurch was that whilst I, because of my recent involvement in local government, was much more aware of the climate change issue, many surveyors were virtually unaware of the debate, and the possible long term consequences.

The thrust of my paper is three fold. I believe climate change is occurring, I believe councils' attitudes and responses to consent applications is changing, and thirdly that this will have an impact upon the work of the profession.

As to the magnitude of any change, it will be future generations of surveyors who will determine which of us was right. Let us hope that both of us are not wrong.

Yours etc.

Alan Milne.