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Contents

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Editorial

This edition comprises several articles, notes and general information. The first article from China describes their research efforts to determine a model to establish the zero calibration point for pressure-type water level/tide gauges. Their experiences with observing water levels at various sites enabled the hydrographers to determine the most appropriate modelling algorithm to correct the data and satisfactorily establish the zero calibration point.

The collaboration between national agencies and industry to provide hydrographic survey capability to meet national charting responsibilities is not new. Programs in the UK, USA and NZ have been in place for some years. In Australia, a similar program will commence in early 2020 and is discussed in the note regarding Project SEA2400. My role in the AHO is to introduce that project into operation and I therefore have an interest in learning from other HO experiences working with industry. The article from New Zealand provides an insight into the difficulties of working in challenging waters, dealing with an earthquake in the middle of the contract and having to meet the data collection requirements for two types of product to meet different needs – charting and science.

A third article from the Netherlands continues the research in determining the appropriate gridded depth model from multibeam data. Well developed models exist and have been implemented in hydrographic survey processing software, so it is of interest that there is continuing research in this field looking at alternative options.

Two notes from Chile and Australia are included. The first note describes the tidal regime in Chile's Kirke Channel and when considered with the other articles from China and NZ, is a timely reminder of the complexity of the natural world which we work in. A second note from Australia provides information of a new project to establish a panel of hydrographic survey companies to undertake surveys for Australia's national charting program. At the time of writing, the tender responses are being evaluated with the first contracts expected to be issued late 2019.

Two news items from the International Association of Oil and Gas Producers (IOGP) have been included in the General Information section. Also published via IOGP pages: http://www.iogp.org/blog/category/press-releases, the items relevant to stakeholders and the wider oil & gas industry, notify the release of:

- Geomatics Guidance Note 24: Vertical Data in Oil and Gas Applications
- Updated version of the Guidelines for the conduct of offshore drilling hazard site surveys

Finally, we include an obituary for Commander Wadhera (India). It is always sad to farewell a fellow professional and it is pleasing to recognise his achievements.

On behalf of the Editorial Board, I hope that this edition is of interest to you and may inspire you to submit a future paper on the work that you have done or are currently engaged in. Thank you to the authors for your contributions and to my colleagues who provided peer reviews for the Articles in this edition.

Ian W. Halls
Editor

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Article

CALIBRATION AND PRECISE DETECTION OF THE IRREGULAR DRIFT OF THE TIDAL ZERO POINT FOR A SHORT/MEDIUM TERM TIDE STATION

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Abstract

The tide gauge is one of the most important auxiliary sensors in hydrographic surveying. Medium and short-term tide stations are established using pressure-type tide gauges to achieve the water level control for the depth measurement along the coast. Affected by the complex marine environment, one of the main factors in determining the accuracy of the water depth measurement is the irregular drift of the tidal zero point, which is usually determined during the engineering practice. However, the relevant theoretical research on detection and correction lags. In this paper, the occurence of irregular drift about tidal zero is analyzed, and a mathematical model for precise processing of drift detection and correction is proposed. Based on the processing of nearly one month of simultaneous tide data at the long-term Dinghai station, the temporary station at Gangxin, as well as the long-term Dafeng station and temporary Sanyazi station, the effect of two daily average sea surface calculation methods on different constituents are analyzed. The results show that the new proposed model is suitable for the precise processing of irregular drift of tide zero point. After the tide zero point correction, the accuracy of the water level observation data of the short-term Gangxin and Sanyazi tide stations is improved from decimetre (dm) to centimetre (cm) levels.

Key words: hydrographic surveying; water level control; drift of the tidal zero point; daily mean sea level

Résumé

Le marégraphe est l'un des capteurs auxiliaires les plus importants en matière de levés hydrographiques. Les observatoires de marée de courte/moyenne durée sont établis à l'aide de marégraphes à pression servant à observer le niveau de la mer en vue de mesurer les profondeurs le long de la côte. Affecté par l'environnement maritime complexe, l'un des principaux facteurs permettant de déterminer la précision de la mesure de la profondeur d'eau est la dérive irrégulière du zéro hydrographique, qui repose habituellement sur les pratiques d'ingénierie. Toutefois, la recherche théorique appropriée en matière de détection et de correction a pris du retard. Dans l'article qui suit, l'occurrence de la érive irrégulière du zéro hydrographique est analysée et un modèle mathématique pour le traitement précis de la détection et de la correction de la dérive est proposé. A partir de presqu'un mois de données de marées simultanées recueillies à l'observatoire Dinghai de longue durée, à l'observatoire temporaire de Gangxin, ainsi qu'à l'observatoire Dafeng de longue durée et à l'observatoire temporaire de Sanyazi, les effets de deux méthodes de calcul quotidiennes du niveau moyen de la mer sur différentes composantes harmoniques sont analysés. Les résultats montrent que le nouveau modèle proposé convient pour le traitement précis de la dérive irrégulière du zéro hydrographique. Après la correction du zéro hydrographique, la précision des données sur l'observation du niveau de la mer des stations de courte durée de Gangxin et de Sanyazi est améliorée et passe de l'ordre du décimètre (dm) au centimètre (cm).

Mots clés : levés hydrographiques ; contrôle du niveau de la mer ; dérive du zéro hydrographique ; niveau moyen de la mer.

Article

Resumen

El mareógrafo es uno de los sensores auxiliares más importantes en los levantamientos hidrográficos. Las estaciones de mareas de medio y corto plazo se establecen utilizando mareógrafos de presión afín de lograr el nivel del mar para el control de la medición de profundidad a lo largo de la costa. Afectado por el complejo entorno marino, uno de los principales factores en la determinación de la precisión en la medición de la profundidad del mar es la deriva irregular del punto cero de la marea, que generalmente está basado en la práctica de la ingeniería. Sin embargo, la investigación teórica pertinente sobre la detección y la corrección toma su tiempo. En este artículo, se analiza la ocurrencia de deriva irregular sobre el punto cero de la marea, y se propone un modelo matemático para el procesado preciso de la detección y corrección de la deriva. Basándose en el proceso de casi un mes de datos de mareas obtenidos simultáneamente en la estación Dinghai de largo plazo, en la estación temporal de Gangxin, y también en la estación Dafeng de largo plazo y la estación temporal de Sanyazi, se ha analizado el efecto de dos métodos diarios de cálculo de la superficie media del mar en diferentes componentes. Los resultados muestran que el nuevo modelo propuesto es adecuado para el proceso preciso de la deriva irregular del punto cero de la marea. Después de la corrección del punto cero de la marea, se ha mejorado la precisión de los datos de observación del nivel del mar de las estaciones de marea de corto plazo de Gangxin y Sanyazi, de niveles de decímetros (dm) a centímetros (cm).

Palabras clave: levantamientos hidrográficos; control del nivel del mar; deriva del punto cero de la marea; nivel del mar medio diario.

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1. Introduction

Hydrographic surveying comprises three major measurement criteria: geodetic position, bathymetric depth and water level control (Liu Y, 2003; Zhao, 2007; Xiao et al., 2016). Monitoring of water level control involves installing tide stations, using tidal harmonic predictions and includes non-tide depth determination based on GNSS techniques (Ke, 2012; Zhao et al., 2008; Zhao et al., 2015). When monitoring water level, the length of the observing period for a tide station can be divided into long-term, medium-term and short-term classifications. Long-term station observations are essential for marine environmental monitoring, harbor design and navigation charting. Detecting and correcting gross and systematic errors of long-term tide gauge stations is achieved using tidal harmonic analysis, probability theory and mathematical statistics (Zhao et al., 2007). For medium-term and short-term tide gauge stations, the water level observation time period is much shorter.

A pressure tide gauge positioned at a fixed-point layout has the advantage of being flexible and of high precision for water level determination when applied to coastal depth measurements. This technology is a common tide measurement method for ocean depth measurement (Liu Y, 2003; Zhao, 2007; Xiao et al., 2016). When installed, the gauge and its housing can be affected by the instrument housing engineering, the settlement of the device on a potentially unstable seabed and other physical effects. Due to these factors, the pressure gauge can produce an irregular jitter that is difficult to eliminate, and will directly affect the tide analysis precision, ultimately affecting the quality of water depth measurement correction (Xiao et al., 2016; Ke, 2012). The Manual on Hydrography (IHO, 2005) attaches great importance to this issue, for this can also lead to serious errors in subsequent benchmark conversions. The drift in the zero point of the pressure gauge cannot be monitored and corrected in real time during the tide observation. It can only be analyzed when the data is returned after the tide observations are finished. Drift in the zero point cannot be adequately determined on medium and short-term tide station data. It should be detected though, based on the strong correlation with the daily mean sea level measured at adjacent long-term tide stations. Such measurements can then be subjected to a method (i.e. sliding mean sea level for each 24 hour) to calculate the average daily sea surface of two tide stations to check how the outcomes can be practical applied (Liu L et al., 2007).

The time synchronization between two stations should be controlled within 24 hours after studying the time varying law of the parameters of the least square water level fitting model (Xu et al., 2007). The method of least squares fitting and the number method are combined to determine the zero point settlement, the specific time of settlement, the efficiency of detection and the accuracy of the correction to be improved (Ke et al., 2013). According to the IHO (2005), if irregularities are found in the quality check of the tide data from the adjacent two tide stations, it is necessary to study whether the difference is caused by the tide gauge malfunction, the sensor drift or other abnormal height changes. The similarity of daily mean sea level can be used to solve it, but does not explicitly express how to calculate the daily mean sea level. It is also known that, for the problem of irregular drift of tide zero point, it is detected and corrected by calculating the difference between daily mean sea level based on the premise of daily mean sea level similarity in the domestic and international hydrographic field. The effect of short-period tidal data will exist if the daily mean sea level is calculated by the mid-range method, which will affect the detection and correction of the irregular drift of the tide zero point (Huang C et al., 2013).

In view of the uncontrollable occurrence of irregular drift in the tide data acquisition processing when using a pressure tide gauge, as well as the lack of published research on precision and detection of these issues, the authors' first analyze the formation mechanism of irregular drift at the zero tide. They then put forward the corresponding precise processing model for drift detection and correction. This can then determine a precise time and quantified settlement of the tide zero point and achieve the precise processing of the correction and detection of the zero point irregular drift.

2. Precise processing for the irregular drift of tide zero point

2.1 Establishing a processing model for irregular drift of tide zero point

The pressure tide gauge is a device with a pressure sensor for measuring water level. The pressure value at a fixed depth position underwater is measured in real time, and then the air pressure value is subtracted. The pressure difference between the two values is converted to the height from the pressure sensor to the instantaneous sea surface, to provide a real-time water level observation. The parameters of the tide gauge will be fixed once in the water, and will not change as external environmental factors change, so the collected data should be corrected by the pressure and density data as soon as the gauge is taken out of the water (Xiao et al., 2016). After the correction of the air pressure and density, the systematic bias of the tide data in the vertical direction is mainly due to the linear and non-linear drift of the tide zero point. This includes the internal drift of the instrument and the irregular drift caused by many external environmental factors.

The first correction principle is relatively simple, and can be accurately calibrated with equipment in a controlled environment such as a laboratory. The second correction can only be analyzed and corrected after the tide observation is over.

This paper focuses on how to solve the second type of irregular zero point drift.

The hourly tide values ($\zeta(t)$), starting from the tide zero point of the pressure tide gauge, can be expressed as:

$$\zeta(t) = MSL + \sum_{i=1}^{m} f_i H_i \cos(\sigma_i t + v_i + u_i - g_i) + \delta(t) + \varepsilon(t)_{MSL} \quad (1)$$

Where, MSL is the long-term mean sea level, H_i and g_i are amplitude and phase lag constitutes, f_i and u_i are the nodal factor and nodal angle, m is the number of constituents, σ_i is the angular velocity, v_i is the astronomical initial phase angle, $\delta(t)$ is increasing or decreasing water, $\varepsilon(t)_{MSL}$ is the hourly drift of the tide zero point (Liu Y, 2003; Zhao J, 2007; Xiao et al., 2016).

Assuming that the long-term tide gauge station is A, and the medium-term and short-term tide gauge station with the pressure gauge is B, normally, $\varepsilon_A(t)_{MSL}$ is 0, thus the difference in the daily mean sea level between the two stations, A and B can be expressed as:

$$\Delta = (MSL_A - MSL_B) + (\overline{h_A} - \overline{h_B}) + (\overline{\delta_A} - \overline{\delta_B}) - \overline{\varepsilon_B(t)}_{MSL} \quad (2)$$

Where $\overline{h}$, $\overline{\delta}$, $\overline{\varepsilon_B(t)}_{MSL}$ are astronomical tide, the increase and decrease of water and the average drift of the B station during the observation period, respectively.

Considering the requirements of the hydrographic survey, the distance between the two tidal stations A and B is generally small. Due to the strong correlation between the increase and decrease of water in a certain spatial scale , $\delta_A(t) \approx \delta_B(t)$ thus $(\overline{\delta_A} - \overline{\delta_B}) \approx 0$ (Ke, 2013, Liu L et al., 2007; Huang C et al. 2007; Huang C et al., 2013; Pei et al., 2007). Equation (2) can be re-written as:

$$\Delta = (MSL_A - MSL_B) + (\overline{h_A} - \overline{h_B}) - \overline{\varepsilon_B(t)_{MSL}} \qquad (3)$$

The daily mean sea level of the adjacent tide stations is strongly correlated. Hence the trend of the two stations should be similar and the magnitude should be close to the value. If the tide zero point of the A and B stations are stable, $MSL_A - MSL_B$ should be a constant and $\varepsilon_B(t)_{MSL} = 0$. The difference in the daily mean sea level between the two stations (Δ) reflects the regular tidal variation caused by the effects of different harmonic constituents. Hence $(\overline{h_A} - \overline{h_B})$ magnitude should be at the cm level (Huang C et al., 2007; Huang C et al., 2013).

If the zero point of the B station is unstable for the tide gauge which has been calibrated indoors, the tide zero point drift will be added to Δ and $\varepsilon_B(t)_{MSL} \neq 0$. The magnitude may be dm or even larger. This will seriously affect the subsequent analysis and use of the tide gauge data. Therefore, in a practical engineering application, the error analysis and detection of the observation data of the medium-term and short-term tide gauge stations should be conducted in advance to determine whether irregular drift exists at the tide zero point. If the value $\varepsilon_B(t)_{MSL}$ is much larger, further corrective action should be taken.

The $\overline{\varepsilon_B(t)_{MSL}}$ should dominate the Δ value and hence $\varepsilon_B(t)_{MSL} \approx \Delta$. The tidal observation of station B can be calibrated by the following formula:

$$\zeta_B'(t) = \zeta_B(t) + (MSL_A - MSL_B) + (\overline{h_A} - \overline{h_B}) - \overline{\varepsilon_B(t)_{MSL}} \qquad (4)$$

This paper establishes a precise model for the irregular drift of the tide zero point. Compared with the reference writing by Ke (2012), the model can ensure the precise time and the value of the tide zero point settlement in one effort.

2.2 Selection of an optimal model for calculating daily mean sea level

If the tidal observation period is long enough to be greater than 1 year, the data from the two tide gauge stations can be analyzed for long-term harmonic analysis based on equation (1) and $(\overline{h_A} - \overline{h_B})$ and $(\overline{\delta_A} - \overline{\delta_B})$ can be calculated accurately. This method can accurately detect and correct the specific time and magnitude of the irregular drift of the B station tide gauge zero point. However, the observation period of the medium-term and short-term tide gauge stations is generally shorter than 1 year or even shorter than 6 months, which does not have the fine tidal harmonic analysis conditions mentioned above.

The key to using formula (4) is how to weaken the tidal vibration caused by the inconsistency in the astronomical tide at the two tide stations, being $(\overline{h_A} - h_B)$. The drift of the zero point of the B tide gauge station is presented as $(MSL_A - MSL_B) - \overline{\varepsilon_B(t)_{MSL}}$. Therefore, this section focuses on how to improve the calculation accuracy of the daily mean sea level.

Daily mean sea level determination predominantly uses the Mean Method (Ke et al., 2012; Liu L et al., 2010), and the mathematical model is:

$$S_0 = \sum_{t=0}^{23} \varsigma(t) \Big/ 24 \tag{5}$$

The corresponding filter spectrum H_{M_0} is,

$$H_{M_0}(\sigma) = \frac{\sin 12\sigma}{24 \sin \sigma / 2} \tag{6}$$

An alternative mathematical model for calculating the daily mean sea level is the Godin Method (Huang C et al., 2013; Huang Z et al., 2005) expressed as:

$$S_0 = \frac{1}{25^2 \times 24} \sum_{j=1}^{24} Y_j \tag{7}$$

$$Y_j = \sum_{i=0}^{24} X_{i+j} \tag{8}$$

$$X_i = \sum_{t=0}^{24} \varsigma_{t+i} \tag{9}$$

The corresponding filter spectrum H_{G_0} is:

$$H_{G_0}(\sigma) = \left(\frac{\sin 12\sigma}{24 \sin \sigma / 2}\right) \times \left(\frac{\sin 12.5\sigma}{25 \sin \sigma / 2}\right)^2 \tag{10}$$

The parameter σ in equations (6) and (10) represents the angular velocity of a tidal component. The filter spectrum shows the attenuation factor of the tidal constituent. The magnitude of the absolute value correlates to the filtering ability of the tide (Liu Y, 2003). According to equations (6) and (10), the spectral values of several years, six months, months, half months, days, half days and shorter periods are calculated respectively. The weakening effect of equations (5) and (7) on $(\overline{h_A} - \overline{h_B})$ is quantified and Q_1, O_1, P_1, K_1, N_2, M_2, S_2, K_2, M_4, M_{S4}, M_6, S_a and S_{Sa} are the 13 main constituents that dominate the change of tidal motion in tidal harmonic analysis whilst the amplitude of the remaining constituents is smaller. The spectral values of different periods are calculated using the Mean and Godin methods and are shown in ***Table 1***.

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Table 1. Spectrum of Tidal Components about different Cycle between Mean and Godin methods

Constituent Name	Constituent Type	Mean Method	Godin Method
Q_1	diurnal	0.117555	0.000649
O_1		0.075374	0.000081
P_1		0.111790	0.000526
K_1		0.002738	0.000005
M_1		0.035077	0.000001
MP_1		0.069196	0.000050
M_2	semidiurnal	0.035160	0.000001
S_2		0.000000	0.000000
K_2		0.002762	0.000005
N_2		0.054448	0.000009
O_{Q2}		0.093161	0.000261
R_2		0.001383	0.000002
M_4	1/4	0.035497	0.000002
M_{S4}		0.017872	0.000010
M_{N4}		0.044559	0.000000
M_6	1/6	0.036082	0.000002
M_8	1/8	0.036960	0.000002
M_{10}	1/10	0.038202	0.000003
M_{12}	1/12	0.039933	0.000004
M_f	Semi-monthly	0.991224	0.972437
M_{sf}		0.992485	0.976366
M_m	Monthly	0.997839	0.993163
S_{sa}	Semi-annual	0.999951	0.999844
S_a	Annual	0.999988	0.999961

As shown in ***Table 1***, the Godin method reduces the effect of Q_1 constituent in $\bar{h}$ from 11.76% to 0.07%. When compared with the Mean method, the effect of weakening the P_1 constituent reduces from 11.18% to 0.05%, and the effect of weakening the O_1 constituent reduces from 7.53% to near 0.00%. The effect of weakening the M_2 constituent reduces from 3.52% to nearly 0.00%. If the Mean method is adopted, the amplitude of the diurnal constituents and semidiurnal constituents are always dm levels and the effect of the short period constituents in $(\overline{h_A} - \overline{h_B})$ can also be dm level. If the Godin method is adopted, the effect of the short period constituents in $(\overline{h_A} - \overline{h_B})$ can be nearly 0.00%. Overall, the Godin method is considered better than the Mean method in weakening the effect of the diurnal, semidiurnal and short period tidal constituents.

The effect of the two methods is basically the same in weakening the annual, semiannual, monthly and semi-monthly period constituents, which reflects that the daily mean sea level has no weakening ability to the tide constituents when the period is over the daily cycle. Generally, the amplitude of the monthly and semi-monthly constituents are at cm level whilst the amplitude of the annual, semi-annual constituents are dm level, so $\bar{h}$ mainly includes the effect of the annual and semi-annual constituents. From tidal harmonic analysis, there is a large spatial scale in the annual and semi-annual constituents and there is no obvious difference between the amplitude and the lag angle over several kilometres between the stations. Therefore, the non-diurnal period of tide in $(\overline{h_A} - \overline{h_B})$ should be at the cm level.

Based on the analysis above, the accuracy of Δ when calculating the daily mean sea level of the tide station could be improved from dm to cm level using the Godin method and equation (3) rather than the Mean method. The outcome being the observation quality of the tidal level of B tide gauge station can be greatly improved after correcting the irregular drift of the zero point.

3. Analysis of Results

3.1 Analysis of Dinghai and Gangxin Station Data

The tidal data collected at the Dinghai long-term station and the Gangxin short-term station near the Zhoushan Islands in Zhejiang Province in the 6 November – 7 December 2014 synchronization period is used as an example. The linear distance between the two tide gauge stations is about 25km and the tidal properties are all regular semidiurnal tide. A RBR TGR-2050 self-contained pressure tide gauge was used at the Gangxin station and the approximate position of the two stations is shown in ***Figure 1***.

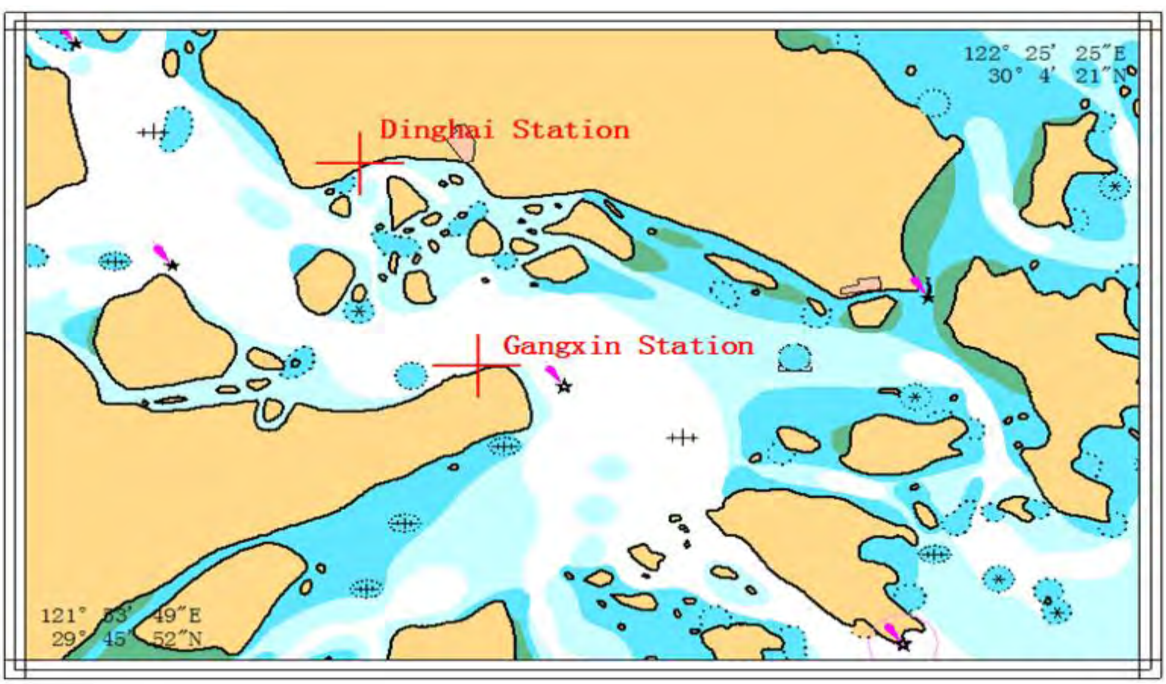

Figure 1. *Approximate position of the Dinghai and Gangxin tide stations*

The internal tide zero point drift of the Gangxin station was calibrated prior to deployment. The tidal data collected after the gauge was taken out of the water was corrected by air pressure and density data. First, the tidal data at the same time in Dinghai station are deduced to the long-term average sea level of the station. Since the depth of the zero point of the Gangxin station can be arbitrarily assumed, the tidal observation data of the station is reduced by a constant in order to conveniently compare the tidal data of Dinghai station in the depth direction. As the tidal data in Gangxin station is shifted in the depth direction, the water level observation value curves for the two stations are shown in ***Figure 2***.

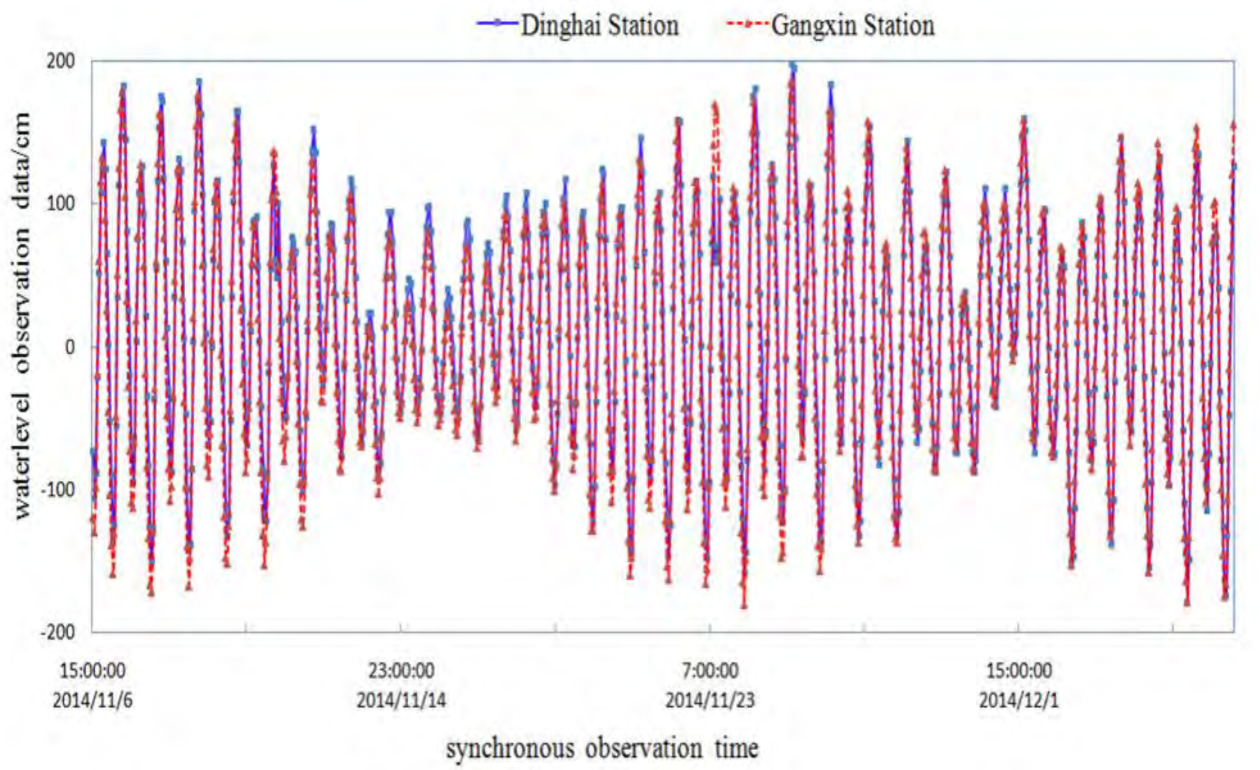

Figure 2. *Original Synchronized Tide Obervations between Dinghai and Gangxin*

It can be seen from ***Figure 2***, that in the period of 11 - 26 November 2014, the water level curve (red) of Gangxin station is beneath the water level curve (blue) of Dinghai station, and the difference is not consistent. However, during the 27 November – 5 December 2014 period, the water level curves of the two stations are basically consistent.

As Dinghai station is a long-term tide station, the tide zero point is stable and reliable, and its data quality is managed through strict controls. Therefore, the water level observation value of the Gangxin station has an irregular zero drift in at least one of the above-mentioned periods, and the maximum value reaches about 30 cm. Hence the specific time and the value of the irregular drift of the tide zero point in Gangxin station should be used for further detailed detection.

3.2 Comparison of calculating daily mean sea level

The Mean Method (equation 5) and the Godin Method (equation 7) were used to calculate the daily mean sea level and the mutual difference. These methods would test whether the accuracy of the calculation can be increased from dm to cm level as discussed in Section 2.2. The results are presented in ***Figure 3***.

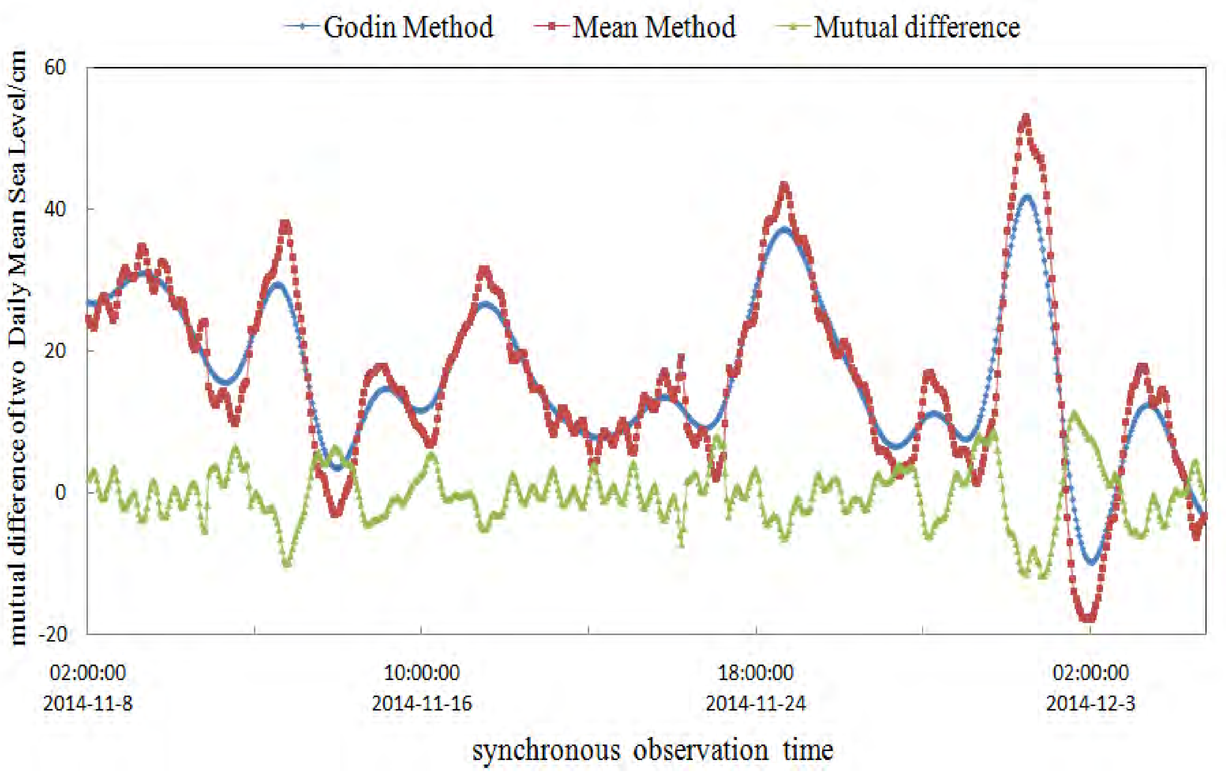

Figure 3. *Mutual difference of two different Daily Mean Sea Level of Dinghai*

From ***Figure 3***, it can be seen that the jitter in the daily mean sea level calculated by the Mean method is more volatile than that of the Godin method and that shorter periodic disturbances are superimposed. The mutual difference of the mean sea level calculated by the two methods is in the range of -12 to 12cm. This indicates that the calculation results using the Mean method are significantly affected by the daily and even shorter tidal constituents. The daily mean sea level calculated by the Godin method is more stable and is consistent with the theoretical analysis of Section 2.2. Therefore, in engineering practice, the Godin method (equation 7) is preferred to calculate the daily mean sea level.

3.3 Precise processing the irregular drift of tide zero point at Gangxin Station

The daily mean sea level and the mutual difference between the daily mean sea level of Dinghai station and Gangxin station are calculated using the Godin method and the partial results are shown in ***Figure 4***.

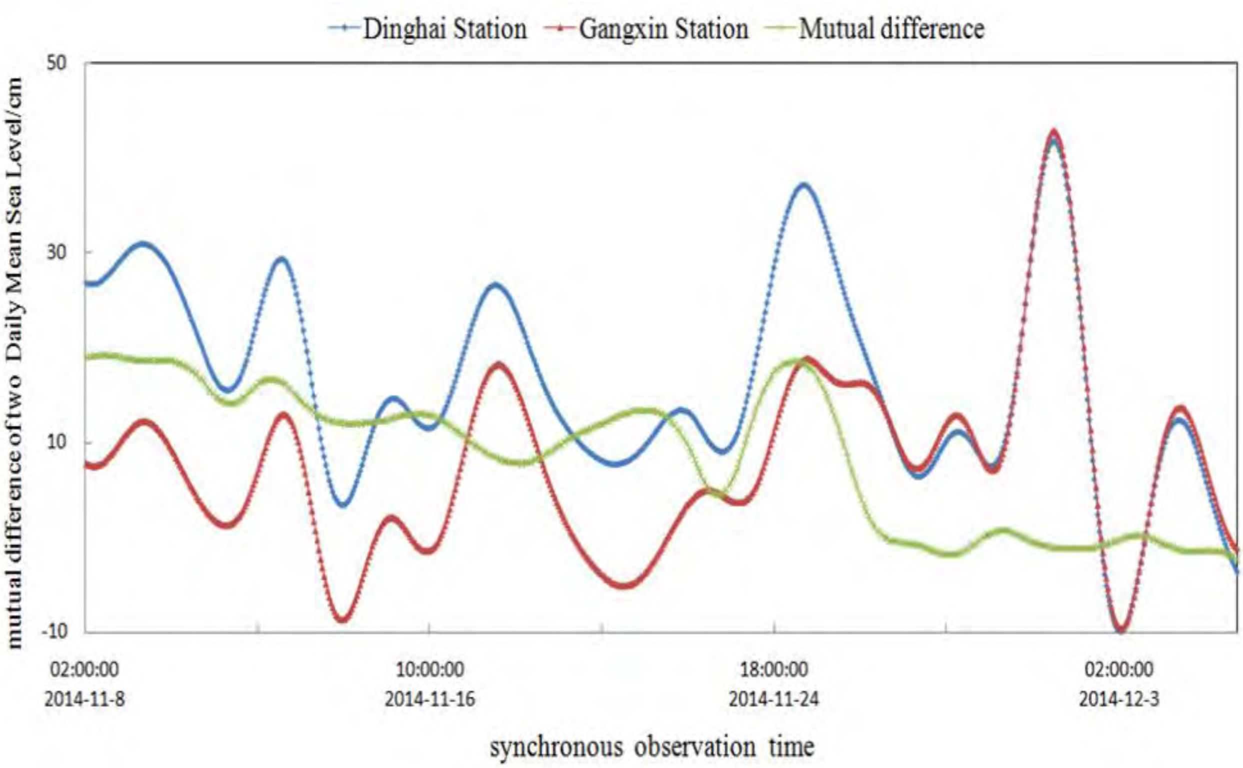

Figure 4. *Mutual difference of Daily Mean Sea Level using the Godin Method between Dinghai and Gangxin*

As shown in ***Figure 4***, during the period of 8 – 27 November 2014, the mutual difference in the daily mean sea level between the two stations ranges from 0 to 20 cm, with continuous and circuitous irregular changes. This shows that the tide zero of the Gangxin station point has circuitous irregular drift. This may be the result of strong ocean currents and the supports of the tide gauge being displaced, overturned or fallen. In this case, a strong irregular jitter at the tide zero point occurs and the drift is significant, requiring the data of this period to be zero point corrected. The phenomenon is more complicated than the simulated data used in the reference writing (Ke, 2012), and the processing is more difficult. In the period of 27 November – 27 December 2014, the mutual difference between the two mean sea levels ranges between -1.5 to 0.3cm. The drift value is in the cm level, and the tide zero point is considered stable during the period. It can be determined that the data between 27 November and 5 December 2014 is reliable for the Gangxin station.

To rectify the mutual difference of the daily mean sea level between the Dinghai station and the Gangxin station shown in ***Figure 4***, equation (4) was used to correct the zero point drift of the whole observation data in Gangxin station during the 6 - 27 November 2014 period. The daily mean sea level and the mutual difference between the two stations was recalculated using the Godin method to assess the actual effect of tide zero irregular drift correction in Gangxin station. Partial results are shown in ***Figure 5***.

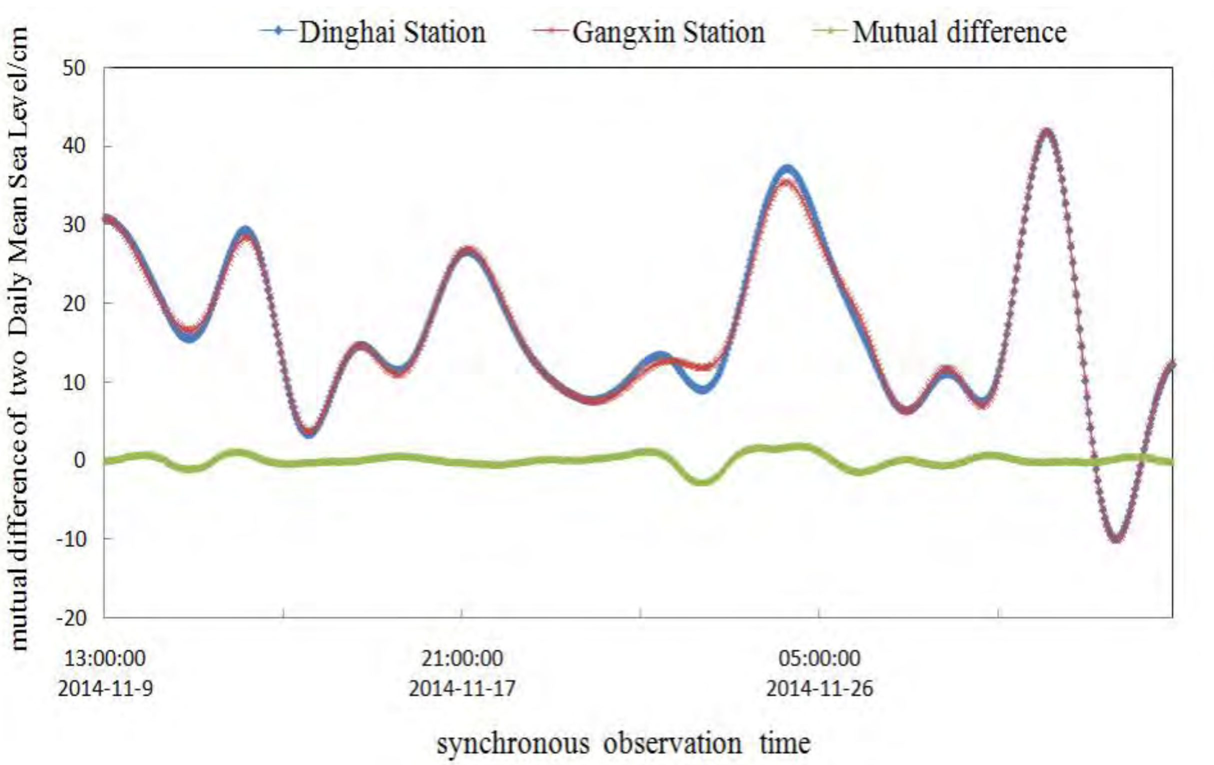

Figure 5. *Mutual difference of Amended Daily Mean Sea Level by the Godin Method between Gangxin and Dinghai*

Comparing ***Figures 4*** and ***5*** following the irregular drift correction of the tide zero point in Gangxin station, the mutual difference of the daily mean sea level between the two stations during 6 November - 7 December 2014 synchronization period is now -2.8 to 1.2cm and the variation range is at the cm level. The difference is mainly caused by the inconsistency of the amplitude and the lag angle of the non-daily period of the two stations of which the magnitude is within the reasonable range. This shows that the tide zero point of the Gangxin station has basically reached a stable state after correction. In this case, the range of zero tidal correction is from 0 to 20cm. From this work, the accuracy of the water level observation data has significantly improved from dm level to cm level after the correction of the tide zero point in Gangxin station.

3.4 Analysis of Jiangsu Dafeng and Sanyazi Station Data

To further validate the precision processing model of the tide zero point proposed in this paper, the hourly data collected between 1 – 31 July 2016 in Jiangsu Dafeng harbour long term tide station and Sanyazi short term station were analyzed.

The linear distance between the two tide gauge stations is about 30km. The tidal properties are similar, being regular semidiurnal tide ports and the difference of tidal time between the two stations is about 50 minutes. The Sanyazi station uses the RGB-3050 self-contained pressure tide gauge. The locations of the two stations are shown in ***Figure 6***.

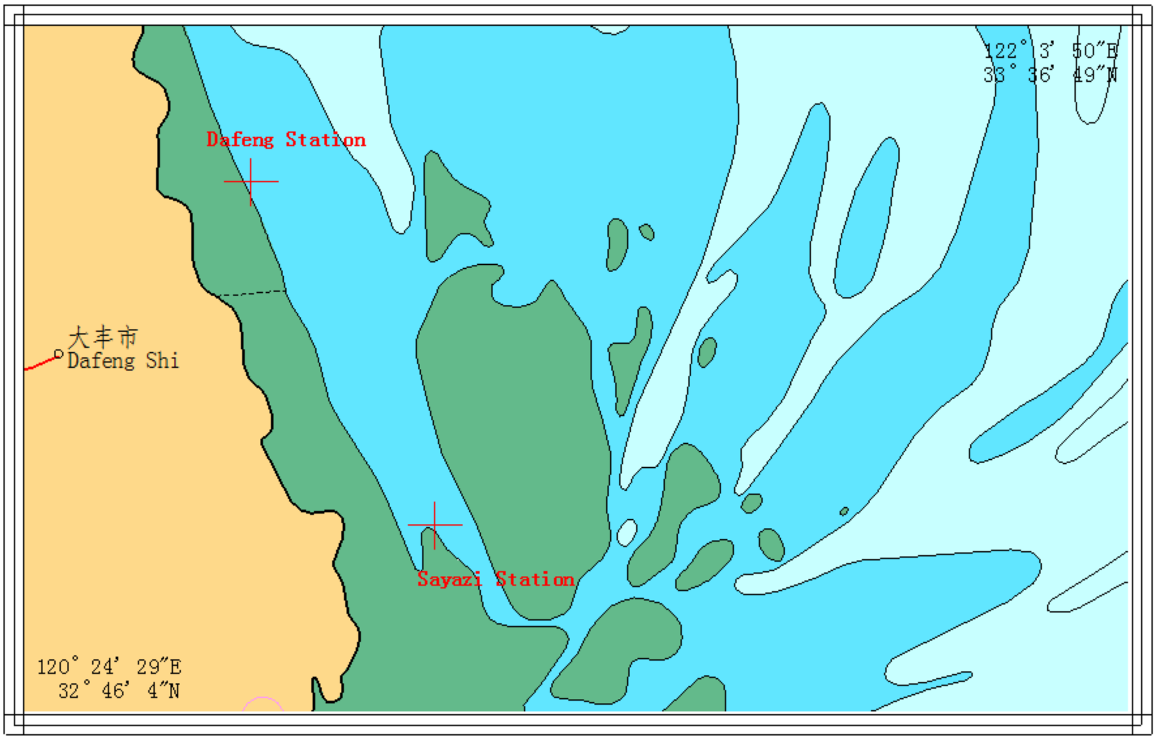

***Figure 6.** Approximate Position of the Dafeng and Sanyazi tide stations*

The tide gauge and data pre-processing used in Sanyazi station are the same as those used at Gangxin station. The synchronous water level curve of the two stations is shown in ***Figure 7***.

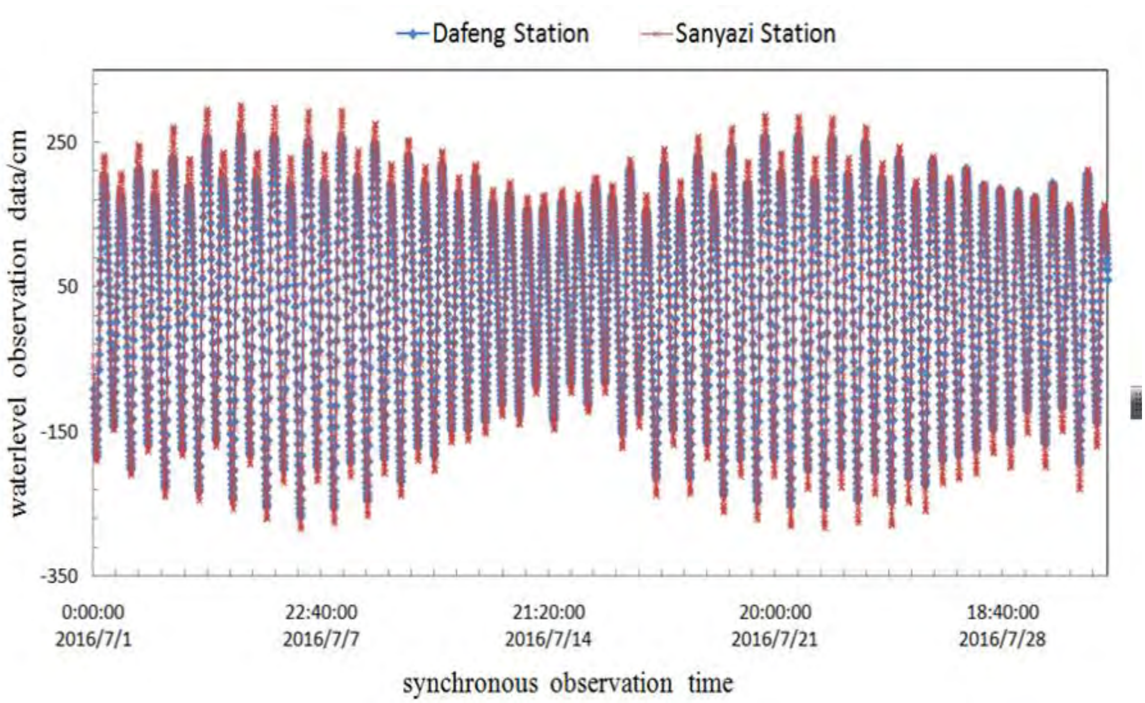

***Figure 7.** Original Synchronized Tide Obervations between Dafeng and Sanyazi*

It can be seen from ***Figure 7,*** that the water level curve (red) of the Sanyazi station is higher than the water level curve (blue) of Dafeng Station during the period of 1 – 14 July 2016 and the difference is not constant. During the period 21 – 31 July 2016, the water level curve of the Sanyazi station is lower than the Dafeng station and the difference is also not constant. When compared with the water level data of the Gangxin station in ***Figure 2***, the tide zero point of the Sanyazi station in the above-mentioned period has a nearly linear irregular drift, with the drift being more significant than that of the Gangxin station.

The daily mean sea level and the mutual difference between the two stations was recalculated using the Godin method to assess the actual effect of tide zero irregular drift correction in Gangxin station. Partial results are shown in ***Figure 8***.

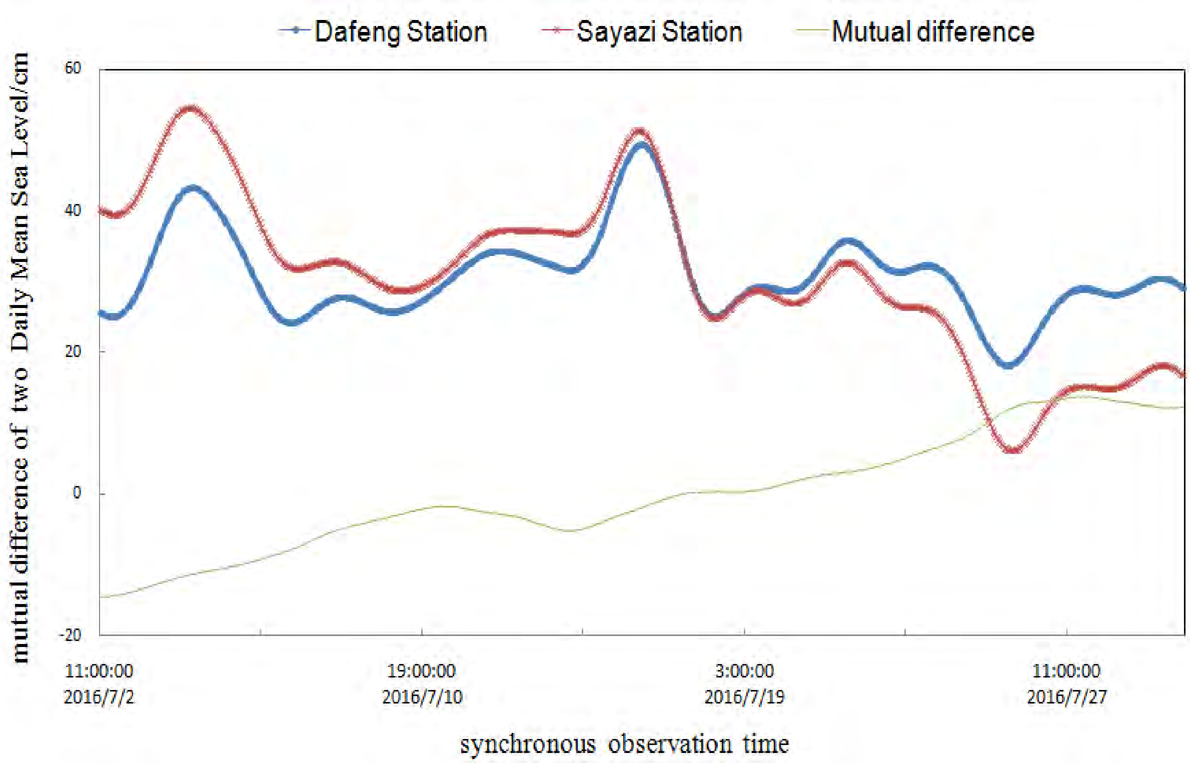

Figure 8. *Mutual difference of different Daily Mean Sea Level between Dafeng and Sanyazi*

Figure 8 shows that the mutual difference of the daily mean sea level of the two stations is -14 to 13cm during the 1 – 31 July 2016 period, and that the change is continuous and irregular. This indicates that the tide zero point in Sanyazi station has been in an unstable state. Sanyazi station is located in the Subei area where the maximum tidal range can be up to 7m. The tidal trend in the area is rapid with the zero point change irregular. This makes planning temporary tide stations difficult.

To rectify the mutual difference of the daily mean sea level between Dafeng station and Sanyazi station shown in Figure 8, equation (7) was used to correct the zero point drift of the whole Sanyazi station observation data during 1 - 31 July 2016. The daily mean sea level and the mutual difference between the two stations was recalculated using the Godin method to assess the actual effect of tide zero irregular drift correction in Sanyazi station. Partial results are shown in ***Figure 9.***

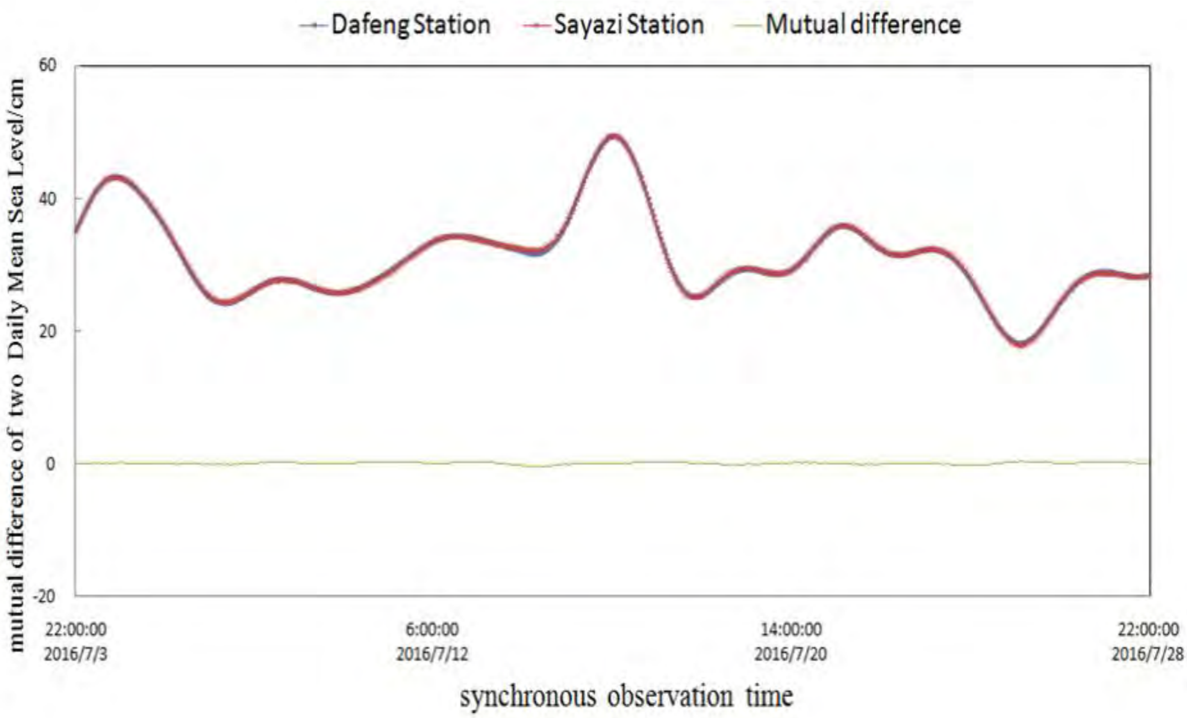

Figure 9. *Mutual difference of Amended Daily Mean Sea Level by Godin Method between Dafeng and Sanyazi*

Comparing ***Figures 8*** and ***9***, following the irregular drift correction of the tide zero point in Sanyazi station, the mutual difference of the daily mean sea level between the two stations during 1 – 31 July 2016 synchronization period is now -0.1 to 0.2cm and the variation range is at the cm level.

Comparing the locations of Dinghai and Gangxin station (***Figure 1***), there are several island barriers, whilst no island barriers exist between Dafeng and Sanyazi stations (***Figure 6***). Although the distance between the latter two stations is larger than the former stations, the tidal characteristics are more similar, hence the effect caused by the inconsistencies of amplitude and phase of the non-daily constituents is also smaller. This can be seen in the comparison between the magnitudes of the mutual difference of daily mean sea level in ***Figures 5*** and ***9***. ***Figure 9*** shows that the tide zero point in Sanyazi station has basically reached a steady state after correction and the zero tidal correction is in the range of -14 to 13 cm.

The accuracy of the observation data has improved from dm level to cm level after the tide zero point correction in Sanyazi station. Although the irregular drift of the Sanyazi station is more significant than that in the Gangxin station, it is simpler to correct the tide zero point, as the tide zero point of Sanyazi station is in a linear drift and the accuracy of the correction is also improved.

4. Conclusion

In this paper, a precise processing model for determining and correcting irregular drift of tide gauge stations in medium-term and short-term tide stations is established, and quantitative analysis is carried out through practical examples. The results show that the new model improves calculation processing, efficiency and accuracy as follows:

- It is feasible and reasonable to adopt the mutual difference of the daily mean sea level as the parameter to detect the tide zero point drift in medium-term and short-term tide stations;

- The daily mean sea level calculated by the Godin method has advantages compared with the Mean method in weakening the influence of diurnal, semidiurnal and even shorter constituents. This is equivalent in weakening the effect of the constituents over diurnal period;
- According to the Godin method, the daily average sea surface is calculated and the detection of tide zero point irregular drift is determined. From field work, the accuracy of the tidal observation data of the Gangxin station is improved from 20cm to cm level. The accuracy of the tidal observation data of the Sanyazi station is improved from 27cm to cm level.

It should be noted that medium-term and short-term tide stations do not have the basic observation periods for accurately determining the astronomical tide level and increasing or decreasing the water using the long-term tidal harmonic analysis. We can however detect and calibrate the random drift of the tidal zero based on the premise of the average sea surface similarity. This is widely practiced in the international hydrographic field.

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Article

EARTHQUAKE, DOLPHINS AND BIG DATA THE CHALLENGES IN HYDROGRAPHIC SURVEYING

By S. CAIE[1], B. WALLEN[2]

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Abstract

In 2016, Land Information New Zealand (LINZ) completed an evidence-based, risk-led assessment (LINZ, 2016a) of the accuracy and adequacy of nautical charting in New Zealand. The results identified Queen Charlotte Sound / Tōtaranui and Tory Channel / Kura Te Au as areas of heightened risk. LINZ, in partnership with Marlborough District Council (MDC), developed a programme of work to carry out hydrographic surveys for safety-of-navigation and scientific purposes. This collaboration was a first for both organisations.

The survey requirements called for a variety of deliverables, in a number of areas, on a variety of dates. Given the size of the survey area (440km^2), the number of water users, time constraints, inquisitive dolphins and large volumes of data, the project posed some known challenges. Throw in an earthquake and the challenges increase.

Managed overall by LINZ, the prime contractor was the National Institute of Water and Atmospheric Research (NIWA), who will deliver all the science components. Discovery Marine Limited (DML) was sub-contracted to provide the hydrographic survey components, which included the provision of the Surveyor-In-Charge and the delivery of safety-of-navigation components. After wading through the vast dataset, final survey deliverables have now been received and accepted by LINZ. The data will be used to update the charts. This article describes the rationale behind the survey and discusses the challenges encountered during the project.

Résumé

En 2016, le *Land Information New Zealand* (LINZ) a achevé une évaluation fondée sur les preuves et axée sur les risques (LINZ, 2016a) de la précision et de la pertinence de la cartographie marine en Nouvelle-Zélande. Les résultats ont identifié les zones suivantes comme étant les plus risquées : le détroit de la Reine-Charlotte / Tōtaranui et le chenal Tory / Kura Te Au. Le LINZ, en partenariat avec le *Marlborough District Council* (MDC), a développé un programme de travail afin d'effectuer des levés hydrographiques à des fins de sécurité de la navigation et dans un but scientifique. Cette collaboration a été une première pour les deux organisations.

Les exigences en matière de levés nécessitent d'entreprendre diverses actions, dans plusieurs zones, à différentes dates. Compte tenu de la taille de la zone à hydrographier (440km^2), du nombre d'utilisateurs des eaux concernées, des contraintes de temps, de la curiosité des dauphins et des importants volumes de données, le projet a comporté plusieurs difficultés connues. Ajoutez un séisme et le défi prend une autre dimension.

Sous la gestion du LINZ, le principal contractuel était le *National Institute of Water and Atmospheric Research* (NIWA), qui a fourni toutes les composantes scientifiques. Un contrat a été signé avec *Discovery Marine Limited* (DML) pour la fourniture des composantes relatives aux levés hydrographiques, incluant la fourniture du responsable des levés ainsi que des composantes relatives à la sécurité de la navigation. Après un travail laborieux dans ce vaste jeu de données, les résultats finaux des levés ont à présent été reçus et validés par le LINZ. Les données seront utilisées afin de mettre les cartes à jour. Cet article décrit la raison d'être de l'étude et aborde les défis rencontrés au cours du projet.

Article

Resumen

In 2016, Land Information New Zealand (LINZ) completó una evaluación basada en las evidencias, guiada por los riesgos (LINZ, 2016a) de la precisión y la conveniencia de la cartografía náutica en Nueva Zelanda. Los resultados identificaron el Pasaje Queen Charlotte/Tōtaranui y el Canal de Tory/Kura Te Au como áreas de elevado riesgo. LINZ, en asociación con el Marlborough District Council (MDC), elaboró un programa de trabajo para llevar a cabo levantamientos hidrográficos para fines de seguridad de la navegación y científicos. Esta colaboración fue la primera para ambas organizaciones.

Los requisitos en materia de levantamientos exigían una variedad de resultados, en una serie de áreas, en diferentes fechas. Dada la dimensión del área del levantamiento (440km^2), la cantidad de usuarios del mar, las limitaciones de tiempo, los delfines inquisitivos y los grandes volúmenes de datos, el proyecto planteó algunos desafíos conocidos. Lanzado en un terremoto y aumento de los desafíos.

Gestionado en general por LINZ, el contratista principal fue el National Institute of Water and Atmospheric Research (NIWA), que entregará todos los componentes científicos. La empresa Discovery Marine Limited (DML) fue subcontratada para proporcionar los componentes de los levantamientos hidrográficos, que incluyeron el suministro del Hidrógrafo responsable y la entrega de los componentes en materia de seguridad de la navegación. Tras haber analizado el vasto conjunto de datos, los resultados finales de los levantamientos han sido recibidos y aceptados ahora por LINZ. Los datos serán utilizados para actualizar las cartas náuticas. Este artículo describe la razón de ser del levantamiento y analiza los desafíos encontrados durante el proyecto.

1. Background

Queen Charlotte Sound / Tōtaranui comprises 320km of deeply indented coastline, formed by a drowned valley system with generally steep sides and a relatively flat seafloor (***Figure 1***). The northern entrance lies between Cape Jackson and Cape Koamaru, an area which shoals from 380m to 20m depths. It contains shallow banks and rock ridges giving rise to extremely turbulent waters with strong currents, eddies and upwellings. The eastern entrance is through Tory Channel / Kura Te Au where very strong tidal streams enter and exit the Sounds through a narrow passage. The two approaches merge at Dieffenbach Point from where the Sound leads inland to Picton and Anakiwa.

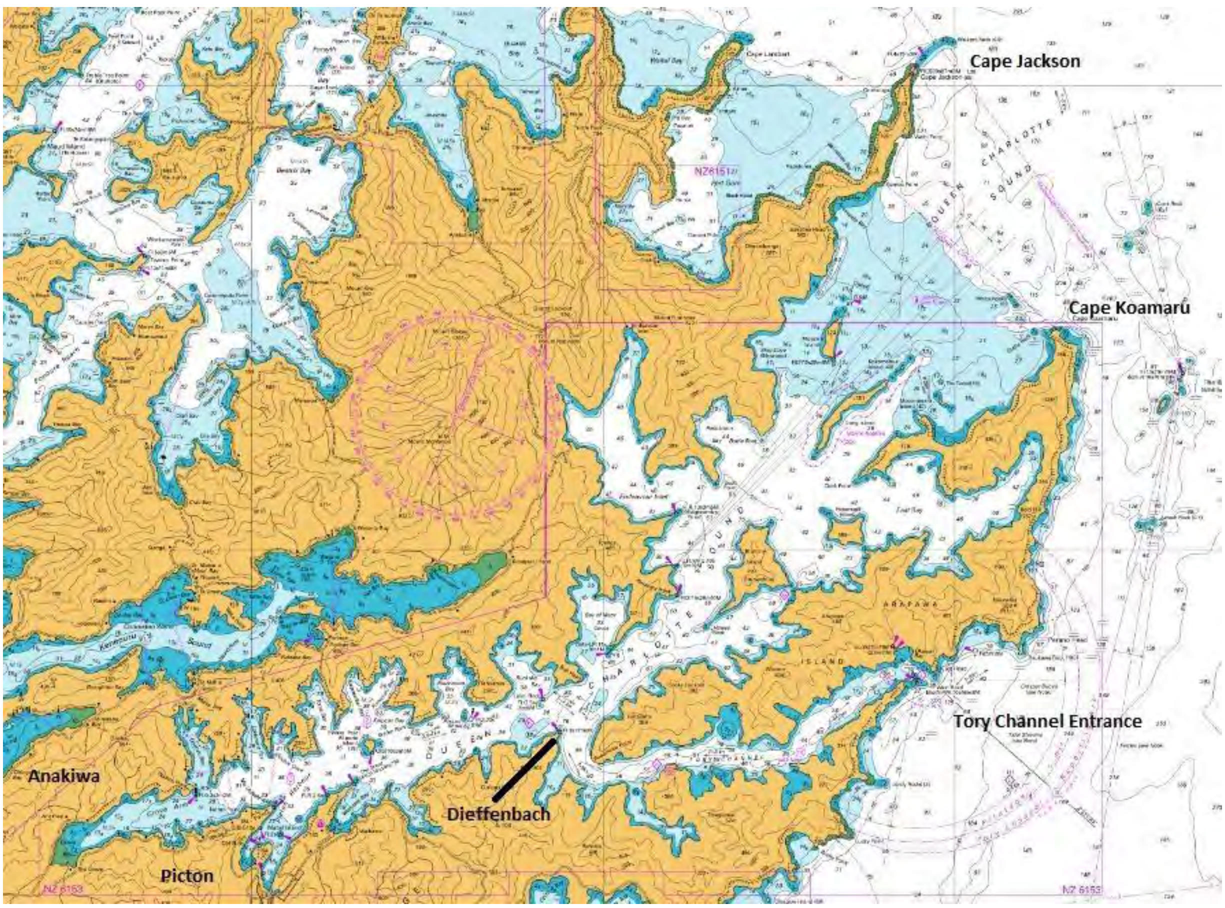


Figure 1. *Portion of LINZ Chart NZ615 Showing Queen Charlotte Sound / Tōtaranui and Approaches*

The last full survey of the area was undertaken in 1942-43 by HMS *Elaine* (***Figure 2***). Additional areas in Tory Channel / Kura Te Au and the northern approaches to Queen Charlotte Sound / Tōtaranui were surveyed by the RNZN in 1978 and 1984. An area adjacent to Long Island was surveyed by MDC in 2005. All these surveys were undertaken with single beam echo sounding (SBES) systems operating either wet paper recorders or electronic stylus digital depth recorders. Positioning was by sextant resection or two range trisponder microwave positioning. Only the 2005 MDC survey used DGPS for positioning.

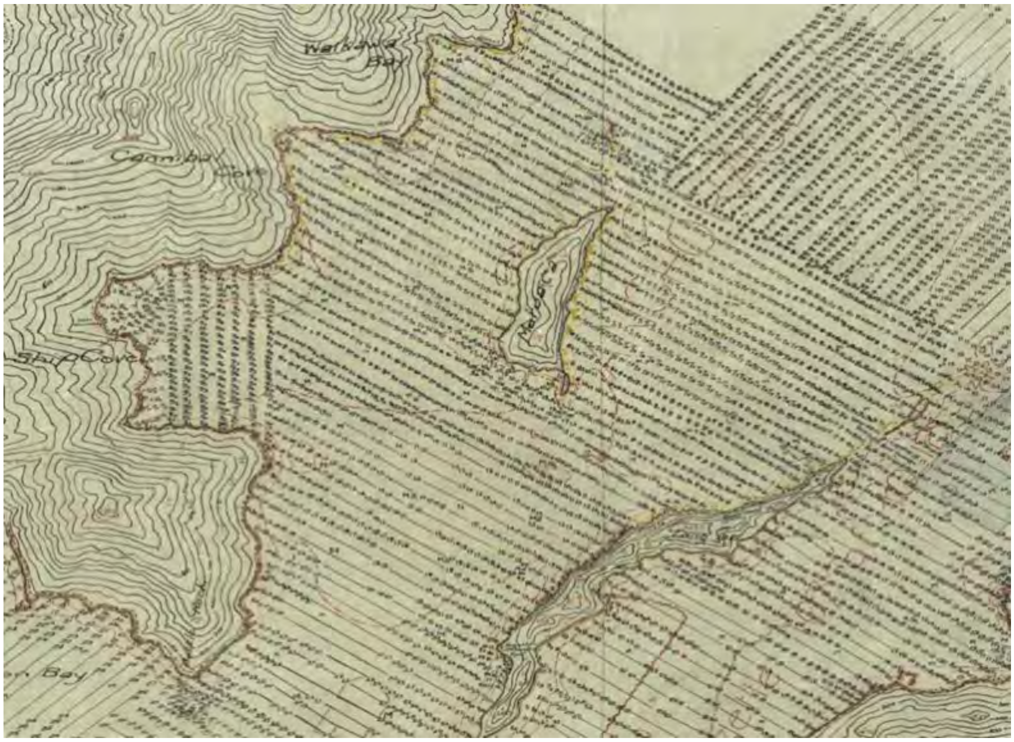


Figure 2. *Portion of 1942-43 HMS Elaine Survey Sheet Showing Ship Cove and Long Island*

Using the results of the New Zealand Hydrographic Risk Assessment (***Figure 3***), LINZ identified Queen Charlotte Sound / Tōtaranui and Tory Channel / Kura Te Au as a priority to undertake a modern hydrographic survey. LINZ was also investigating opportunities to collaborate with stakeholders to maximise efficiencies by utilising the survey assets for other activities closely aligned to LINZ objectives. Following discussions with MDC, LINZ discovered they had scientific-focused survey needs in the Sounds and through a Memorandum of Understanding, both parties worked together to redefine the survey requirements.

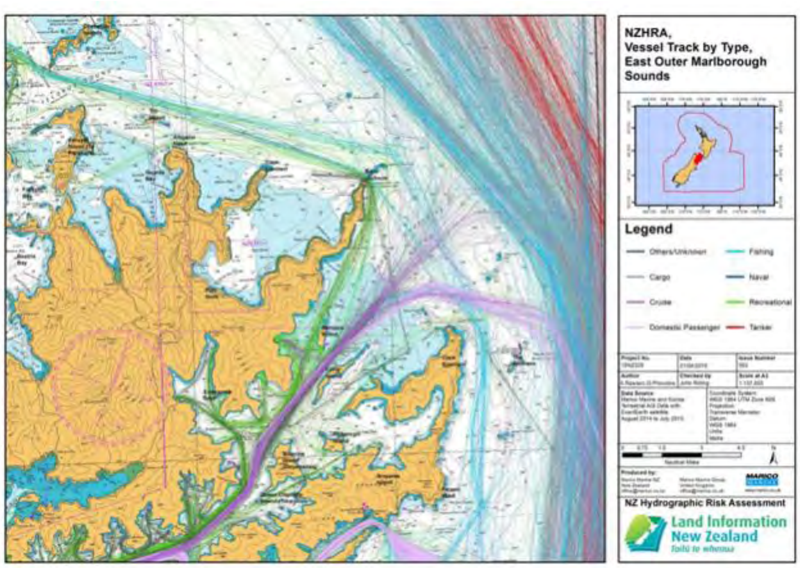


Figure 3. *Vessel track by type, East Outer Marlborough Sounds (August 2014 to July 2015)*

As the New Zealand Hydrographic Authority, LINZ requires data and information to improve the accuracy and adequacy of the nautical charts for the area. The LINZ requirements and specifications (LINZ, 2016b) are well known, have been in use for decades and are based on the International Hydrographic Organization (IHO) Standards for Hydrographic Surveys, S-44 (IHO, 2008).

As the agency responsible for maritime safety within their area of jurisdiction, MDC has similar requirements for safety of navigation. Of priority was the delivery of data by January 2017 to enable the MDC harbour master to make a decision on the location of a pilot boarding station close to Long Island (Figure 4 - Area A), and preferred routes for larger vessels entering the Sound from the north east. In addition, in late 2019 large-scale celebrations in Ship Cove and other locations around New Zealand will commemorate the 250th anniversary of Lieutenant James Cook's arrival in New Zealand. As there is expected to be a large number of vessels attending, and the current published chart uses survey data from 1942-43, there is a need to ensure the chart is updated with new data well in advance.

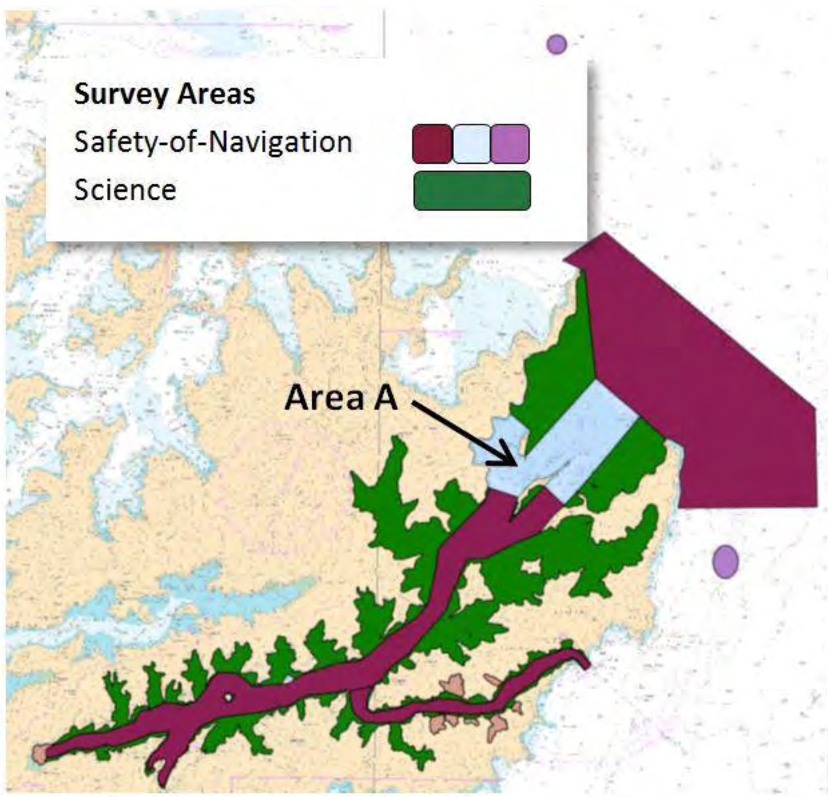


Figure 4. *Area A and different areas depicted for hydrographic and scientific data collection*

MDC also requires information to support its environmental monitoring, management and decision making processes. In particular, the characterisation and mapping of seabed habitats, benthic terrain modelling to classify habitats and ecosystems, and the identification of biogenic (or living) habitats important for biodiversity throughout the entire Sounds area were all required. Specifications for the science component took some time and effort to finalise to ensure the requirements were well understood and explained.

2. Survey Fieldwork

Two vessels were used for the survey, RV *Ikatere*, operating a Simrad EM2040 multibeam echo sounder (MBES) and RV *Rukuwai* operating a Simrad Geoswath to provide Side Scan Sonar (SSS) coverage and an ODOM CV100 single beam echo sounder (SBES) system. NIWA and DML personnel operated from local accommodation established in Waikawa for two periods of fieldwork, from 12 October to 16 December 2016 and from 7 February to 22 June 2017. There were between 3 and 5 DML personnel and a similar number of NIWA personnel on site at all times. The survey involved 195 days on the survey ground during which both vessels were operating. The MBES sounding took 136 days and the Geoswath and SBES work took 44 days each. Collecting ancillary data such as positioning of lights and beacons, measuring light sectors, seabed sampling and checking the coastline took a further 24 days. Installing seven tide stations, levelling the associated benchmarks and monitoring tide throughout the survey took 43 days. Weather downtime was only 6 days, whilst 16 days were lost to MBES component failures/replacement/recalibrations. During some of the MBES downtime, the survey vessel was used for other survey tasks.

3. Challenges

Tides

A total of seven tide stations were installed for the survey to provide vertical control and connect to Chart Datum throughout the survey area. It was anticipated that these gauges could all be linked together and a linear interpolation tidal correction model be developed to provide a seamless surface representing Chart Datum. However, after logging water level data for several weeks, it became apparent that the tidal regime was non-linear and uniquely different in various parts of the Sound. Time lags, seiching, varying range and the effects of weather in Cook Strait were seen in the tidal data. Figure 5 shows overlapping tide curves for 5 gauges.

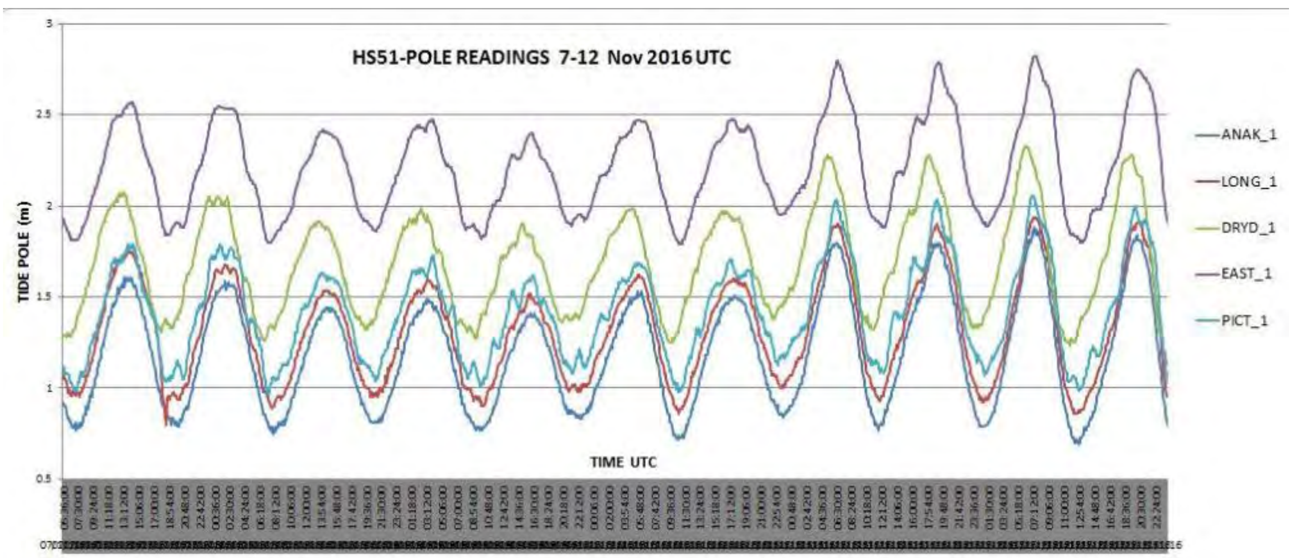


Figure 5. *Tide curves for 5 gauges throughout the survey area*

The application of standard datum transfer methodologies to derive datum was replaced by undertaking a series of harmonic analyses using at least 30 days' data for each tide station. The first complete 30 day dataset was expected late November/early December 2016, allowing the datum to be defined and depths for the priority area reduced and validated in time for rendering to MDC by January 2017.

This first 30 day set of data for tidal observations was disrupted by the Kaikōura Earthquake on 14 November 2016 (***Figure 6***). The tidal data was corrupted for several days and required additional checks and levelling between benchmarks to verify that relationships between gauges, tide poles and benchmarks had not changed. Only minor shifts (<3cm) were observed at all stations. This disruption to data caused by the earthquake meant the determination of datum was not possible until February 2017 at the earliest.

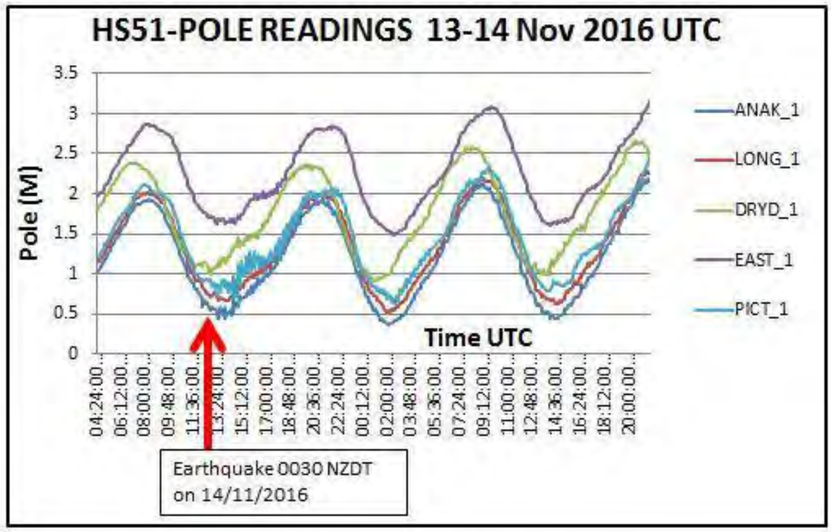


Figure 6. *Tide curves showing the impact of the earthquake.*

In view of the challenges with the tidal regime and the delay in defining effective sounding datum for each site, the tidal correction methodology was changed from a linear interpolation to applying simple block corrections based on a defined geographic area around each tidal station. This approach allows tidal corrections to be re-applied at a later date post-survey should a better tidal model be developed. The boundaries for the area within which each tidal station was applied, were set to ensure there was minimal step in tide between adjacent tide reduction blocks. Using a survey line that crossed each boundary, a comparison was able to be made on each side to verify that the tidal step was within the allowable total vertical uncertainty (TVU) of the specifications. The steps across boundaries were quite small and varied between 0.01m to 0.17m, with one boundary step at 0.25m which was in an area of water depth greater than 40m depth.

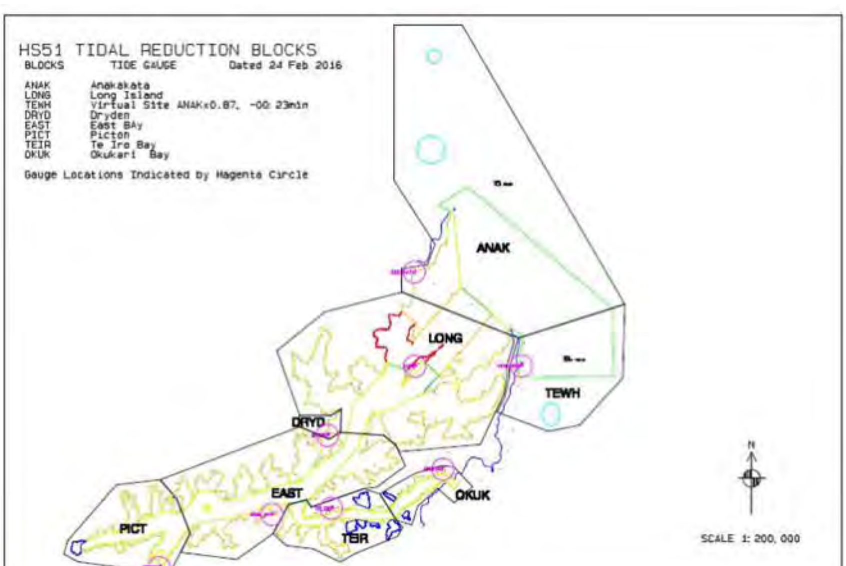


Figure 7. *Tidal Reduction Blocks.*

The challenge of defining datum at each station also meant that field processing and checking of survey data for coverage and gaps were undertaken using provisional sounding datums for each tide station. Whilst the best value at the time, using provisional datums meant that all data needed to be reprocessed for final tides post-survey.

<u>Deliverables and deadlines</u>

For most hydrographic survey work, clients receive results at the end of the job, when all data has been checked and validated to ensure specifications have been met. For this survey, three sets of deliverables were required at different times during the survey:

i) MDC required bathymetry and coastline for Area A (Figure 4) by January 2017;

ii) LINZ required complete deliverables of the same area by May 2017, and

iii) LINZ draft deliverables for the entire survey area by January 2018.

The challenge of these various deliverable requirements and dates lay in the planning, co-ordinating, monitoring and directing personnel involved in processing and survey fieldwork at the same time. As data capture continued, specific activities such as checking aids to navigation and the coastline, were undertaken in addition to processing, checking and rendering portions of the survey data. Having a robust process for recording which data had been processed and what had happened to it was essential to avoid any loss or duplication. Essentially the work involved running two smaller surveys inside a larger survey.

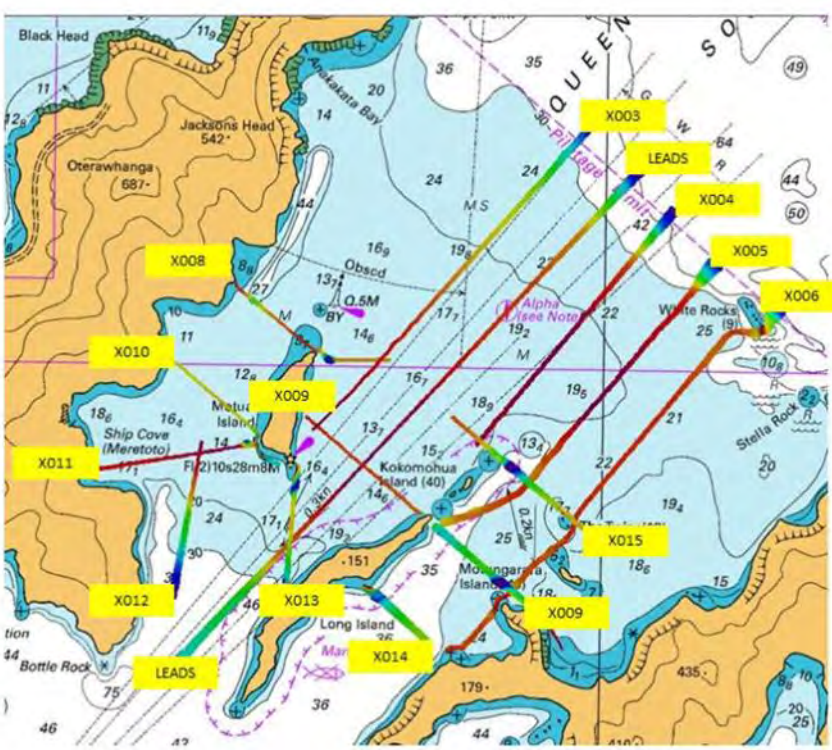


Figure 8. Location and Names of Area A Cross Lines

Achieving the MDC requirements meant completing all fieldwork for Area A before departing the survey ground in December 2016. Sounding of Area A was top priority and was proceeding on schedule until the Kaikōura Earthquake occurred on 14 November 2016. A possibility existed that the earthquake had altered the already surveyed seafloor and that work may need to be repeated. To determine if this had occurred, a series of close spaced MBES check lines (Figure 8) were run through the area already sounded to identify whether there had been any changes to the seafloor that exceeded survey depth accuracy specifications. The range of mean differences was -0.03m to +0.04m. These checks confirmed depths were within the required accuracy standards and there had been no significant change to the seabed as a result of the earthquake. However, the earthquake also disrupted the time series to be used for the determination of datum for Area A. This resulted in depth data rendered to MDC being classed as provisional.

In addition to these checks, MDC requested checks were carried out around the wharves in Picton to understand what, if any, changes had occurred before permitting vessels alongside.

Data for Area A delivered to MDC in January 2017 included a dense XYZ depth dataset of 32 Megabytes, 2 Megabytes of plotted XYZ depths, 4x 1:10,000 plots and a survey report. This was adequate for MDC planning purposes and has enabled decisions about pilotage routes and Aids to Navigation to be progressed (***Figure 9***). A comparison of the difference in density of data points from Cook's 1770 chart (***Figure 10***) and surveys used for charting between the 1942-43 survey (***Figure 11***) and the 2017 survey (***Figure 12***) of Ship Cove is readily seen (images at approximately same scale).

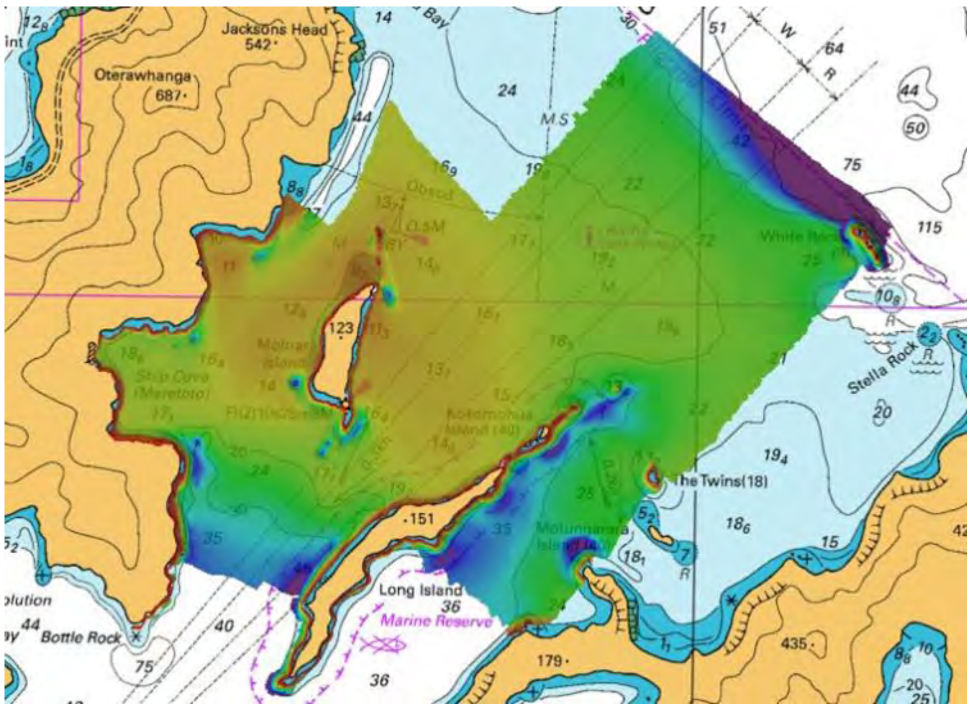


Figure 9. *Area A - MBES final coverage*

Figure 10. *Portion of Cook's 1770 chart of Cook Strait and Queen Charlottes Sound*

Figure 11. *Ship Cove survey 1942-43 (depths in fathoms), Depths represented at a scale 1:25,000*

Figure 12. *Ship Cove survey 2017 (depths in metres), Depths represented at a scale 1:10,000*

Compilation of the LINZ May 2017 deliverables for Area A required full reprocessing of the dataset using the approved tidal datums and a thorough checking of the combined final surface and compilation of LINZ specified reports and datasets. Draft LINZ deliverables for the entire survey were compiled and rendered in late December 2017 and data volumes are listed at ***Table 1***.

Table 1. Volume of data delivered to LINZ

Area	Bathymetry	
	Raw	Processed
Area A	1.1 Tb	284 Gb
Entire area	13.0 Tb	914 Gb

Due to the large data volumes, processing computers were not available for other work at times. The time required to load daily project files and generate a bathymetric surface ranged from 12 to 48 hours per block. When edits made to the block surface (***Figure 13***) were unloaded back to raw files or data was exported the time required could be as long as 48 to 96 hours. Making a backup copy of a block project could take anywhere between 12-18 hours. Examples of the data density are shown at ***Figures 14*** (chart) and ***15*** (MBES data overlay).

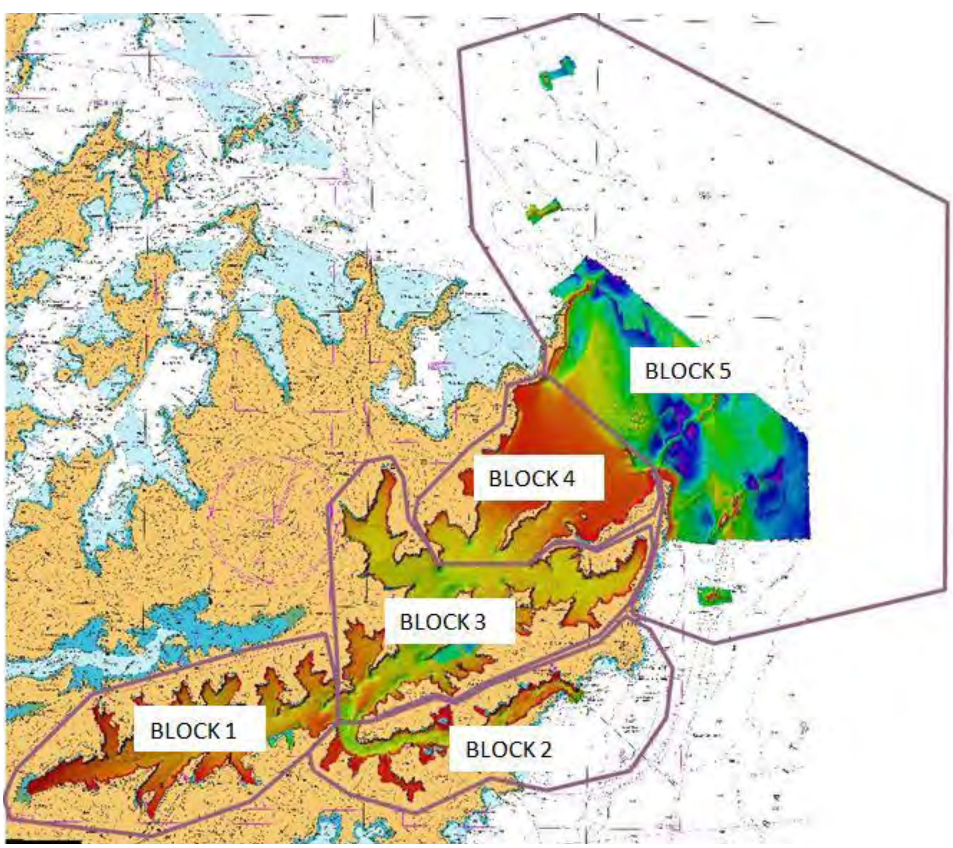


Figure 13. *Five Processing Blocks*

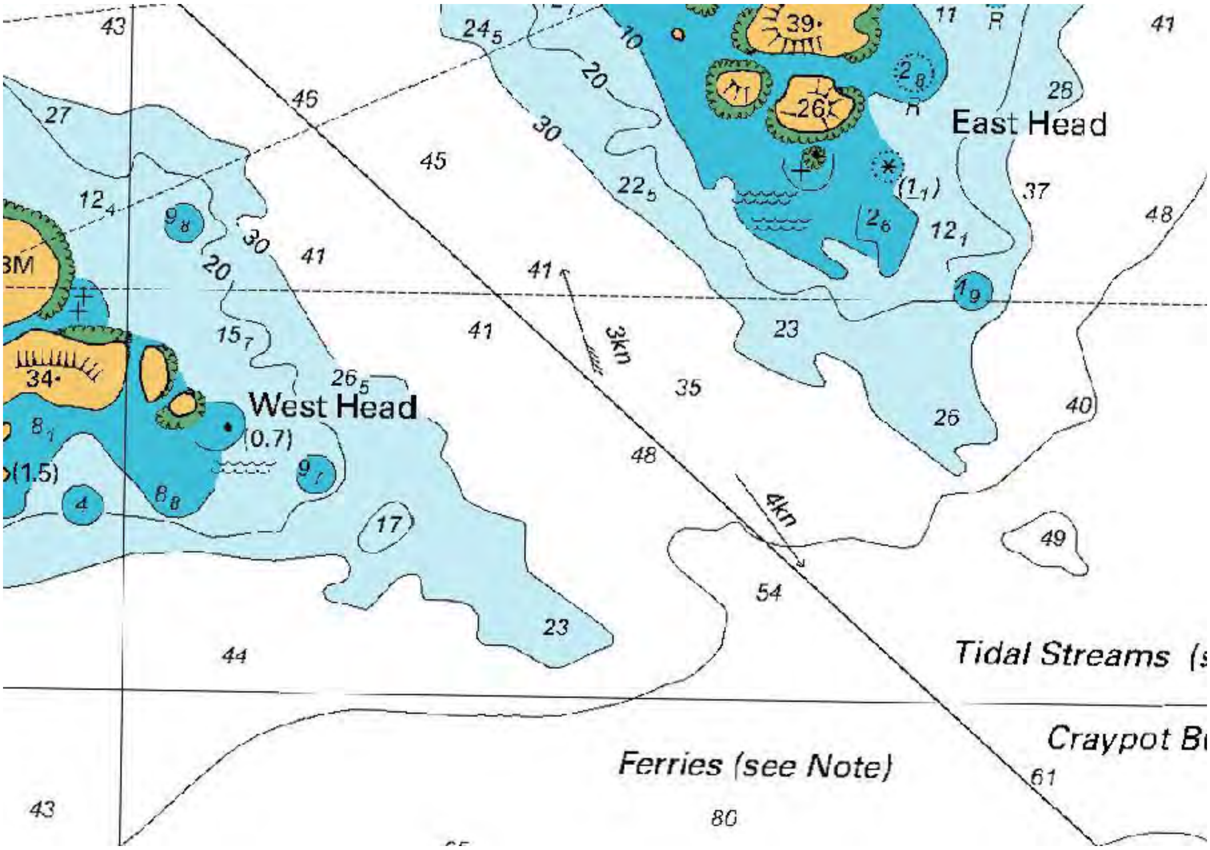


Figure 14. *Tory Channel / Kura Te Au Entrance Chart*

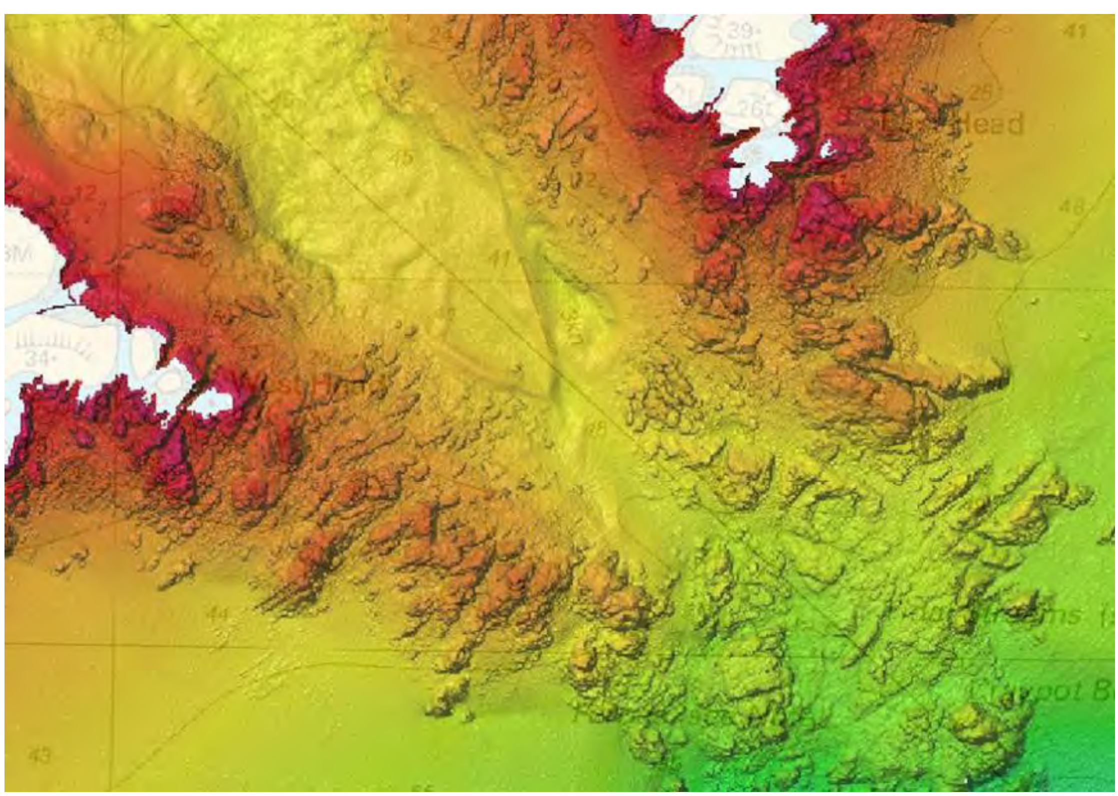


Figure 15. *MBES data overlaid on Figure 14 area*

Achieving the processing task took a total of 6,700 man hours expended by a dedicated team of four personnel working in shifts of two each day from 8 July to 5 December 2017. Apart from the tedium of data cleaning for 6 hours, personnel were challenged with managing and tracking the volume of data as they worked across different data blocks containing 14,084 MBES and 964 SBES data files.

Data Collection to achieve specifications in outer QCS and Approaches

When planning an MBES survey, the estimated time to be spent collecting data is derived by assessing the expected depth of water, the anticipated swath coverage (in degrees), the ping rate of the MBES (number of times the sounder will transmit/receive per second) and the required survey depth accuracy specifications. For this survey, the specifications were order LINZ-1 (LINZ, 2016b) depth accuracy in depths greater than 5m. LINZ-1 requires that the total allowable depth uncertainty (TVU) in metres at 95% confidence level, is obtained from the following formula.

$$TVU = \pm M\sqrt{0.25^2 + (0.0075d)^2}$$

(Where M is the LINZ order multiplier, in this case M =1.5, d = depth, and 0.25 and 0.0075 are the maximum allowable TVU values at 95% confidence level for IHO Special Order surveys (IHO, 2008). The resulting graph of depth accuracy (***Figure 16***) shows that at a depth of 5m the accuracy required is $\pm$0.38m, at depth 20m$\pm$0.44m, at depth 50m$\pm$0.67m, at depth 100m$\pm$1.18m, and at depth 200m$\pm$2.28 m. LINZ-1 specification also defines criteria for the minimum horizontal size of a target that must be detected. For depths less than 40m, a target size of 2m or more must be detected by 3 pings along-track and 3 pings across-track. In water depths greater than 40m, the minimum target size is 5% of the depth. The graph of target size for depth (***Figure 17***) shows that at 50m deep, a target 2.5m in size must be detected, likewise at 100m, a target 5m, and at 200m, a target 10m.

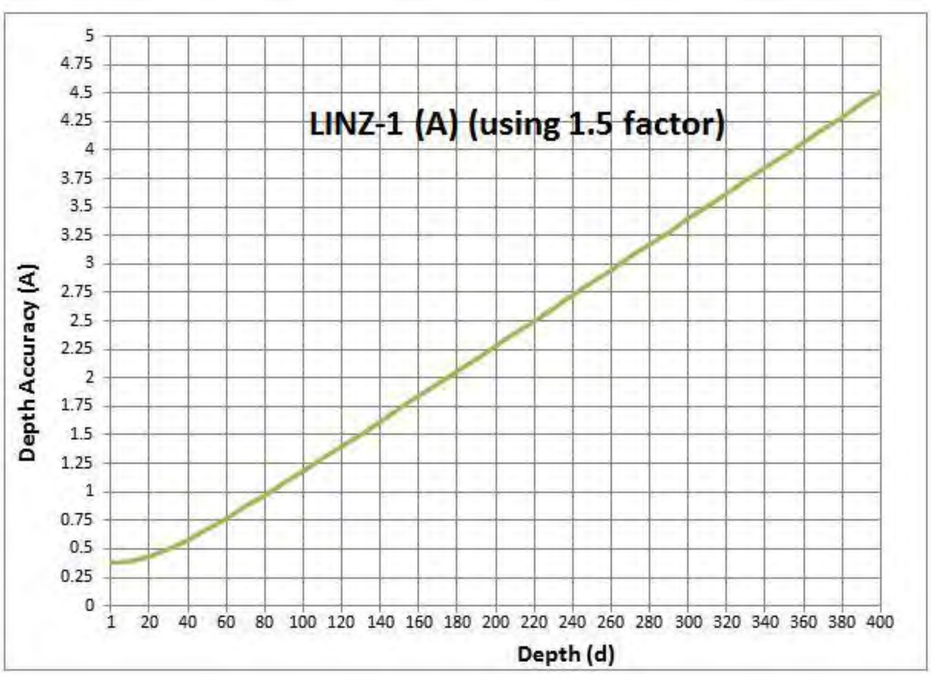


Figure 16*. Depth Accuracy for LINZ-1*

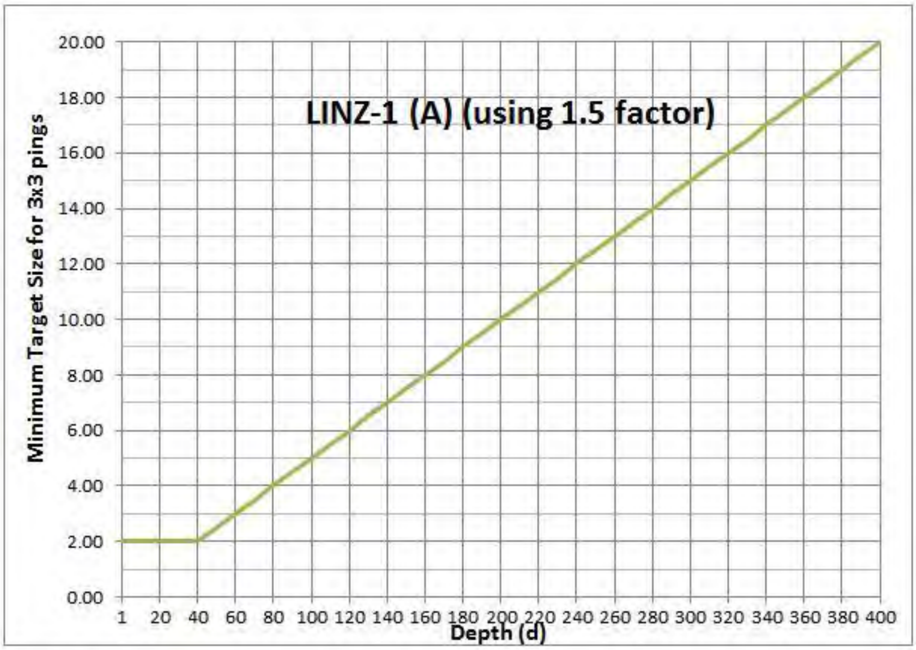


Figure 17. *Target Detection Criteria for LINZ-1*

There are a number of factors to be considered when operating MBES in changing water depths. As depths increase, the ping rate decreases due to additional time required for the MBES to receive seabed detections between individual pings. To maintain high ping rates the swath width can be reduced e.g. from 120° to 110° or less, but this sacrifices seafloor coverage. As ping rates reduce in deeper water, the vessel speed must be reduced to ensure target detection criteria are maintained. Additionally the vessel track needs to be straight to ensure horizontal ping spacing is consistent and not cartwheeling or swinging around making gaps in the data. When depths exceed 75-100m, the MBES transmit frequency may need to change to enable seafloor tracking and detection to continue. To ensure survey specifications were achieved, the on-line hydrographic surveyor constantly monitored the relationship between MBES swath coverage, ping rates, frequency, target detection and depth.

Several challenges were encountered during the survey when collecting MBES data in the outer areas of this survey. One was the impact that the seafloor topography and tides had on the sea surface. Strong currents, eddies, upwelling (***Figure 18***), overfalls and turbulence caused by the ridges and valleys across the Entrance and by the Brothers Islands, meant that the vessel survey line orientation, vessel speed and at times heading and motion were affected. To ensure the target detection criteria was met, there were times when the vessel could only survey in one direction - heading into the tidal stream. Sounding in the same direction as the stream would mean the vessel was travelling too fast to meet the criteria. Also, at times the vessel heading could be thrown 30° off course by turbulence, causing gaps in MBES data necessitating reruns.

Figure 18. *Example of upwelling seaward of White Rocks*

A second challenge was how quickly depths fluctuated in the area requiring operators to monitor swath widths to ensure satisfactory ping rates for target detection. This challenge was overcome by limiting operations for that period to particular depth bands and covering the deeper areas another day. A set of guidelines (***Table 2)*** were developed for operators to use to ensure specifications were met.

Table 2. Operator guidelines to ensure specifications were met

Depths	Swath Max	MAX Speed over Ground	Frequency / Ping Rates	
Coastlining	+/-75-45 deg Generally +/-65 deg.	As required	300 /set to 15 max	May swing swath shoreward on inshore line (coastline). Overlap into 5m (green) colour band from Rukuwai work
< 25m	+/-65 deg.	6.5 knots	300 /15 max	
Increasing beyond 25-30m	+/-60 deg.	6.5 knots	300 />12	Where depth is continuing to increase then reduce the swath width
25-65	+/-60deg	6-6.5	300 />10	
60-110	+/-55	5.5	300 />8	
110 - 150	+/-50	5-5.5	200 />6	Use freq to 200kHz over 100m and deeper
150-220	+/-45	5	200 />4	
200-300	+/-40	5	Change to FM Mode at 200 m	Change mode once deeper than 200m
300-400	+/-40	4-5	FM Mode	

The third challenge was managing the best use of weather conditions, as this outer area was at least 1 hour vessel transit time each way from the operating base. Unfortunately weather forecasts were not always reliable which meant a vessel was sent to survey in this area only if at least four hours work on site could be achieved within the forecast conditions.

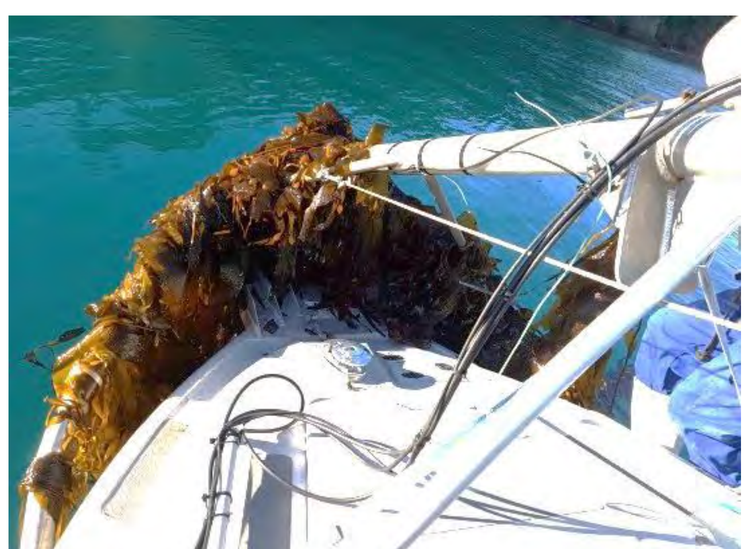
The greatest challenge of this outer area was in exceeding the time planned for sounding and the potential for this time overrun to impact on other survey tasks. Estimates of the effort before the job were that it would take 80 hours (10 days) to survey. In reality, due to the challenges listed above; the need to infill gaps; and re-survey areas where data did not meet specification, it took a total of 230 hours of sounding spread over 35 days to complete.

Kelp and dolphins

One of the more entertaining challenges of the survey involved the SBES work in Tory Channel / Kura Te Au where survey lines were 150m apart. There are extensive areas of fast growing kelp (*Macrocystis pyrifera*) that rise from depths of approximately 8m to the surface along both sides of the Channel (***Figure 19***) and then flow along the surface, changing direction with the tidal stream. To sound through these areas meant dragging and collecting clumps of kelp on the echo sounder frame (***Figure 20***), necessitating frequent pauses in work to cut the kelp free and clear the sounder.

Figure 19. *Kelp at Scraggy Point*

Figure 20. *Clump of Kelp on SBES*



Vessels inevitably attract the attention of dolphins (***Figure 21***) who want to investigate what this interesting sound is and play in the vessel wake. From the outset, MDC recognised the need to ensure dolphins were not harmed or impacted by survey operations and commissioned an independent review to determine what, if any, risk existed. The report provided operational guidelines to ensure interactions with dolphins were kept to a minimum. When dolphins were sighted close to the survey vessels, work was halted until they had moved on. MDC also established a Marine Mammal Liaison Group to help manage public concern about the MBES interactions with dolphins. The group involved iwi, an Environmental Non-Governmental Organisation and members of the community. This provided a useful mechanism for keeping people informed through regular reports from NIWA. The outcome was that public expressions of concern quickly evaporated. A record of all sightings and interactions with dolphins was maintained and supplied to MDC.

Figure 21. *Dolphins alongside the survey boat*

4. Conclusion

The survey of Queen Charlotte Sound / Tōtaranui and Tory Channel / Kura Te Au presented all involved with a number of challenges, some not previously experienced. During the project development stage, LINZ and MDC worked closely together to understand each other's requirements and how they should be translated into a specification and tender documentation. As mentioned, specifications for a hydrographic survey are well known and understood by LINZ and survey contractors. However, clearly describing the requirements and specification for the science component posed challenges as no standard set of specifications exist. International best-practice for the collection of seafloor backscatter was followed, although this only forms part of the specifications.

Subsequent to this survey, LINZ is collaborating with the Ministry of Primary Industries (MPI) on a survey between Kaikōura Peninsula and Cape Campbell. Learnings from the Queen Charlotte Sound / Tōtaranui survey were applied to the science specifications for this survey, which are generally the same.

NIWA and DML experienced challenges due to the location's geography, natural environment, technical difficulties and, of course, an earthquake. The results will provide a new dataset for LINZ to update the navigation charts in areas last surveyed in 1942-43. It will also provide MDC with a significant baseline dataset to monitor environmental changes in the Sounds. Of note, it is estimated that over 5.5 billion depth points were collected during the survey by the MBES and is a significant dataset that will be freely available to the public (***Figure 22***).

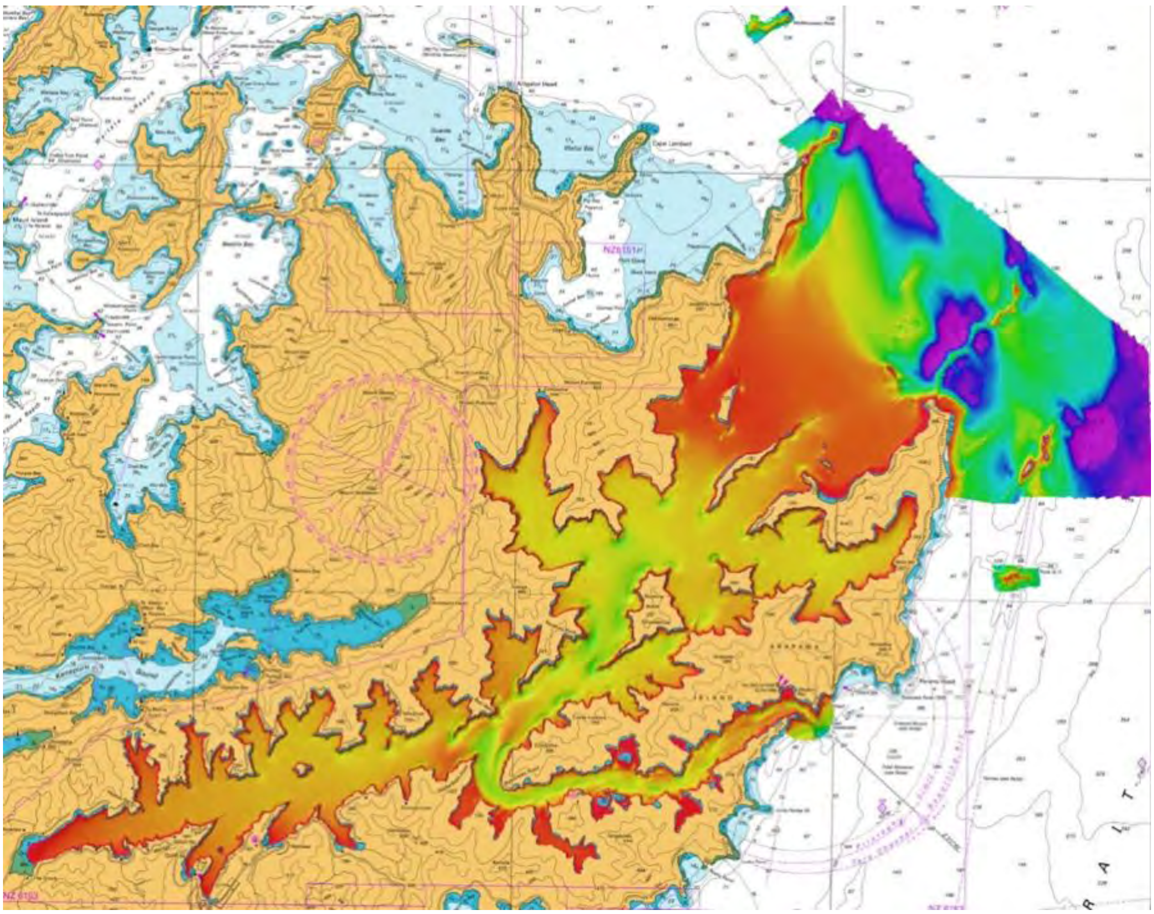


Figure 22. *Total survey coverage*

Benefits of the survey go far beyond the chart updates and baseline environment data. There is a need for standardised national specifications for the collection, processing and representation of science data and information. It is recognised that scientific aims may vary in different regions, so a standard specification may be difficult to develop. However, it would be reasonable to have a common approach, such as the guidelines produced by the GeoHab Backscatter Working Group (Geohab, 2015) as well as the production of benthic terrain modelling and seafloor classification.

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6. Author Biographies

Stuart Caie, after completing a BSc. (Hons) Surveying and Mapping Sciences degree in 1989, Stuart spent 16 years working as a Hydrographic Surveyor in the Oil & Gas and telecommunications industry based in the UK. In 2005 Stuart moved to New Zealand and joined Land Information New Zealand (LINZ) in May 2006 as a Senior Hydrographic Surveyor within the New Zealand Hydrographic Authority.

Stuart lead the New Zealand Hydrographic Risk Assessment project, an evidenced based, risk lead assessment to prioritise future hydrographic surveys around New Zealand. The subsequent long-term prioritised survey programme, HYPLAN, was published in 2017. Stuart has responsibility for maintaining HYPLAN and has oversight of the assessment of maritime safety information for Notices to Mariners and radio navigational warnings; and the validation and verification of hydrographic survey data rendered as part of LINZ contracted surveys for use in the production of nautical charts.

Within the region, Stuart has represented New Zealand at the IHO South West Pacific Hydrographic Commission meetings and led a number of workshops funded by the IHO Capacity Building Sub-Committee. The workshops aim to build the capacity and capability of Pacific Island Countries to meet their international obligations for the provision of hydrographic services.

Stuart is also working on a NZ Aid programme, the Pacific Regional Navigation Initiative, which is focusing on navigation-safety aspects in the South West Pacific, where LINZ is the charting authority responsible for producing and maintaining charts for the Cook Islands, Niue, Samoa, Tokelau and Tonga.

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Bruce Wallen has been involved in the hydrographic industry in New Zealand for over 30 years. Initially with the Hydrographic Service of the RNZN, then as Hydrographic Advisor for LINZ, he is now a practising field surveyor with Discovery Marine Ltd. Based in Auckland, Bruce is a qualified IHO Cat-A hydrographic surveyor and served as a Member of the Council of the NZIS representing the NZIS Hydrographic Professional Stream from 2013 to 2017. Throughout his career he has been involved in a range of single beam and multibeam surveys for national charting, port and marina maintenance and coastal and inland waterway monitoring and management. He has surveyed throughout New Zealand and as far afield as Antarctica and the Pacific Islands. He has been involved in national policy and technical specification design and development and recently received an Australasian Hydrographic Society Award of Merit for

Career Achievement in Hydrography.

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Article

MINIMUM DEPTH, MEAN DEPTH OR SOMETHING IN BETWEEN?

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Abstract

Reliable information about the seafloor and river-bed bathymetry is of high interest for a large number of applications. A Multi-Beam echo sounder (MBES) system is able to produce high-resolution bathymetry data at relatively small cost. These measurements, providing a depth for each beam and every ping, are processed to obtain a more ordered structure, such as a grid. Most approaches for assigning a depth to the centre of a cell (in a grid) use the shallowest or the mean depth in each cell. However, while the grid derived from the mean depth might be too deep compared to the shallowest depth, using the shallowest depth approach can result in an artificially shallow grid, affected by outliers. This paper introduces a number of alternatives to the current methods by combining the mean depth with statistical properties derived from the point cloud of the MBES data. In addition, the possibility of assigning a depth based on the regression coefficients of each cell is considered. The methods introduced have been tested on data acquired in different survey areas. The resulting grids have been compared to their shallowest and mean counterparts to obtain a better understanding of their advantages and limitations.

Résumé

Des informations fiables sur la bathymétrie des fonds marins et des lits fluviaux présentent un grand intérêt pour de nombreuses applications. Les systèmes de sondeurs acoustiques multifaisceaux (SMF) sont à même de produire des données bathymétriques à haute résolution à un coût relativement faible. Ces mesurages, qui fournissent une profondeur pour chaque faisceau et pour chaque ping, sont traités afin d'obtenir une structure plus ordonnée, une grille par exemple. La plupart des approches permettant d'attribuer une profondeur au centre d'une cellule (dans une grille) utilisent la profondeur la plus petite ou la profondeur moyenne au sein de chaque cellule. Néanmoins, si la grille dérivée de la profondeur moyenne peut être trop profonde par comparaison à la profondeur minimale, l'utilisation de l'approche de la profondeur la plus petite peut aboutir à une grille artificiellement peu profonde, affectée par des valeurs anormales. Cet article présente plusieurs alternatives aux méthodes actuelles en combinant la profondeur moyenne avec des propriétés statistiques dérivées du nuage de points des données issues de SMF. En outre, la possibilité d'attribuer une profondeur basée sur les coefficients de régression de chaque cellule est envisagée. Les méthodes présentées ont été testées sur des données acquises dans différentes zones hydrographiées. Les grilles qui en ont résulté ont été comparées à leurs équivalents en eaux peu profondes et de profondeur moyenne afin de parvenir à une meilleure compréhension de leurs avantages et de leurs limites.

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Article

Resumen

La información fidedigna sobre la batimetría del fondo marino y del fondo fluvial es de gran interés para un gran número de aplicaciones. Un sistema de ecosonda multihaz (MBES) puede producir datos de batimetría de alta resolución a un coste relativamente pequeño. Estas mediciones, que proporcionan una profundidad para cada haz y cada pulso, son procesadas para obtener una estructura más ordenada, como una retícula. La mayoría de los enfoques para atribuir una profundidad al centro de una celda (en una retícula) utilizan la profundidad menos profunda o la profundidad media en cada celda. Sin embargo, mientras que la retícula derivada de la profundidad media podría ser demasiado profunda comparada con la profundidad menor, el uso del enfoque de la profundidad menor puede resultar en una retícula artificialmente poco profunda, afectada por valores anómalos. Este artículo introduce un número de alternativas a los métodos actuales mediante la combinación de la profundidad media con propiedades estadísticas derivadas del punto de la nube de los datos MBES. Además, se considera la posibilidad de atribuir una profundidad basada en los coeficientes de regresión de cada celda. Los métodos introducidos han sido probados en datos adquiridos en diferentes áreas de levantamientos. Las retículas resultantes han sido comparadas a sus contrapartidas menos profundas y medias para lograr una mayor comprensión de sus ventajas y limitaciones.

1. Introduction

An accurate representation of the seafloor or river-bed bathymetry is of high importance for purposes such as safe navigation and nautical chart production. Currently, MBES systems are used for the collection of high-resolution bathymetry data by performing a large number of measurements which are processed to obtain a more ordered structure such as a grid. Approaches for assigning a depth to the grid cell's center often employ the shallowest or mean depth in a cell. In this paper, we introduce a number of alternatives to the two current approaches based on a combination of the mean depth and statistical properties of the depth measurements.

2. Mean and Shallowest Depths

The most straightforward candidate for the depth at the cell center is the shallowest depth which is of primary importance for safe navigation. The disadvantage of using this depth value, is that the resulting grid might be unrealistically shallow due to the presence of erroneous (shallow) measurements. To overcome this drawback, one can use the mean depth. However, problems might occur as hazardous objects might be left undetected.

3. Mapping depths based on regression coefficients

Considering all soundings that are located within a cell (assuming a large enough cell and/or hit count), a linear plane can be fitted through these depth measurements, where its regression coefficients account for the potential presence of slopes. The depth at an arbitrary location in the cell can be derived by using the intercept of the plane and the regression coefficients. As the slopes are assumed constant over the cell, the mathematical shallowest depth is derived by identifying the shallowest depth amongst the depths at the four corners.

4. Mapping depths based on (corrected) standard deviation

To mitigate the drawbacks of the mean and shallowest depth, one has to ensure that the effect of outliers is accounted for, while avoiding an artificially deep grid. One approach is to use the combination of the mean depth and standard deviation of the depth measurements. The standard deviation can be seen as a measure that also accounts for the presence of slopes. Hence, the standard deviation is not solely a representative of the measurement uncertainties.

Another alternative is to use a combination of the mean depth and the standard deviation corrected for the slopes present in the cell. This measure should represent the mean depth in a cell, while being corrected for the uncertainties in the measurements. However, for regions with slopes this might overestimate the depths.

5. Results

5.1 Data Description

The introduced alternatives are applied to data derived from two surveys, one in the vicinity of the Eemshaven seaport (*A*) and one in the Westerschelde estuary (*B*) (***Figures 1 and 2*** *respectively*). The MBES used for the data acquisition was an EM3002D and around 85 million soundings were obtained in each survey.

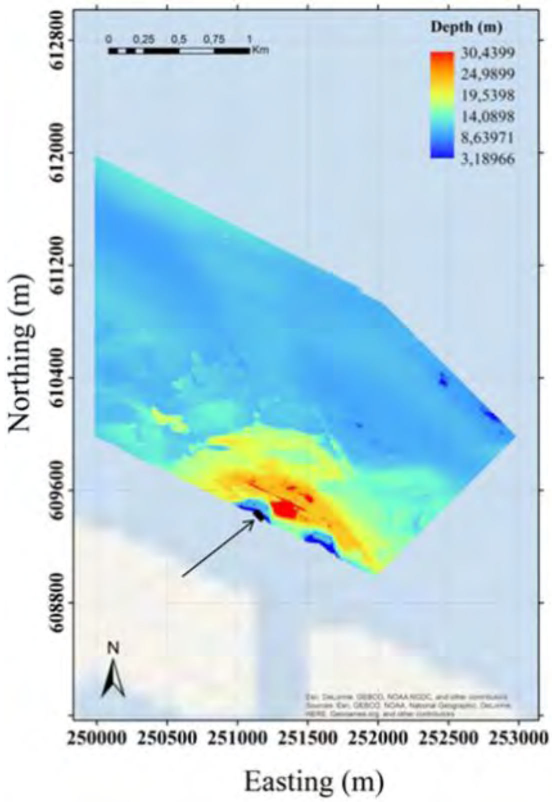

Figure 1. *Bathymetry map of the area A in the vicinity of the Eemshaven seaport. The black thick line indicates the location where the seafloor profile is obtained (see Figure 8).*

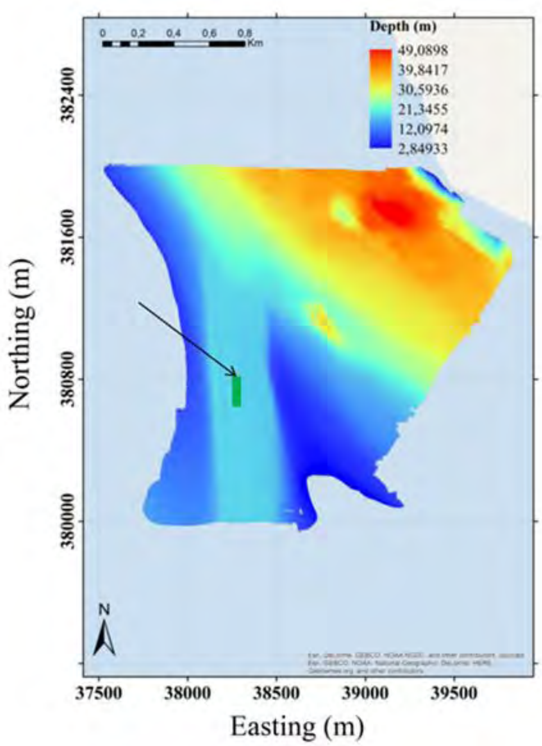

Figure 2. Bathymetry map of the area *B* in the Westerschelde estuary. The green thick line indicates the location where the seafloor profile is obtained (see Figure 9).

Depth variations occurring over a relatively small distance in the southern part of area *A* (***Figure 1***) and the existence of a man-made trench in area *B* (***Figure 2***), have motivated us to assess the performance of the different alternatives in these regions.

It should be noted that the statistical features (regression coefficient, corrected and uncorrected standard deviation) are calculated using a dedicated software module. The module enables statistical features to be calculated only if the number of soundings in a cell exceeds five (at least 3 are required to determine the parameters of the linear plane and the additional soundings are for increasing the degrees-of-freedom). Otherwise, Not-A-Number (NAN) values are returned for the cell. In order to assign a realistic value to the statistical features for the cell with less than 6 soundings, use is made of the average values of eight neighboring cells.

5.2. Shallowest depth using regression coefficients

Using the mathematical shallowest depth based on the regression coefficients, results in unrealistic depth values for some cells. As an example, for a cell in the area with a mean depth of 40.2 m, the mathematical shallowest depth returned by the method is 14.9 m which is unrealistic given the cell size. The point cloud of the data is processed to investigate the cause. ***Figure 3*** shows the distribution of the soundings within this cell. As can be seen, the points are spatially not well distributed.

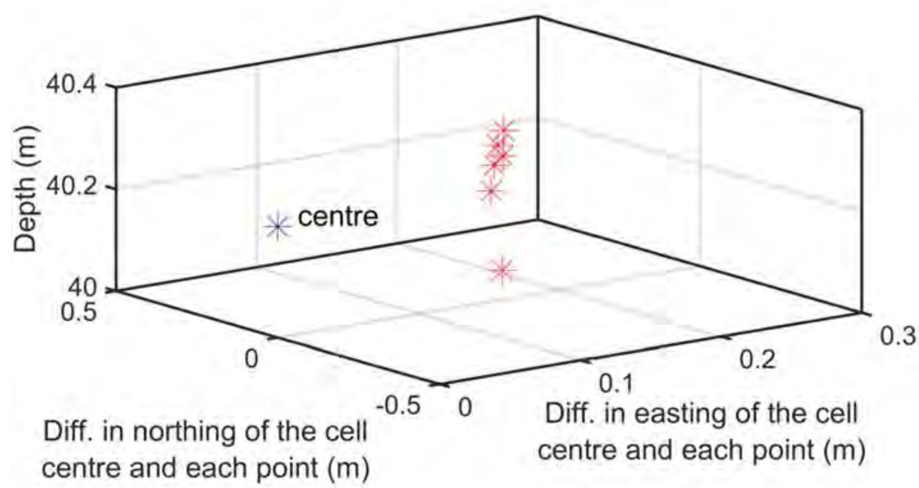

Figure 3. *Distribution of the points in the cell with unrealistic depth values at the corners. The mean depth in the cell is 40.22.*

This results in coefficients which actually should only be used to determine the depth in close vicinity of the points and not the cell corners. A possible solution is to consider a threshold and discard the regression coefficients of the cells where the coefficients exceed the threshold. The feasibility of adopting this solution is currently being assessed.

5.3. Shallowest depth using (corrected) standard deviation

Figures 4 and 5 show the differences between the mathematical shallowest depth derived from the mean depth and uncorrected standard deviation (1-σ confidence level) and the actual shallowest depth measured for the cells in the areas *A* and *B* respectively. For nearly 6% of the cells, the former is shallower than the latter. The results also show a dependency along the sailing direction at the outer parts of the swaths which is not observed in the bathymetry map of either areas and is due to the larger depth uncertainties for the outer parts of the swaths. This results in a larger difference between the mean and shallowest depths.

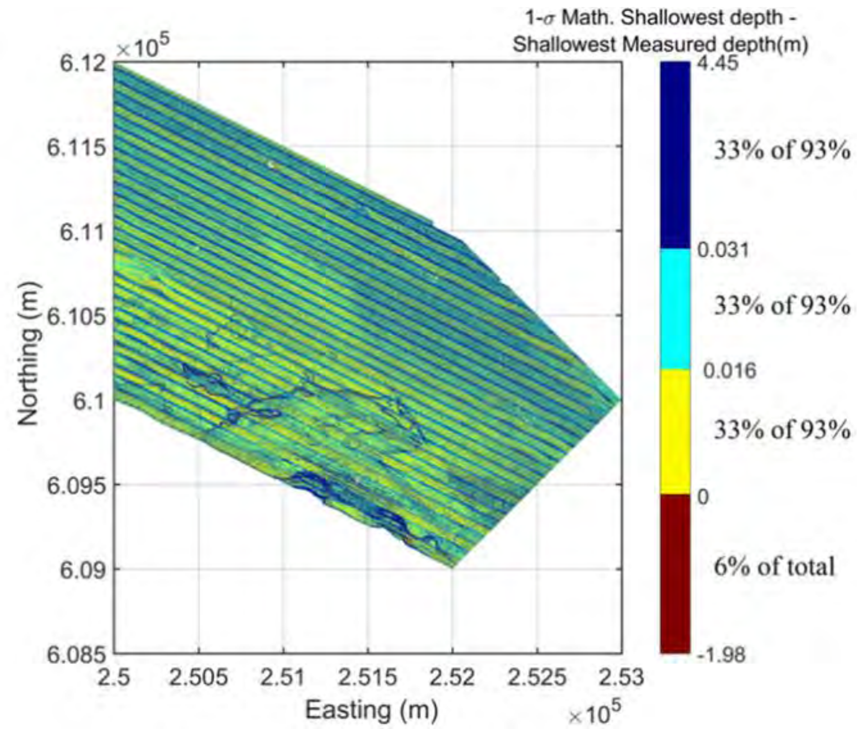

Figure 4. *Map of the difference between the 1-σ mathematical shallowest and the actually measured shallowest depth in area A.*

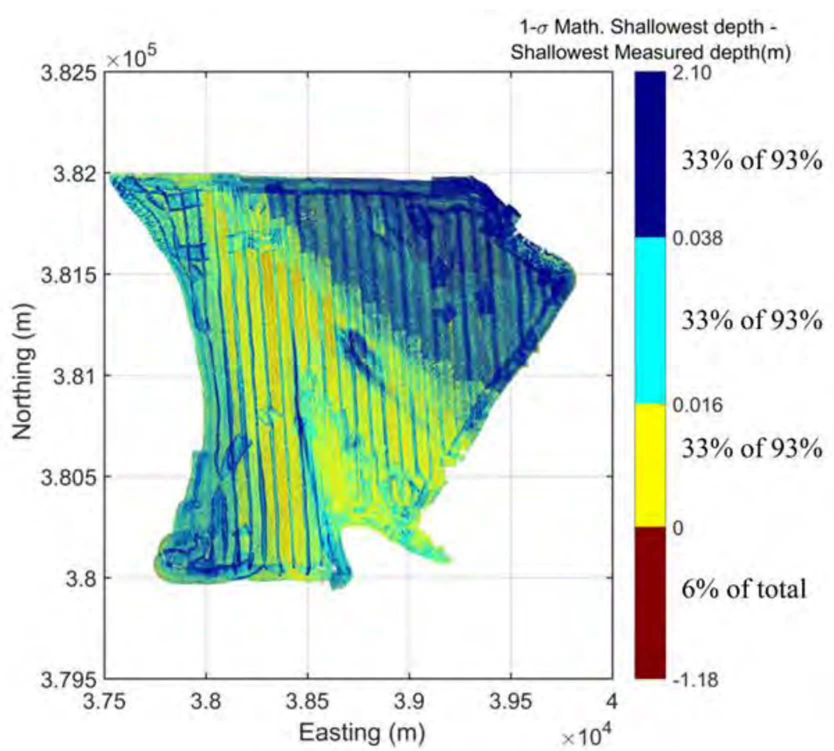

Figure 5. *Map of the difference between the 1-σ mathematical shallowest* and the actually measured shallowest depth in area *B*.

Note: For ***Figures 4, 5, 6 and 7***, the positive range of values represented by each colour is selected such that each range represent equal percentages of data points for which the derived depths are deeper than the shallowest measured depths. The red colour presents those data points where the derived depths are shallower than the shallowest measured depths.

These depth uncertainties are caused by a variety of contributions, such as uncertainties in the MBES range measurements, uncertainties in the beam angle, the water column sound speed and position of the MBES and the attitude sensors on the ship. For illustration purposes, ***Figures 6 and 7*** represent the differences between the mathematical shallowest depth derived from the mean depth and the corrected standard deviation (1-*σ* confidence level) and the actual shallowest depth measured for the cells in the areas *A* and *B* respectively.

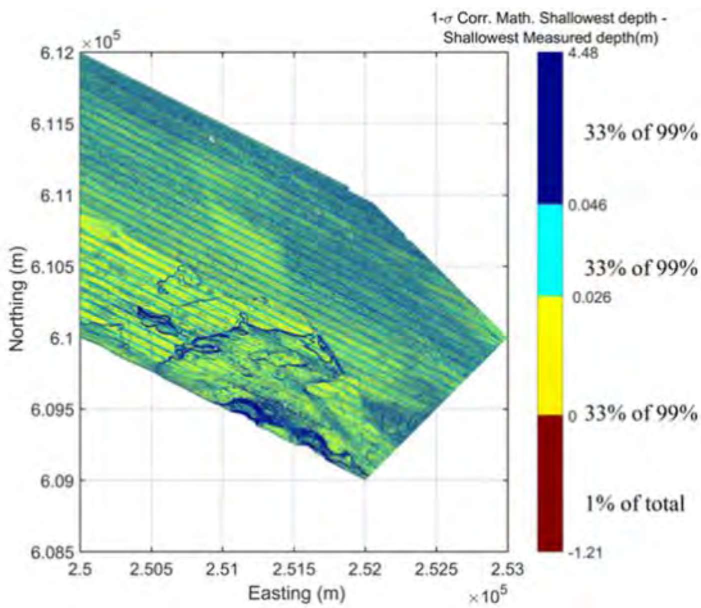

Figure 6. *Map of the difference between the 1-σ corrected mathematical shallowest and the actually measured shallowest depth in area A.*

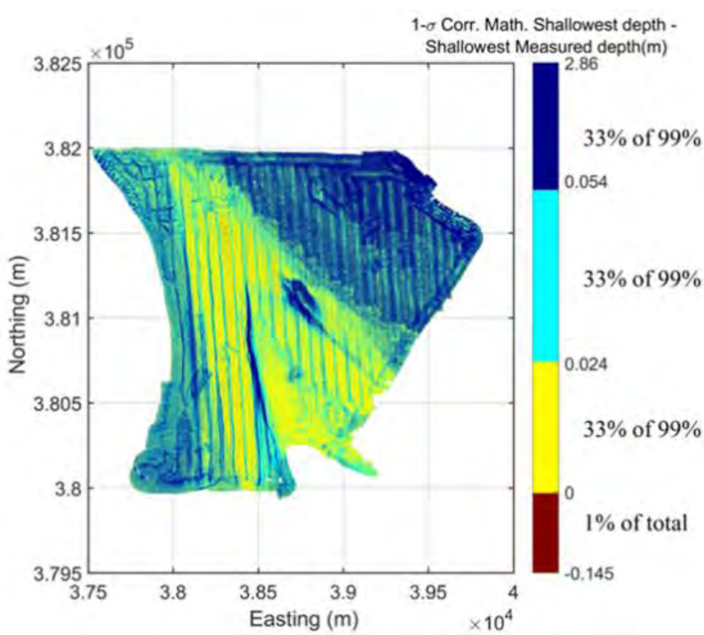

Figure 7*. Map of the difference between the 1-σ corrected mathematical shallowest and the shallowest depth measured in the area B.*

As expected, the percentage of cells in which the obtained depth is shallower than the actual shallowest measured depths is decreased to around 1%. This measure can be considered to capture both the mean and the uncertainties in the MBES measurements, but neglects any effect of the slopes. In this respect, it has a large risk in not capturing the actual shallowest depths. Still, the maximum increase in depth differs only slightly from that obtained by using the uncorrected standard deviation (***Figures 4 and 5).*** A more mathematically sound approach is to use the shallowest depth at the corners, derived from the linear fit to the depth measurements within a cell, which is a topic for further investigation.

5.4. Seafloor profile based on introduced alternatives

Figures 8 and 9 depict the profiles of the seafloor along the black line (shallowest part in area *A* in ***Figure 1***) and the green line (relatively flat area in area *B* in ***Figure 2***) for the shallowest, mean, and the two depths based on the mean and (corrected and uncorrected) standard deviation. As the corrected standard deviation is always smaller than the uncorrected value, the mathematical shallowest depth derived using the former is closer to the mean depth compared to one obtained from the latter.

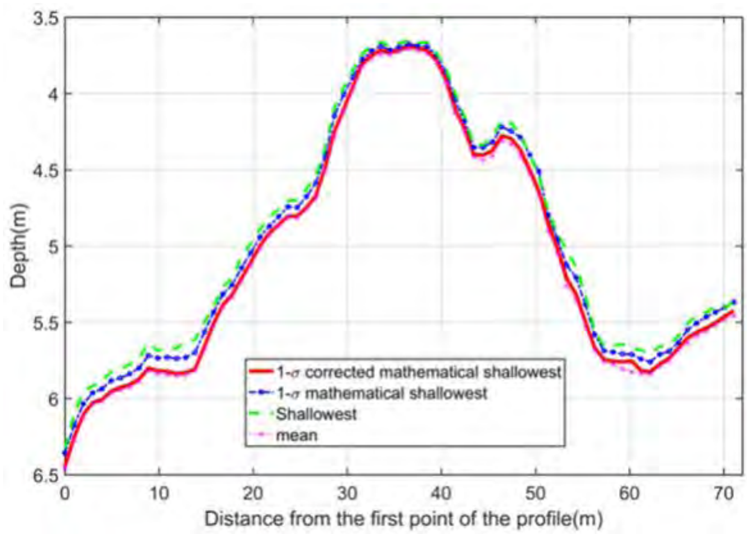

Figure 8. *Profile of the black line shown in the bathymetry map of area A (Figure 1) using four different depths.*

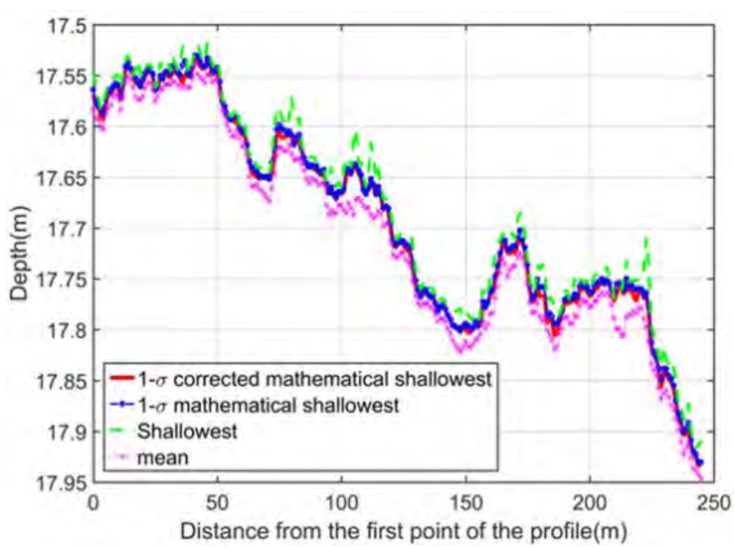

Figure 9. *Profile of the green line shown in the bathymetry map of area B (Figure 2) using four different depths.*

6. Conclusions

There is a need for alternatives to determine the mean and shallowest depths in a grid cell as hazardous objects might be left undetected and the final grid depth value might be too shallow. Combination of the mean depth and standard deviation of the cell is considered a successful candidate. However from tests conducted, this method resulted in depths that are often (6%) shallower than the shallowest measured depth.

A further alternative solution could consider the combination of the mean and corrected standard deviation, which takes the effect of the possible slopes in a cell into account for the calculation of the standard deviation and does not require the calculation of regression coefficients. This results in less cells with depths that are shallower than the shallowest measured depths.

However, this combination is not recommended at this time and research on more realistic measures to account for the depth variation in a cell is still needed. Considering the features, it was found that neither of these representations prohibits the identification of the real bathymetric features.

7. Author Biographies

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Dick G. Simons received his Master degree in physics and his Ph.D degree from the University of Leiden, The Netherlands in 1983 and 1988, respectively. In 2006, he became Full Professor at the Faculty of Aerospace Engineering at TU Delft. He is Associate Editor of the IEEE Journal of Oceanic Engineering and a member of the scientific committee of European Conferences on Underwater Acoustics.
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Ben Dierikx received his Bachelor degree in Hydrography from the Hogeschool Amsterdam, The Netherlands in 1993 and his Master degree in Geodesy from the TU Delft, The Netherlands, in 1997. He was the Senior Advisor on Hydrography. Currently he is a Technical Manager at Rijkswaterstaat. He is responsible for the specifications of Hydrographic tenders.
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Simon Bicknese studied at the Nautical College Noorder Haaks in Den Helder. He sailed for several years as a deck officer with the merchant navy. He joined the survey department from Rijkswaterstaat in 1984. He is now technical advisor for hydrographic issues.
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Notes

PECULIARITIES OF THE TIDE IN KIRKE CHANNEL SOUTH OF CHILE

Lt M. I. Sifon - Hydrographer Engineer
Chilean Navy Hydrographic and Oceanographic Service

1. Introduction

Shipping provides the most important means of transporting goods on a national, regional and global scale. Shipping is particularly important for Chile as the bulk of its commercial trade relies on export and import movements through ports located along its long coast. The Chilean coast is particularly complex in its southern half, where channels, fiords, narrows, inlets and straits exist. The geography of southern Chile present significant navigation challenges. Reliable and precise nautical charts, nautical publications and aids to navigation play a vital role to ensure shipping operations are conducted safely.

Puerto Natales is the port city capital of the Ultima Esperanza Province in the Magellan and Chilean Antarctic Region. Access to the port through the Kirke Channel presents difficult environmental conditions for navigation. The Kirke Channel is approximately 5 nautical miles long with a mean width of 3 cables and a mean depth of 60 metres. At the eastern entrance, between Zeta Island and Punta Restinga, the Kirke Narrow presents a significant and challenging limitation as its navigable width is reduced to approximately 0.2 cables. Further, a phenomenon exists that distorts the tidal wave, making its propagation an irregular wave. This presents range attenuation and a notable mismatch with the wave at the two entrances of the channel. This phenomenon is called “Tidal Choking” and is generated due to one or more constrictions that exist in the channel.

A study of the tidal choking in the Kirke Channel was conducted to model the characteristics of the tide in the area. Through field observations and analysis of historical and observed data, variations of the phase and range of the tide were determined along the channel.

2. Development

To measure the tidal wave, five tide sensors were installed along with atmospheric pressure sensors for a period of two months. The sensors were distributed along the Kirke Channel as indicated in ***Figure 1***.

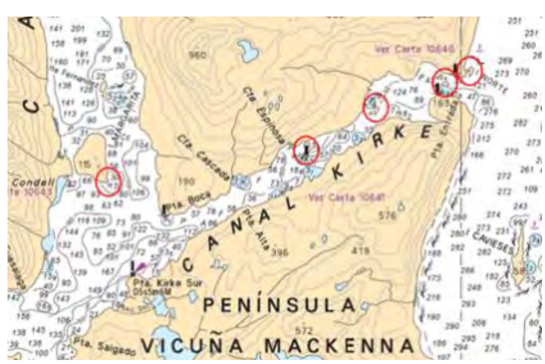

Figure 1. *Sensor positions along Kirke Channel based on SHOA Chart N°10640*

The layout was designed to consider the three constrictions and both entrances to the channel. The main constriction is the Kirke Narrow located at the eastern end of the channel (***Figure 2***).

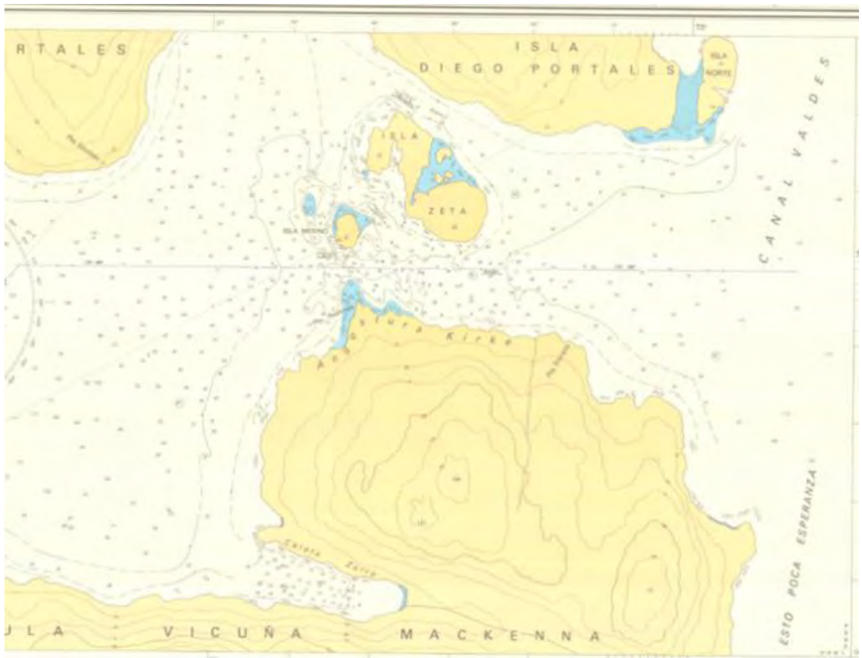

Figure 2. *Kirke Narrow (SHOA Chart N° 10641)*

In this location, the main variations of the tidal wave were observed and required an additional three temporary sensors to be installed for a shorter period (24 hours). This improved the precision of the measurements in the choke zone, close to the eastern entrance between Punta Entrada and the access to the Mal Paso passage. In this location the observed tidal wave was of similar characteristic to that observed close to Isla Norte, but different from that observed close to Isla Zeta. This indicated that the phenomena are developed due to the constrictions between Islas Zeta and Merino with the coast of Isla Diego Portales and the Peninsula Vicuña Mackenna respectively (***Figure 3***).

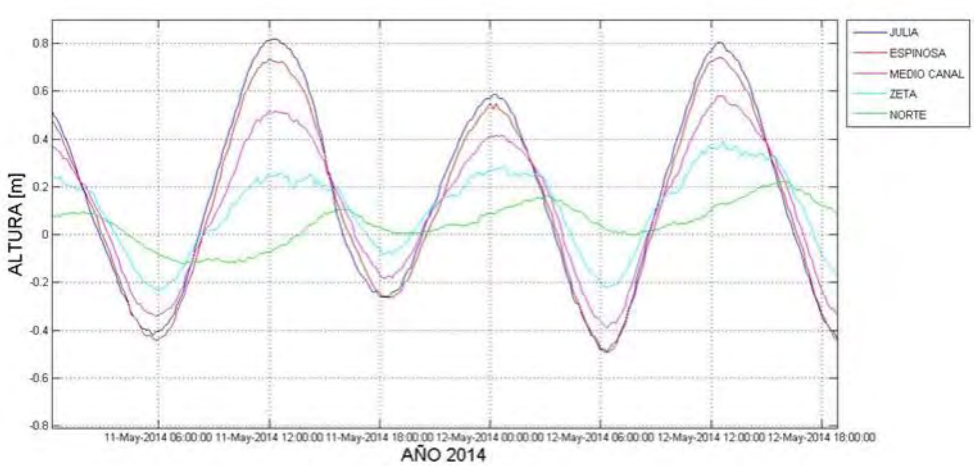

Figure 3. *Tidal wave registered between 11th and 12th May 2014*

A harmonic analysis was conducted using the observed data to determine the tidal harmonic constituents for the sites and the tidal wave was characterized according to the tidal regime. Also a forecast was calculated and registered values were compared with historic data for Punta Restinga. The results were similar for the tide for Isla Zeta and Isla Norte and that in this sector, the choke is produced and affects the narrow. The observations located to the west (Islote Julia, Isla Espinosa and Isla Medio Canal) demonstrated that the tide experiences a progressive attenuation in its range, without presenting significant changes to the phase (***Figure 3***).

From the harmonic analysis, a study of the non-linear component generated by sea-floor friction was conducted to determine if these impacted symmetric and asymmetric distortions of the tidal wave was conducted (***Figure 4***). Based on the established relations it was verified how these distortions take place in the channel.

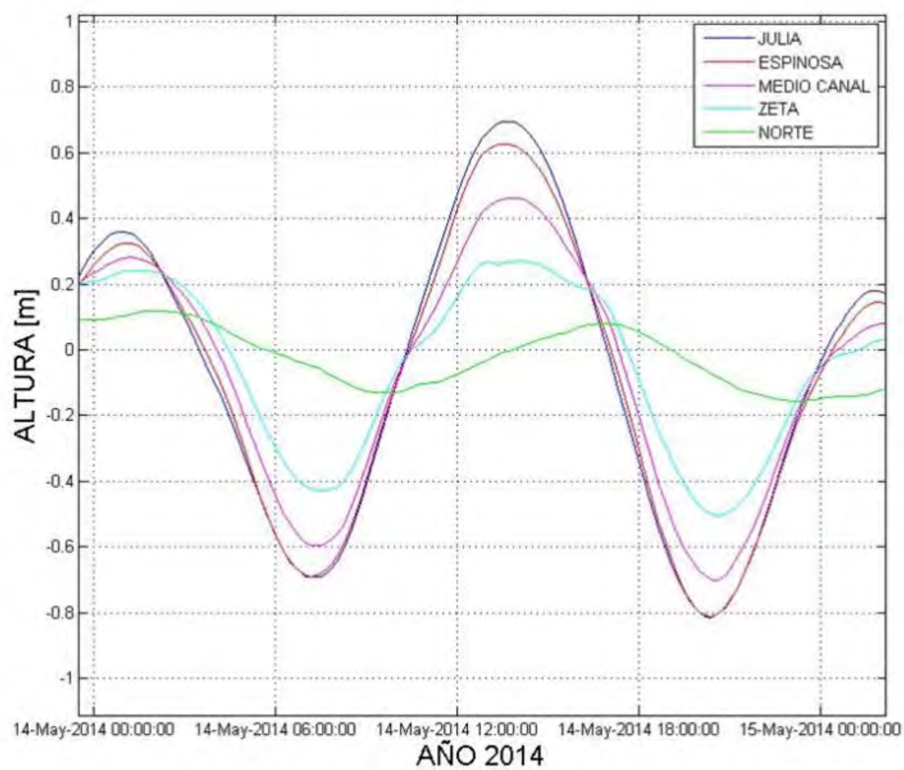

Figure 4. *Tidal wave observed between 14th and 15th May. An asymmetric distortion can be seen in the tidal waves in Isla Zeta and Isla Norte sensors.*

From the collected data, considerable variations were observed and sea level is significantly influenced by atmospheric pressure (***Figure 5***). Due to the importance of this vector in determining the range variability, the height observed, without atmospheric pressure corrections between the two entrances of the channel exists with an attenuation range of 1.35 metres and a mean phase gap of approximately 3 hours (***Figure 6*** and ***Table 1***).

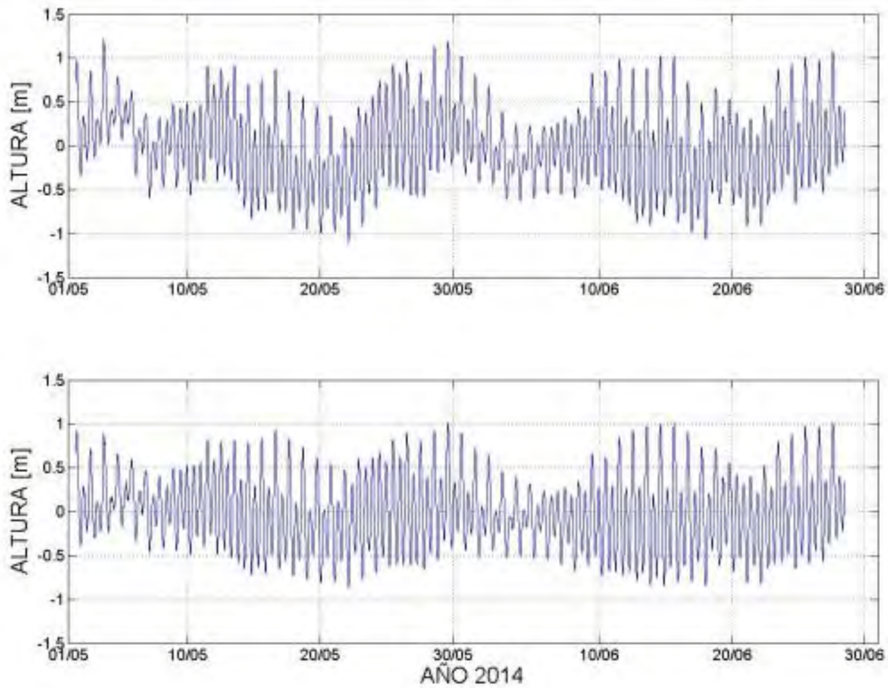

Figure 5. *Isla Julia sensor observations: Tidal wave (upper part) and data corrected with atmospheric pressure information (lower part)*

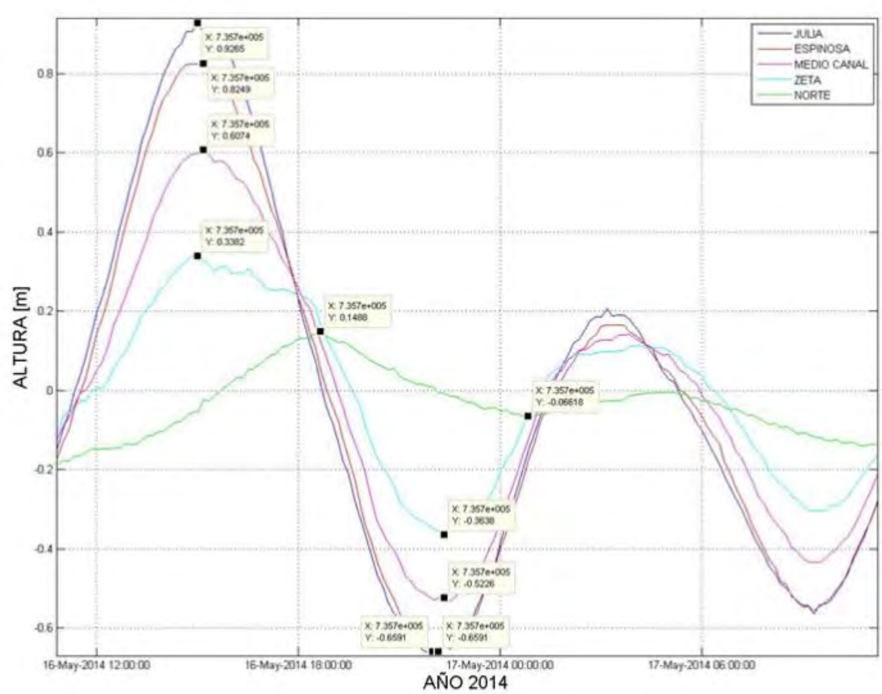

Figure 6. *Tidal wave registered with maximum and minimum height values for each sensor defined as variable "y" (16th and 17th May)*

Table 1. Arrival time of the tidal wave at each station, of a high or low peak for the same day (HH:MM).

Date	High or Low	JULIA	ESPINOSA	MEDIO CANAL	ZETA	NORTE
03 May	H	16:20	16:20	16:20	18:40	21:30
04 May	H	17:30	17:30	17:40	19:10	20:40
06 May	H	20:20	20:30	21:00	21:10	22:30
12 May	H	12:20	12:10	12:20	12:40	13:50
15 May	L	20:50	20:50	20:40	20:50	23:10
16 May	H	02:20	02:30	02:40	02:20	04:40
25 May	H	11:40	11:50	11:50	11:50	14:50
27 May	H	12:50	12:50	13:10	13:10	16:30

6. Conclusions

Kirke Channel has several constrictions that create a tidal pattern generating anomalies in the characteristics, ranges and phases of the tide. The most significant effect is produced by the constriction that exists in the vicinities of Isla Zeta and Isla Merino at the eastern end of the Kirke Channel. At this location, the greater gap is produced and there is a notable attenuation of the tidal range. The wave in this sector is distorted due to the effect of the sea-floor friction which was determined from the non-linear harmonic constituents. Despite the distortions that the wave presents along the channel, this wave is classified as a semidiurnal mixed tide regime, along its entire extension. It was also observed that the atmospheric conditions, particularly the atmospheric pressure have considerable influence along the Channel.

7. Author biography

Lt Matías I. Sifón graduated from the Chilean Naval Academy in 2008. Following different postings, he was selected to undertake the Hydrographic and Oceanographic Engineer Course for Officers, recognized as Cat ”A” in SHOA. After graduation, he participated in hydrographic surveys as Leader of the Hydrographic Teams. Since 2017, he is the Head of the Hydrographic Department at SHOA, responsible for the planning, execution, processing and production of nautical charts.

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Notes

AUSTRALIAN DEFENCE PROJECT SEA 2400 PHASE 1 HYDROSCHEME INDUSTRY PARTNERSHIP PROGRAM (HIPP) TENDER

On 8 December 2017, the Australian Department of Defence released Request for Tender (RFT) documents relating to the Project SEA 2400 Phase 1 HydroScheme Industry Partnership Program (HIPP). The RFT closed 29 March 2018.

Since 1920 the Department of Defence, on behalf of the Australian Government, has been responsible for providing both national and military hydrographic services across the vast Australian Charting Area (ACA). The Australian Hydrographic Office (AHO) is the national authority on hydrographic matters and is responsible for delivering hydrographic services to meet the demands of the maritime community in line with national and international standards. The requirement for these services stems primarily from Australia's obligations under the International Convention for the Safety of Life at Sea (SOLAS), the United Nations Convention on the Law of the Sea (UNCLOS) and the Navigation Act 2012. Previously the majority of hydrographic services undertaken by Defence supported these requirements to ensure safety of navigation for mariners but left little capacity to undertake data collection activities that directly support military interests.

To realise greater efficiencies, the SEA 2400 Phase 1 – Hydrographic Data Collection Capability project will implement a combination of military and commercial environmental data collection capabilities, driving fundamental change to how these services will be delivered. The HydroScheme Industry Partnership Program (HIPP) is the commercial element, which will enable industry to grow and deliver a sustainable, productive and efficient program to support the National Survey Task.

The strategic intent for HIPP seeks to complement other national strategic plans and outlines the research, infrastructure, skills, partnerships and investment that will drive the required changes over the future years. For example, Australia's National Marine Science Plan 2025 states that, 'to fulfil the known potential and yet-to-be-discovered possibilities of our ocean estate, we face seven challenges', with the identified challenges as:

- maintaining marine sovereignty and security
- achieving energy security
- ensuring food security
- conserving our biodiversity and ecosystem health
- creating sustainable urban coastal development
- understanding and adapting to climate variability and change
- developing equitable and balanced resource allocation

Activities undertaken through the HIPP program will contribute to better understanding and mitigating these identified challenges in order to deliver long-term and beneficial economic, environmental, and security outcomes for Australia.

Through the HIPP, the Australian Government will partner with Industry to meet national survey task obligations that will, over the medium to long term, help drive fundamental change in the delivery of defence hydrographic and oceanographic services and the development and innovation of environmental data collection capabilities. As we embrace and prepare for the next generation of hydrographic services, the AHO will continue to evolve and be in a position to fully leverage partnerships and collaborative relationships with both Industry and a range of other Government agencies and organisations.

For further information, please send an email to the Project Contact Officer via the SEA.2400@defence.gov.au email address.

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FOR IMMEDIATE RELEASE

Press release

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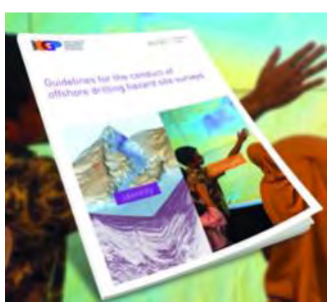
IOGP releases updated version of the Guidelines for the conduct of offshore drilling hazard site surveys

(London) A properly-conducted drilling hazard site survey for an offshore drilling location is essential to minimize the risk of harm to personnel and equipment and to protect the natural environment.



In 2013, IOGP published the *Guidelines for the conduct of offshore drilling hazard site surveys* ('Guidelines'; IOGP Report No. 373-18-1) that describes good practice for conducting geophysical and hydrographic site surveys of proposed offshore drilling locations. In 2015 IOGP issued a supplementary report *Conduct of offshore drilling hazard site surveys – Technical Notes* ('Technical Notes'; IOGP Report No. 373-18-2) that provides supporting technical information.

IOGP has now published an update to the Guidelines, reflecting feedback on use of the original document from regulators from around the world, IOGP member companies, contractors, verification bodies and consultants. The document has also been reviewed to ensure alignment with the Technical Notes and other Geomatics Committee publications.

A dedicated Task Force of the IOGP's Geomatics Committee has worked closely with marine survey industry representatives to review the feedback received. This resulting document reflects the continued development of drilling hazard site survey rationale and the latest technologies and techniques being applied for all relevant water depths and geological settings around the world. The document also includes an updated Glossary of terms.

While the Guidelines and the Technical Notes was developed for drilling hazard site surveys, the techniques described may also be applied in the planning and delivery of other types of seabed surveys, such as those for pipeline and cable routes.

Copies of the Guidelines and the Technical Notes can be downloaded free from the IOGP Bookstore at http://www.iogp.org/bookstore.

About IOGP

The International Association of Oil & Gas Producers (IOGP) is the voice of the global upstream industry. Oil and gas continue to provide a significant proportion of the world's energy to meet growing demands for heat, light and transport.

Our Members produce 40% of the world's oil and gas. They operate in all producing regions: The Americas, Africa, Europe, the Middle East, the Caspian, Asia and Australia.

We serve industry regulators as a global partner for improving safety, environmental and social performance. We also act as a uniquely upstream forum in which our members identify and share knowledge and good practices to achieve improvements in health, safety, the environment, security and social responsibility.

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FOR IMMEDIATE RELEASE

Press release

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IOGP releases Geomatics Guidance Note 24: Vertical Data in Oil and Gas Applications

(London) The IOGP has released the Geomatics Guidance Note 24 (IOGP Report Number: 373-24), *Vertical Data in Oil and Gas Applications*.

The guidance note discusses issues associated with the use of vertical coordinate data in the oil and gas industry, and is aimed at geoscientists, data managers and software developers.

Horizontal and vertical data are equally important in oil and gas exploration and development processes, and incomplete attention to either can impact the integrity, resolution and accuracy of the resultant datasets. Typically, vertical data is not worked to the same level of detail as horizontal data, and the perceived accuracy of the vertical data is often higher than it is in reality. There is generally insufficient attention to reference surfaces and inconsistent use of terminology which can result in erroneous offsets being introduced to datasets.

Axis directions (heights and depths) are frequently interchanged without an appropriate audit trail. These errors are often the result of transferring data between applications, either through software exchanges or common data exchange formats without the transfer of the associated metadata including an explicit definition of the vertical geodetic datum and coordinate reference system (CRS).

This guidance note describes the basic concepts of vertical CRSs and reference surfaces used with vertical data. Guidance is provided for the appropriate use of vertical coordinate reference system definitions and on the importance of the correct unit of measure and vertical axis direction definitions. The use of audit trails to record all coordinate operations performed on data is recommended, with worked examples to provide clarification on the level of detail required.

Copies of the Guidance Note 24 can be downloaded free from the IOGP Bookstore at http://www.iogp.org/bookstore.

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General Information

OBITUARY

Commander Kulwant Bir Singh Wadhera

Commander Kulwant Bir Singh Wadhera was commissioned as a Sub-Lieutenant in the Indian Navy in October 1959 and underwent the Hydrographic Surveying Officers Course at the Hydrographic School in December 1961. During his 24 year-long Professional Naval Career, Cdr. Wadhera participated in several challenging Hydrographic Surveys, off either coast of India and outlying Islands, first as Officer-in-charge of the Survey Teams on board IN surveying ships Sutlej, Jamuna and Investigator, and subsequently, as Charge Hydrographer, when he was in Command of IN Surveying ship Jamuna from 1979-80.

Cdr. Wadhera was heading the Naval Hydrographic School at Kochi since 1977, when the School was relocated to the present location at Vasco Da Gamma Goa, where Cdr. Wadhera continued to head the Hydrographic School, now known as National Institute of Hydrography (NIH). It was due to the dedicated efforts and professional approach of Cdr. Wadhera and his successors that the Hydrographic School has risen to its present stature. The foundation of UNDP Assistance for Augmentation of Training facilities in India was laid during his tenure as Officer In-Charge of the Hydrographic School.

Cdr. Wadhera also served on the staff of Chief Hydrographer to the Government of India twice, between 1967-68 and later during 1973-76, where he was coordinating and overseeing the issuance of Maritime Safety Services and Notices to Mariners in addition to being responsible for setting up of QA/QC processes of Hydrographic Data acquired by the surveying ships prior to its incorporation in Indian Hydrographic Charts.

Post premature retirement from active services in 1982, Cdr. Wadhera briefly sailed as a Master Mariner before returning to Delhi where he worked as Manager in the most reputed Indian Offshore Survey Company Elcome Surveys for nearly a decade, before finally calling it a day as an active Hydrographer.

Cdr. Wadhera was married to late Mrs. Surjit Wadhera and is survived by his daughter Mrs. Pamita Oberoi (pamitakauroberoi@yahoo.in)

The Hydrographic community will always remember and recall Cdr. Wadhera as a professional par excellence, and a gentleman to the core, who was always willing to contribute to professional and social cause. His contribution to the growth of the Hydrographic profession in India during his various appointments with the Indian Hydrographic Surveying service in the Indian Navy shall always be remembered.