National Report of Great Britain, 2007

M. Greaves & C. Fane[1], R. Bingley[2] & D. Baker[2], G. Appleby[3], M. King[4], R. Ioannides[5]

1 Introduction

National geodetic activity in the past year has included:

- the ongoing development and expansion of Ordnance Survey's OS Net™ RTK GPS network – the network is now almost complete;
- distribution of national RTK corrections from OS Net data via licensed Ordnance Survey partners;
- the ongoing submission of data to the EPN and the submission of raw data to the EUREF-IP project, plus contributions to EUVN_DA;
- development of an improved geoid model;
- the continued development of the NERC BIGF (British Isles GPS archive Facility), housed at the Institute of Engineering Surveying & Space Geodesy (IESSG),University of Nottingham;
- continued space geodesy and gravity observations at Herstmonceux;
- research of interest to EUREF at GB universities.

2 National GPS network

The Ordnance Survey National GPS Active Network (www.ordnancesurvey.co.uk/gps) has continued to expand and now contains all the stations of the OS Net RTK network. This is due to switching the data flow to come from the OS Net data store and also to improved hardware on the web server.

Investigations have begun into creating a fully monumented zero order network of around 12 permanent GPS stations from a subset of the National GPS Network. These stations will be at ground level and connected to solid rock. Consultation on the monumentation is being held with Geomatics, Geology and Geophysics experts from academia, the British Geological Survey, the Environment Agency and Proudman Oceanographic Laboratory.

[1] Ordnance Survey, Romsey Road, Southampton, SO16 4GU, UK.
mark.greaves@ordnancesurvey.co.uk, colin.fane@ordnancesurvey.co.uk

[2] IESSG, Nottingham University, University Park, Nottingham, NG7 2RD, UK.
richard.bingley@nottingham.ac.uk, david.baker@nottingham.ac.uk

[3] NERC Space Geodesy Facility, Herstmonceux Castle, Hailsham, East Sussex, BN27 1RN, UK.
GAPP@nerc.ac.uk

[4] School of Civil Engineering & Geosciences, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK
m.a.king@ncl.ac.uk

[5] CAA Institute of Satellite Navigation, University of Leeds, LS2 9JT, UK
r.t.ioannides@leeds.ac.uk

3 Network RTK GPS developments

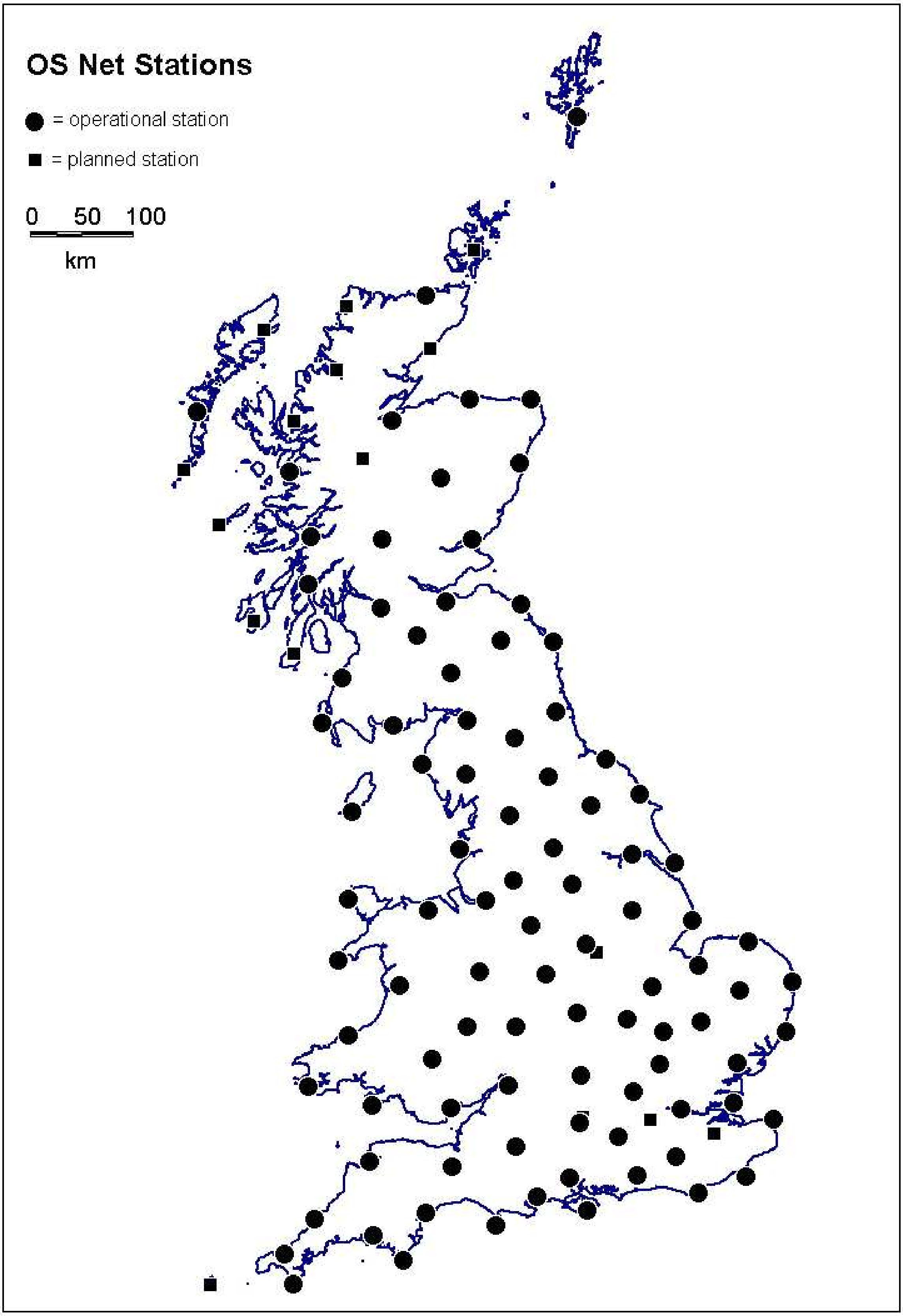

Figure 1. OS Net RTK GPS network.

Ordnance Survey's national RTK GPS network OS Net has continued to expand and now covers the majority of GB with 98 stations. To increase the coverage and improve error modelling some stations from Ireland and Northern Ireland have been added. See Figure 1 above for a map of the current (as at 29th May 2007) and planned network. Expansion into the north west of Scotland to complete the coverage of GB is planned to be completed by the end of this year. The full network is planned to consist of approximately 110 stations.

The network is managed via the GPSNet™ software from Trimble and delivers RTK corrections via GSM and GPRS. The correction data is used by approximately 130 Ordnance Survey surveyors. Public services are now available via Ordnance Survey commercial partners. There are currently two partners – Leica (SmartNet service) and Trimble (VRS Now™ service). Partners take the raw GPS data streams from OS Net servers via NTRIP and use them to generate their own correction services.

Four GNSS (GPS+GLONASS) reference receivers have been purchased and are due to be deployed around London's rapidly developing Thames Gateway and the 2012 Olympic site. This will not only create a test network where further investigation on using dual constellations can be carried out but also enhances the real-time commercial services offered by our OS Net partners. One of the new stations will be within or very close to the main Olympic site in order to facilitate positioning during construction.

Starting next year a complete upgrade of all the station hardware is planned. Receivers will be upgraded to GNSS and antennas will be upgraded to be GNSS compatible including Galileo signals.

4 EUREF related activities

4.1 EPN / EUREF-IP data submissions

Current EPN submissions from GB are hourly data from HERS, HERT and MORP plus 24 hour files from DARE, INVE, NEWL and NPLD. Data integrity problems currently prevent us from switching DARE and INVE to hourly submissions but some planned new hardware should enable us to do this.

Raw GPS data from DARE and INVE also goes to the EUREF-IP project. This is in addition to the RTK data from HERT.

4.2 EUVN_DA / Channel Tunnel levelling

Work has started with colleagues of the French Institut Geographique National to finally come to a common answer for the levelling through the Channel Tunnel carried out in 1994. This will enable a better connection of the GB levelling network to UELN. IGN is presenting a paper on their work so far and further work will continue through out the year.

We express our thanks to our French colleagues - Alain Coulomb, Francoise Duquenne, Henri Duquenne, Alain Harmel and Paul Rebischung for their extensive work on the levelling data sets. We also thank Carl Calvert and Roger Hipkin for once more being involved in some of their "old" work.

5 Geoid model improvement

Geodetic GPS observations have been taken at 30+ levelling points in the north west of Scotland and on the Scottish islands in order to improve the OSGM02 geoid model. Further observations were taken at other fundamental bench marks around GB. A new geoid model OSGM07 will be published later this year.

6 BIGF British Isles GPS archive Facility

The NERC British Isles GPS archive Facility (BIGF) is operated from the IESSG, with funding from the UK Natural Environment Research Council (NERC), until at least 2009. Figure 2 shows the current network.

BIGF is the long-term national archive for GPS data, from a continuously recording network of currently in excess of 120 stations sited throughout mainland UK. This network comprises all the Ordnance Survey of Great Britain active stations, 5 Ordnance Survey Northern Ireland active stations and 25 scientific stations. The scientific stations have been established by various agencies and organisations, who are: DEFRA; the Environment Agency; the Met Office; the National Physical Laboratory; NERC Proudman Oceanographic Laboratory; NERC Space Geodesy Facility; Newcastle University and the IESSG. Data are provided and transmitted free-of-charge to the archive by these collaborators, with whom long-term agreements to supply are in place.

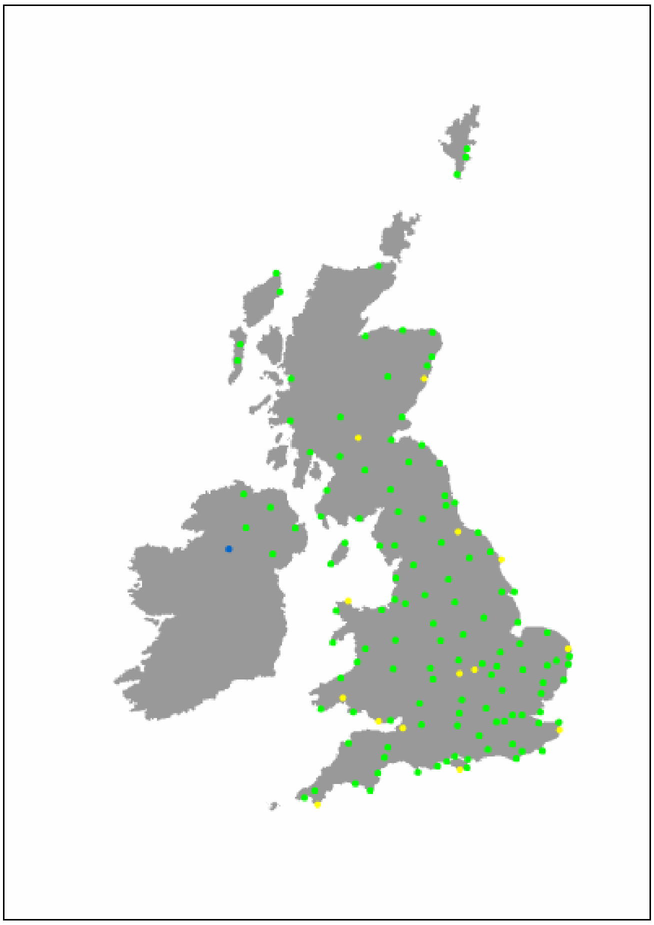

Figure 2. The current BIGF Network. Green = active, yellow = historical data available, blue = planned data

Cumulative demand on the archive since its inception in 1998 has now exceeded 1,700 site years. More importantly the number of scientists annually making use of the archive increased from 4 to more around 150 over the same period. This growing user base has elevated BIGF's profile in the scientific community, increasing the possibilities for infiltration of new scientific fields, the enabling of new applications, and cross-fertilisation and collaboration between experts in satellite positioning technology and experts in other disciplines.

During the period from 1998 to present, there has been a steady net growth in the BIGF network to the current live complement of 128 stations (a further 21 have ceased operation but data are preserved in the archive). The current status of the network is shown on the map in Figure 2.

In 2006/7, there were eight major users of BIGF data:

- Rutherford Appleton Laboratory researching the impact of space weather on communications and navigation systems.
- UK Met Office for research into near real-time estimation of atmospheric water vapour content.
- IESSG for research on vertical land movements at tide gauges, as part of UK-funded work being carried out in collaboration with NERC Proudman Oceanographic Laboratory, and EC-funded work being carried out as part of the European Sea Level Service (ESEAS).
- Newcastle University for research into ocean tide loading, funded by the RICS.
- EUMETNET (Network of European Meteorological Services) funded E-GVAP Project, for research on near real-time tropospheric water vapour estimation, represented by the Met Office in the UK.
- Geodetic Institute of the Norwegian Mapping Authority, for research into the of GPS humidity measurements in meteorology, the TOUGH project, funded by the EC under Framework 5.
- University of Nevada for the inter-comparison of absolute gravity and GPS at Lerwick, funded by the US National Research Foundation.
- Nottingham Scientific, for research into monitoring GPS performance across the UK, funded by the British National Space Centre.

Other research supported by archive data in 2006/7 included, amongst many others:

- Assessing the role of cellular modelling in eco-hydraulics.
- Establishing geodetic control in the monitoring of urban subsidence using InSAR.
- GPS surveys of scarce tree species in European protected sites.
- Hydro-ecological modelling of braided rivers.
- Limestone Country Project, tracking cattle with GPS.
- Mapping and visualisation of sub-surface utility networks.
- Morphological mapping of a small channel with bed forms.
- Mechanisms of coastal erosion in Devensian tills on the East Yorkshire coast.
- New approaches to estimating flood flows via surface videography and 2 and 3D modelling.
- Safety critical applications of GNSS in the rail environment.
- The integrity of integrated GPS/INS systems in the presence of slowly growing errors.
- Tropospheric delay compensation in radio astronomical imaging with the European VLBI network.

The long-term nature and increasing spatial density of the BIGF network lends itself to take on a facilitative role as an environmental laboratory, enabling the more incisive determination of spatially dependent environmental variables, and isolation of lower frequency components of parameters such as ocean tide loading and vertical land movement. The availability of three new active stations established by the Ordnance Survey of Northern Ireland increases the spatial extent and utility of the archive, which is of particular importance to meteorological scientists.

Seven of the stations are part of the IGS and EPN (DARE, HERS, HERT, INVE, MORP, NEWL and NPLD) and four CGPS@TG stations contribute to the IGS TIGA Pilot Project (ABER, NEWL, NSTG and SHEE).

BIGF has a website at http://www.bigf.ac.uk providing detail of the archive's history, archive users, and the current network. Data can be requested using an online form at this site

7 Space Geodesy Facility at Herstmonceux

The Space Geodesy Facility is operated at Herstmonceux, UK, with funding from the Natural Environment Research Council, the British National Space Centre and the UK Ministry of Defence. It is an observational Facility with a highly productive and precise Satellite Laser Ranging system, two continuously operating IGS GNSS receivers and a permanent Absolute Gravimeter. Frequent, on-site automated meteorological and water table depth observations augment the geodetic observations.

7.1 Satellite Laser Ranging.

The system is a core International Laser Ranging Service station, making daytime and night time range measurements to geodetic, gravity-field, altimeter and GNSS satellites at heights of from 500 to 23,000km. The precision of the range normal points is about 1mm, and the station is ranked about 6th in the ILRS network in terms of data productivity. The system is nearing completion of an upgrade to include a short-pulse high repetition rate (2 kHz) laser and a very high accuracy event timer which when combined will increase system accuracy to the mm level. In spring 2006 the system was the first in the world to range to the prototype Galileo In-Orbit Validation Experiment, GIOVE-A. The Facility is now an ILRS Analysis Centre, and computes weekly global station coordinate and Earth orientation solutions in support of the ILRS' contribution towards rapid ITRF realisation work in collaboration with the other IAG Services.

7.2 GNSS

The two Ashtech (Z12 and Z18) receivers HERS and HERT remain in continuous operation, with HERT also streaming GPS and GLONASS navigation data into the Internet in support of the EUREF-IP and IGS Realtime Projects. Given the age of these systems, serious consideration into upgrade options is due. A valuable GPS analysis capability has been initiated based on the GAMIT package. Daily solutions for HERS and HERT coordinates and precise HERS-HERT baselines inform a rapid quality check on the observations as well as providing a valuable local site-stability solution.

7.3 Absolute Gravity

Regular weekly operations of the FG5 absolute gravimeter began in October 2006. The baseline observational programme is a 30-hour session centred on mid-GPS week, resulting in hourly average gravity values of precision about 1-2 µgal, equivalent to a vertical precision of around 3mm. This is a joint programme with Proudman Oceanographic Laboratory (POL) and will strengthen UK work in this field as well as providing what is hoped will be a stable series of gravity measurements to complement the high precision SLR and GNSS measurements from Herstmonceux. A long series of gravity measurements will strengthen in particular the interpretation of the long series of SLR and GNSS height solutions from the site.

8 University research work

Several GB universities have been involved in projects and research of interest to the EUREF community. There follows a summary of some of this work.

8.1 Newcastle University

Contact Matt King [m.a.king@newcastle.ac.uk] in the first instance for further details of these projects.

8.1.1 Global Navigation Satellite Systems

Systematic Errors

Extensive studies of the propagation of unmodelled periodic ground displacements into GPS coordinate estimates and time series used in geophysical studies are detailed in Penna and Stewart (2003), Stewart et al (2005) and Penna et al. (2007). It has been demonstrated that unmodelled semi-diurnal and diurnal tidal displacements can propagate to fortnightly, semi-annual and annual signals, purely due to the GPS constellation repeat period and basic functional model used. Unless all tidal displacements are perfectly modelled, geophysical interpretation of such GPS coordinate time series can be problematic, and provides further evidence of how tidal models must be as accurate as possible across all regions of the world.

Sidereally-repeating (predominantly multipath) error has been studied by Ragheb et al (2007), who confirmed previous findings that the dominant “sidereal” repeat period is in fact 10 s less than the true sidereal interval. They showed that in a double-difference single epoch processing strategy, the use of a common repeat period is adequate and that a filter based on residual coordinate differences is marginally superior in precision but significantly slower than one based on double-difference residuals. Stacking of residuals for 7 days prior to filter application yields the most effective filter.

8.1.2 National, International networks and Reference frames

No Net Rotation Reference Frame determination

Kreemer et al [2006] have determined a new No Net Rotation (NNR) reference model of the Earth’s horizontal surface velocity from ~5700 geodetic velocities, using data sets that included SINEX solutions from the EUREF IGS Regional Network Associate Analysis Center. The most important implication of this work is for the International Terrestrial Reference Frame (ITRF), since by convention the ITRF is a NNR. The sensitivity of the new NNR frame is tested according to data input and model assumptions: these differences are ~0.6 mm/yr, and much smaller than the differences with the current ITRF of 3.1 mm/yr, so it is concluded that the ITRF does not satisfy the NNR condition. This work also highlights the sensitivity of NNR determination to the realisation of the ITRF origin.

Geocenter motion determination

Lavallée et al. [2006] present a new precise method for determining geocenter motion from GPS. This unified approach utilizes constraints on elastic properties of the Earth to allow precise GPS baseline determination and improve the determination of the GPS geocenter despite orbit modelling imprecisions. The application of this approach to GPS improves consistency among different GPS solutions, agreement with SLR geocenter motion estimates and those from surface mass loading models. This unified approach has been developed from work on surface mass loading which has been undertaken at Newcastle (see below). This work has implications for the ITRF since geocenter motion is not included in the current ITRF realisation because of past disagreements between different techniques; this is a well known shortcoming of the current ITRF realisation which needs to be addressed in the near future.

New GLONASS/GPS monument

A new monument has recently been installed at the Cockle Park Farm site where MORP is located, about 7m from the existing monument. As with the existing MORP site, MORG (proposed name only) is monumented on a ~3m high slab of quarried stone to provide a robust connection between the local bedrock and the antenna. We have installed a GPS/GLONASS receiver at the site and will soon request it be included in the IGS/EPN networks along with MORP with daily data transmission envisaged. We expect to upgrade the receiver to GPS/GLONASS/Galileo once suitable receivers are available.

8.1.3 Geophysical, Glaciological and Oceanographic Applications of GNSS

Monitoring Tectonic Deformation

Studies have been undertaken to monitor plate boundary deformation in the Central and Eastern Mediterranean regions using GNSS applications. One such study processed data from more than 100 permanent GPS sites across Central Europe using the precise point positioning technique and obtained rigorous estimates of site velocities and their confidence limits via simultaneous estimation of the secular velocity, annual and semi-annual harmonic displacements, and power-law characteristics of the coordinate time series noise. Plate rotation rates were derived and the compatibility of site velocities within the Adriatic region with Eurasian, African and local (microplate) motions were tested. On a regional scale, campaign GPS data was reprocessed for the Hellenic region of Greece and represented in a common reference frame. Geodetic strain was estimated and compared to seismic strain rates derived from earthquake catalogues to determine seismic hazard potential.

8.1.4 References

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8.2 University of Leeds

Contact Rigas Ioannides [r.t.ioannides@leeds.ac.uk] for further details of this work.

There are several projects that take place with the support of the Civil Aviation Authority Institute of Satellite Navigation at the University of Leeds, relating to the ionospheric effects on GNSS applications. Current work includes the characterisation of the effects of scintillations to the GNSS receiver acquisition and tracking performance and the development of a new receiver design that would be able to outperform in acquisition and tracking the current state of the art receiver designs under these conditions.

The effect of the ionosphere, including horizontal gradients, scintillations and geomagnetic field effects, to the GNSS signals is another area of research that takes place in our group, developing new algorithms that will accurately predict through new developed fast ray-tracing models, model and correct for the first and higher order ionospheric and geomagnetic field effects for relative positioning applications.

8.3 University College London

Contact Marek Ziebart [marek@ge.ucl.ac.uk] for more information on this work.

Vertical Offshore Reference Frames Project (VORF)

The VORF project is a two year research contract with the UK Hydrographic Office to develop a modern and seamless reference frame for offshore charting and navigation. The aim of the VORF project is to derive a homogenous minimum sea surface and model the relationship between this, ETRS89 and several other vertical datums.

Around the coasts of Great Britain and Ireland there are more than 500 definitions of Chart Datum. This is the reference level with respect to which depths are expressed, and these values vary with respect to each other by significant amounts. Moreover, they bear little relation to the reference datums that are used on land to express heights above sea level.

As well as Chart Datum, hydrographers also use reference surfaces such as Mean High Water Springs to give clearance heights under bridges. Until recently, hydrographic surveys have generally been kept separate from land surveys, and surveys at sea often used such sparse data sets that changes in the datum were not readily apparent. All this is changing.

With the advent of technology such as GPS and LIDAR, and increasing interest in areas such as the coastal zone, there is an imperative need for a system that will seamlessly transform between all the different reference surfaces and extend our knowledge of vertical datums offshore. This is what VORF will achieve, through a set of transformation models integrated into one software package. Scientifically, we also expect to develop a very detailed understanding of phenomena such as mean sea level behaviour around the coast of the British Isles.