Defra / Environment Agency
Flood and Coastal Defence R&D Programme

R&D Technical report FD2301

# Absolute fixing of tide gauge benchmarks - Phase 2

## Background to R&D project

The sea level rise trends around the British Isles consist of 2 components: the climate related changes in mean sea levels and the vertical movements of the land. The tide gauges in the National Tide Gauge Network measure the sea level relative to a local tide gauge bench-mark (TGBM). Thus a measured rise in mean sea levels can be due to the effects of climate change or it can be due to subsidence of the land at the TGBM (due to very local or regional subsidence or larger scale processes). In practice, the climate related component and the land movement component are of a similar order of magnitude at most sites and therefore it is important to measure the vertical land movements, so that these effects can be separated. In this project the new advanced geodetic techniques of GPS and absolute gravity are used to measure the land movements at a number of UK tide gauges. The improved knowledge and understanding of the variability of sea level changes around the coasts will provide important guidance for flood defence design.

This research project followed on from previous MAFF R&D projects (funded from 1990-2000 as FD0305: The Geodetic Fixing of Tide Gauge Bench Marks). In the earliest projects, from 1990-1996, episodic GPS campaigns were used for the geodetic fixing of tide gauge bench marks in the UK. These campaigns were observed by using a large number of GPS receivers, deployed simultaneously for 5 days. Through these projects, extensive research and development was carried out on the mitigation of systematic biases and errors for high precision GPS (Ashkenazi et al, 1994; Ashkenazi et al, 1997). In the last of these projects, from 1997 to 2000, continuous GPS (CGPS) stations were established at the 5 tide gauge sites of Sheerness, Newlyn, Aberdeen, Liverpool and Lowestoft in 1997 and 1998, and two sets of episodic GPS (EGPS) measurements were carried out at 12 other tide gauge sites in the UK in 1999, using a small number of 'roving GPS receivers'. Research was then concentrated on the development and testing of automated procedures for GPS data processing and analysis (Bingley et al, 2000).

The scientific objective of this research project was to improve the monitoring of long term vertical land movements at sites of the UK National Tide Gauge Network using the Global Positioning System (GPS).

## Results of R&D project

Permanent Continuous GPS (CGPS) stations were set up at the tide gauges at Sheerness (1997), Newlyn (1998), Aberdeen (1998), Lowestoft (1999) and Liverpool (1999). In the present project additional CGPS stations were installed at the tide gauges at North Shields (2001) and Portsmouth (2001). The data from these 7 tide gauge CGPS stations, together with data from 13 other UK CGPS stations were downloaded on a daily basis using the automated procedures developed as part of the previous project. The CGPS data from the UK stations and 4 European reference stations (Kootwijk, Onsala, Villafranca and Wettzell) were processed and analysed on a daily basis using the final precise satellite coordinates given by the International GPS Service (IGS). Coordinate time series for the UK CGPS stations were found in a consistent global reference frame (ITRF2000) by tightly constraining the coordinates and velocities of the 4 European reference stations to their ITRF2000 values.

The vertical station velocities for the tide gauge CGPS stations were found to be in the range from approximately –2mm/year to +2mm/year. However, taking into account the uncertainties, none of the individual vertical station velocities can be considered to be statistically significant yet. It was concluded that for high quality CGPS stations at least 6 years of data are required to reduce the 1-sigma statistical uncertainty to +/- 1mm/year. Using CGPS data from Newlyn and Camborne, which is on solid rock about 20km from the tide gauge, it was shown that the tide gauge is not experiencing

any significant localised land movement that is different from the regional geophysical movement observed at Camborne. This dual-CGPS concept can be usefully applied at other tide gauges in order to check how representative the vertical land movements observed at a tide gauge are of the land movements over a wider area.

In the previous project, episodic GPS (EGPS) measurements were made for 3 to 5 days at 10 further tide gauges. These episodic GPS measurements were repeated in the present project using roving GPS receivers. At 4 of these tide gauges (Dover, Immingham, Holyhead and Stornoway) the GPS receiver was installed for 3 to 6 weeks. These, so called quasi-continuous GPS (QCGPS), measurements allow better estimates of the uncertainties than is possible with the EGPS measurements. It was concluded that the EGPS measurements are sufficient for calibrating satellite altimeters or determining mean sea surface topography but are not sufficient for measuring vertical land movements. CGPS is the preferred GPS technique for determining vertical land movements on a national scale.

It has been shown that the procedures developed for making absolute gravity measurements to the highest international standards have successfully been used to determine vertical land movements at the 3 core UK tide gauges. Within the error estimates, the vertical velocities are in agreement with models of large scale land movements due to post-glacial rebound and subsidence.

It is recommended that the CGPS and absolute gravity measurements should be continued in order to increase the lengths of the time series and reduce the uncertainties. Where possible, EGPS stations should be replaced with QCGPS, or preferably, CGPS stations. The vertical velocities determined from the absolute gravity measurements will provide an important assessment of any systematic biases in the estimated vertical velocities from CGPS.

**R&D Outputs and their Use**

The deliverables for the research project were an improved monitoring network providing estimates of vertical land movements and recommendations on a strategy for long term monitoring.
The absolute gravity results allow assessment of any systematic biases in the vertical velocities determined from GPS.
Improved guidance on long term sea level rise around the coasts will improve the design of coastal defences and other works. Once statistically significant estimates of vertical land movement at the tide gauges are available, it will be possible to separate this from the water level readings to assess the true sea level rise at the tide gauge.

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This R&D Final Report relates to R&D Project FD2301 and the following R&D outputs:

- **R&D Final Report - Absolute fixing of tidal gauge benchmarks – Phase 2**

Publication Internal Status: Released internally External Status: Released to public domain

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The above outputs are available under the Risk, Evaluation and Understanding of Uncertainty theme on the Defra website ( http://www2.defra.gov.uk/research/Project_Data ). Copies are held by all EA Regional Information Centres and can be purchased from the EA's R&D Dissemination Centre, c/o WRc, Frankland Road, Blagrove, Swindon, Wiltshire SN5 8YF (Tel: (+44) 1793-865012; Fax: (+44) 1793-514562; email: publications@wrcplc.co.uk).