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Scoping Study to assess the status of Irelands tide gauge infrastructure and outline current and future requirements

FINAL REPORT

REPORT PREPARED FOR:

DEPARTMENT OF COMMUNICATIONS, MARINE AND NATURAL RESOURCES

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19 DECEMBER 2003

Proudman Oceanographic Laboratory
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Glossary

BODC	British Oceanographic Data Centre
CLDG	Centre Littoral de Géophysique
COST	European **Co**-operation in the field of **S**cientific and **T**echnical Research
DEFRA	Department for the Environment, Food and Rural Affairs
EOSS	European Sea Level Observing System
EPA	Environmental Protection Agency
ESEAS	European Sea Level Service
GCN	GLOSS Core Network
GLOSS	Global Sea Level Observing System
GODAE	Global Ocean Data Assimilation Experiment,
IEO	Instituto Espanol de Oceanografia
IGN	Institut Géographique National
IGS	International GPS Service
INSS	Irish National Seabed Survey
IOC	Intergovernmental Oceanographic Commission
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
LEGOS	Laboratoire d'Etudes en Géophysique et Océanographie Spatiale
MAFF	Ministry of Agriculture, Fisheries and Food
MSL	Mean Sea Level
NTSLF	National Tidal & Sea Level Facility
OPW	Office of Public Works
OSi	Ordnance Survey Ireland
PSMSL	Permanent Service for Mean Sea Level
RONIM	Réseau d'Observatoires du NIveau de la Mer
RTQC	Real Time Quality Control
SHOM	Service Hydrographique et Océanographique de la Marine
SONEL	Système d'Observation du Niveau des Eaux Littorales
STFS	Storm Tide Forecasting Service
UH	University of Hawaii
UHSLC	University of Hawaii Sea Level Centre,
WMO	World Meteorological Organisation

1 Introduction

1.1 Executive Summary

Sea level recording has a relatively long history in Ireland with measurements in Dublin (for example) dating back to 1938. However, there has never been a coordinated network of gauges around the coastline similar to those operated in most other European countries. In August 2003 the Department of Communications, Marine and Natural Resources commissioned the Hydraulics and Maritime Research Centre (HMRC) and the Coastal and Marine Resources Centre (CMRC) both of University College Cork and Proudman Oceanographic Laboratory (POL) to investigate Irelands requirements in terms of tide gauge measurements.

This report, which is the outcome of the above commission, addresses a number of issues with regard to tidal observation, data archiving and dissemination in Ireland. These include:

- Justification for gauges in Ireland within national, European and global contexts.
- Inventory of existing tide gauge infrastructure in Ireland
- Determination of Irish Stakeholder Requirements
- GLOSS (Global Sea Level Observing System) and its implications/requirements for Ireland
- Details of relevant statutory bodies with respect to water level measurement
- Examples of European networks
- The design of a baseline Irish network from the perspectives of long term sea level change, flood defence and oceanographic studies.
- The suitability of sites for inclusion in the network.
- The requirements of the gauges to be used in the network.
- The need for efficient ‘fast’ and ‘delayed’ mode information to a data centre.
- The automatic and off-line quality control procedures and data management methods to be employed.
- The requirements for ancillary meteorological data, geodetic levelling at gauge sites and GPS equipment.
- The establishment of a framework for managing the network
- Indicative costings for the network

This report contains recommendations for a new network of sea level stations with emphasis on the establishment of a number of high quality stations. These stations will consist of tide gauges together with ancillary sensors to provide meteorological data. In addition sites set up for tracking long term trends in mean sea level will also contain Global Positioning System (GPS) receivers. In terms of timescale it is recommended that immediate attention be given to fully establishing two GLOSS sites and two additional sites that are of national (and international) strategic importance. Issues with regard to the funding of further new gauges, and long term management and maintenance of the infrastructure and data emanating from them must be addressed. This will require detailed discussions/negotiations between various government departments/agencies and stakeholder groups that in the absence of a timed strategic plan could potentially stretch over a number of years.

1.2 Network Justification

It is important to establish from the onset the relevance of establishing a formal network of tide gauges in Ireland. Such a network has long term funding implications so to be justified must be clearly shown to constitute a valuable national asset. Experience in other countries indicates that a properly managed network of gauges can provide data for a range of practical and scientific applications. Opinion among Irish stakeholders accords strongly with this view, and questionnaire responses evidence overwhelming support for the establishment of a co-ordinated and coherent network.

For an Irish network the following applications are envisaged:

- Production of precise tidal predictions.
- Provision of flood warning during periods of high tide and storm surge.
- Provision of data aids to navigation (e.g. via automatic updates to electronic chart depth information).
- Geodetic studies including datum determination for land and hydrographic applications.
- Determination of the heights of extreme sea levels for coastal engineering design.
- Studies of Irish Sea and Atlantic sea level variability including determination of long term changes in mean and extreme sea levels as a consequence of climate change.
- Oceanographic studies of circulation change in the adjacent deep Atlantic on various timescales.
- Assimilation into a range of numerical ocean models for operational monitoring of marine ecosystems and water quality.

It can be seen that data from the network would serve a number of communities across the sciences and within the commercial marine world. Data from the same stations would provide information in both ‘fast’ (or ‘real-time’) and ‘delayed’ modes, thereby serving different types of users. Two-way data exchange with the UK and France (and in principle with more distant European countries) would provide further benefits through combined analysis of information.

2 Irelands Tide Gauge Infrastructure

The current status of gauges operating in Ireland is first assessed as it will give information on locations where there has been an identified need for water level measurement and could also provide the framework on which a national tide gauge network could be based. This analysis excludes the many gauges used for river level monitoring and detailed discussion on the Malin Head gauge which will be dealt with in greater detail in Section 5.

2.1 Overview of Gauge Types

Prior to discussing current Irish sites a brief overview of the different gauge types currently used to measure water level is provided, as these will be referred to repeatedly in later sections. Tide gauges come in four basic types (float, acoustic, pressure and radar), each of which have been reviewed in IOC (Intergovernmental Oceanographic Commission) (2002) and will be reviewed again in the near future in the proceedings of a GLOSS (Global Sea Level Observing System) Technical Workshop held in October 2003:

i. Float gauges – these are the traditional gauge type. However, they are difficult to install, requiring a 'stilling well', and, while they can be adapted to provide real-time digital data by means of shaft encoders or potentiometers, they do not necessarily measure the same level as the outside water if installed in estuaries. They also tend to be labour-intensive, requiring frequent maintenance of float mechanisms and clearing of sediment accumulation in the well.

ii. Acoustic gauges – these come in two main types: the 'shining' of an acoustic pulse from a transducer to the sea surface and back to the transducer in the open air (or sometimes inside a stilling well); and the shining of a pulse inside a plastic tube equipped with calibration hole (called SEAFRAME systems in Australia and Next Generation systems in the USA). The GLOSS Technical Workshop demonstrated that the first type is to be avoided. The second type is now the standard gauge in a number of countries and would probably be suitable at locations in Ireland where there is a harbour wall or pier on which to attach the acoustic sounding tube. Such systems are operated in France, Portugal and Turkey. One was tested by POL for a year at Holyhead with the conclusion that it was not suitable for most UK locations owing to the large tidal range and therefore the need for a long sounding tube: a long tube implies temperature gradients and therefore differential changes in the speed of sound along the tube (Vassie et al., 1992). In Ireland the tidal range is generally not large (in comparison to some UK locations) and concerns on temperature gradients might not be so acute.

iii. Pressure gauges – also come in several types but all provide an indirect measurement of water level by making assumptions on water density. Bubbler gauges form the UK standard and a bubbler system has been installed at Malin Head. In the case of the bubbler the pressure sensor is located out of the water and water level is measured by passing air at a metered rate down a tube to a pressure point located below the lowest expected water level. The pressure point takes the form of an open bottomed cylinder and has a small hole drilled in its side. Air entering the pressure point pushes the water down the cylinder until it reaches the bleed hole where it 'bubbles' to the surface. At this point the pressure of air in the system is equal to the combined effects of the head of water plus atmospheric pressure.

There are also ‘transducer in the sea’ and ‘B gauge’ systems. The latter are used throughout POL’s South Atlantic network but are very expensive to manufacture and are not commercially available. The advantage of pressure systems (but not bubblers) is their ability to measure high frequency phenomena (wind waves, seiches, tsunami) as well as the conventional sea level recording with sampling intervals of several minutes. All pressure systems have the advantage of operating safely below the sea surface but may over time be subject to fouling.

iv. Radar gauges – are relatively new and so there is only limited experience of their use. Nevertheless, the GLOSS Technical Workshop included presentations by several speakers, which indicated that they are capable of making measurements to a standard similar (and better) to other systems (e.g. Woodworth and Smith, 2003). Their main advantages are ease of installation and maintenance, and in most cases relatively low cost. Their main disadvantages at the moment appear to be their exposure (hence security and environmental damage concerns) and the need to develop *in situ* ongoing calibration methods. POL has experience only of OTT Kalesto radar gauges and possesses three at the moment. It plans to install them first at sites near river mouths where rapid density changes occur (e.g. Newport in south Wales and possibly Sheerness) and where bubblers occasionally provide inaccurate sea level data because of density uncertainties. A Kalesto will also be installed in Gibraltar before the end of 2004.

2.2 Gauge Details

Each of the gauges operating in Ireland will now be described. Information was collected by a combination of means but mainly through questionnaires, telephone calls, emails and in a number of cases, site visits. It was endeavoured that as complete an information set as possible be collected for all sites but sometimes this was not possible for various reasons. Figure 2.1 below shows all the tide gauges surveyed in this study.

Appendix 1 shows the questionnaire that was sent to all the identified operators whilst Appendix 2 contains their names and contact details.

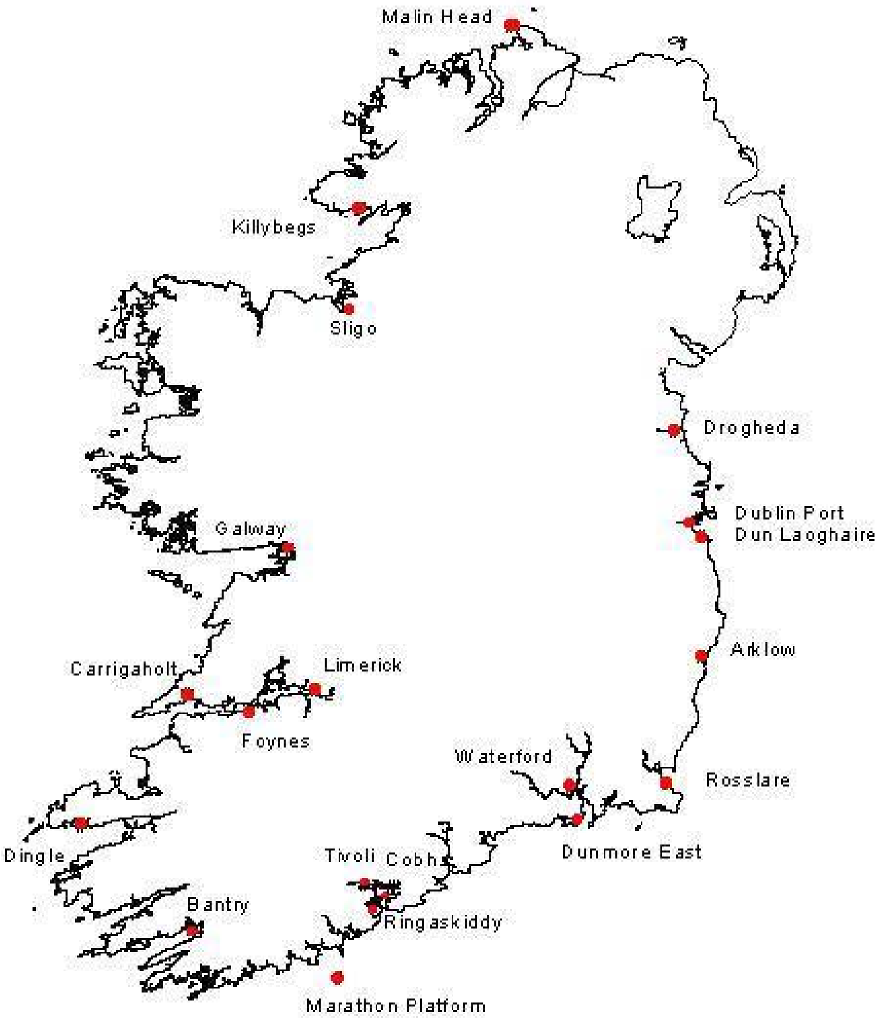

Figure 2.1 Tide Gauge locations

2.2.1 Malin Head

For detailed information on the Malin Head site see Section 6.1. In summary this location has had an operating tide gauge since 1958. A new OTT NIMBUS bubbler type gauge was installed in July 2003.

2.2.2 Killybegs

Overview

This gauge was installed on the 1/11/00 and the Department of Communications Marine and Natural Resources are the responsible organisation. Data is being stored in a data logger and downloaded regularly on to an excel worksheet by Department personnel. The logger has limited capacity (256k) and because of this there have been memory overflows and data has been lost on a few occasions (Data Availability; 2/11/00 – 27/6/01, 30/10/01 – 30/5/02 and 9/10/02 – present). It is expected that this problem has now been solved (by increasing the unit's capacity) and in addition it is planned to install a radio link in 2004. The tide gauge main function is to assist the harbour master in bringing vessels into the harbour on very low tides but it is also used to assist hydrographic surveys in the area.

Technical description of gauge
The Killybegs gauge is bubbler type (NIMBUS) manufactured and installed by OTT - Hydrometry (http://www.ott-hydrometry.de/). It logs the tide level every 15 minutes and has an accuracy of +/- 0.5cm. The instrument is zeroed to 0.0m chart datum Killybegs by use of a local benchmark approximately 150m from the gauge site and readings are checked regularly against a tide staff.

Location of gauge
The tide gauge is located at Irish National Grid reference 376500N and 171650E under the main pier of the harbour secured to a steel pile. There is excellent water depth at the gauge site with the operator reporting the bed level to be approximately –7m CD.

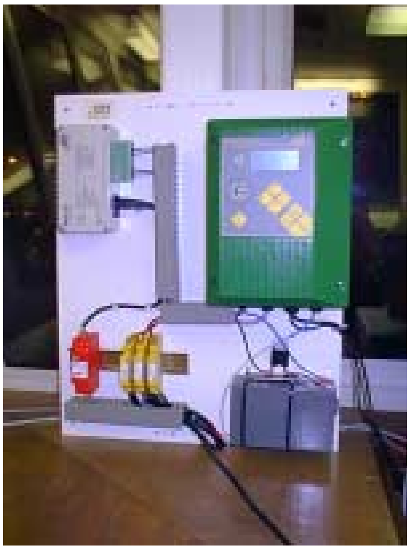

Plate 2.1(a) Killybegs Nimbus and Corrosion Sensors

Plate 2.1(b) Killybegs Harbour Building

2.2.3 Sligo

Overview
This gauge has recently been installed and is owned and operated by Sligo Harbour Commissioners. It is not fully operational as yet as the operator is in the process of purchasing a computer. When operational, data will be transferred via telemetry from the gauge site to the harbour offices where it will be stored on an access database. Tides at the site are considered to be very much influenced by shallow water effects and so not representative of open ocean conditions. The main purpose of the gauge is to help with navigation into and out of Sligo Harbour.

Technical description of gauge
The Sligo gauge is of the pressure transducer type made by Ohmex Instrumentation, http://www.ohmex.co.uk. It was installed by Halia Oceanographic, Easkey, Co. Sligo (http://www.haliaoceanographic.com/) and as yet has not required any maintenance or calibration checks. Readings once they commence will be referenced to Chart Datum from an OS benchmark.

Location of gauge

The tide gauge located off the end of the deep-water berth in Sligo Harbour and about 1km from the harbour offices. An ESB pole was erected to bring power to the site and a small control box is located on the quay.

Figure 2.2(a) Sligo Gauge Location (green box) (Copyright UK HO)

Figure2.2(b) Tide Gauge Installation

Figure 2.2(c) View from end of quay

2.2.4 Galway

Overview: A gauge was installed for the construction of the Mutton Island Treatment Plant project and was left in place after completion. It was owned and operated by ASCON Construction Ltd. with the approval of the Galway Harbour Company. The gauge was hardwired back to the gatehouse where it recorded on to a paper trace. It has not been operational now for a few years and it is difficult to get information due to relevant personnel having moved on to other jobs. Galway Harbour Company are currently in the process of establishing a new gauge which should be operational sometime in 2004.

Technical description of gauge

The Galway gauge was of the pressure transducer type made by Valeport (http://www.valeport.co.uk). As far as is known the transducer is still in place at the site. Halia Oceanographic were asked by Galway Port Company in 2002 to examine the possibility of re-establishing the gauge but concluded that the instrument was obsolete and that installing a new gauge would be a better option.

Location of gauge

The location of the gauge can be determined from the various photographs below. It was sited just on the seaward side of the dock gates. There were no particular problems with the site although it is possible that some minor distortion of the water levels could occur due to the operation of the dock gates.

Plate 2.2 Galway Docks showing Gauge Location (green box)

Plate 2.3 Galway Gauge Location (1)

Plate 2.4 Galway Gauge Location (2)

Plate 2.5 Sensor Cable Pipe

Plate 2.6 Cable End in Gate House

2.2.5 Shannon Estuary

The Shannon and Foynes Port Company (SFPC) operate three tide gauges within the confines of the Shannon Estuary; Foynes, Carrigaholt and in the Limerick Dock area. The tide gauges main function is to assist navigation in the Shannon Estuary but data is also used for calibrating numerical models and assisting local hydrographic surveys. SFPC would be willing to allow these gauges to form part of a national network but suggest that there may be a charge for the data. Whether this charge can be offset against gauge maintenance and data handling work as carried out by the network operator will need to be discussed.

2.2.5.1 Carrigaholt

Overview

This gauge was installed in November 2001 and has been operating successfully since that date. Data is recorded continuously and transmitted via UHF signal every 60 seconds. It is analysed by personnel of SFPC on an annual basis.

Technical description of gauge

The Carrigaholt gauge is of the pressure sensor type manufactured by Aandara, model 3610 (http://www.aanderaa.com). The instrument is zeroed to 0.0m chart datum by use of a local benchmark approximately 10m from the gauge site. The operator carries out any servicing and maintenance work when required or at worst on an annual basis.

Location of gauge

The tide gauge is located on the seaward side of the pier head at Carrigaholt (see plates below). The sensor cables run through an aluminium conduit that is fixed to the pier wall. The sensor is located inside this conduit, which is also intended to act as a stilling well. This location was considered necessary given the general lack of depth in the area – it is estimated that minimum water depths are less than 1m. It is possible that wave effects could influence the water levels and the data should be examined for variations in the normal tidal signal. Gauge equipment is stored in a steel box (1m x 0.5m x 0.4x) located behind the ice plant (Plate 2.11). There is a small length of exposed cable between the aluminium conduit and the steel box and this should be secured (Plate 2.10). In addition it would seem that various items are tied to the conduit and this practice should be avoided.

Plate 2.7 Carrigaholt pier showing Gauge location

Plate 2.8 Carrigaholt Gauge Location (1)

Plate 2.9 Carrigaholt Gauge Location (2)

Plate 2.10 Conduit to Pressure Sensor

Plate 2.11 Gauge Control Box

2.2.5.2 Foynes

Overview

This gauge was also installed in November 2001 and it too has been operating successfully since that date. Data is recorded continuously and transmitted via telephone line to the harbour office. It is analysed by personnel of SFPC on an annual basis. According to the operator the data is not stored so there is no availability at the moment.

Technical description of gauge

The Foynes gauge is of the pressure sensor type manufactured by Aandara, model 3610 (http://www.aanderaa.com). The instrument is zeroed to 0.0m chart datum but the operator indicates that it has not been surveyed into local benchmarks. The operator carries out any servicing and maintenance work when required or at worst on an annual basis.

Location of gauge

The tide gauge is located at a corner of jetty no. 1 at the end of a dredged channel (see plates 2.12 to 2.14). The sensor cables run through a pipe that is fixed to the pier wall (Plate 2.15). This location is subject to siltation and it is estimated that the minimum water depth is less than 1m. Gauge equipment is stored in a steel box located about a meter back from the quay face (Plate 2.13 and 2.16).

Plate 2.12 Foynes Jetty showing Gauge Location

Plate 2.13 Foynes Gauge Location (1)

Plate 2.14 Foynes Gauge Location (2)

Plate 2.15 Pipe to Pressure Sensor

Plate 2.16 Gauge Control Box

2.2.5.3 Limerick

Overview

This gauge was also installed on the 22/5/1997. Data is recorded continuously and transmitted via hardwire to the dock gate hut, where it is available in both digital and paper formats. It is then transmitted to the harbour office in Foynes and is displayed on VTMIS. It is analysed by personnel of SFPC on an annual basis. Data (since the installation of the gauge) is available for this site.

Technical description of gauge

The Limerick gauge is of the pressure sensor type manufactured by Druck, model PTX164 (http://www.druck.com/). The instrument is referenced to –1.67m O.D. Poolbeg but the operator indicates that it has not been surveyed into local benchmarks. The operator carries out any servicing and maintenance work when required or at worst on an annual basis.

Location of gauge

The tide gauge is located at the entrance to the dock, on the south wall beside the gate (see plate 2.17). The sensor cables run through a pipe that is fixed to the quay wall. This location has good water depth (min. of 2m) but is subject to occasional surging by passing vessels.

Plate 2.17 Limerick Docks showing gauge location

2.2.6 Dingle

Overview

This gauge was installed in 2001 but as yet has not been operational due to problems in transferring the data to the harbour masters office. It is believed that this problem is now close to being resolved and the gauge should come on line shortly. The operator would fully cooperate with using the gauge as part of a network but would like a separate data logger and transmission to be used.

Technical description of gauge

The Dingle gauge is of the pressure sensor type manufactured by Valeport, (http://www.valeport.co.uk) and installed by Hydrographic Surveys Ltd. The instrument is zeroed to 0.0m chart datum based on various benchmarks located on the pier. Wind speeds and directions will also be recorded once the system is up and running and it was suggested that air pressure should also be measured.

Location of gauge

The tide gauge is located at the end of the pier behind the ice plant as shown in plates 2.18 to 2.20). The sensor cables run from the ice plant through a pipe that is buried in the concrete deck. This pipes outlets at a ladder recess and runs vertically down the pier face (plate 2.21). The various gauge equipment is located inside in the ice plant as shown in plate 2.22.

Plate 2.18 Dingle Harbour showing gauge location

Plate 2.19 Dingle Gauge Location (1)

Plate 2.20 Dingle Gauge Location (2)

Plate 2.21 Pipe to Pressure Sensor

Plate 2.22 Gauge Control Box

2.2.7 Bantry

Overview

This gauge was installed in 1997 and initially the data was transmitted via radio link to the harbour masters office. However this is no longer the case and at the moment the gauge is largely un-used for water level measurements. Historical data has been lost as it is overwritten, as space is required on the computer. Generally this gauge is under utilised and it would not require much effort to get it fully functioning again.

Technical description of gauge

The Bantry gauge is of the radar type (WaveRadar), manufactured by Saab Marine Electronics. It is distributed exclusively by R.S. Aqua Ltd (http://www.rsaqua.co.uk/products/wave_radar.html). The device is a derivative of Saab's TankRadar, which is in global operation. The waveradar is described as a non-invasive, highly stable system for the measurement of waves and sea level in the offshore environment. The Bantry installation uses the Oceantec Interface software. There is not much information available on the operation of the gauge, data availability and datum references. It is suggested that after salvaging whatever data is available, the station should be re-established based on the GLOSS criteria.

Location of gauge

The tide gauge is located on the terminal on Whiddy Island and was not visited over the course of the study.

2.2.8 Marathon Platform (off Kinsale Head)

Overview

Marathon Oil established this gauge in 1997 to fulfil their licensing requirements. Data is transmitted back to a shore station every 20 minutes and then transferred to Met Eireann in Dublin every hour. The water level data is used by Met Eireann for monitoring storm surges whilst the wave data is displayed on the Marine Institutes data buoy website, (http://www.marine.ie/scientific+services/data+services/data+buoy/observations.htm). The operator already sees the station as providing a national service and would have no problem with it being included in a national network. Marathon Oil has indicated that the platform should remain operational for another 20 years.

Technical description of gauge

The Marathon Platform gauge is of the radar type (WaveRadar), manufactured by Saab Marine Electronics (see section 2.2.7). Recorded levels are related back to a datum based on the deck level on the platform.

Location of gauge

The platform location is 51° 22' 15" N 7°56' 42"W. There is no other information available.

2.2.9 Cork

Overview

The port of Cork operate two principal gauges within the harbour confines which are used only to support port operations-principally by the Pilots. These were substantially modified and upgraded in 1999 by OTT technician (Simon Wills). The main port operations gauge is sited at Cobh, whilst a subsidiary gauge at Tivoli is equipped with a telephone dial-in function for multi-user access. Both gauges undergo some maintenance checks and occasionally require minor readjustments. On aggregate the performance of these instruments has been estimated at 75% (combination of accuracy, reliability, percentage time operational). Whilst the gauges do not always agree with predicted levels no further details of long term trends are currently available. In general the gauges are investigated when spurious or questionable readings are reported by the Pilots. There is another gauge in Ringaskiddy but indications from the Port of Cork are that they are no longer maintaining this instrument. Only brief mention will be given to this gauge.

The Port Authorities (contact Kevin O’Callaghan) archive all data on a PC via Hydras™ software and make it available on request for third party use, as well as forwarding it to the UKHO on an *ad-hoc* basis. It has been ascertained that is would be technically feasible to remotely access tidal data that has been archived within the VTS system via its own maintenance service internet connection. (Liam Kelly *pers comm*, SGN Atlas Service Engineer for VTS). The Port considers the current arrangement to be suitable for their present needs but can see advantages in having tidal data sources linked directly to the main Port Offices. The Port would also like to know what would be involved in terms of inputs in order to enable their gauges to become part of a national network.

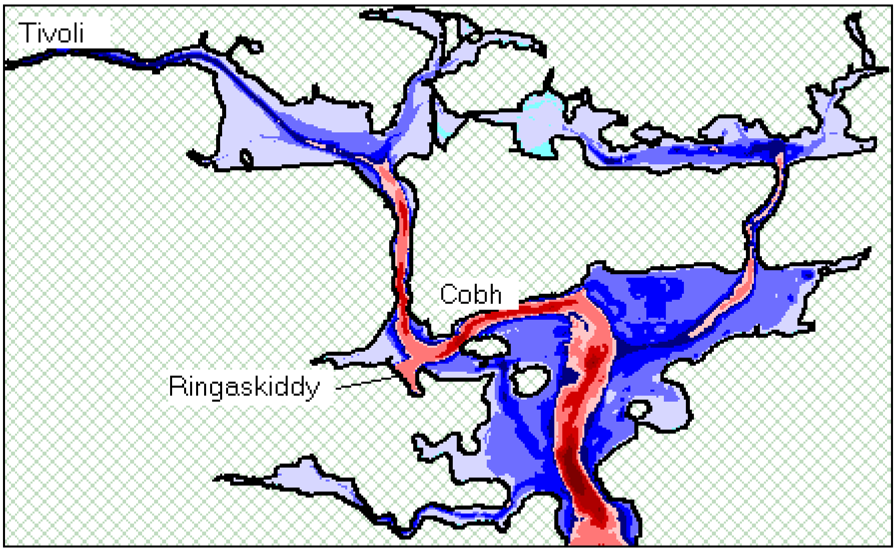

Plate 2.23 Sites of gauges in Cork Harbour

2.2.9.1 Cobh

Technical description of gauge

The gauge at Cobh is an OTT float and weight system, which has been equipped with an OTT shaft encoder. Digital output is transmitted to the main readout in Port Operational HQ via a UHF radio link. This output is also fed into the Cork VTIS and logged at 15 minute intervals. There is a meteorological station sited at the Cobh Port Operations building.

Location of gauge

This gauge is sited on the quay wall in the eastern small boat/pilot harbour in Cobh where it is easily accessed by road, and 2.0m of water is available at low tide. This location would allow good representation of levels for the water mass of the lower harbour, but at times is likely to differ significantly from open sea conditions owing to constriction at the harbour mouth. In close proximity to the gauge is a datum check point that was established by GPS with the following description and co-ordinates (ING 180749.4 E, 66526.2N, 5.296m CD. GPS level location is at top of corner of slab near ESB pole near head of pier in Pilot Harbour).

Plate 2.24 Cobh Gauge Location

Plate 2.25 Gauge Details

2.2.9.2 Tivoli

Technical Description of Gauge

The Tivoli gauge is an OTT bubbler type with a data logging facility. A dial-in facility allows users (principally Port Pilots) to access current water levels by mobile phone. Logged data (15min time-step) are downloaded at approximately six-month intervals and stored with Hydras software on a PC at the Port of Cork main office. Problems with siltation have been noted and there is an ongoing requirement for this to be purged from the system on a regular basis. Inaccuracies have been cited (Jim Walsh, Irish Hydrodata *pers comm.*) in relation to readings obtained by phone from this instrument, and it seems likely that these can be attributed to aforementioned problems with sediment.

Location of Gauge

The sensor is fixed to the face of the sheet-piling in close proximity to the Ro-Ro berth in front of the main Port of Cork terminal building/office block. The measuring and logging unit is housed in a disused office on the ground floor of the terminal building, where it is supplied with electrical power, and telephone connection. The area is fully accessible by road. Five metres of water are available at the site at low tide, and there is a GPS control point within 30m. Hydrographic conditions are such in the Lee estuary that water levels recorded at Tivoli are valid for the immediate locality only and significant differences in time and level can be experienced within a distance of 2.0 km of the site.

Plate 2.26 Tivoli back-up gauge

Plate 2.27 Tivoli main sensor

Plate 2.28 Port of Cork terminal building

Plate 2.29 Processor and air compressor

2.2.9.3 Ringaskiddy

The gauge at Ringaskiddy is an OTT float and weight system that has been equipped with an OTT shaft encoder. Digital output is recorded on site and in the past was downloaded at regular intervals. The Port of Cork no longer maintains this gauge so it is unlikely that current measurements are being logged. The gauge is located on one of the dolphins of the new Ro-Ro extension at Ringaskiddy.

Plate 2.30 Ringaskiddy Gauge Details

2.2.10 Waterford/River Suir.

Overview

There are three gauges at various sites on the River Suir operated by the Office of Public Works (OPW) and Waterford Port Authority. Individual details are listed under separate headings below.

The OPW (main contact Gerry Leahy, Kilkenny) have been operating a temporary portable gauge at Adelphi Quay (confluence of R. Suir and Johns River) in Waterford city in association with inundation studies. These observations have generated various sets of records from 1999 to present, all data being forwarded to the central office in Headford Co.Galway for processing and storage. The ESB operated an OTT analogue paper recording gauge near the power station at Kilmokea until it was transferred to the OPW in 1999.

Port operations in Waterford operate a portable gauge at Great Island with a repeater unit at Passage East, and would be in favour it being linked to the national tide-gauge network.

Technical description of gauge 1.

1. OPW-Adelphi Quay. This is an OTT Orphimedes digital data logger with a bubbler sensor (http://www.ott-hydrometry.de/english/cmcshome.htm) which was installed in 1999. The unit is self contained and battery powered logging data on a 15m interval. It is referenced to 0.0m ODPoolbeg and is fixed to a 150mm plastic standpipe.

Location of Gauge 1.

It is sited at Adelphi Quay in Waterford city.

Technical description of gauge 2.
2. OPW-ESB Power Stn Kilmokea. This is an OTT Type-X autographic chart recorder installed in 1967. (Paper records of variable quality may be available for this period directly from the ESB). It is set to a reference zero of 0.0m O.D. Poolbeg and is checked and re-calibrated since 1999 every two months.

Location of Gauge 2.
The gauge is sited in a hut on the wooden jetty extending seawards from the ESB power station at Great Island, Co Wexford. This is close to the confluence of the Rivers Suir and Barrow and some 12kms from the open sea and this strongly subject to multiple estuarine effects. It can be reached by vehicle to within 25m, the nearest telephone connection is 85m away but there is power in the hut.

Technical description of gauge 3.
Port of Waterford operates a David Vyner LP1 Radio gauge with internal data logger and pressure transducer. Data is transmitted to a repeater unit offsite, however one month of data can be stored on board for subsequent download. A software upgrade has been recommended for this gauge(http://www.ohmex.co.uk/TidalLite.htm).

Location of Gauge .
The gauge is sited beside the older OTT gauge described above, i.e. in the hut on the wooden jetty extending seawards from the ESB power station at Great Island, Co Wexford (52deg 16min 39sec N, 06deg 59min 45secW). This is close to the confluence of the Rivers Suir and Barrow and some 12kms from the open sea and thus strongly subject to multiple complex estuarine effects. It can be reached by vehicle to within 25m, the nearest telephone connection is 85m away but power is available in the hut.

2.2.11 Dunmore East.

Overview
Dunmore East is a strategically important location that currently hosts an ageing OTT paper Chart Recorder gauge. The gauge is owned by the OPW hydrometrics division. Paper charts are changed and forwarded by a local assistant in Dunmore. Apparently there is little current interest in this gauge although its readings are checked against a nearby tide staff (see plate 2.34) each time the paper is changed.

Technical description of gauge/s
OTT Type X autographic Chart Recorder. The gauge is set to a reference zero 2.6261m below OD Malin. The gauge is powered by clockwork and is of the float type within a stilling well. The support frame for the housing is in the process of being replaced.

Location of gauge/s
The gauge is located in a corner of Dunmore East harbour near the harbour masters offices. The stilling well is located about 1m back from the quay face and has an outlet below the minimum water level. This stilling well arrangement can give errors in the water level readings.

Plate 2.31 Dunmore East Gauge Location

Plate 2.32 Dunmore East Gauge Location (1)

Plate 2.33 Dunmore East Gauge Location (2)

Plate 2.34 Dunmore East Gauge Location (3)

Plate 2.35 Gauge Chart Recorder

2.2.12 Rosslare Gauge

Overview

The gauge in Rosslare was installed in 1996 and is owned and operated by Iarnrod Eireann. Data is passed by cable to the Port Operations Tower where the main readout is sited. The gauge outputs are connected directly to the port VTMS (Vessel Traffic Management System) which logs and archives data at ten minute intervals. Records have been passed to the Admiralty on a regular basis, however readings are apparently higher than predicted for the location. Rosslare harbour meteorological station is sited in the vicinity. The operator is in favour of the gauge becoming part of a national tidal network, and is currently considering re-locating the gauge to avoid siltation.

Technical description of gauge/s

The Rosslare Gauge is of the pressure transducer type made by Observator Instruments, model :OMC329B (http://www.observator.com/uk/index.html,). It is subject to routine maintenance including calibration checks at six monthly intervals, which are conducted by Hydrographic Surveys Ltd., Crosshaven, Co. Cork. Owing to its location the gauge suffers from periods of unreliable or inconsistent readings caused by heavy depositions of silt around the transducer (use of a radar gauge may be the most appropriate technique for future recording at this site). Readings are referenced to Chart Datum from an OS benchmark which is 4.89 above CD and situated approximately 300m from the site.

Location of gauge

The tide gauge located at Rosslare Europort (51° 15.3'N 6°20.2'W) and is housed in a small dry hut. This hut has mains power, is accessible directly by road in the north-east corner of the harbour near the western housing for berth No.3 linkspan (Ro-Ro ramp). This is a good location in terms of representing open sea conditions whilst being sheltered from excessive wave action, however it suffers from heavy siltation from sediments mobilised by propeller wash. The nearest telephone line is 50m from the gauge, but a fixed cable transfers data to the nearby harbour control office.

Plate 2.36 Rosslare Gauge Location

Plate 2.37 Rosslare Gauge Location (1)

Plate 2.38 Rosslare Gauge Location (2)

Plate 2.39 Rosslare Gauge Location (3)

Plate 2.40 Gauge Control Box

2.2.13 Arklow

Overview

It is a temporary gauge installed in Nov ‘02 by the OPW hydrometrics division principally for studying the behaviour of the Avoca River in relation to flooding in Arklow (see Appendix 2).

Technical description of gauge

This gauge comprises an Isodaq data logger with Druck pressure sensor, which is mounted in a 150mm plastic pipe. It is a self-contained independent and battery-operated unit, which logs tidal data every 15minutes. The gauge is set to a reference datum of 0.00m OD Malin and is frequently checked against heights from an adjacent tide board.

Location of gauge

The gauge is fixed to the inner wall of the main enclosed dock just inside the mouth of Arklow Harbour (see figure 2.3 and plates 2.41 to 2.43). This location is completely sheltered from wave action and based on local tide–board observations (Michael Fitzgerald *pers.comm.*) appears to be fully representative of open sea levels. The local lifeboat station is within a few metres of the site offering the potential for mains power and telephone connection (this would have to be scoped with the RNLI). Michael Fitzgerald is the local RNLI engineer and has a keen interest in tidal matters and has offered to facilitate as far as possible. The RNLI station would also provide a suitable location for housing meteorological or CGPS equipment should the need arise.

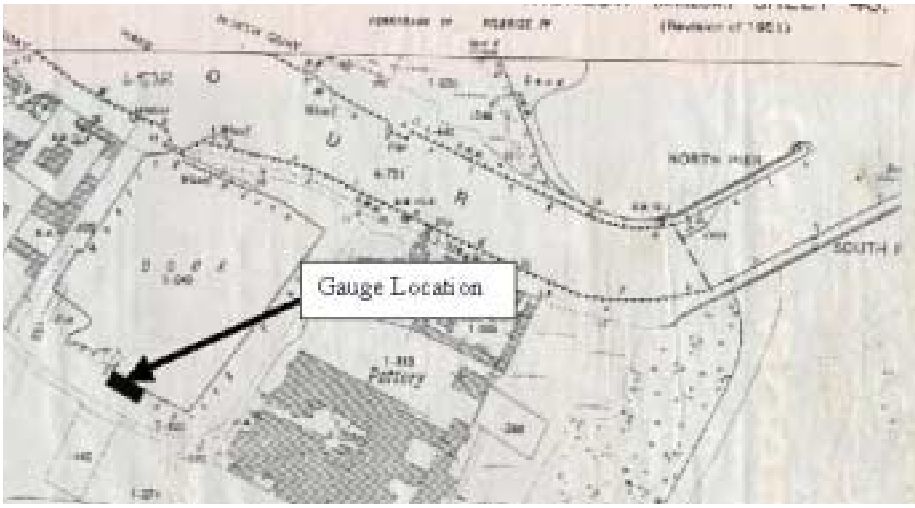

Figure 2.3 Arklow Gauge Location (Copyright OSi)

Plate 2.41 Gauge Detail (1)

Plate 2.42 Gauge Detail (2)

Plate 2.43 Gauge Detail (3)

2.2.14 Dun Laoghaire

Overview

The Dun Laoghaire Harbour Authority operates a single acoustic tide gauge that is conveniently located at St Michaels Pier between the Port Operations Ferry Terminal Buildings (see Figure2.4 and Plate 2.44). The harbourmaster Capt. Jim Carter and Assistant Mr. Simon Coate jointly administer all matters pertaining to the gauge, repeater units and data archiving. In general the Port has a pro-active stance in relation to monitoring activities and facilitates hourly windspeed and direction from its East Pier meteorological station to be accessible to the public at the ferry terminal and via the web (http://www.dlharbour.ie/). They are keen to participate in a national network and await information on what would be involved. The Geological Survey of Ireland GSI have undertaken a series of checks on this gauge as it has been used in support of survey operations in Dublin Bay during November 2003. A calibration report is currently being prepared by the GSI, however preliminary feedback confirms the accuracy and repeatability of the gauge, and closeness of fit with levels recorded at Dublin Port.

Technical description of gauge

The instrument is a SRD Tide Monitor (http://www.srduk.com/), which uses an acoustic pulse to calculate tidal heights (see section 2.1ii for an account of operational theory). It has a self-calibration facility to offset errors caused by temperature gradients, and the Port Authority carries out no other forms of routine checking or maintenance. Digital data are output on a serial port as well as being stored internally. The instrument is connected directly to three repeater displays distributed around nearby buildings, and a pc where digital records have been continuously logged since mid 2003. Two further remote displays are supplied by telemetry link. The zero of this gauge is set to Chart datum, which is stated to be 0.2m above OD Poolbeg. This was established by datum transfer from the original OPW tide board on Carlisle Pier.

Location of gauge

The instrument is mounted in a pipe that is accessed through a manhole in the pier deck between two buildings on St Michaels Pier. It can easily be reached from the adjacent car park beside the main Ro-Ro ramp and both power and telephone are available in close proximity. This location is sheltered from excessive wave action but ideally sited to represent open sea conditions. The actual sensor itself is rather inaccessible rendering direct measurements of sensor to datum point offsets difficult.

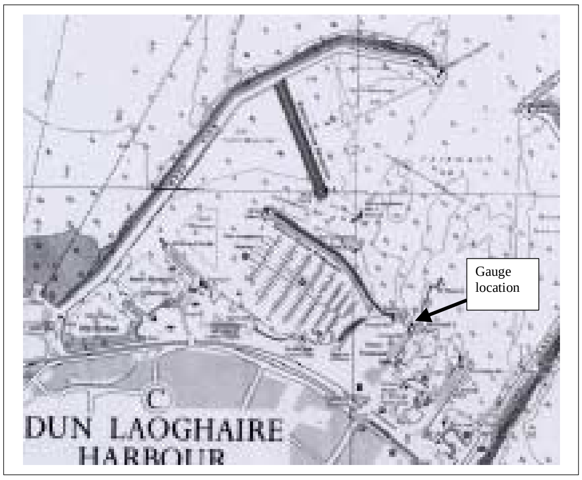

Figure 2.4 Dun Laoighaire Gauge Location (Copyright UK HO)

Plate 2.44 Acoustic Sensor

2.2.15 Dublin.

Overview

Dublin Port operates a single tide gauge in support of Port Operations the main contact being Aidan Clear. In general the Port regard this gauge as being completely suitable without change or upgrade for these purposes but of no use or relevance in wider contexts. This is apparently due to the particular nature of locally prevailing hydrographic conditions. There is no meteorological station nearby. Whilst this gauge could be used as part of a national network it lacks a GPS timestamp (Aiden Clear, *pers comm*.). An analysis of Dublin's tidal records has recently been completed as part of the flood study project that was carried out for Dublin.

Technical description of gauge

This gauge has been assembled as a custom solution from a number of individual elements. The system consists of a Druck (http://www.druck.com/uk/index.htm) pressure transducer that is linked to a pc which both logs data and controls UHV radio telemetry of data to a number of repeater units around the Port. The pressure sensor is mounted in a pipe and zero is set to Port Datum (apparently equivalent to LAT).

Location of gauge

The gauge is sited beneath the lighthouse on the North Quay Extension in Dublin Port at (318828E and 234291N). It was checked against a local benchmark during installation (319095E, 234456N, 5.196m LAT). The lighthouse is fully weather proof and has power, however the nearest telephone connection is 1km away. Full time road access is to within a few metres. This location is ideal for the day-to-day operation of the port however questions remains regarding its suitability as a representative marine station. It has been suggested that the location is subject to localised hydrographic influences from the River Liffey and changes in the bed conformation brought about by dredging operations (Aiden Clear, *pers comm*.).

Plate 2.45 Gauge Location

Plate 2.46 Telemetry unit

Plate 2.47 Gauge Computer Equipment

2.2.16 Drogheda

Overview

Drogheda Port operates a single gauge, which is situated near to the mouth of the River Boyne. The Harbour Master Capt. Martin Donnelly is responsible for maintaining and operating the gauge and takes a pro-active stance to all matters pertaining directly to port operations and in wider contexts. He notes the following in relation to the local tidal situation.

> *"Please note that I have concerns about the mean level at Drogheda used for the purpose of tidal predictions. Recorded levels generally well above predicted levels even allowing for the effects of southerly winds and barometric pressure effects. Examination of the mean level from Dublin (standard port) and Dundalk (secondary port) would show that the level of Drogheda considering the coastal gradient is not correct, hence the concern about the levels. A full recording of the actual tide over a 12 month period required to analysis the tides to re-evaluate the predictions. The current gauge is located too far inland and therefore not satisfactory for this purpose"*

There is a weather station nearby and Capt Donnelly is in favour of Drogheda data feeding into a national network and is interested in learning more of what might be involved in terms of cost. A site near the breakwaters would be ideal for this purpose and would also fit with the Ports own requirements.

Technical Description of Gauge

The instrument, which was installed in 1999, is a Valeport model VTM710 (http://www.valeport.co.uk/indexlayers.htm) which employs a vented pressure sensor, digital data logger and VHF transmitter to relay realtime height data (1 minute update) to Port Operations. Datasets are also downloaded and stored on a pc at the main Port Office. The instrument is considered to be accurate and reliable and is used and checked for calibration during dredging and hydrographic survey operations. It does however dry out at low water.

Location of Gauge

The gauge is located approximately 2km from the open sea on the north bank of the Boyne river at (53deg 43.94min N, 06deg 15.70min W). This location offers complete protection from the open sea but is subject to river influences particularly during winter spate. The sensor is secured to a hydrographic wire attached to the concrete wall that forms the riverbank at this point, and there is no water at low tide. The location is accessed by service road leading to the Premier

Periclase pump house system just south of this company's main seawater reservoir. The data logger and transmission system is housed in the pump control room which is secure, dry and supplied with power. The gauge is set to Chart Datum and there is a TBM nearby which was levelled to 5.802m above CD. The closest benchmark is in Baltray Village 300-400m distant.

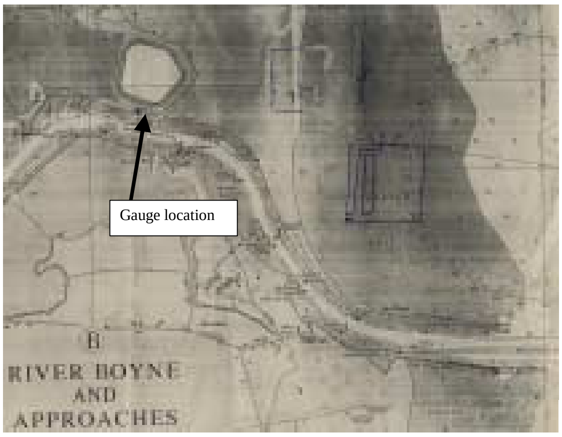

Figure 2.5 Drogheda Gauge Location (Copyright UK HO)

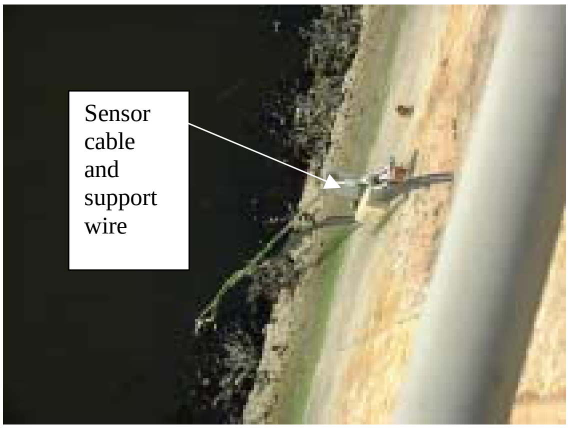

Plate 2.48 Site Set-up

Plate 2.49 Control Cabin

Plate 2.50 Instrument Box

2.3 Additional Notes

A table containing details of the OPW marine/estuary sites, mainly used for hydrometric purposes, is provided in Appendix 3.

OTT who supply gauges to the Irish market also provided information on the sites where their instruments operate and this is shown in Appendix 4.

Mr. Liam Kelly of Martek, Dublin who is an agent for SGN Atlas (liam@martek.ie, 086-8233837 was contacted over the course of the study. Mr. Kelly installed and services the VTS systems at Belfast, Dublin, Rosslare, Cork and Shannon all of which are linked to gauges and log data on a regular cycle into digital files. External access is technically feasible via ISDN.

It has been suggested that a useful approach could be to present the Irish Tide Gauge network concept to the Association of Irish Harbour Masters who meet on a bi-monthly basis. The April Meeting has been suggested.

2.4 Irish Tide Gauges: General Remarks

The above inventory has shown that that there are a variety of different instruments and technologies being used to measure water levels in Ireland. Each owner/operator (generally) independently purchases a gauge based on either past experience, cost or advice. Pressure sensors, supplied by a number of manufacturers, are most common and are often seen as the simplest and cheapest solution. Whilst these are generally satisfactory, errors can arise due to water density variations, sensor drift, lack of datum control and sensor fouling. The possibility of such errors is often not considered at the installation stage and in any case most operators are happy with an overall accuracy of 10cm. In terms of being able to supply reliable, high quality data (1cm accuracy) a number of currently operating Irish tide gauge stations are using the wrong type of gauge that has been installed in an unsuitable location on the site.

It has been shown that about nine different manufacturers supply gauges to Irish operators. Clearly this is too many and as the idea of a tide gauge network develops, the advantages of standardising the technologies used become apparent. Not only are there economies of scale but data handing and processing also become easier as does maintenance and repair. Whilst it is not recommended that all existing gauges be immediately replaced it is suggested that over time some standardisation of technologies will take place based on informed choices. The basis of these choices will now be discussed.

The selection of tide gauge technology at sites depends critically upon the locations at which they are to be installed, although some general principles can be found in the IOC Manual on Sea Level Measurements (IOC, 2002). Factors to be considered include:

1. Suitability of technologies for the environmental conditions at each site (currents, waves, temperatures, exposure).
2. As few different technologies as possible overall to keep installation and maintenance overheads to a minimum.
3. Need for ancillary ocean (waves, temperature etc.) and meteorological measurements.
4. Good data transmission systems (almost certainly telephones in the case of Ireland).
5. Site security.

It is advised to remove float and acoustic systems from the list of technologies under consideration for GLOSS and other high quality sites. Float systems do not seem to be the modern way forward for a <u>new</u> network. The GLOSS Technical Workshop (Paris 2003) included presentations, which demonstrated that, if a country already possesses stilling-well infrastructure, then there are cost-effective methods to provide digital, real-time data flow. In addition, acoustic gauges are not recommended, as experience with them has been limited and, so far as it goes, not favourable (although US and Australian tide gauge operators would disagree). In order for an Irish network to use acoustic gauges it would also need to equip itself with a SEAFRAME calibration facility (or share such a facility with another country).

That would appear to limit the choice for sea level technology for high quality sites to either:

(i) Bubbler gauges – these could be of the 'A Class' type with a mid-tide bubbler datum control channel, and would have the advantage of sharing experience with the POL Tide Gauge Inspectorate. Alternatively, a company such as OTT, which supplied the Malin Head gauge, could provide them.

(ii) Pressure gauges (transducer not bubbler type) would also be suitable if some kind of ongoing datum control could be ensured; they would be promoted to first choice if wave measurements were also required. There are large numbers of such pressure systems on the market and some are relatively inexpensive. However, their low cost is sometimes achieved by means of the use of cheap transducers which will be liable to long term drift.

(iii) Radar gauges – provided suitable locations exist.

Whatever the choice of gauge hardware, it is important that the gauge sites are operated overall to GLOSS standards. Of particular importance are the specifications for datum control by means of precise and regular geodetic levelling within a local benchmark network (IOC, 2002).

As regards new gauges for storm surge monitoring then almost any technology could be considered in the short term, although the UK experience (see Section 7) has been that in the long term it is more efficient and cost effective to operate a coherent national network to the same high standard.

3 Relevant Statutory Bodies

A brief discussion of various government departments and agencies with responsibility in the marine sector will now be provided.

3.1 Department of Communications, Marine and Natural Resources

This Government Department has a wide range of roles and functions in the areas of maritime transport, public safety, environmental protection and coastal zone. The main elements of the Departments work and responsibilities are listed below (http://www.marine.gov.ie/),

- Aquaculture Policy - Economic and sustainable development of the aquaculture sector
- Coastal Zone - Management and development of the marine coastal zone
- Engineering - Coastal Infrastructure, coastal protection and environmental work
- Foreshore Administration - Leases, licences and offshore electricity generating stations
- Inland Fisheries - Management and development of the inland fisheries sectors
- Marine Leisure and Research - Marine research and marine tourism and leisure
- Maritime Safety Directorate - Marine safety promotion
- Maritime Security
- Irish Coast Guard - Marine emergency response
- Marine Survey Office
- Maritime Radio Affairs Unit - Radio operator certification for maritime communications
- Maritime Transport - Development of maritime transport and port services
- Sea Fisheries - Management and development of the seafood and sea fisheries sectors
- Sea Fishery Harbours - Fishery Harbour Centres

The Engineering Division of the Department of Communications, Marine and Natural Resources has a requirement for water level data to support their various activities; coastal protection works, harbour development and operations, dredging etc. In addition they have an interest in mean sea level changes and its implications for the Irish coastline. Whilst under no direct statutory responsibility to install and maintain tide gauges the DCM&NR would be seen as being a key organisation to support the establishment of a co-ordinated tide gauge network.

3.2 Marine Institute

The Marine Institute is an agency of the Department of Communications, Marine and Natural Resources. It's function under the Marine Institute Act (1991) is to undertake, co-ordinate, promote and assist in marine research and development and provide such services related to marine research and development that in the opinion of the Institute will promote economic development, create employment and protect the environment (http://www.marine.ie/).

The Institute's role aims to support existing marine business and related activities through the provision of key scientific services and advice and to support research technology development and innovation activity to promote growth in the marine area. The Marine Institute also carries out environmental monitoring programmes in areas such as physical aspects, water quality, ecological, hazardous substances, and human health. These relate specifically to the disciplines of, marine chemistry, marine biology, oceanography, food safety, aquaculture, fisheries, and the national seabed survey. The Institute also plays a role in themes such as data management.

The Marine Institute in association with the Environmental Protection Agency has just published a discussion document entitled 'The National Environmental Monitoring Programme for

Transitional, Coastal and Marine Waters'. This document can be downloaded from http://www.epa.ie/. The Marine Institute’s website says the following about this publication,

> *This is a comprehensive review of existing and proposed environmental monitoring in Ireland's estuarine, coastal and marine waters. The document outlines the existing and future monitoring and reporting roles of national, regional and local bodies, in order to guide the protection of the Irish marine environment and its quality for human use. The monitoring programme takes into account the requirements of the EU Water Framework Directive and of other commitments, such as those arising from the OSPAR Convention’. The document outlines the existing and future monitoring and reporting roles of national, regional and local bodies, in order to guide the protection of the Irish marine environment and its quality for human use. The monitoring programme takes into account the requirements of the EU Water Framework Directive and of other commitments, such as those arising from the OSPAR Convention.*
>
> *Reflecting the complexity of the tidal water environment, there are 36 separate monitoring programmes outlined in the document and these are grouped under six main categories:*
>
> - *Physical Aspects (Physical Oceanography and Meteorology)*
> - *Ecological Integrity and Biodiversity*
> - *Water quality*
> - *Hazardous substances*
> - *Food Safety and human health*
> - *Radioactivity*
>
> *In order to cover this range of topics, other relevant national bodies participated with the EPA and Marine Institute in the preparation of the national monitoring programme. These included National Parks and Wildlife, Met Éireann and the Radiological Protection Institute of Ireland. The anticipated outcome of this programme is more relevant, consistent and accessible information that will provide a basis for policy formulation and the management of the environment of our tidal waters.*
>
> *A Marine Monitoring Forum is proposed to oversee the implementation of the Programme on an ongoing basis. The implementation of the proposed Programme will have a number of benefits. For the national bodies responsible for monitoring, it provides a detailed framework to plan and review their activities and to ensure that all gaps in monitoring are identified and filled. For the wider public, the Programme provides a clear understanding of the justification of monitoring, identifying the bodies responsible and detailing how the results are reported. Also, by making it easier to identify instances where increased coordination of monitoring activities might be possible, it provides a means to increase value for money in monitoring the tidal water environment.*

Although the document does not specifically mention water level measurements it would be assumed that it would need to be part of any all-inclusive programme.

Over the course of this study the Marine Institute signed a Public Private Partnership with an Irish company called Marine Informatics with the aim to set-up an Irish National Tide Gauge Network. It is planned to do the following,

1. In the initial phase for which there is funding available, select about 5 of the existing stations and establish the telemetry network and the Internet based tide portal to allow proper data transmission and dissemination. The sites that will form part of the network have not yet been decided but the conclusions from this study will help in making the choices. Marine Informatics will install either the FlexiData POD or the FlexiData Integrator at each of the network nodes. The decision will depend on the initial site survey and local requirements of the persons contributing the station. Both systems are data loggers with telemetry and share many components. The only difference is that the Integrator includes a graphic touch screen for reviewing data more easily when on site. The Pod has no screen, is intended for long unattended operation and has a much greater data capacity than the Integrator (up to 256MB). Marine Informatics will also develop the web-based portal and it will be based on Microsoft .Net technology and use MS SQL Sever as the back end. The site will include a network home page, a discussion group (initially un moderated) a feedback function and a page for each node on the network. It is envisaged that the network will deliver data in real-time or near real-time. This includes some automatic quality control and maintenance of the stations.

2. The expansion of the network to include up to 20 tide stations. The rate at which this phase progresses will depend on the availability of resources and the possible interest and contribution from third parties.

It is planned that to cover some of the costs of setting up the network that a series of charges will be levied for the data. The nature of these charges has not been fully worked out as yet but some data will be available free of charge to users.

This initiative is a welcome development and shows (along with this study) that sea level measurement is being given a higher priority in Ireland. Both Marine Informatics and the Marine Institute realise that more discussion and consultation with relevant stakeholders and government agencies is required before embarking on any work. The partners to this project will readily co-operate particularly in terms of sharing expertise and preventing duplication of work that may already have been done in other countries. The only cause for concern would be that, given the national importance of tide level data it would become the property of a private company.

The Marine Institute can thus be seen as an organisation that has already and will continue to play a vital part in any Irish Tide Gauge Network development.

3.3 Geological Survey of Ireland

The Geological Survey of Ireland is part of the Department of Communications, Marine and Natural Resources and has responsibility for gathering, storing and disseminating geological information. It carries out its duties of gathering information by a number of different means including:

- Field mapping and recording of data
- The compilation and interpretation of geological data gathered by others.
- The drilling of boreholes for stratigraphic data, quaternary sediments or aquifer characteristics

Of the diverse range of activities in which the GSI participates under this remit the Irish National Seabed Survey (INSS) is of particular relevance in the context of the present study. It is important to note that the INSS is technology-driven and will be underpinned by a significant IT infrastructure. Work in Zone2 (50-200m water depths) is being conducted in close partnership and co-operation with the Marine Institute, and the national research vessels managed by the Marine Institute are playing a prominent part in the survey work. The strategic importance of the INSS can be recognised in the following GSI statement

> "*In managing the Seabed Survey, the Geological Survey of Ireland has been conscious of the need to build up national marine expertise, and its partnership with the Marine Institute is important in this regard. It is important that the right mix of skills is developed so that we derive maximum benefit from our marine resources and these skills should reside in government agencies, third level institutions and a strengthened private sector.*"

The INSS is based principally on the use of Multibeam Echosounder (MBES) technology, which enables the seabed to be mapped at high resolution with reference to the level of the sea at the location of the survey vessel at any particular time. Work in the deeper Zone 3 (200m-4500m) of the project has now been completed, and current efforts are focused on completion of Zone 2 (50-200m) where it is critical that all datasets gathered will have to have a tidal correction applied to them in order to achieve meaningful, valid and coherent results (Sutton et al., 1999). Unfortunately Ireland does not currently possess a consistent tidal model, which would enable the required reductions to be made. In order to address the practical and technical challenges involved in developing the Irish Tidal Model, the Marine Section of the GSI have recently produced a proposal to establish such a model, a complete copy of which can be found in Appendix 6.

In summary the main elements of this proposal are:

1. To establish a network of coastal datum points with marked plates set to Ordnance Survey Geoid Model 2002) OSGM02 at locations suitable for carrying tide level observations.
2. To conduct a staged, co-ordinated program of tide-level observations at these stations.
3. To conduct a series of offshore tidal observations in close association with item (2).
4. Establish a network of permanent gauges at strategic locations onshore and offshore. The latter should include as many existing offshore structures as possible (e.g. MI weather buoys, islands, oilrigs, wind turbine pylons).

The GSI team have already begun to implement this program and have successfully used newly acquired RTK equipment to establish a number of tidal observation stations as described in support of Zone 2 operations during 2003. It is planned to continue and extend this work in the future with the support of the Marine Institute Survey Team (MIST).

The marine section of the GSI (in partnership with the MI and others) has a clear imperative to ensure that a coherent Irish Tidal model is established as soon as practicable. This should be of an equivalent or better standard than adjoining UK/French models and contiguous with them towards the goal of a standard reference surface for the regional continental shelf. The Marine section of the GSI possess the relevant Hydrographic and Geodetic expertise to play key and important role in all activities pertaining to tidal matters in Ireland.

There is a strong need for ongoing or planned GSI tidally related initiatives to be harmonised within a nationally co-ordinated strategic plan, that would include the full range of active participants and stakeholders.

3.4 Met Éireann

Met Éireann is the Irish National Meteorological Service and is part of the Department of the Environment, Heritage and Local Government. It is the main provider of weather information and related services for Ireland. Met Éireann's mission statement is stated as being (http://www.met.ie/): *To meet the national requirement for high-quality weather forecasts and associated services, with optimum efficiency and value for money.* This mission statement implies that Met Éireann as the National Meteorological Service will:

- Help to ensure the protection and safety of life and property by issuing public weather forecasts and warnings.
- Contribute effectively to national prosperity and to Government objectives by supplying relevant meteorological services to all sectors of the economy.
- Ensure customer satisfaction by continually improving the range and quality of our forecasts, the cost-effectiveness of our operations and our overall standard of service.
- Ensure the maintenance of a high-quality and cost-effective meteorological infrastructure, consistent with national requirements and resources.
- Enhance the quality of our climatological archives and provide easy and effective access to our databases.
- Participate in the on-going development of meteorological science and its applications in collaboration with our European partners and with the wider international community.
- Contribute to the effective monitoring and good management of the natural environment.

Met Éireann have a requirement for real time tidal data to form part of their flood warning service. At the moment they only have data from Malin Head and the Marathon Gas Platform. In the last major flooding episode in Dublin there were very high water levels recorded at Marathon several hours earlier. Therefore the Marathon Gas Platform data is now used as a check on potential flooding incidents in Dublin. However, as there were many other factors which contributed to the same flood in Dublin, Met Éireann’s policy is to just let the forecasters have real-time access to the data and they do the rest based on other factors like – wind conditions, barometric pressure, tide type (spring or neap) etc.

In the future Met Éireann see themselves as a major user of tide data. They would most definitely like to have real-time access to any and all tidal data available in Ireland.

3.5 Ordnance Survey Ireland *(OSi)*

The Ordnance Survey Office was established in 1824 to carry out a survey of the entire island to update land valuations for land taxation purposes. The present day activities of the OSi are outlined in the mandate from Government, which also outlines their principal responsibilities. Relevant responsibilities in the context of tidal data include:

- To maintain and develop the underlying physical infrastructure to support mapping and mapping applications, including to maintain a national grid and the geodetic and height frameworks and to link these to international systems.

- To create and maintain for the entire State mapping and related geographic databases which have national consistency of content, currency, style and manner.

- To provide mapping and related geographic data to the public and private sectors in support of social, economic, legislative, security, business and administrative functions and requirements.

- To encourage and promote the benefits of the use of OSi's national mapping and related databases and to promote the development of its products, services and markets to meet national and user needs.

- To advise Government and public sector organisations on matters relating to the policy and practice of survey, mapping and geographic information and on the development of national spatial database infrastructures.

The OSi are responsible for the data recorded by newly installed digital tide gauge located at Malin Head. This gauge is primarily used to monitor differences in mean sea level (MSL) and acts as the fundamental datum for all maps produced and supplied by the OSi. There is no statutory responsibility or legislative obligation on the OSi to produce or record tidal data. At present there are no plans to expand or further increase their involvement in tidal data recording.

3.6 Environmental Protection Agency

The Environmental Protection Agency (EPA) was established in July 1993 under the Environmental Protection Act, 1992. It is a semi-state body and exists as an independent authority, which is part financed by the Department of the Environment, Heritage and Local Government budget.

The EPA operates on a regional structure with headquarters in Wexford, five regional offices (Castlebar, Cork, Dublin, Kilkenny and Monaghan) and four sub-offices (Athlone, Letterkenny, Limerick and Mallow). The EPA is the lead authority for the implementation of the Water Framework Directive in Ireland. The main responsibilities of the EPA include:

- The licensing and regulation of complex industrial processes, and other processes with significant polluting potential, on the basis of integrated pollution control and the application of the best available technologies for the purpose.

- The monitoring of environmental quality (air, water [including rivers, lakes, coastal and estuarine areas and ground waters], noise and soil).

- Advising public authorities including Local Authorities.

- Assisting local authorities in the performance of their environmental protection functions.

The EPA is engaged in research and monitoring pertinent to climate change and the Water Framework Directive. An element of this work is detailed in the water monitoring conducted by the EPA. As well as assessing water quality the EPA also monitor the heights and flows of terrestrial waters throughout the country.

Within the framework of the EPA there are seven regional hydrometric offices (e.g., Mallow, Castlebar, etc.), which correspond to the river basin districts. Each office is staffed by two hydrometric officers who are responsible for gauges installed within their region. The activities of the various hydrometric offices are co-ordinated by the Water Data Unit, which is located in the Dublin regional office of the EPA.

In addition, the Water Data Unit co-ordinates the collection of data from all hydrometric gauges operated nationally, including those owned by the Office of Public Works (OPW). In 1995, the EPA published a *Register of Hydrometric Gauging Stations in Ireland* (EPA 1995). An updated version of this document was published in 2003 (EPA 2003) and is also accessible online at www.epa.ie. Whereas the collection of gauge data by the EPA is largely driven by environmental requirements the collection of gauge data by the OPW is very much in the context of engineering (see Section 3.6).

The EPA operates the gauges, downloads and processes the data, which in all cases they then provide to the relevant Local Authorities. The gauges are the property of the Local Authorities but the EPA collates the data, and operates and maintains the gauges on behalf of the Local Authorities. One of the main objectives of the Water Data Unit is to answer the information needs of the Local Authorities. Therefore, if a Local Authority in one region requires data on flood levels, efforts will be made to provide this data as soon as practicable. However, other areas may have a requirement for flow rates or other measured parameters. The EPA meets regularly with Local Authorities to review their hydrometric requirements. In Cork the EPA and the Local Authority are in the process of implementing a flood monitoring system.

The number of gauges per hydrometric division may vary. Many of the gauges are automatic data loggers that record heights every 15 minutes. EPA staff downloads the data and produce hydrographs and represent flow measurements as plots on a rating curve.

3.7 Office of Public Works (OPW)

One of the main roles of the OPW is as the Government's principal engineering agency. It provides an engineering service in its own right to other divisions within the OPW and to other Government Departments on an agency basis. The skill and experience of the OPW in water related engineering, structural and construction work is regarded as a major national resource.

Within the OPW the Hydrology and Hydrometrics section is based in Headford, Co. Galway (contact Alex McAlister). This office has responsibility for collecting information on water levels at a number of specific locations throughout the country. From these levels, indices of flow condition are estimated. Access to records and statistical data and information for nearly 300 stations in rivers, lakes and estuaries over 60 years can be obtained by reference to the "Hydro-Data" website. (http://www.opw.ie/hydro/index.asp).

Specific details of all gauges operated by the OPW are contained in the Register of Hydrometric Gauging Stations in Ireland, which published by the EPA and updated in 2003 (see Appendix 3). Of these gauges few are in a wholly or even partially tidal situation, and those that are have been documented in Section 2. It is important to note that there exists a certain degree of overlap between the roles of the EPA and OPW in regard to hydrometry. The main distinction is that the EPA do not own gauges, rather, they operate, maintain and collate data on behalf of the local authorities with whom ownership is retained. These duties are discharged within the EPA routine monitoring framework that includes a broader suite of environmental water quality and associated parameters that are supplied to County Councils. The OPW operate their own independent gauges and are principally concerned with obtaining engineering related data in support of specific projects associated with flood monitoring and relief.

Careful consideration in the organisation of any tide gauge network should be given to ensure the integration of these existing roles and responsibilities in respect of any future tidal gauging networks or infrastructure.

4 Survey of Irish Stakeholder Requirements

As part of the overall study the requirements of tidal data end users (potential stakeholders in a national tide gauge network) were collated and analysed. A questionnaire survey was undertaken by the study team to collect relevant data for the stakeholder analysis specifically;

- On the requirements for sea level information in a national and international context; and

- On issues such as data collection, analysis, usage, distribution and archiving.

By analysing such data it is possible to elucidate information on the requirements of end users of tidal data and on the overall trends in current use of tidal information.

4.1 Methodology

Throughout the course of the study two questionnaires were disseminated to a wide variety of end users of tidal data. The questionnaire was distributed via e-mail and by post. In some instances members of the study team completed the questionnaire as they interviewed respondents over the telephone or in person.

A generic stakeholder questionnaire was sent to representatives from local authorities, government departments, state bodies, universities, consultant engineering firms, hydrographic surveyors and small to medium enterprises (SMEs) representing commercial organisations within the marine sector. The aim of the questionnaire was to establish trends in current usage of tidal information and attitudes towards the establishment of a national tide gauge network.

A second questionnaire was developed for individuals (typically representatives from port authorities/companies, local authorities and the Office of Public Works [OPW]) to provide details on tide gauges in their possession or under their responsibility. This questionnaire was an extended version of the generic questionnaire, which allowed respondents to elaborate on the location (e.g., co-ordinates and water depth at gauge location), housing conditions (e.g., shelter, power supply, accessibility, distance to and availability of a telephone line) and the gauge specifications (e.g., make, model, maintenance and calibration, output, data storage and archiving, data availability and data transmission). In addition, a section in the questionnaire was allocated for respondents to provide details on previous gauges where applicable.

For the purpose of the study, a single analysis was conducted for all returned questionnaires both generic and owner/operator. This is possible as Part 1 and 2 in the generic questionnaire was identical in format to the Part 2 and 3 of the owner/operator questionnaire, which is shown in Appendix 4.

4.2 Questionnaire Response Details

Throughout the study the questionnaire was disseminated to approximately 130 individuals nationwide within the sectors of activity outlined above; 55 completed questionnaires (see Appendix 5 for details of respondents) were returned equating to a response rate of 42%. The results of the questionnaire survey are largely presented in graphical form and correspond to the questions as they appeared in the questionnaire.

4.3 Analysis Details

The following charts details stakeholders' responses to the questions posed in Parts 2 and 3 of the questionnaire (as shown in Appendix 4).

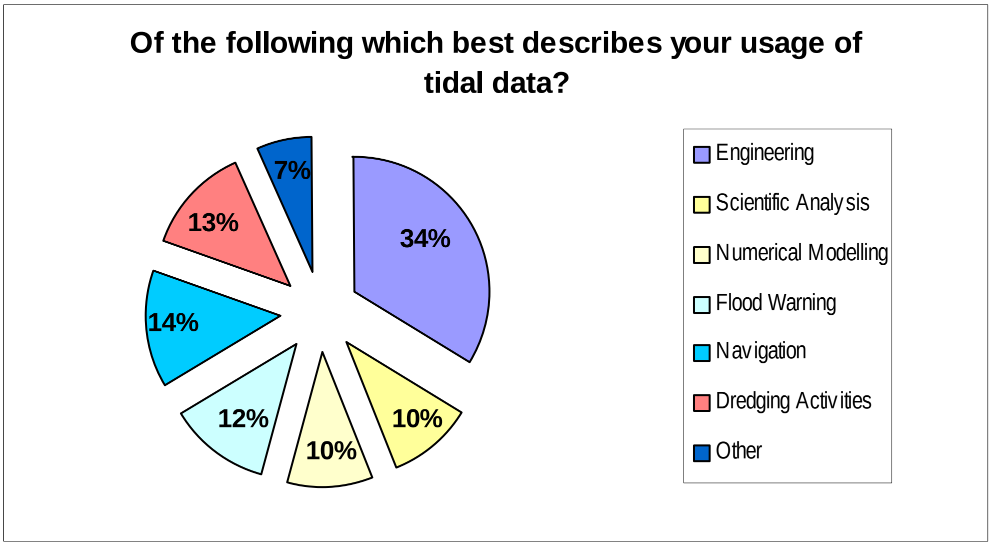

Figure 4.1. Respondents' use of tidal data and information

From the response received engineering represents the most common activity using tidal data (34%) followed by navigation (14%) and dredging (13%) respectively. Flood warning (12%), scientific analysis (10%) and numerical modelling (10%) all feature to a comparable extent in the remainder of the response.

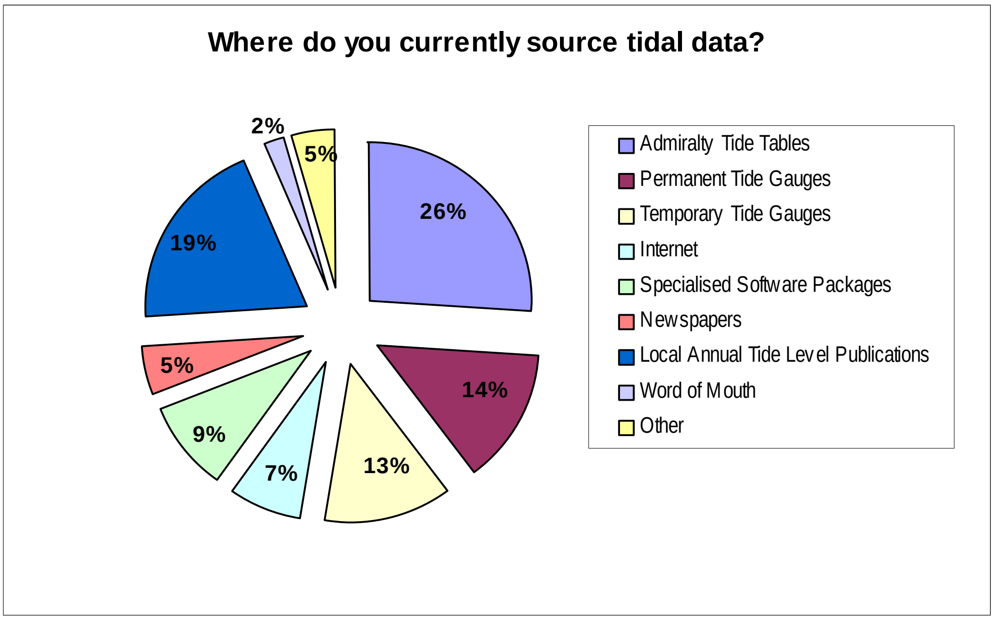

Figure 4.2. Sources of tidal data as indicated by questionnaire respondents.

The responses indicate that that stakeholders source tide data in a number of different ways. Such a wide variety of data sources have sometimes lead to conflicting information being supplied. As a summary, admiralty tide tables are the most popular source of tidal data (26%)

followed by local annual tide table publications (19%). Word of mouth (2%) and newspapers (5%) are the least popular sources for tidal data among respondents.

The following figures (Figure 4.3a-f) relate to respondents opinions in relation to their current use of tidal data.

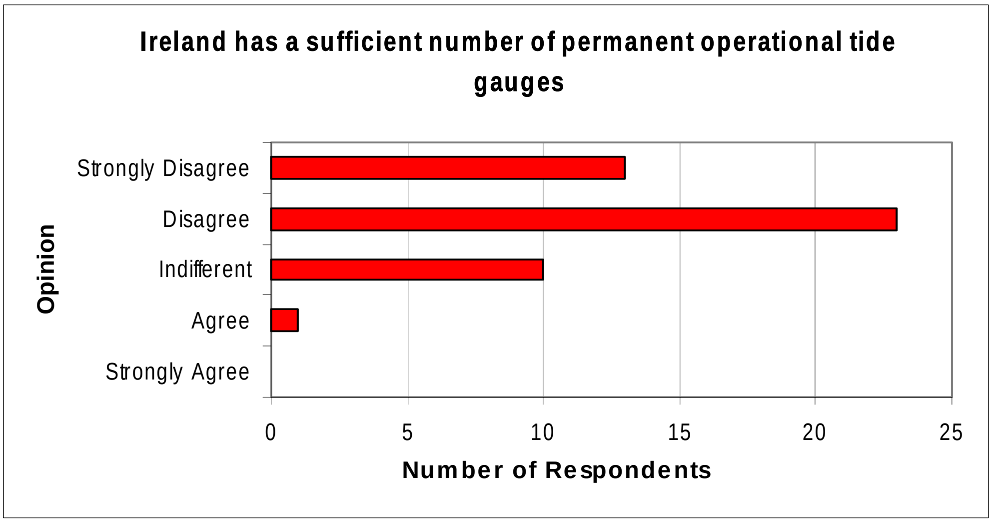

Figure 4.3a. Respondents views on the number of permanent operational tide gauges in Ireland.

The responses show that an overwhelming number of stakeholders are not happy with the current level of tide gauge infrastructure (76%).Only 2% of respondents agreed that there is a sufficient number of permanent operational tide gauges in Ireland.

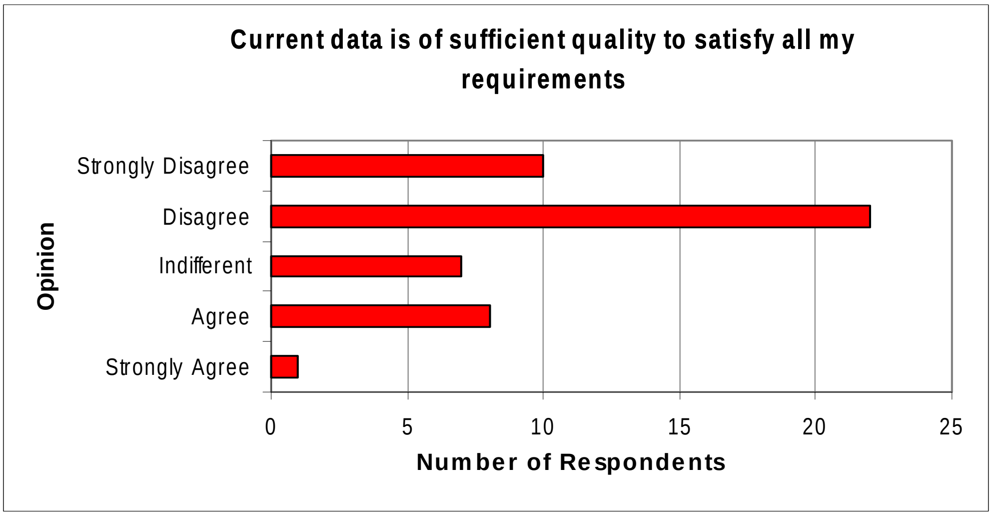

Figure 4.3b. Respondents views on the quality of current data.

The main trend is that stakeholders felt that the currently available water level data was unsatisfactory (67%). However approximately 17% do not have any problem with current data.

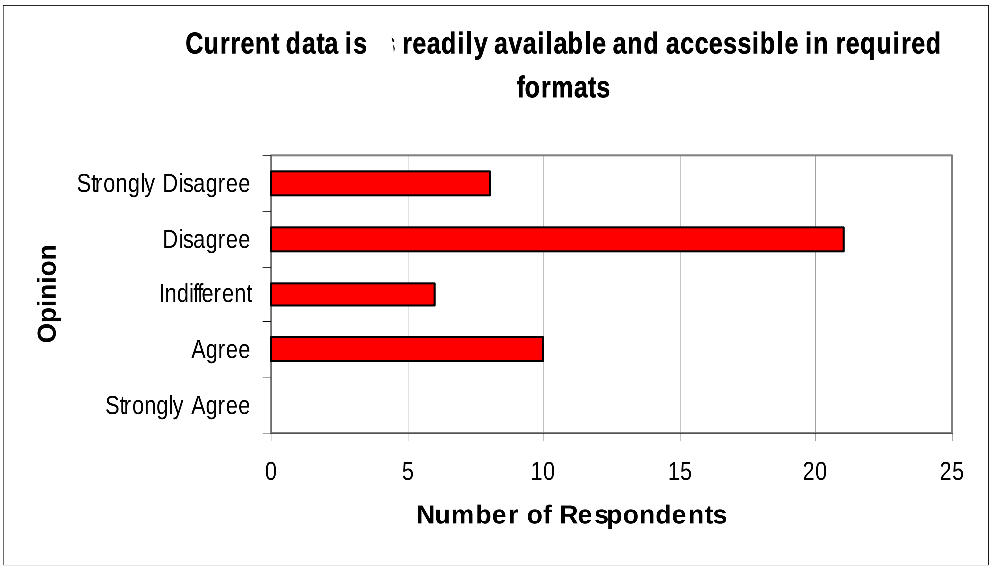

Figure 4.3c. Respondents views on the availability and accessibility of current data formats.

The above chart shows that 63% of respondents were dissatisfied with the availability and accessibility of current data in required formats. Only 22% were satisfied.

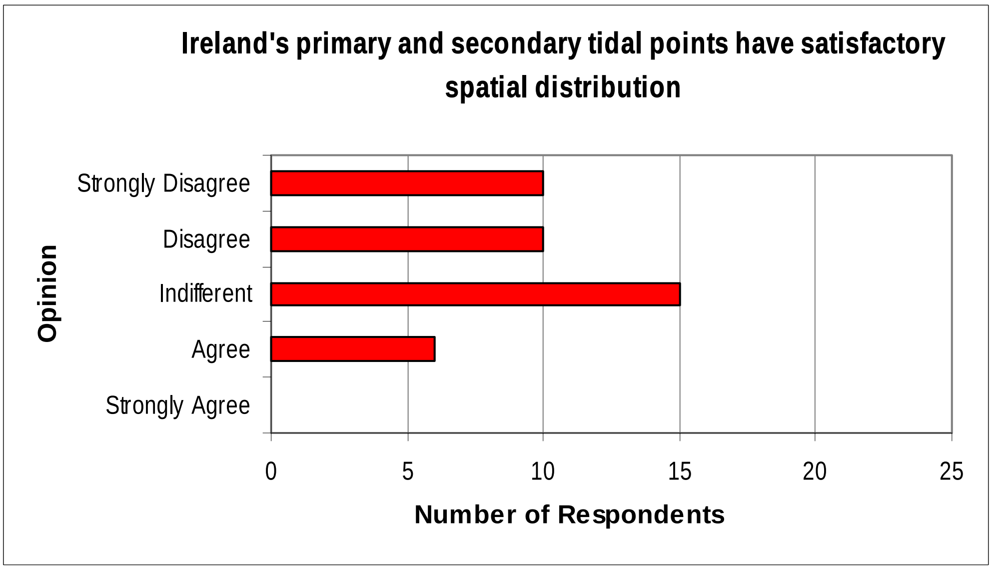

Figure 4.3d. Respondents satisfaction with the spatial distribution of Ireland's primary and secondary tidal points.

This chart shows that 49% of stakeholders are not satisfied with spatial distribution of primary and secondary tidal ports. However the main trend is that these locations are not of direct relevance to a lot of users (37%). Of the total response only 19% were satisfied with the spatial distribution of Ireland's primary and secondary tidal points.

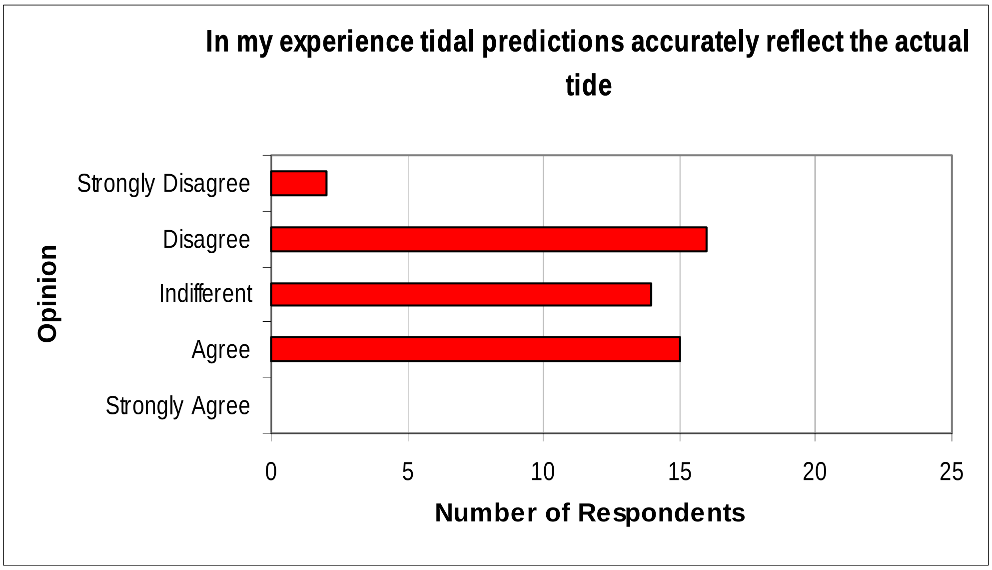

Figure 4.3e. Respondents views on the accuracy of tidal predictions.

The response to this section of the question was almost equally spilt between those respondents who disagreed (34%), agreed (32%) or felt indifferent (30%) to the accuracy of tidal predictions.

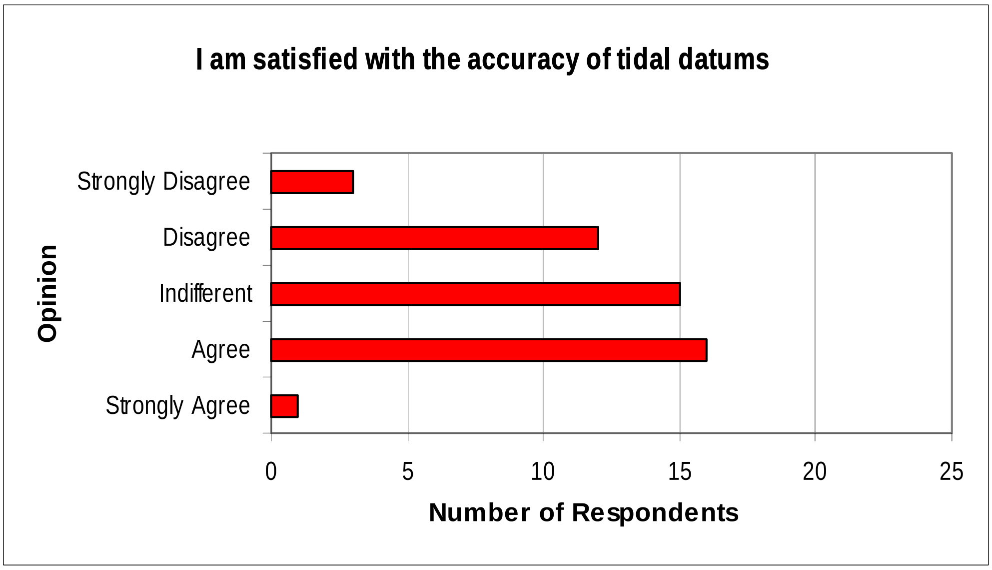

Figure 4.3f. Respondents views on the accuracy of tidal datums.

36% of respondents agreed that the accuracy of tidal datums is satisfactory whilst 32% of respondents disagreed. A large proportion of stakeholders (32%) were indifferent to this issue.

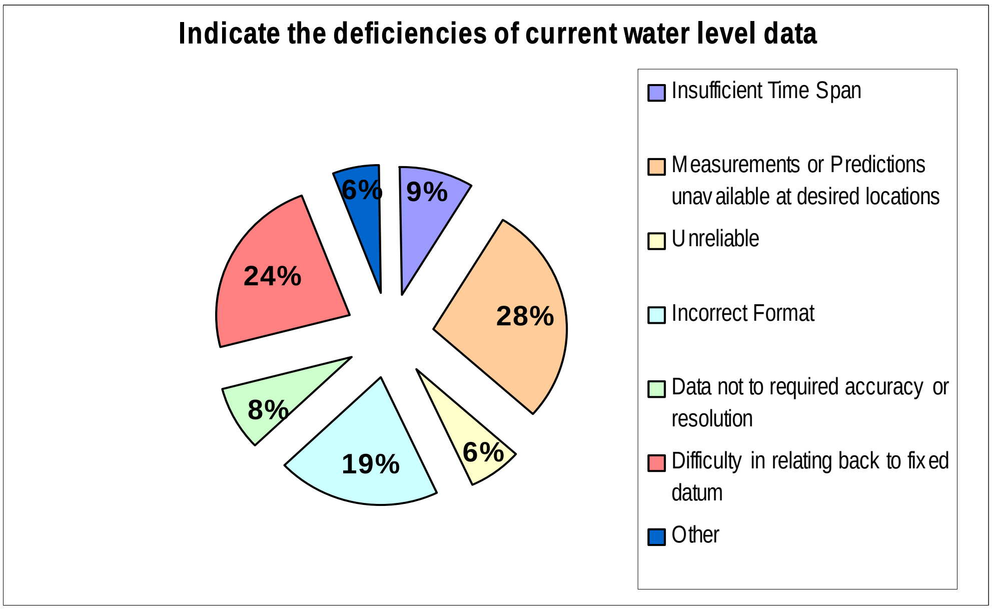

Figure 4.4. The deficiencies of current water level data
as indicated by respondents to the questionnaire.

The greatest identified deficiency of current water level data was the unavailability of measurements or predictions at desired locations; 28% of respondents selected this option. Difficulty in relating back to a fixed datum (24%) and incorrect format (19%) also featured strongly as deficiencies of current water level data. The remainder of the response was divided between insufficient time spans (9%), poor data accuracy and resolution (8%) and unreliability (6%).

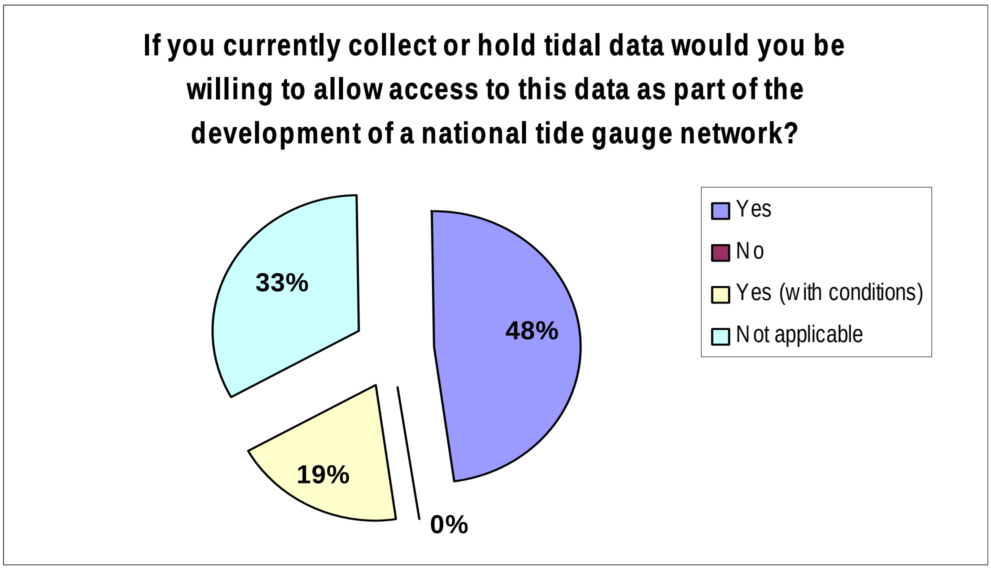

Figure 4.5. Respondents willingness to allow access to data they collect
or hold as part of the development of a national tide gauge network,

The majority of respondents replied with an unconditional yes (48%, n=20) to the request to allow access to data they hold or collect. A further 19% (n=8) agreed to allow access to data they hold or collect as long as certain conditions were met (e.g., it would not be free access, there may be a [nominal] cost involved, may require the agreement of a third party). No respondent (0%) refused to allow access to their data holdings or collections under any circumstances.

The following figures (Figure 4.6a-d) relate to respondents opinions on the establishment of a national tide gauge network.

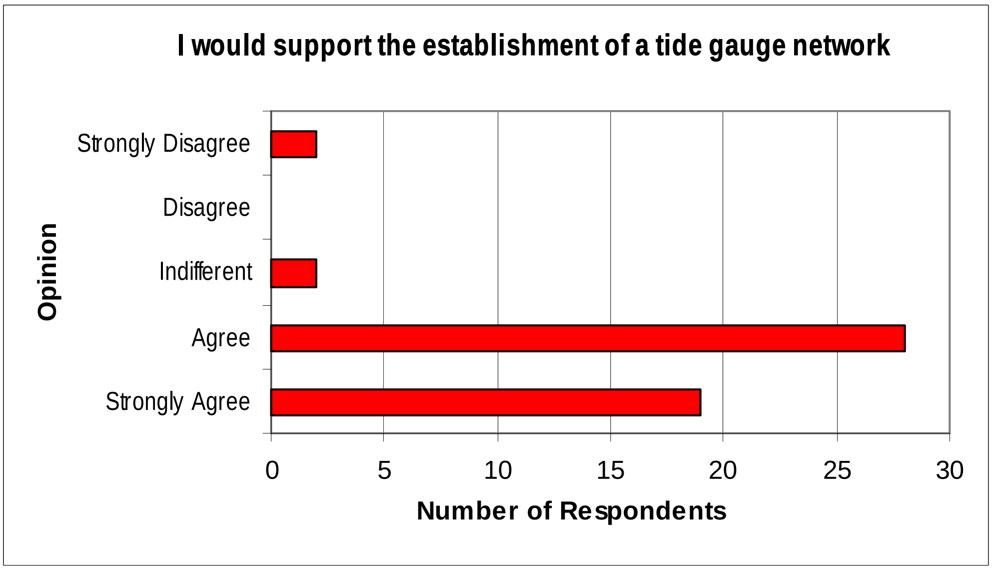

Figure 4.6a. Respondents views on the establishment of a national tide gauge network.

Figure 4.6a shows that 92% of stakeholders would support the establishment of a national tide gauge network. Only 4% of respondents thought that it was not necessary.

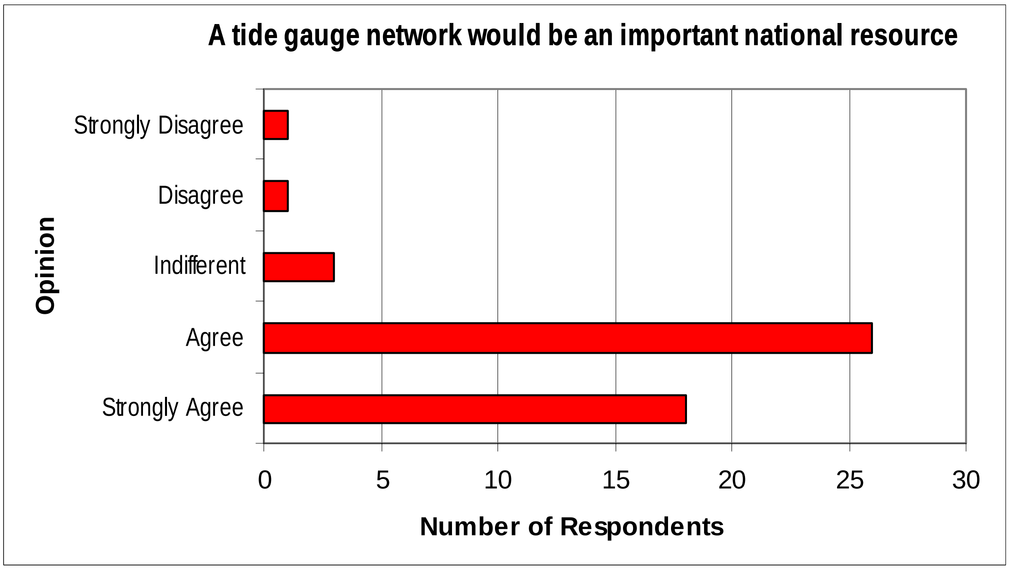

Figure 4.6b.Respondents opinions on a national tide gauge network as an important national resource.

The responses to this question are similar to the previous with 90% of respondents agreeing that a national tide gauge network would be an important national resource. Only 4% of respondents disagreed.

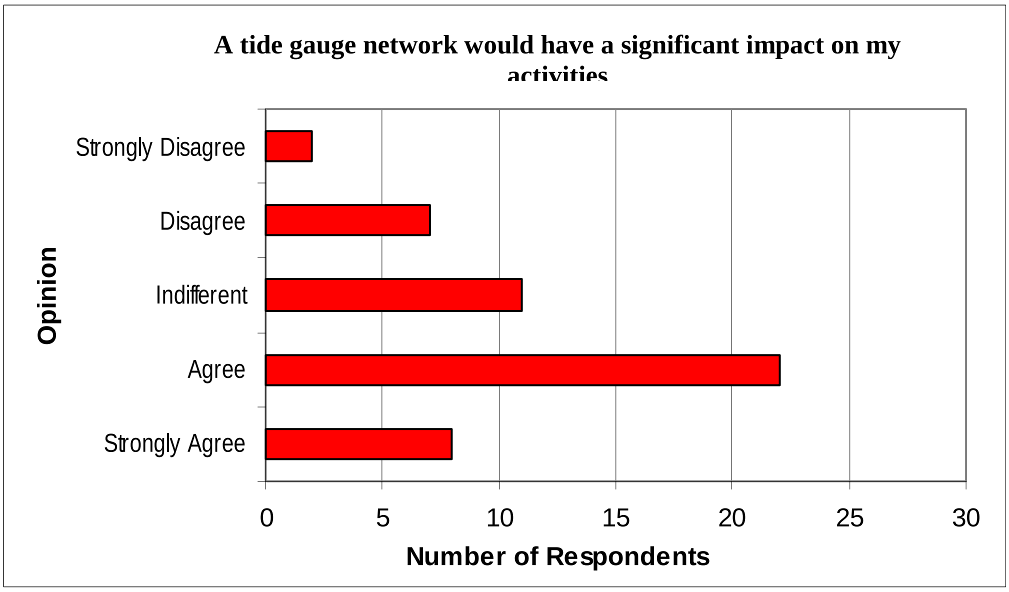

Figure 4.6c. Respondents' views on the impact of a national tide gauge network on their activities.

The responses show that 60% of stakeholders believe that a national tide gauge network would have a significant impact on their activities. Only 14% disagreed whilst 22% were indifferent.

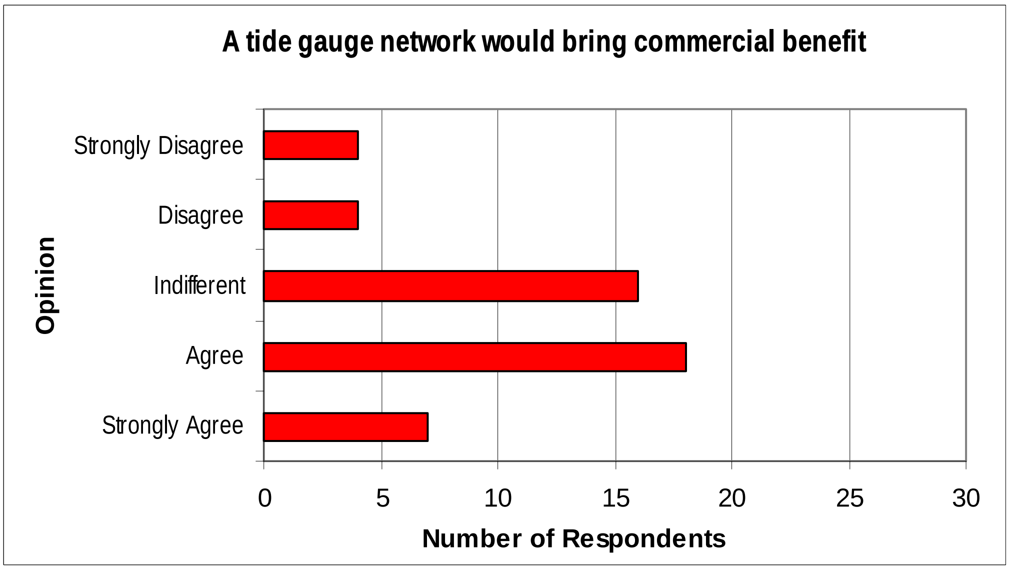

Figure 4.6d. Respondents views on the commercial benefit of a national tide gauge network.

About 51% of respondents believed that a national tide gauge network would generate a commercial benefit. Of the total response 33% felt indifferent whilst 16% of respondents disagreed that it would be of any commercial benefit.

The following figures (Figure 4.7a-d) relate to respondents opinions on the proposed benefits of establishing a national tide gauge network.

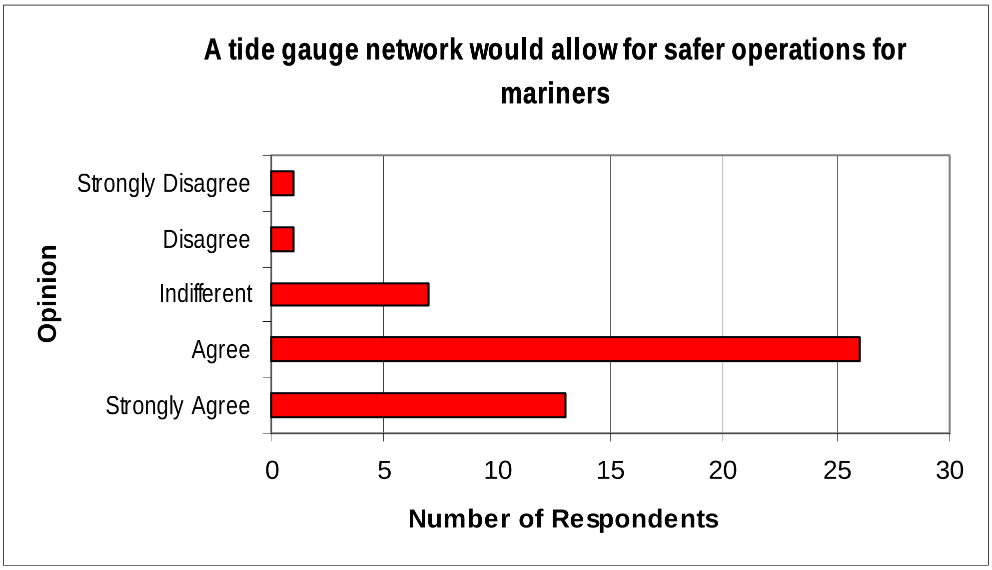

Figure 4.7a. Respondents views on the proposed benefit of a national tide gauge network for the safety of mariners.

An overwhelming proportion of respondents (81%) thought that a national tide gauge network would allow for safer operations for mariners.

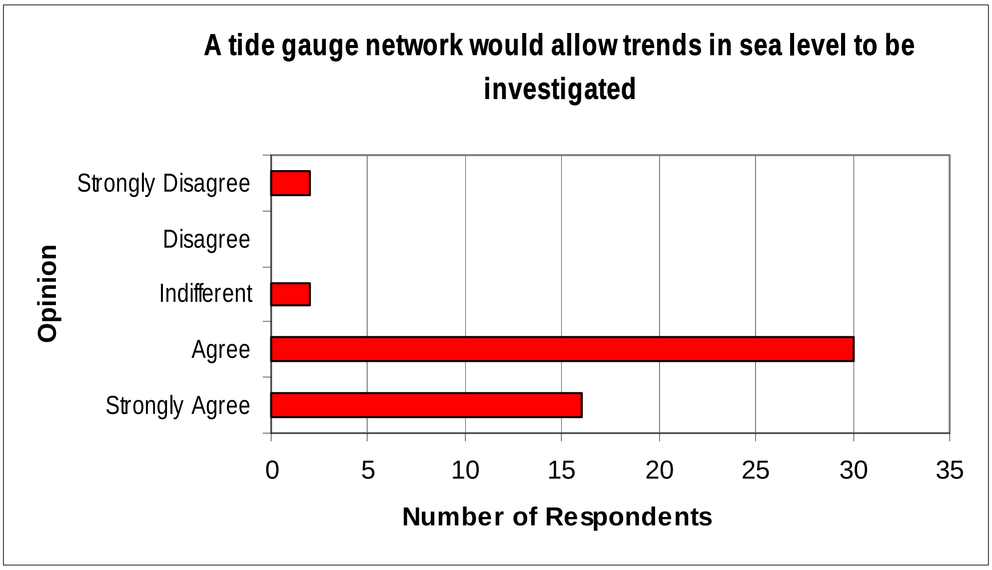

Figure 4.7b. Respondents views on the proposed benefit of a national tide gauge network for the investigation of sea level trends.

The majority of respondents (92%) believe that a national tide gauge network would benefit any investigation of sea level change. The remainder of the response was made up of those who felt indifferent (4%) about or strongly disagreed (4%).

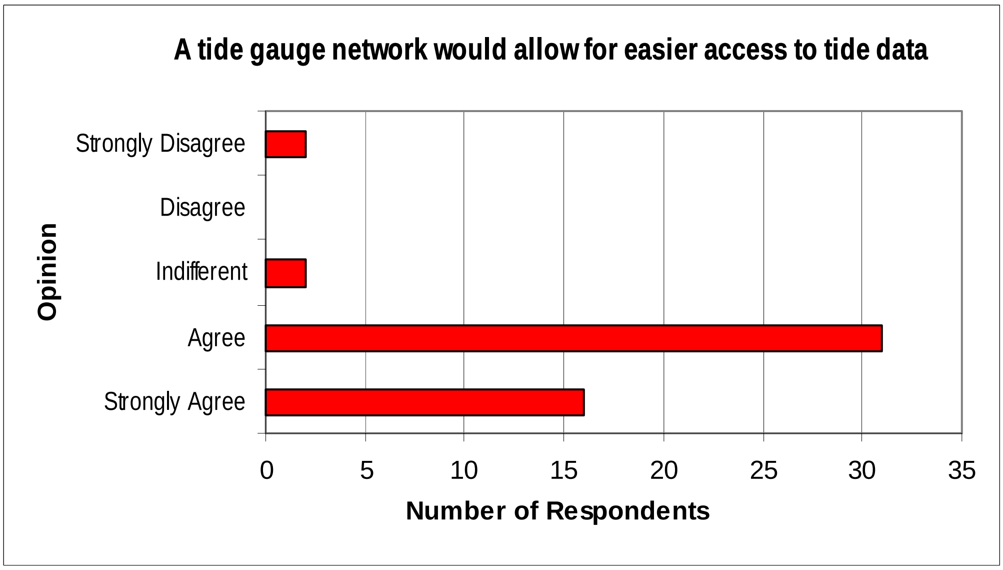

Figure 4.7c. Respondents views on the proposed benefit of a national tide gauge network in accessing tidal data.

A similar type of response as the previous question with an overwhelming number of respondents (92%) agreeing that a national tide gauge network would allow for easier access to tidal data. Again the remainder of the response was made up of those who felt indifferent (4%) about or strongly disagreed (4%).

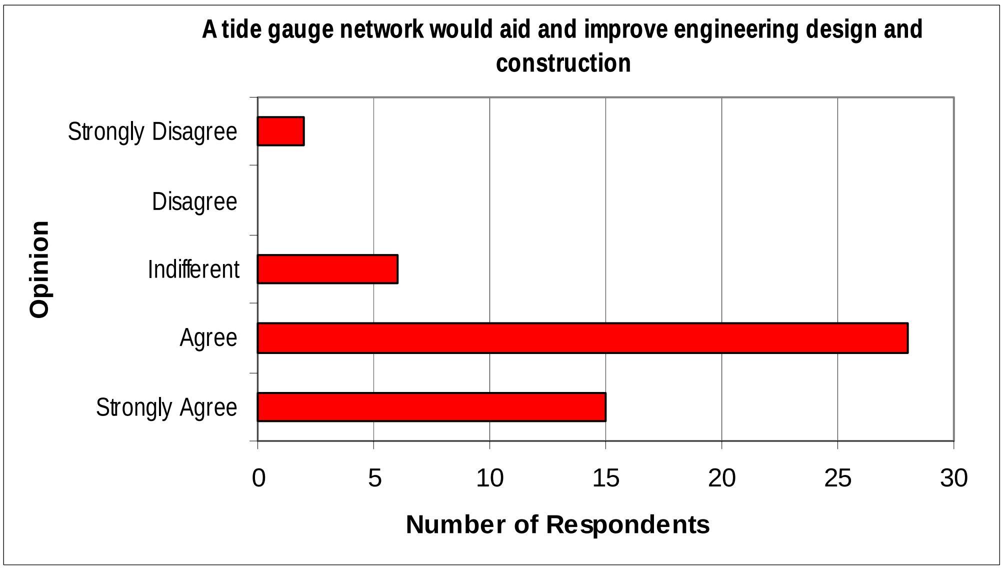

Figure 4.7d. Respondents views on the proposed benefit of a national tide gauge network to engineering design and construction.

A similar pattern again with 84% believing that a national tide gauge network would aid and improve engineering design and construction. A higher proportion of stakeholders are indifferent to this question (12%) but this would be expected given than a lot of respondents are not involved in engineering related activity.

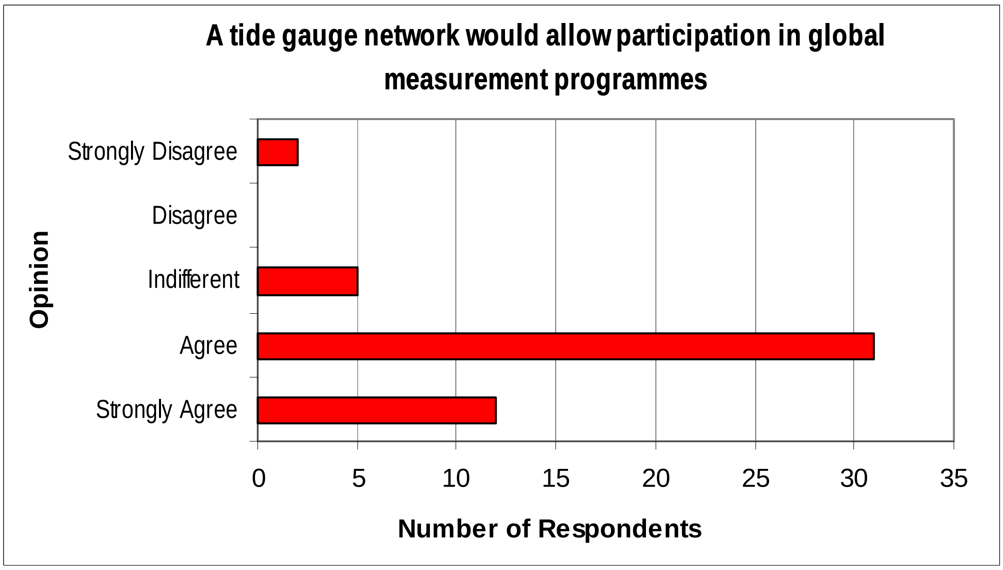

Figure 3.7e. Respondents views on the proposed benefit of a national tide gauge network in allowing participation in global measurement programmes.

The majority of respondents (86%) felt a national tide gauge network would be a positive step in allowing participation in global measurement programmes.

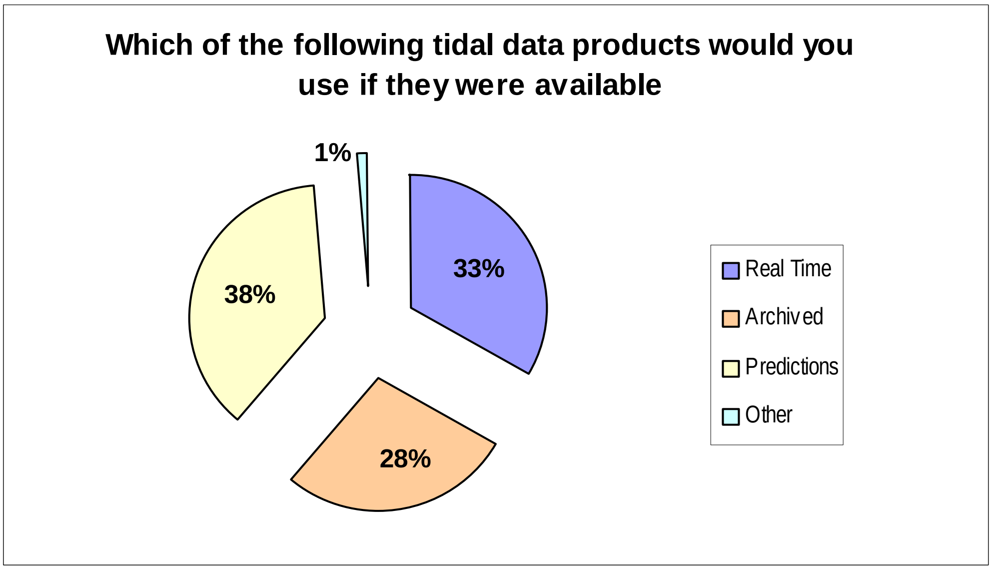

Figure 3.8. Respondents use of different forms of tidal data products (if available).

From the response received it is clear that predictions (38%,) and real time data (33%) were the most popular choices.

4.4 Comments and Observations from Respondents

The questionnaire allowed respondents to add their own comments and provide feedback on issues relating to tidal data, tide measurement or the proposed tide gauge network and archiving facilities. The following are comments received throughout the course of the study. They are grouped under the headings datums, tide gauge network, meteorological factors and other and are largely unedited.

4.4.1 Datums

1. *" Relating the chart datum to the OS datum would be of huge benefit to our work. Recording the highest astronomical tide (HAT) is essential for tidal flooding schemes. This information is not currently available."*

2. "It would be very helpful if the datum for tidal predictions could be related more clearly to land levelling datum (preferably OD Poolbeg) at numerous locations around the coast – e.g. by a table that would be regularly checked & updated as tide reading are collated and analysed. At a minimum these locations should include primary & secondary ports, and preferably also intermediate locations. The convention of Chart Datum causes unnecessary difficulties for designers working in the intertidal zone, e.g. pier and slipway design."

3. "Using OD Malin causes needless confusion, and is counter-intuitive when working in the intertidal zone, since the zero level is at mid-tide approx. Most structures are built to accommodate conditions at low tide, so a zero at or close to this level is far more satisfactory – i.e. OD Poolbeg."

4.4.2 Tide Gauge Network

1. *"Any new gauges should be operated in conjunction with the existing network for at least 5 years so a good statistical relationship can be established prior to hand-over. This will allow historical trends to be progressed into the future."*

2. "There must be a standard calibration methodology adopted and ideally restricted access to tide gauges. Tide gauges should be centrally linked and monitored, archiving will occur as a by-product of this. There should be a comparison between measured and predicted. There is a need for better info and chart datum determination in any part of the country."

3. "The need for a co-ordinated accurate and readily accessible source of data is vitally important."

4. "I believe that gauge maintenance, datum establishment and data collection need to be taken away from local control. Only way to do that is a telemetry or tele-web based communication to central agency. Need to move away from historical port control to other body so as to gear whole process into 21st century. The old local gauge is not required and we should not be trying to patch onto an outdated model of data collection. Only possible reason to mirror any existing sites is to be able to try and get some continuity of record."

5. "A primary tide gauge network is very desirable with say five gauges covering entire coast. This would allow proper analysis of mean sea level changes. For day to day survey activities tide gauges are of little use unless they are within 2 - 3km of the survey site."

6. " It is vital that the accuracy of readings from a network is continually verified to ensure user confidence in the system. For example the dial up gauge in Cork can sometimes give significant errors which significantly reduces its value."

4.4.3 Meteorological factors

1. *"Engineering design invariably requires data on highest tides and tidal range. In the case of highest tides it is important to have correlation with climatic or meteorological data such as barometric pressure, wind force and wind direction."*

2. "Weather conditions can have a significant effect on tide levels in particular onshore/offshore winds, high/ low pressure, etc. Although predicted tide levels provide a good baseline with which to work, based on consideration of these other factors. We currently use data from the UK National Tide Gauge Network that is of great benefit, for projects in Ireland we would also use data as commissions arise and if the data was available."

3. "Tide Gauges need to be located and maintained where they can provide long term reliable data. Ideally there should be wind and atmospheric pressure records kept for the same locations to assist with surge correlation."

4.4.4 Other comments

1. "Our main need is for flood defence. We have a need for current information and predictions that we can relate back to an ordnance datum, say Malin Head. We can access Drogheda Port Company records and we use their annual tide tables to predict tide levels and times. Tide tables are also useful for beach management and coastal construction works."

2. "The temporal time span of measurements is of prime importance, with hydrographic surveying (20mins max) and harmonic analysis (1hr). Also the maintenance of continuous records for analysis and prediction is very important. The method of analysis (i.e. UKHO / ISO versus the NODC (US) should be determined in advance, as the constituents used in harmonic analysis as different, thereby resulting is a variance in the predicted tidal levels."

3. "I believe there is now an accurate geoid for the world. I presume any new station would be referenced to this. This is important since isostasy (especially in the Malin Head area) is a problem in Ireland when trying to identify sea level rise and datum migration."

4. "The ability of a west Cork gauge to provide storm surge warnings to cities such as Dublin & Cork should be emphasised. At least two portable automatic tide gauges should be available for mapping the tide field in local areas."

5. "Tide gauges for use in the navigation of ships need only be accurate to approximately 50 – 100mm. The tidal predictions derived from the information provided by a local gauge is accurate to that gauge to a few millimetres It is relatively straight forward to install tide level gauges to accuracies of 1mm. This reading will never be better than 1 centimetre accuracy when referenced to an external or national benchmark (e.g. Poolbeg or Malin).

Depending on the accuracy of time and height required, tidal data from one tide gauge location cannot be used to generate the tidal constituents for any other location (e.g. Dublin and Dun Laoghaire and Howth). Using tidal measurements to measure sea level is extremely problematic as tide level is an extremely noisy measurement."

6. "We normally use specialist firms to collect etc. tide and other data for us, however, in the design etc. of marine works and river bridges we have constant need for HAT and MHWS types of levels – target design levels. Increased availability of long term historical data to permit the accurate determination of MHWS etc. would be useful. It is recognised that no matter how many *locations there are, we will probably need data at a location somewhere else, however a wider spread would improve the situation."*

7. "We used Tide Tool on Palm (a derivation of X-Tide I believe) instead of paper tide tables as a general aid in terms of knowing conditions before we visit site or making preliminary evaluations. However, the Admiralty have now insisted that the harmonic equations are their property rather than public domain and so the current versions of the prediction tool (which is free) can predict tides all over the world except the British Isles and Ireland. I would welcome the wider availability of tide data in the public domain."

4.5 Concluding Remark

The overall conclusion that can be drawn from the analysis of stakeholder requirements is that the majority are generally dissatisfied with all matters related to tide measurement and data availability in Ireland and would overwhelmingly welcome the establishment of a co-ordinated network.

5 Global and Regional Contexts

The importance of Irish water level measurements from a global perspective has already been highlighted. Information from Irish gauge stations would aid studies on oceanography, climate change and geodesy. In this section international initiatives to develop sea level monitoring programmes are discussed. These include GLOSS, which is a global initiative and ESEAS, which is part of a EU programme.

5.1 GLOSS

The Global Sea Level Observing System (GLOSS) was conceived in the mid-1980s as a network of tide gauges (sea level stations) around the world, providing the key data needed for international sea level programmes related to oceanography, geophysics and climate change. GLOSS was until recently a programme coordinated by the Intergovernmental Oceanographic Commission (IOC). Along with other ocean programmes, it is now an activity of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of IOC and the World Meteorological Organisation (WMO).

The main objective of GLOSS, as originally envisaged, was to improve the quality and quantity of monthly mean sea level (MSL) data provided by countries to the Permanent Service for Mean Sea Level (PSMSL). The PSMSL, which was established in 1933 and is hosted by POL, has received data from countries for many years but on a rather *ad hoc* basis. The GLOSS Core Network (GCN) was envisaged as providing a 'global baseline' around which more dense regional and national networks would be constructed for local and practical purposes (Figure 5.1). The GCN would be operated with high quality gauges and to common standards, and each country would contribute to the collaborative international programme out of national funds with coordination from IOC. Even though GLOSS is now formally a JCOMM activity, rather than a purely IOC one, the ethos of its organisation remains the same.

By the mid-1990s, major technological developments had taken place, especially in satellite radar altimetry and GPS, which meant that the need for the GLOSS *in situ* network had to be reconsidered. This was accomplished by means of the GLOSS Implementation Plan 1997, which was approved by the IOC Assembly the same year (IOC, 1998). The Plan confirmed the need for the GCN and for specialised sub-networks required for long term sea level change studies, altimeter calibration and ocean circulation monitoring. It also required that GCN stations deliver higher frequency data (i.e. raw data, typically hourly values) in 'delayed mode' form to GLOSS Centres (in practice either the PSMSL again or University of Hawaii Sea Level Centre, UHSLC) with a maximum delay of 6 months. The higher frequency data are required by the programme for good reasons: (i) to provide the possibility for essential quality control checking of the monthly and annual MSL values to common, modern standards; (ii) to provide access to the higher frequency section of the sea level variability spectrum, thereby aiding interpretation of interesting signals which may be less evident in the monthly means; and (iii) to enable long term archiving of irreplaceable GLOSS data sets.

The major development which has arisen since the 1997 Plan has been the recognition of the need for 'fast' (near-real time) data sets in addition to the 'delayed mode' MSL and higher-frequency sets described above. 'Fast' means different things in different applications. For example, fast data should be provided within several days to one week if required for assimilation into the new generation of deep ocean models (e.g. within the Global Ocean Data

Assimilation Experiment, GODAE) and for ready use in altimeter calibration. On the other hand, fast data are needed within an hour or two for use in local flood warning schemes. In 1999, GLOSS established the GLOSS Fast Centre at UHSLC as a logical evolution of UH's previous fast role for the World Ocean Circulation Experiment (WOCE). It was realised that 'fast' data could imply expenditure in both upgrades to gauge hardware and data transmission methods and in staff resources.

With regard to the operation of GPS receivers at tide gauge sites, in 1997 the PSMSL, GLOSS and the International GPS Service (IGS) established a joint working group called the Continuous GPS at gauges (CGPS@TG) group. The IGS has since initiated a Tide Gauge GPS project (TIGA), which aims to collect data from as many gauge sites as possible and to learn how measurement errors in the determination of rates of vertical land movements can be reduced.

To summarise, there are 4 data streams within GLOSS:

(1) MSL data to the PSMSL
(2) Delayed mode higher frequency data to UHSLC or PSMSL (GLOSS Archiving Centres)
(3) Fast higher frequency data to UHSLC (GLOSS Fast Centre)
(4) GPS data to the TIGA (IGS) data centre at Potsdam, Germany.

Organisations and countries participating in the programme should contribute to all 4 streams. A recent review of GLOSS status worldwide can be found in the GLOSS Adequacy Report (IOC, 2003a).

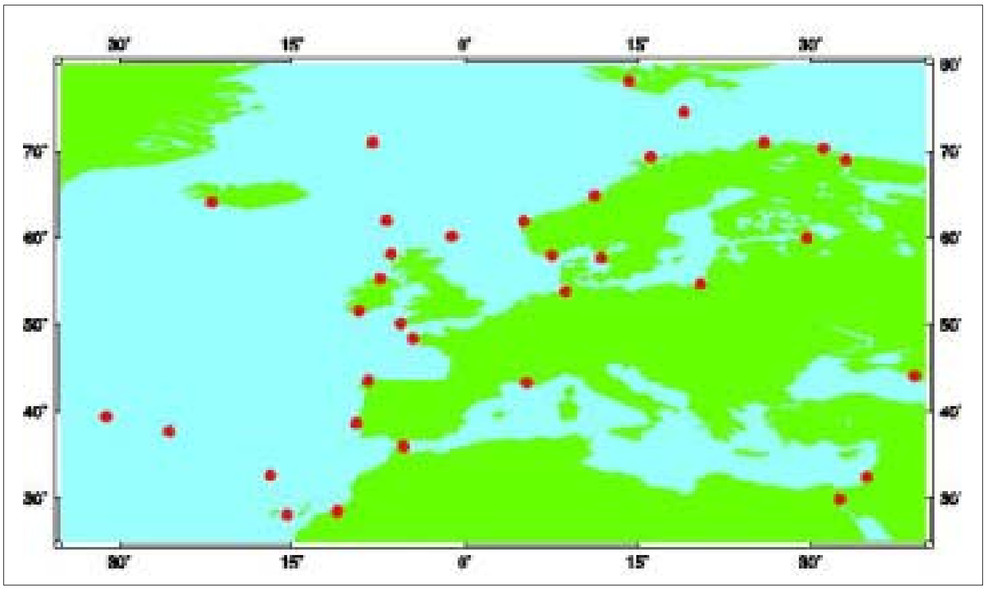

Figure 5.1: The European component of the GLOSS Core Network around which more densified regional and national networks can be constructed.

5.1.1 Implications of GLOSS for Ireland

Ireland is a developed nation with important marine and coastal interests. It is a Member State of IOC and has voted for (or at least has not voted against) GLOSS developments at every IOC Assembly for the last 20 years. Therefore, from a GLOSS perspective, Irelands participation in the programme thus far has been disappointing. Some implications of Ireland's membership of IOC and GLOSS can be mentioned:

- In the original GLOSS Implementation Plan and in its 1997 revision, Ireland was asked to install and maintain stations in the north and south which would provide data to the GCN as described above. Gauge sites were selected primarily on the basis of their historical record, although it was recognised that local expertise would be important in deciding upon alternative locations along the coast if other sites were more appropriate for long term monitoring. Malin Head was selected in the north and has an operating tide gauge since 1958. Castletownsend was selected in the south but there never has been any long term tide gauge installation at this site (only 2 short term deployments).

- Any sea level specialist in Ireland has access to GLOSS reports and software concerning tide gauge installation and maintenance, data quality control and management. Irish specialists are welcome to apply to attend GLOSS training courses, held at typically yearly intervals. GLOSS Experts meetings also provide a forum at which Irish specialists are welcome and within which experiences can be shared and common high standards transferred.

5.2 ESEAS

GLOSS has always stressed the importance of regional networks to provide components of the GCN and to effectively densify it. The first major attempt to define a European regional network was called EuroGLOSS (Baker et al., 1997). This proposal resulted in a European Union (EU) COST (European **Co**-operation in the field of **S**cientific and **T**echnical Research) Action called the European Sea Level Observing System (EOSS), which was replaced more recently by the European Sea Level Service (ESEAS) (http://www.eseas.org). Ireland took part in EOSS activities (represented by Dr. Peter Bowyer of University College Galway) but has not taken part in ESEAS. During 2002, a 3 year EU FP5 programme called ESEAS-RI (ESEAS-Research Infrastructure) was initiated which provides a number of European countries with the hardware and community links to, in effect, fill holes in the regional GLOSS network. Irish groups did not participate in ESEAS-RI.

The objectives of ESEAS can be summarised as the installation of modern networks of gauges around Europe, optimised for regional needs but also satisfying global (GLOSS) requirements. Data will be shared and quality controlled to the same standards. ESEAS has been endorsed by the IOC/JCOMM GLOSS Experts Group as the European regional mechanism by which GLOSS can be established. It would be very beneficial if Ireland could participate in ESEAS by means of sharing data from the proposed network.

6 GLOSS Irish Sites

When the GLOSS network was designed, two sites, with a history of tide gauge measurements, were selected for Ireland. One gauge on the north coast of Ireland, Malin Head, Co. Donegal, and the other on the south coast, Castletownsend, Co. Cork. Each of these sites will now be described along with details of an investigation to find an alternative site on the south west coast.

6.1 Malin Head

The Malin Head site has had a functioning tide gauge since 1958 and has been operating as a GLOSS site for a number of years. The measurement sensor has been changed a number of times since recordings began. Float type gauges were used until 1990 when a new pneumatic water level gauge type HBe 20.501 was installed. It was installed in a new hut as the old gauge and the shed were removed. This gauge was subsequently replaced with another bubbler type gauge in July 2003 (the OTT NIMBUS gauge). The installation of the new gauge coincided with refurbishment work on the pier (Plate 6.1). The instrument hut is shown in Plates 6.2 and 6.3 and the tube for the bubbler gauge runs through a pipe buried in the pier deck which exits at a ladder recess and then runs vertically down the pier face to below the lowest tide level (Plate 6.5). A similar set-up is used for the temperature gauge (Plate 6.6). Both these gauges are located in a new section of pier. There are a number of benchmarks on the pier and one in a nearby rock outcrop and these are used for levelling purposes. The current tide gauge (Plate 6.4) has allowed digital recording of data although the PSMSL has digitised a lot of the old recordings. Information on mean sea levels is provided to PSMSL regularly and a plot of some historical annual levels is shown in Figure 6.2. It should be noted that the dip in the early 1990s has now been removed by the re-digitisations carried out by the Irish OS and QU Belfast. It was caused by an instrumental/datum problem. Higher-frequency delayed mode data have been contributed to GLOSS on an irregular basis (most recently via Queen's University, Belfast) but a fast data stream has not been established.

Although Malin Head currently acts as a GLOSS site it is likely that some further upgrading will be required to bring it in line with current requirements. The Nimbus bubbler gauge is regarded as being acceptable in terms of achieving the necessary accuracy (1cm) however data logging and transmission needs to be reviewed to allow near real time access to the data. In addition a GPS antennae and receiver need to be installed to allow vertical land movements to be separated from the mean sea level readings.

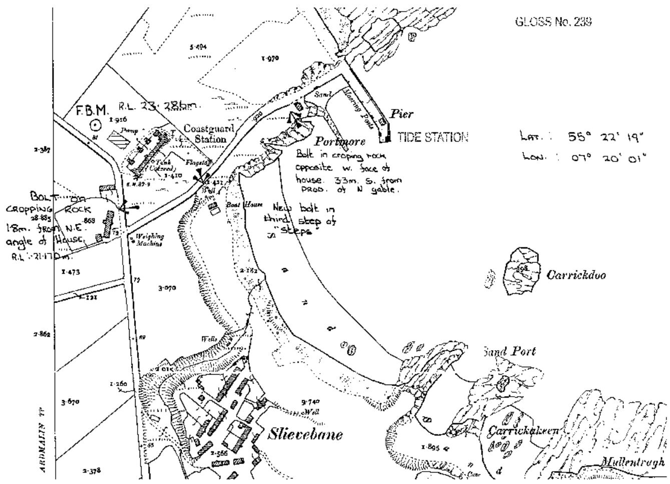

Figure 6.1 Malin Head Location Detail (Copyright OSi)

Plate 6.1 Malin Head Site (Hut and gauge locations marked by green boxes)

Plates 6.2 and 6.3 Instrument Hut

Plate 6.4 Tide Gauge Instrumentation (inside hut)

Plate 6.5 Bubbler gauge pipe

Plate 6.6 Temperature gauge pipe

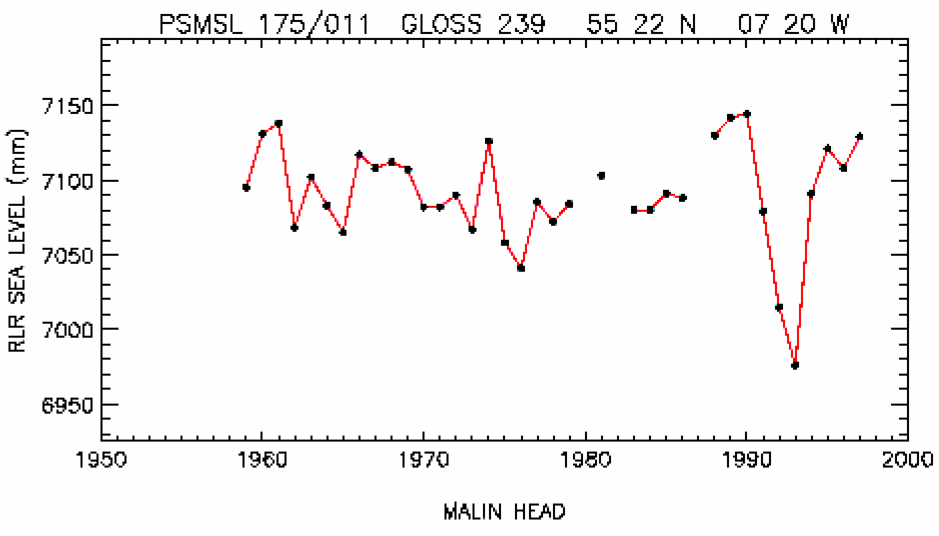

Figure 6.2 GLOSS report on mean sea level

6.2 Castletownsend

The second GLOSS location is not as well defined and is the only non-operational GLOSS site on the European Atlantic coast. Castletownsend was chosen as a GLOSS site because two water level measurement campaigns were carried out at this location. Airy carried out tide pole recordings from June - Aug 1842, whilst Pugh installed a bubbler gauge between July 1977 and May 1978. Pugh used the original Airy benchmarks for his measurements which were located in the garden of the old Coastguard station.

There are a number of problems with using Castletownsend as a site for a permanent tide gauge as were outlined after a visit by Mr. David Smith of POL in 1993. The major issue relates to the siting of the gauge. The old Coastguard station, which has been the location of previous measurements, is now private property so cannot readily be used. In any case there is no structure here onto which a gauge can be readily fixed. Acoustic or radar gauges would not be suitable and a bubbler gauge would require a long tube that would have to extend over the rocky foreshore to get adequate water depth. An alternative location is the quay located at the end of the main street. However this is a busy working structure with very little water at low tides. The current GLOSS report on Castletownsend states that a "Gauge does not and probably will not exist". Finding a suitable alternative GLOSS site on the South-west coast of Ireland forms a major part of this study.

Figure 6.4 below shows the coastguard station (at base of figure) and the quay structure and these locations can also be identified in the aerial photograph (Plate 6.7). Plates 6.8-6.10 provide different views of the coastguard station and the quay.

Figures 6.3 and 6.4 Location Maps of Castletownsend (Copyright OSi)

Plate 6.7 Aerial view of Castletownsend

Plate 6.8 View up inlet from old Coastguard Station

Plate 6.9 View out inlet at old coastguard station

Plate 6.10 Castletownsend Pier/Quay

6.3 GLOSS Site Selection

From the previous discussion it can be concluded that Malin Head should continue operating as a GLOSS site but Castletownsend is generally unsuitable for siting a permanent tide gauge. Therefore the suitability of alternative sites along the southwest coast of Ireland was examined. Discussions with GLOSS indicated that an alternative site would be acceptable provided that it met certain criteria.

The 'ideal' site requirements are listed below,

- Located on relatively straight section of coastline – not on major headland or far up a bay or estuary
- Tides should be representative of open ocean so thus site needs to be close to the shelf edge
- Sheltered from major wave effects – do not want wave set-up effects added to tidal signal
- Location must never dry out or be subject to significant siltation
- Currents in the area of the gauge should be low
- Gauge should be placed on stable structure (not subject to subsidence)
- Clear view of the sky in all directions for elevation angles above 15 degrees - this is a relatively new requirement (to allow the proper operation of a GPS antennae) and could lead to the exclusion of sites located under cliffs or near high buildings

Other desirable characteristics for the site include

- Availability of power, telephone lines and GSM signal
- Local Support – someone local to visit the gauge
- Ability to place gauge in location, which minimises risk of damage either accidentally or through acts of vandalism.

The HMRC examined Admiralty Charts, Ordnance survey maps, aerial photographs and Cork County Council reports and choose a number of potential sites that were considered to generally satisfy the GLOSS criteria. These locations were examined by POL and a short list of sites to visit was drawn up. It included the following locations, as indicated on Figures 6.5, Rosscarbery, Mill Cove, Glandore, Union Hall, Castletownsend, Schull and Castletownbere. On the 18th November 2003 Mr David Smith from POL and manager of the UK tide gauge network inspected these sites. Details of each of these sites and comments regarding the inspections are provided below.

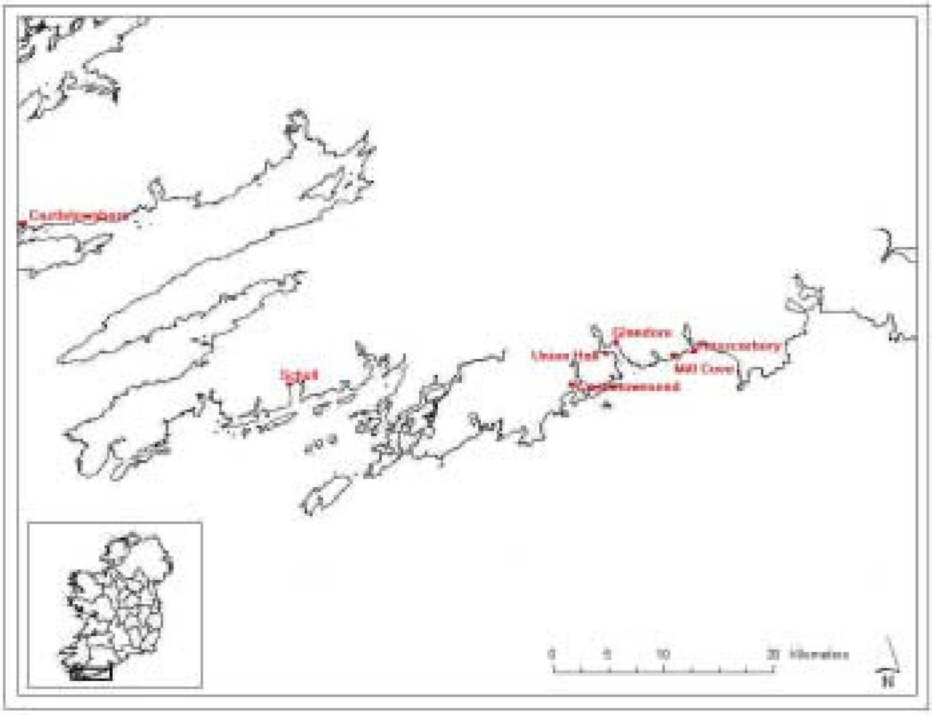

Figure 6.5 Potential GLOSS Site Locations

Figure 6.6 Location Map for Rosscarbery, Mill Cove, Glandore and Union Hall Sites (Copyright OSi)

6.3.1 Rosscarbery

The pier is situated on the western entrance to Rosscarbery Bay 2.5km south of Rosscarbery. It is built on a stone outcrop with some sheet piling at the seaward end and has a concrete decking, which is in good condition. Table 6.1 below gives details of the pier and Plates 6.11 to 6.13 show different views of the structure.

Pier No.	**Pier Name**	**Townland**			
120	Rosscarbery, New pier	Downeen			
Road Category	**Road No.**	**Road Width**	**Road Condition**	**Distance to Regional Road**	**Regional Road No.**
County	L-8337-0	4.5m	Fair	1.7km	N71
Facility	**Construction Type**	**General Condition**	**Description**	**Repairs Required**	
Pier with Steps	Mass concrete/Sheet piles at head of pier	Good, overall	Some sections of deck cracked & showing settlement	Sections of deck. Cracking on storm wall requires repair	
Length of Pier	**Width of Pier**	**Berthage Length**	**Water Depth**		
89m	8.8m/9.2m	65m-tide dependant	6.1m		
Pier Usage	**Water Supply**	**Power Supply**	**Lighting**	**Safety Equipment**	
Tourism	No	No	No	1 Ringbuoy	

Table 6.1 Rosscarbery Pier Details

Plate 6.11 Aerial View of Rosscarbery Pier

Plate 6.12 Rosscarbery Pier – High Tide

Plate 6.13 Rosscarbery Pier – Low Tide

The following general comments can be made about the site,

Pros

- Site very open to the ocean
- Pier possibly very stable site due to construction on bedrock
- Strong GSM signal

Cons

- Lack of Facilities and support
- Pier possibly subject to relatively large wave attack
- Possibility of strong flows past the pier
- Pier head only location that does not dry out
- Isolated – risk of vandalism

Possible Installation Type

Site would be suitable for a radar type gauge located on head of pier. The installation would have to be self-contained using a solar panel and batteries and a GSM or satellite connection for data transmission. The sensor would need to be located at a height where it would not be subject to impacts from overtopping flows and could not be easily vandalised.

6.3.2 Mill Cove

This pier is sited on the east side of the next inlet west of the Rosscarbery jetty. It was chosen due to its proximity to the edge of a small relatively sheltered inlet as shown in Plate 6.14. The pier is built on a rock outcrop with a rough stone top. The outcrop extends on both the landward and seaward side of the pier and is visible at low tide as the pier dries up along most of its length. Table 6.2 below gives details of the pier and Plate 6.15 shows the leeward side of the structure.

Pier No.	**Pier Name**	**Townland**			
119	Millcove	Downeen			
Road Category	**Road No.**	**Road Width**	**Road Condition**	**Distance to Regional Road**	**Regional Road No.**
County	L-4248-0	3.8m	Fair, a few potholes	2.6km	R597
Facility	**Construction Type**	**General Condition**	**Description**	**Repairs Required**	
Pier with steps	Mass concrete pier built on rock. Mass conc edge pier.	Good	Cobble deck with some grass.Old mass concrete storm wall.	Storm wall.Possibly new deck.Pier requires 20-30m extension.Cracking between edge beam & structure	
Length of Pier	**Width of Pier**	**Berthage Length**	**Water Depth**		
54.6m	6.2m	40m approx	1.5-4.15m		
Pier Usage	**Water Supply**	**Power Supply**	**Lighting**	**Safety Equipment**	
Tourism & Fishing	No. Fire hydrant at start of pier.	No	No	1 Ringbuoy	
Observations					
Good sheltered mooring in cove.(Previous) Harbour master & Local committee					

Table 6.2 Mill Cove Pier Details

Plate 6.14 Aerial View of Mill Cove

Plate 6.15 Mill Cove Pier – Low tide

The following general comments can be made about the site,

Pros

- Site very open to the ocean
- Pier possibly very stable due to construction on bedrock

- Proximity of power and telephone lines, good GSM signal
- Possibility of local support – harbour master and local committee

Cons

- Pier possibly subject to relatively large wave attack
- Pier head only location that does not dry out
- Remote location - access to the site is difficult along narrow road
- Pier in relatively poor condition
- Busy location and not a lot of free space on pier

Possible Installation Type

A pressure type gauge located at the head of the pier would likely be the most suitable sensor types for this site. Radar or acoustic gauges would not be suitable given that vessels may berth beneath the sensor and also as there would be a high risk of accidental damage. Even the pressure and bubbler gauges would be at a greater than normal risk of damage. Nearby power and telephone lines can be extended to gauge location.

6.3.3 Glandore

Glandore Pier, in Glandore Harbour is a fairly sheltered structure although it is located relatively far into the bay (from a GLOSS perspective). The stone pier is in the village and built on a rock outcrop with deep water on the quayside and end. Although the quay was quiet on the visit the jetty is very busy during the holiday season. Table 6.3 below gives details of the pier and Plates 6.16 and 6.17 show different views of the structure.

Pier No.	**Pier Name**	**Townland**			
116	Glandore	Rushanes			
Road Category	**Road No.**	**Road Width**	**Road Condition**	**Distance to Regional Road**	**Regional Road No.**
Regional	R-597-19		Good	0m	R597
Facility	**Construction Type**	**General Condition**	**Description**	**Repairs Required**	
Pier with steps + slip	Stone with concrete deck	Good	New concrete deck on upper section	Deck could be upgraded. Handrails around top of steps	
Length of Pier	**Width of Pier**	**Berthage Length**	**Water Depth**		
151.6m	6.4m	134.4m excl. slip	?		
Pier Usage	**Water Supply**	**Power Supply**	**Lighting**	**Safety Equipment**	
Fishing, Tourism & Leisure	Yes,small tap.	Yes, 1/2 Kiosks.	Yes, 3 lights on pier + adjoining s	Yes, 3 Ring bouys.	
Observations					
None					

Table 6.3 Glandore Pier Details

Plate 6.16 Aerial View of Glandore Pier

Plate 6.17 Glandore Pier – High Tide

The following general comments can be made about the site,

Pros

- Proximity of power and telephone lines
- Pier possibly not subject to large wave attack
- Does not dry out over significant length of structure

Cons

- Busy location especially during summer season
- Not many locations on structure where gauge can be placed
- Site far into bay
- No GSM signal (on day of site visit)

Possible Installation Type

Given the nature of the pier and its usage a pressure type gauge located at the head of the pier would likely be the most suitable sensor type for this site. Radar or acoustic gauges would not be suitable given that vessels may berth beneath the sensor and also as there would be a high risk of accidental damage. Even the pressure and bubbler gauges would be at a greater than normal risk of damage as there are not any recesses on the pier face into which the tube/wiring could be placed.

6.3.4 Union Hall

Union Hall is a busy fishing port located south of the village and on the opposite side of Glandore Harbour as Glandore Pier (see Figure 6.6). This is a modern concrete commercial fishing quay along side an older stone jetty. The stone jetty has suffered damage and appears to be unstable.

Plate 6.18 Union Hall Quay

The following general comments can be made about the site,

Pros

- Quay in sheltered location
- Does not dry out
- Local Support
- Availability of power and telephone lines

Cons

- Busy fishing port
- Not many suitable locations where gauge can be placed
- Site far up bay
- No GSM signal (on day of site visit)

Possible Installation Type:
One possible location for the installation of a tide gauge was found at this site – on a section of quay that is running normal to the shoreline north of the ice plant. This is a relatively quiet spot in the harbour and would be suitable for any of the gauge types. A radar gauge would probably be most suitable primarily as all instrumentation would be out of the water.

6.3.5 Castletownsend

Castletownsend was visited to determine whether there had been any significant change since the previous site visit in 1993. It was determined that this location remains unsuitable as a site for a permanent tide gauge station for the same reasons as previously outlined.

6.3.6 Schull

Schull has a medium sized harbour that caters for fishing vessels, leisure craft and island ferries. It is located in a bay and is sheltered from all conditions except those ranging from directions south to south south west.

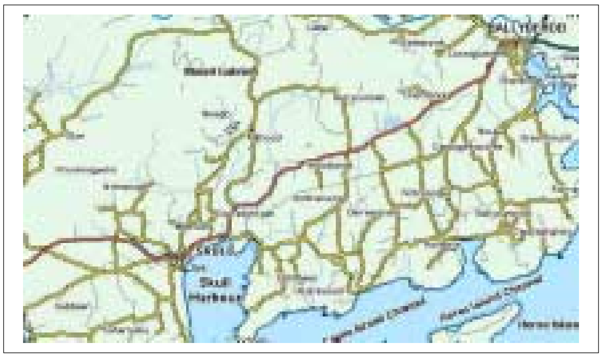

Figure 6.7 Schull Location Map (Copyright OSi)

Plate 6.19 Aerial View of Schull Harbour

The following general comments can be made about the site,

Pros

- Proximity of power and telephone lines, good GSM signal
- Does not dry out
- Local Support available

Cons

- Pier subject to relatively large wave attack
- Busy harbour
- Difficulty in finding suitable location to site gauge
- Site inside bay

Possible Installation Type

The only possible site for a gauge is at the landward end of the pier but it looks like that dries out at low water. Given the level of activity around the pier it is likely that a pressure type system would be the most suitable installation at this site.

6.3.7 Castletownbere

A large fishing port with busy modern quays administered by the Department of the Communications, Marine and Natural Resources.

Figure 6.8 Castletownbere Location Map (Copyright OSi)

Plate 6.20 and 6.21 Aerial Views of Castletownbere and Dinish island

Plate 6.22 View across harbour to Syncolift

Plate 6.23 Syncolift Control Cabin

Plate 6.24 Jetty Edge Detail

Plate 6.25 Jetty Structure and Control Cabin

The following general comments can be made about the site,

Pros

- Proximity of power and telephone lines
- Sheltered location
- Does not dry out
- Very Good Local Support
- Building available for housing gauge instrumentation (Dinish Island location)
- No potential problems with GPS signals
- Good locations for siting gauge either on mainland or Dinish Island
- Important strategic location
- Good Security (Dinish Island Location)
- Opening in deck slab for instrument cables to pass through

Cons

- Busy fishing port
- Site not directly open to the ocean

Possible Installation Type

Two potential locations for a gauge were found. The first on the mainland on a section of quay near to where the Island ferries dock and the second on the Syncolift structure (open jetty supported on concrete piles) on Dinish Island. For the mainland site the only location for measuring instruments would be in the face of the quay in areas protected by fendering. A location for instrument housing was identified (on wall of small hut used mainly by people waiting for ferry) but given its very public location it would be vulnerable to vandalism. The site on Dinish Island was considered to be the more suitable as it is more secure, has better facilities and is on Department of Communications, Marine and Natural Resources property. Both locations would be unsuitable for radar or acoustic gauges as the high level of activity in the harbour would increase the risk of damage. The other option is to use pressure type system, probably a bubbler. A temporary installation of a Valeport pressure gauge took place at the Dinish Island site for six months in 2003 without any problems.

6.4 Conclusion

The conclusion of the site visits was that Dinish Island at Castletownbere would be the best location to site a permanent tide gauge. The open construction of the jetty affords good protection for the measuring system with the data logging system housed in the control building for the Syncolift. The building has power, a telephone line and space is available to site the data logging and communications systems. The other sites visited had problems with locating the gauge or were deficient in terms of their degree of exposure or lack of facilities and local support, which made them less attractive as tide gauge sites. In addition Castletownbere is an important strategic location in terms of the fishing industry and a gauge here could also provide early warning of possible flood events along the south and east coasts. POL do not see its location behind Bere Island as being a problem given the openness and depth of the entrance channel and the absence of strong currents. In fact the site's closeness to the shelf edge is seen to be a particular advantage, which makes it (according to POL) much superior to existing GLOSS sites in Newlyn (UK) or Brest (France) in this regard.

It is suggested that a bubbler type gauge be a first choice for Castletownbere as this type is already being used in Malin Head. This could be either:

- Another OTT Nimbus
- A bubbler similar to those of the UK network. In this case, POL could provide such a system together with a mid-tide 'B gauge' datum control bubbler channel.

A GPS antenna could be installed on the roof of the control building and a number of benchmarks could be established at suitable locations on the jetty, island and mainland. There would also be staff of the Department of Communications, Marine & Natural Resources available to routinely check the system.

7 International Tide Gauge Networks

Before considering the concept of an Irish tide gauge network a brief review of a few international networks will be provided. Almost every developed maritime country worldwide has established national tide gauge networks so Ireland can benefit from this experience. In this section the UK, French and Spanish networks are described. Particular emphasis will be given to the UK network as POL (project partners) are directly involved in its upkeep.

7.1 UK 'A Class' Network

The UK National (or 'A Class') Network evolved out of an uncoordinated set of gauges operated by many different authorities for different purposes (Woodworth et al., 1999). Some of these purposes were scientific, such as the Ordnance Survey's installation of gauges at Newlyn and Dunbar. Practical purposes included the requirements of British Railways and the Royal Navy for data for port operations. The 1953 floods led to the recognition that a coherent monitoring system was required for flood defence, and technical developments, including the perceived superiority of bubblers over traditional float gauges, eventually resulted in the early 1980s in what is now called the National Network. This network is operated by POL with funding from the Department for the Environment, Food and Rural Affairs (DEFRA) which superseded the Ministry of Agriculture, Fisheries and Food (MAFF). It consists of 44 sea level stations, almost all of which are bubbler gauges, and of which 2 are in Northern Ireland (Figure 7.1). The nominated GCN stations are Lerwick, Stornoway and Newlyn, which are sites where (it is thought) sea level changes reflect open ocean variations.

It is probably true to say that MAFF did not, until perhaps 10 years ago, consider topics such as long term sea level change to be particularly important. Such studies require typically 1 cm accuracy (the 'GLOSS standard', see IOC, 2002), compared to the typically 5-10 cm accuracy needed for flood warning. Nevertheless, the A Class gauges were always maintained by POL at the cm accuracy level because of POL's scientific interests. This leads to an important point about 'multi-use', which is always stressed in GLOSS correspondence between IOC and Member States:

- That, when gauges are installed for practical purposes, there is relatively little (if any) extra cost if good quality equipment is installed and if gauges are maintained to scientific (GLOSS) standards.

That is why, throughout POL's management of the National Network, separation of the GLOSS and long-term sites into a 'super-set', with the remainder of the 44 relegated to a 'B Class' network operated to lower standards has always been resisted.

More recently, MAFF (and now DEFRA) have taken on board the need to monitor sea and land levels to accuracies needed to identify long term change, such as that identified by the Intergovernmental Panel on Climate Change (Church et al., 2001). This is reflected in support for UK GLOSS activities, dual redundancy instrumentation at GLOSS and other UK long record sites, and a programme of CGPS at a subset of 'A Class' gauge sites (Figure 7.2, Bingley et al., 2002; Teferle et al., 2002a, 2002b).

7.1.1 Data Management

The following is the data flow and quality control that takes place in the UK network. Most data from the 'A Class' network are made available to users through the National Tidal & Sea Level Facility (NTSLF) web site, which contains a catalogue of all data available. Data arrives at POL by means of downloads from gauges at roughly weekly intervals. A separate data stream for some gauges, over which the NTSLF has no control, goes to the Storm Tide Forecasting Service (STFS) at the Met Office.

Quality control is carried out in accordance with internationally agreed standards (e.g. GLOSS and ESEAS). The goal of the quality control is to detect and, if possible, correct errors, in order to maximize the data available. The basis of quality control of tide gauge data is the visual inspection of observed data and residuals (i.e. the difference between observations and predictions, calculated from a tidal analysis). This enables the detection of non-physical values, instrument faults and other problems including timing errors, datum shifts, spikes, gaps, etc. Suspect data is also checked against records of a nearby site, to detect if the suspect values are due to a tide gauge fault or to meteorological conditions. In case of a fault data may be corrected or interpolated, and flagged to indicate what action has been taken. Otherwise the data are kept as they are, and the event or unresolved problem documented. Quality control also extends to other factors. For example, the documentation of datum information (relationship of the recorded sea levels to the level of benchmarks on land) is essential. Diagrams, maps and other meta-data are also stored along side the observed data.

Whether data can be obtained from the NTSLF immediately or not depends primarily upon its age:

- Data at least 3 months old together with accompanying documentation, all of which will have been subjected to quality control to modern standards, are freely available via the NTSLF web site. The delay of 3 months allows full manual quality control by an experienced person to take place. At present, data back to 1990 are available in this way and more historical data will be added to the web as resources permit.
- Data older than 1990 have at present to be requested by email and will provided as soon as staff resources permit.
- Historical data from the 3 UK GLOSS sites back to the start of their records (i.e. pre-1990 data also) are available from the GLOSS Handbook web site. Recent data from the same 3 sites are available from the GLOSS Fast Centre at the University of Hawaii Sea Level Centre.
- Data newer than 3 months old, also have to be requested by email and will be provided with a short delay, quality-controlled or uncontrolled depending on whether staff resources have already been allocated to the task. Delivery of recent data to commercial users will incur a charge.
- Plots of sea levels from a small number of sites are available in real-time on the web without quality control. Modems have been purchased which will enable approximately 12 stations to be added to this set in the near future and which will provide a larger number of users with access to near-instantaneous UK sea level information. The corresponding data values are not made available in this way but can be obtained eventually via one of the above methods. (Another small set of real-time information is available from Dutch and Danish web sites, which receives its information indirectly via the STFS.)

It can be seen that the main gap in data flow is concerned with making recent data (newer than 3 months) available to users. POL's present philosophy, with which DEFRA is in full agreement, is to avoid as far possible providing data to users which contain errors. The vast majority of 'A Class' data are considered 'accurate' and are not deleted or modified in any way by subsequent quality control. Nevertheless, errors do occur, and the provision of uncontrolled data to possibly inexperienced and unknown users via the web is not considered acceptable. Delivery to users such as the STFS or oceanographers engaged in data assimilation exercises is clearly quite a different matter as they are experienced enough to spot occasional errors. Therefore, the 3-month gap between data acquisition and provision on the web was intended to allow full quality control to take place.

Although this caution is understandable, it means that some users with a *bona fide* interest in access to recent data will be inconvenienced to some extent (and, in the case of commercial users, they will be subject to a charge). Consequently, it is intended that future NTSLF development must work towards partial or full removal of the 3-month gap. This can be accommodated by either:

- Allocating more NTSLF staff resources so that the 3 month gap is reduced to perhaps 1-2 months. This is not considered to be acceptable as staff resources are limited and very few users would benefit from the modest reduction in the gap.

- Investigating the use of Real Time Quality Control (RTQC) which is used by tide gauge agencies in Spain and USA. Such software searches for spikes, timing errors and datum shifts etc. and flags suspect data. In some circumstances, it could be dangerous to use. For example, one could envisage a large, short-duration surge being flagged as suspect data. Therefore, RTQC cannot be regarded as a substitute for full manual quality control by an experienced person. Nevertheless, it could be used as an in-between product, which if suitably qualified, could be made available to users.

Figure 7.1 The UK National (or 'A Class') Network**.**

Figure 7.2 The UK CGPS network maintained by the University of Nottingham and POL

7.2 France RONIM Network

The RONIM (Réseau d'Observatoires du NIveau de la Mer) network contains about 20 stations and consists of mainly radar and acoustic instruments mainly deployed in traditional stilling wells. The RONIM network is managed by SHOM (Service Hydrographique et Océanographique de la Marine) the French hydrographic and oceanographic service. SHOM is in charge of tidal analysis and predictions, in particular for nautical chart datum definition and sounding reduction. To carry out its hydrographic and tidal activities it needs to operate a network of tide gauges. In addition SHOM operates a permanent GPS station at the historical sea level station of Brest. Brest and Marseille are among the longest tide gauge time series available in the world, beginning in 1807 and 1885 respectively. These stations are part of the GLOSS Core Network (GCN). Both SHOM and IGN (Institut Géographique National) aim to make French stations comply with the GLOSS quality station requirements, especially the geodetic monitoring of the tide gauge zero. Brest and Marseille have been equipped with continuous GPS receivers with measurements starting in July 1998 in Marseille and in November 1998 in Brest. These organisations are also working to upgrade the French tide gauge network. This includes (i) the modernization of the tide gauges themselves by replacing the old floating devices by radar gauges and (ii) the geodetic monitoring of the zero reference point of the tide gauge in the well defined and maintained ITRS global reference frame. A recent study comparing the performance of different gauge types have indicated large errors with acoustic gauges due to temperature gradients. It is now planned to phase out all acoustic gauges from the network. All RONIM sites are equipped to allow data transmission back to SHOM headquarters. Figure 7.3 shows both operational and proposed new sites.

7.2.1 Organisational aspects

At the moment SHOM manages the French network but it has been proposed that a more multi-disciplinary approach be taken. Bringing together a wider level of expertise would help ensure that the data requirements of all stakeholders will be met. This has lead to the SONEL (Système d'Observation du Niveau des Eaux Littorales) monitoring system and it will now be described as it could help form the framework for the Irish network organisation. SONEL aims are as follows,

(i) An integrated sea level monitoring system (different types of data, sources, time and space scales...)
(ii) A sea level information system handling the data measured by different observation networks
(iii) A national component of international sea level observing systems (GLOSS, ESEAS...)
(iv) A national interface to related projects and databases at European and Global scales (PSMSL, TIGA...)
(v) A service based on long term commitment as most sea level studies related to climate change require time series spanning over a long period of time.

The following are the participating organisations, SHOM, IGN, CLDG (Centre Littoral de Géophysique) and LEGOS (Laboratoire d'Etudes en Géophysique et Océanographie Spatiale).
These groups have expertise on various aspects of tide gauges, levelling and space geodesy and compose a favourable technical framework in which each organisation can make its specific contribution to establish and maintain fully integrated tide gauge - GPS stations. In particular the following is proposed:

- To install, operate and maintain the different observing devices,
- To guarantee high quality measurements according to the current international standards,
- To asses the accuracy of the data,
- To perform repeated local ties between GPS and tide gauge benchmarks on a routine basis, depending on the local topography and geology,
- To gather and make available the required data and metadata.

The main components of SONEL have been listed as:

- networks of permanent stations, either geodetic or sea-level oriented,
- a data gathering, archiving and distribution system,
- specific and partner operational data centres,
- specific and associate analysis centres for data quality control, reductions, comparisons and combinations,
- a steering committee that will include representatives willing to contribute to one of the components of SONEL : users, partners, policy makers.

The main tasks of SONEL are summarised in Figure 7.4.

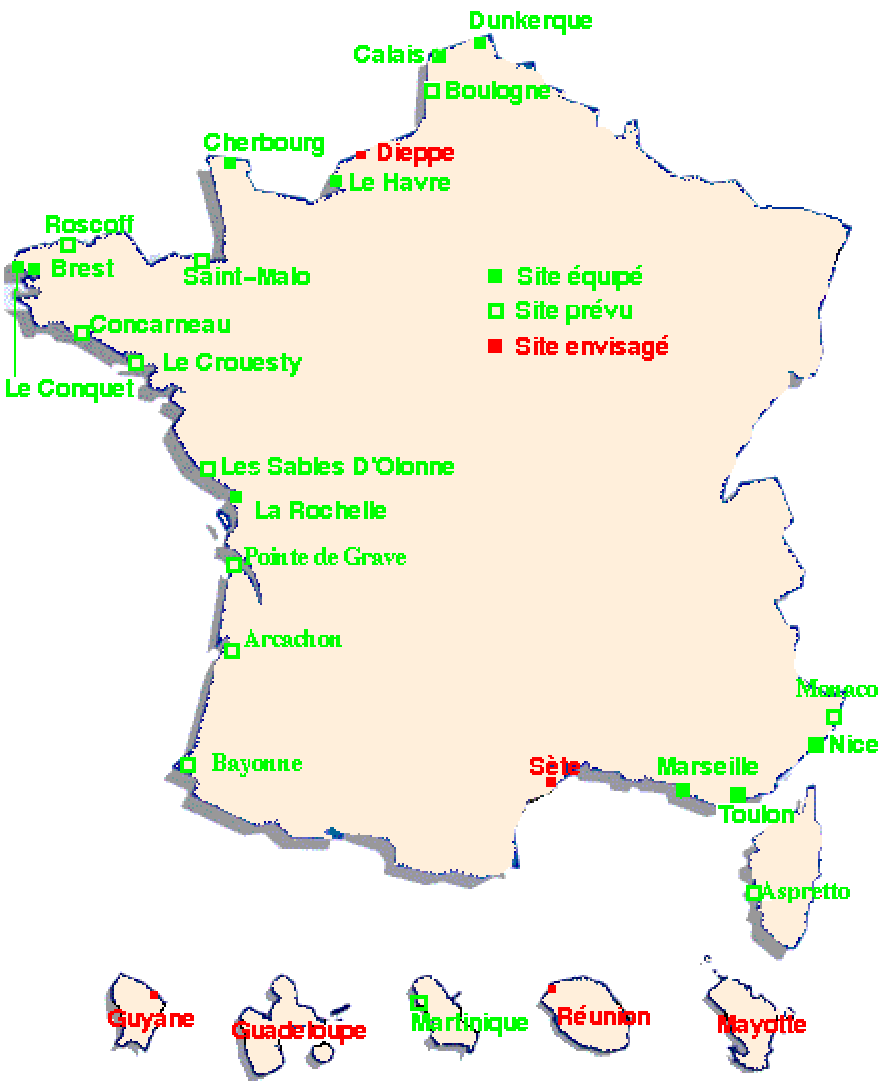

Figure 7.3 Operational and scheduled RONIM stations

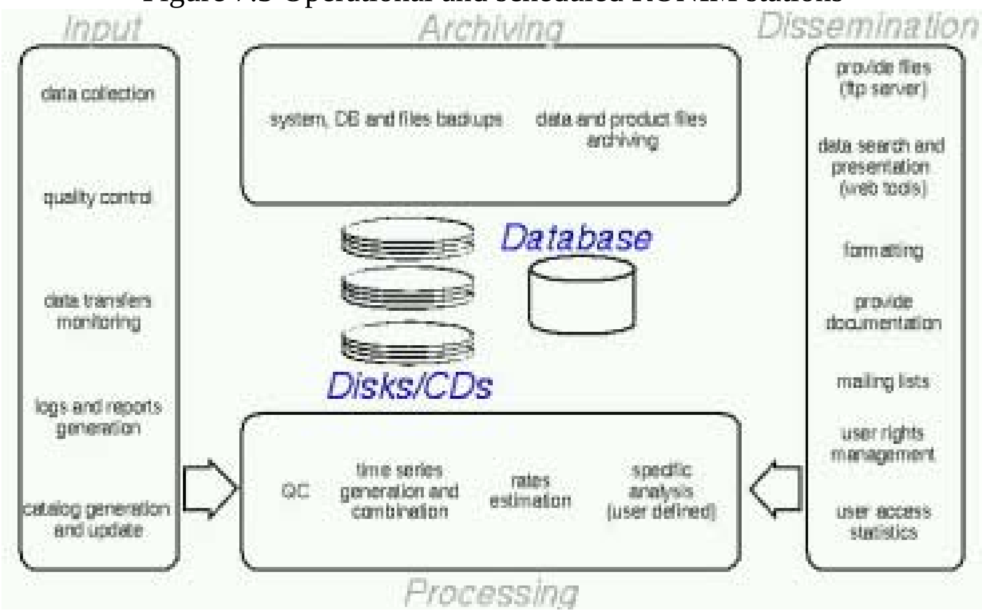

Figure 7.4 SONEL Main Tasks

7.3 Spain REDMAR Network

The REDMAR tide gauge network is in operation since 1992 and currently comprises of 15 SONAR acoustic sensors and 4 Aanderaa pressure sensors (see Figure 7.5). Its goal is the real time monitoring of sea level and the generation of historical series for their further study. There is near real time data transmission and the data is subject to an automatic quality control before being made available to users (still in near real time). On a quarterly basis all stations have their TGBM calibrated to the gauge contact point and annually the TGBM is checked by GPS levelling. In addition meteorological data is collected from nearby weather stations. All tide data is assimilated into the Nivmar system of sea level forecast. The general scheme of data flow and treatment for the REDMAR network is shown in Figure 7.6.

The network is operated by the Puertos del Estado [State Ports Authority]. This is a state body that is part of the Spanish Ministry of Public Works. The Puertos del Estado is charged with implementing the governments ports policy, efficiently co-ordinating and controlling the Spanish port system, which comprises the 27 port authorities and catering for the existing 53 ports of general interest.

The accuracy of the acoustic gauges is currently being assessed through a comparison study with other instrument types. Also it is planned to install a GPS at the Ibiza site.

Also it should be noted that as well as REDMAR there is a Spanish network operated by the Instituto Espanol de Oceanografia (IEO) which consists mostly of older float gauges.

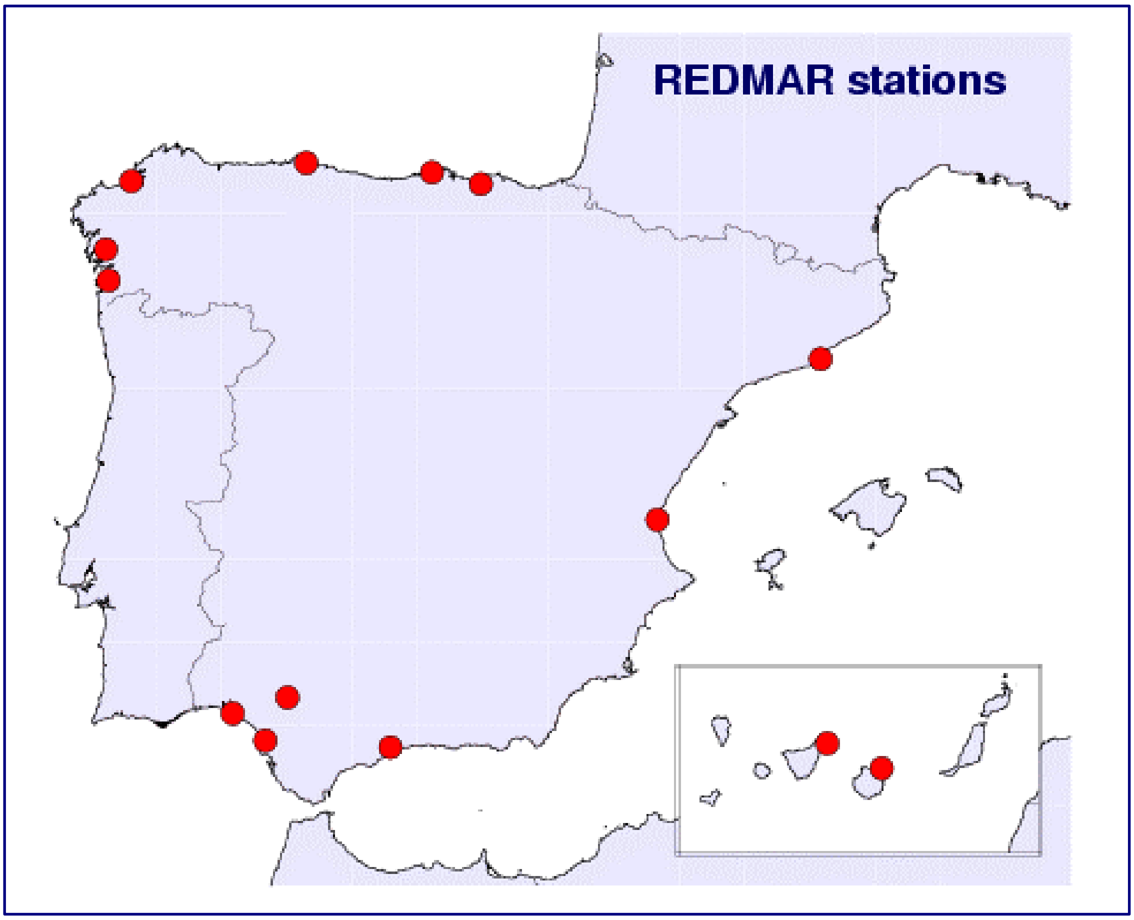

Figure 7.5 REDMAR Stations

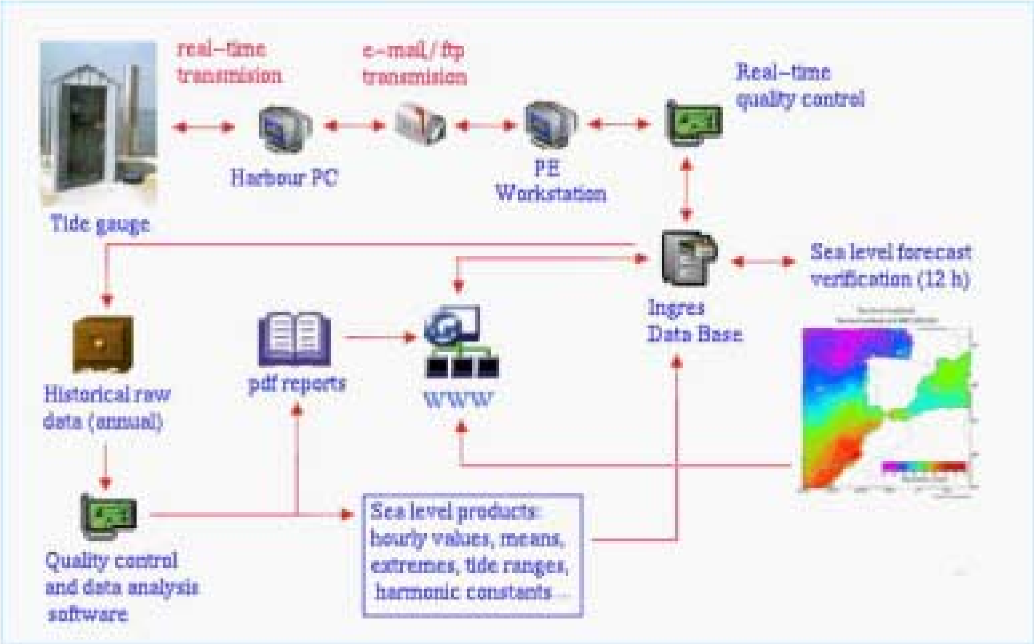

Figure 7.6 Data Flow and Treatment

8 Proposed New Tide Gauge Stations In Ireland

The Irish tide gauge history has some similarity with that of the UK. In both countries the Ordnance Surveys took the main lead in the 20th century from the perspective of national datums. Elsewhere, harbour authorities provided data as by-products of port operations. In addition many poor-quality gauges are operated by power stations, river agencies etc. which provide sea level data of relatively little long term value. Therefore, it is to be hoped that some of the UK 'A Class' history has a parallel in Ireland in leading to a national network. Discussion of the two networks together is also highly relevant as the possibilities of data sharing with regard to topics such as flood forecasting (Flather, 2000) and Irish Sea Observatory studies (Proctor and Howarth, 2003) are very attractive. It is envisaged that an Irish tide gauge network will begin with upgrading communications and data transmission at existing sites whereby near real time data will be made available to users and progress to the establishment of new stations as resources become available. This section considers issues related to installing tide gauges as well as sites that should form part of the network.

8.1 Gauges For Storm Surge Monitoring And Prediction In The Irish Sea

The main discussion up to now has been on the gauge for the second GLOSS site on the southwest coast. The need for gauges, which could aid the monitoring and prediction of storm surges in the Irish Sea are now considered.

The Irish Sea has historically had less of an association with flooding by storm surges than the North Sea. Nevertheless, they can be significant, as demonstrated recently (Flather, 2002). A Dublin Bay forecast scheme is under development using a UK Met Office (in effect POL) model for the Irish Sea together with a local nested model for Dublin Bay itself, and one might expect such schemes to be developed further in future.

From the perspective of modelling and forecasting storm surges, tide gauges are needed for the following reasons:

- To help understand the generation and propagation of surges
- To monitor the accuracy of model surge forecasts in areas prone to flooding
- To provide data for assimilation into models, by correcting initial forecast data and so improving forecast accuracy.

Data requirements are for information in both real-time (e.g. for monitoring surge development in the flood warning system, and for assimilation) and delayed-mode (e.g. for validation, and for research). Gauges should be sited to be representative of the regional surge, and even, for some cases, of the local surge where there is a local flood risk.

Long records providing good tidal analyses are required to enable accurate tide predictions and hence accurate estimation of actual surge from the measured data. Therefore, gauges should not be sited where analysis problems are likely to occur. Such locations include extensive shallow areas, where too much tide-surge interaction may render surge data unreliable; and in estuaries, where the measurement of the whole tidal range is not made, and maybe recording the river level for a period near low water.

Details of existing gauges in Ireland were provided in Section 2 and in general they are distributed quite well. However, there are gaps, such as on the east coast and gauges on the south coast are in bays (e.g. Bantry) or estuaries (e.g. Shannon, Cork and Waterford Harbours) which are not ideal for open-sea monitoring. The only true open-sea gauge is that at the Marathon Oil Platform and it already provides data on tides, waves and weather. The company has stated that the platform is likely to be operational for another 20 years.

From the modelling perspective, additional gauges could usefully be deployed in the Irish Sea area:

<u>(i) Near regional model open boundaries.</u>

As part of the proposal to develop a surge forecast scheme for the Irish Sea, which would employ forecast data from UK shelf scale model together with local modelling (cf. Flather, 2002 Dublin Bay study), local gauges to Dublin at Dun Laoighaire and Howth would be established. Nearly all the other main population centres along the coast (Waterford, Cork and Limerick) have already got operational gauges of sorts of their own.

However, in addition to very local information, there is a need to constrain the open boundary inputs to such a model, which would cover the entire Irish Sea with boundaries at ~8°W, ~51°N, and ~56°N. Suitable tide gauges could include:

<u>North:</u> Malin Head with UK gauges at Portrush, Port Ellen and perhaps Tobermory.

<u>South:</u> Marathon Oil Platform, Cork or a new gauge near to Ballycotton, with UK gauges at Newlyn, St Mary’s and possibly Ilfracombe.

<u>(ii) To provide data for assimilation inside an Irish Sea model.</u>

Given that existing harbour gauges near Cork and Waterford may not be very useful, then Rosslare, Dublin and new gauges at Dunmore East, Kilmore Quay, Arklow and Clogherhead could be suggested, together with selected UK gauges. Pairs of gauges (e.g. Rosslare – Fishguard; Dublin – Holyhead; Clogherhead – Port Erin; Bangor – Portpatrick) should help constrain transports in the model.

8.2 Network Station Locations

The gauge sites are divided into three groupings, which reflects different usages and perhaps is also a prioritisation on the order in which they should be upgraded or established. If the recommendations of this study are fully implemented then the whole network will consist of 27 stations. It should be noted that, similar to the UK network it should be the objective that all sites operate to the 1cm accuracy requirement regardless of how they are grouped. This will increase the value of the data in terms of scientific studies, navigation and flood prediction and analysis. The three groupings are described as follows,

Group 1 GLOSS Stations

The north (Malin Head) and south (Castletownbere) primary Irish Sea level stations that will comprise the main Irish contributions to GLOSS and ESEAS. These two sites should be equipped with high quality tide gauges and meteorological packages and CGPS and would provide data of ‘climate change’ quality.

Figure 8.1 Group 1: GLOSS Sites

Group 2 Nationally Important Stations

Gauges in this grouping are considered to be of significant strategic importance in terms of oceanographic studies and modelling, offshore surveying, engineering work and flood warning. The chosen sites are (or will be) located close to the open ocean and so are not appreciably affected by shallow water effects. The following existing gauges are included in this subset (see Figure 8.2), Killybegs, Carrigaholt, Dingle, Marathon Platform, Dunmore East, Rosslare, Arklow and Dun Laoighaire. New sites in this grouping should include,

- Two high quality gauges along the west Connaght coastline to fill gaps between existing gauges and also to aid open-ocean studies. The proposed sites would be,
    1. Rossaveal, as it is an important location in terms of the fishing industry and Island transport
    2. Blacksod Pier or Ballyglass Pier, again for strategic reasons but also due to the existence of a long standing weather station.
- Ballycotton (depending on the long term availability of data from the Marathon Oil Platform)
- Kilmore Quay/Helvick as an intermediate node of strategic relevance in the context of the very steep time and amplitude gradients on the south coast (see Figure 8.3) and also its proximity to the Irish Sea outer boundary
- Clogherhead for flood monitoring purposes and model calibration

POL have suggested that in the future other sites along the east coast be considered primarily due to the unusual nature of the tides in the south Irish Sea (see Figure 8.3). Suggested sites would be Courtown or Wicklow as measurements have previously been conducted (by POL) at each of these sites in the 1970s, see Pugh, (1981).

Figure 8.2 Group 2: Nationally Important Sites

Figure 8.3 Co-tidal and Tidal Range Lines

Group 3 Locally Important Stations

These are stations where gauges already exist and are considered important for navigation purposes and other harbour operations e.g. dredging. The chosen sites are located either in estuaries, inlets, harbours or bays and so water levels may not be representative of open ocean conditions. Many of the gauges are sited near large population centres and so are necessary for monitoring water levels particularly during flood events. This allows for better predictions of flood return periods and levels. The following gauges are included in this grouping, Galway, Foynes, Limerick, Bantry, Ringaskiddy, Cobh, Tivoli, Waterford, Dublin Port and Drogheda (See Figure 8.4). There is only a requirement for two new gauge sites of this type,

a. On the north side of Dublin Bay to aid and improve the flood models. A suggested location for this is Howth (after consultation with Dublin City Council).
b. Galway for navigation and flood monitoring purposes. A radar gauge located by the Harbour Offices would be a suitable option

Figure 8.4 Group 3: Locally Important Sites

8.3 Network Requirements

The current instrumentation requirements for each of the three groupings will now be discussed.

8.3.1 Group 1: GLOSS Sites

The Malin Head site is already well established so only issues related to data transmission need to be addressed. At Castletownbere an entirely new station needs to be installed. As already discussed a bubbler system appears to be most suitable, while a radar or acoustic system would require more installation planning so as to fit into a busy area. Given that the other GLOSS station already contains a bubbler system it is suggested that a bubbler be also a first choice for Castletownbere.

It is suggested that the bubbler integrates sea level over either 15 minutes (as for most UK sites) or 6 minutes (as for US sites). Fifteen minutes should be adequate for most tide, surge and mean sea level studies.

As a duplicate, redundant backup to the bubbler, and as a potential source of information on wave conditions, it is suggested that a relatively cheap pressure transducer be deployed in the sea alongside the pier, if the local sedimentation rate is not too great, so as to provide a second source of sea level information and data on wave conditions if made to sample at 1 Hz. The simple transducer would need to be levelled using a tide pole, which should be provided for general use anyway. The gauges should be connected to a data centre preferably by telephone landline or mobile phone if necessary.

GLOSS standards require that sea level data are accompanied by air pressure, sea and air temperature data and, if possible, winds although they are often difficult to measure in a crowded port. However, this does not apply if there is a nearby meteorological station (e.g. Valentia).

8.3.1.1 CGPS at GLOSS Sites

It is suggested that CGPS should be installed at the GLOSS tide gauges at Malin Head, Castletownbere and possibly also at the long record site at Dublin. These will be important for the separation of vertical land movements from the climate related changes in mean sea levels. The CGPS measurements can also be used for testing geophysical models of vertical land movements due to post-glacial rebound and subsidence. At the moment these models suggest that in the north of Ireland the land is uplifting by the order of 0.5mm/year and in the south of Ireland the land is subsiding by about 1mm/year. Such trends need to be properly validated based on accurate measurement of both water levels and land movements. The GPS measurements would also help to show whether there are any local movements near the tide gauges, in addition to the larger scale post-glacial movements. Absolute gravity measurements would also provide valuable data on vertical land movements.

The details of the methods of installation of CGPS at tide gauges are described in http://imina.soest.hawaii.edu/cgps_tg. This web page also gives case studies of the installation of CGPS at the UK tide gauges at Newlyn and Sheerness and the French tide gauge at Marseille. Most of the CGPS stations at UK tide gauges use Ashtech MicoZ Continuous Geodetic Reference Systems (www.thalesnavigation.com). Recent analyses of the time series from the UK CGPS stations show that the vertical rates can be determined to a precision of +/- 1mm/year from 6 years of continuous GPS data from a high quality station. The absolute accuracy of the vertical rates depends upon the stability of the global geodetic reference frame, which is currently being investigated in the International GPS Service (IGS) Pilot Project called TIGA (Tide Gauge).

8.3.1.2 Ancillary Met Data

As regards meteorological data, there is a GLOSS requirement for air pressure, air and sea temperatures to be measured normally alongside sea levels. However, meteorological measurements may not be necessary if there is a nearby weather station, and winds are one parameter, which are often measured poorly in a port environment. The data loggers of tide gauges have been proposed as 'coastal data platforms' for the collection of a wide range of additional ocean parameters (oxygen etc.) by the Global Ocean Observing System Coastal Module (IOC, 2003b). However, the latter does not comprise a normal GLOSS requirement.

8.3.2 Group 2: Nationally Important Sites

The following are the instrumentation requirements for this grouping of gauges,

- Up to four new stations to be established at Blacksod/Ballyglass, Rossaveal, Kilmore Quay/Helvick and Clogherhead. These sites have not been properly scoped but it would be expected that the discussion in Section 2.4 would be relevant to any choices made.

- New gauges are required at Dunmore East and at Arklow. The gauge in Arklow should be sited on either the north or south pier depending on which provides a better site. In Dunmore East the stilling well should be abandoned for all but providing a conduit for cables or tubes from either a pressure or bubbler system.

- Although not an immediate priority the Rosslare pressure gauge should be replaced with a radar type instrument to help alleviate problems with reliability and siltation. The site is perfectly suited to a radar gauge.

8.3.3 Group 3: Locally Important Sites

Generally at these sites existing gauges should continue to be used and there would not be any immediate requirement to upgrade the present technology. At the Galway and Howth sites local Agencies (City Councils, Harbour Authorities etc.) should work to establish new gauges.

8.3.4 Ancillary Equipment

A number of sites regardless of grouping will require the following,

- Installation of communication links and data loggers telephone lines or GSM connections modems and where required for currently operational gauges
- Real-time and delayed-mode data exchange between gauges in the Republic, Northern Ireland and the west coast of Great Britain.

8.4 Data Centre Requirements

Although the network will be relatively small, it will need a data centre to process information received from the gauges and make them available to users. It is recommended that the centre be located at the same place as the people responsible for gauge maintenance, so that proper information flow takes place.

The centre should not only be responsible for data flow from the GLOSS and other high quality sites, but also from all Irish sites and possibly, including data from Northern Ireland gauges. In addition, it would be responsible for all necessary metadata (data analysis reports, maps, levelling information, documentation, products etc.). GPS data is rather a separate issue and could best be coordinated by Ordnance Survey Ireland.

If the UK experience is adapted to the Irish network, then it is clear that the data centre has to equip itself with computer and telecommunication resources to enable:

- Data to be received from all gauges in near real-time.
- RTQC (Real Time Quality Control) and delayed mode software to quality control data.
- Data base management resources.
- Web management resources including a facility for keeping track of which users access which data.

From the stakeholder questionnaire analysis it was seen that a large proportion currently require real time data and it is likely that in the future that this demand will increase further. Therefore, the data transmission, RTQC and web aspects will need development to a level of sophistication that the NTSLF is itself just dealing with. However, consultation with the Spanish network operators may be useful in this respect.

Some hardware and software at the NTSLF could be replicated in the Irish data centre (e.g. data base and web management). However, British Oceanographic Data Centre (BODC) hardware is at present Silicon Graphics (Unix) based with in-house SG-dependent software, which would not be easily transportable. A development programme is in place to convert most functions to run under Linux. It is likely that the whole Irish network could be controlled, quality controlled and web-managed with a small network of such machines.

Once data is in the data centre, then there will be a need for dissemination both nationally and internationally (ESEAS and GLOSS). In addition special arrangements should be made between the data centre and NTSLF for exchange of data around the Irish Sea.

In the UK, the separate real-time data stream to the STFS (Storm Tide Forecasting Service) is merged with information from storm surge forecast models in order to generate flood warnings to operational agencies (e.g. closure of the Thames Barrier). Given that there are developments to construct surge models for the Irish coast, an important user of the real-time data into the centre would be a STFS in Ireland, which would itself be most logically located at the data centre.

9 Organisational Aspects

The organisation and funding of a tide gauge network needs careful consideration and ultimately will require collaboration between a number of statutory bodies and possibly private organisations. The public private partnership between the Marine Institute and Marine Informatics has started the process of establishing a framework for the proper management of the tide gauges and the data produced. However, it may ultimately fail if the relevant responsible agencies do not provide the necessary support for the long term.

This section first considers organisational aspects in relation to the UK network and then proposes a way forward for Ireland.

9.1 UK Network

If the UK network is considered as an example the following points provide a brief overview of UK organisational aspects.

- The physical tide gauge network, which is the responsibility of the Tide Gauge Inspectorate (TGI) at POL (contact person David Smith), together with the management of its data by BODC (contact person Lesley Rickards), together comprise a large part of what is now called the UK National Tidal & Sea Level Facility (http://www.pol.ac.uk/ntslf/).
- The costs of the NTSLF (tide gauges, data management, and to some extent GPS and Absolute Gravity data gathering) are provided to a large extent by DEFRA via an annual contract, with some costs provided from the Natural Environment Research Council (NERC) science budget. (DEFRA is technically responsible for England and Wales only; details concerning the Scottish and North Ireland Executives are not included here.)
- DEFRA approves major expenditure for new gauge installation or refurbishment, negotiates a ‘service level agreement’ for minimum acceptable delay for the TGI to remedy faults etc., and receives regular (quarterly) reports on financial expenditure, network performance and data delivery.
- The NTSLF is managed within POL/BODC by means of committee composed of the main people involved in the network and chaired by Philip Woodworth. (The committee also concerns itself with aspects of sea level recording by POL gauges at Gibraltar and in the South Atlantic.)
- DEFRA’s direct involvement in such management is low. POL have tried to initiate a broader NTSLF Advisory Committee composed of DEFRA, Environment Agency, Hydrographic Department and other interested bodies. However, the suggestion has not been taken up so far. (The STFS at the Met Office, which is primarily concerned with flooding issues, holds annual meetings, which provide partial oversight of network performance). Nevertheless, POL continue to believe that such an Advisory Committee would be useful for the UK and suggest that a similar committee would also be useful in Ireland.
- The NTSLF maintains a web page, which gives users such as the Environment Agency information on which gauges are operating or have problems.
- The NTSLF has little administrative overhead. As explained above, they endeavour to make as much data as possible available via the web. To be consistent with European legislation, all such data are free of charge to users.

As for resources that POL/BODC devote to the network, it has first to be recognised that POL has a long history and continued interest in tidal science and technology and hosts BODC with its extensive expertise in data management. Consequently, the operation of the National Network at POL fits easily into the wider laboratory activities, and POL remains the 'natural' home for the NTSLF. Nevertheless, the POL and BODC Directors are keen to see that costs for the NTSLF are transparent so that DEFRA-related activities (which are subject to full economic costing including agreed overheads) are not seen to be subsidised by science (or vice versa). Such a principle would be necessary for whichever organisation is chosen to manage the Irish network.

Staff associated with the routine operation of the network include:

- 2 people in the TGI who maintain the 44 tide gauges and perform ancillary measurements (e.g. annual levellings). One member of staff is always on call.
- 1 person-equivalent who is responsible for down-loading data from gauge data loggers to BODC and for subsequent QC.
- Fractions of several people who are responsible for data base activities and web management, and for workshop and electronics support.

Staff associated with scientific aspects of the network include:

- Approximately 1 person-equivalent who monitors the performance of the operational surge models at the Met Office by comparison to tide gauge data.
- Fractions of several people responsible for product generation (tidal constants, extreme levels etc.) from resulting data sets.
- POL senior scientists who provide a high level form of quality control by using network data within their own research. This aspect is clearly where DEFRA and NERC interests most obviously complement each other.

9.2 Possible Irish Network Organisation Framework

It is not easy to determine how well the above UK organisation model can be adapted to the Irish situation. It is definitely recommended that one home be found for both tide gauge maintenance and data management so that the fullest interaction can take place. It is believed that whilst Marine Informatics is in the process of setting up a network (see www.irishtides.com) more discussion is required between the main stakeholders and responsible agencies to establish operational procedures that are acceptable to all. In addition it is recommended that an Advisory Committee be established with representatives of the main user agencies. Among the organisations that should be included are,

- Department of Communications, Marine and Natural Resources
- Marine Institute
- Met Eireann
- Ordnance Survey Ireland
- Office of Public Works
- Environmental Protection Agency
- Certain County and City Councils
- Geological Survey of Ireland
- Association of Harbour Masters
- Academic sea level experts.

In devising the optimum approach to further initiatives towards an Irish tide gauge network it would be useful to further develop a number of international collaborative links. It is apparent from the current study that each country has arrived at different arrangements based on individual national structures, agency responsibilities and the configuration of relationships between stakeholder organisations. Direct liaison should be established with personnel holding senior operational roles in French (SONEL), Spanish (REDMAR), and UK networks in order to benefit directly from their individual and collective experiences.

It is recommended that the current arrangement of more or less *ad hoc* initiatives would become fully integrated and organized within a formally managed “project” environment. Such a project should include a clear overall mission statement (based largely on scoping initiatives established herein), a definite time frame, and clearly identified goals with established roles, responsibilities and quality standards. Furthermore an official sponsor or sponsors will have to be clearly identified together with funding sources for capital and operational budgets.

9.3 Implementation and Timescale

It is recognised that with a large number of agencies involved, reaching an agreement and moving toward full implementation of the tide gauge network with data handling centre may take some time. Given the importance of basic data acquisition particularly in relation to the clear network gaps in both GLOSS and Nationally Important sites, it is recommended that the Department of Communications, Marine and Natural Resources undertake the following in 2004,

- Establish a new GLOSS site in Castletownbere
- Upgrading as required of the GLOSS site at Malin Head
- At both these sites install CGPS
- Install a new gauge at Dunmore East
- Establish a new gauge site at Rossaveal

The Department of Communications, Marine and Natural Resources operates Castletownbere, Rossaveal and Dunmore East Harbours so gauges can be readily established at these locations. At Malin Head consultation will be required with Ordnance Survey Ireland.

It is also recommended that the process of standardising technologies should commence with the installation of these new gauges.

In parallel to this work discussions should commence between the organisations as set out in Section 9.2, with the view to securing agreement on the long term management of both the gauges and the data.

10 Indicative Costs

A preliminary set of estimates is provided as a provisional guide to the level of costs associated with implementing various elements in the proposed tide-gauge network and archiving system for Ireland. It is clear that the parallel PPP initiative that has been put in place between the MI and Marine Informatics will have a considerable impact on the future direction and therefore cost structure of any subsequent plans. In order to provide precise costings, for each individual gauge, it will be necessary to formalise agreements with existing operators regarding the balance of funding required to bring their instruments up to a common standard within the network.

10.1 Capital Costs:

This section will only consider the capital costs in relation to the requirement for new gauges. It is assumed that costs in relation to data logging, telemetry and data centre requirements are taken care of as part of the MI initiative.

Gloss Sites

The following are estimated to be the capital costs of establishing a new site in Castletownbere and upgrade the Malin Head station. A weather station would also need to be set up at Castletownbere but a cost for this has not been included.

Castletownbere Instrument Purchase and Installation	€15,000
Second sensor at Malin Head	€5,000
CGPS receiver (2 @€15,000 each)	€30,000
Monumentation and data links for GPS (2 @€10,000 each)	€20,000
Total Cost	€70,000

Nationally Important Sites

Seven new gauges will be required if the Dunmore East, Rosslare and Arklow sites are included. It may be that significant cost savings would be achieved by using the same manufacturer for all gauges. One particular manufacturer (OTT) have indicated that this would be the case and a service agreement could also be arranged.

Seven Gauges purchase and installation (approx €12,000 each)	€84,000

Locally Important Sites

Two new gauges at Howth and Galway (approx. €12,000 each)	€24,000
Total	€178,000

10.2 Annual Running Costs:

If the UK model is scaled down slightly then it is estimated that in order to manage and maintain an Irish National Tide Gauge Network one full time and one part time staff are required. In addition there would be maintenance, administration and other running costs. These are difficult to estimate but the following indicative figures are provided,

Staff Costs	€75,000
Maintenance and administration costs	€25,000
Other Running Costs	€10,000
Total Annual Cost	**€110,000**

11 Complementary Activities

In addition to the installation of a new network, it is recommended that a major programme of data archaeology and maintenance of historic benchmarks be initiated.

Queen's University Belfast, UCC and other groups have recently begun the conversion from paper-based to computer-compatible form of historical data from Malin Head etc., which will provide valuable data sets. POL has recently discovered in its basement the original Belfast paper charts from the late 19th century onwards which have received recent chemical treatment, and which will eventually be digitised thereby providing one of the longest sea level records in the UK. It is suggested that someone take responsibility to compile a catalogue of all Irish paper-based sea level information (charts, tabulations etc.), which could be potentially converted to computer form.

Ireland's different history of industrialisation to the UK has meant that many original benchmarks associated with historical tide gauge measurements still survive, even if the gauges were removed long ago. The most famous of these is the set of marks installed at over a dozen sites as part of Airy's tidal measurements in Ireland (e.g. Pugh, 1982). Some years ago, Philip Woodworth established through colleagues at the Irish Ordnance Survey that almost all of these marks still exist and are clearly marked on modern maps. A similar inventory of such marks associated with historical tidal measurements should also be constructed. That would allow the possibility to install temporary gauges near to the original sites to establish how sea level has changed over a century or more. That would provide interesting information on long term sea level change in Ireland, in the absence of continuous tide gauge records from most parts of the island.

In addition standardisation of methodologies for temporary tide gauge installations should be initiated. Each year many short term data sets are acquired as part of coastal development work but very often the data is not suitable for providing 'secondary port' predictions. It is recommended that the contracting authorities would issue standardised instructions for the undertaking of tidal measurements (gauge location, duration of deployment, datum control etc.) such that over time a comprehensive inventory of sites for which tidal constituents are available can be developed. In addition 'temporary gauges' should be deployed at existing secondary ports to check constituents.

12 Concluding Remarks

The main driver for a sea level monitoring network is the existence of user communities, which recognise the need for the network, and can lobby Government to pay for it. The main user communities, which need to be assembled to make use of the sea level data include:

- Climate change and oceanographic scientists.
- Operational oceanographers who can employ data together with numerical models: most obviously tide-surge models for flood forecasts.
- Coastal consulting engineers and local authority engineers.
- Mapping (Ordnance Survey) and charting (Hydrographic Office) specialists and port operators.

POL's experience is that such communities will benefit from data to the maximum extent if the data are available freely on the web without restriction. By this means, other communities (e.g.

school or university students) may also begin to make use of it in different ways. Then, with the widest use of data, the case for maintaining and strengthening of network becomes self-perpetuating. That means that the operators of the new network have to work hard to ensure the recognition of its importance as widely as possible. POL (and other groups associated with GLOSS and ESEAS) would be very willing to work with the owners to ensure that the new network is highly successful.

13 Acknowledgements

The project partners would like to express their gratitude to all individuals and organisations that contributed to this project.

The aerial photographs used in this report were supplied by the Marine Institute and were taken as part of the National Coastline Survey.

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Appendix 1: Tide Gauge Operator and Stakeholder Questionnaire

Part 1 Tide Gauge Details
(Note: Please copy questionnaire if required to include information on more gauges)

Gauge Location Details

Location Name:
Co-ordinates:
Location Description: (i.e. position within harbour, type of structure on which gauge is mounted)
Specific Problems with location (if any)
Min water depth at gauge location

Housing Details

Description of tide gauge hut (i.e. type of structure, approx. dimensions etc)
Condition of hut:
Shelter (from wind and waves)
Accessibility (vehicular etc.)
Telephone Line available at gauge (yes/no) **If no how far to nearest line**
Power available in hut (yes/no) **If no, how far to nearest power source**
Comments

Gauge Details

Current Gauge

Installation Date:
Type (Float, pressure, bubbler, acoustic, radar etc.):
Make:
Model:
Details of Gauge maintenance/calibration **How often:** **Organisation Responsible:** **How often is gauge reset:**
Instrument Performance (Accuracy, reliability, percentage of time operational etc.):
Data Output Format (digital/paper):
Data Sampling Details (recording interval time-step, vertical resolution in cms):
Data Transmission: (none, telephone, GSM, satellite, radio)
Data Analysis/Quality Control: **How often:** **Organisation Responsible:**
Data Storage/Archiving Details:
Data Availability:

Previous Gauges (if applicable)

Installation Date:
Duration of Record
Type:
Make:
Model:
Details of Gauge maintenance/calibration:
Instrument Performance (Accuracy, reliability etc.)
Data Output Format:
Data Sampling Details:
Data Analysis/Quality Control
Data Storage/Archiving Details
Data Availability

Levelling and Datums

What is location and exact value of gauge reference datum or control point (please state Chart Datum, OD Poolbeg, OD Malin, WGS84 values if available)?
Distance to and value of nearest Ordnance Survey benchmark (please indicate order/type of bench mark where known)?
Is gauge CP checked against local benchmarks? **If Yes** **How often** **How many benchmarks**

General

Does gauge agree with predicted water levels?
Is there a weather station near tide gauge?
What would you regard as the shortcomings of current system?
What upgrading would you recommend?
Would you be in favour of the gauge becoming part of a national tide gauge network?

Part 2 Information on Existing Data Usage

1. Of the following which best describes your usage of tidal data?

☐ Engineering Design and Construction
☐ Scientific analysis
☐ Numerical Modelling
☐ Flood Warning
☐ Navigation
☐ Dredging Activities
☐ Other (please **specify**____**)**

2. How frequently do you use the following forms of tidal data?

	Never	Occasionally	Frequently	Very Frequently
Standard Water Levels (HAT, MHWS etc.)	☐	☐	☐	☐
Tidal Constituents	☐	☐	☐	☐
High and Low Water Times	☐	☐	☐	☐
Real time water level data	☐	☐	☐	☐
Measured time series data	☐	☐	☐	☐
Other (please specify)__________________	☐	☐	☐	☐

3. Where do you currently source tidal data (please tick relevant options)

Admiralty Tide Tables	☐
Permanent tide gauges	☐
Temporary tide gauge installations	☐
Local annual tide level publications	☐
Specialised software packages	☐
Newspapers	☐
Internet (e.g. UKHO website)	☐
Word of Mouth	☐
Other (please specify)	☐

4. In the context of your current use of tidal data, please indicate the degree to which you agree with the following:

	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
Ireland has a sufficient number of permanent operational tide gauges	☐	☐	☐	☐	☐
Current data is of sufficient quality to satisfy all my requirements	☐	☐	☐	☐	☐
Current data is readily available and accessible in required formats	☐	☐	☐	☐	☐
Irelands primary and secondary tidal points have satisfactory spatial distribution	☐	☐	☐	☐	☐
In my experience tidal predictions accurately reflect the actual tide	☐	☐	☐	☐	☐
I am satisfied with the accuracy of tidal datums	☐	☐	☐	☐	☐

5. Please indicate what you think are the deficiencies of current water level data

☐ Insufficient time span (temporal coverage)
☐ Incorrect format (paper rather than digital)
☐ Unreliable
☐ Measurements or predictions unavailable at desired locations
☐ Data not to required accuracy or resolution (temporal or physical)
☐ Difficulty in relating back to fixed datum (Ordnance or Chart)
☐ Other (please specify____)

6. If you currently collect or hold tidal data would you be willing to allow access this data as part of the development of a national tide gauge network?

____

Part 3 Views on a national tide gauge network

Proposal is to set up a framework whereby a network of tide gauges would be established at strategic locations over time. This will necessitate the upgrading of the gauges of most existing sites and possibly the establishment of a number of new sites. It is likely that a number of gauges in the network would be of such a standard that trends in mean sea level change could be determined. All collected data would be transmitted to a central location where it would be subject to quality control before being made available to stakeholders.

7. In relation to the establishment of a tide gauge network, please indicate the degree to which you agree with the following:

	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
I would support the establishment of a tide gauge network	☐	☐	☐	☐	☐
It would be an important national resource	☐	☐	☐	☐	☐
It would have a significant impact on my activities	☐	☐	☐	☐	☐
It would bring commercial benefit?	☐	☐	☐	☐	☐

8. In the context of the proposed benefits of a tide gauge network, please indicate the degree to which you agree with the following:

	Strongly Agree	Agree	Indifferent	Disagree	Strongly Disagree
It would allow for safer operations for mariners	☐	☐	☐	☐	☐
It would allow trends in sea level change to be investigated	☐	☐	☐	☐	☐
It would allow for easier access to tide data	☐	☐	☐	☐	☐
It would aid and improve engineering design and construction	☐	☐	☐	☐	☐
It would allow participation in global measurement programmes	☐	☐	☐	☐	☐

9. Which of the following tidal data products would you use if they were available (please state preferred temporal resolution and accuracy required)

☐ Real time ____________________

☐ Archived ____________________

☐ Predictions ____________________

☐ Other (please specify____________________)

10. In your opinion where should Irelands primary tide gauges be located?

____

____

____

11. Please feel free to make any comments on either tide data, tide measurement or the proposed tide gauge network and archiving facilities, in the space provided below.

____

Thank you for your co-operation

Appendix 2: List of Tide Gauge Operators

Station	Operator/Owner	Email	Tel
Malin Head	Ordnance Survey Ireland Mr. Colin Bray	cbray@osi.ie	01 8025308
Killybegs	Dep. Of Communications, Marine and Natural Resources Mr. John Campbell	john.campbell@dcmnr.gov.ie	071 9852561
Sligo	Sligo Harbour Capt. Bob Kieran	sligoharbourmaster@indigo.ie	071 9161197
Galway	Galway Harbour Company Capt. Brian Sheridan	info@galwayharbour.com	091 562329
Limerick, Foynes and Carrigaholt	Shannon Foynes Port Company – Mr. Hugh Conlon	hconlon@sfpc.ie	069 73103 (087) 2542266
Dingle	Dingle Marina Lt. Comdr. Brian Farrell	bmfdingle@eircom.net	066 9151629
Bantry	Bantry Harbour Commissioners Capt. Alec O'Donovan **or** Bantry Terminals Mr. Barry O'Driscoll	alec@bantrybayport.com b.odriscoll@btl.ie	027 51253 027 50384
Marathon Platform	Marathon Oil Mr. Morris McCarthy	mpmccarthy@marathonoil.com	021 4356233
Cork	Port of Cork Capt. Michael McCarthy or Mr. Kevin O'Callaghan	mmccarthy@portofcork.ie	086 2556278
Dunmore East	OPW Mr. Gerry Leahy	Gerry.leahy@opw.ie	056-7772641
Rosslare	Rosslare Port Capt Aedan Jameson	aedan.jameson@irishrail.ie	053 57920
Arklow	OPW Mr Gerry Leahy	Gerry.leahy@opw.ie	056-7772641
Dun Laoghaire	DunLaoghaire Port Company. Capt. Jim Carter and Mr. Simon Coates	james@dlharbour.ie	01-2801130
Dublin	Dublin Port Company – Mr. Aidan Clear	aclear@dublinport.ie	01 8876008
Drogheda	Drogheda Port Company Capt. Martin Donnelly	martindonnelly@droghedaport.ie	041-9838378 0862547827
Dundalk (Tide boards only)	Dundalk Port Company Capt. Frank Allen		042-9334096 087-2524188
Office of Public Works-Hydrometrics Division Galway	Mr. Alec McAlistair-Snr Engineer Hydrometrics. (Active contact)	alex.mcallister@opw.ie	093-35456

Appendix 3: OPW Operated Gauges

Station Name	Station No.	Location	NGR	Installed	Recorder Type	Power	Sampling Intervals	Calibration Intervals	Reference Zero	Housing	Comments
Dunmore East	17061	Waterford Harbour	X691999	n/a	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	-2.6261m Malin	Box enclosure approx. 600mmx600mm on standpipe	Chart record only. Records retained by Harbour Master. Bench mark near recorder 3.0630m Malin. Malin - Poolbeg Difference is 2.702m
Malin	40060	Portmore Pier	C422585	n/a	OTT Hydrosens Data Logger with Nimbus sensor	Mains Electricity	15 min	<6 weeks	-3.1431m Malin	Blockwork hut approx. 1200mmx1000mm	Records retained by Ordnance Survey. New recorder hut installed in 1990. New recorder with data logger installed 07/03. Data available by telemetry. Data logger also records sea temperature for Malin Head Met Station
Arklow Harbour	91102	Avoca Harbour	T252728	11/02	Isodaq data logger with Druck pressure sensor	Battery	15 min	<6 weeks	0.000m Malin	150mm pipe	Digital record. Near the outfall of the Avoca River to the sea. Installed for study into flooding in Arklow
Ferrycarrig Br.	91301	Slaney Esty	T015222	04/03	Isodaq data logger with Druck pressure sensor	Battery	15 min	<6 weeks	0.607m Poolbeg	150mm pipe	Digital record. Installed for study into flooding in Enniscorthy
Assaly	12063	Assaly Esty	T068152	03/79	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	1.444m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	Chart record only. Flood monitoring station.
Fiddown	16061	Suir Esty	S466197	09/68	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	0.598m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	Chart record only. Good record
Carrick on Suir	16062	Suir Esty	S402214	12/72	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	2.000m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	Good record. Digital record available since mid 2002. Used in design and monitoring of recent flood relief scheme.

OPW Gauges Cont.

Station Name	Station No.	Location	NGR	Installed	Recorder Type	Power	Sampling Intervals	Calibration Intervals	Reference Zero	Housing	Comments
Blennerville	23062	Lee Esty	Q813130	06/60	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	1.467m Poolbeg	150mm pipe	Chart record only. This recorder has a poor record due to siltation at the site. New recorder recently installed 09/03 at NGR Q815131 at Blennerville bridge
Moneycashen	23068	Feale Esty	Q858380	10/80	Isodaq data logger with Druck pressure sensor	Battery	15 min	<6 weeks	2.076m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	Data logger installed 01/99
Ferry Bridge	24061	Maigue Esty	R482524	01/40	Isodaq data logger with Druck pressure sensor	Battery	15 min	<6 weeks	0.002m Poolbeg	Blockwork hut approx. 1000mmx1000mm	Good record since data logger was installed 11/98. There was a lot of problems prior to that due to siltation of the stilling well
Wolfe Tone Bridge	30061	Corrib Esty	M296249	10/50	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	1.939m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	To be relocated due to proposed bridge widening.
Ballina	34061	Moy Esty	G250192	04/52	OTT Type X autographic Chart Recorder	None	Continuous	<6 weeks	2.938m Poolbeg	Blockwork hut approx. 1000mmx1000mm	Good record.
Adelphi Quay	90605	Suir Esty	S613123	09/99	OTT Orphimedes data logger	Battery	15 min	<6 weeks	0.000m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	Installed for study into flooding in Waterford
Clarecastle Bridge	91208	Fergus	R352742	06/02	OTT Thalimedes data logger	Battery	15 min	<6 weeks	0.000m Malin	150mm pipe	Installed for study into flooding in Ennis. Previous record available.
Great Island	16065	Waterford Harbour	S686144	n/a	OTT Type X autographic Chart Recorder	None	Continuous	2 months	0.000m Poolbeg	Box enclosure approx. 600mmx600mm on standpipe	Transferred to OPW by ESB in 1999 following gap in record.

Appendix 4 OTT Gauges in Ireland

Gauge Location Details

Location Name:	***Tivoli***	***Cobh***	***Malin Head***	***Killybegs***	***Lisahally Derry***
Co-ordinates:					
Location Description: (i.e. position within harbour, type of structure on which gauge is mounted)	*Bubble tube mounted along dock wall protected by galvanized tubing*	*4" steel pipe mounted on jetty*	*Bubble tube mounted on pier wall protected by galvanized tubing*	*Bubble tube mounted on quay side protected by galvanized tubing*	*Located at quay side on custom built bracket*

Housing Details

Description of tide gauge hut (i.e. type of structure, approx. dimensions etc)	*Housing in office of port building*	*Gauge in steel tube connected to housing with radio transmission to Control Room*	*Concerte hut on pier approx 1.5 * 3 m*	*Harbours Master Office*	*Steel Weather Proof housing 10 m from sensor approx 400 * 1000 * 200*
Condition of hut:			*Good*		*Good*
Shelter (from wind and waves)	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Accessibility (vehicular etc.)	*Yes*	*Yes*	*Yes*		*Yes*
Telephone Line available at gauge (yes/no)	*Yes*	*No*	*Yes (GSM)*	*No*	*Yes (GSM)*
If no how far to nearest line		*500 m*			
Power available in hut (yes/no)	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Gauge Details

Installation Date:			*Jul-03*	*2001*	
Type (Float, pressure, bubbler, acoustic, radar etc.):	*Bubbler*	*Float*	*Bubbler*	*Bubbler*	*Radar*
Make:	*OTT*	*OTT*	*OTT*	*OTT*	*OTT*
Model:	*Type 25*	*OWK-16*	*Nimbus*	*Nimbus*	*Kalesto*
Data Output Format (digital/paper):	*Digital*	*Digital*		*Digital*	*Digital*
Data Sampling Details (recording interval time-step, vertical resolution in cms):	*15 mins*	*15 mins*	*15 mins*	*15 mins*	*15 mins*
Data Transmission: (none, telephone, GSM, satellite, radio)	*Local and Voice Announcement*	*Local and Radio*	*Local and GSM*	*Local Only*	*Local and GSM*

Appendix 5 Summary details of questionnaire respondents.

Respondent	Organisation	Questionnaire Type
Martin White	NUI Galway	Generic
Eamon Scanlan	Kerry County Council	Generic
Marcus Phillips	Halcrow Group Ltd.	Generic
Alex McAllister	Office of Public Works	Generic
Sean Cullen	Geological Survey of Ireland	Generic
Alec O’Donovan	Bantry Bay Harbour Commissioners	Generic
Donal Clarke	Louth County Council	Generic
David Buttimer	Tralee & Fenit Harbour Commissioners	Generic
Brendan Brice	RPS – MCOS Ltd.	Generic
Shane Bennet	SM Bennett & Co. Ltd.	Generic
Anonymous	Waterford County Council	Generic
Adrian Bell	Kirk McClure & Morton	Generic
Anne-Marie Conibear	JB Barry & Partners Ltd.	Generic
Brendan Dollard	Enterprise Ireland	Generic
Pat Doyle	Sligo County Council	Generic
Brian Farrell	Dingle Harbour Commissioners	Generic
Edward Fitzgerald	TJ O’Connor & Associates	Generic
Kevin Fitzgibbon	DJ Fitzgibbon & Co.	Generic
Ben Gaffney	TJ O’Connor & Associates	Generic
Michael Garrick	Tobin Consulting Engineers	Generic
Karen Griffin	Seabed Surveys International Ltd.	Generic
Mike Haberlin	Hydrographic Survey Ltd.	Generic
Thor Hannevig	Sure Engineering	Generic
Shay Hickey	Commissioners of Irish Lights	Generic
Trudy Higgins	PH McCarthy & Partners	Generic
Bill Jones	Rockall Marine Ltd.	Generic
Con Kehely	Meath County Council	Generic
Eugene Kelly	Malone O’Regan Consulting Engineers	Generic
John Lombard	Carl Bros. Ireland	Generic
Kieran Lynn	Mayo County Council	Generic
Martin Manning	Halia Oceanographic Consulting Services	Generic
Tom McMahon	McMahon Design & Management Ltd.	Generic
John Murphy	Mott MacDonald EPO	Generic
Hubert Newell	Clare County Council	Generic
Maurice O’Donoghue	JB Barry & Partners Ltd.	Generic
Peter O’ Donoghue	Cork County Council	Generic
Julian Orford	Queens University	Generic

Appendix 5 contd.

Respondent	Organisation	Questionnaire Type
Rory Quinn	University of Ulster, Coleraine	Generic
Gary Salter	Sligo County Council	Generic
Oliver Shortall	Inland and Coastal Marine Systems Ltd.	Generic
Patrick Sides	CPM Engineering	Generic
Laurence Spain	Fingal County Council	Generic
Jim Walshe	Irish Hydrodata Ltd.	Generic
Guy Westbrook	Marine Institute	Generic
John Wilson	Kirk McClure Morton	Generic
Tony Maguire	Dublin City Council	Generic
Jim Carter	Dun Laoghaire Harbour	Owner/Operator
Kevin O'Callaghan	Port of Cork Company	Owner/Operator
John Campbell	DCMNR	Owner/Operator
Aidan Clear	Port of Dublin	Owner/Operator
Aedan Jameson	Rosslare Port	Owner/Operator
Hugh Conlon	Shannon Foynes Port Company	Owner/Operator
Michael Cluny	Port of Waterford	Owner/Operator
Martin Donnelly	Drogheda Port	Owner/Operator

Appendix 6 GSI proposal to establish an Irish Tidal Model

The Irish National Seabed Survey (INSS) is now at the end of its fourth year by the end of 2003. Because of the 200m – 4500m depth range of Zone 3 of the project it was accepted that the use of a tidal model was not critical, whilst still being desirable. Work however in Zone 2 within depths of 50m – 200m, does require use of a tidal model correction applied to the data gathered. In the absence of an existing Irish Tidal Model, it was decided to use the Proudman Oceanographic Laboratory (POL) predicted tides (PolPred) for Zone 2. This has worked to an acceptable level in depths greater than 70m, however, bad tidal correction induced anomalies are starting to appear in the final data in depths less than 70m.

It has now become imperative for Ireland to create an Irish Tidal Model for all the future INSS work within the 0m – 70m depth range. As approximately 14% of all data to be gathered in Zone 2 and all of the data within the Zone 1 fall within this requirement. This proposal tries to explain an approach towards achieving such a model for the Donegal coastline west of Malin Head initially. Leading to a methodology that can be applied to the remainder of the Irish coastline over time. The Donegal coastline has been chosen as the starting point as it is the number 1 priority area required by the INSS for work to progress in early 2004, tidally reduced by an Irish Tidal Model and resultant Co-Tidal Model.

All of the data gathered offshore by the INSS has been based on a geodetic and survey control network observed using the Global Positioning System (GPS). I.e. the ETRS89 ellipsoid.

The Ordnance Survey Ireland (OSI) has put in place a new geodetic and survey control network (IRENET) observed using GPS. This network consists of 12 new ‘zero-order’ control stations (8 in the Republic, 3 in Northern Ireland and one on the Isle of Man) connected to some of the defining International Terrestrial Reference Frame (ITRF) stations in Europe. The resulting adjustment was accepted as an official extension to the European Terrestrial Reference System (ETRS) by sub-commission X (EUREF) of the International Association of Geodesy (IAG) in Ankara, Turkey, 1996. These zero order stations were used to control a densification of the network to a further 173 stations throughout Ireland between May and December in 1995 (see Figure 1). Co-ordinates have been computed in terms of ETRS89 and Irish Grid (1975 Mapping Adjustment), and these stations will form the basis for all future scientific and mapping control work.

It is now possible to realise both vertical datums (Malin Head and Belfast Lough) in Ireland using GPS instrumentation by means of an Ordnance Survey geoid model which is known as OSGM02 (Ordnance Survey Geoid Model 2002). The use of OSGM02 will allow conversion of ellipsoidal heights relating to the GRS80 ellipsoid to orthometric heights that relate to the local Malin Head (ROI) or Belfast Lough (NI) vertical datums. The OSGM02 heighting has become the de facto new vertical positioning standard for the Republic of Ireland.

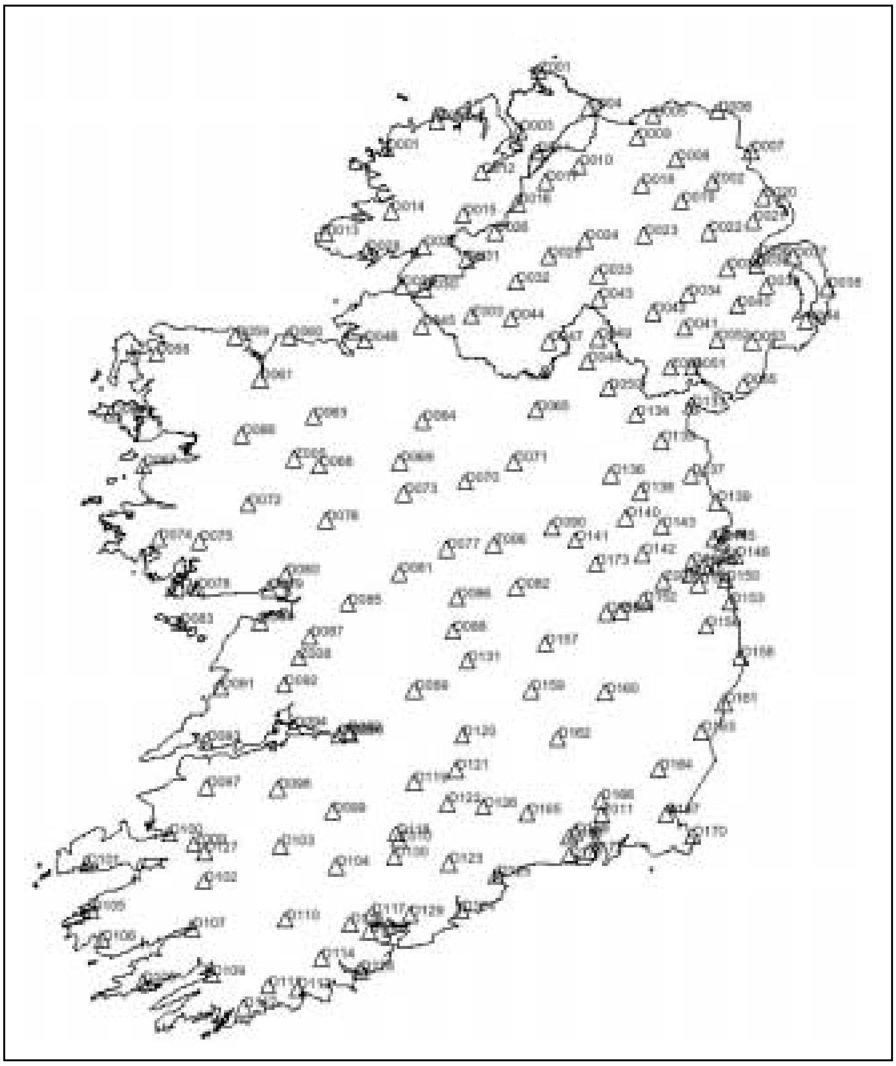

Figure 1: IRENET 95 stations

IRENET 95 stations have been connected to the pre-existing mapping framework known as the Irish Grid. This enabled a comparison to be made between the size and position of Ireland, as defined from the older terrestrial based techniques with Ireland as measured today using satellite based GPS techniques. Results appear to indicate that Ireland is longer and wider than the previous measurement. In addition, the positions of points between reference systems appear to have shifted by an average of 54.3 metres to the NW as depicted in Figure 2 below.

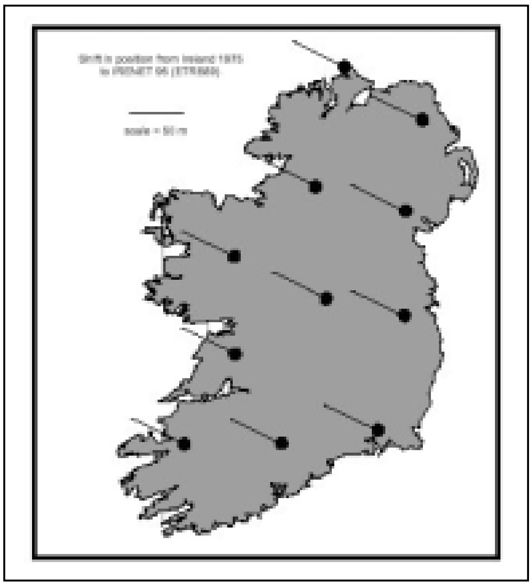

Figure 2 : Position shift from Irish Grid to IRENET.

It is proposed to initially outline an approach towards achieving a tidal model based on the OSI IRENET 95 station geodesy for the Donegal coastline west of Malin Head as shown in Figure 3. This would allow the INSS to apply the resultant model to data acquisition in 2004 and appraise the methodology before continuing either in the Irish Sea or the coast to the east of Malin Head in order to tie into the UK tidal network at Port Rush.

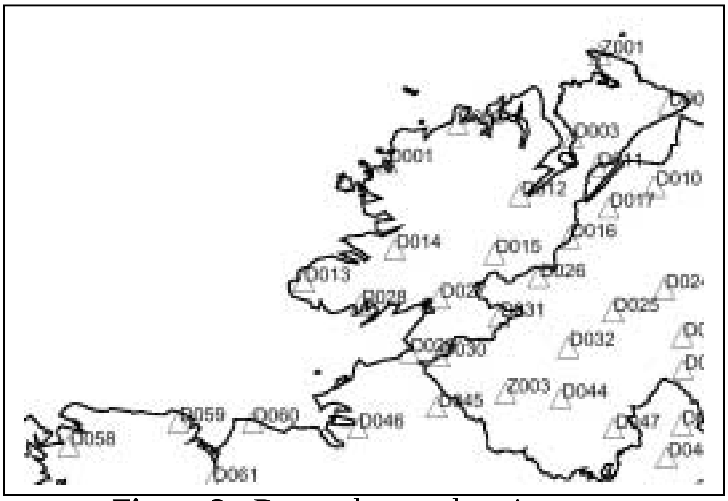

Figure 3 : Donegal control stations

Proposed Methodology

Step1.

To transfer the OSI GPS control down to positions on the coastline where tide gauges can be safely located. The purchase of an RTK system is required in order to obtain accurate ellipsoidal heights. (Hiring was ruled out as a few months hire would cover the cost of purchase)

Step2

Descriptions of all the existing OSI control near the coastline can be be acquired for free via the OSI website. A comprehensive search for available tidal recording systems must be undertaken.

Step3

Coastal locations of tide gauge positions have to be reconnoitered all along the Donegal coast and in particular on offshore islands along the coast. Some existing desktop studies and actual survey data will need to be collated.

Step4

Close to all proposed tide gauge positions, brass markers set in concrete have to be deployed. It is proposed that these are set out upon the reconnoiter mission in order to minimize time during the surveying in of these stations.

Step5

Each of these tide gauge GPS control points have to be described accurately and methodically. It is proposed that a GIS database be developed for easy dissemination of the acquired data.

Step6

All of these tide gauge GPS control points have to be observed by using the RTK system with a minimum of a half hour to a maximum of an hour set up over each point. (To maintain accuracy from OSI control to tide gauge GPS control traverse increments of no greater than 10k distances at a time should be used where feasible)

Step7

Tide gauges have to be deployed at these new positions. The number of gauges deployed should be no less that 5 at one time period. Coverage down along the coast can then be achieved by periodically moving the gauges to new positions further down the coast as acquisition at sea progresses.

Step8

Lowest Astronomical Tide (LAT) has to be verified by independent computation for each TG position. Co-Tidal models have to be derived from all the tide gauge data.

Step9

As acquisition of INSS data at sea proceeds, so additional offshore tide gauges will be integrated with the shoreside installations. During acquisition the shoreside tide gauges can be ‘leap-frogged’ down the coast. During the off season it is proposed that future priority areas are targeted.

Step 10

Ultimately the goal should be to place permanent tide gauges both along the coast and on any offshore installations that are applicable. These offshore installations should include the national weather data buoys installed by the Marine Institute, out lying islands, offshore structures (oil rigs, wind farms etc.) and seabed deployments.

Initial Equipment Requirements.
It is proposed to approach SIS* to purchase the RTK equipment required as this was the same company that provided the equipment to the OSI to produce their IRNET 95. (They will therefore also provide training on the equipment with a total estimated cost of €46,000).

*Survey Instruments Services (SIS)
Unit 6A, Ballymount Cross Industrial Estate, Dublin 24, Ireland.
Phone: [+353-1] 456 8650

The GSI own one shoreside tide gauge.
NUI Cork (CMRC) own one shoreside tide gauge.
NUI Galway own two shoreside tide gauges.
Some port authorities also maintain tidal systems that could be integrated.

The GSI has a passenger certified RIB that can be used for offshore island access.

It is proposed to use a mixture of GSI and MI people to man the project.

If approved, vehicles should be available from the GSI for INSS related work.