Technical report produced for Fingal County Council

Methodology for Coastal Monitoring Programme at Portrane and Rush Beaches, Co. Dublin

Max Kozachenko & Jeremy Gault

October 2009

Table of Contents

1. Introduction

This report has been prepared by the Coastal & Marine Resources Centre, University College Cork for Fingal County Council in response to a tender **to develop a methodology for a community-based coastal monitoring programme for the Fingal coast at Rush and Portrane**. The coastline at Rush and Portrane in North County Dublin (Figure 1.1) is a dynamic system. The beach and dune systems on either side of the mouth of the Rogerstown Estuary are part of one hydro-geological system, reflected in the simultaneous growth and decline of the extent of the beaches and dune system. Sedimentation and erosion processes seem to occur on a cyclical basis within this sub-cell of the Irish Sea. In recent years, however, coastal erosion is accelerating and sedimentation is occurring where it never did before. **Dune Conservation Plan**, prepared for Fingal County Council in 2007 (Gault et al., 2007), **recommended that a coastal monitoring programme be established**. The local community has indicated that it wishes to be actively involved in this monitoring programme and Fingal County Council is keen to facilitate their involvement. Fingal County Council envisages that once established this monitoring should be carried out over a timescale of 5-25 years (Hans Visser, personal communication).

Figure 1.1: Rogerstown Estuary, Co. Dublin with Portrane and Rush beaches. Image source: Google Earth, 2009.

The tender document requested that the monitoring programme should address the following objectives:

1. Monitor the rate of dune toe erosion and expansion along the dunes at Portrane and Rush;
2. Find out why erosion is taking place at particular locations;
3. Establish the rate of erosion and/or growth of beach levels on both beaches;
4. Establish the spatial patterns of erosion and sedimentation within this subcell of the Irish Sea (e.g. how does sand move throughout this area);
5. Find out how the estuary affects the sediment transport regime;
6. Assess the influence of human activities and external natural forces that may affect erosion and sedimentation patterns and rates;
7. To develop a computer model of the area showing the erosion and sedimentation patterns.

The overall aim of this report is to provide a concise overview of the potential monitoring techniques that can be used to address these objectives and to suggest implementation plans for such monitoring programme.

If we were to summarise the above objectives – there are three main processes that this monitoring programme should measure:

1. Record lateral changes of the coastline (cliff line; high water mark) position due to erosion/accretion processes;
2. Record vertical changes in beach profiles (e.g. due to tidal currents and waves);
3. Map sediment movement patterns in the near shore and intertidal area (e.g. due to tidal and river currents).

The methodology proposed should evaluate the changes and dominant processes affecting the coastline. It is envisaged that a series of monitoring methods proposed will allow to locate, name and understand these processes (e.g. erosion and accretion). It will also allow the assessment of general trends in these processes as well as evaluate the contribution of extreme weather events such as storms. The monitoring should also aim to establish whether beach erosion/accretion is a cyclical process or represents part of a long term trend. In order to answer these questions it is important to implement monitoring at various time scales (e.g. hours, days, weeks, months, seasons, annual, multi-annual).

In other words, in order to produce useful results the monitoring programme implemented should include surveys of a number of variables conducted at consistent spatial and temporal scales. Once off measurements wouldn't have any value for monitoring with the exception of cases where the data can be compared with similar historical data. Therefore, a basic principle is repeatability: monitoring should include repeat surveys at consistent time intervals. Only repeat measurements over a number of time cycles of various scales (tidal, seasonal, annual, etc.) will be useful to achieve a better understanding of the dominant coastal processes and evolution. Out of schedule surveys should be performed following strong storms when the beach will most likely be sediment starved, and during prolonged periods dominated by moderate swell and alongshore winds when the beach levels are likely to be recovering.

2. Proposed methodology

2.1 Overview of monitoring techniques

Described below are monitoring techniques that can be used to address objectives stated above.

The following should be considered during the monitoring planning stage:

1) The choice of technique to be used.
2) Frequency of implementation to get the required outputs (e.g. monthly, seasonally, annually, etc.).
3) The number of staff and level of expertise/qualification required.
4) Costs associated with equipment, materials and staff.

All monitoring techniques can be subdivided into three groups: **observations, measurements** and **modelling**. For instance, visual observations of the coastline supported with photo or video evidence is a monitoring technique in itself as it allows the establishment of visible changes on the coastline that can be interpreted as erosion, accretion or if there are no changes, a stable condition. The measurements of change in beach levels or coastline position using landmarks, sedimentation plates or levelling surveys will be grouped under measuring techniques. Numerical models can subsequently be set-up for the study area using the information obtained through observations and measurements to produce detailed simulations of how the system will respond to future scenarios under various environmental conditions. The application of numerical models is outlined in more detail in Section 2.4.

Monitoring techniques described below have been grouped in accordance with a level of expertise required for their implementation.

2.2 Coastal monitoring techniques for community based approach

This chapter describes monitoring techniques that can be implemented by the local community enthusiasts. However, some supervision from relevant County Council staff will be helpful/required. As part of the supervision process the council should look after strategic planning of the monitoring, implementation and database entry of survey results. The results should also undergo quality control and metadata for each dataset should contain a note regarding data reliability/quality (e.g. low, medium, good).

The community based approach should achieve the following:

- Improve peoples' understanding and awareness of ongoing coastal processes;
- The above is closely linked with the educational value of these monitoring exercises for people of all ages;
- Involve the local community in the process of assessing ongoing changes to the coastal environment;
- Involve the local community in the future decision making process regarding the Integrated Coastal Zone Management (ICZM) strategy for this area.

A note on health and safety: For health and safety reasons it is strongly recommended that any monitoring should be undertaken in groups of at least two people at any given time.

2.2.1 Manual measurements of coastline position in relation to fixed landmarks

Materials and equipment:

- Coastal monitoring posts (wooden, plastic or metal; length 2.4-4m)
- 50m measuring tape
- Compass
- Digital photo camera
- Hand held GPS
- Logging sheet/notebook + pen/pencil
- Soil drill
- Spade
- Heavy hammer
- Spirit level
- Post fix mixture (optional)

Coastal systems are dynamic and subjected to changes due to currents, waves and other weathering factors including wind, rain, animal and human activities. The changing position of the coastline (cliff line or high water mark) can be monitored through manual measurements (this section) and surveys using GPS systems (sections 2.2.2 and 2.3.1).

Methodology:

This method will record changes in coastline position in relation to a set of fixed landmarks (benchmarks). For this purpose it is suggested to utilise all suitable existing landmarks (Figure 2.1) and where necessary to install new landmarks **(coastal monitoring posts)**. New landmarks should be installed at regular intervals along the beach. The installation position can be decided individually for each location taking into account site specific aspects. Preferably the posts should be made from metal and treated against rust as they will be in contact with salt water over a long period of time (e.g. galvanised, Zink plated, painted with rust resistant paint). However, as a cost saving measure, posts from treated wood may also be used, which is also a more environmentally friendly option.

A note on post installation: The coastal monitoring posts should sit tight in their place and not be able to move as a result of various weathering factors. The installation technique should be adapted on a site specific basis.

- Installation technique 1: Drive the post at least 1m into the beach sediment using a heavy hammer.
- Installation technique 2: Drill a hole into the ground of substantial depth (e.g. 1-2m) of the same diameter as the monitoring post and inset the post inside this hole without any additional fixing.
- Installation technique 3: Drill or dig a hole in the ground of substantial depth (e.g. 1m) of the bigger diameter than the monitoring post, inset the post inside and fix it with postfix (mixture of cement, gravel and sand).

Posts should be installed vertically, which should be checked with a sprit level. Following installation the location of each coastal monitoring post should be recorded using a GPS, each post should be assigned a reference number and locations of all posts integrated within a desktop GIS system. A reference number should also be printed on each post (e.g. painted, burned, cut, label attached with screws, etc.).

There are two implementation options:

Option 1: Install one monitoring post at each monitoring location.

- Posts are installed at equal intervals along the beach on the beach or dune side depending on local setting.
- It is envisaged that installation at 50-200m interval will suffice the purpose of this monitoring programme. The frequency of installation can be decided upon taking the available budget into account. Therefore, the total number of posts will be as summarised in the following table.

Table 2.1: Optional numbers for new coastal monitoring posts if installed at 50, 100 or 200m intervals. These numbers may be reduced if the use of the existing landmarks is made (Figure 2.1).

	Beach Length	**Number of posts if installed at 50m interval**	**Number of posts if installed at 100m interval**	**Number of posts if installed at 200m interval**
Portrane Beach	c.2300m	46	23	12
Rush Beach	c.2100m	42	21	11
Total:		88	44	23

- Measurement of the distance between the coastal monitoring post and a cliff line (high water mark) will require a 50m **measuring tape** and a compass. When making these measurements the surveyor should keep in mind that the location of the coastline (cliff line; high water mark) will not necessarily be parallel to its position at the time of previous measurement. Therefore, the shortest distance from the post will not necessarily reflect the actual change in the coastline position. Hence, it is suggested to use a compass to correctly orientate the measuring direction. The first reading should measure the shortest distance between the pole and the cliff line (high water mark) and a note should be taken of the orientation of this line by compass. All subsequent readings of this distance should be made in the same compass direction.
- Measurements should be performed at regular scheduled time intervals. During the first year of monitoring it is suggested to perform measurements once a month during a similar stage of the tidal cycle. Following evaluation of the first year results it might be reasonable to reduce measuring intervals to a seasonal frequency depending on how dynamic the system is.
- It is advised to do out of schedule measurements immediately after storms.
- It is suggested to photograph the environment at each monitoring station at a time of each measuring campaign.

Option 2: Install monitoring posts in sets of two at each monitoring location (Figure 2.2-2.3).

- Two posts should be installed at each monitoring location: one on the beach (dune face marker) and one well back from eroding surface (backshore marker). Post should be aligned on the line perpendicular to the present coastline.
- Pairs of posts should be installed at equal intervals along the beach. It is envisaged that installation at 50-200m interval will suffice the purpose of this monitoring programme. The frequency of installation can be decided upon the available budget. Therefore, the total number of posts will be as summarised in the following table.

Table 2.2: Optional numbers for new coastal monitoring posts if installed in pairs at 50, 100 or 200m intervals (Figure 2.2-2.3). These numbers may be reduced if the use is made of the existing landmarks (Figure 2.1).

	Beach Length	Number of posts if installed at 50m interval	Number of posts if installed at 100m interval	Number of posts if installed at 200m interval
Portrane Beach	c.2300m	92	46	24
Rush Beach	c.2100m	84	42	22
Total:		176	88	46

- The measuring technique will only require a 50m measuring tape (no need for compass), which should be stretched between two posts and position of the coastline relative to the post installed on the beach recorded into a survey log sheet.
- Measurements should be performed at scheduled time intervals. During the first year of monitoring it is suggested to perform measurements once a month during a similar stage of the tidal cycle. Following evaluation of the first year results it might be reasonable to reduce the measurement intervals to a seasonal frequency depending on how dynamic the system is.
- It is advised to do out of schedule measurements immediately after storms.
- It is suggested to photograph the environment at each monitoring station at the time of each measuring campaign.

Limitations:

- This method produces a record of coastline changes at single points and does not provide information on changes between coastal monitoring posts.
- Measurements are performed manually by different people. Therefore, it is important to agree on how the coastline should be defined and where to measure. Otherwise the definition of the coastline (cliff line, high water mark) by different people might be different.
- Monitoring posts may be lost due to environmental factors and vandalism. Therefore, care should be taken to replace any missing posts in due time.
- Visual impact as well as health and safety of beach users should be accounted for when deciding on the frequency and location of installation of the coastal monitoring posts.

Figure 2.1A: Examples of existing landmarks that can be used in this monitoring programme, Portrane Beach, Co. Dublin, August 2009 (Photos by Dr. Max Kozachenko).

Figure 2.1B: Examples of existing landmarks that can be used in this monitoring programme, Rush Beach, Co. Dublin, August 2009 (Photos by Dr. Max Kozachenko).

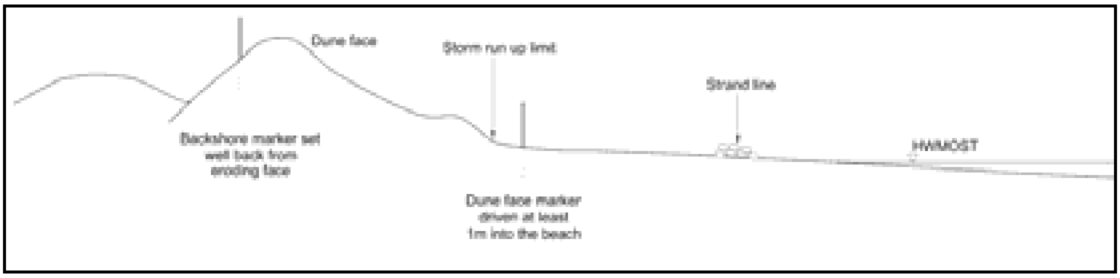


Figure 2.2: Schematic beach and dune cross section showing potential locations for coastal monitoring (marker) posts (Image source: http://www.snh.org.uk).

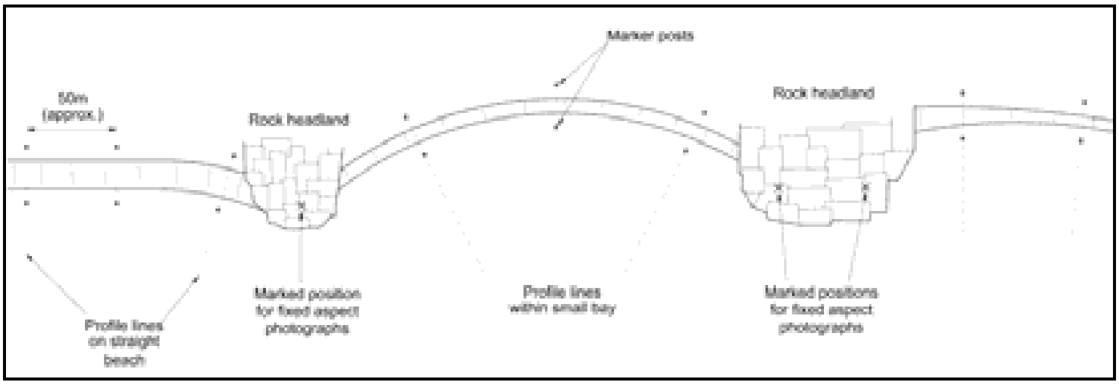


Figure 2.3: Schematic plan of beach and dunes showing potential locations for coastal monitoring (marker) posts and measuring profiles layout (dry land is at the top of the drawing) (Image source: http://www.snh.org.uk).

Note: Monitoring coastal changes through installation of coastal monitoring posts has been successfully used by other beach monitoring programmes. Figure 2.4 demonstrates the results of monitoring of the east Riding coastline (UK) started in 1951 and based on regular measurements at over one hundred monitoring posts.

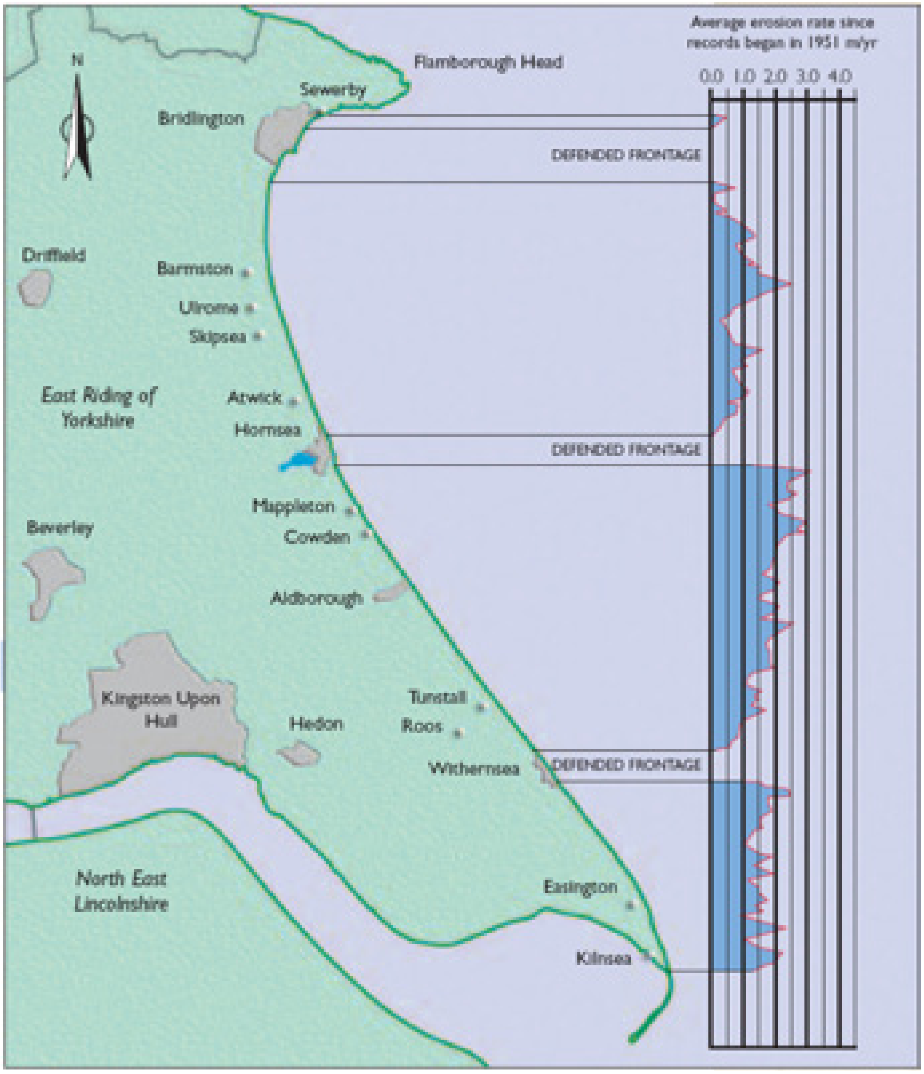


Figure 2.4: Cliff erosion rates from East Riding coastline of Yorkshire Council (UK) based on erosion post data.
(Image source: http://www.eastriding.gov.uk/coastalexplorer/)

2.2.2 GPS measurements of coastline position

Materials and equipment:
• Hand held GPS

Methodology:

- This technique would be implemented by a surveyor who should be walking along the beach holding a GPS receiver directly over or close to the cliff line (Figure 2.5) or high water mark (Figure 2.6). The GPS receiver will automatically record the positions along the way, therefore, producing an uninterrupted record of the cliff line position.
- Surveys should be undertaken on "good" GPS days. The satellite signals should be checked before commencing a survey. The vertical and horizontal accuracies should be noted with the results.
- For better accuracy it is suggested to record the survey line twice as anyway the surveyors will have to return to where they started the survey (e.g. car park).
- The GPS will record a track, which can be imported into a desktop GIS system. The analysis of data acquired during the first few surveys will demonstrate whether it is worth to continue with this type of monitoring at the current level of GPS technology (see Limitation section). *First of all, the comparison should be made between the two survey lines recorded during the same day. If they nearly match (with a discrepancy of 1-2m) – it is a good sign. The second stage may involve comparison of the survey line recorded with a recent areal photograph of the study area in a GIS.*
- GPS surveys should be performed at scheduled time intervals. During the first year of monitoring it is suggested to perform measurements once a month. Following evaluation of the first year results it might be reasonable to reduce measuring intervals to a seasonal frequency.
- It is advisable to do out of schedule measurements immediately after storms.
- These surveys may also be carried out simultaneously with other monitoring methods including visual surveillance supported with photo evidence of physical changes (see 2.2.6) and also recording human activities (see 2.2.7). This should be undertaken by a second person in the survey group in order not to interrupt GPS record.

Limitations:

- The manufacture's manuals state that at present the accuracy of an average hand held GPS system is in the range of +/-3-10m. However, practical experiments show that at times the real accuracy could be much better (in the region of 1m). Therefore, it is still worth testing the usefulness of walking GPS coastline location surveys. Even if this won't produce a dataset of required accuracy it will still involve local community in the coastal monitoring programme and raise their interest and awareness of the ongoing coastal processes. Having a particular task people will start paying attention to things and processes they never did before. **Another aspect to keep in mind is the technical progress and it may well be that in the near future hand held GSP systems will reach accuracy comparable to DGPS.**
- Measurements are performed by different people. Therefore, it is important to agree on what should be measured as definition of the coastline (cliff line, high water mark) by different people might be subjective.

Figure 2.5: Cliff line, Rush Beach, Co. Dublin, August 2009 (Photo by Dr. Max Kozachenko).

Figure 2.6: High water mark where dunes are absent, Rush Beach, Co. Dublin, August 2009 (Photo by Dr. Max Kozachenko).

2.2.3 Manual measurements of beach sediment levels

Materials and equipment:
• Hand held GPS • Spade or a small portable excavator (digger) • Metal detector • Spirit level • Metal sedimentation plates • Wooden or plastic lags (optional) • Graded metal rod (made from 10mm steel) • Logging sheet/notebook + pen/pencil

Tidal currents that flush up and down the beach system twice a day have substantial force to transport sand and gravel particles. Therefore, vertical beach profiles are constantly changing on an hourly, daily and longer term (seasonal, annual, multiannual) scales.

There are several manual methods to measure changes in the beach topographic levels:

- Installation of sedimentation rods;
- Installation of depth of activity rods;
- **Installation of sedimentation plates**.

The first two methods involve the installation of thick metal rods sticking out from the beach sediments. Therefore, they will possess health and safety risk to beach users and, hence, are not recommended. The method of sedimentation plates may be tested in the context of this monitoring programme and is described in more detail below.

Methodology:

- In order to collect an accurate record of changes in vertical beach levels, a reference system must be established. The technique suggested will take the preinstalled metal plates as such a reference and record changes in vertical beach profiles in relation to this reference assuming that plates are relatively stable and do not move.
- Regular measurements of the thickness of sediments overlaying the plates will be used to obtain a consistent temporal record of changes in beach elevation at monitoring points that can be spaced along and across the beach.
- The locations for installation of sedimentation plates should be carefully selected using GIS analysis of aerial photographs and site investigations.
- The suggested design of the sedimentation plate is shown in Figure 2.7. The metal pin welded to the plate should point vertically down to add extra stability. Spirit level should be used to check that the plate is installed horizontally before covering it with sediments.
- In order to install a plate a hole of a suitable dimension should be dug in the sediment with a spade or a small portable excavator (digger). It is suggested to install plates at least at 1m depth below the beach level. Wooden lugs may be placed underneath the plates to add stability (Figure 2.8).
- The location of the plate should be recorded using a hand held GPS system.

- The plate should be covered with the original sediment in order to return the original beach level and smoothed over so as not to leave any mound or excess sediment or any troughs.
- **Measuring technique:** The measurements are performed by means of a graded metal rode (a rode which is marked as a ruler or measuring tape at e.g. 1cm intervals). As the plates are buried in sand, it will be relatively challenging to find them. Therefore, the surveyors should be equipped with a handheld GPS and a metal detector in order to ease the retrival of the plate locations. First the surveyor arrives to the right place using GPS. Due to the fact that any portable GPS provides realistic accuracy between 3-10m – the precise location of the plate should then be determined utilising a metal detector. The thickness of sediment above the plate is determined using a graded metal rod. Any change in elevation can then be seen by calculating a change in distance from the beach surface to the plate.
- The measurements should be performed at scheduled time intervals. During the first year of monitoring it is suggested to perform measurements once a month during a similar stage in the tidal cycle. Following evaluation of the first year results it might be reasonable to reduce measuring intervals to a seasonal frequency.
- It is advised to do out of schedule measurements immediately after storms.
- Results obtained in the field should be entered into a database table and integrated within a desktop GIS for further analysis.

Figure 2.7: Schematic drawing of the sedimentation plate. The size of the plate can be around 30x30cm or 50x50cm. The bigger size will add more stability to the plate when installed. The plate should be manufactured from 3-10mm thick stainless steel. The metal leg (c.50-70cm) is welded to the bottom of the plate to add stability.

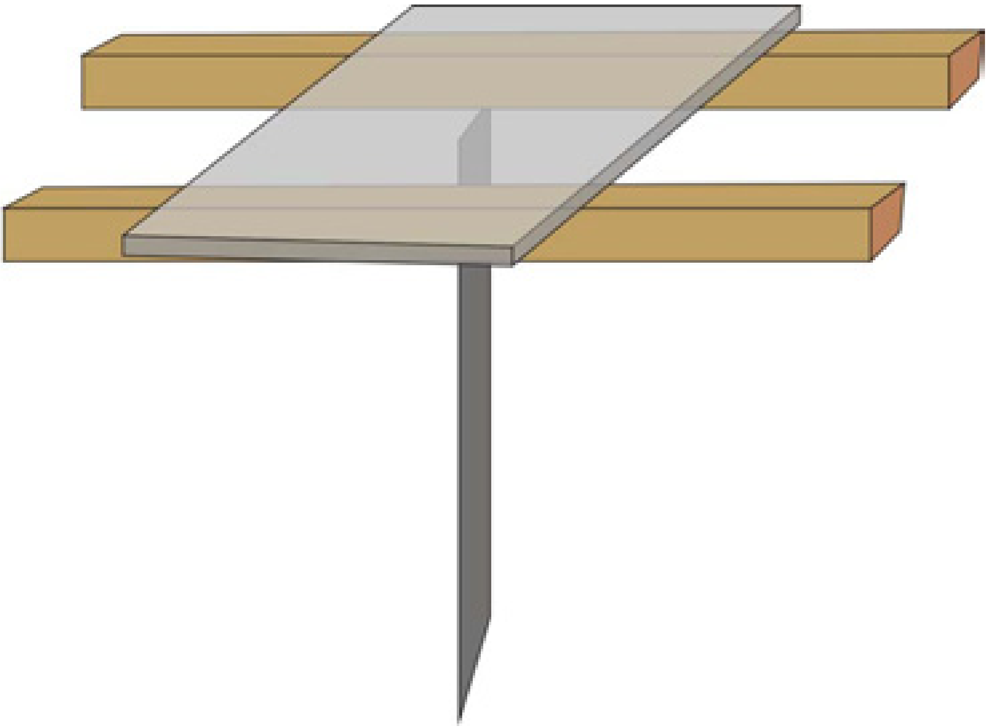


Figure 2.8: Schematic drawing showing how wooden or plastic lugs may be placed underneath the plate to add stability when installed in soft sediments.

Limitations:

- Sedimentation plates may move. This will depend on plates' design and sediment type. Therefore, it is suggested to implement this technique in few locations and only after decide if it should be used for the whole study domain.
- Sedimentation plates may be difficult to find.
- This method only provides single point measurements.
- Installation of the plates can only be performed in sandy sediments as plates do move in soft muddy sediments and making measurements in gravelly sediments will be nearly impossible.

2.2.4 Evaluation of sediment movement patterns in the intertidal area though compass supported measurements of ripple crests orientation

Materials and equipment:
• Hand held GPS • Compass • Digital photo camera • Logging sheet/notebook + pen/pencil

The direction and strength of currents in the intertidal area can be estimated from analysis of the shape and crest orientation of the current induced ripples. This analysis can contribute towards improving the understanding of the sediment movement patterns in the intertidal area.

Methodology:

- The measurement points should be planned using a desktop GIS through analysis of the aerial photographs taken at low tide. The matrix of measurement

points should be distributed evenly to cover the whole study area. The density of measurement points will depend on the availability of resources.

- The measurements should be performed between 1-3 times during each season during different stages in the tidal cycle (neap, spring, in between). Based on analysis of results collected during the first year of monitoring a decision should be taken in relation to continuation of these measurements.
- **Measuring technique:** The surveyor should arrive to the approximate location of each monitoring station using a hand held GPS. A compass should be placed on the beach surface and photographed (Figure 2.9). The reference number of the digital photograph taken should be recorded into the survey log sheet. It would also be logical to switch on the date and time stamp mode in the digital camera when taking the photographs in order to avoid confusion during post-fieldwork interpretation.
- **Post-field work processing and outputs:** Consequently during post-fieldwork data processing each photograph should be renamed to contain information about place and time (e.g. File name structure: **N_hhmm_ddmmyyyy**, where N=Number of monitoring point, hhmm=time, ddmmyyyy=day+month+year). Orientation of ripples is normally perpendicular to the current flow. Therefore, these photographs can then be used to derive current direction. A note should also be taken in relation to the type of ripples (Collinson et al., 2006). If different types of ripples noted in different locations – this may allow to quantify the relevant current strength. Results should be entered into a database table, which may consequently be used to plot vectors of current direction and possibly relevant strength using desktop GIS. It is hoped that comparison of these derived datasets obtained for each monitoring campaign will provide temporal record of variability in current directions and, hence, sediment transport patterns.

Figure 2.9: Illustration of how the measurements of ripple crests orientation should be performed, Rush Beach, Co. Dublin (Photo by Dr. Max Kozachenko).

Figure 2.10: Example of larger beach surface topography that indicate recent sediment transport and beach level changes under the influence of tidal currents, Inchydoney beach, Co. Cork, September 2009 (Photos by Dr. Max Kozachenko).

Limitations:

- This method only provides single point measurements.
- Measurements are performed by different people, and, therefore, subjected to human errors.

Notes:

- Even if data obtained though this monitoring method will not be used for further computer modelling it is still of high educational value as while undertaking it people will become really aware of the sediment transport processes and start thinking about the morphodynamic processes that influence the changes to their beach.
- While in the field, attention should also be paid to other signatures of sediment transport such as larger bedforms (e.g. sand waves, sand dunes), steep beach level changes (Figure 2.10) and erosional channels. These should also be photographed with compass in plane and oblique view and their locations recorded with a GPS.

2.2.5 Evaluation of sediment movement patterns in the intertidal area though experiments with tracing (dyed) sand

Materials and equipment:
• Tracer material (sand particles coated with tracer) • Hand held GPS • Digital photo camera • Floating survey platform (boat) [optional] • 4x4 vehicle • Logging sheet/notebook + pen/pencil

This method can be used to monitor the sediment transport pathways in the intertidal area (Black et al., 2006; Ingle, 1966). Two types of tracers are commonly used:

- Labelled (coated) natural particles;
- Labelled synthetic particles.

Most workers give preference to the coated natural particles as they are more likely to retain the transport properties of the natural sediment particles. A number of tracer studies have been carried out in the surf zone to determine the alongshore bed load and near-bed suspended sediment transport (White, 1998).

In the community based context of this monitoring programme the technique will be to dump few bags of dyed sand in different locations throughout the intertidal and near-offshore area. Ideally sand dumped at each location should be of different colour. The movement of sand should then be monitored through visual observations on a daily basis.

Methodology:

- Locations for dumping dyed sand should be planned using desktop GIS.
- The required amount of sand should be prepared. Ideally sand to be dumped at different locations should be dyed in different colours.
- Few bags of dyed sand should be dumped in different locations throughout the study domain at low tide. Use 4x4 vehicle for access to the dumping points.
- Few bags of dyed sand should be dumped in different locations throughout the study domain in the near shore location and estuary using floating platform (e.g. fishing boat, RIB).
- Few bags of dyed sand should be dumped in different locations along the coastline (cliff line; high water mark) at spring tide in order to understand where the sand eroded from the dunes goes.
- The coordinates of each dumping (sediment source) location should be recorded using a GPS.
- Walking surveys should be undertaken over the next few days at low tide to establish the sediment movement patterns. The spread of coloured sand should be recorded using GPS during walking surveys.
- The results should be subsequently integrated within a desktop GIS for further analysis.

The results from this method together with the results obtained from technique described above (section 2.2.4) should contribute towards understanding of the sediment movement patterns within the study domain. Moreover, assessment of these findings in comparison with the record of the beach level changes and changes in the location of the cliff line will aid understanding on the functioning of the beach system (e.g. sediment supply sources, sediment transport patterns).

Limitations:

- Buying sand particles coated with tracer might be very expensive. Therefore, self production options should be explored.
- More detailed investigations into the methods of introducing a tracer material into a beach system should be carried out as there might be more effective ways then simply dumping material on the surface as suggested above. The potential alternatives would be to pump the tracer inside the sediments or simply dig it slightly below the surface to eliminate the risk of the tracer being washed away immediately after dumping.
- Recording the movement of the tracer material might be complex due to the fact that it can get dispersed or buried in sediments.
- **Due to complexity of issues surrounding the tracing techniques this method is recommended with low priority.**

2.2.6 Visual surveillance of coastal changes supported with photo/video evidence

Materials and equipment:

- Digital photo camera (with high definition video functionality [optional])
- Tripod
- Hand held GPS
- Compass
- Logging sheet/notebook + pen/pencil

Methodology:

Notes documenting observations of coastal changes or processes leading to such and photo or video evidence especially if date and location stamped represent a useful monitoring technique (e.g. Figure 2.11). Such surveillance could be of two principle types as outlined below.

Figure 2.11: Example of what should be photographed. Recent evidence of coastal erosion, Garryvoe beach, Co. Cork (Photos by Dr. Max Kozachenko).

Non-systematic surveillance:

- This is when any member of public notes, photographs or records on video any aspects of the beach or processes affecting the beach which are related to erosion/accretion processes.
- Such surveillance will only be useful if it is date stamped and if it can be located on the map. Ideally, GPS coordinates should be recorded for each surveillance point. Alternatively, the person performing surveillance should take a note and also try to photograph/film a well recognised landmark (e.g. information sign, building, etc.).

Systematic surveillance:

- This is when observations and photo/video recordings are strategically scheduled. It is suggested to establish a number of landmarks (posts) throughout the study area from which fixed aspect photographs should be taken at scheduled time intervals, preferably in the same direction (by compass), with the same camera focal lens (zoom level), and same height of camera above ground.
- Some of the existing landmarks mentioned in section 2.2.1 may also be used for this task (e.g. information posts, rubbish beans, etc.). The location for placing a camera can be marked on these landmarks using weather proof paint.
- Landmarks including newly installed and existing should be systematically numbered and their locations integrated within a desktop GIS.

- Alternative approach would be to place a camera on a tripod in the planned positions utilising a hand held GPS and a compass.
- Imagery recorded during the surveys should be appropriately labelled and catalogued. It is suggested to perform such surveys at least once a month at the same stage of tide.
- Additional surveys should be performed following extreme weather conditions.
- Along with routine once a month surveys aimed at imaging beach appearance and, therefore, any temporal changes to the dunes' cliff line – it is also useful to perform photo/video sessions during high spring tides in order to record how the process of erosion is taking place. For this purpose it is suggested to locate several members of community monitoring team at different locations along the high water mark and ask them to take photo and/or video records of the water-cliff interface.

Note: It is important to have all photographs time and date stamped and GPS location of each surveillance station noted.

Limitations:

- This technique will only create a record of processes happening at a time the person involved in monitoring programme present at a particular location. Thus, the outcomes are subjective and limited both spatially and temporally.

2.2.7 Visual surveillance of human activities on the beach supported with notes, photo and/or video evidence

Materials and equipment:
• Hand held GPS • Digital photo camera • Logging sheet/notebook + pen/pencil

Methodology:

Human activities on the beach and dunes may also be the cause of coastal erosion. Therefore, it is useful to supplement factual measurements of physical changes of the cliff line position and beach levels with observation of human activities that may have a potential impact on the beach evolution. In principal, human activities on the coastline can be divided into two types: regular and once of. Particular attention should be paid to activities that substantially disturb the upper sediment layer or form artificial obstruction to the natural sediment movement (highlighted in bold below).

Regular activities would include: walking, running, **quad biking**, cycling, **joy driving of 4x4 vehicle, driving of vehicles with the purpose of launching a jet ski or a boat**, etc.

Once off activities may include: **installation of coastal defence, digging channels, installing drainage pipes, dumping of construction materials, fencing**, etc.

Therefore, local residents especially those regularly walking on the beach should be alerted of the importance to keep a record of such activities. Any of the above activities if observed should be noted and entered into a database recording activity type, time/date and location. A photograph or video record of any such activities

should also be made and If possible a GPS reading should also be taken. GIS integration of a regular record of human activities over a several year period supported with time stamped photographs or videos will form an important dataset that will potentially help to assess the role these activities play in changes to the beach/dune system.

Another aspect could be surveys performing regular counts of people using the beach at any given time. These surveys should be planned in consultation with the local community taking into account their enthusiasm and availability. Ideally, the survey should be conducted on 5 week days and 2 weekends during each season. This data compared with beach level changes might help to unravel the role the number of visitors and their activity play in the evolution of the beach.

Limitations:

- This technique will only create a record of activities happening at a time the members of monitoring team are present at a particular location. Thus, the outcomes are subjective and limited both spatially and temporally.
- Care should be taken when taking photographs of people as some people don't like to be photographed or filmed and might become aggravated.

2.3 Coastal monitoring techniques requiring professional input

Described below are monitoring techniques that will require some professional input at some or all of the following: preparation, implementation and data analysis stages. Depending on the in-house equipment and expertise availability at the Fingal County Council some of the techniques reviewed in this section might be not necessarily more expensive then techniques suggested for community based approach. Therefore, a detailed cost benefit analysis should be undertaken before enrolling with any monitoring technique.

2.3.1 DGPS measurements of coastline position

Materials and equipment:
• DGPS (Differential GPS) • Walky-talky (optional)

The accuracy of the DGPS (differential GPS) systems is on centimetre scale in comparison to a normal hand held GPS that has an accuracy on the scale of few meters. This accuracy is achieved due to the fact that it is not only calculating the exact distance between the receiver and each of the satellites in the range (like an ordinary GPS), but also relates itself to a second receiver placed in the known position, therefore, providing correction to the satellite signal. This second receiver is normally called a GPS reference station, which is connected to the moving GPS undertaking the survey through a radio link.

Methodology:

- For health and safety reasons at least four people are required to undertake this survey: two walking with a DGPS receiver and two keeping an eye on the GPS reference station. Surveyors should communicate by means of radio or mobile phone. *[Less people might be required if base station data is downloaded via the OSI website. This will depend on the survey set up and decided by professionals undertaking the survey.]*
- This technique is implemented by a surveyor who should be walking along the beach holding the DGPS receiver directly over or close to the cliff line (Figure 2.5) or high water mark (Figure 2.6). The GPS receiver will automatically record the positions along the way, therefore, producing an uninterrupted record of the coastline position (Figure 2.12).
- DGPS surveys should be performed at scheduled time intervals. During the first year of monitoring it is suggested to perform measurements once a month during a similar stage of the tidal cycle. Following evaluation of the first year results it might be reasonable to reduce measuring intervals to a seasonal or six months frequency.

Limitations:

- For better results this technique should be implemented in good weather conditions.
- It is important to agree on what should be measured as definition of the coastline (cliff line, high water mark) by different people might be subjective.

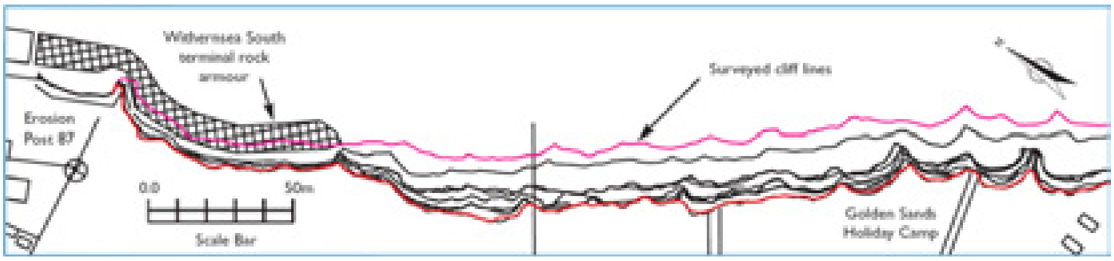


Figure 2.12: Example of graphical presentation of the results of the DGPS cliff monitoring carried out at six months intervals south of Withernsea, East Riding coastline of Yorkshire Council (UK).
(Image source: http://www.eastriding.gov.uk/coastalexplorer/)

2.3.2 Beach level surveys at low tide (DGPS or levelling)

Materials and equipment:
• DGPS (Differential GPS) • Optical levels or EDM (optional) • Walky-talky (optional)

Changes in beach vertical levels can be measured through DGPS, levelling (optical level) or using electronic distance measurement (EDM) surveys at low tide. These surveys should be undertaken by qualified professionals in accordance with manufacture's manuals of the relevant equipment. Levelling would be a more time consuming and less effective monitoring method and, therefore, is not recommended for this monitoring programme. However, it may still be used for the purpose of community involvement.

The DGPS will be the most precise and logistically less complicated technique.

The accuracy of the DGPS (differential GPS) systems is on centimetre scale in comparison to a normal hand held GPS that has an accuracy on the scale of few meters. This accuracy is achieved due to the fact that it is not only calculating the exact distance between the receiver and each of the satellites in the range (like an ordinary GPS), but also relates itself to a second receiver placed in the known position, therefore, providing correction to the satellite signal. This second receiver is normally called a GPS reference station, which is connected to the moving GPS undertaking the survey through a radio link.

Methodology:

- Beach levels should be measured by the DGPS receiver mounted on a small vehicle (e.g. quad bike or similar) or by foot. Alternatively, the DGPS receiver can be mounted on a trailer pulled behind a 4x4 vehicle. However, this will result in more destruction to the beach surface.
- The lateral and vertical accuracy of data recorded by this method is on a centimetre scale (approx. 0.03m).
- It is recommended to survey beach level along parallel lines (beach profiles) spaced at 50-200m intervals. The survey lines should be pre-planed using GIS. The survey lines should be perpendicular to the coastline and cover the beach surface between low and high water marks.
- Same survey lines (beach profiles) should be surveyed during each survey.

- It is also recommended to record one or more cross lines.
- Results should be integrated within the XL software or similar and results for each profile presented graphically (Figure 2.13).
- Results from each survey should also be used to create a digital elevation model (DEM) of the whole study domain using ArcGIS, Surfer or similar software package. Comparison between DEMs from different surveys can be used to graphically present temporal changes in beach levels (Figure 2.14).

Limitations:

- A vehicle or trailer on which the DGPS is mounted during the survey will penetrate into the beach surface (c.3-7cm). The penetration depth should be noted and the most reasonable correction applied.

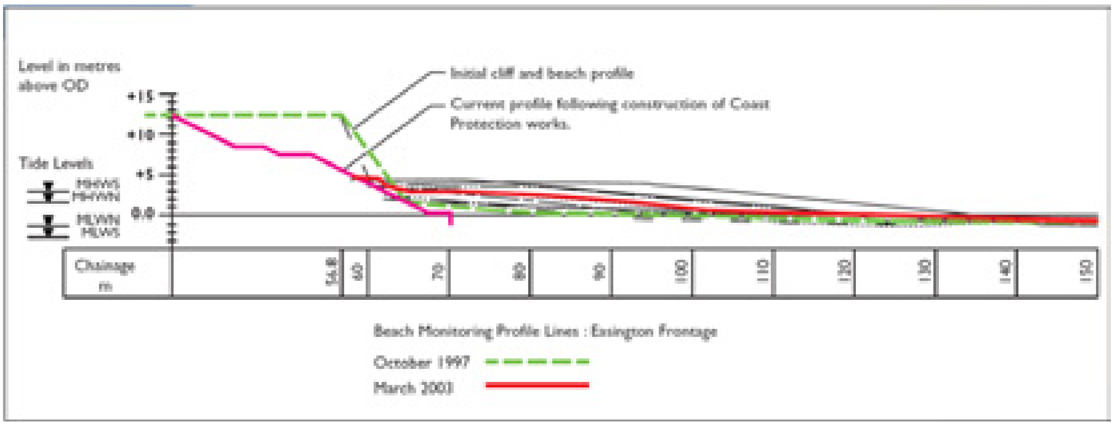


Figure 2.13: Typical presentation of beach profiles measurements for one of locations from the East Riding coastline of Yorkshire Council (UK). (Image source: http://www.eastriding.gov.uk/coastalexplorer/)

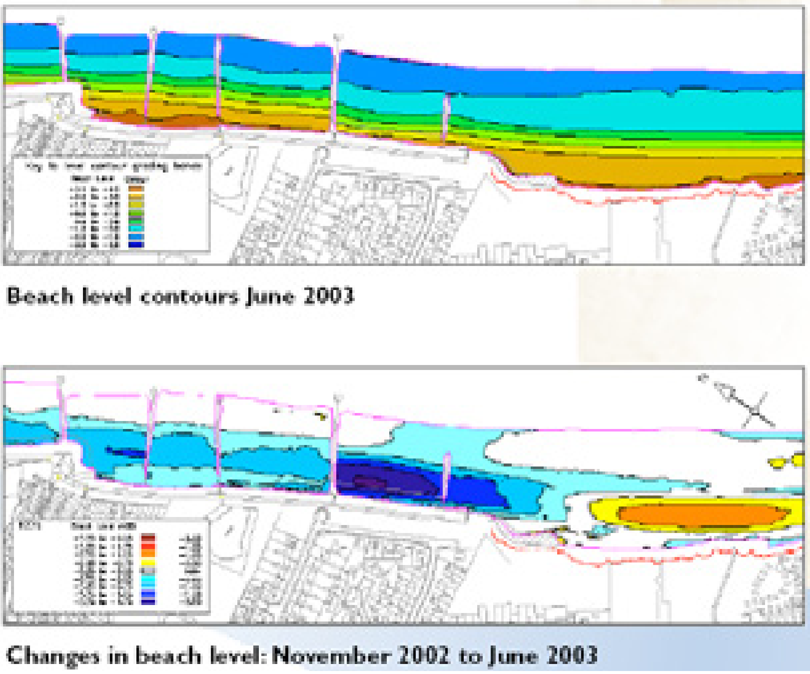


Figure 2.14: Typical presentation of processed beach monitoring results, East Riding coastline of Yorkshire Council (UK). (Image source: http://www.eastriding.gov.uk/coastalexplorer/)

2.3.3 Installation of professional weather stations

Materials and equipment:
• Professional weather stations • Laptop (with relevant software provided by weather station manufacture) + connection cable

To aim of this monitoring technique is to record wind speed and direction. This data can be useful together with tidal data (see Section 2.3.4) as periods of relatively stronger onshore winds and higher then usual spring tides will most likely correspond to erosion processes. These data can also be used in the set up of the numerical models (see Section 2.4).

Methodology:

- Weather stations (Figure 2.15) should be installed in exposed locations on both sides of the estuary. It is proposed to install three weather stations:
  - No 1: on the northern edge of Rush beach;
  - No 2: on the southern edge of Rush beach or northern edge of Portrane beach;
  - No 3: on the southern edge of Portrane beach.
- The installation should be performed as instructed in the manufacture's manual.
- Following installation, positions of the weather stations installed should be recorded with the GPS.
- The weather station will automatically record the data in relation to wind speed and direction onto the data logger. This data should be regularly (e.g. monthly) downloaded by a member of the coastal monitoring team.
- Every time a member of monitoring team is downloading the data – a full check of the system should also be performed.

Limitations:

- Weather stations if installed in the public place may be subjected to vandalism. It is preferential that weather stations are installed in relatively safe locations (e.g. within somebody's private property).

Figure 2.15: Typical weather station (Image source: http://www.onsetcomp.com).

2.3.4 Installation of tide gauges

Materials and equipment:
• Tide gauge set • Laptop (with calibration software provided by tide gauge manufacture) + connection cable • Water poof box for the tide gauge recorder (durable enough to withstand vandalism) • Protective plastic pipes for the tide gauge pressure cable (2 inch in diameter) • Portable drill (if installation requires attachment of the protective pipe to the pier) • Cable tires • Chain and lock • Tape measure with weight attached at the end • Information sign to be attached to the box (e.g. Tide Gauge, Property of Fingal County Council, etc.)

These data can also be used in the set up of the numerical models (see Section 2.4).

Methodology:

- The onshore tide gauge should preferably be installed on the pier in the location that never dries out (e.g. Figure 2.16).
- Installation should be performed in accordance with manufacture's manual.
- Details on the suitable equipment are provided in Appendixes 1 and 2.
- Record the position of the tide gauge installed using a GPS for further integration of this position within monitoring GIS.

These are the main steps that should be taken when installing a Portable Tide Gauge (Model 740 by Valeport) [Based on the authors' personal experience. Manufacture's manual still need to be consulted prior to installation]:

1) *Mark the tide gauge pressure cable at 1m intervals. This will allow to calculate the distance between transducer and datum point.*
2) *Make notes regarding installation process (to include sketch drawing), record and indicate on drawing distances to some apparent reference points (landmarks). Also take a note of all times during the installation and calibration process.*
3) *Set the tide gauge using the fieldwork laptop with the TideLog software installed (File name + correct time; set time interval (Burst Cycle) to 10min; length of reading (Burst Length) to 30sec).*
4) *The reading will start after the demi plug is in.*
5) *Perform the reading for 20min. During this time also perform manual measurements of the distance between pier and water surface with a tape measure (Figure 2.17). Connect the tide gauge to computer, retrieve data and check that the data is recorded, makes sense and match with manual readings of the tide height.*
6) *The tide gauge is now ready for deployment.*
7) *The data should be downloaded at least once a month. At the same time a full system check should be performed. Attention should be paid to any signs of physical damage especially to the pressure cable, batteries should be checked when the system is connected to the laptop.*

Limitations:

- Tide gauges may be subjected to vandalism. Therefore, members of the local community should be alerted to keep an eye on them and to watch out for any antisocial behaviour in the vicinity of their installation.

Figure 2.16: Example of the tide gauge (Model 740 by Valeport) installation, Dunmore East, Co. Waterford (Photos by Dr. Max Kozachenko). See Appendix 2 for full technical description of this system.

Figure 2.17: Example of the tide gauge (Model 740 by Valeport) installation, Co. Cork. The measuring tape with a metal bar attached to it is used for manual measurements of the tide height during the tide gauge set up process (Photo by Dr. Max Kozachenko).

2.3.5 Current and wave measurements

Materials and equipment:

- ADCP, AWAC
- Portable current meters

There are several options for suitable equipment details of which are provided in Appendixes 1 & 2.

This monitoring technique will aim to collect data on strength and direction of water currents and wave height and direction in a number of locations throughout the study

domain. These data can after be used in the set up of the numerical models (see Section 2.4).

There are two different equipment types and data collection options:

- Option 1: manual data collection from a pier or small boat using hand held light current meter (e.g. Model 106 Lightweight Current Meter by Valeport);
- Option 2: automated data collection using dedicated equipment installed on the seabed surface (ADCP (ADP – Acoustic Doppler Profiler) by SonTek, AWAC (Acoustic Wave and Current Profiler) by Nortek, etc.).

Option 2 is certainly more effective as it allows the collection of continuous record of current and wave data.

Equipment should be used and deployed following instructions provided in the manufacture's manuals.

Limitations:

- Option 1 has a temporal limitation as it is not possible to ensure 24hr manual data collection.
- Option 2 is more expensive on the equipment side and there is a risk of loosing equipment due to sediment transport or fishing activities.

2.3.6 Installation of stationary video observation stations

Materials and equipment:
• ARGUS Video System

Details in relation to the ARGUS Video System are provided in Appendix 3. The following website may also be consulted: http://www.planetargus.com/.

The cheaper option would be to install CCTV (web) cameras in several locations within the study domain from where the coastline can be clearly observed. These cameras can be set to either filming or snapshot mode.

The advantage of automated video observations in contrast to manual fixed aspect photographs that it allows to obtain continues record of coastal processes even during extreme weather conditions.

Limitations:

- As any other equipment left unattended, the video cameras may be subjected to vandalism.

2.3.7 Repeat aerial photography surveys

It is suggested to perform repeat annual areal photography surveys of the study domain. The aim is to collect high resolution areal digital photographs. These photographs should be geo-referenced using GIS. Further GIS analysis should provide information in relation to annual changes in position of the coastline as well as sediment movement patterns (if photographs are taken at low tide). This will,

therefore, supplement on the ground observations and measurements obtained through the use of GPS and coastal monitoring posts.

This data can be requested from the Ordinance Survey Ireland (OSI) (see Section 4.2). Alternatively, data collection can be commission to a private contractor.

Limitation:

- The surveys must be performed with consistent quality using same methods.
- The quality of the imagery obtained will be weather dependant. Therefore, survey days must have perfect weather conditions (no rain or clouds).

2.3.8 Repeat LIDAR surveys

LIDAR – Laser Imaging Detection and Ranging is a near-shore surveying technique particularly useful in rugged or complex bays (Figure 2.18). The use of aircraft allows the laser measurements to be made much more efficiently than surveying the same areas with boats and echo sounders. Tenix LADS Corporation of Australia (http://www.tenix.com) was contracted to undertake the survey for the INFOMAR programme (http://www.infomar.ie/). Their LADS system is based in a de Havilland Dash 8 aircraft and utilises pulses of light to measure water depth in shallow coastal regions. Sensors onboard the planes measure the difference between laser returns from the sea surface and seabed allowing the water depth to be calculated. Good quality data is normally achievable to depths of 20m and requires 200% coverage (i.e. to be flown twice), to manage tides, turbidity and low cloud levels.
(Info source: http://www.gsi.ie/Programmes/Marine/INFOMAR+2006+LIDAR.htm)

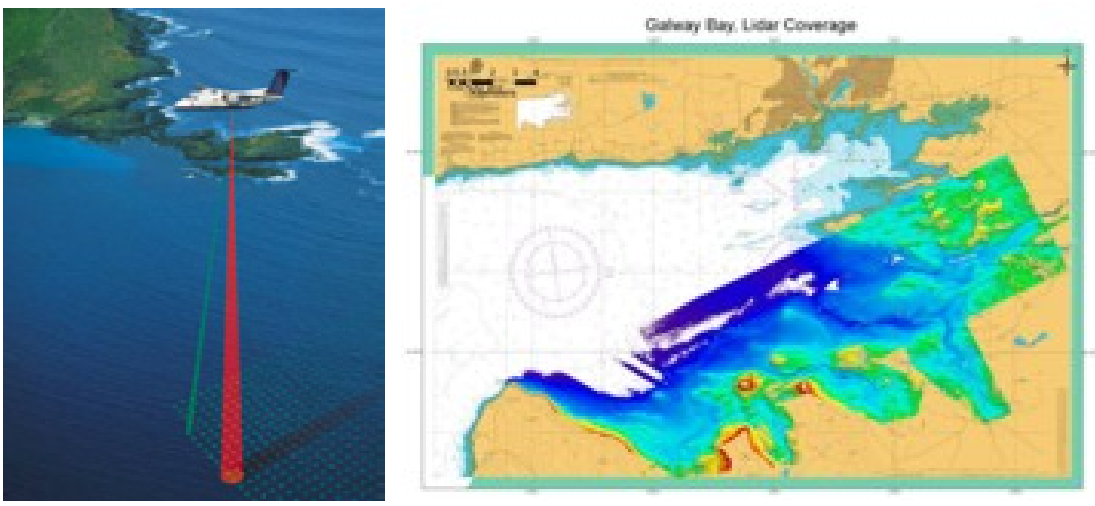


Figure 2.18: LIDAR data collection (left) and example of LIDAR data obtained for Galway bay (right).

The INFOMAR programme of the Irish Government will most likely map the intertidal area of the Rogerstown estuary using a LIDAR system in the next couple of years (Koen Verbruggen, INFOMAR coordinator, personal communication). This data will be made publically available free of charge. The data for some other bays around Ireland (incl. Bantry, Clew, Dunmanus, Galway, Killala, Mulroy) is already available for download from Interactive Web Data Delivery system (https://jetstream.gsi.ie/iwdds/index.html).

Following acquisition and processing the LIDAR data is integrated with multibeam data obtained for deeper waters to produce full coverage for the surveyed bays.

Repeat surveys can be performed by qualified subcontractors.

Depending on budget limitations it is suggested to perform repeat surveys at biannual or five-year intervals.

2.3.9 Repeat bathymetrical surveys

Multibeam technology delivers two data types: bathymetry and backscatter (Figure 2.19). The multibeam transducers (Figure 2.20-2.21) installed on the hull of the vessel send acoustic signal illuminating the seabed at a set angle, thus, producing high-resolution image of the seabed (Figure 2.19). This technique provides the basis for establishing overall seabed morphology and mapping the distribution of bedforms, whilst also allowing the distribution of various different sediment types to be inferred based on their acoustic characteristics. Shaded relief colour imagery allows to understand both seabed morphology and the distribution of bedforms, and hence to draw conclusions concerning localised hydrodynamic and morphodynamic conditions. Backscatter (greyscale) imagery reflects the acoustic characteristics of surface and near surface sediments. It is the function of sediment density and surface roughness and therefore is a valuable parameter for use in the process of seabed type classification. For instance, lighter backscatter tones are associated with sandier sediments, while darker tones are usually associated with coarser e.g. gravelly sediments.

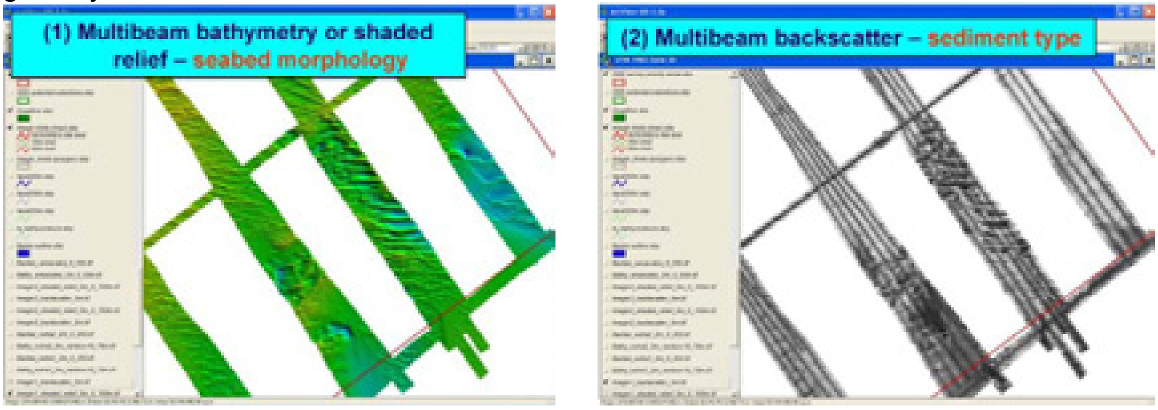


Figure 2.19: Two types of multibeam data simultaneously collected: (1) multibeam bathymetry and (2) multibeam backscatter.

Figure 2.20: Kongsberg Simrad EM 3002 multibeam transducer on RV Celtic Voyager.

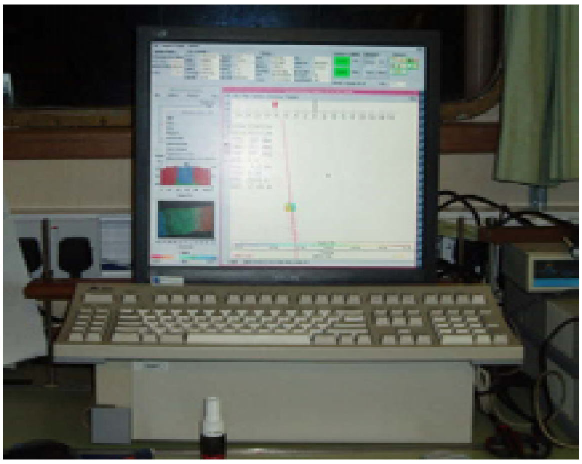


Figure 2.21: Multibeam acquisition system onboard RV Celtic Voyager (left) and multibeam acquisition principle (right).

The INFOMAR programme (http://www.infomar.ie/) of the Irish Government is planning to map the Rogerstown estuary using multibeam bathymetry in the next couple of years (Koen Verbruggen, INFOMAR coordinator, personal communication). This data will be made publically available free of charge. The data available to date can be downloaded from Interactive Web Data Delivery system (https://jetstream.gsi.ie/iwdds/index.html). This will produce a high quality baseline dataset that can be used for computer models (see Section 2.4).

Repeat bathymetrical surveys will also be very useful to understand sediment dynamic (sediment movement patterns in the near shore area). Calculation of sediment volume changes within the study domain will provide clues to understanding sediment sources that feed sediment supply to the beaches at Portrane and Rush. Due to shallow water depths in the near shore area it will take several days or maybe weeks to produce a complete coverage of the entire estuary using mutlibeam echosounder. Therefore, the cost of obtaining such data can be very expensive within the budget of this monitoring programme as the cost of one survey day will be on the scale of few thousand (e.g. €5,000 per day). However, there are alternatives to multibeam. For instance, repeat surveys can be carried our by subcontracted hydrographic companies or research organisations with the single beam echosounder. The cost of survey day can then be negotiated in the region of €1,000 per day. Extra costs will normally be charged for data processing.

Depending on budget limitations it is suggested to perform repeat surveys at biannual or five-year intervals.

2.4 Data required for a predictive computer model of the area

A number of coupled hydrodynamic and sediment models can be used to integrate the data from the monitoring programme in order to simulate the hydrodynamic and morphological behaviour of the system: e.g. MIKE 21 suite or the Delft3D modelling suite, XBeach etc. Setting up and applying a numerical model requires a complex of input and validation data. Knowledge is also required on how to correctly operate the software in order to obtain meaningful results. Once adequate monitoring data has been collected, the application of a numerical model may be considered to aid in further understanding the processes that are causing changes to occur in the system and to simulate the morphological changes occurring as a result of these processes.
For any model of beach and nearshore behaviour the following data will, at least, be required:

- An accurate bathymetry;
- Water levels/astronomic constituents at the boundaries of the model;
- Flow (current) data to calibrate and validate the hydrodynamic model;
- Information of the nature of the bed sediments i.e. particle size analysis to input into the sediment/morphological model;
- The volume of freshwater input;
- Information on salinity or thermal stratification in the estuary;
- Meteorological data (winds);
- Wave measurements if wave modelling is to be included.

Additional Information:

Mike 21 suite: http://www.dhigroup.com/Software/Marine/MIKE21.aspx

- **"MIKE 21 - Inland, Coastal Waters and Seas in 2D:** MIKE 21 is a professional engineering software package for the simulation of flows, waves, sediments and ecology in rivers, lakes, estuaries, bays, coastal areas and seas. The modelling system is designed in an integrated modular framework with a variety of add-on modules. This, in combination with the range of dedicated and easy to use tools and editors, allow you to customise your personal software package to suit your own specific needs, whether for simple or more complex 2D flow modelling needs."
- Contact Information:
  DHI
  Agern Allé 5
  DK-2970 Hørsholm
  Denmark

  Tel: +45 4516 9200 (Monday to Friday 8:30 to 16:30 GMT+1).
  Fax: +45 4516 9292
  General e-mail: dhi@dhigroup.com

Delft3D modelling suite:

The following packages developed by Deltares can be used for the purpose of this monitoring programme:

- **Delft3D-FLOW** models hydrodynamics, sediment transport and morphological change in three dimensions

- **Delft3D-WAVE**: The SWAN wave model simulates wave generation and propagation in coastal regions and harbours. It can be coupled with Delft3D-FLOW to provide a full current-wave simulation

The software is continuously updated and improved based on the latest research. For more information see http://delftsoftware.wldelft.nl/

Xbeach

Xbeach is a two-dimensional model for wave propagation, long waves and mean flow, sediment transport and morphological changes of the nearshore area, beaches, dunes and backbarrier during storms. It is a public-domain model that has been developed with funding and support by the US Army Corps of Engineers, by a consortium of UNESCO-IHE, Deltares, Delft University of Technology and the University of Miami. The main objective of the XBeach model is to provide a robust and flexible environment in which to test morphological modelling concepts for the case of dune erosion, overwashing and breaching.
For more information see http://www.xbeach.org/

2.5 Matrix of applicability of techniques for addressing objectives outlined in the tender.

The tender document specifies the following objectives:

- **Objective 1:** Monitor the rate of dune toe erosion and expansion along the dunes at Portrane and Rush;
- **Objective 2:** Find out why erosion is taking place at particular locations;
- **Objective 3:** Establish the rate of erosion and/or growth of beach levels on both beaches;
- **Objective 4:** Establish the spatial patterns of erosion and sedimentation within this subcell of the Irish Sea (e.g. how does sand move throughout this area);
- **Objective 5:** Find out how the estuary affects the sediment transport regime;
- **Objective 6:** Assess the influence of human activities and external natural forces that may affect erosion and sedimentation patterns and rates;
- **Objective 7:** To develop a computer model of the area showing the erosion and sedimentation patterns.

Table 2.3 lists monitoring techniques suggested in the previous sections of this report. These techniques have been colour-coded to reflect their usefulness, reliability of results and applicability to this study using the following colour scheme:

- **Green = Priority 1** (Useful and realistically applicable to this study and are likely to produce good quality results);
- **Yellow = Priority 2** (Useful and realistically applicable, but are likely to produce dubious results);
- **Red = Priority 3** (Useful if implemented correctly. Correct implementation is very complicated logistically).

Table 2.3: A list of coastal monitoring techniques suggested by this report.

2.2 Coastal monitoring techniques for community based approach
• 2.2.1 Manual measurements of coastline position in relation to fixed landmarks
• 2.2.2 GPS measurements of coastline position
• 2.2.3 Manual measurements of beach sediment levels
• 2.2.4 Evaluation of sediment movement patterns in the intertidal area though compass supported measurements of ripple crests orientation
• 2.2.5 Evaluation of sediment movement patterns in the intertidal area though experiments with tracing (dyed) sand
• 2.2.6 Visual surveillance of coastal changes supported with photo/video evidence
• 2.2.7 Visual surveillance of human activities on the beach supported with notes, photo and/or video evidence
2.3 Coastal monitoring techniques requiring professional input
• 2.3.1 DGPS measurements of coastline position
• 2.3.2 Beach level surveys at low tide (DGPS or levelling)
• 2.3.3 Installation of professional weather stations
• 2.3.4 Installation of tide gauges
• 2.3.5 Current and wave measurements
• 2.3.6 Installation of stationary video observation stations
• 2.3.7 Repeat aerial photography surveys
• 2.3.8 Repeat LIDAR surveys
• 2.3.9 Repeat bathymetrical surveys

The following table presents a matrix of applicability of techniques for addressing objectives outlined in the tender document.

Table 2.4: Applicability matrix of monitoring techniques for addressing objectives outlined in the tender document.

	Monitoring Techniques	**2.2.1**	**2.2.2**	**2.2.3**	**2.2.4**	**2.2.5**	**2.2.6**	**2.2.7**	**2.3.1**	**2.3.2**	**2.3.3**	**2.3.4**	**2.3.5**	**2.3.6**	**2.3.7**	**2.3.8**	**2.3.9**
Objectives	Objective 1	Y	Y				Y		Y						Y	Y	
	Objective 2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Objective 3			Y						Y					Y	Y	Y
	Objective 4	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
	Objective 5			Y		Y			Y	Y		Y	Y		Y	Y	Y
	Objective 6						Y	Y			Y	Y	Y	Y			
	Objective 7									Y	Y	Y	Y			Y	Y

3. Proposed optional plans for implementing monitoring programme

The following figure presents an overview of the optional plan for implementing monitoring programme described above for the whole study domain.

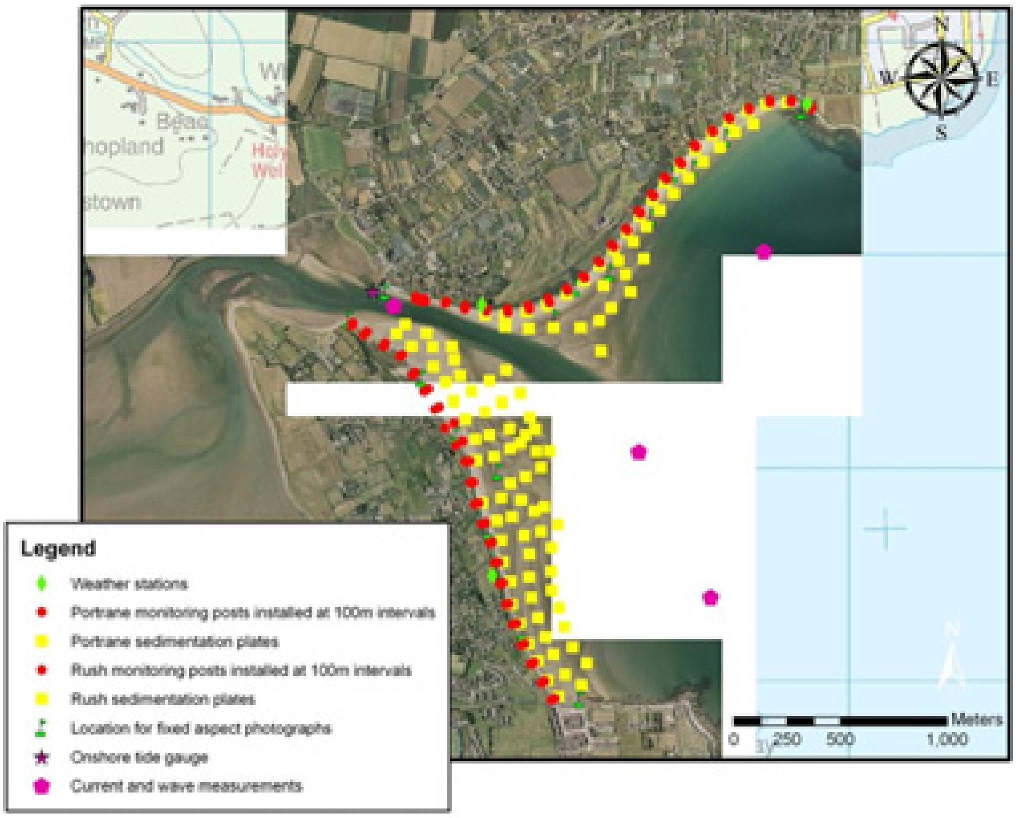


Figure 3.1: Overview map showing suggested optional locations for monitoring stations at Portrane and Rush beaches, Co. Dublin. Coastal monitoring posts are installed in pairs at c.100m intervals. Sedimentation plates are distributed throughout the study domain to provide information on changing beach sediment level at resolution comparable to monitoring post data. Potential locations for implementing other monitoring techniques described in section 2 are also indicated.

Figure 3.2: Zoom into the northern part of the Rush beach showing suggested locations for monitoring stations.

3.1 Portrane beach

The following figure presents the optional plan for implementing monitoring programme described above for the Portrane beach, Co. Dublin.

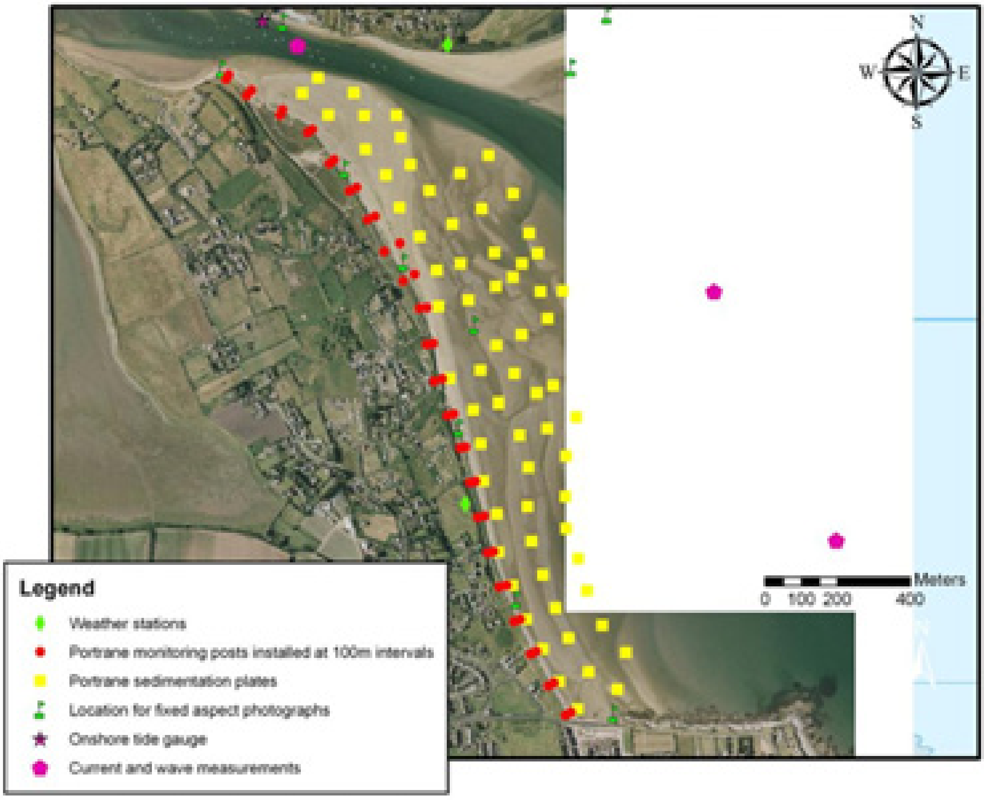


Figure 3.3: Overview map showing suggested optional locations for monitoring stations at Portrane beach, Co. Dublin. Coastal monitoring posts are installed in pairs at c.100m intervals. Sedimentation plates are distributed throughout the study domain to provide information on changing beach sediment level at resolution comparable to monitoring post data. Potential locations for implementing other monitoring techniques described in section 2 are also indicated.

3.2 Rush beach

The following figure presents the optional plan for implementing monitoring programme described above for the Rush beach, Co. Dublin.

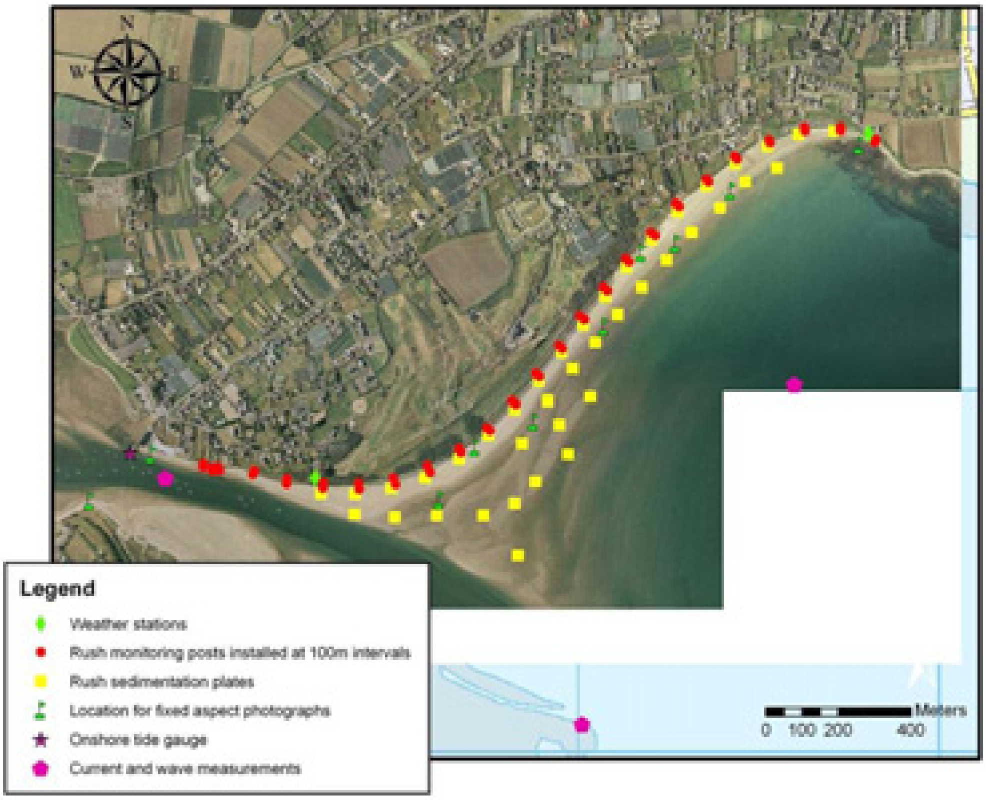


Figure 3.4: Overview map showing suggested optional locations for monitoring stations at Rush beach, Co. Dublin. Coastal monitoring posts are installed in pairs at c.100m intervals. Sedimentation plates are distributed throughout the study domain to provide information on changing beach sediment level at resolution comparable to monitoring post data. Potential locations for implementing other monitoring techniques described in section 2 are also indicated.

4. Overview of existing baseline relevant data

Before setting up any monitoring programme it is recommended to collate and evaluate all relevant baseline data. Analysis of some historic baseline data might potentially help to find out what changes to the coastal system happened in the past and, therefore, such analysis might help to predict the future trends.

Moreover, the existence of a baseline dataset (e.g. DTM, aerial photograph, etc.) makes it cheaper to turn this into a monitoring programme through obtaining same data on a regular basis at consistent time intervals. For example, the following monitoring methods can be developed from some of the baseline data described below:

- Repeat multibeam or single beam bathymetrical surveys (at 5 years interval);
- Repeat aerial photography surveys (at 1 year interval);
- Repeat LIDAR surveys of the intertidal area (at 1-2 year interval).

The following sections summarise information in relation to data most relevant for the purpose of this monitoring programme.

4.1 Google Earth

Google Earth is a free online application that provides free access to satellite imagery. It can prove to be useful for planning your fieldwork and site visits. It is also useful for quick post-fieldwork visualisation of your GPS points and tracks due to a user-friendly interface that allows hassle-free importing of data from your hand-held GPS (Figure 4.1). Google Earth also allows you to overlay any raster data converted to kmz format (e.g. multibeam bathymetry, Lidar coverage, etc.).

Figure 4.1: Example of integration of the survey tracks and survey points from a hand held GPS within Google Earth (site visit to the Fingal coast undertaken by the authors during preparation of this report).

4.2 Aerial Photography by OSI

"The Ordnance Survey can provide monochrome or colour aerial photography from a large archive dating back to the 1960s. Photography is available as prints, or diapositives. Enlargements in both full colour or black and white are also available. A number of additional services are also available, including scanning of imagery and flying photography to customer specified requirements." (Info source: http://www.osi.ie)

Contact Information:

Ordnance Survey Ireland,
Phoenix Park,
Dublin 8

Reception: +353-1-802-5300
Lo-Call Number: 1890-674 -627
Office Opening Hours
Monday - Friday 9.00am to 4.45pm

Aerial Photography Sales
e-mail: photosales@osi.ie
phone: +353-1-824-7577
fax: +353-1-822-0979

4.3 Oblique areal photographs (Dept of Transport)

Oblique geo-referenced areal photographs of the complete coastline of the Republic of Ireland have been collected from a helicopter in 2003. These are available free of charge from http://gis3.dcmnronline.ie/imf5104/imf.jsp?site=Helicopter.

4.4 Terrestrial LIDAR by OPW

Some terrestrial LIDAR data have been collected by the Office of Public Works (OPW) as part of the flood monitoring programme. For more information please refer to http://www.opw.ie.

4.5 Future INFOMAR bathymetrical survey

See Section 2.3.9. The coverage obtained to date by the INFOMAR and other partner projects can be viewed at http://www.infomar.ie.

4.6 Future INFOMAR LIDAR survey

See Section 2.3.8. The coverage obtained to date by the INFOMAR and other partner projects can be viewed at http://www.infomar.ie.

5. Conclusions and recommendations

The monitoring programme at Portrane and Rush beaches, Co. Dublin should be undertaken in the following stages:

- First, the baseline data available should be collated and analysed. This should include existing aerial photographs, historical maps, plans and charts; bathymetrical, LIDAR, meteorological, tide, wave and current data.
- Based on these analyses a detailed implementation plan for the monitoring programme should be developed taking into account recommendations presented by this report.
- Each of the monitoring technique described above should be first undertaken on a pilot basis before implementing to the whole study domain.
- Following successful completion of the pilot (test) exercises, full monitoring programme should be strategically implemented.
- For all monitoring techniques it is important to keep up regular measurements at consistent scheduled time intervals.
- In order to stimulate the involvement of the local community it is suggested to disseminate monitoring results on the ongoing basis through a webGIS interface (e.g. http://imagin.ucc.ie; http://mida.ucc.ie; http://multiclass.ucc.ie; http://www.eastriding.gov.uk/coastalexplorer).

6. References and links to relevant online information

Black, K.S., Athey, S., Wilson, P. and Evans, D. (2006) The use of particle tracking in sediment transport studies: a review. In: Balson, P., et al., (Eds.) Journal of the Geological Society of London (Special Issue) Measuring Sediment Transport on the Continental Shelf. 2006.

Collinson, J.D., Mountney, N. and Thompson, D.B. (2006) Sedimentary Structures. Terra Publishing, ISBN: 1-903544-19-X, 292pp.

Gault, J., Morrissey, C., Devoy R. (2007) Dune Protection Plan for the Fingal Coast, Co. Dublin. Report for Fingal County Council. University College Cork.

Ingle, J.C. (1966) The movement of beach sand. Developments in Sedimentology, Vol. 5, 221 pp.

White, T.E. (1998) Status of measurement techniques for coastal sediment transport. Coastal Engineering, Vol. 35, p. 1745.

Strategic Regional Coastal Monitoring Programmes of England (The Channel Coastal Observatory is the data management centre for the Regional Coastal Monitoring Programmes and is hosted by New Forest District Council, in partnership with the University of Southampton and the National Oceanography Centre, Southampton.) http://www.channelcoast.org/

Scottish Natural Heritage. A guide to managing coastal erosion in beach/dune systems. Appendix 2 Monitoring erosion and change in dune systems. http://www.snh.org.uk/publications/on-line/heritagemanagement/erosion/appendix_2.shtml

Beach Erosion Monitoring, Results from BEACHNED-e/ OpTIMAL Project, edited by Enzo Pranzini & Lilian Wetzel. Available online from http://www.beachmed.eu/Portals/0/SOUSPROJETS/2_1%20OPTIMAL/BeachErosion%20lowres.pdf

EU CoastView Program http://coastalresearch.nl/research/finished-projects/eu-coastview

Manual Sediment Transport Measurements in Rivers, Estuaries and Coastal Seas. by L.C. van Rijn (Delft Hydraulics and University of Utrecht, The Netherlands) issued by Rijkswaterstaat (Public Works Department in The Netherlands) and Aqua Publications. L.C. van Rijn is senior research and project engineer of the Delft Hydraulics Laboratory. 2006-2007.
http://www.wldelft.nl/rnd/intro/fields/morphology/manual.html#indexmanual

ENCORA Coastal Portal. The Coastal Wiki - short name for Coastal and Marine Wikipedia - is an Internet encyclopaedia providing up-to-date high quality information for coastal professionals, which is continuously improved, complemented and updated by expert users. http://www.coastalwiki.org/coastalwiki/Main_Page

Coastal Research. This website presents an overview of the activities of the Coastal Research group at the Department of Physical Geography at Utrecht University, the Netherlands. http://coastalresearch.nl/

Coastal Explorer. Web portal developed by East Riding of Yorkshire Council, UK. http://www.eastriding.gov.uk/coastalexplorer/

http://www.aquapublications.nl/ This site provides information on books on fluid mechanics (currents and waves), sediment transport (mud, sand and gravel), morphology (sedimentation and erosion), in rivers, estuaries and coastal seas.

Environmental Tracing - Sand Tracers.
http://www.emulimited.com/laboratories/microbiowq/environmentaltracing.htm

Appendix 1: Approximate costs for selected materials and equipment

As part of this project provisional quotes have been obtained for the key equipment required to implement monitoring methods described in Section 2 of this report. This Appendix presents tables summarising equipment and material, cost per unit and quantity required. This is followed by more detailed quotes and information about selected equipment.

Instruments required for community based monitoring
Hand held GPS
Digital photo camera
Compass
Measuring tape
Metal detector
Spirit level
Spade for digging sand
Soil drill (same as for taking sediment cores or drilling for water or post fixing holes)
Heavy hammer

Other materials and consumables
Notepad with pen and pencil + waterproof casing
Sedimentation plates
Metal graded measuring rods
Metal/wooden/plastic coastal monitoring posts
Information signs
Tracing (coloured/dyed) sand

Additional instruments that may be required for professional monitoring
ADCP
Current meters
DGPS
Optical or digital level (EDM)
Rib or small boat with echosounder (for bathymetrical surveys)
Tide gauge
Weather station (Anemometer)
Laptop for data logging

Table A1.1: Summary of approximate prices for the main equipment. Please note that several equipment options are listed for certain equipment types. The most reasonable model should be selected following consideration of available budget and local setting (e.g. operational water depth, sediment type, risk of loss, etc). Please also note that some prices are approximate and some were quoted to the University College Cork at a time of report production. Therefore, variation of the factual price should be expected. Extras such as radio transmitting units for some equipment come at an extra cost.

No	Equipment	Approximate Price per unit (€)	Delivery costs (€)	Number of units required
1	Hand held GPS (GARMIN eTrex HC series) (e.g. supplier: CH Marine)	150	NA	5-10
2	Digital photo camera (e.g. CANON IXUS 100)	210-300	NA	5
3	Compass (e.g. from Argos)	15-25	NA	10
4	Metal detector (e.g. from Argos)	100-150	NA	2
5	Spirit level (STANLEY) (e.g. from B&Q)	20-30	NA	10
6	50m measuring tape (e.g. from B&Q)	20-50	NA	10
7	**AWAC (Acoustic Wave and Current Profiler) (Nortek)****	**c. 17,000**	**Included**	**1-3**
8	**ADCP (ADP) (SonTek)**	**c. 17,000**	**TBC**	**1-3**
9	**Model 106 Lightweight Current Meter (Valeport)**	**TBC**	**Extra**	**1**
10	**Model 001 & 002 Open Channel Flow Meters (Valeport)**	**1,900-2,000**	**Extra**	**1**
11	**MODEL 801 SINGLE AXIS ELECTROMAGNETIC FLOW METER (Valeport)**	**2,312**	**Extra**	**1**
12	**Model 740 Portable Tide Gauge (Valeport)**	**1,720**	**Extra**	**1**
13	**TideMaster Portable Tide Gauge (Valeport)**	**1,950**	**Extra**	**1**
14	**MIDAS WTR Wave & Tide Recorder (Valeport)***	**6,380**	**Extra**	**1**
15	**MIDAS DWR Directional Wave & Tide Recorder (Valeport)***	**10,200**	**Extra**	**1**
16	**DGPS *****	**NA**	**NA**	**1**
17	Laptop for data logging	500-1000	NA	1-2

* NOTE: Maximum operating depth for wave monitoring is 20m.
** NOTE: Maximum operating depth for wave monitoring is 60m.
*** Available in-house within the Fingal County Council.

Table A1.2: Summary of approximate prices for other materials and consumables.

No	Materials	Approximate Price per unit (€)	Delivery costs (€)	Number of units required
1	Wooden posts (3000x80x80mm)	15	Extra*	23-176**
2	Recycled plastic posts (3000x100x100mm)	55	Extra*	23-176**
3	Recycled plastic posts (3600x100x100mm)	62	Extra*	23-176**
4	Metal posts (3000x100x100mm)	150	Extra*	23-176**
5	Metal sedimentation plates	75-150***	Extra*	20-150
6	Metal graded measuring rod	20-50	NA	5
7	Notepad with pen and pencil + waterproof casing	10-15	NA	20

***** Taking into account that this will be a comparatively large order it is likely that most supplies will offer free delivery.

** The number of posts will depend on the monitoring implementation approach chosen (see Section 2.2.1: Tables 2.1-2.2).

*** The price will depend on the size of the plates.

Note on cost saving measures:

As a cost saving measure it is worth testing the use of the standard concrete paving tiles 400x400x50mm as sedimentation plates. The average cost of such tiles is in the region of €3.5-5 from any DIY/Garden Centre or from a factory. There are two main issues: 1) to establish if the tiles moves (vertically, tilt) after the installation; 2) the tile will be more difficult to find as it will not be detected by a metal detector.

Costs may also be significantly reduced if the use is made of DIY capabilities of members of the local community involved in the monitoring programme. People from relevant trades (e.g. welders, plumbers, etc.) as well as DYI enthusiasts should be consulted if they are willing to do the work required on a voluntary basis or below market price prior to subcontracting any job to a commercial contractor.

More detailed quotes obtained for selected equipment are listed below:

Quotes from Nortek (http://www.nortek-as.com/)

AWAC (Acoustic Wave and Current Profiler)
================================
Direct reading / Self recording 3D Acoustic current meter
with directional wave data option (Acoustic Surface Tracking).
Includes Temperature, Flux-gate compass, Tilt and Pressure
sensors. Internal 2 Mb memory, RS232 (10m) comms cable,
RS 232 output with single analogue in (8 pin)
c/w Basic configuration and deployment software
plus spares, toolkit, manual and professional transit case.
Prices including AST:
600 KHz Four beam system (0-100m Press sensor)
Euro 15220

Memory Upgrade
176Mb (Total capacity 178Mb)
Euro 963

External Battery Packs (includes batteries)
Aluminium housing for 36 D cell pack (540 Wh)
c/w cable (Depth rated to 500m)
Euro 814

Total cost = 16997 Euro
==================

Alternative System configurations

- Alternative memory option 352MB (Total capacity 354MB)
  Euro 1718

- Aluminium housing for 2 x 36 D cell pack (1080 Wh)
  c/w cable (Depth rated to 500m) Euro 1200

- Storm post processing software for extracting wave
  data c/w full graphics package. Euro 1840

Notes
====
Prices at quoted in Euros and include delivery to Cork

Weather stations can be ordered from the following company:

Eileen Sandherr, Sr. Application Specialist

e-mail: Eileen_Sandherr@onsetcomp.com

Direct: 1-508-743-3154

Toll free: 1-800-564-4377 X 3154

Fax: 508-759-9100

http://www.onsetcomp.com

Note regarding costs: Price will depend on the particular configuration. The fully functional weather station purchased by University College Cork in 2005 cost $1750.

Appendix 2: Technical information for selected equipment

Recommended Hand held GPS system:

eTrex Venture® HC (https://buy.garmin.com) system represents a good combination of price and quality.

eTrex Venture HC is an essential for any outdoor excursion. It features a high-sensitivity GPS receiver for peak performance in any environment and includes 24 megabytes (MB) of internal memory, a detailed basemap and crisp color screen.

Enjoy Clear Reception
With its high-sensitivity, WAAS-enabled GPS receiver, eTrex Venture HC locates your position quickly and precisely and maintains its GPS location even in heavy cover and deep canyons. The advantage is clear — whether you're in deep woods or just near tall buildings and trees, you can count on Venture HC to help you find your way when you need it the most.

Add More Detail
eTrex Venture HC's basemap contains lakes, rivers, cities, interstates, national and state highways and coastlines. Venture HC also includes 24 MB of internal memory, so you can load waypoints and routes from the included MapSource® Trip & Waypoint Manager software and add map detail from Garmin's entire line of optional MapSource® mapping products. Its 256-color, sunlight-readable display makes it easy to distinguish map details — even in bright sunlight.

Specs:

Physical & Performance:	
Unit dimensions, WxHxD:	2.2" x 4.2" x 1.2" (5.6 x 10.7 x 3.0 cm)
Display size, WxH:	1.3" x 1.7" (3.3 x 4.3 cm)
Display resolution, WxH:	176 x 220 pixels
Display type:	256 level color TFT
Weight:	5.5 oz (156 g) with batteries
Battery:	2 AA batteries (not included)
Battery life:	14 hours
Waterproof:	yes (IPX7)
Floats:	no
High-sensitivity receiver:	yes
Interface:	USB
RoHS version available:	yes

Maps & Memory:	
Basemap:	yes
Preloaded street maps:	no
Ability to add maps:	yes
Built-in memory:	24 MB
Accepts data cards:	no
Waypoints/favorites/locations:	500
Routes:	50
Track log:	10,000 points, 10 saved tracks

Features:	
Automatic routing (turn by turn routing on roads):	no
Electronic compass:	no
Touchscreen:	no
Barometric altimeter:	no
Geocaching-friendly:	yes
Camera:	no
Outdoor GPS games:	yes
Hunt/fish calendar:	yes
Sun and moon information:	yes
Tide tables:	no
Area calculation:	yes
Custom POIs (ability to add additional points of interest):	no
Unit-to-unit transfer (shares data wirelessly with similar units):	no
Picture viewer:	no

AWAC™

with Acoustic Surface Tracking (AST)

- ✓ **Wave height**
- ✓ **Wave direction**
- ✓ **Full current profile**

...all with a single instrument

The Nortek AWAC is a revolutionary instrument that gives you both a current profiler and a wave directional system in one unit. You can measure the current speed and direction in 1-m thick layers from the bottom to the surface and you can measure long waves, storm waves, short wind waves, or transient waves generated by local ship traffic.

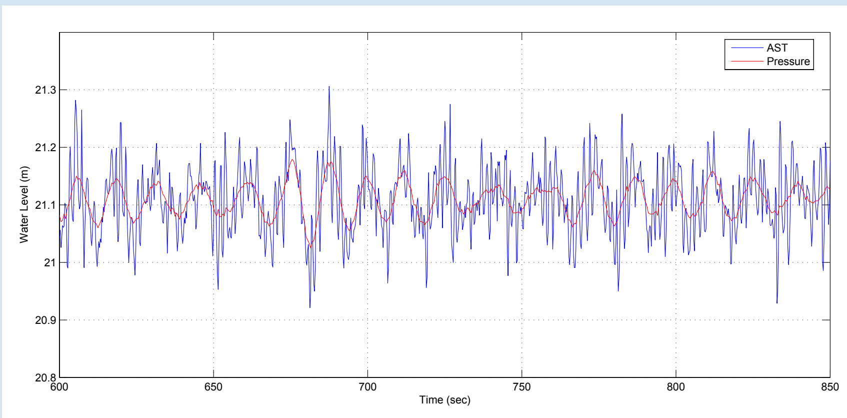
The AWAC is designed as a coastal monitoring system. It is small, rugged, and suitable for multi-year operation in tough environments. It can be operated online or in stand-alone mode with an internal recorder and batteries.

The sensor is usually mounted in a frame on the bottom, protected from the harsh weather and passing ship traffic.

The mechanical design is all plastic and titanium to avoid corrosion. Online systems can be delivered with protected cables, interface units on shore, acoustic modems and backup batteries. In stand-alone use, the raw data are stored to the recorder, and power comes from an external battery pack. A variety of options are available to achieve your required combination of deployment length and sampling interval.

The AWAC software is used to configure the instrument for deployment, retrieve the data and convert all data files to ASCII, and view all the measured current profiles and wave data. In order to calculate the wave parameters, the non-graphical "Quickwave" software will generate ASCII files with all the interesting wave parameters, "Storm" gives you several graphical views of the processed data, and "SeaState" provides online information.

As the plotted time series indicates, both the AWAC's pressure and AST time series capture the long waves. The notable difference is that the AST is capable of measuring the shorter waves superimposed on the longer waves. The AST advantage becomes more relevant and clear as the deployment depths become greater.



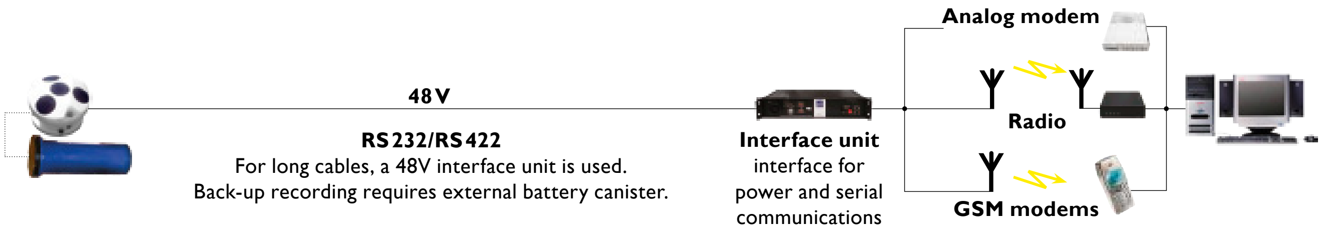
NORTEK AS

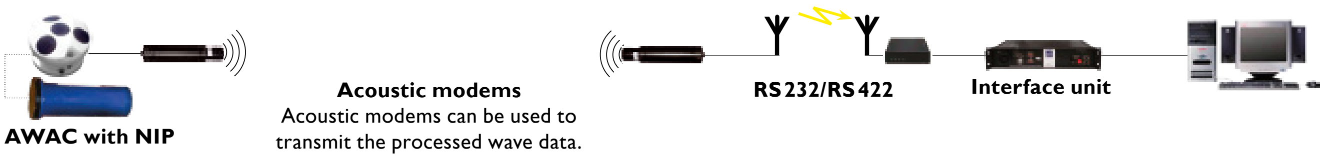
www.nortek.no

Online Solutions

AWACs can be deployed for long term monitoring of the local wave and current conditions.
Depending on the specific circumstances, Nortek can provide long cables, radio/telephone communication equipment, acoustic modems, etc., that can meet the requirements of your specific project.

For cable lengths < 100 m, standard cable can be used. For lengths > 100 m and/or tough environments, offshore cable should be used.
In RS422 configuration, cable communication can be achieved for distances up to 5 km.





NIP- Nortek Internal Processor

The NIP is a micro computer that fits inside the AWAC. It processes the raw wave data to provide estimates of wave height, period, and direction. Reduction of wave data is valuable when considering low bandwidth communications (e.g. acoustic modems).

The NIP is easily configured with the NIPtalk software or the online software SeaState. Data output may be as detailed as full spectral information or simple as basic wave estimates; the output format is either binary or user defined ASCII strings.

NIP Specifications

Memory	25 Mb
Processor	320 MHz
Dimensions	54 X 110 mm

Power Consumption

Active state	600 mW
Low power state	110 mW
Sleep state	10 mW

Modes

Command
Transparent
Master (data streaming)
Polled (request data/measurement)

Data Products (binary or ASCII)

Current Profiles
Sensor data
Wave estimates (Height, Period, Direction)
Energy spectra
Directional spectra
Spreading spectra
Fourier coefficient spectra

Stand-alone Solution

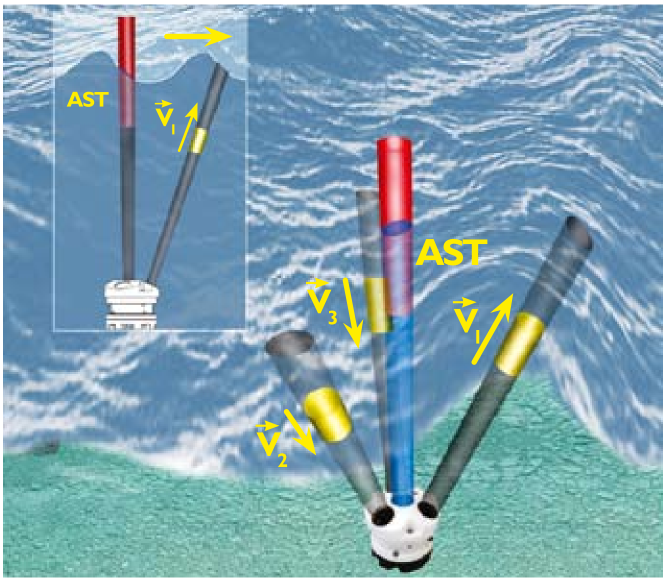
The AWAC can collect data to the internal recorder if it is deployed with an external battery canister. The AWAC software is used to configure the data collection interval for both current profile and wave data.
Typical deployment duration is 1-6 months, depending on the recorder size, battery option and data collection strategy.

AWAC Wave Measurements

Optimized wave data collection measurements begins with a well designed instrument. The AWAC measures three different wave quantities that allow us to arrive the estimates of wave height and wave period. These quantities are pressure, wave orbital velocity, and surface position. The pressure is measured with a high resolution piezo-resistive element. The orbital velocity is measured by the Doppler shift along each beam. The surface position is measured with Acoustic Surface Tracking (AST), a special mode where the instrument acts as an inverted echo sounder.

The fact that waves are a random event requires that measurements are made over defined periods of time, or bursts. Typically these bursts are 512, 1024, or 2048 seconds in length and sampled at 1–4Hz.

The measurement cells and the AST window are adaptively configured during the current profile which immediately precedes the wave burst. The position and size of the velocity cell as well as the AST window are determined based on the minimum pressure. By adaptively configuring the burst measurements, the AWAC not only ensures a maximized signal level and data quality for widely varying wave conditions, but it also permits the AWAC to automatically account for extreme tidal variations.



The AWAC measures three different wave quantities that allows us to arrive at the estimates of wave height and wave period. These quantities are pressure, wave orbital velocity, and surface position. The pressure is measured with a high resolution piezo-resistive element. The orbitual velocity is measured by the doppler shift along eack beam. The surface position is measured with Acoustic Surface Tracking (AST), a special mode where the instrument acts as an inverted echo sounder.

Wave Processing

The non directional wave estimates are available from the three independent spectra: pressure, velocity, and AST. The frequency range of these estimates increases respectively: pressure, velocity, AST.

The determination of wave directional estimates is a little more complicated, and may be performed with either the Maximum Likelihood Method (MLM) or a special triplet solution known as the SUV method. The MLM exploits the time-lag between the array of the three spatially separated velocity and AST measurements to determine wave direction.

The solution attempts to determine the direction that provides the best agreement between all four of these measurements. This calculation is performed at discrete frequencies. The end result is a description of the energy distribution in both direction and frequency.

One distinct advantage of using array measurements, is that the method is capable of resolving waves at the same frequency coming from two different directions. One scenario would be identifying incident and reflected waves from a coastal structure.

The SUV approach differs from the MLM approach in the sense that it uses the measurements as a triplet (similar to a wave buoy or PUV instrument). The triplet is composed of the AST and the horizontal velocity estimates of U and V. The advantage of the SUV method is that the AWAC may be mounted on a subsurface buoy allowing it to rotate freely, which is not possible with array solutions like the MLM. The ability to mount the AWAC on a subsurface buoy comes from the fact that the tilt and heading sensors are sampled at a similar rate as the wave measurements, and as a result these estimates may be converted to an Earth frame of reference.

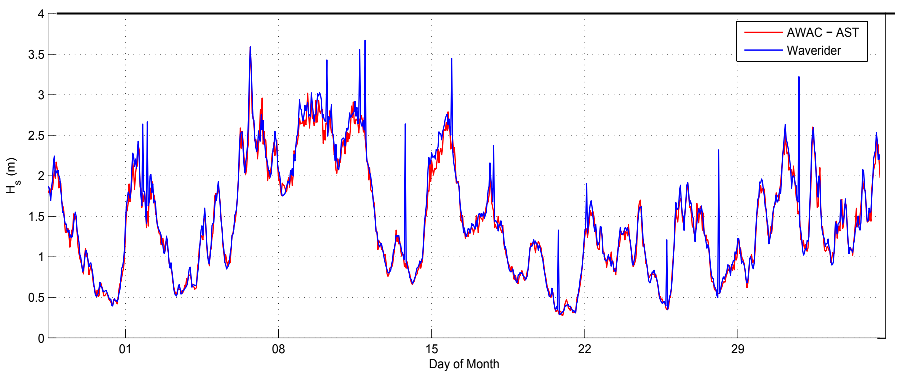
AST defined

For AST it all lies in a dedicated vertical beam where a short acoustic pulse is transmitted by the center beam and the return is finely resolved such that a sub centimeter resolution is achieved.

The AST is not subjected to attenuation as the velocity and pressure signals, so it provides a direct measurement of the free surface. This means that the AWAC is not limited to measuring just the long waves, but all ocean waves. Resolvable wave periods can be as low as 0.5 seconds.

Apart from circumventing the limitations associated with measuring an attenuated quantity, the AST provides a time series of the free surface which allows for enriched data analysis. This includes identifying nonlinear waves, evaluating transient waves (ship wake), and important time series estimates such as H_{max}, H_{10}, T_{mean}, T_{max}, etc. These estimates are unique to AST and cannot be properly determined with just the velocity or pressure measurements. Furthermore, when the AST is included in the MLM solution, the directional estimates becomes much more accurate than without the AST.

Significant wave height estimates compared for the AWAC-AST (red) and the Waverider buoy (blue). Data shows both small and large wave measurement capabilities. Data was collected on the east coast of the UK in 32 meters depth.



Specifications

System

Acoustic frequency	1MHz or 600kHz
Acoustic beams	4 beams, one vertical, three slanted at 25°
Operational modes	Stand-alone or online monitoring

Current Profile

Maximum range	30m (1MHz), 50m (600kHz) (depends on local conditions)
Depth cell size	0.4 – 4.0m (1MHz) 0.5 – 8.0m (600kHz)
Number of cells	Typical 20–40, max. 128
Maximum output rate	1s

Velocity measurements

Velocity range	±10m/s horizontal, ±5m/s along beam
Accuracy	1% of measured value ±0.5cm/s

Doppler uncertainty

Waves	3.5cm/s at 1Hz for 2m cells
Current profile	1cm/s (typical)

Wave measurements

Maximum depth	40m (1MHz), 60m (600kHz)
Data types	Pressure, one velocity cell along each slanted beam, AST
Sampling rate (output)	1Hz/2Hz standard, 2Hz /4Hz AST (1MHz), 1Hz standard, 2Hz AST (600kHz)
No. of samples per burst	512, 1024, or 2048

Wave estimates

Range	-20 to +20m
Accuracy/resolution (Hs)	<1% of measured value/1cm
Accuracy/resolution (Dir)	2° / 0.1°
Period range	0.5-30sec

Depth (m)	cut-off period (Hs)	cut-off period (dir.)
5	0.5 sec	1.5 sec
20	0.9 sec	3.1 sec
60	1.5 sec	5.5 sec

Sensors

Temperature	Thermistor embedded in housing
Range	–4°C to 40°C
Accuracy/ Resolution	0.1°C/0.01°C
Time constant	<10 min
Compass	Flux-gate with liquid tilt
Accuracy/Resolution	2°/0.1° for tilt <20°
Tilt	Liquid level
Accuracy/Resolution	0.2°/0.1°
Up or down	Automatic detect
Maximum tilt	30°
Pressure	Piezoresistive
Range	0–50m (standard)
Accuracy/Resolution	0.5% of full scale/ Better than 0.005% of full scale per sample

Transducer configurations

Standard	3 beams 120° apart, one at 0°
Asymmetric	3 beams 90° apart, one at 5°

Data Recording

Capacity (standard)	2 MB, expandable to 26/82/154MB
Profile record	Ncells×9 + 120
Wave record	Nsamples×24 + 46

Data Communication

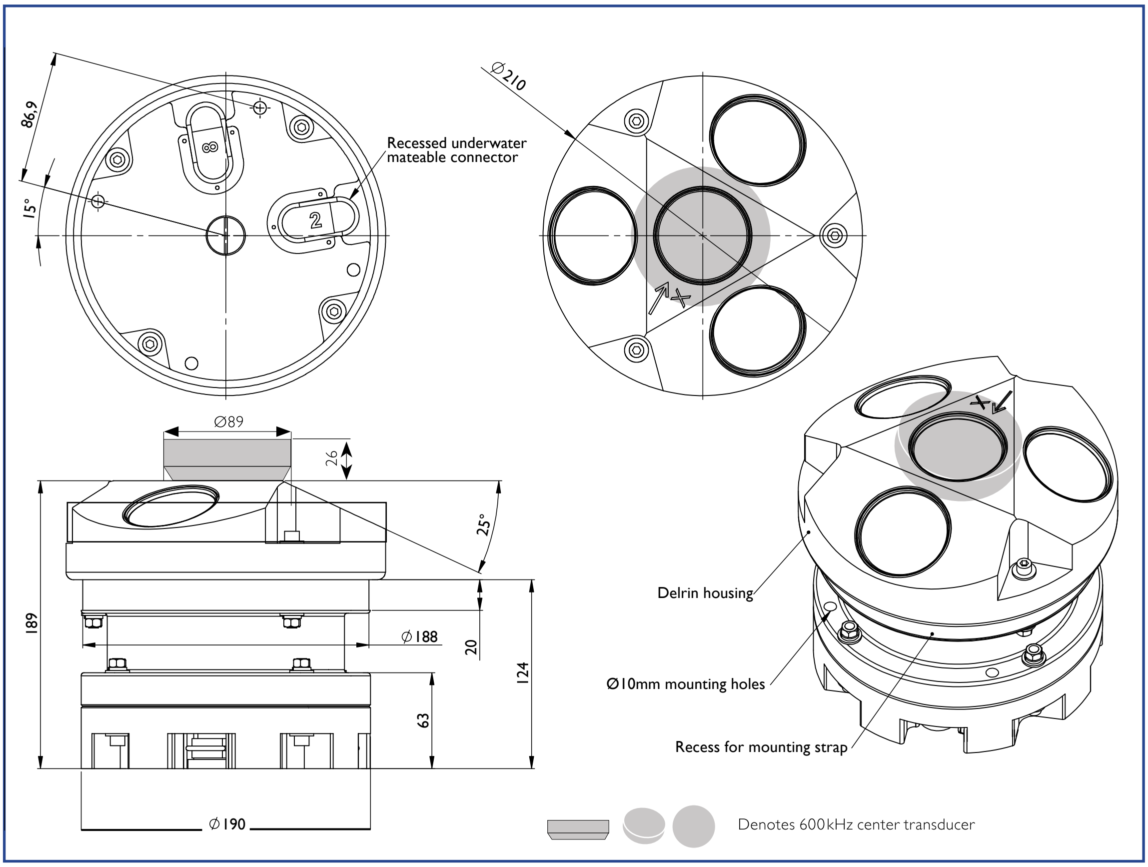
I/O	RS232 or RS422
Baud rate	300–115200, inquire for 1MBit
User control	Handled via "AWAC" software, NIPtalk or ActiveX® controls

Power

DC input	9–16VDC
Peak current	2A
Power consumption	see AWAC software

Offshore Cable

The Nortek offshore cable can, when properly deployed, withstand tough conditions in the coastal zone. In RS422 configuration, cable communication can be achieved for distances up to 5km.



11.2006

www.nortek.no

NORTEK AS
Vangkroken 2
NO-1351 Rud
Norway
Tel: +47/ 6717 4500
Fax: +47/ 6713 6770
E-mail: inquiry@nortek.no

青岛诺泰克测量设备有限公司
地址：中国青岛香港西路65号
汇融广场1302
邮编：266071
Tel: 0532-85017570, 85017270
Fax: 0532-85017570
E-mail: inquiry@nortek.com.cn

NortekUK
Mildmay House, High St.
Hartley Wintney
Hants. RG27 8NY
Tel: +44- 1428 751 953
Fax: +44- 1428 751 533
E-mail: inquiry@nortekuk.co.uk

NortekUSA
222 Severn Avenue
Suite 17, Building 7
Annapolis, MD 21403
Tel: +1 (410) 295-3733
Fax: +1 (410) 295-2918
E-mail: inquiry@nortekusa.com
www.nortekusa.com

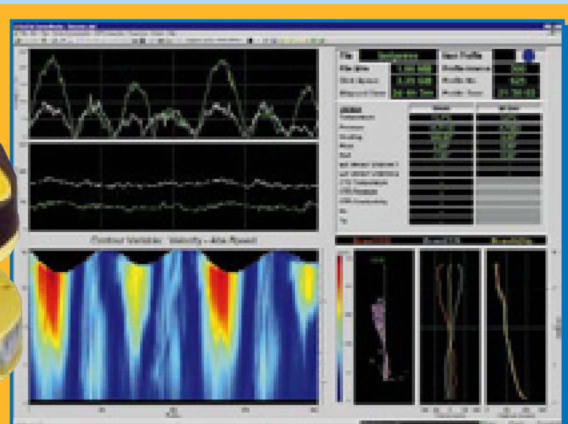
More Than Just A Current Profiler

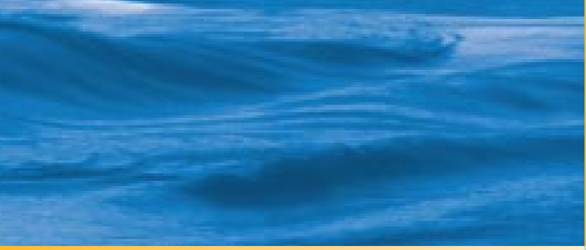
SonTek ADP™ Acoustic Doppler Profiler

With hundreds of satisfied users around the world, the ADP is proven, capable and versatile. Whether your application is hydrology, oceanography or harbor monitoring, there is an ADP configuration to suit your needs.

OPTIONS AND FEATURES

- Bottom tracking and GPS input for moving boat applications
- Windows 95/98/NT software for real-time and post-processing
- Side-looking configurations for horizontal profiling
- Water level and wave spectra
- Optional external sensors including CT and turbidity

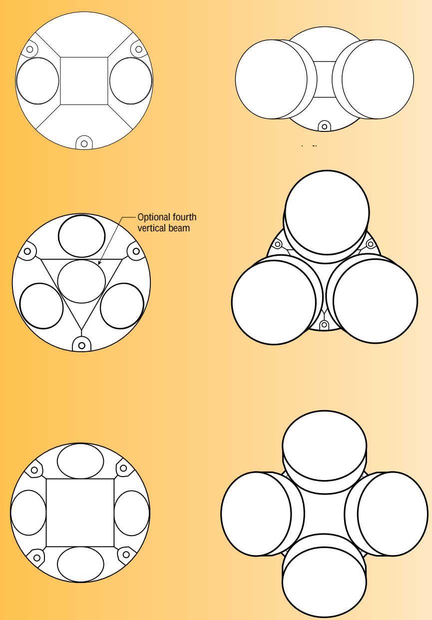




PERFORMANCE SPECIFICATIONS

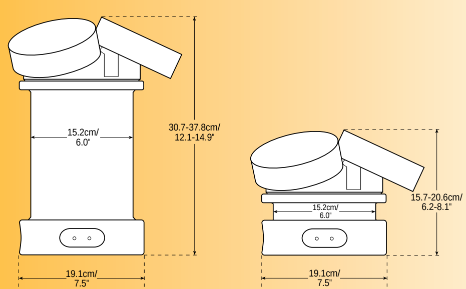
SonTek ADP™ Acoustic Doppler Profiler

Transducer Configurations



1000 kHz and Higher | 500 kHz and Lower

Housing Configurations



Standard | Low-Profile

**Actual dimensions are dependent upon system frequency and transducer configuration.*

SonTek™

The World Leader for Water Velocity Measurement

A D P S P E C I F I C A T I O N S

Available Frequencies and Ranges

Frequency (kHz)	3000	1500	1000	500	250
Maximum Profiling Range (m)	3-6	15-25	25-35	70-120	160-220

Velocity Data

- Range: ±10 m/s
- Resolution: 0.1 cm/s
- Accuracy: ±1% of measured velocity, ±0.5 cm/s
- Up to 100 range cells

Standard features

- Robust, digital signal processing
- 8 bit A/D conversion
- Three-beam transducer for 3D current measurement
- Transducer shading for minimal sidelobes
- Oversize piezoelectric ceramic for narrow beams
- Recessed wet-matebale connector
- Temperature sensor

Hardware options

- Two-beam side-looking configuration for horizontal profiling
- Four-beam Janus configuration
- Four beam configuration with one beam oriented vertically
- Low-profile housing (DSP electronics located in a separate splash-proof box)
- Full ocean depth rating
- Internal recorder (20, 40, 85, 170 or 340 MB)
- Internal compass/two axis tilt sensor
- External battery case
- Self-contained configuration with batteries and electronics in a single housing
- Strain gage pressure sensor (0.1% accurate)
- Internal RPT pressure sensor (0.01% accurate)

Performance options

- Bottom tracking/DGPS interface for use from a moving boat
- SonWave wave spectrum package
- Pulse-coherent mode for high resolution profiling (contact SonTek for details)

Windows 95/98/NT Software options

- RiverSurveyor package for real-time river discharge measurements from moving boats
- CurrentSurveyor for velocity profiling from a moving vessel
- CurrentMonitor for fixed installations
- ViewADP for post-processing

External sensor options

- SeaBird MicroCat CT
- D&A OBS turbidity
- Paroscientific quartz pressure sensor
- Other sensor interfaces are available, please contact SonTek

Power Consumption (Typical Continuous Operation)

- 12-24 VDC
- 2.0-2.5 W Operating mode
- Less than 1 mW Sleeping mode
- Total battery capacity (3 packs at 5° C): Alkaline 1800 Wh

Compass/Tilt Sensor

- Resolution: Heading, Pitch, Roll 0.1°
- Accuracy: Heading ±2°
- Accuracy: Pitch, Roll ±1°

SonTek's customer support is unsurpassed in the industry. Our experienced and professional staff is ready to assist you with the use and application of the ADP.

CORPORATE HEADQUARTERS

9940 Summers Ridge Road

San Diego, CA 92121

Tel: (858) 546-8327

Fax: (858) 546-8150

e-mail: sales@sontek.com

website: www.sontek.com

MADE IN U.S.A.

MIDAS WTR

The MIDAS WTR replaces the old Model 730 Wave Recorder. Whilst continuing to use the proven Linear Wave Theory wave analysis method, the MIDAS WTR benefits from Valeport's latest sensor measurement technology, together with 64 bit data processing, and an improved range of sampling options. USB data upload, quick change battery carousel and intuitive operating software make the MIDAS WTR one of the most versatile yet easy to use pressure based wave recorders available.

Sensors

The MIDAS WTR is fitted with a choice of strain gauge or high accuracy piezo-resistive pressure sensors, and a fast response PRT temperature sensor as standard. Note that whilst the piezo-resistive sensor offers a higher absolute accuracy, the quality of wave data owes more to deployment location and sampling pattern than to sensor performance. Optional additional sensors include Conductivity and Turbidity (others available on request).

Sensor	Type	Range	Accuracy	Resolution
Pressure (high accuracy)	Piezo-Resistive	100dBar (90m water)	±0.01%	0.001%
Pressure (standard)	Strain Gauge	50dBar (40m water)	±0.04%	0.001%
Temperature	PRT	-5 to +35°C	±0.01°C	0.005°C
Conductivity (optional)	Inductive Coils	0 - 80 mS/cm	±0.01 mS/cm	0.004 mS/cm
Turbidity (optional)	Seapoint STM	0 - 2000 FTU	±2%	0.005% Scale

Data Acquisition

In order to correctly measure wave activity, Linear Wave Theory requires a specific number of data points to be sampled over a period of time. These data points are then processed on board the instrument to generate an accurate summary of the wave activity during the measured period. The MIDAS WTR therefore operates in a strict pattern of "sample, process, sleep", with the user controlling the number of samples and the sampling rate, together with the duration of the sleep period. This may be minimised for almost continuous sampling, but obviously at the expense of battery and memory usage.

Sample Rate: 1, 2, 4 or 8Hz.
No of Samples: Powers of 2, 128 - 4096 (more samples = better data)
Cycle Time: Minimum cycle time is nearest whole number of minutes after processing has finished.
Delay Start: Instrument can be programmed to begin sampling at a specific time.
Conditional: Wave Sampling only occurs if pressure activity exceeds a defined level.

Electrical

Internal: 32 x D cells, 1.5v alkaline or 3.6v lithium
External: 9 - 30vDC
Power: 0.7W (sampling), <1mW (sleeping)
Battery Life: Depends on sampling setup, typically:
>2 months operation (alkaline)
>5 months operation (lithium)
Connector: Subconn Titanium MCBH10F

Communications

The instrument will operate autonomously, with setup and data extraction performed by direct communications with PC before and after deployment. It also operates in real time, with a choice of communication protocols for a variety of cable lengths, all fitted as standard and selected by pin choice on the output connector:

USB For rapid upload or laptops without serial port
RS232 Up to 200m cable, direct to serial port.
RS485 Up to 1000m cable, addressable half duplex comms
RS422 Up to 1500m cable, addressable full duplex comms
Baud Rate: 2400 - 115200 (USB 460800)
Protocol: 8 data bits, 1 stop bit, No parity, No flow control

Memory

The MIDAS WTR is fitted with 64Mb solid state non-volatile FLASH memory. Total capacity depends on setup. User may save any or all of the following:

- Raw sensor data from each burst
- Summary statistics of wave burst
- Tide & additional sensor data
- Spectral analysis of wave burst.

If all data is saved, memory will typically record over 4000 data bursts. Sampling once per hour, this is over 5 months data.

Physical

Materials: Acetal housing, optional stainless steel (316) cage
Depth Rating: Housing rated to 500m, pressure sensor may be less
Size: 300mmØ x 290mm deep
Cage Size: 950 x 950 x 400mm

Software

System supplied with WaveLog 400 Windows based PC software, for instrument setup, data extraction and display. All data in text format for easy export to other packages.

Ordering

0730033 MIDAS WTR Wave Recorder, piezo-resistive type, supplied with WaveLog 400 software, RS232 and USB data leads, operating manual and transit case)
0730034 MIDAS WTR Wave Recorder, strain gauge type, supplied with WaveLog 400 software, RS232 and USB data leads, operating manual and transit case)
0730037 Stainless steel deployment cage
0400011 Optional Conductivity Sensor
0400021 Optional Turbidity Sensor

MIDAS WTR is compatible with the Model 750 telemetry buoy.

Datasheet Reference Number: MIDAS WTR v1B

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

MIDAS DWR

The MIDAS DWR replaces the old Model 730D Directional Wave Recorder. Whilst continuing to use the proven Linear Wave Theory wave analysis method, the MIDAS DWR benefits from powerful 64 bit data processing, which allows on board real time generation of directional wave spectra. USB data upload, quick change battery carousel and intuitive operating software make the MIDAS DWR the most powerful yet easy to use PUV wave recorder available.

Sensors

The MIDAS DWR is fitted with a choice of strain gauge or high accuracy piezo-resistive pressure sensors, fast response PRT temperature sensor, flux gate compass and Valeport 2 axis EM current sensor as standard. Note that whilst the piezo-resistive sensor offers a higher absolute accuracy, the quality of wave data owes more to deployment location and sampling pattern than to sensor performance. Optional additional sensors include Conductivity and Turbidity (others available on request).

Sensor	Type	Range	Accuracy	Resolution
Pressure (high accuracy)	Piezo-Resistive	100dBar (90m water)	±0.01%	0.001%
Pressure (standard)	Strain Gauge	50dBar (40m water)	±0.04%	0.001%
Temperature	PRT	-5 to +35°C	±0.01°C	0.005°C
Compass	Fluxgate	0 to 360°	±1°	0.1°
Current	Valeport 2 axis EM	±5m/s	±1%	0.001m/s
Conductivity (optional)	Inductive Coils	0 - 80 mS/cm	±0.01 mS/cm	0.004 mS/cm
Turbidity (optional)	Seapoint STM	0 - 2000 FTU	±2%	0.005% Scale

Data Acquisition

In order to correctly measure wave activity, Linear Wave Theory requires a specific number of data points to be sampled over a period of time. These data points are then processed on board the instrument to generate an accurate summary of the wave activity during the measured period. The MIDAS DWR therefore operates in a strict pattern of "sample, process, sleep", with the user controlling the number of samples and the sampling rate, together with the duration of the sleep period.

Sample Rate: 1, 2, 4 or 8Hz.
No of Samples: Powers of 2, 128 - 4096 (more samples = better data)
Cycle Time: Minimum cycle time is nearest whole number of minutes after processing has finished.
Delay Start: Instrument can be programmed to begin sampling at a specific time.
Conditional: Wave Sampling only occurs if pressure activity exceeds a defined level.

Electrical

Internal: 32 x D cells, 1.5v alkaline or 3.6v lithium
External: 9 - 30vDC
Power: 1.7W (sampling), <1mW (sleeping)
Battery Life: Depends on sampling setup, typically:
>1 months operation (alkaline)
>2 months operation (lithium)
Connector: Subconn Titanium MCBH10F

Communications

The instrument will operate autonomously, with setup and data extraction performed by direct communications with PC before and after deployment. It also operates in real time, with a choice of communication protocols for a variety of cable lengths, all fitted as standard and selected by pin choice on the output connector:

USB For rapid upload or laptops without serial port
RS232 Up to 200m cable, direct to serial port.
RS485 Up to 1000m cable, addressable half duplex comms
RS422 Up to 1500m cable, addressable full duplex comms
Baud Rate: 2400 - 115200 (USB 460800)
Protocol: 8 data bits, 1 stop bit, No parity, No flow control

Memory

The MIDAS DWR is fitted with 64Mb solid state non-volatile FLASH memory. Total capacity depends on setup. User may save any or all of the following:

- Raw sensor data from each burst
- Summary statistics of wave burst
- Tide & additional sensor data
- Spectral analysis of wave burst.
- Directional spectral analysis of wave burst

If all data is saved, memory will typically record over 800 data bursts. Sampling once every 2 hours, this is over 2 months data.

Physical

Materials: Acetal housing, optional stainless steel (316) cage
Depth Rating: Housing rated to 500m, pressure sensor may be less
Size: 300mmØ x 375mm deep
Cage Size: 950 x 950 x 400mm

Software

System supplied with WaveLog 400 Windows based PC software, for instrument setup, data extraction and display. All data in text format for easy export to other packages.

Ordering

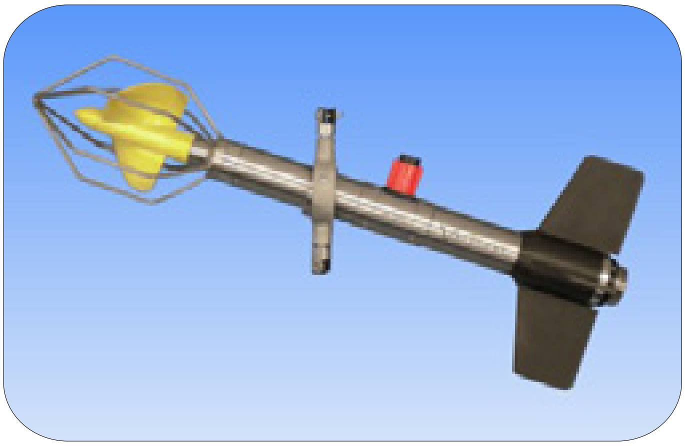
0730035 MIDAS DWR Wave Recorder, piezo-resistive type, supplied with WaveLog 400 software, Rs232 and USB data leads, operating manual and transit case)
0730036 MIDAS DWR Wave Recorder, strain gauge type, supplied with WaveLog 400 software, RS232 and USB data leads, operating manual and transit case)
0730037 Stainless steel deployment cage
0400011 Optional Conductivity Sensor
0400021 Optional Turbidity Sensor

Datasheet Reference Number: MIDAS DWR v1B

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

VALEPORT

MODEL 106



The Model 106 Current Meter is a light weight, cost effective impeller current meter, designed for real time current measurement or short to medium term autonomous deployments. Titanium construction ensures durability, and the optional temperature and pressure sensors increase the versatility of the instrument. Ideal for use in rivers and coastal applications, or from small boats, the Model 106 is simple to use with either the Windows based PC software supplied, or an optional dedicated display unit.

Sensors

Speed

Type:	High Impact Styrene Impeller
Size:	125mm diameter by 270mm pitch
Range:	0.03 to 5m/s
Accuracy:	±1.5% of reading above 0.15m/s ±0.004m/s below 0.15m/s

Direction

Type:	Flux gate compass
Range:	0 to 360°
Accuracy:	± 2.5°
Resolution:	0.5°

Temperature

Type:	Thermistor
Range:	-5 to 35°C
Accuracy:	± 0.2°C
Resolution:	0.01°C

Pressure

Type:	Strain Gauge Transducer
Range:	50, 100, 200 or 500 dBar
Accuracy:	± 0.2% Range.
Resolution:	0.025% Range

Data Acquisition

The current meter works on a basic 1 second cycle, during which the impeller counts are taken and a single compass heading reading is made. From this, East and North velocity vectors are calculated, which are then summed over the averaging period. The additional parameters of temperature and pressure (if fitted) are sampled once every sample period, and averaged over the averaging period.

Data Recovery

Direct to PC via communications port. Maximum RS232 data rate of 19200 baud.

Switching On/Off

The meters are switched on and off through software control, either by the DataLog™ software or by using the Model 8008 CDU. However, for autonomous, self recording operation the 106 is supplied with a subconn switch cap which fits in place of a direct cable connection.

Software

DataLog™ Windows™ based PC software for data display, instrument set up, data extraction and tabular and graphical data plots.

Display Unit

The Model 106 may be used with a dedicated display unit for real time operations allowing instrument setup and data display.

Size:	244 x 193 x 94mm, 2kg
Protection:	IP67 (10 secs @ 0.3m)

Memory

512 Kbyte Solid State Memory. Each parameter record uses 2 bytes. As an example, this gives a duration of over 1 week with full parameter sampling every 10 seconds, or 220 days with sampling every 5 minutes.

Power

Internal:	1 x D cell. 1.5v alkaline cell gives approximately 30 days at 10 second sample rate, or 56 days at 5 minute sample rate. 3.6v Lithium cell gives approximately 90 days at 10 second sample rate, or 180 days at 5 minute sample rate.
External:	For external supply, 12-20v DC is required. Power can also be taken from the Model 8008 CDU.

Communications

Fitted with Subconn MCBH10F (Brass)

RS232 to PC over cable lengths up to 50m. Digital Current Loop to Model 8008 CDU, or to PC over longer cable lengths (requires additional adaptor).

Physical

Instrument

Materials:	Titanium, acetal and ABS plastic
Size:	640mm x 50mm Ø, (tail 133mm wide x 270mm high)
Weight:	3kg (air), 2kg (water)
Depth Rating:	500m

Shipping

Model 106 Size:	83 x 43 x 36cm
Model 106 Weight:	17kg
50m Cable Size:	42 x 33 x 49cm
50m Cable Weight:	11kg

Ordering

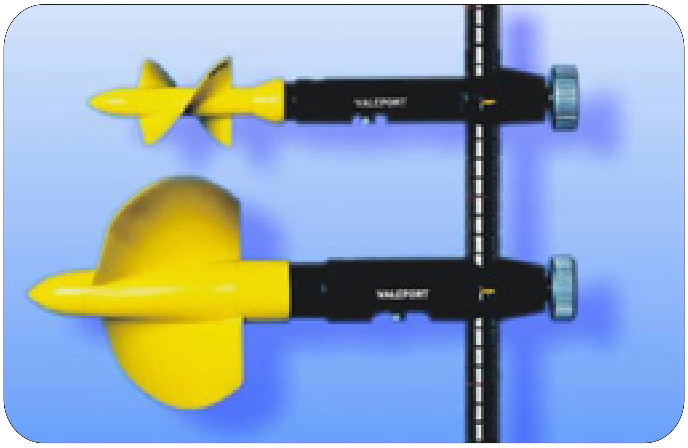
0106001SC	Model 106 Self Recording/Direct Reading unit, fitted with speed and direction sensors. Supplied with communications lead (3m Y lead), switch cap, operating manual, software and system transit case.
0105003	Temperature option
0105004	Depth option
0105005	Control Display Unit set, comprising deck lead and Model 8008 CDU.
0105006	50m cable on hand reel

Datasheet Reference Number: MODEL 106 v1C

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

Models 001 & 002

The Model 001 & Model 002 Flow Meters represent a standard in open channel flow measurement. First introduced under the "Braystoke" brand over 30 years ago, both meters use the simple premise of converting speed of rotation of the helical impeller into speed of water. Available as a wading set for hand held use in shallow water, or as a hand-suspension system for use from bridges or boats, the Models 001 & 002 offer a quick, cost-effective method of measuring flow in a variety of open channel applications.



Specifications

Model 001

Type:	8011 series High Impact Styrene Impeller
Size:	125mm diameter by 270mm pitch
Range:	0.03 to 10m/s
Accuracy:	±1.5% of reading above 0.15m/s ±0.004m/s below 0.15m/s

Model 002

Type:	1178 series High Impact Styrene Impeller
Size:	50mm diameter by 100mm pitch
Range:	0.046 to 5m/s
Accuracy:	±2.5% of reading above 0.5m/s ±0.01m/s below 0.5m/s

What's the Difference?

Quite simply, the size of the impeller. The larger impeller of the Model 001 gives three key benefits over the smaller Model 002:

- Lower stall speed - greater surface area means that the minimum water speed required to turn the impeller is lower.
- Higher top speed - longer pitch means less revolutions for any given speed of water, so a greater speed range is possible.
- Higher accuracy - any variations in manufacturing tolerance, wear and tear, or deployment technique will have less effect on the larger impeller than on the small one.

However, the smaller Model 002 does have one major advantage over the Model 001:

- Since the impeller is smaller, it may be used successfully in very shallow water - provided the impeller is submerged, it will operate correctly.

Both impellers feature water lubricated PTFE bearings, requiring no oil for correct use, and a unique design that inhibits silt and weed from entering the bearings, allowing use in a wide variety of environments.

Calibration

Both instruments are offered as standard with a "Group Calibration", according to BS3680, Part A (1973). Within limits, the performance of an impeller is primarily a function of its shape, provided that its bearings work and it is spinning freely. Since all our impellers are manufactured to the same standard shape, we guarantee that they fall within the tolerances of the group calibration, as given above. Note that the Group Calibration for each impeller is up to 3m/s - calibration above 3m/s is by linear extrapolation. Specific calibration of any individual impeller may be performed on request, at Valeport's own premises up to 1m/s, or via a third party for higher speeds.

Data Acquisition

The Model 001 & 002 Flow Meters are supplied with a dedicated surface display unit, the Model 0012B. As the impeller rotates, it opens and closes a magnetic reed switch, generating pulses. The Model 0012B measures the frequency of these pulses, and uses the calibration equation to calculate speed of flow from the pulse frequency.

Data may be averaged over any number of seconds from 1 to 600, or according to number of impeller revolutions. The Model 0012B will display real time speed data, as well as the result of the data average, together with a Standard Deviation figure to give added data confidence. A solid state memory records all results, and the data may be downloaded to PC using the RS232 interface lead supplied.

Configurations

Both instruments are available in two standard configurations:

Wading Set

Designed for hand held use, with the operator standing in the channel, holding the instrument in position. System is supplied with 1.5m wading rod (3 x 0.5m sections), graduated in cm, and a 2m cable from instrument to display unit.

Alternatively, a "top-setting" wading rod system is available, which allows the vertical position of the instrument to be set without removing the wading rods from the water.

Suspension Set

Designed for hand suspension use, with the operator lowering the instrument on a cable into deeper water or from a high bridge. System includes a 35m suspension cable, together with an extended tail fin for ensuring that the instrument is aligned into the water flow. A range of streamlined weights is also available to aid suspension deployments - contact Valeport for details.

Also available is a "Conversion Kit", which contains all the necessary additional parts to also allow a Wading Set to be used as a Suspension Set.

Ordering

0001001	Model 001 Wading Set
0001002	Model 001 Suspension Set
0001003	Model 001 Conversion Kit
0002001	Model 002 Wading Set
0002002	Model 002 Suspension Set
0002003	Model 002 Conversion Kit
0001050	Top Setting Wading Rods (for either Model 001 or 002)

Datasheet Reference Number: Model 001 & 002 v1A

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

VALEPORT

Model 801

The Model 801 Electromagnetic Flow Meters measure the speed of water in Open Channel environments with exceptional accuracy. Two sensor types are available,to suit different application requirements, but both offer excellent durability, reliable accurate data, and are suitable for use in clean water and dirty or difficult environments.

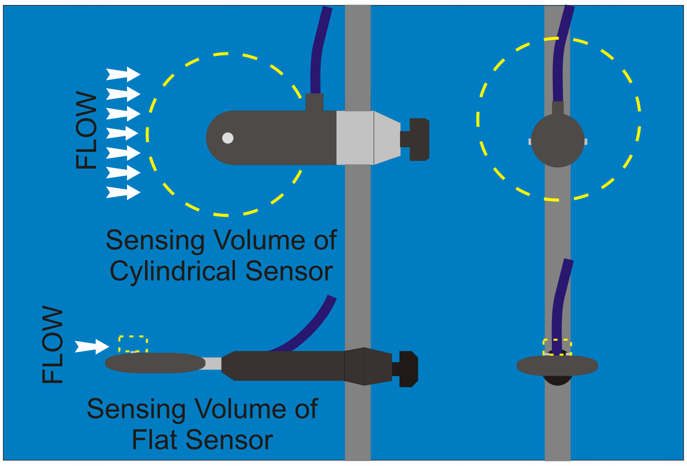
Specifications

Model 801 - Cylindrical Type

Range:	-5m/s to +5m/s
Accuracy:	±0.5% of reading plus 5mm/s
Zero Drift:	<5mm/s
Sensing Volume:	Sphere of approx 12cm diameter around sensor
Minimum Depth:	15cm

Model 801 - Flat Type

Range:	-5m/s to +5m/s
Accuracy:	±0.5% of reading plus 5mm/s
Zero Drift:	<5mm/s
Sensing Volume:	Cylinder of approx 20mm Ø x 10mm high
Minimum Depth:	5cm



What's the Difference?

The smaller sampling volume of the flat sensor makes it very much more suitable for shallow flows, or measurements in confined spaces. However, it is also very much more sensitive to turbulent flows, which may manifest as apparently noisy real time readings. This effect can be minimised by using a long (>30secs) average period. The larger sampling volume of the cylindrical sensor effectively eliminates the turbulence noise, but also means that a greater depth of water is required for measurements.

Calibration

Both instruments are calibrated to NAMAS traceable standards at Valeport's own premises up to speeds of 1m/s. Higher speed measurements are based on linear extrapolation. Specific high speed calibrations can be arranged at a third party facility on request.

Data Acquisition

The Model 801 Flow Meters are supplied with a dedicated surface display unit, which both drives the sensor and provides data display of the measured water velocity.

Data is updated at 1Hz, and may be averaged over any number of seconds from 1 to 600. The display will show real time speed dataat a resolution of 1mm/s, as well as the result of the data average, and a Standard Deviation figure to give added data confidence. A solid state memory records all results (up to 999 averaged readings), and the data may be downloaded to PC using the RS232 interface lead supplied.

Display Unit

Size:	244mm x 163mm x 94mm, 2kg
Environmental:	Sealed to IP67
Power:	8 x alkaline C cells, lasting for up to 37 hours
Operating Temp.:	-5°C to +50°C (display unit)
	-5°C to + 40°C (sensor)

Configuration

Both instruments are available for use as hand held "Wading Sets" only, with the operator standing in the channel, holding the instrument in position. The system is supplied with 1.5m wading rod (3 x 0.5m sections), graduated in cm, and a 3m cable from instrument to display unit.

Alternatively, a "top-setting" wading rod system is available, which allows the vertical position of the instrument to be set without removing the wading rods from the water.

Ordering

0801001	Single axis cylindrical sensor, c/w 3m cable, control display unit (with logging facility), and operation manual. Supplied in ABS transit case.
0801002	Single axis flat sensor, c/w 3m cable, control display unit (with logging facility), and operation manual. Supplied in ABS transit case.
0801003	Wading rod set c/w 3 x 0.5m graduated rods, base, direction knob, and canvas carrying bag.
0801011	*Option* - Large transit case to take instrument and wading rods (small case and canvas bag not supplied).

Datasheet Reference Number: Model 801 v1A

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

Model 740

Valeport's popular Model 740 tide gauge has been designed to provide an accurate, easily deployed tide gauge for use in short or long term hydrographic survey operations. Low power consumption and user selectable sampling regime allow up to 2 years' autonomous operation, whilst the optional radio transmission package extends the capabilities for real time operations. Data output is compatible with the MIDAS Surveyor GPS Echo Sounder system.

Transducer

Type: Vented strain gauge, with stainless steel mounting bracket.

Range: Standard 10dBar (approx 10m), with 20m cable. Other ranges and lengths available.

Accuracy: ±0.1% Full Scale.

Calibration: Held within logging unit.

Dimensions: 18mm diameter x 80mm.

Logging Unit

Housing: Black anodised aluminium, waterproof to IP67 (0.5m for 30 secs), but system includes transducer vent to atmosphere. The electronics are sealed from the vent.

Power: 4 "D" cells within housing. Alkaline cells provide power for over 900 days at 20 minute sampling with burst length of 10 secs.

Memory: 128kbyte solid state, allowing over 65,000 data points. Equivalent to over 900 days at 20 minute sampling. New data file created every time unit is switched on by user.

Sampling: Raw data sampled at 4Hz and logged as average over burst. Burst length is selectable between 1 and 60 seconds. Cycle time is selectable from 1 minute or from 5 to 1440 minutes (1 day) in 5 minute steps

Switching: Delay start time set by PC. Switch on by fitting waterproof plug or comms lead to comms port.

Resolution: Data logged to 1mm resolution. Raw data sampled at 14 bit (1:16384) resolution.

Comms: RS232 via 3m cable to PC, or via 1m cable to radio unit.

Dimensions: Housing 47mm x 110mm x 235 mm.

Weight: 1.7kg (approx) including batteries.

Radio

Frequency: Selectable frequency UHF synthesised radio transceiver, operating in UK licence exempt band (458.5 - 458.9 MHz).

Power output: Supplied as nominal 100mW peak output.

RS232 output: 4800 baud, 8,1,N.

Aerials

Transmitter: ¼ wave 'rubber duck' (standard, ~2km). 3dB omni-directional (option, ~10km)

Receiver: 3dB omni-directional.

Power input

Transmitter: Takes power from Model 740, or from external 12vDC supply.

Current: 0.04mA sleep, 120mA receive, 410mA transmit.

Receiver: requires external 12vDC input

Current: 120mA receive, 410mA transmit.

Transmitter Physical

Materials: IP67 Black anodised aluminium box.

Size: 200mm x 200mm x 70mm.

Connectors: To antenna, Model 740 & external power supply.

Receiver Physical

Materials: Desktop style anodised aluminium box.

Size: 200mm x 180mm x 70mm.

Connectors: To antenna, 12vDC input & RS232 output.

Ordering

0740006 Portable water level recorder set c/w 1 Bar Titanium vented transducer, wall mounting bracket and 20m cable, electronics/logger in rugged anodised aluminium housing with batteries. Supplied with Windows based TideLog software and operating/instruction manual.

0740011 Selectable frequency UHF synthesised radio transceiver (remote station) in IP67 housing. Supplied with 'rubber duck' antenna and comms lead to Model 740.

0740012 Selectable frequency UHF synthesised radio transceiver (base station) in desktop housing. Supplied with 3dB omni-directional antenna, 10m cable, 12vDC input lead and RS232 output lead (9 way D type).

0740014 Optional 3dB omnidirectional antenna with 10m cable for transmitter unit.

Datasheet Reference Number: Model 740 v1A

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk


TideMaster

TideMaster has been designed to provide an accurate, versatile and easily deployed tide gauge for use in short or long term survey operations. Optional control/display panel, Bluetooth, SD card memory and optional weather sensor provide unrivalled functionality. Low power consumption and user selectable sampling regime allow for up to a year of autonomous operation, whilst optional telemetry packages extend the capabilities for real time operations. TideMaster is compatible with a wide range of hydrographic software and tools.

Pressure Transducer

Type:	Vented strain gauge, with stainless steel mounting bracket.
Range:	Standard 10dBar (approx 10m), with 20m cable. Other ranges and lengths available.
Accuracy:	±0.1% Full Scale.
Calibration:	Held within logging unit.
Dimensions:	18mm diameter x 80mm.

Weather Sensor

Type:	Ultrasonic - Wind Speed and Direction
Range:	0-60m/s 0-359°
Accuracy:	±2%@12m/s
	±3°@12m/s
Calibration:	Held within Sensor.
Dimensions:	142mm x 160mm.

Logging Unit

Housing:	Injection moulded housing rated to IP67, with injection moulded mounting bracket.
Display:	Optional control/display (128x64 OLED) panel for system configuration and data display.
Power:	4 "C" cells within separate sealed compartment.
	Tool-less battery change.
	Alkaline cells provide power for up to a year of autonomous sampling
Memory:	512 MB SD card memory allowing for effectively unlimited data storage.
Sampling:	Raw data sampled at 8Hz, mean and standard deviation of burst samples is logged.
	5 pre-programmed burst modes + custom sampling mode.
	Continuous Sampling Mode (1Hz)
Switching:	Power switch on unit.
Resolution:	Data logged to 1mm resolution.
Comms:	Integral Bluetooth for short range wireless communication
	RS232/RS485 for cabled communication
Dimensions:	Housing 52 mm x 144.5 mm x 197 mm.
	Bracket 35 mm x 210 mm x 159 mm.
	Mounted 61.5mm x 210 mm x 197 mm
Weight:	1.1 kg (approx) including batteries.

Radio Telemetry

Frequency:	Selectable frequency UHF synthesised radio transceiver, operating in UK licence exempt band (458.5 - 458.9 MHz).
Power output:	Supplied as nominal 100mW peak output.
RS232 output:	4800 baud, 8,1,N.

Aerials

Transmitter:	¼ wave 'rubber duck' (standard, ~2km). 3dB omni-directional (option, ~10km)
Receiver:	3dB omni-directional.

Power input

Transmitter:	External 12vDC supply.
Current:	0.04mA sleep, 120mA receive, 410mA transmit.
Receiver:	External 12vDC input
Current:	120mA receive, 410mA transmit.

Transmitter Physical

Materials:	IP67 Black anodised aluminium box.
Size:	200mm x 200mm x 70mm.
Connectors:	To antenna, TideMaster & external power supply.

Receiver Physical

Materials:	Desktop style anodised aluminium box.
Size:	200mm x 180mm x 70mm.
Connectors:	To antenna, 12vDC input & RS232 output.

GSM/GPRS/Bluetooth Telemetry

Please contact Valeport to discuss GSM/GPRS/Bluetooth telemetry requirements

Ordering

0741001	TideMaster Portable water level recorder set c/w 1 Bar Titanium vented transducer, wall mounting bracket and 20m cable, electronics/logger (**with display**) in rugged injection moulded housing with batteries. Supplied with Windows based TideMaster Express software and operating/instruction manual.
0741002	TideMaster Portable water level recorder set c/w 1 Bar Titanium vented transducer, wall mounting bracket and 20m cable, electronics/logger (**without display**) in rugged injection moulded housing with batteries. Supplied with Windows based TideMaster Express software and operating/instruction manual.

.
As part of our policy of continuing development, we reserve the right to alter at any time, without notice, all specifications, designs, prices and conditions of supply of all equipment.

Datasheet Reference Number: TideMaster v1A

Valeport Limited, St. Peter's Quay, Totnes, Devon TQ9 5EW UK
Tel: +44 (0)1803 869292 Fax: +44 (0)1803 869293 E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

Appendix 3: ARGUS video system: Extracted from van Rijn, L.C. (2006-2007) "Manual Sediment Transport Measurements in Rivers, Estuaries and Coastal Seas", Delft Hydraulics and University of Utrecht, The Netherlands.

11. ARGUS VIDEO SYSTEM

11. 1 Introduction

Until only a few years ago, all information on nearshore morphodynamics had to be gathered from comprehensive field experience. This way of data collection has some fundamental limitations. One problem is the fact that such experiments are relatively expensive. Another and even more important characteristic is the fact that the observation time scale is in practice limited to several weeks. Finally, surveying during severe weather and wave conditions is hardly possible.

With the recent advent of new digital imaging technology, shore-based video systems now provide the additional capability of automated data collection, encompassing a much greater range of time and spatial scales than were previously possible.

Figure 1
ARGUS video monitoring station at Noordwijk, The Netherlands

The history behind video imaging in nearshore studies probably goes back to the 1940s, where the first attempts to study coastal processes were made with the help of aerial photography. In 1980, developments on video techniques for the monitoring of coastal changes have been initiated by the Coastal Imaging Lab of the Oregon State University, USA. Being continuously improved since 1992, the so-called ARGUS system nowadays features fully digital video technology which provides high image quality in combination with detailed pixel resolution. Continuous (typically every daylight hour) collection of image data with a resolution of centimetres to meters, extending along regions of hundreds of meters to several kilometers, is now routinely undertaken at sites in the USA, Europe, Australia and Asia.

An ARGUS monitoring system typically consists of four to five video cameras, spanning a 180º view, and allowing full coverage of about four to six kilometers of beach. The cameras are mounted on a high location along the coast and connected to an ordinary PC on site, which in turn communicates to the outside world using conventional techniques such as analog modems, ISDN, DSL, or a wireless LAN. Data sampling is usually hourly (although any schedule can be specified) and continues during rough weather conditions. As the process of data collection is fully automated, the marginal operating costs are virtually zero .

Each standard hourly collection usually consists of three types of images. A snapshot image serves as simple documentation of the ambient conditions but offers little quantitative information. Time exposure images average out natural modulations in wave breaking to reveal a smooth pattern of bright image intensities, which are an excellent proxy for the underlying, submerged sand bar topography. Time exposures also

'remove' moving objects from the camera field of view, such as ships, vehicles and people. Variance images help identify regions which are changing in time (like the sea surface), from those which may be bright, but are unchanging (like the dry beach).

Plan view, merged images can be composed by geo-referencing the images from all the cameras of an ARGUS station. This facilitates the measurement of length scales of morphological features like breaker bars and the detection of rip currents. Besides time-averaged video data, data sampling schemes can be designed to collect time series of pixel intensities, typically at 2 Hz, with which wave and flow characteristics can be investigated.

11.2 History of ARGUS

In 1980, the Coastal Imaging Lab (CIL) at Oregon State University began early efforts in optical remote sensing with the use of time-lapse movie measurements of wave runup as a diagnostic method of sampling infragravity edge waves (**Holman, 1981**). While the move from the traditionally in-situ sensors was largely dictated by the intimidating surf conditions of the U.S. Pacific Northwest, the logistics, cost and data benefits soon drove the lab to an all-optical approach to nearshore sampling. This was boosted enormously by the early discovery that ten-minute time-exposure (timex) images could be used to locate submerged sand bars and rip channels, a remarkable simplification over traditional surveying approaches (**Lippmann and Holman, 1989**). The power of the timex technique led to the development in 1992 of automated unmanned stations called ARGUS Stations, programmed to collect these images hourly at any site of research interest.

Time exposure images have been the primary product of the ARGUS Program, revealing surprising nearshore morphologies and very dynamic behavior on nearly every beach sampled to date. For example, **Lippmann and Holman (1990)** documents statistics of morphological states at the much-studied Duck Field Research Facility (FRF), showing that simple or rhythmic morphologies are rare, with the median system state being a complex pattern. The simplicity and robustness of image collection and the high information content of time exposure images have strongly supported the arguments for optical remote sensing as an important nearshore monitoring tool and have made the ARGUS Program very successful.

1980: Initiated by Coastal Imaging Lab, Oregon State University
1980-1990: Follow-up of initial video imaging studies in late eighties
1992: CIL-based program, installation of unmanned, automated video stations
1992: First installation in Yaquina Head, OR, USA
1995: First installation outside USA (Noordwijk, NL)
1999: First installation for CZM purposes (Egmond JvS, NL)
Now: Presently over 30 ARGUS sites worldwide

11.3 ARGUS worldwide

Since the first automated ARGUS station was installed at Agate Beach on the Oregon Coast in 1992, the CIL-based program has expanded to 12 locations around the world. Sites were selected to span the parameter space considered relevant to nearshore processes research (ranges in wave period, wave height, tide range and beach slope).

In addition, approximately 30 ARGUS stations and 120 cameras are now operating daily in 8 countries (Figure 2). The greatest acceptance has been in Europe, where ARGUS technologies are at the heart of the three-year EU CoastView program, and in Australia, where 10 stations are now operating. These stations provide hourly measurements of a variety of topographic, geomorphic and fluid variables and are usually focused on practical Coastal Zone Management (CZM) issues.

Figure 2
Locations of ARGUS stations over the world

11.4 ARGUS image types and conventions

Image Types
Three types of images are gathered from the ARGUS cameras (see Figures 3, 4 and 5). Every hour, a snapshot, a time exposure and a variance image are collected for each of the stations cameras. A snapshot serves as simple documentation of conditions, but offers little quantitative information. The time exposure images provide us with much more information. The ten minute time exposures of the nearshore wave field average out natural modulations in wave breaking to reveal a smooth band of white which has been shown to be an excellent proxy for the underlying, submerged sand bar topography (**Lippman and Holman, 1989 and Van Enckevort and Ruessink, 2001**). The third type, the variance image, displays the variance of the light intensity signal during the same ten minutes of time exposure. Variance images help identify regions which are changing in time, from those, which may be bright in the time exposure, but are unchanging in time.

Figure 3
A snapshot image at Egmond aan Zee

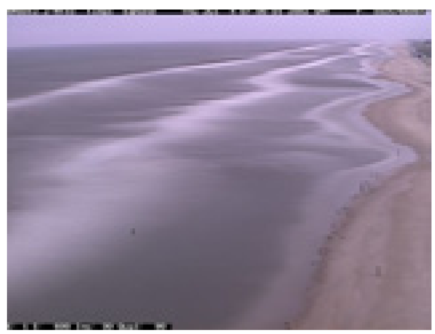


Figure 4
A time exposure image at Egmond aan Zee

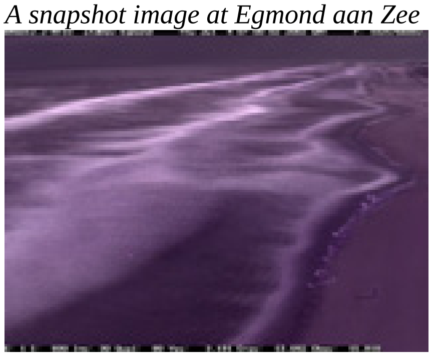


Figure 5
A variance image at Egmond aan Zee

Besides time-averaged video data, data sampling schemes can be designed to collect time series of pixel intensities, typically at 2 Hz, with which wave and flow characteristics can be investigated. Pixel intensity time series show the fluctuations in time of the intensity in a pixel. A time stack image is an image in which the intensity of an array of pixels is plotted against time. To illustrate, Figure 6 shows the strong correlation which is commonly observed between a time series of pixel intensities and the wave height signal obtained from a wave gauge at the same location (**Lippmann and Holman, 1991**). The small phase lag between the two indicates that maximum intensities correspond to the white, foam-covered face of the breaking wave, which precedes the passage of the actual wave top. Comparisons for non-breaking waves also show strong coherence, but often a larger, still fixed, phase difference.

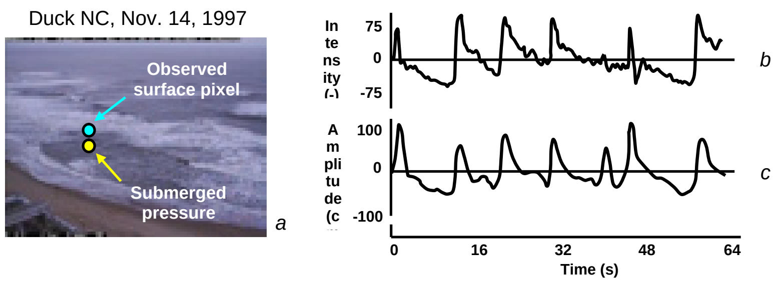


Figure 6
Relation between a pixel intensity time series and a wave height signal at Duck, USA

In extension of this approach, time series of pixel intensities can be sampled along a cross-shore or alongshore array. The resulting data collection, I(t,y;x), yields a time stack image (see Figures 7, 8 and 9). Due to the digitalisation process, the intensity data are normalised over the lens's intensity range and thus dimensionless. The dark, slightly curved patterns represent individual waves propagating onshore. The slope of the wave traces can be used to determine the approximate speed of the shoreward progressive waves, before being dissipated through wave breaking at the shoreline (around x=170 m).

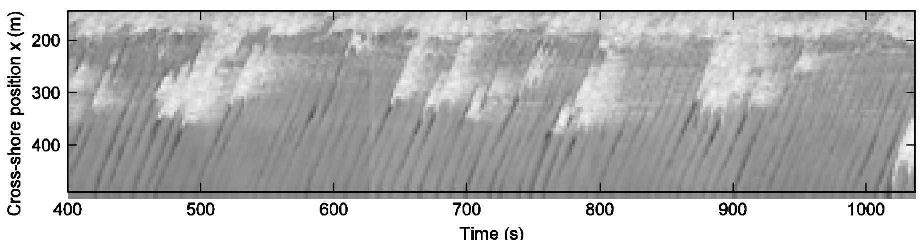


Figure 7
A time stack image collected along a cross-shore array at Duck, USA

A third type is the longshore timestack from which the longshore current velocity is estimated. The targets for the longshore current analysis are the foam patches that appear on the water surface after the waves have broken on the nearshore bar. These foam patches move slowly alongshore carried by the longshore current. The velocity of the foam patches therefore gives a measure of the longshore surface current velocity (**Chickadel & Holman, 2004**).

Figure 8
Snapshot of the surf zone at Duck NC. The line indicates the location of the alongshore pixel array where the video record was taken.

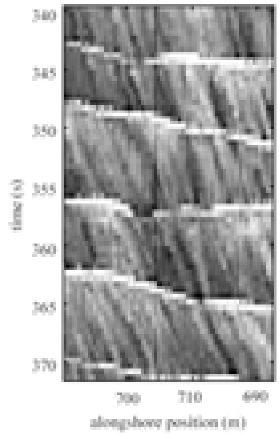


Figure 9
A time stack, collected at Duck NC. The time stack reveals the bright horizontal bands of passing breaking waves and the oblique traces of foam patches drifting with the prevailing longshore current.

ARGUS conventions
At every ARGUS site, the orientation of the x-axis is normal to the shore, with the positive x-axis pointing in seaward direction. The y-axis is directed perpendicular to the x-axis, such that the co-ordinate system thus obtained is positive in mathematical sense. The latter means that the rotation from the x-axis towards the y-axis indicates the counter-clockwise (or 'positive') turning direction. As an example, Figure 10 shows the ARGUS co-ordinate system for Miyazaki, Japan:

Figure 10
ARGUS co-ordinate system at Miyazaki, Japan

The vertical reference level (z = 0) is generally set to match the mean tidal level or a commonly used (often national) ordinance level (like NAP in the Netherlands).

Three different time frames are used within the ARGUS Runtime Environment:

- Epochtime: represents the number of seconds since January 1, 1970, 00:00:00. This is the nine or ten-digit number an ARGUS image filename begins with. By nature, epochtimes are relative to GMT.

- Julian days: represents the serial number of a day within a year, e.g. Feb 1st = 32.
- Matlab's 'datenum' time frame: represents the number of days since January 1, 0000, 00:00:00. Matlab times are obtained from the standard Matlab function *datenum* (see help on datenum). Matlab provides a set of standard functions to convert datenumbers to more accessible formats, the most important ones being *datevec* and *datestr*. See the Matlab help on timefun for further details regarding Matlab time processing.

11.5 ARGUS standard image processing

Geo-referencing of oblique video data

Quantification of image features like sand bars, shorelines and foam patterns demands the conversion of image coordinates (u,v) to field coordinates (x,y,z). This conversion depends on the camera location (x_c, y_c, z_c), the camera orientation defined through three camera angles, namely the tilt τ, the azimuth ϕ and the roll σ (see Figure 11), and the effective focal length f, which directly relates to the camera horizontal field of view δ. The angles τ, ϕ and σ represent the rotation with regard to the vertical *z*-axis, the orientation in the horizontal xy-plane and the rotation of the focal plane with respect to the horizon, respectively. The transformation of field to image coordinates is thus a rotation about three successive angles τ, ϕ and σ and can be expressed by the linearised version of the collinearity equations, following standard photogrammetric procedures, as follows (**Holland et al., 1997**):

$$u = \frac{L_1 x + L_2 y + L_3 z + L_4}{L_9 x + L_{10} y + L_{11} z + 1} \qquad (11.1)$$

and

$$v = \frac{L_5 x + L_6 y + L_7 z + L_8}{L_9 x + L_{10} y + L_{11} z + 1}, \qquad (11.2)$$

The coefficients L_1 to L_{11} are linear functions of the camera orientation (τ, ϕ, σ), the camera position (x_c, y_c, z_c) and the effective focal length (f). The inverse transformation from image to field coordinates results in a system of two equations with three unknowns. The z-coordinates are assumed in this transformation to match a certain horizontal reference level or the tidal water level.

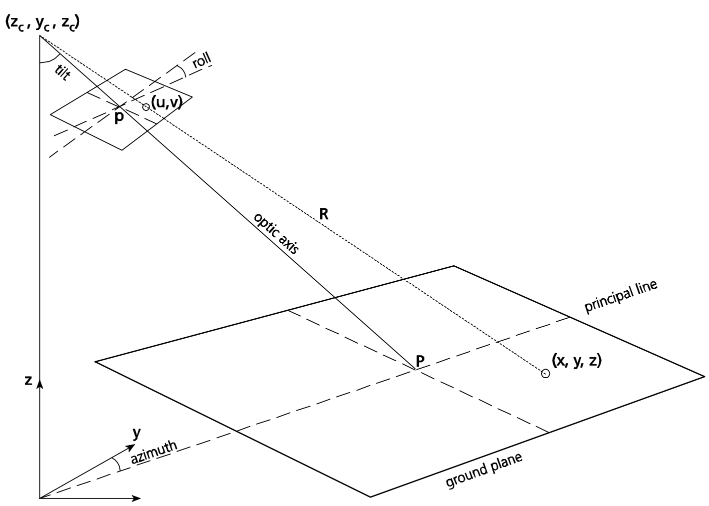


Figure 11

Relation between image (u,v) and real world (x,y,z) co -ordinates

Standard photogrammetric procedures (**Holland et al., 1997**) enable the transformation from real world coordinates (x,y,z) to image coordinates (u,v) on the basis of the collinearity equations (Equation (11.1) and (11.2)) .The latter contain 11 coefficients L_1-L_{11}, which are described as

$$
\begin{aligned}
L &= -\left(x_c m_{31} + y_c m_{32} + z_c m_{33}\right)\\
L_1 &= \frac{\left(u_0 m_{31} + f m_{11}\right)}{\left(\lambda_u L\right)}\\
L_2 &= \frac{\left(u_0 m_{32} + f m_{12}\right)}{\left(\lambda_u L\right)}\\
L_3 &= \frac{\left(u_0 m_{33} + f m_{13}\right)}{\left(\lambda_u L\right)}\\
L_4 &= -\left(L_1 x_c + L_2 y_c + L_3 z_c\right)\\
L_5 &= \frac{\left(v_0 m_{31} + f m_{21}\right)}{\left(\lambda_v L\right)}\\
L_6 &= \frac{\left(v_0 m_{32} + f m_{22}\right)}{\left(\lambda_v L\right)}\\
L_7 &= \frac{\left(v_0 m_{33} + f m_{23}\right)}{\left(\lambda_v L\right)}\\
L_8 &= -\left(L_5 x_c + L_6 y_c + L_7 z_c\right)\\
L_9 &= \frac{m_{31}}{L}\\
L_{10} &= \frac{m_{32}}{L}\\
L_{11} &= \frac{m_{33}}{L}
\end{aligned}
\tag{11.3}
$$

In Equation (11.3), (x,y,z) are the camera *xyz*-coordinates, (u_0,v_0) are the image center *uv*-coordinates, f is the effective focal length and λ_u and λ_v are the horizontal and vertical scale factors. The *m*-coefficients describe the successive rotations around the azimuth ϕ, tilt τ and roll σ,

$$
\begin{aligned}
m_{11} &= \cos\phi\cos\sigma + \sin\phi\cos\tau\sin\sigma\\
m_{12} &= -\sin\phi\cos\sigma + \cos\phi\cos\tau\sin\sigma\\
m_{13} &= \sin\tau\sin\sigma\\
m_{21} &= -\cos\phi\sin\sigma + \sin\phi\cos\tau\cos\sigma\\
m_{22} &= \sin\phi\sin\sigma + \cos\phi\cos\tau\cos\sigma\\
m_{23} &= \sin\tau\cos\sigma\\
m_{31} &= \sin\phi\sin\tau\\
m_{32} &= \cos\phi\sin\tau\\
m_{33} &= -\cos\tau
\end{aligned}
\tag{11.4}
$$

The theoretical formulations presented here are valid for use with distortion-free lenses. Owing to the incorporation of λ_u and λ_v, the formulations embody a correction for the slightly non-squareness of individual pixels. The latter is induced by a minor difference in sampling frequency between the camera and image acquisition hardware, which causes a minor mismatch between the number of horizontal picture elements at the camera CCD and the number of columns at the image frame buffer, where the image processing system stores the video data.

ARGUS Database

The ARGUS data base of meta information (hereafter referred to as ARGUSDB) is a key-component of the ARGUS Runtime Environment. Without ARGUSDB, no quantitative interpretation of image features would be possible. The ARGUSDB contains all information needed to quantitatively interpret ARGUS video images. This concerns the characteristics of the local site, video station, image processor, cameras applied, the available ground control points and geometry solutions, etc. All meta information is accessible on the basis of the ARGUS image filename (that is: epochtime, name of the station and camera number). The different components of ARGUSDB are all inter-connected. For instance, on the basis of the site identifier, all video stations available at that site can be found. On the basis of the station identifier, all cameras of that station can be found. On the basis of a camera identifier, all geometry solutions available for that camera can be found, etc. Using the epochtime of interest as an additional constraint yields a unique geometry solution, etc.

Merging images

Panoramic and plan view merged images can be composed by geo-referencing the images from all the cameras of an ARGUS station. Plan view images enable the measurement of length scales of morphological features like breaker bars and the detection of rip currents. A very useful post-processing tool is the ARGUS Merge Tool which enables to rectify and join together single time averaged ARGUS images. This results in a plan view of the nearshore zone (Figure 12).

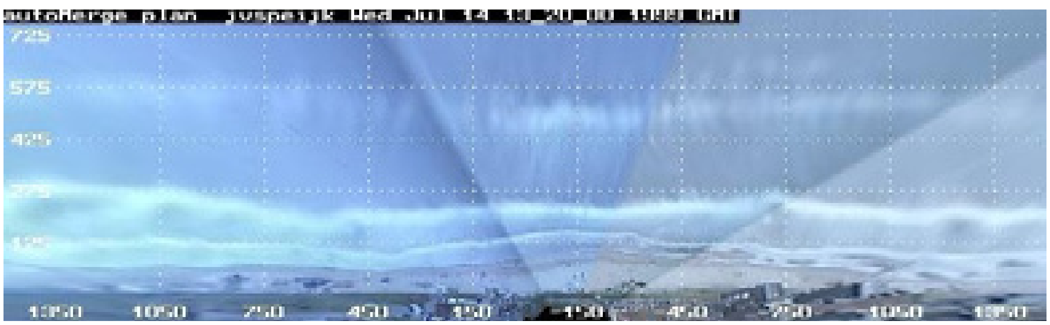


Figure 12
Merged image

The bright regions indicate regions of intense wave breaking hence the location of shallow water depth. In this way, morphologic features like the shoreline and breaker bars can easily be identified. Within the ARGUS merge tool it is possible to specify the condition at which moments images are collected to create a merged image. The condition can either be a tidal level or a wave height, both user-defined. Specifying a condition with wave heights larger than 1.5 m produces merged images on which the bars are clearly visible by the smooth white bands at locations with a lot of wave breaking. These images are appropriate to analyse the behaviour of bars. When a low-tide level condition is specified, for example NAP -0.60 m, the rendered merged images are very useful to analyse the morphological features of the intertidal beach.

11.6 ARGUS tools

At present, ten applications are part of the standard set of ARGUS analysis tools. These are summarized in Table 11.1.

No	Application	Functionality
1	DBOrganizer	Organise database entries (add, delete, edit)
2	geomtool2002	Make geometry solutions on ARGUS images for geo-referencing
3	ARGUSMergeTool	Merge ARGUS images (plan and panoramic view)
4	MovieMaker	Make a movie of ARGUS images
5	ARGUSStackTool	Sample intensities along one array, creating stacked images
6	IBMapper	Interactive mapping of shorelines on ARGUS images
7	iBathy	Interpolate intertidal bathymetry based on mapped shorelines
8	IBProcessor	Analyse data intertidal beach (shorelines and bathymetry)
9	PixPack	Design and analyse pixel timestacks
10	autoGeom	Automatic generation of geometry solutions

Table 11.1
Overview of standard ARGUS Analysis Tools

An eleventh application named ARGUSDesignTool (ADT), that can be applied to design the camera configuration of new ARGUS stations, is meant for specialized use only.

11.7 ARGUS applications

Successful use of video monitoring techniques in support of coastal management and engineering involves the quantification of relevant coastal state information from video data. Sophisticated, operational video analysis methods nowadays enable:

- the quantification of shoreline evolution and beach width, to evaluate the potential for recreation or to assess the morphological impact of a storm event (*cf. Application 1*);
- the quantification of erosional and accretional sediment volumes at the intertidal beach, for example to evaluate the morphological impact of coastal structures, to investigate seasonal fluctuations in beach dynamics and beach nourishments or to study the behaviour of morphological features such as sand spits and tidal flats near a harbour entrance (*cf Application 2*);
- the quantification of subtidal beach bathymetry, to evaluate coastal safety, to assess the behaviour and performance of shoreface nourishments or even to facilitate military operations (*cf. Application 3*);
- the quantification of wave run-up, to evaluate the stability of coastal structures such as seawalls, harbour moles and revetments (*cf. Application 4*);
- quantification of Coastal State Indicators with a high resolution in time through assimilation of model computations with ARGUS observations (*cf. Application 5*).

In a research context, video monitoring techniques have been applied to quantify alongshore flow velocities, wave characteristics such as wave angle and period, the occurrence of algae bloom and the distribution and persistency of rip currents. Future applications may involve the monitoring of visitor density at the beach and the prediction of rip currents.

The continuous collection of long-term, high-resolution data sets carries the additional advantage of a posteriori data selection, for instance for the consistent assessment of storm damage to public and private property and the early recognition of important erosion trends.

Application 1: quantification of storm-driven shoreline changes

At Barcelona (Spain), a shoreline detection model was used to assess storm-driven shoreline changes in front of Puerto Olimpico. The model derives the location of the shoreline from time exposure images on the basis of the colour contrast between the dry and the wet beach (**Aarninkhof et al, 2003**). Detailed observations show a shoreline retreat up to tens of meters during a single storm event, see Figure 13.

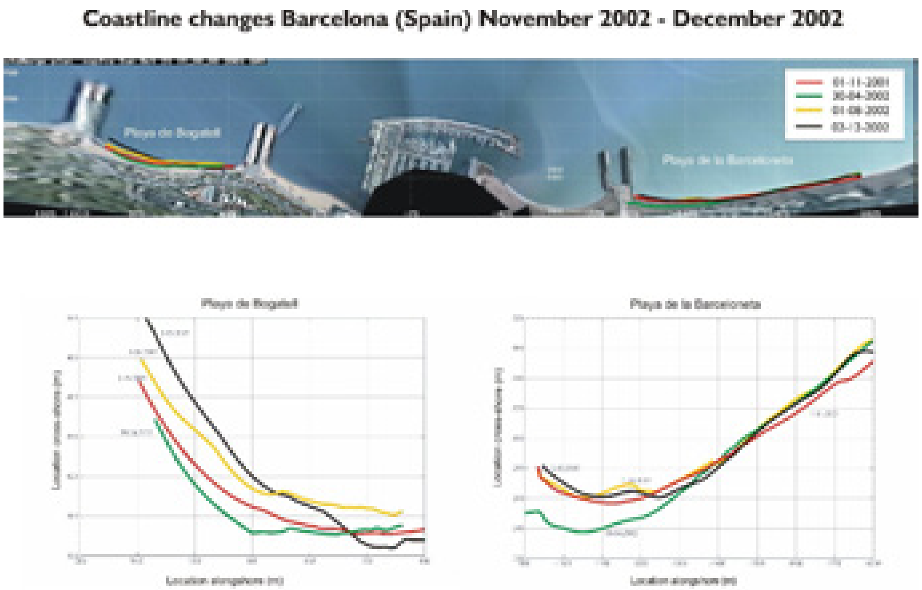


Figure 13
Coastline changes in Barcelona between November and December 2002 (courtesy of Dr. J. Guillén, CSIC, Barcelona)

Application 2: intertidal morphological changes at a nourished beach

At Egmond (The Netherlands), intertidal beach bathymetries were determined on a monthly basis by mapping a series of video-derived shorelines at different water levels throughout a tidal cycle. The mean vertical offset of this model is less than 15 cm along 85% of the 2 km wide study region. The resulting bathymetries (e.g., Figure 14a) were used to quantify patterns of erosion and accretion after a combined beach and shoreface nourishment. Example results are presented in the graphs (Figure 14b and c), which show average values of the monthly volume changes ΔV_{IB} per meter coastline (bars), as well as the cumulative morphological changes (lines). Negative values denote erosion. Figure (14b) presents the volume changes at a location 400 m to the south of the ARGUS station; Figure (14c) presents volume changes at a location 400 m to the north of the station. The analysis shows a tendency towards erosion during the first year. High-resolution video monitoring indicated that the additional beach nourishment implemented in the left-hand section (b) in July 2000 disappears from the intertidal beach within a few months.

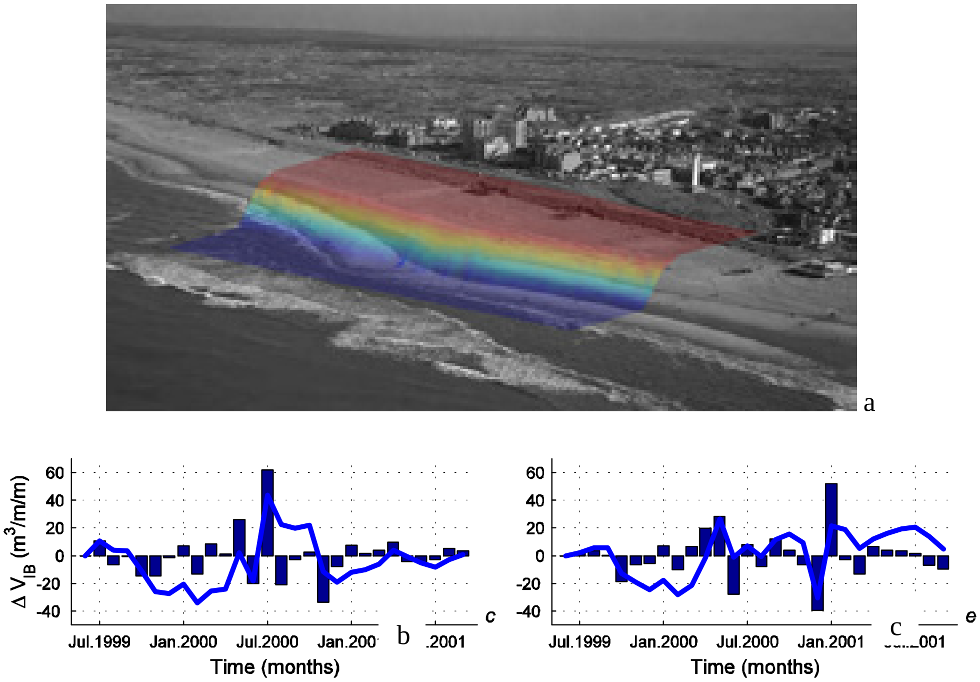


Figure 14
Intertidal bathymetry at Egmond aan Zee derived from ARGUS images. Volume changes are shown in two cross-shore arrays 400 m from the cameras to the north and south respectively.

Application 3: measurement of surf zone bathymetry

At Egmond (The Netherlands), ARGUS video imagery has been used to monitor the evolution of surf zone bathymetry (Figure 15) after implementation of a shoreface nourishment in July 1999. The bed elevation is continuously updated on the basis of a comparison of video-derived and model-computed patterns of wave dissipation (**Aarninkhof, 2003**). This approach yields marginal deviations in the order of 10 to 20 cm at the seaward face of the bars, which increase up to 20 to 40 cm near the bar crest. The results show a shoreward migration of the outer bar after deployment of the shoreface nourishment in combination with a net accretion of sediment along the shallow part of the beach profile above the -2 m depth contour, thus confirming the beneficial impact of the nourishment.

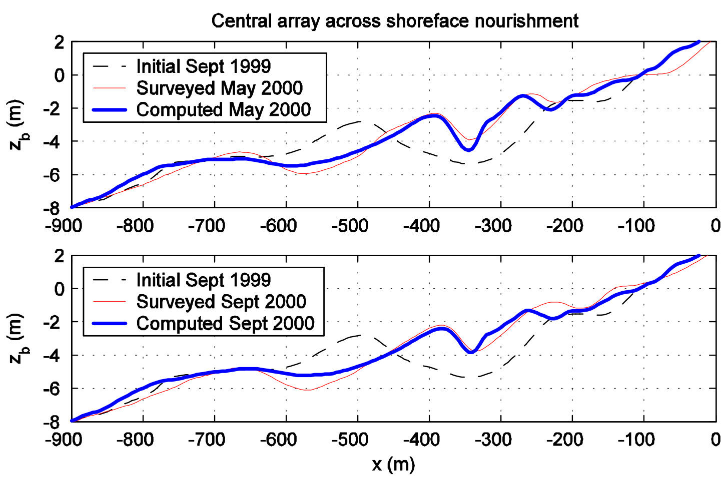


Figure 15
Subtidal bathymetry derived from ARGUS (blue), compared with a surveyed bathymetry (red) in May 2000 and September 2000. The computation started with a known bathymetry of September 1999.

Application 4: quantification of wave run -up on coastal structures

Wave run-up and wave overtopping are two of the mechanisms that may cause damage or even failure of coastal structures such as seawalls, harbour moles and groins. High frequency video observations (typically at 2 Hz) can be used to determine the statistics of wave run-up at beaches and coastal structures. Figure 16 shows an example of a timestack image, where pixel intensities are sampled along a cross-shore array in the swash zone and stacked over time. The position of the swash edge can be visually identified by the sharp change in intensity between the darker beach surface and the lighter 'foamy' edge of the swash bore (**Holland and Holman, 1993**). This type of monitoring yields information on the wave attack at structures during a single storm event or throughout the year.

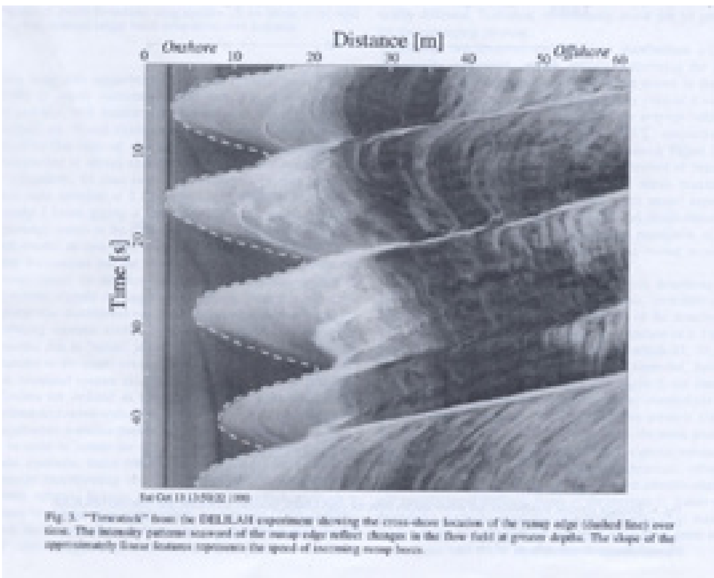


Figure 16
Time stacks of wave runup

Application 5: Beach Wizard, assimilation of model computations and video observations

The Beach Wizard model involves sophisticated use of high-resolution video observations in combination with a 2DH morphological model, which opens the door towards the nowcasting of nearshore hydrodynamics and bathymetric evolution with a high resolution in time and space, Figure 17. The Beach Wizard approach involves the application of a morphological area model to compute nearshore wave propagation and flow circulation patterns. Key-element of the model is the updating of bathymetry on the basis of high-resolution ARGUS video observations of the surf zone. This is achieved through assimilation of video-observed and model-predicted patterns of wave dissipation, wave celerity and intertidal beach bathymetry. Confidence intervals are determined for each bathymetry estimate, to enable a weighed assimilation of the different data sources and the model. Given the high resolution of video observations in time, this approach allows for virtually continuous monitoring of the evolution of surf zone bathymetry.

The technique has been applied to a synthetic case and two field sites at Duck, NC (USA) and Egmond (The Netherlands). The model is validated for a synthetic case which shows that the assimilation scheme is capable of recovering a barred beach bathymetry starting from an initially plane beach and only "knowing" the dissipation rate and celerity fields. The application to the Duck case shows that over a short time span (including one major storm) the model is capable of predicting the bathymetry rather accurately given a sequence of remotely observed inputs. The model was then applied to the longer term case of Egmond. Here, the model is also capable of predicting the profile change with the same parameter settings as in the Duck case. The agreement is better for the winter months with stronger observed signals than in the summer months.

The model output was used to estimate Coastal State Indicators. The intra-annual behavior shows a large variability which is of the order of the long-term (decadal) variation that is captured by the annual ground-truth surveys. While the net sum gain or loss over an alongshore area is smaller than the variation over an individual cross-section, the fact that beaches are very active over short time scales may have consequences for coastal management.

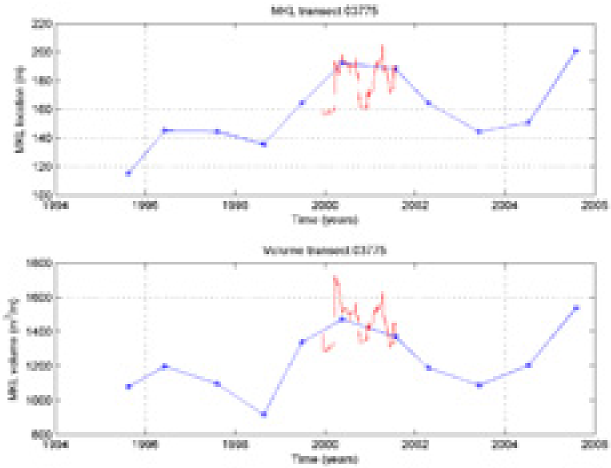


Figure 17
MCL position and volume at JARKUS transect 3775 from JARKUS data (blue) and assimilation model (red).

References

Aarninkhof, S.G.J. (2003). *Nearshore bathymetry derived from video imagery. PhD. Thesis, Delft University of Technology, 175 pp.*

Aarninkhof, S.G.J. and Holman, R.A. (1999). *Monitoring the nearshore with video. Backscatter, 10(2), pp. 8-11.*

Aarninkhof, S.G.J., Turner, I.L., Dronkers, T.D.T., Caljouw, M. and Nipius, L. (2003). *A video-technique for mapping intertidal beach bathymetry. Coastal Engineering 49, pp. 275 -289.*

Chickadel, C.C., R.A. Holman, and M. Freilich (2003). *An optical technique for the measurement of longshore currents. Journal of Geophysical Research, 108 (C11), 3364, doi: 10.1029/2003JC001774, 2003.*

Cohen, A.B., Aarninkhof, S.G.J. and Chicadel, C.C. (2004). *Video-derived observations of alongshore currents. Proceedings of the 29th ICCE, ASCE, Lisbon.*

Enckevort, I.M.J. Van and Ruessink, B.G. (2001). *Effect of hydrodynamics and bathymetry on video estimates of nearshore sandbar position. Journal of Geophysical Research, 106(C8): 16969 -16980, 2001.*

Holland, K.T. and Holman, R.A. (1993). *The statistical distribution of swash maxima on natural beaches. Journal of Geophysical Research, 98, pp. 10271 -10278.*

Holland, K.T., Holman R.A., Lippmann T.C., Stanley J.and Plant N.G. (1997). *Practical use of video imagery in nearshore oceanographic field studies. IEEE Journal of Oceanic Engineering, Vol. 22, No. 1.*

Holman, R.A. (1981). *Infragravity energy in the surf zone, Journal of Geophysical Research, 86(C7), 6442-6450, 1981.*

Holman, R and Chickadel C., (2004). *Optical remote sensing estimates of the incident wave angle field during NCEX. Proceedings of the 29th ICCE, ASCE, Lisbon.*

Holman, R.A., Sallenger Jr, A.H., Lippmann, T.C. and Haines, J.W. (1993). *The application of video image processing to the study of nearshore processes. Oceanography, Vol. 6, No 3.*

Lippmann, T.C. and Holman R.A. (1989). *Quantification of sand bar morphology: A video technique based on wave dissipation. Journal of Geophysical Research, 94 (C1), 995 -1011, 1989.*

Lippmann, T.C. and Holman R.A. (1990). *The spatial and temporal variability of sand bar morphology, Journal of Geophysical Research, 95 (C7), 11,575-11,590, 1990.*

Plant, N.G., Holland, K.T. and Puleo, J.A. (2002). *Analysis of the scale of errors in nearshore bathymetric data. Marine Geology 191, pp. 71-86.*

Stockdon, H. F. and Holman, R. A. (2000). *Estimation of wave phase speed and nearshore bathymetry from video imagery. Journal of Geophysical Research, 105(C9): 22015 -22034, 10. 1029/1999JC000124, 2000.*

Wijnberg, K.M.., Aarninkhof, S.G.J., Van Koningsveld, M., Ruessink, B.G. and Stive, M.J.F. (2004). *Video monitoring in support of coastal management. Proceedings of the 29 th ICCE, ASCE, Lisbon.*