The Scottish Government
Riaghaltas na h-Alba

Marine Scotland

A Technical Standard for Scottish Finfish Aquaculture

Developed by the Ministerial Group for Sustainable Aquaculture's Scottish Technical Standard Steering Group

June 2015

marine scotland

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FOREWORD

This Scottish Technical Standard has been developed by experts from the Ministerial Containment Working Group charged with minimising fish escapes in Scotland, chaired by Steve Bracken, Marine Harvest Scotland.

It has been designed to be appropriate and proportionate for the Scottish finfish farming industry; and informed by wide ranging consultation and engagement since 2010. It builds on *A report presenting proposals for a Scottish Technical Standard*[1], funded and published through the Scottish Aquaculture Research Forum (SARF) in 2012. It was further advised by a series of co-ordinated meetings and workshops in 2014-15.

The Standard determines technical requirements for fish farm equipment. It will be implemented by a regulation under the Aquaculture and Fisheries (Scotland) Act 2013, which allows Scottish Ministers to require Scotland's fish farming industry to adopt a Technical Standard and ensure a suitably trained workforce.

The Standard will be regularly reviewed and updated to reflect innovation and best practice development across the industry.

All equipment will be expected to meet the requirements by 2020 at the latest.

This Standard applies to the farming of all species of finfish in Scotland. It should be used alongside operational procedures, codes of practice, operators' manuals, and the training of staff to ensure equipment is used and maintained appropriately and that procedures are followed correctly.

[1] http://www.sarf.org.uk/cms-assets/documents/48448-527836.sarf073.pdf

CONTENTS

1 INTRODUCTION AND GUIDING PRINCIPLES

A finfish pen farm

1.1 Purpose

The purpose of this Standard is to help prevent escapes of finfish as a result of technical failure and related issues at Scottish finfish farms.

It relies upon the latest scientific information, and:

- The expertise within the Steering Group
- Industry expertise through consultation and workshops.

1.2 Scope

The core Standard focuses on **technical issues relating to equipment** used on fish farms, and includes operations and procedures that are necessary to provide information relating to technical issues and specifications and conducted by appropriately trained staff.

Escapes from fish farms can occur as a result of routine **farming operations**, and Section 1.3 refers to operating procedure guidance.

The Standard applies to the farming of all species of finfish in Scotland:

- At all seawater pen sites (stocked and un-stocked sites);
- At all freshwater pen sites (stocked and un-stocked sites);
- When transferring and storing pens and nets;
- At all land based farms (including tanks, ponds and raceways) regarding screens, flood risk and power failure; and
- When using fish transfer pipes and helicopter bins for transferring fish.

This Standard applies to a wide range of persons involved with the above operations in Scottish finfish farming including (but not limited to):

- Equipment suppliers including the provision of pens, nets, mooring systems and components, weighting systems and ancillary equipment;
- Service providers including site surveyors, mooring designers, transport companies, boat suppliers (including work boats, well boats and feed boats) and mooring installers; and
- Finfish company owners, directors and managers, purchasing managers, health and safety managers, environmental managers, boat skippers and operatives, maintenance personnel and certain operational staff.

1.3 Site Operating Procedures

Standards for conducting certain routine site farming operations are also important in ensuring containment, and these are included in the template for a **Site Operating Procedures (SOP) manual in Annex 4**.

It is anticipated that every farm in Scotland will have its own SOP manual. In many cases this will contain company-specific guidance to staff in addition to the provisions shown in the SOP template in Annex 4, but for the purpose of compliance with the overall Standard, the numbered guidance elements in the template are mandatory and auditable.


Routine fish farm operations

1.3.1.1

There must be a Site Operations Procedure manual available for all fish farm staff, containing the mandatory elements from Annex 4 of this Standard

1.4 Dialogue with suppliers

There will be many occasions where this Standard will apply to changes or modifications, or additions to existing farms or farm operations, and it is important to consult with equipment suppliers before doing so.

1.4.1.1

Every effort must be made to consult with equipment suppliers before making changes, modifications or additions to existing farms or farm operations

1.5 Documentation

It is necessary to be able to provide documentation which proves that all the compliance points contained within this Standard have been adhered to. The exact nature, format and location of the documentation is a matter for individual companies to decide. For example, there is no lack of clarity in relation to 1.4.1.1. above, if the farmers can show the compliance assessor any written communication relating to the consultation.

1.5.1.1
Adequate documentary evidence of compliance with all the mandatory provisions of this Standard must be made available for inspection

1.6 Competency

The site operator must be able to demonstrate appropriateness/suitability of equipment for that site (by someone of proven/demonstrable competence) for the key stages of design and operation of the equipment. The following stages require demonstration/evidence of competency by a competent person:

- Design
- Manufacture
- Supply
- Installation
- *In situ* checking
- Site operation
- Maintenance
- Kit/component replacement

In some cases it is likely that the same person or company may be the "competent" person for a number of stages. For example – the same company might design, manufacture and supply.

Environmental sampling

1.7 Training

Staff should receive appropriate training in connection with the installation, maintenance and operation of equipment.

2 SITE SURVEYS

East Loch Tarbert

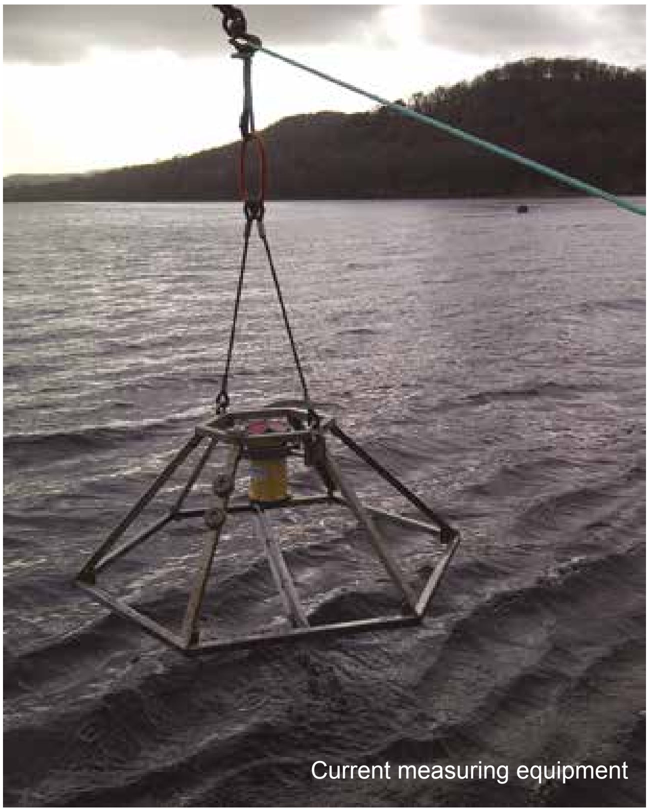
The purpose of this section is to determine the dimensioning currents, where appropriate basic wave parameters and pertinent geographical features which will be used as a basis for dimensioning and specifying the primary equipment at a fish farming pen site. Such information is obtained from a combination of site monitoring and desk based research and, where required, is further processed to determine wind, wave, and current conditions with a return period of 50 years that might be expected at the site. The importance of obtaining representative and robust information from site surveys is crucial to ensuring that aquaculture equipment is appropriate for use in the intended environment because it is used as a basis for calculating the forces to which the equipment will be subjected. Consideration of current, particularly tidal and wind generated, is of central importance since it usually generates the greatest forces on the equipment.

All the information generated from the provisions of Section 2 should be recorded in a single Site Survey Report.

2.0.1.1

A Site Survey Report shall be prepared for all new finfish sites or sites where significant equipment changes, for example regular use of a new and larger wellboat, which will alter the loading conditions on the mooring system are planned. The template provided in Annex 5 may be used, or an alternative if all points from Annex 5 are included. The Report must be made available to the organisations listed in the introduction to the template, and any others as deemed necessary.

2.1 Determination of current at seawater pen sites



Current measuring equipment

2.1.1 Approach to current monitoring

2.1.1.1

Current monitoring shall be undertaken following the methodology of certain requirements of Attachment VIII (SEPA, 2008) as outlined in Annex 6

2.1.1.2

Dimensioning currents shall be obtained in at least eight concurrent directions aligned to include the direction(s) in which the highest speed current(s) may be expected

2.1.1.3

Current measurements shall be collected over a period of 90 days (see Annex 6), noting that:

2.1.1.3.1

The 90 days of measurement need not be continuous, but contributing recording periods shall not be shorter than 15 days

2.1.1.3.2

Sampling frequency shall be as high as economical use of the current measuring equipment permits, with a sampling interval of at most a few minutes

2.1.1.3.3

As a general rule, the record shall be obtained from depths representative of pen net depths, and as close to the surface as practicable

2.1.1.3.4

Measurements that have been made over a period totalling 90 days at times of lower tidal ranges may be scaled up to simulate the continuous 90 day period of highest tidal ranges in the year, by a multiplier greater than 1 (typically 1.1 or thereabouts), based on the ratio of the average tidal range in each of these periods.

2.1.1.4

The maximum current velocity (MCV) obtained from the current monitoring described above will be adjusted by two multiplying factors (initially precautionary) to provide a dimensioning current – see Annex 6. The steps are as follows:

1. Adjustment for time of year

Monitored over 90 day period which includes the highest tides of the year	MCV x 1
Monitored over 90 day period which excludes the highest tides of the year	MCV x 1.1

NOTE:

a. For the avoidance of doubt, 90 day periods which include the full months of the equinoxes in March or September cover the highest tides of the year

The result from Step 1 is designated MCVb.

2. Adjustment for tidal strength of site

Strongly tidal site	MCVb x 1.4
Weakly tidal site	MCVb x 1.7

The result from Step 2 is the dimensioning current for use in subsequent design calculations.

NOTES:

a. The standard acknowledges that there is as yet no single agreed methodology to identify whether a site is weakly or strongly tidal, but Annex 6 presents one way to approach this assessment. However the assessment is undertaken, individual developers and their advisors should provide documentary evidence of the approach taken

b. In the absence of an assessment as suggested above, developers shall adopt the precautionary approach, and use the factor of MCVb x 1.7

2.2 Determination of current at freshwater pen sites

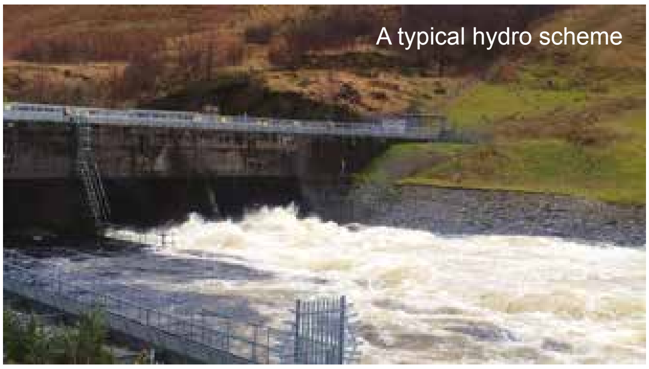
2.2.1 Approach to current monitoring

The assessment of dimensioning currents for freshwater pen sites is generally viewed as less critical than that for seawater sites, and also less amenable to standardisation across the different types of freshwater body in Scotland. Furthermore, the standard of equipment being installed in freshwater pen sites is believed to be sufficiently high – having been derived from seawater specifications – as to render the risks associated with currents to be low.

Nevertheless, the additional provisions of Section 2.3 to 2.5 should be considered when designing systems for freshwater pens.

2.3 Additional current monitoring considerations for seawater and/or freshwater pen sites

2.3.1 Consideration of currents of intermittent origin


A typical hydro scheme

Some sites may also be affected by currents other than tidal or wind-induced, such as, but not limited to, river flows, wave reflections and discharge from hydroelectric schemes. If this is likely to be the case, the current assessments referred to in 2.1 and 2.2 must be augmented as indicated below. Should such conditions be foreseen, the installation of a fish farm at the site should only proceed if it can be demonstrated that these will not adversely affect the integrity of the fish farm.

2.3.1.1

The 90 day monitoring period for seawater sites shall be timed to coincide with peak currents arising from the temporal element, are far as is practicable

2.3.1.2

If provision 2.3.1.1. is not able to supply the necessary information in the case of freshwater sites, the additional contribution to the current velocity shall be calculated

2.3.2 Using existing current monitoring results

Existing historic or alternative current monitoring results may be used as a basis to determine the dimensioning currents providing they meet the requirements in 2.1.1 above. Different monitoring depths are acceptable, and can be accommodated as indicated below:

2.3.2.1

Should the historic monitoring have been at alternative depths, these can be interpolated to obtain the results for the required depth(s)

2.4 Determination of wind velocity

Wind velocity is necessary for the determination of the dimensioning currents and wave parameters in freshwater sites but should also be considered for seawater sites.

2.4.1.1

The wind velocity for the site may be determined by an approach based on BS EN 6349, but it is highly likely that it can be ascertained from publicly available records, such as the Met Office[2]. Reference shall be made to BS EN 1991-1-4:2005+A1:2010 for identifying the 10 and 50 year wind speed for seawater and freshwater pen sites.

2.5 Determination of waves at sea sites

The combined sea state should be determined by combining the parameters determined for ocean swells with those calculated for wind-induced waves – see below.

2.5.1 Determination of wind induced waves for seawater pen sites

Wind induced waves may be determined by direct *in situ* measurements, or by calculation, as indicated below.

2.5.1.1

In situ wave measurements may be made, but there is no established sampling and analysis programme for Scottish aquaculture. Some Acoustic Doppler Current Profiler equipment can also measure waves[2]

2.5.1.2

Determination of wind induced wave parameters by calculation shall follow the process set out in Annex 7

2.5.2 Consideration of ocean swells

Whether the site is subject to ocean swells should be determined through observation and/or desk study. This decision, and the accompanying rationale, will be documented. In the case of doubt, it will be assumed that ocean swells do affect the site.[3]

2.5.2.1

The significant wave height and peak period shall be calculated by recognised and validated methods for return periods of 10 and 50 years. Refer to BS 6349
Alternatively, see: http://www.metoffice.gov.uk/research/areas/ocean-forecasting/ocean-waves

2.6 Seabed Surveying

Whilst it is inappropriate to suggest a detailed mandatory approach to seabed surveying in this initial iteration of the Standard, this topic is relevant to both design and installation of farming equipment, and particularly moorings and anchors.

[2] See for example: http://www.metoffice.gov.uk/renewables/metocean

[3] http://ww.rdinstruments.com/tiops/tips–archive/adcpWarray_0203.aspx

The correct installation of drag anchors is fundamental, but full load testing post-installation is impossible because of the types of vessels currently available to the industry and its suppliers. As an alternative approach, an accurate sub-bottom profile of the seabed in the areas where anchors will be installed would assist designers in terms of specifying the anchors for the underlying substrate. Post-installation visual inspection would then help to confirm that anchors have embedded as expected.

If alternative methods of scaled-down load testing are developed and validated, this type of seabed profiling may become less relevant in the future.

3 REQUIREMENTS FOR MOORING OF PENS

A diagram of pens and part of the mooring system

This section relates to moorings for pens. The mooring of feed barges is addressed in this section, but also in Section 7, and Section 8 includes mooring of boats and secondary equipment.

The distinction between the designer of a mooring system and the supplier of a mooring installation and its components should be made. In some cases these are the same organisations and in others they are not. Nevertheless, the key responsibilities outlined in this section should be self-evident for compliance auditing purposes. Specifically, suppliers who were not responsible for the design cannot provide any assurances of the appropriateness of the equipment for the intended environmental conditions, other than in relation to manufacturing, materials and installation standards which are within their control.

3.1 The mooring design process

The design of the mooring system should ensure that it is suitable for the envisaged environmental conditions and all conceivable operations at the site(s) at which it is to be deployed, and that it is suitable for all primary and secondary equipment and boats which the mooring designer has been informed will be used at the site: refer to Section 1.4.

3.1.1.1

Prior to finalising a specification for a new or completely refurbished/upgraded mooring system, the mooring designer shall be provided with:

3.1.1.1.1

A copy of the Site Survey Report produced in accordance with this Standard, including the location of the site – Annex 5

3.1.1.1.2

Details of the pen(s), for which the mooring system is to be designed, including size, shape and main construction materials

3.1.1.1.3

Details of the net (including overall dimensions and net porosity) and weighting system for which the mooring system is to be designed

3.1.1.1.4

Details of any secondary equipment and boats for which the mooring system will be designed including well boats, work boats and feed boats

3.1.1.1.5

Alternatively, a set of generic parameters addressing the points .1.1 to .1.4 above, but with a minimum of the information stated in the table in Annex 5, may be provided to enable a mooring system to be designed for use with a range of primary and secondary equipment

3.1.1.2

The mooring design shall be shown on a mooring specification sheet

3.1.1.3

Mooring designers should state a limitation on secondary equipment and/or operating conditions in relation to attachment to the mooring system they have specified

3.2 Key design issues

3.2.1.1

The mooring system shall be designed in respect of all envisaged environmental conditions during all conceivable operations:

3.2.1.1.1

To consider the fatigue and accidental limit states as well as the ultimate limit state

3.2.1.1.2

To tolerate all expected loads and deformations with satisfactory safeguarding against failure – such safeguarding is applied through the use of various load, material and environmental factors contained within this Standar*d*

3.2.1.1.3

To maintain all primary and secondary equipment, as planned

3.2.1.1.4

To prevent a significant deterioration of an initial incident – particularly ensuring that the failure of any single mooring component would not lead to the failure of any other component

3.2.1.1.5

To protect against those mechanical, chemical, physical or biological processes that could have a significant negative impact on the equipment taking into account planned maintenance and expected operational life

3.2.1.1.6

Such that for steel pens mooring lines in the same direction will be of approximately the same tension, allowing the use of different materials

3.2.1.1.7

Such that unless the anchor is designed to carry vertical loads, the mooring lines shall be designed to avoid vertical loads

3.2.1.1.8

Such that all elements of the mooring system shall not be subject to chafing or snagging

3.2.1.1.9

To prevent the unplanned wear and/or damage of all primary and secondary equipment

3.2.1.2

The following shall be included in the manufacturer's instructions:

3.2.1.2.1

The maximum adjustment that can be made to any element of the mooring system

3.2.1.2.2

The maximum draught for boats in respect of grid ropes (and any other relevant components of the mooring system)

Site-specific experience should be taken into account during the design process, and the basic principle of redundancy should be applied at all design stages.

3.3 Designing the mooring system

All design activities, including calculations, assumptions, analysis and specification shall be documented by the mooring designer and be available to the fish farmer throughout the life of the mooring system.

3.3.1 Determining the loads

3.3.1.1

The loads acting on the mooring system shall be determined as follows:

3.3.1.1.1

The types of loads that may affect the mooring system shall be identified with reference to Annex 9

3.3.1.1.2

The magnitude of the loads identified above shall be determined using static, quasi-static or dynamic analysis as follows:

3.3.1.1.2.1

It will be based upon the load factors in Annex 10

3.3.1.1.2.2

It will use a verifiable method of calculation – this shall either follow the example in Annex 11 or shall follow a similar premise

3.3.1.1.2.3

An assumption should be made that 50% of the net surface of a seawater pen is solid with respect to drag, as a result of a combination of twine area + worst-case fouling. See Annex 15 for a table of twine areas

3.3.1.1.2.4

An assumption should be made that 40% of the net surface of a freshwater pen is solid with respect to drag, as a result of a combination of twine area + worst-case fouling – unless site specific experience indicates that a higher figure should be used

3.3.1.1.2.5

All other factors shall be identified and justified

3.3.1.2

Should waves be calculated, different combinations of environmental parameters shall be considered and the most unfavourable combination used for dimensioning each ultimate limit state for:

3.3.1.2.1

The 50 year current and 10 year wave; and

3.3.1.2.2

The 10 year current and the 50 year wave

3.3.1.3

Alternatively, should waves not be considered when designing the moorings, the 50 year current shall be used

3.3.2 Determining the resistance to the loads

3.3.2.1

The mooring system, and all component parts thereof, shall be designed so as to be able to resist the loads acting upon it as identified in Section 3.3.1. This analysis shall be based upon the material factors in Annex 10 and shall be documented; note that material factor shall be applied to the certified minimum break load of the materials as identified by the manufacturer

3.3.3 Confirming satisfactory capacity

3.3.3.1

The mooring system shall be designed such that the structure is able to resist the loads acting upon it in response to the ultimate limit state. This shall be assessed through partial co-efficient analysis as detailed in Annex 12 and shall be documented

3.3.4 Characteristic values

3.3.4.1

The mooring designer shall determine all relevant characteristic values for all elements of the mooring system which the mooring system will not exceed with respect to the envisaged environmental conditions and during all conceivable operations

3.4 Requirements for mooring boats and secondary equipment

Smaller boats moored to pens during harvesting

3.4.1.1

The mooring designer shall identify any requirements for the provision of mooring facilities by:

3.4.1.1.1

Confirming with the fish farmer the requirements for mooring boats and secondary equipment for which the site should be designed[4]

3.4.1.1.2

Identifying and designing the mooring positions

3.4.1.1.3

Confirming any restrictions on the use of mooring positions including, but not limited to, environmental conditions and boat characteristics

3.4.1.2

With regard to boat moorings:

3.4.1.2.1

Specific boat moorings shall be provided for all boats which are in excess of the capacity of the pens and/or the pen mooring system

[4] The fish farmer shall consider all conceivable operations and the range of environmental conditions in which specific opartions may be conducted, including the most unfavourable combinations.

3.4.1.2.2

Any limitations in mooring well boats and other larger vessels shall be specified, including the maximum environmental conditions in which boats of specified characteristics *(such as length, tonnage, draught, windage etc.)* can be moored to boat moorings or to the pen mooring system

3.4.1.2.3

Moorings (whether specific or as part of the pen mooring system) shall be provided for all relevant secondary equipment so that there is no requirement to moor directly to the pens when not in use

3.4.1.2.4

Any mooring points provided for boats and secondary equipment within the vicinity of the pens shall be dimensioned, constructed, installed and maintained in accordance with this Standard

3.5 Requirements for components and materials

Chain plate

3.5.1 Connector testing

3.5.1.1

All connectors require a certificate where the strength has been documented either through testing or through calculations. Certificates shall be provided to and checked by the supplier, and included in the site documentation. This shall include, but is not limited to:

3.5.1.1.1

Coupling discs, plates and rope rings

3.5.1.1.2

Pen couplings

3.5.1.1.3

Slings

3.5.1.1.4

Shackles

3.5.1.1.5

Chains

3.5.1.1.6

Ropes

3.5.1.1.7

Buoys if they are connecting components of the mooring system

3.5.1.2

Documentation shall be available stating that knots and splices in the type of rope and adjoining hardware are of appropriate strength for use in the given application. The mooring designer shall ensure that the material factors used in this Standard are appropriate on the basis of this documentation and shall, if required, increase these appropriately; such factors, however, shall not be decreased.

3.5.2 Chains

This section is related to new installations and modifications to existing sites.

3.5.2.1

Chain used in mooring or anchor lines should be of a suitable grade and strength to meet the required design loads but not greater than grade 4

3.5.2.2

Chains other than those used in mooring or anchor lines shall be:

3.5.2.2.1

Protected against corrosion and tempered if appropriate

3.5.2.2.2

A maximum of Grade 8

3.5.2.3

All chain shall be tested post galvanisation to 62.5% of the break load

3.5.2.4

All chain shall be accompanied with Test Certificate 3.1 in accordance with BS EN 10204

3.5.2.5

When chain is re-used:

3.5.2.5.1

Reference shall be made to the material factors in Annex 10

3.5.2.5.2

The actual diameter shall be used for calculation purposes, rather than the diameter when the chain was new

3.5.3 Shackles

3.5.3.1

Only Certified shackles shall be used in the mooring system and the design shall meet the requirements of the site as given in Annex 5

3.5.4 Grid connectors

3.5.4.1

All steel connectors including chain plates and rope rings shall have sufficient three-dimensional strength for the intended use and attachment points which have been designed as lifting equipment in accordance with BS EN 1677

Chain

3.5.5 Rope

Splicing rope

3.5.5.1

All ropes shall comply with a relevant standard, such as a BS, where appropriate – see Annex 10

3.5.5.2

All rope shall be accompanied with a material certificate

3.5.5.3

As well as meeting the material factors in Annex 10, fibre ropes that pass around a curved shape shall be curved at a minimum of three times the rope diameter

3.5.6 Buoys

3.5.6.1

Buoys shall be specified by the pen and moorings designers so as to be able to satisfactorily withstand forces from moorings

3.5.6.2

Cushion floats shall demonstrate balanced buoyancy in regard to the vertical loads generated

3.5.6.3

All steel elements of buoys shall be resistant to corrosion to a minimum equivalent as specified in BS EN ISO 1461:1999

3.5.6.4

The connection point shall be designed as lifting equipment in BS EN 1677 when manufactured, but not necessarily maintained as lifting equipment for operational purposes

A typical buoy

3.5.7 Anchors and mooring attachment points

3.5.7.1 Anchors

3.5.7.1.1

Specification of anchors, including consideration of the anchor type and, for drag anchors blade angles and geometry where relevant, shall be undertaken by the mooring designer with regard to the topography and type of sea/loch bed at the site and on the basis of test loads and/or demonstrable performance in similar conditions

3.5.7.2 Rock bolts

3.5.7.2.1

Rock bolts shall be specified by the moorings designer to withstand the loads in the mooring lines using the relevant material factors in Annex 10

3.5.7.2.2

Rock bolts shall be installed in accordance with the manufacturer's instructions, with specific reference to the penetration angle and the application of epoxy grout if used

3.5.7.3 Dead weight moorings

3.5.7.3.1

Should dead weight moorings be used, their resistance to sliding and rising should be calculated and documented by the mooring designer. The holding power is required to be at least twice the calculated design load in the mooring line.

3.6 Swinging moorings

3.6.1.1

Swinging or swivel moorings should comply with BS 6349

3.7 Previously used equipment

3.7.1.1

Mooring systems, or parts thereof, that are constructed from components previously used in operational installations shall comply with exactly the same standards as outlined in this section, and unless the mooring designer can attest to this, use of such components is not permitted.

Rock bolt system

4 PEN DESIGN AND CONSTRUCTION

Finfish pens

The pen in which fish are held is the principle containment unit in Scottish aquaculture, and this section provides guidance on the design and construction of all the solid aspects of the pen, excluding the nets, which are considered in Section 5.

4.1 The pen design process

There is no internationally accepted certification or accreditation for companies manufacturing aquaculture pens, but for the purpose of the Standard it is assumed that all manufacturers operate to the standards outlined herein, and in Annex 3. This applies equally to manufacturing techniques and materials.

4.1.1.1

The pen manufacturer shall specify on the pen specification sheet:

4.1.1.1.1

The range of environmental parameters, including current and wave characteristics, for which the pen has been designed

4.1.1.1.2

Any other restrictions/limitations on use

4.2 Suitability of the pen for use

4.2.1.1

The pen and associated connectors shall be designed and constructed:

4.2.1.1.1

To be suitable for the environmental conditions stated on the pen specification sheet

4.2.1.1.2

To be able to withstand the forces imposed from all loads acting upon them

4.2.1.1.3

So as not to chafe and/or snag the net or mooring system in the environmental conditions for which it has been designed (assuming the net and weighting systems are handled and installed in accordance with the manufacturer's instructions)

4.2.1.1.4

So that it is capable of being towed to and from the site in the environmental conditions that may be encountered without damage – any restrictions in this regard shall be documented in the manufacturer's instructions

4.2.1.1.5

So that the net, top net and weighting system is easily installed

4.2.1.1.6

So that it is easy to keep the pen equipment clean and remove growth/algae

4.2.1.1.7

To minimise the retention of water and debris on the pen equipment

4.2.1.1.8

To meet HSE advice for floating fish farm installations

4.3 Dimensioning the pen(s)

4.3.1 Determining the loads

4.3.1.1

The loads acting on the pen(s) system shall be determined as follows:

4.3.1.1.1

The types of loads that may affect the pen shall be identified with reference to the list in Annex 9

4.3.1.1.2

The magnitude of the loads identified above shall be determined using static, quasi-static or dynamic analysis based upon the load factors in Annex 10. A verifiable method of calculation shall be used

4.3.2 Determining the resistance to the loads

4.3.2.1

The pen(s) shall be dimensioned so as to be able to resist the loads acting upon it/them as identified in 4.3.1 above. This analysis shall be based upon the material factors in Annex 10 and shall be documented; note that material factor shall be applied to the certified strength of the materials as specified by the manufacturer

4.3.3 Confirming satisfactory capacity

4.3.3.1

The pen(s) shall be dimensioned such that the structure is able to resist the loads acting upon it in response to the ultimate limit state. This shall be assessed through partial co-efficient analysis as detailed in Annex 12

4.3.4 Characteristic values

4.3.4.1

The manufacturer shall determine all relevant characteristic values for the primary equipment and/or components thereof which the pen will not exceed with respect to the envisaged environmental conditions and during all conceivable operations

4.4 Specific requirements for steel pens

Steel finfish pens

4.4.1 Strength calculations

4.4.1.1

Strength calculations shall be undertaken and documented regarding global strength analysis and local strength analysis, including:

4.4.1.1.1

Maximum shear stress of sections

4.4.1.1.2

Maximum shear and torsional stresses at hinge positions

4.4.1.1.3

Maximum tensile stress at mooring positions

4.4.2 Materials and fastenings

4.4.2.1

Material factors shall be in accordance with BS EN 1993-1-1 and Annex 10. Safety factors shall be in accordance with BS EN 1990. The yield strength shall be used to describe the capacity of the steel

4.4.2.2

Fastenings using bolts, screws and similar shall be undertaken as follows:

4.4.2.2.1

Bolts and screws shall be compatible with the materials being joined

4.4.2.2.2

The materials in which bolts and screws are located shall be able to satisfactorily resist wear from their use in the envisaged environmental conditions and during all conceivable operations

4.4.2.2.3

Bolts and screws shall be pre-stressed

4.4.2.2.4

Locking nuts shall be used

4.4.2.2.5

Bolts shall be of sufficient length that at least one thread pitch is visible when the nut is secured

4.4.2.2.6

Appropriate washers shall be used to distribute the load and also to prevent galvanic corrosion if relevant

4.4.2.2.7

Appropriate grades of bolts and nuts shall be used to prevent thread stripping

4.4.2.2.8

All fastening devices and secondary equipment shall be used in accordance with the manufacturer's instructions, unless documented agreement has been made to deviate from these in defined circumstances

4.4.2.3

Confirm that with reference to the envisaged environmental conditions and during all conceivable operations that the connections:

4.4.2.3.1

Are of sufficient strength

4.4.2.3.2

Will perform satisfactorily for the intended use

4.4.2.3.3

Will not chafe the net

4.4.3 Steel fatigue

4.4.3.1

Fatigue calculations shall be undertaken for all critical parts in accordance with BS EN 1993-1-1. Dynamic loads with oscillation periods within the expected wave period range shall be taken in to consideration

4.4.4 Floatation

4.4.4.1

Floatation must be calculated, installed and maintained to take account of all possible loads from equipment.

4.5 Specific requirements for plastic pens

Plastic finfish pens

4.5.1 General

4.5.1.1

Dimensioning shall be undertaken in regard of the ultimate limit state in accordance with the load combinations detailed in Annex 9. The calculations, as well as the following, shall be documented:

4.5.1.1.1

The loads and load combinations used

4.5.1.1.2

The load factors used

4.5.1.1.3

The material factors used

4.5.1.2

When dimensioning:

4.5.1.2.1

The capacity of the cross section of plastic pipes shall not be exceeded

4.5.1.2.2

Creep and temperature dependency should be taken into account when calculating the capacity of the cross section

4.5.2 Strength calculations for plastic pens

4.5.2.1

When designing plastic pens, the pen's geometry, situation and external forces should be taken into account using either:

4.5.2.1.1

Standard mechanical engineering formulae in situations with small displacement, unchanged geometry and linear visco-elasticity, or

4.5.2.1.2

Non-linear finite element analysis in cases of non-linear material deformation or large geometrical changes

4.5.2.2

Producers of plastic used in pens shall provide data on stretch and shear strength of the materials they produce and these shall be used in design calculations. Materials shall also be tested independently by pen manufacturers taking account of stress time, type, static or dynamic situation, temperature and environmental conditions. The strength characteristics of the pen, especially in relation to long-term loads, shall be documented.

4.5.2.3

The following material factors for plastic shall be used:

4.5.2.3.1

Accident limit state: 1.0

4.5.2.3.2

Ultimate limit state: 1.25

4.5.2.4

Standards that apply include: BS EN 12201-2, DIN 16842:2013 and WIS 4-32-08

4.5.2.5

Pens that are constructed from pipe previously used in smaller pens must comply with exactly the same standards as outlined in this section, and unless the manufacturer can attest to this, use of these is not permitted

4.5.3 Localised buckling

4.5.3.1

The buckling stress shall be calculated in areas where plastic pipes are exposed to significant bending forces, including areas with locally concentrated loads, using the following formula:

4.5.3.1.1

Fe = (0.5T)D-1)(E)
Where: Fe = buckling stress
D = pipe diameter
T = pipe wall thickness
E = elasticity module

4.5.4 Assessment of fatigue

4.5.4.1

A documented assessment of the probability of fatigue shall be undertaken for materials which may be subject to high and varying stress

4.5.5 Production of polyethylene pipes

4.5.5.1

The production of all polyethylene pipes shall be in accordance with BS EN 12201-2

4.6 Specific requirements for timber pens


Timber finfish pens

4.6.1 Strength calculation

4.6.1.1

Strength calculations shall be undertaken and documented to include:

4.6.1.1.1

Global strength analysis, including the forces from mooring; and

4.6.1.1.2

Local strength analysis

4.6.1.2

The manufacturer's instructions shall include the frequency and methodology of inspection and the qualifications and experience required of the inspector

4.6.1.3

All elements shall be in accordance with the relevant parts of BS EN 1995-1-1 Part 1-1

4.6.2 Materials

4.6.2.1

Material factors shall be in accordance with BS EN 1995-1-1 Part 1-1

4.7 Requirements for other types of pens

4.7.1.1

For any types of pens not covered by this Standard, the above principles for pen design and construction shall apply. Full documentation is required to support the dimensioning process

4.8 Requirements for integrated feed barges, ancillary equipment and pens

4.8.1.1

Where a feed barge is directly attached to the pen to form a single unit, the principles of this Section shall be applied to the integrated installation

4.8.1.2

In addition, the movement, or potential for movement, between the barge and the pen(s) shall be assessed and any specific measures required to protect against breach of containment specified; this assessment shall be documented

4.8.1.3

For any other ancillary equipment such as rafts which might be attached to a pen unit, the possibility of movement and chafing in the system shall be assessed, and mitigation measures put in place and documented in relation to components of the main pen

4.9 Statement of conformity

4.9.1.1

The manufacturer shall confirm that each completed pen has been manufactured:

4.9.1.1.1

In full accordance with the pen specification sheet, or with any deviations clearly indicated

4.9.1.1.2

In full accordance with this Standard; and

4.9.1.1.3

Provide the date of completion and unique identifier

Salmon feeding

5 NET DESIGN AND CONSTRUCTION

The integrity of the net component of the pen is vital to containment, and this section covers all aspects of net design and construction. It should be noted that nylon nets are considered in Section 5.3 and non-nylon nets in Section 5.5. The other parts of this section apply to nets of all materials.

5.1 The net design process

Nets for use in finfish pens are constantly evolving. There are developments in new materials for net construction, and also innovation in aspects such as anti-fouling treatments. These innovations may, in turn, change the routine farm operations involving nets. Such innovations will be constantly reviewed, and may be incorporated in future updates to the Standard.

5.1.1.1

The net manufacturer shall specify on the net specification sheet any restrictions/limitations on use of the net

5.2 Suitability of the net for use

5.2.1.1

The net shall be designed and constructed:

5.2.1.1.1
To be suitable for the pen(s) in which it is to be deployed

5.2.1.1.2
To be suitable for the weighting system(s) with which it will be deployed

5.2.1.1.3
To prevent chafing on the pen, weighting system and mooring system through consideration of sizing, design, choice of materials and construction

5.2.1.1.4

To properly fit the pen

5.2.1.2

All nets shall be provided with manufacturer's instructions in accordance with Annex 13

5.3 Nylon nets

5.3.1 Netting size

5.3.1.1

Netting size shall be described by the half-mesh measurement undertaken as detailed in Annex 14. *It should be noted that this measurement is not a measurement of the net aperture*

5.3.2 Key design issues

5.3.2.1

The net shall be designed, manufactured and assembled so that:

5.3.2.1.1

Forces are transferred through ropes rather than the twine throughout all operations when the net is used in accordance with the manufacturer's instructions

5.3.2.1.2

Lifting ropes shall tolerate the load when the net is lifted as detailed in the manufacturer's instructions

5.3.2.1.3

The net shall be inspected following manufacture for all quality issues, including the absence of holes. This shall be documented

5.3.2.1.4

The potential for damage to the net during transportation or installation should be addressed during post installation – see Section 8.7 of this Standard

5.3.2.1.5

The potential for the reduction in rope strength from splices shall be taken into account in the design process

5.3.3 Down ropes

5.3.3.1

The net will be designed such that the weight of the net, the weighting system and any other equipment attached to the net is taken by the down ropes and not by the netting

5.3.3.2

Down ropes shall be:

5.3.3.2.1

Consistently spaced around the circumference of the net in a circular pen, and lined up with the handrail stanchions

5.3.3.2.2

With maximum intervals of 5.1m

5.3.3.3

Down ropes:

5.3.3.3.1

Shall cross the base of the net and proceed up the opposite side in a continuous length or process

5.3.3.3.2

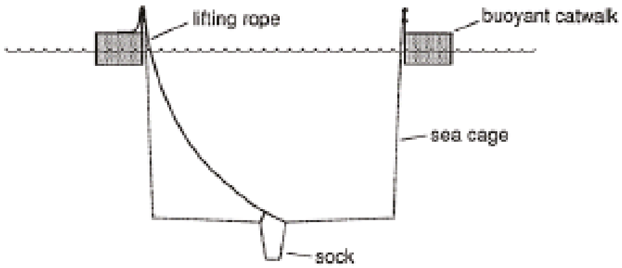
Will be capable of being used as lifting ropes when used in accordance with the manufacturer's instructions

5.3.3.3.3

Must be attached to the netting in such a way that when the weighting system is attached the netting is sufficiently tensioned to deter potential predators without being put under undue strain

5.3.3.4

Mortality socks shall be constructed with support ropes, which should be attached with a rope framework grid connected to the main span ropes



Typical arrangement for a mortality sock

5.3.4 Horizontal ropes

5.3.4.1

All nets with i) a circumference of ≥ 49m for use with circular pens and ii) all nets for use on square pens shall be constructed with a horizontal rope within ± 0.2m of the designed waterline of the net – this rope is known as the 'waterline rope' or sometimes the ' waist rope'

5.3.5 Attachment points

5.3.5.1

On nets deployed from circular pens, the attachment points for transmitting the main vertical loads of the net to the pen shall be:

5.3.5.1.1

Taken from attachment points connected to the down ropes of the net at a depth of between 0.4m and 0.75m below the waterline; or

5.3.5.1.2

Taken from the point where the down rope crosses the waterline rope; and

5.3.5.1.3

Designed such that their weight is taken by the flotation tube(s)

5.3.5.2

On nets deployed from square pens, the location of the attachment points for transmitting the main vertical loads of the net to the pen shall be identified by the manufacturer and documented on the product specification sheet and in the manufacturer's instructions

5.3.5.3

All attachment points shall be designed and constructed so that the net integrity is maintained when design loads are applied. This will include, but is not limited to, situations where two attachment points are located close together on the same down rope (for connection to a lifting rope and the weighting system) which may result in loads being applied from different directions thereby creating additional strain on the net

5.3.5.4

Nets to be used with sinker tubes shall have the attachment points from the net to the sinker tube at a point where a down rope joins a base rope

Diagram of a pen showing the sinker tube (Froya Ring) at the bottom

5.3.6 Net protection and reinforcing

5.3.6.1

Nets used with mortality baskets or similar systems, shall be fitted with double netting of the same mesh size as used in the net in the vicinity of the basket to protect against chafing from the mortality system. This double netting shall extend as appropriate to give sufficient protection in all operational situations and shall be on the inside of the net

5.3.6.2

Nets used with air lift mortality collection systems shall have netting of sufficient mesh strength so as to be able to satisfactorily support the lift up system to prevent damage to the net; this netting shall extend for an appropriate area to give sufficient support. Alternatively, other means of strengthening or reinforcing the net shall be used for this purpose

5.3.6.3

Where appropriate, the net manufacturer shall confirm what mortality systems the net is and is not suitable for use within the product specification sheet and manufacturer's instructions and any associated limitations for use in this regard

The type of tubing used in an airlift mortality collection system

5.3.7 Net strength and rope strength

5.3.7.1

The minimum mesh strength shall be as detailed in Table 1 for freshwater pen sites and Table 2 for seawater pen sites

Table 1: Net mesh and rope strength for freshwater nets

Net Class	FW1	FW2	FW3	FW4	Notes:
Net Depth (m)	Irrelevant	Irrelev ant	Irrelevant	Irrelevant	***1***
Net Perimeter	Irrelevant	Irrelevant	Irrelevant	Irrelevant	***2***
Mesh Size (mm)	**Minimum net strength for new nets (kg)**				
6.0-8.5	30	30	30	30	
8.6-11	42	42	42	42	
11.1-15	55	55	55	55	
Rope Diameter	12mm	12mm	14mm	14mm	***3***
Minimum breaking load for ropes (kg)	2210	2210	3050	3050	

Ropes and netting

Table 2: Net mesh and rope strength for sea water nets

Net Class	SW1	SW2	SW3	SW4	SW5	SW6	Notes:
Net Depth (m)	**Net perimeter (m)**						
0-15	<49	50-69	70-89	90-109	110-149	150-169	
15.1-30		<69		70-109	110-129	130-149	4
Mesh Size (mm)	**Mesh break point in kg when new**						
13.1mm-18mm	60	60	66	66	89	89	5
18.1mm-22.0mm	66	66	78	114	114	138	
22.1mm-29.0mm	78	109	109	114	138	138	
29.1mm-35.00mm	130	130	136	136	138	138	
Rope Diameter	12mm	14mm	16mm	16mm	18mm	18mm	6
Minimum breaking load for ropes (kg)	2200	3000	3700	3700	4800	4800	7

Notes:

1. It is rare to have any freshwater nets in Scotland Deeper than 10m
2. The important criteria here should be the vertical spacing, which tends to be the same regardless of circumference
3. There is no case for using anything less than 12mm diameter rope
4. The rope frame is key to the strength and ropes every 5m will enhance this
5. The important criteria here should be the vertical spacings, which tends to be the same regardless of circumference
6. Even on most sheltered site, there is no reason for using less than 12mm rope
7. Even 14mm ropes is rarely specified these days other than for very sheltered sites
8. Mesh strength is not specified for mesh size smaller than 6mm.
9. In all cases, the mesh strength for a net shall be the lowest test result. Each test result shall be the mean of three mesh strength tests undertaken on the same panel of the net. The number of strength tests required per net is detailed in Annex 4
10. Mesh size refers to the half mesh measurement

5.3.7.2

Nets tested on-shore with a mesh strength result of ≤60% of their new mesh strength shall be retired immediately

5.3.7.3

Nets in use with a mesh strength result of over 50% or less than ≤60% of the strengths shown in Tables 1 and 2 tested in accordance with this Standard shall be retired from use within a maximum of forty days

5.3.7.4

Nets in use with a mesh strength result of ≤50% of the strengths shown in Tables 1 and 2 tested in accordance with this Standard shall be retired from use within a maximum of five days

5.3.8 Specification of net ropes

5.3.8.1

The minimum strength of ropes used in the construction of the net shall meet the requirements of Tables 1 and 2. When determining the load that can be applied at the attachment point, a material factor of 3.0 shall be used for ropes without knots and 5.0 for ropes with knots

5.3.9 Net construction

5.3.9.1

Net panels shall be joined prior to being attached to the ropes

5.3.9.2

When fixing netting to rope, the netting shall be sufficiently slack and evenly distributed so that the rope takes the loads when the net is in use

5.3.9.3

The start and end of a seam shall be properly secured to ensure integrity

5.3.9.4

Lacing twine shall be joined using a reliable knot

5.3.9.5

All fixings shall be on the outside of the net unless there are specific design requirements that require attaching on the inside; in such cases, the reasons for this shall be documented on the net specification sheet

5.3.9.6

The breaking strength of all seams shall be equal to or greater than the breaking strain of the net mesh

5.3.9.7

When fixing rope to net pens, the threads shall be wound over the rope and twine through i) at least every second mesh and ii) every mesh for nets with a half mesh size of 15.5mm or above). There shall be a maximum of 12cm between each attachment point (knot). There shall be at least three hitches or other reliable knots per attachment point

5.3.9.8

The use of net treatments and other chemical applications shall be determined on an efficacy basis. All coating development and innovations should be accompanied with a documented analytical trial plan with all relevant permissions from SEPA.
These shall include, but not be limited to, a risk assessment of finfish breakout possibilities as a result of the trial evaluation.

5.3.10 Sacrificial panels

5.3.10.1

Where sacrificial panels are required, for subsequent net testing they shall be:

5.3.10.1.1

Constructed from the same batch of netting that the net itself was made from

5.3.10.1.2

Of the same specification of the netting that the net itself was made from

5.3.10.1.3

Subject to the same treatments applied in the same manner as the netting that the net itself was made from, including pre-shrunk, UV treatments and any antifoulants and/or any other treatments including those designed to inhibit the ingress of foreign materials and/or to enhance the net strength

5.3.10.1.4

Large enough to allow three strength tests to be carried out on each panel

5.3.10.1.5

Individually marked with permanent markers such that each is referenced to the net on which it will be attached and each having its own unique identifier

5.3.10.1.6

Firmly attached to the netting so that it will remain attached throughout the operational use through the lifetime of the net, but can also be easily removed

5.3.10.1.7

Sufficient panels should be fitted to enable testing in accordance with this standard during the life of the net, subject to the requirements of the fish farmer

5.3.11 Quality assurance of incoming materials

5.3.11.1

The net manufacturer shall confirm and document that all incoming materials meet its requirements

5.3.11.2

Incoming bales of netting shall be tested in terms of half-mesh size and mesh strength by the net manufacturer to ensure that it meets the required specification as follows:

5.3.11.2.1

Bales of netting of a specification that is regularly and frequently used and supplied by the same supplier shall be tested periodically

5.3.11.2.2

Each bale of netting that is of an infrequently used specification shall be tested

5.3.11.2.3

When using a new supplier, the first three bales of each type of netting shall be tested

5.3.11.2.4

Additional testing is required when the results of testing of materials from a given supplier indicates issues of concern

5.3.11.2.5

Three areas of netting shall be tested on each occasion, taken from approximately the start, middle and end of a bale, and each is to be tested three times with the result averaged

5.3.11.2.6

Should the results be less than the quoted specification, with a 5% tolerance level, additional tests shall be undertaken. Unless the additional tests confirm otherwise, the bale should be considered out of specification

5.3.11.2.7

The above tests shall be undertaken and the results shall be documented. There shall be full traceability to enable each manufactured net to be traced back to individual bales and hence to individual mesh testing

5.3.12 Yarn

5.3.12.1

Yarn shall be:

5.3.12.1.1

From a certified producer

5.3.12.1.2

Appropriate to meet the requirements of the net specification sheet

5.3.12.1.3

Protected against ultraviolet light

5.3.13 Netting


Equipment/process for pre-shrinking

5.3.13.1

Netting shall be pre-shrunk prior to use in construction

5.3.13.2

The net and rope shall be designed and constructed such that it will not shrink in use so that it a) neither transfers forces from the rope to the net nor b) does not properly fit the pen

5.3.14 Rope

5.3.14.1

Rope shall be:

- **5.3.14.1.1**
  From a certified supplier
- **5.3.14.1.2**
  Tested in accordance with BS EN ISO 2307
- **5.3.14.1.3**
  Labelled as 'yarn construction' rope
- **5.3.14.1.4**
  Mixed polyolefine rope shall also satisfy the requirements in BS EN 14687

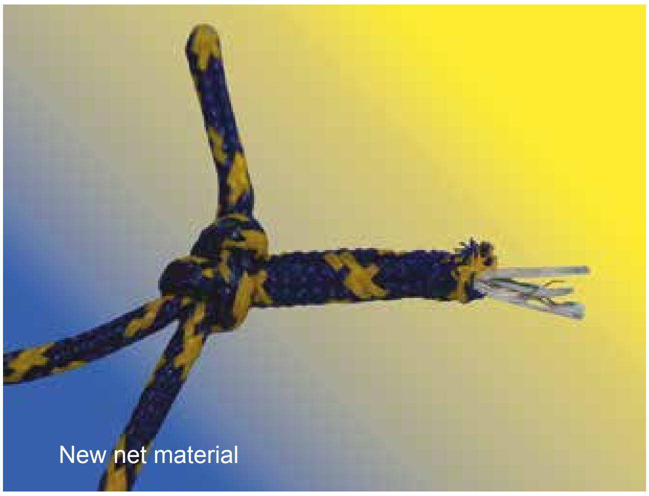
5.4 Net repair

5.4.1.1

The materials used in net repair should:

- **5.4.1.1.1**
  Be of at least the strength required for the relevant specification of new net
- **5.4.1.1.2**
  And otherwise meet the requirements of this Standard
- **5.4.1.1.3**
  Be utilised by members of staff who have received training in net repair techniques

5.5 Nets manufactured from material other than nylon



New net material

5.5.1.1

Other netting and rope materials can be used providing it is documented that as a minimum they satisfy the functional requirements in this Standard

5.5.1.2

The minimum mesh strength for nets made of materials other than nylon shall be as detailed in the same or higher than the nylon standards shown in Tables 1 and 2

5.6 Net identification tag

A typical net identificaton tag

5.6.1.1

Each net shall be permanently marked with two tags:

5.6.1.1.1

Permanently attached to two different areas of the top rope of the net

5.6.1.1.2

That will remain clearly readable when the net is in use

5.6.1.1.3

Which indicate the manufacturer and the unique identifier

5.7 Statement of conformity

5.7.1.1

The manufacturer shall confirm that each completed net has been manufactured:

5.7.1.1.1

In full accordance with the net specification sheet, or with any deviations clearly indicated

5.7.1.1.2

Provide the date of completion and the serial number and unique identifier

5.8 Manufacturer's Instructions

5.8.1.1

Each shipment of nets shall be accompanied by manufacturer's instructions designed as a reference for fish farmers on-site in accordance with Annex 13

6 FEED BARGES

A typical feed barge used in Scotland

Feed barges are an important component in a modern marine finfish farm, and have the potential to interact with other physical components of the farm.

6.1.1.1

A stand-alone feed barge shall not be moored directly to a pen group or grid, but a feed barge can be connected where the link is weaker than any other mooring component. Should the barge come adrift, the link will break before any damage is done to the cages or group

6.1.1.2

Feed barges moored in a stand-alone mooring system shall be moored by adhering to the requirements of Section 3 amended as follows:

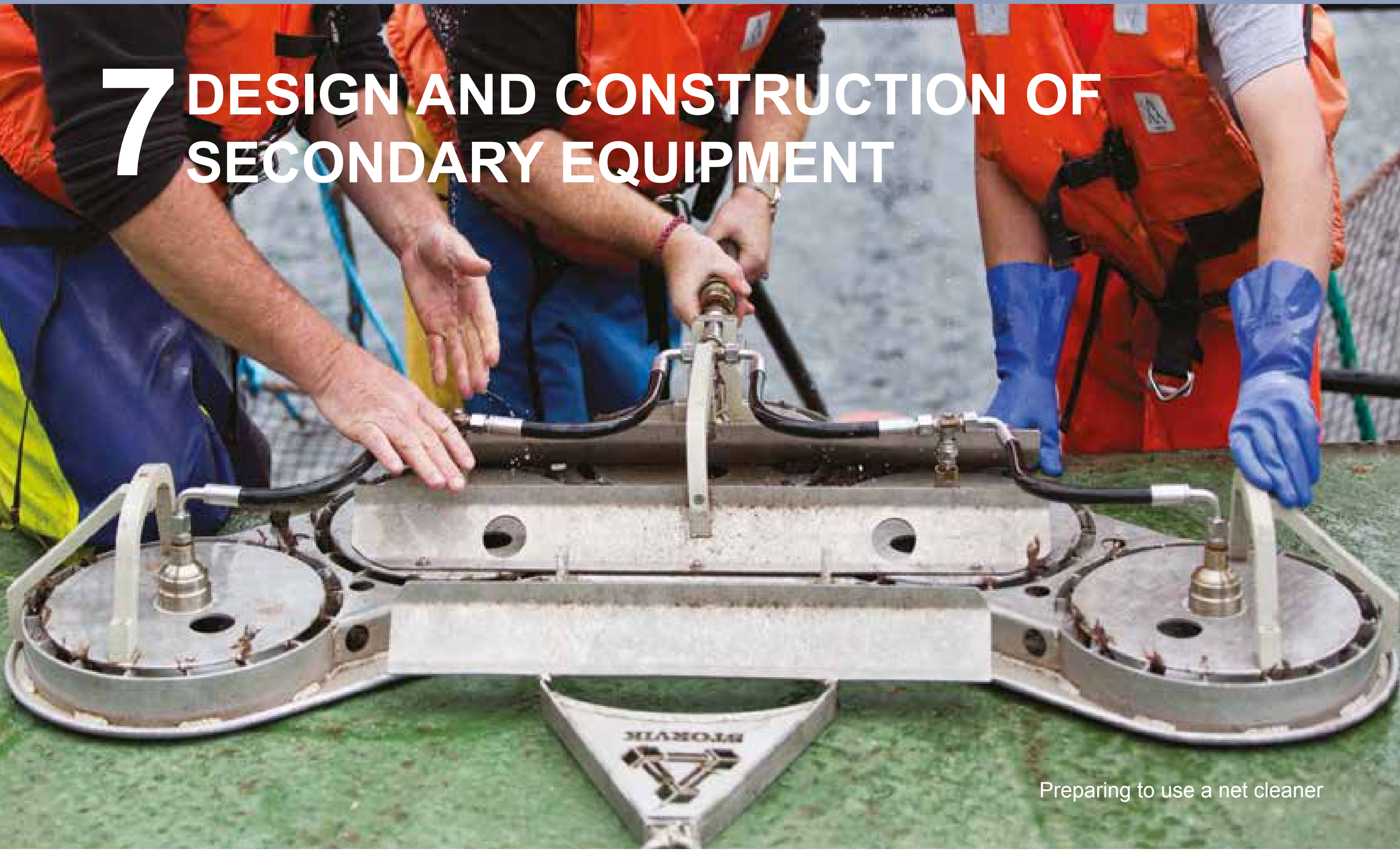
6.1.1.2.1

Consideration of waves is required as appropriate for the site

6.1.1.2.2

Consideration of the direct wind loads on the structure is required

7 DESIGN AND CONSTRUCTION OF SECONDARY EQUIPMENT



Preparing to use a net cleaner

Secondary equipment of various types are also important components in a modern finfish farm, and some types of equipment have the potential to interact with other physical components of the farm.

7.1 Weighting Systems

7.1.1.1

Weights and weighting systems at sea water pen sites shall:

7.1.1.1.1

Not be placed within the net at sea water pen sites (this does not preclude the use of a lead line)

7.1.1.1.2

Have a smooth surface

7.1.1.1.3

Be designed to not cause significant net abrasion in the envisaged environmental conditions and during all conceivable operations

7.1.1.2

Weights and weighting systems at all pen sites shall:

7.1.1.2.1

Use connectors that will not cause significant net abrasion

7.1.1.2.2

Be of sufficient strength

7.1.1.2.3

Be designed to avoid trapping or snagging of the net

7.1.1.2.4

Not exert loads beyond the design loads of pens and nets specified elsewhere in this Standard

7.1.1.3

Sinker tubes (also known as Froya or weight rings) shall be hung from an appropriate position on the floating pen structure. The pen manufacturer should verify that this will not adversely affect the buoyancy and/or stability of the pen in all envisaged environmental conditions and during all conceivable operations

7.1.1.4

Weighting systems shall not have parts in which the net can become trapped underwater. This prohibition includes, but is not limited to, systems utilising a component that slides underwater on a chain or rope

7.1.1.5

Weighting systems purchased as complete entities shall be provided with manufacturer's instructions in accordance with Annex 13

7.1.1.6

All individual components used to attach sinker tubes to the net and/or pen shall be in accordance with this Standard

7.2 Mortality collection systems

7.2.1.1

Mortality collection systems shall be designed to not significantly chafe on the net in the envisaged environmental conditions

7.2.1.2

Systems purchased as complete entities shall be provided with manufacturer's instructions in accordance with Annex 13

7.3 Barges, rafts, pontoons and floating support structures

A work raft

7.3.1.1

The requirement to moor any work barges (but not including feed barges – see Section 6), rafts, pontoons and other floating support structures shall be brought to the attention of the mooring designer and, for equipment that may be moored directly to pens, to the pen manufacturer who will:

7.3.1.1.1

Identify and/or provide specific moorings or mooring locations on a pen for such equipment for when they are in use

7.3.1.1.2

Identify and/or provide specific moorings or mooring locations away from the pen for such equipment so that they do not need to be moored to the pens when not in use

7.3.1.1.3

Ensure that the loads are taken into account for such moorings by following the mooring requirement in Section 3

7.3.1.1.4

Specify the maximum characteristics of equipment that can be moored to the designated locations and any environmental restrictions

7.3.1.1.5

Highlight any specific requirements in the product specification sheet and/or manufacturer's instructions as appropriate, to ensure the integrity of the farm pens, nets and moorings

7.4 Other secondary equipment

The use of high pressure net cleaning equipment is an area which may be of interest to a future development of this Standard, and relates to the innovations that are taking place with nets – see Section 5.1

7.4.1.1

All other secondary equipment that may be used within or in the vicinity of nets and which has the potential to cause chafe or damage shall be:

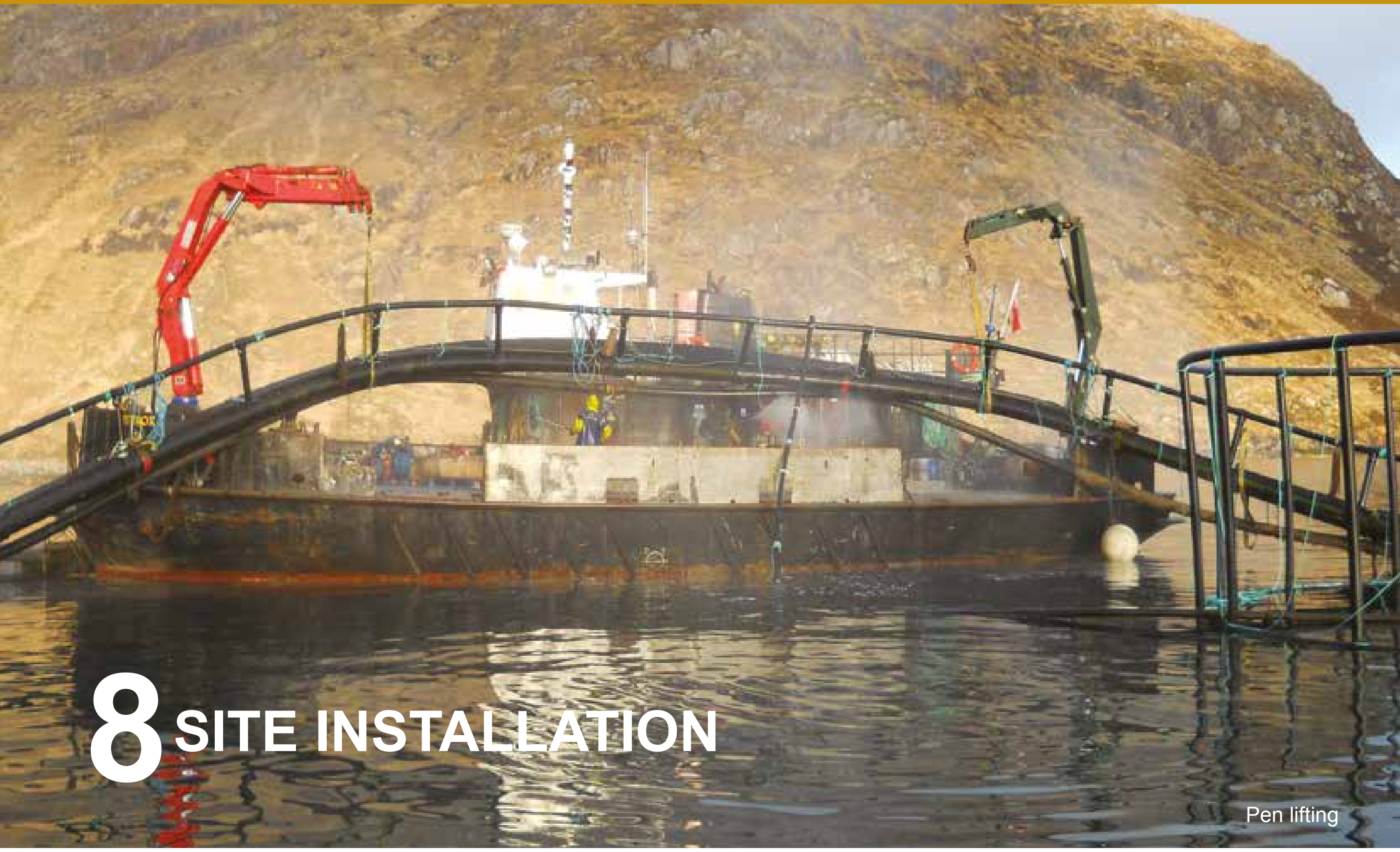
7.4.1.1.1

Designed and constructed to avoid chafing the net

7.4.1.1.2

Provided with manufacturer's instructions in accordance with Annex 13 should poor installation, handling, operation, or maintenance have the potential to cause an escape incident

8 SITE INSTALLATION



Pen lifting

The correct receipt, checking and installation of equipment is as important as having purchased the correctly specified equipment in the first instance.

8.1 Planning

8.1.1.1

The person and/or position within the aquaculture production business with overall responsibility for the installation of primary equipment shall be identified and documented

8.2 Availability and use of documentation

8.2.1.1

The relevant manufacturer's instructions and specification sheets shall be made available to all appropriate personnel, and be acknowledged as read and understood, prior to the handling and assembly of primary equipment and for secondary equipment when required

8.3 Transport of primary equipment

8.3.1.1

The transport of all primary equipment, including towing, shall be undertaken in accordance with the manufacturer's instructions

8.4 Post-delivery assessment

8.4.1.1

All main primary equipment shall be inspected post-delivery and prior to assembly and/or installation as appropriate to ensure that they are i) in accordance with the relevant specification sheet and ii) undamaged

8.5 Handling and assembly of primary equipment

8.5.1.1

All main primary equipment shall be handled and assembled in accordance with the manufacturer's instructions and product specification sheet in such a manner as to avoid damage

8.6 Installation of primary equipment Anchors

8.6.1.1

All equipment should be installed by competent personnel appointed by the person and/or position named in 8.1.1.1, in compliance with all the mandatory provisions of this Standard

8.6.1.2

All primary and, where relevant, secondary equipment shall be installed at the site as per manufacturer instructions, and specifically for drag anchors, these should be installed as appropriate for the surveyed seabed composition, and inspected post-installation

8.6.1.3

General provisions for mooring systems:

8.6.1.3.1

The position(s) of all anchors (this excludes rock bolts) shall be assessed for dragging following installation using sight lines or electronic instrumentation; should this be identified in excess of the tolerance specified in the manufacturer's instructions, the anchor shall be re-laid

8.6.1.3.2

That no element of the mooring system or nets can be chafed by or snagged upon any other equipment, components, sub-sea structures or anomalies of whatever origin

8.6.1.3.3

Mooring lines within a pen group shall not cross one another. Should mooring lines from barge moorings cross pen moorings, sufficient separation shall be provided to prevent chafe

8.6.1.3.4

All mooring lines, components of the mooring grid and bridles are adjusted in accordance with the techniques and tolerances in the manufacturer's instructions

8.6.1.3.5

Any materials used to protect individual components are positioned correctly, undamaged and protected against chafe

8.6.1.3.6

The likelihood of galvanic corrosion is reduced to an insignificant level through the use of appropriate materials and/or the positioning of individual components

8.6.1.3.7

The final length of all mooring lines following final adjustments is i) recorded and ii) verified as being within the tolerances in the manufacturer's instructions

8.6.1.3.8

The actual positions of all anchor points (including rock bolts) and pens are recorded using electronic instrumentation

8.6.1.4

All drag anchors installed in seawater and freshwater pen sites shall be embedded using a gradual, substantial and prolonged application of force

8.7 Post installation inspection

8.7.1.1

The installation of any primary equipment, and where relevant any secondary equipment, shall be inspected prior to stocking as follows:

8.7.1.1.1

The inspection shall be by person(s) independent to those who undertook the installation

8.7.1.1.2

The inspection shall assess whether the primary equipment installation has been satisfactorily undertaken by addressing each point in Section 8.6

8.7.1.1.3

The inspection of mooring and/or weighting systems shall include a visual assessment of all mooring lines and connectors and weighting systems

8.7.1.1.4

The inspection shall be documented; this shall include the retention of photographic and/or video images of anchor emplacement and the routing of mooring lines

8.7.1.1.5

The inspection shall include access to manufacturer's instructions

8.7.1.1.6

The inspection shall include an assessment of whether the primary and secondary equipment have been satisfactorily installed and detail any anomalies

8.7.1.1.7

Any such anomalies will either be satisfactorily addressed and re-inspected in accordance with this Standard prior to stocking, or confirmation shall be obtained from the relevant manufacturer/supplier that stocking can commence and be maintained with this anomaly outstanding

8.7.1.1.8

The documented records shall be retained by the aquaculture production business, with appropriate back-up held separately, for the life of the relevant primary equipment – or until further installation and/or inspections render these records obsolete. These records shall be passed on if the site or equipment is sold

9 LAND BASED SITES

A modern land based smolt unit

9.1 Site design and construction

9.1.1.1

Sites shall be arranged or protective measures employed to prevent fish holding units being damaged by vehicles

9.1.1.2

Professional and qualified engineering advice shall be sought and followed where appropriate or required by planning or other controls to ensure facilities are correctly designed and constructed

9.1.1.3

Sites shall be designed to withstand all extremes of weather reasonably anticipated or experienced at the location

9.2 Site Operating Procedures

9.2.1.1

All land based sites shall have Standard Operating Procedures in place and staff shall be fully trained in their methodology and implementation. SOP's shall cover:

9.2.1.1.1

All fish production activities at the site which provide the potential for fish escapes, including stocking, grading, movement and harvesting, grid sizing

9.2.1.1.2

Actions in the event of mass mortality

9.2.1.1.3

Adverse weather conditions which may prejudice site integrity and lead to the potential for escapes, including freezing, flooding, gales

9.2.1.2

Standard Operating procedures shall be regularly reviewed and updated where necessary taking into account technological or other advances in knowledge or experience. All staff shall be fully trained in the implementation of any changes. Procedures should cover:

9.2.1.2.1

The primary screen becoming completely blocked

9.2.1.2.2

The water level in the tank rising beyond the normal operational level

9.2.1.2.3

Freezing temperatures experienced (including protecting against the primary screen lifting out of position and/or becoming partially or fully blocked due to icing)

9.2.1.3

In addition to the primary screen, there shall be a second screen between the holding units outflow and the final site discharge. Note that if such a provision would result in an increased risk of escapes due to particular farm layout – e.g. fine mesh screens constantly blocking and overflowing – alternative approaches to ensuring containment in the eventualities outlined below may be approved. These approaches, along with any other on-site containment structures, shall be capable of preventing any fish entering any water courses in the event of:

9.2.1.3.1

Fish escaping into the effluent or other internal channels or pipes at the site

9.2.1.3.2

The total failure of any fish holding unit

9.2.1.3.3

An escape incident occurring during a fish handling and/or transfer operation

9.2.1.3.4

An escape incident occurring during a power failure

9.2.1.3.5

Freezing temperatures (including protecting against the screen moving out of position and/or becoming partially or fully blocked due to icing)

9.2.1.4

All screens and any associated containment structures shall be:

9.2.1.4.1

Designed, constructed and installed so that during any conceivable operation and/or environmental condition:

i) Fish cannot escape around the edges,

ii) They cannot be inadvertently dislodged or otherwise removed

9.2.1.4.2

Of an appropriate material such that they will not break or deform during any conceivable operation and/or any conceivable situation, including if they are completely blocked

9.2.1.4.3

Such that complete containment will be maintained during inspection and maintenance – for secondary screens, this would normally require facilities for a replacement screen(s) to be installed in a manner which meets the requirements of this Standard prior to the removal of the first screen(s)

9.2.1.4.4

Sufficient to maintain effective containment in flood conditions

9.2.1.5

Primary screens shall be of sufficient size to prevent the smallest fish escaping. Secondary screens, if installed, shall be of sufficient size to prevent the smallest fish escaping which the screen would be expected to encounter, given the primary screen and alternative containment measures in place referred to in point 9.2.1.3.

9.2.1.6

Screens shall be inspected regularly, and at least daily when the relevant units are stocked, in accordance with a documented maintenance regime

9.2.1.7

Sufficient spare screens, and repair materials as appropriate, shall be available on-site to ensure effective containment in the case of damage or unexpected variations in the size of fish

9.3 Flooding

9.3.1.1

Where sites are to be located in an area where the probability of flooding is equal or greater than 0.5% in any given year a documented flood risk assessment shall be undertaken

9.3.1.2

Sites shall be designed to contain fish at the highest flood level determined by the flood risk assessment. This shall be documented

Annexes

CONTENTS

ANNEX 1 Members of the Scottish Technical Standard Steering Group

The STS Steering Group composition is listed in the table below:

Steve Bracken (Chairperson)	Marine Harvest
Andy Smith	BTA
David Bassett	ex BTA
Ian MacIntyre	The Scottish Salmon Company
Jamie Smith	SSPO
Jamie Young	GaelForce
John Offord	GaelForce
Kenny Black	SAMS
Lawrie Stove	GaelForce
Paul Haddon	Marine Scotland
Peter Davies	University of Dundee
Rhuaraidh Edwards	Fusion Marine
Reay Whyte	Scottish Sea Farms
Roger Dehany	W&J Knox
Ron Smith	Marine Scotland Science
Steve Divers	Fusion Marine
Tom MacRae	ex Sunderland Marine Insurance

ANNEX 2 A Glossary of Terms

Accessory: a piece of plant and/or equipment other than primary and/or secondary equipment.
All conceivable operations: see conceivable operations.
Anchor: includes drag anchor, dead weight moorings and any other system/component to attach the moorings to the loch bed with the exception of rock bolts.
Anchoring point: the point at which the mooring system is connected to the loch bed and/or the loch side. This includes, but is not limited to, drag anchors, dead weight moorings and rock bolts.
Authoritative source: the quoted material parameters should be based upon tests, measures or other verifiable and repeatable means undertaken, where relevant, in accordance with appropriate standards by reputable organisation(s).
Barge specification sheet: see product specification sheet.
Base rope: A rope which secures the join walls of netting to base netting.
Boats: includes all boats that may be used at the site when considering all conceivable operations, including feed delivery boats; well boats; boats used for transporting equipment, consumables, harvested fish, fish mortalities (including mass mortality situations); boats used for handling nets, pens, moorings, other equipment; boats used for undertaking fish farm operations including net installation, net handling, mooring installation, maintenance; boats used for harvesting fish; personnel boats; tow boats; and, any other type of work boat.
Bridle: the connector (of whatever material type or combinations thereof) from pen(s) to the mooring grid system.
Buoy line: – For pens situated in a mooring grid: the rope and/or chain which connects the grid line to the cushion float in a mooring grid system; or, – For pens not situated in a mooring grid: the rope and/or chain which connects pen(s) to the cushion float or which connects the pen(s) to the connector underneath the cushion float.
Characteristic value: maximum values of structural properties in respect of specific loads and defined probabilities (i.e. return periods) which should not be exceeded.
Competent/competency: demonstrated ability to apply knowledge and skills on the basis of education, training and/or experience.
Component: see individual component.
Conceivable operations: all planned and unplanned operations that may be undertaken at the site during the foreseeable future and/or the next production cycle in respect of the envisaged environmental conditions.
Contract/sub-contract personnel: persons working for or on behalf of an organisation who are employed by a different organisation and/or who are self-employed.
Current direction: the direction in which the current flows.
Current velocity: the mean velocity of current averaged over a ten minute measurement period.
Cushion float: the buoy or float that supports the mooring grid, connector(s) and/or mooring line(s).
Depth of net: see net depth.
Diffraction and refraction analysis: the calculation of wave characteristics at a site from consideration of how ocean swells are affected by the local topography.
Dimensioning: the process of designing and specifying primary equipment so they are able to withstand the envisaged environmental conditions and all conceivable operations based on the use of calculations, experiments/tests and/or empirical data. The term implies design, specification and analysis.

Down ropes: ropes designed to be vertical or near vertical (including the down ropes on cone shaped nets) on a net and which support the weight of the net.
Dynamic analysis: analysis where a calculation is done of loads from wind, current and waves as well as acceleration as a result of wave movements in addition to mass, damping and rigidity of the construction.
Envisaged environmental conditions: the dimensioning current, dimensioning waves and dimensioning wind speed determined in the site survey.
Feed barge: a standalone fully integrated buoyant structure that includes the storage for feed and the related equipment to transport the feed directly to the pens along with all relevant equipment and facilities. These are usually either steel or concrete structures and may be purpose built or converted. A feed barge is different to a raft or other floating structure onto which feed storage and transportation equipment have been attached.
Fetch: the distance over which the wind can blow unobstructed across open water.
Fish washout: the process by which fish may be lost through relatively high waves which could transport fish over the jump net and the handrail. This would usually only be expected in unfavourable weather conditions at more exposed sites and may be prevented by securely attaching an appropriately sized top net to the pen (usually by lacing to the handrail or taking it over the hand rail and down to be laced to the pen).
Flood/flooding/flood conditions: the situation occurring at a land based site when any plant, equipment, stock holding facilities, fish transfer equipment, inflow, effluent treatment and outflow facilities are immersed in water above the volume for which they have been designed, including that arising from unplanned natural and operational events.
Generic connection point: this refers to the notion on certain types of pens, notably plastic circles, that certain attachments may be made at any point on the pen providing that they occur to specific localities on the pen and at specified separation distances. This may include, but is not limited to, the means of attaching i) the net to the bridles, ii) the net to the pen, iii) the net to the handrail and iv) the weighting system to the pen.
Grid line: the rope and/or chain to which pens are attached via bridles in a mooring grid system and to which the mooring lines are attached.
Half mesh: a measurement of net mesh size pertaining to the length of one side of a square mesh – note that this is a different measurement to the net mesh aperture. The methodology for determining the half mesh measurement to comply with this Standard is given in Annex 8.
Individual component: a single element of primary and/or secondary equipment.
In-house personnel: staff directly employed by an organisation.
Irregular sea state: heterogeneous wave characteristics.
JONSWAP wave spectrum: the 'Joint North Sea WAve Project' spectrum can be used to describe wave conditions in coastal waters with a limited fetch.
Jump net: the upper portion of the net which is above the design water line; the area of the net between the water line and the handrail.
Lead line: a weighted line or other length of weighted material permanently attached to the net at the join of the side wall and base.
Lifting rope: a down rope on a net which can be used to lift the net in accordance with the manufacturer's instructions without damage to the net. A lifting rope shall cross the bottom of the net and proceed up the opposite side as a single entity or be securely joined to other down rope(s) or a central grommet in the base of the net dimensioned such that the rope can be used as a lifting rope.

Load factor: a factor to take account of the load variation from limit state design. Load factor times calculated load gives design load.
Material factor: a factor to take account of the variability of materials strength from limit state design. Material factor times yield strength gives design strength.
Manufacturer: the organisation that designs, manufactures and/or supplies primary and/or secondary equipment and/or boats.
Manufacturer's instructions: this refers to a set of instructions provided by the manufacturer and/or supplier of primary and/or certain secondary equipment designed to help prevent escapes from the use of the relevant equipment in the envisaged environmental conditions and during all conceivable operations. Users are required by this Standard to comply with the manufacturer's instructions unless documented permission has been obtained from the manufacturer to deviate from those instructions in defined circumstances. The responsibility to provide the manufacturer's instructions shall rest with the following organisations unless otherwise agreed and documented: – The mooring designer in regard of the mooring system; – The pen designer in regard of the pen; – The net designer in regard of the net; – The feed barge designer in regard of the feed barge; – For complete installations, the principal contractor; and, – The designer in regard of the provision of any secondary equipment.
Marker Buoys: buoy deployed to mark site boundaries
Mesh aperture: a measurement of open distance of a single net mesh pertaining to the size that a fish could pass through – note that this is a different measurement to the half mesh measurement.
Mooring grid system: a system whereby one or more pens are secured to a grid which is usually made of rope which is held in position through mooring lines.
Mooring line: – For pens situated in a mooring grid: the rope and/or chain that connects the mooring grid to the anchoring point. – For pens not situated in a mooring grid: the rope and/or chain that connects the pen to the anchoring point. This would typically be the line from the cushion float to the anchoring point or from the connecting point beneath the cushion float to the anchoring point.
Mooring specification sheet: see product specification sheet.
Mooring system: a complete installation of all the elements required to hold a pen or pens (and associated nets and secondary equipment and boats as required) in their planned position. Depending upon the type of installation, this may include the anchors (or rock bolts or other means to secure the mooring system), mooring lines, connectors, cushion floats, buoys, bridles, grid ropes and any other required components.
Mousing: the repeated passing of a small line or similar across the end of a shackle or other device to prevent accidental opening.
Navigation markers: an aide to marking the location of a site.
Net depth: – For non-cone shaped nets: the vertical depth of the net from the designed waterline (which does not necessarily have to be at the exact location of the waist rope) to the bottom of the side wall, measured with the down ropes held taught. – For cone shaped nets: the vertical depth of the net from the designed waterline (which does not necessarily have to be at the exact location of the waist rope) to the bottom of the net, measured with the down ropes held taught.

Net mesh aperture: see mesh aperture.
Net porosity: the total area of the net voids (i.e. aperture spaces) divided by the total area of the net.
Net specification sheet: see product specification sheet.
Net supports: A method or structure for supporting a top net.
Ocean swell(s): waves which can affect the site which have been formed in the open sea.
Partial coefficient method: an approach which provides satisfactory margins of safety through the use of safety and/or material factors along with consideration of specific loads and the structure's resistance.
Peak period/peak wave period: the wave period associated with the greatest energy.
Pen specification sheet: see product specification sheet.
Pens: any floating installation that provides the support for a net used to contain fish. It includes all related elements, including: the walkways used to access nets, flotation elements to provide buoyancy, stanchions and handrails. It does not include rafts or barges, such as those used purely for storage or for undertaking ancillary operations. The term, pen, applies to the circular plastic installations and square steel/wooden/rubber installations that are in common use in Scottish aquaculture and other less common structures such as semi-submersible or closed containment units. Note that the term 'pen' is considered to have the same meaning in this Standard as 'cage,' 'floater' and 'floating collar'.
Plastic pen: a generic term relating to flexible fish farm pens made from polyethylene.
Porosity: see net porosity.
Principal contractor: the organisation with primary responsibility for the installation of primary equipment.
Primary equipment: a pen, net, mooring system and/or feed barge. This does not include boats and/or secondary equipment.
Product specification sheet: the document detailing the key design and parameters of primary equipment.
Quasi static analysis: simplified analysis where only constant loads are considered. Contribution from time dependent loads are included as constant loads.
Redundancy: the duplication of critical components or functions of a system to protect against the failure of a critical component.
Regular sea: homogenous wave characteristics.
ROV: remotely operated vehicle.
Responsible person: the person within an organisation responsible for the activity in question. This will typically, but not necessarily, be a site manager, area manager, senior manager or director. Whilst the activity may be designated, responsibility rests with the responsible person. The relevant responsibilities shall be included in a job description and/or company organisation chart.
Return periods: an estimate of the period of time between events of a defined magnitude.
Sacrificial panels: pieces of netting representative of the netting itself which are attached to the net and yet which can be easily removed for strength testing without making a hole in the net.
Safety shackle: a shackle with a closure that has a secondary means to ensure that the primary closure cannot become undone. This may include, but is not limited to, the use of a clevis pin and/or mousing to hold the shackle bolt in place.

Secondary component: these relate to specific plant and equipment used on pen sites including a weighting system (including individual weights, sinker tubes and other weighting systems), feed system, mortality collection system, cameras and/or fish observation/counting devices, rafts (including, but not limited to, rafts used for feed systems, the storage of feed or other consumables/materials, the storage and/or use of plant and/or equipment, harvesting, grading, treatment systems etc.), pen lighting, fish treatment systems and mobile pens used to transport fish.
Significant wave height: the mean wave height for the highest third of the waves in a defined period of time.
Sinker tube: the use of a weighted ring suspended from the pen to which the net can be tensioned through the use of ropes (or perhaps chains) attached either directly to the ring or led through blocks attached to the rink for adjustment at the surface. Also known as a Frøya ring and weight ring.
Site: – The area defined by the Local Authority planning permission in which a pen based fish farm can be installed; – A set of pens and nets in a defined mooring system.
Span rope: a radius rope from the circumference to the centre
Specification sheet/relevant specification sheet: see product specification sheet.
Square pen: square or rectangular pen. This may also be used to refer to other shapes of pens based on a polygon design.
Stanchion: a vertical support for carrying the handrail and which, in fish farming applications, may be the point on some design of pens at which the net down ropes are attached.
Static analysis: simplified analysis where only constant loads are considered. All time dependent loads and load responses are neglected.
Stiffness: a measure of rigidity.
Swivel mooring(s): a mooring system whereby the pen(s) and/or secondary equipment and/or a boat or boats is connected to the sea bed through the use of a single line (or, possibly multiple lines) around which it is free to swing due to effects of the current and wind. Also known as a swing mooring.
Tension: The state of being stretched tight.
Thread pitch: the distance between parallel sides of the profiles of two adjacent thread forms measured along the axis. The pitch is usually measured along a line on which the width of the thread forms is equal to the width of the groove. Multiple threads have both a pitch and a lead; the latter is defined as the distance through which the screw is displaced in one full turn in a stationary nut, that is, the pitch of one screw line of the thread. The lead is equal to the product of the screw-thread pitch and the number of starts; for single-start threads the lead is equal to the pitch
Ultimate limit state: the condition associated with structural failure of primary or secondary equipment, or individual components, which is usually the maximum load carrying capacity.
Velocity of wind: see wind velocity.
Verifiable method of calculation: a method that can be verified either against experiments or method that utilizes internationally acknowledged methods of calculation.
Velocity of current: see current velocity.
Waist rope: a horizontal rope on a net within ± 0.2m of the designed waterline of the net.
Washout: see fish washout.
Wave direction: the direction from which the waves come.

Wave height: the vertical difference between an adjacent wave trough and crest.
Wave length: the horizontal distance between successive wave crests.
Wave period: the time taken for successive wave crests to pass a given point.
Weighting system: the system used which helps maintain the desired shape and tension of the net. This includes, but is not limited to, the use of i) individual weights, ii) sinker tubes and iii) systems where a net is tensioned through the use of a rope led through a block attached to a sub-surface weight which can be adjusted at the surface.
Wellboat: a boat having a well in which fish can be held/transferred alive or dead.
Wind direction: the direction from which the wind is blowing.
Wind velocity: the ten minute wind velocity measured at 10m above ground [or sea] level.

ANNEX 3 Normative References

The following normative documents are referred to in this document and, by so doing, constitute provisions of this Standard. For dated references only the edition referred to applies. For undated references, the last edition of the reference (including erratum) applies.

BS EN 13889:2003+A1:2008. Forged steel shackles for general lifting purposes. Dee shackles and bow shackles. Grade 6. Safety.

BS ISO 1704:2008. Ships and marine technology. Stud-link anchor chains.

BS EN 1677-4:2000+A1:2008. Components for slings. Safety. Links, Grade 8.

BS EN 10204:2004. Metallic materials. Types of inspection documents.

BS EN 1993-1-1:2005. Eurocode 3. Design of steel structures. General rules and rules for buildings.

NA to BS EN 1993-1-1:2005. UK National Annex to Eurocode 3. Design of steel structures. General rules and rules for buildings.

NA to BS EN 1990:2002+A1:2005. UK National Annex for Eurocode. Basis of structural design.

BS EN 1990:2002+A1:2005. Eurocode. Basis of structural design.

BS EN 12201-2:2003. Plastic piping systems for water supply. Polyethylene (PE). Pipes.

BS EN 3490:2007. Aerospace series. Steel FE-PM3901 (X15CrNi17-3). Air melted. Hardened and tempered. Bar for machining. De ≤ 200 mm. 900 MPa ≤ Rm ≤ 1100 Mpa.

BS 6349-1-4:2013 Maritime works. General. Code of practice for materials.

BS EN ISO 1346:2012. Fibre ropes. Polypropylene split film, monofilament and multifilament (PP2) and polypropylene high tenacity (PP3). 3-, 4- & 8- strand ropes.

BS EN ISO 1140:2012. Fibre ropes. Polyamide. 3-, 4- and 8-strand ropes.

BS EN ISO 1141:2012. Fibre ropes. Polyester. 3-, 4- and 8-strand ropes.

BS EN 1991-1-4:2005+A1:2010. Eurocode 1. Actions on structures. General actions. Wind actions.

BS EN ISO 1461:1999. Hot dip galvanized coatings on fabricated iron and steel articles.

BS EN 1995-1-2:2004. Eurocode 5. Design of timber structures. General. Structural fire design.

BS EN ISO 2307:2010. Fibre ropes. Determination of certain physical and mechanical properties.

BS EN 14687:2004. Mixed polyolefin fibre ropes.

BS EN 12201-2: Plastic Piping Systems for Water Supply, and for Drainage and Sewerage Under Pressure – Polyethylene (PE), Pipes.

DIN 16842:2013: Polyethylene (PE) pipes. PE-HD for pressureless applications. General quality requirements, dimensions and testing. *Partially replaces DIN 8074 and DIN 8075.*

WIS 4-32-08: Specification for the Fusion Jointing of Polyethylene Pressure Pipeline Systems Using PE80 and PE100 Materials. *(UK site installation for EF and BF including butt welding parameters).*

See also: http://www.fao.org/docrep/010/ah827e/AH827E03.htm

ANNEX 4 Site Operating Procedures – Guidance

This Annex provides details of farm/site operating procedures that are considered essential in delivering the objectives of the Standard. Having a Site Operating Procedures (SOP) manual for every finfish site in Scotland is *mandatory* under the Standard, as is the inclusion within the SOP of the points contained in this Annex.

The detailed format of the overall SOP is, however, a matter for individual companies.

General Provisions

A4.1 Operational Planning for New Equipment

Prior to installing any primary and/or secondary equipment, the fish farmer shall undertake the following at an appropriate level of seniority with respect to the envisaged environmental conditions and all conceivable operations at the site:

Number	Detail
A4.1.1.1	Identify any potential scenarios which could lead to a risk of a breach of containment and address these through operational procedures
A4.1.1.2	Assess the availability of resources, including human and mechanical, to satisfactorily implement the above procedures at the site and develop a plan to address any outstanding requirements in a timely fashion

A4.2 Installation of un-stocked primary equipment

Number	Detail
A4.2.1.1	This Standard shall apply to all installations whether stocked or un-stocked unless the components will not be used at stocked fish farms again. This will be documented
A4.2.1.2	Should primary or secondary equipment have been installed in a situation which was not in accordance with this Standard, including the situation when a decision to retire them has been reversed, an independent damage assessment is required prior to use

A4.3 Lack of historical information on equipment use

Number	Detail
A4.3.1.1	Should there be i) a lack of historical information of primary or secondary equipment, or ii) doubts about the accuracy of such information, operators should go back to the general provisions of this Standard before
A4.3.1.1.1	The site is stocked; or
A4.3.1.1.2	For sites which are already stocked, at the earliest opportunity and within four weeks of the first input of fish
A4.3.1.2	The operator shall verify that the equipment is i) acceptable for use, ii) acceptable for use providing that specific modifications/actions are undertaken, or iii) unacceptable for use;
A4.3.1.2.1	The equipment shall not be used in the new situation unless the operator's assessment has confirmed it is i) acceptable or ii) that the work specified in the operator's assessment has been satisfactorily undertaken

A4.3.1.2.2	Should the equipment be stocked, any required work shall be undertaken as specified in the operator's assessment or, for unacceptable equipment, the net/site shall be emptied as soon as possible as specified by the assessment

A4.4 Operating in accordance with the manufacturer's instructions and product specification sheets

Number	Detail
A4.4.1.1	The use of all primary equipment and, where relevant, secondary equipment and individual components shall be in complete accordance with the relevant manufacturer's instructions and product specification sheets at all times
A4.4.1.2	In some cases the farmer may obtain documented approval from the relevant manufacturer to deviate from the manufacturer's instructions in a specified manner

A4.5 Changes in operations, activities, equipment and consumables

Number	Detail
A4.5.1.1	The use of all primary equipment and, where relevant, secondary equipment and individual components shall be in complete accordance with the relevant manufacturer's instructions and product specification sheets at all times
A4.5.1.2	In some cases the farmer may obtain documented approval from the relevant manufacturer to deviate from the manufacturer's instructions in a specified manner
A4.5.1.3	Should the fish farmer wish to change the use of a given site installation and/or the use of primary and secondary equipment[5] such that this may result in equipment being used i) outwith its design parameters or ii) outwith the manufacturer's instructions, the supplier or an independent engineer shall confirm that:
A4.5.1.3.1	The proposed changes are acceptable; or
A4.5.1.3.2	The proposed changes are acceptable with specific modifications and/or restrictions
A4.5.1.4	In the case of the latter, the change(s) shall only commence once the modifications have been made and/or the restrictions are in place
A4.5.1.5	The above shall be documented
A4.5.1.6	The fish farmer shall also require verification as above that any primary equipment may continue to be used in the event of:
A4.5.1.6.1	Damage of a level which could reduce the integrity of the installation; and/or
A4.5.1.6.2	Concern that the actual environmental conditions experienced at the site are significantly different to the envisaged environmental conditions; and/or
A4.5.1.6.3	The possibility that the actual operations that are, or could conceivably be, undertaken at the site are different, or may be undertaken differently, to those originally considered

[5] This shall include a) the use of boats for which the existing moorings and/or pens were not designed, b) the introduction of additional pens into a mooring system, c) a change in the type/dimensions of pens and/or nets in a mooring system, d) a significant change in the weighting system or e) a change in orientation of a mooring system.

A4.6 Icing in Freshwater Sites

Number	Detail
A4.6.1.1	An assessment of the likelihood of icing at freshwater pen and landbased sites shall be made based on local knowledge and/or desk based research. This shall be documented and a summary included in the product specification sheet and manufacturer's instructions
A4.5.6.2	Fish farmers at freshwater pen and landbased sites that have been identified as at risk from icing shall develop an action plan to reduce the likelihood of a containment incident from icing. This plan shall be displayed on-site and implemented in the event of icing. All equipment identified in the plan shall be available at the required time of year

Moving Fish

A4.7 Operational Planning for Moving Fish in Pens

Moving fish pens, i.e. by pushing or towing, carries inherent risk if the bottom of the net is damaged by an unexpected object on the sea/loch bed. The risk is likely to be very site-specific, and practical steps to be taken by staff are outlined below.

Number	Detail
A4.7.1.1	The bottom depth and type shall be charted across an area extending 100m beyond the consented site boundary on a grid of 10m squares or less. Any large irregularities shall be recorded
A4.7.1.2	Assess the availability of resources, including human and mechanical, to satisfactorily implement the above procedures at the site and develop a plan to address any outstanding requirements in a timely fashion
A4.7.1.3	The depth of water shall be available/determined along paths in which pens with deployed nets are towed or pushed
A4.7.1.4	In cases where the water depth may be less than 5m between the lowest point of the net and the loch bed, the towing route and a sufficient margin on each side to allow for unexpected course deviation shall be:
A4.7.4.1	Sounded on a grid of 10m squares or less
A4.7.4.2	Swept by wire or similar to check for obstructions
A4.7.1.5	These water depths, along with identities and positions of obstructions, shall be available to the site manager and any personnel involved in moving pens
A4.7.1.6	All equipment should be lifted and secured to avoid snagging prior to cage transfer
A4.7.1.7	When moving fish in pens if fish are to be temporarily held in the transfer pen (e.g. overnight) consideration must be given to the appropriate mooring of the pen as per section 7.3 of the Standard

A4.8 Stock transfer: using fish transfer pipe

This sub-section relates to the transfer of fish in locations outwith areas which are protected by screens and/or containment structures such that an incident could lead to the escape of fish into a watercourse. Therefore, it does not include the transfer of fish within the areas of a land based site protected by screens and containment structures as detailed above.

Number	Detail
A4.8.1.1	Pipes used to transfer fish shall:
A4.8.1.1.1	Be adequately supported to prevent undue stress on the pipe
A4.8.1.1.2	Be constructed from material that is sufficiently strong and suitable for the purpose
A4.8.1.2	When using transfer pipes:
A4.8.1.2.1	Both the input and output shall be continuously observed when fish are being transferred
A4.8.1.2.2	Staff shall be stationed to allow the transfer to be instantaneously stopped
A4.8.1.2.3	Appropriate communications devices shall be provided to ensure instantaneous communication between those observing and operating the transfer
A4.8.1.2.4	The upstream and downstream ends shall be secured and/or positioned so as to prevent the opportunity for an escape incident
A4.8.1.2.5	Connectors shall be secured to the transfer pipe with a secondary device such as a clip or clamp and in accordance with manufacturer's instructions
A4.8.1.2.6	The pipe shall be protected against fish escape, should any intermediate join/connection fail, by the use of a tube of net of an appropriate mesh size being placed around the pipe at each join and extending at least one metre each side of the join. The pipe shall be well secured by two clamps or clips or other appropriate mechanical connecting devices each side of the join so as to prevent fish loss in the event of failure
A4.8.1.2.7	Water pressure in pipe should be applied gradually
A4.8.1.3	Maintenance requirements for transfer pipe connectors and valves shall be determined, documented and implemented

A4.9 Stock transfer: using helicopter bucket

Number	Detail
A4.9.1.1	Ensure weather conditions are assessed with pilot to ensure flight conditions are suitable and will not result in a sudden loss of lift for the helicopter
A4.9.1.2	A helicopter bucket overflow screen shall be securely attached to the top of the helicopter bucket when loading other than when fish are being loaded by hand net
A4.9.1.3	It shall be ensured that all areas where the helicopter bucket will be landed are sufficiently:
A4.9.1.3.1	Large and free of obstructions so that the bucket cannot be damaged or the locking mechanism inadvertently opened
A4.9.1.3.2	Flat and horizontal to prevent any likelihood of the bucket toppling over

A4.9.1.4	The locking mechanism of a helicopter bucket containing fish shall be checked:
A4.9.1.4.1	Following landing if it is to be subject to a further lift (whether by crane or helicopter) to ensure that it has not been damaged or inadvertently opened during landing
A4.9.1.4.2	Prior to loading fish

Maintenance and Inspections

A4.10 Inspection regime and preventative maintenance plan

Number	Detail
A4.10.1.1	An assessment of the likelihood of icing at freshwater pen sites shall be made based on local knowledge and/or desk based research. This shall be documented and a summary included in the product specification sheet and manufacturer's instructions
A4.10.1.2	An inspection regime and a preventative maintenance plan shall be developed for all components of the installation to include:
A4.10.1.2.1	Requirements in the relevant manufacturer's instructions
A4.10.1.2.2	Frequent and regular checks by site staff
A4.10.1.2.3	Actions required to prepare a site for the arrival of poor environmental conditions
A4.10.1.2.4	A preventative maintenance programme for engineers
A4.10.1.2.5	Issues that could lead to a breach of containment, including mooring integrity, connector wear and net abrasion
A4.10.1.3	The a) requirements, b) compliance with, c) reporting of and d) actions arising from the inspection and preventative maintenance plans shall be documented.

A4.11 Responding to maintenance requirements

Number	Detail
A4.11.1.1	The fish farmer shall have sufficient resources, whether in-house or contracted, to undertake planned and corrective and reactive maintenance in accordance with this Standard so as to maintain effective containment
A4.11.1.2	The fish farmer shall identify a list of spare parts, consumables and associated materials which may be required for maintenance, including unplanned situations, to maintain effective containment and shall ensure these are available as may be required. This list and associated stock shall be documented

A4.12 Post acquisition inspection

Number	Detail
A4.12.1.1	Following the acquisition of an existing site, or equipment thereof, a full installation inspection shall be undertaken in accordance with Section 8

Nets

A4.13 Suitability of the pen net for use

Number	Detail
A4.13.1.1	At all times when the pen net is deployed, the pen net shall:
A4.13.1.1.1	Be suitable for the pen
A4.13.1.1.2	Properly fit the pen
A4.13.1.1.3	Be hung in accordance with the manufacturer's instructions
A4.13.1.2	Any holes or tears in the net when it is stocked (including the jump net) shall be repaired immediately. It is acceptable to use a temporary repair providing that a more permanent repair is affected as required – a more permanent repair is required when:
A4.13.1.2.1	The nature of a temporary repair may be of insufficient strength to last until the net is available for a long-term repair or when it is retired
A4.13.1.2.2	When the temporary repair may give rise to forces on the netting for which it was not designed; or
A4.13.1.2.3	Should the temporary repair in itself give rise to other containment concerns including, but not limited to, increasing the potential for net chafing
A4.13.1.3	Equipment shall not be attached to any element of the net unless specified in the manufacturer's instructions or following the documented agreement of a net manufacturer or net service company

A4.14 Top nets

Number	Detail
A4.14.1.1	Sites where washout is possible should be identified on the basis of experience and/or the site survey and documented by the fish farmer. The potential for escapes from washout should be addressed by the use of top nets which are:
A4.14.1.1.1	Of the same aperture size as the pen net in a band near the outer circumference so as to prevent wash out of fish, with larger mesh size over the rest of the top net; and
A4.14.1.1.2	Securely attached to the pen so as to prevent escapes by methods (this may include lacing to the pen net)

A4.15 Selecting the net mesh/screen aperture

Number	Detail
A4.15.1.1	Nets/screens/grids shall be of sufficient size to prevent the smallest fish escaping

A4.16 Net depth requirements

Number	Detail
A4.16.1.1	The fish farmer shall ensure that all nets (excluding predator nets) used at pen sites are sized such that they cannot come in to contact with the bed of the loch and/or basal obstructions when fully deployed at the location in which they are to be used in all conceivable environmental conditions

A4.16.1.2	An appropriate margin of safety shall be included, and partial deployment of nets is not permitted as a means of achieving this aim

A4.17 Net damage assessment

Number	Detail
A4.17.1.1	An assessment of the potential for net damage from abrasion during transport, installation, use and recovery shall be undertaken prior to stocking in respect of the equipment to be used at the site. This shall include i) the identification of hazards (predators), ii) associated control measures, iii) applicable monitoring, iv) corrective actions and v) records and responsibilities for planned and unplanned operations
A4.17.1.2	With reference to the net damage assessment:
A4.17.1.2.1	Control measures shall be considered through a hierarchical approach, as follows: i) elimination of the risk, ii) substitution of materials, iii) protection of materials and iv) changes in operational procedures
A4.17.1.2.2	Monitoring/preventative maintenance shall reflect the level of certainty about the potential for damage and any reliance on net protection measures; an increased likelihood of damage and/or reliance on protective measures shall require a more regular and robust monitoring and maintenance programme

A4.18 Net inspection: on-site

Number	Detail
A4.18.1.1	Nets shall be visually inspected for wear and tear and damage as a minimum:
A4.18.1.1.1	Prior to stocking
A4.18.1.1.2	Every six weeks when stocked
A4.18.1.1.3	During/after each operation when the net is lifted[2]
A4.18.1.1.4	Should an escape incident be suspected
A4.18.1.1.5	Following a prolonged stormy period of weather once safe to do so
A4.18.1.2	Net inspections shall include inspecting the following elements of the net for a) damage, b) correct alignment, and c) any issues that may increase the risk of future escapes:
A4.18.1.2.1	All attachment points
A4.18.1.2.2	All ropes
A4.18.1.2.3	Each net panel
A4.18.1.3	Any required repairs shall be identified and undertaken as required. An assessment shall be made of the suitability of the net for continued use
A4.18.1.4	Inspection findings shall be documented along with the name and company of the person(s) undertaking the inspection, the name and company of the person in charge of the inspection and the method and date of inspection

[2] The inspection can be undertaken as the net is being lifted and/or lowered. In the case of net changes and swim throughs, the inspection shall be undertaken as soon as is reasonably practical to the time the net is stocked.

A4.19 Annual net strength testing

Number	Detail
A4.19.1.1	Nets shall be tested for strength annually
A4.19.1.2	Results shall be expressed as a) a numerical value in kg and b) as a percentage of the net's dimensioned class and shall include the net's unique identifier and manufactured class, date of manufacture, date of first use, date of the test, name and company of the person undertaking the test and details of the equipment used to undertake the test. The tester shall sign to confirm that the testing equipment was appropriately calibrated

A4.20 Annual net inspection

Number	Detail
A4.20.1.1	Nets shall be visually inspected 12 months after manufacture and annually thereafter to assess general wear and tear and identify any specific damage. Note that this provision does not apply to nets that are stored over long periods of time between use, but these should be inspected and tested when taken out of storage for re-deployment. Inspections shall:
A4.20.1.1.1	Be undertaken by person(s) independent to those with responsibility for the management of the site from which the net will be tested
A4.20.1.1.2	Be undertaken within two weeks of the annual net strength testing
A4.20.1.1.3	Include the detailed examination of all areas of the net mesh, all ropes, all connecting points and any areas of net reinforcement
A4.20.1.1.4	Include an assessment as to whether the net is a) suitable for use at the present time, b) suitable for use following specific repair work, or c) unsuitable for further use
A4.20.1.1.5	Be fully documented
A4.20.1.2	Any nets which are deemed unsuitable for further use shall not be used. Those requiring specific additional work shall not be returned to use until such work is undertaken. Any repair work shall be documented

Mooring System

A4.21 General mooring system provisions

Number	Detail
A4.21.1.1	The mooring system must be designed and installed to prevent chafing of any primary or secondary equipment
A4.21.1.2	Should the partial or complete removal of any component of the mooring system be required for operational reasons, the operational scenarios and environmental conditions in which this can take place shall be identified; the rationale and accompanying calculations shall be documented. All relevant information shall be included in the manufacturer's instructions

A4.22 Mooring of boats and secondary equipment

Number	Detail
A4.22.1.1	Boats and secondary equipment shall not be moored to pens (including on mooring points specified by the manufacturer) when:
A4.22.1.1.1	Not in use (excluding short work breaks)
A4.22.1.1.2	When environmental conditions exceed those stated in the manufacturer's instructions as appropriate for the specific equipment or mooring point

ANNEX 5 Site Survey Report Template

The following template contains recommendations for presenting information gained under Section 2 of the Standard, together with other relevant information about the site, in a single Site Survey Report format. The template is included in this Annex to the Standard for guidance only. Producing a Site Survey Report is mandatory under the Standard, *but the exact format of the Report is a matter for individual companies.*

It is recommended that a full sea bed survey is carried out to determine the nature of the sea bed at and near the expected position of every anchor. This is to establish the sub surface nature of the strata.

This dossier of information may be of use to a number of different organisations, and should be delivered to them at an appropriate time. Such organisations may include, but are not limited to:

- The suppliers of primary equipment during any design and dimensioning process
- Senior personnel and the site manager at the aquaculture production business operating the site
- Persons involved in the installation, maintenance, and operation of the site
- Persons involved in towing and pushing equipment
- The operators of well boats, feed boats and work boats servicing the site

AQUACULTURE PEN MOORING – SITE INFORMATION

Item	Description
1 Name contact:	
2 Company name:	
Address:	
Email address:	
Phone & Fax:	
2.1 Site name:	
2.2 Latitude and Longitude chart position of proposed site:	
2.3 Maximum wind speed [m per sec/ knots]: *	
Prevailing wind direction [from]:	
Maximum fetch: (miles)	
Maximum fetch direction:	
Significant wave height [m]:	
Charted water depth around grid – supply separate drawing if necessary [m]: *	

Item	Description
Maximum tidal height [m]: *	
Maximum current velocity [m per sec/knots]: *	
Direction of strongest current [from/to]: *	
2.4 Circular or square pens: *	
Total number of pens: *	
Circumference of circular pens [m]: *	
Dimensions of square pens [m]: *	
System layout e.g. 2x6 pens: *	
Depth of grid from surface [m]: * ***(If pen is circular)***	
Grid square size required: *	
Net description:	
Net depth: *	
Net breadth:	
Note dimensions and description of any sub surface predator nets to be used:	
Sea bed type: * **(sand, mud, shale, rock, clay etc)**	
Seabed holding: (poor, good, excellent)	
Additional information: (please supply any additional information you feel may be relevant to the specification of this moorings installation)	

ADDITONAL INFORMATION (E.G.BOATS, RAFTS ETC)

Information supplied by:	
Date supplied:	

*Items marked with an * are mandatory requirements to provide a full site specification.*

ANNEX 6 Approach to Current Monitoring

A6.1 Specific Approach

The approach to current monitoring shall be carried out in accordance with Box 1 below.

Box 1: Current monitoring requirements with reference to Attachment VIII (SEPA 2008)
2.1, Position Fixing: the elements regarding the current meter apply in their entirety.
2.3, Data Reporting: the location of the current meter shall be identified in accordance with this section.
3.1, Duration and Resolution: applies in its entirety.
3.3, Equipment: applies in its entirety, except that SEPA should not be approached regarding equipment 'slightly outwith' the specifications – in these situations, the use of such equipment should be justified and documented.
3.4, Data Quality Assurance: applies in its entirety.
3.5, Deployment Position and 3.6, Depth of Data Retrieval: these apply in their entirety except that: • Data is only required to meet the sub-surface and cage-bottom current requirements. • SEPA should not be contacted to discuss uncertainties regarding current meter locations; instead, the use of an additional monitoring location(s) should be utilised – such a decision should be justified and documented. In addition to the requirements in Section 3.5, the following apply: • The monitor shall be positioned at 5m and 15m and then use the highest value. If the net depth is greater than 15m then the Site Survey must include a measurement at 20m depth. Interpolation between 2 points is allowed, extrapolation not allowed where the highest velocities of current from tidal and wind induced factors are expected. • The monitoring point shall be in the location where the fish farm pens are to be located. • One or more additional monitoring points are required where variations in tidal or wind induced current may be expected across the area where pens and, if appropriate, feed barges will be located which could affect the design and specification of equipment at the site. • One or more additional monitoring points are required where a significant contribution to total current velocity from variables other than tidal or wind induced current may be expected across the area where pens and, if appropriate, feed barges will be located. This could include, but is not limited to, discharge from rivers/estuaries and hydroelectric schemes.
3.7, Meteorological Data: applies in its entirety except that there is no need to meet the requirements of the quoted maximum wind speeds during the monitoring period.
3.8, Numerical Data: data shall be stored in accordance with the requirements of this clause except that there is no requirement to submit data to any authority.
Notes: a) Numbers refer to paragraph numbers in Attachment VIII (SEPA, 2008). b) Clauses other than the above do not apply.

A6.2 Attachment VIII SEPA 2008

For details of this SEPA guidance, please download from:

http://www.sepa.org.uk/water/water_regulation/regimes/aquaculture/marine_aquaculture/idoc.ashx?docid=38420d21-0875-4de5-93f7-7295ee8c65f7&version=-1

http://www.sepa.org.uk/water/water_regulation/regimes/aquaculture/marine_aquaculture/fish_farm_manual.aspx

A6.3 Background to current recording recommendations

A Note on the Estimation of Extreme Currents in West Scottish Coastal Waters

For
Technical Steering Group
Scottish Aquaculture Research Forum

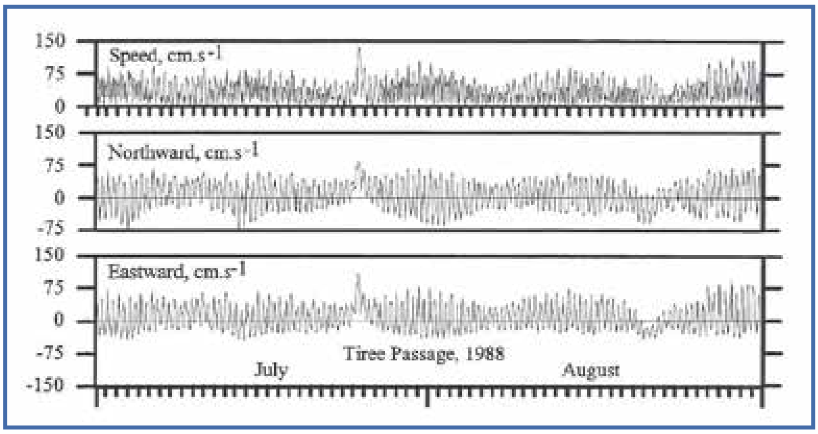
Anton Edwards, CPhys, FInstP

1 PROBABILITY ANALYSIS: ESTIMATING EXTREMES

1.1 The Problem

Measurements of ocean currents usually contain tidal frequencies, a residual mean flow over the period of observation, and other motions driven by the wind, turbulence, or density differences associated with freshwater or heat redistribution. As an example, **Figure 1** shows a typical record, in this case from the Tiree Passage. There are tidal, residual and other motions in the record.

Figure 1: Time series of current measurement in the Tiree Passage

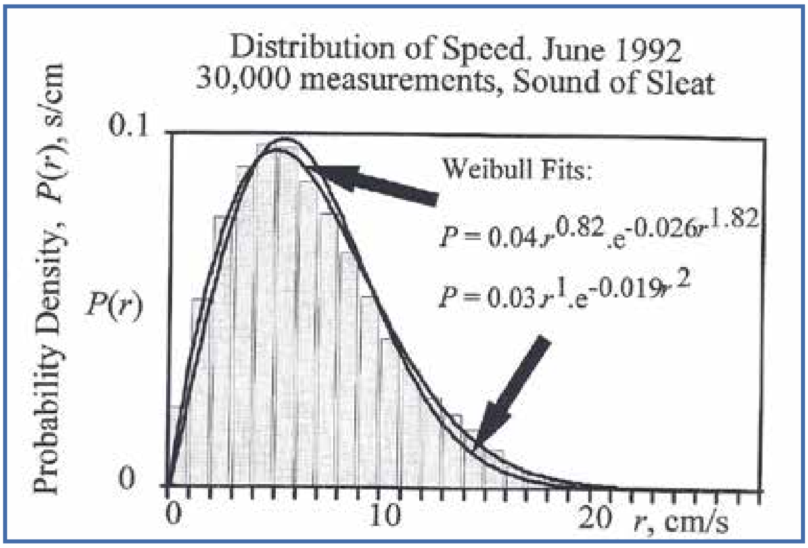


An extreme is visible in this record towards the end of July. The question then arises: how may we estimate the size of extremes over longer periods in such places?

1.2 Probability Distributions

Figure 2 shows the probability of various speeds in a record from the Sound of Sleat.

Figure 2: Probability distribution of speeds in the Sound of Sleat, 3 to 18 metres, June 1992



From this distribution it may be seen that the most likely speed is around 5 cm.s^{-1}, and that there is a decreasing proportion of measurements at higher speeds, becoming vanishingly small around 20 cm.s^{-1}. How are we estimate the likelihood of speeds higher than the maximum observed in this short period?

One approach is to measure from now to eternity: expensive and slow. Perhaps – if the motions were purely astronomically tidal and therefore completely deterministic – the maximum could be calculated with standard techniques of tidal prediction. However, overlying wind currents, turbulence and residuals are not deterministic and a statistical approach is needed.

It might be assumed that the extreme must occur somewhere within the annual and seasonal variation of current; this suggests a measurement period of a year, which we believe to have been specified elsewhere. The assumption is plausible but ignores the possibility of exceptional years, which themselves arise statistically. It also implies great expense in instrumentation. A more subtle approach is needed.

1.3 Weibull Extrapolation

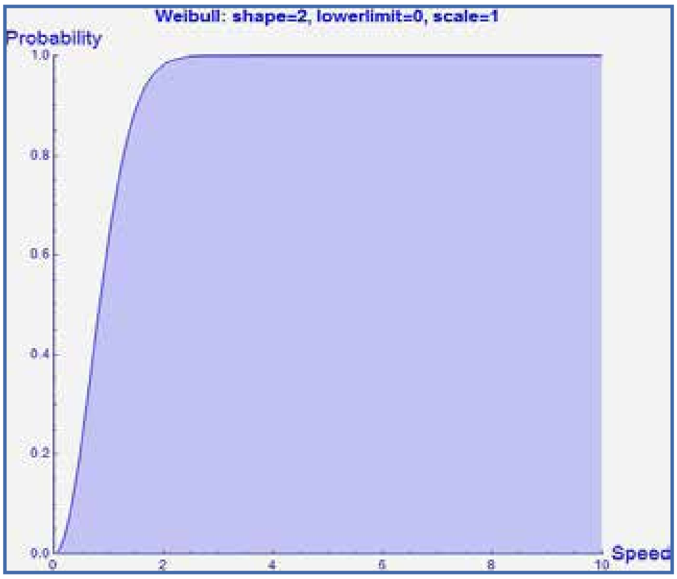
Figure 2 shows a couple of possible fits to the Sound of Sleat current record probability distribution, according to Weibull's Distribution. Such distributions are often presented in the form of a cumulative probability distribution, to show the probability of a speed being equal to or lower than the given speed. **Figure 3** shows an example.

In Weibull's probabilistic distribution, which has often been found to be applicable to analysis of extremes of phenomena such as winds and currents and for which there may be a statistical mechanical explanation (Edwards, Griffiths and McDougall, 1996), the three parameter cumulative distribution of speed *v* (cm/s) shows the probability *R(v)* that the speed is not exceeded. It has the form:

$$R(v) = 1 - e^{\left(-\frac{v-ll}{scale}\right)^{shape}}$$

The units of the three parameters are: an offset *ll* cm.s^{-1}, *scale* cm.s^{-1}, and *shape* is a pure number. The shape of this cumulative distribution is exemplified by **Figure 3**.

Figure 3: Cumulative probability of encountering a given speed or less



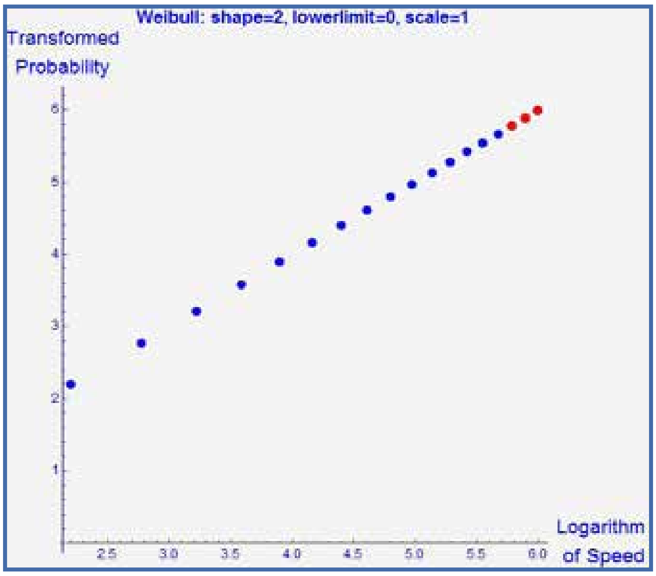
It is difficult to fit real data gathered from current records to such a shape, or to see the probabilities associated with extreme currents. Such distributions are therefore often linearized by algebraic manipulation by using or seeking suitable transformations of the axes such as:

$$y = Log(Log(1 - R(v))$$

$$x = shape\ (Log(v) - Log(scale))$$

With these transformations, the relationship of probability of exceedance and the speed becomes very clear and usefully linear as in **Figure 4**.

Figure 4: Points from a linearized cumulative Weibull Distribution



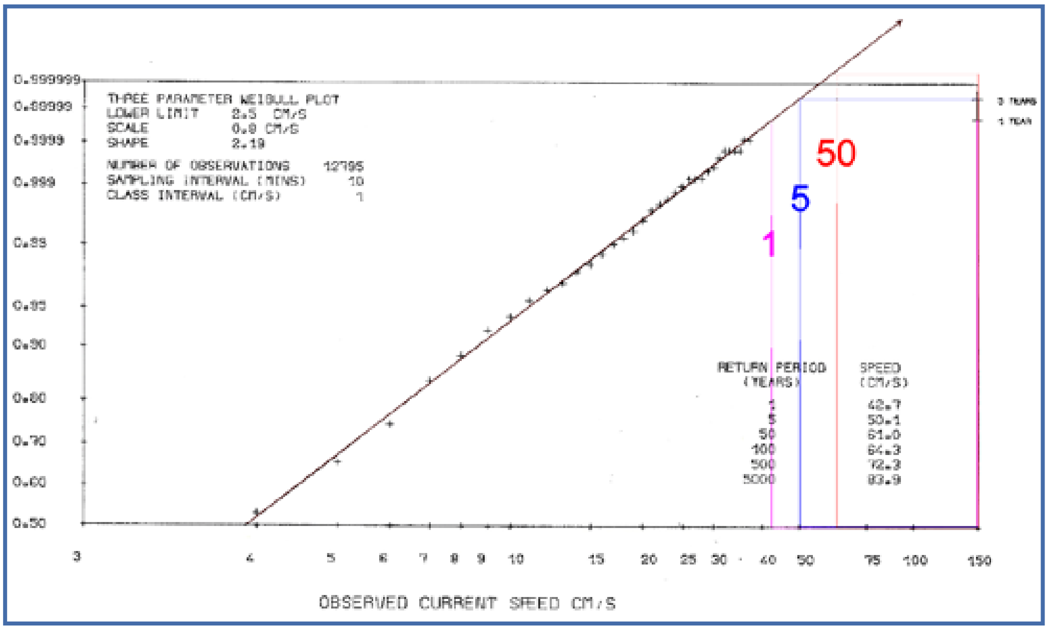
With such conveniently linear relations as in **Figure 4** it is easy to visualize how to extrapolate the exceedance probabilities measured from a short record (such as the blue series) into the probabilities of higher speeds absent from the short records but which might have been obtained from a longer record (such as the red points).

The following example (**Figure 5**) is taken from one of many analyses at various depths and positions of about three months of current measurements (every 15 minutes) in the Gareloch (Clyde), a Scottish west coast loch. The measurements were made during the winter months from December to April, on the "worst case" assumption that wind and atmospheric driven current activity is greatest at that time of year.

The observed current speed cumulative distributions were fitted to the Weibull Distribution using iterative correlation techniques in which a least squares fit for scale and shape was sought for the upper 50% of the measurements for various values of ll. The best fit was used to extrapolate to the likely extreme in 50 years or more.

Such techniques may be applied to any record, either to the whole record, or to the random part alone, which might then be considered in recombination with predicted tides.

Figure 5: Prediction of extremes. About 3 months record, Gareloch, depth 4 m, 1, 5 & 50 years



1.4 Derivation of extrapolation factors in the Gareloch

From such extrapolations as Figure 5, a table of current and return periods may be constructed.

Table 1 shows such a table for two sites in the Gareloch.

Table 1: Factors relating the extreme speed in various periods to the extreme in 3 months

	Gareloch N, 4m	Factor	Gareloch S, 4m	Factor	Average
Years	Speed (S), $cm.s^{-1}$	$S/S_{(0.25)}$	Speed (S), $cm.s^{-1}$	$S/S_{(0.25)}$	$S/S_{(0.25)}$
0.25	35	1.00	37	1.00	1.00
1	42.7	1.22	42	1.14	1.18
5	50.1	1.43	49.3	1.33	1.38
50	61	1.74	60.1	1.62	1.68
100	64.3	1.84	63.4	1.71	1.78

This table also shows a factor that relates the predicted extremes to the measured extreme of the three-month period. For example, a factor of about 1.7 x three-month extreme might serve to predict the fifty-year extreme.

Were most sites similar to the Gareloch Table 1 might serve as an indication of the factors to be applied to extremes measured in a period of about three months so as to derive extremes over longer periods.

However, the Gareloch is not typical of open water.

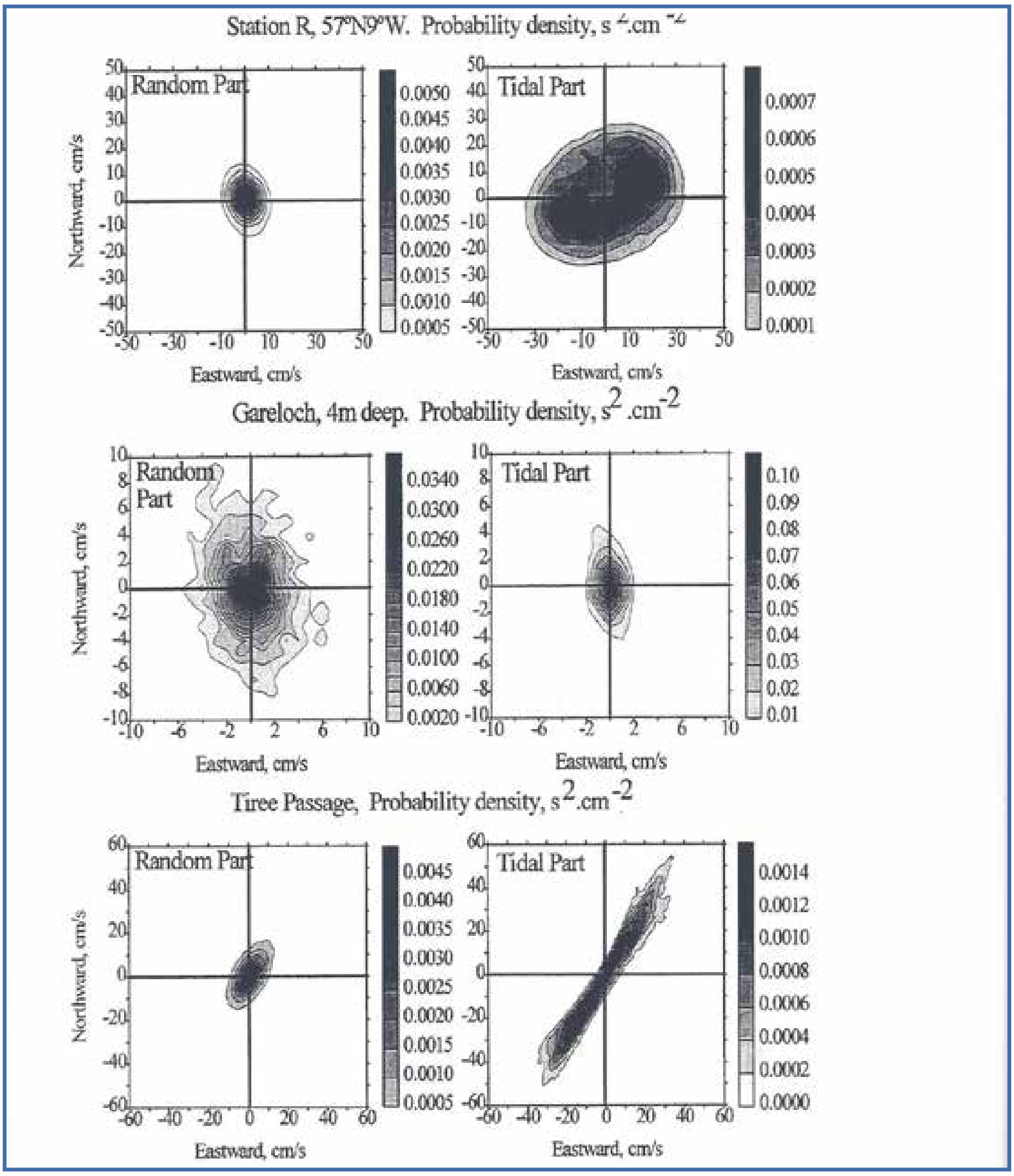
2 THE BALANCE OF TIDAL AND RANDOM MOTIONS

2.1 Some West Scottish sites

The Gareloch is sheltered, has low tides and is stratified. The stratification allows the wind to move the near surface layers and to dominate much of the motion in the loch. This section is taken from other work (Edwards, Griffiths and McDougall, 1996) and demonstrates that more open sites are tidally dominated.

Figure 6 shows the distribution of currents (separated into tidal and random parts) at the Tiree Passage, Gareloch, and a station R on the continental shelf at 57ºW, 9ºN. The open sites are dominated by tidal currents whereas the Gareloch is dominated by random currents.

Figure 6: 2-D Tidal and random velocity distributions, West Scottish sites



Similarly, **Figure 7** shows the probability distributions of the separated tidal and random parts of current at the three sites (with fits to a GMB distribution).

Figure 7: Probability distributions of tidal and random parts of the current at three sites

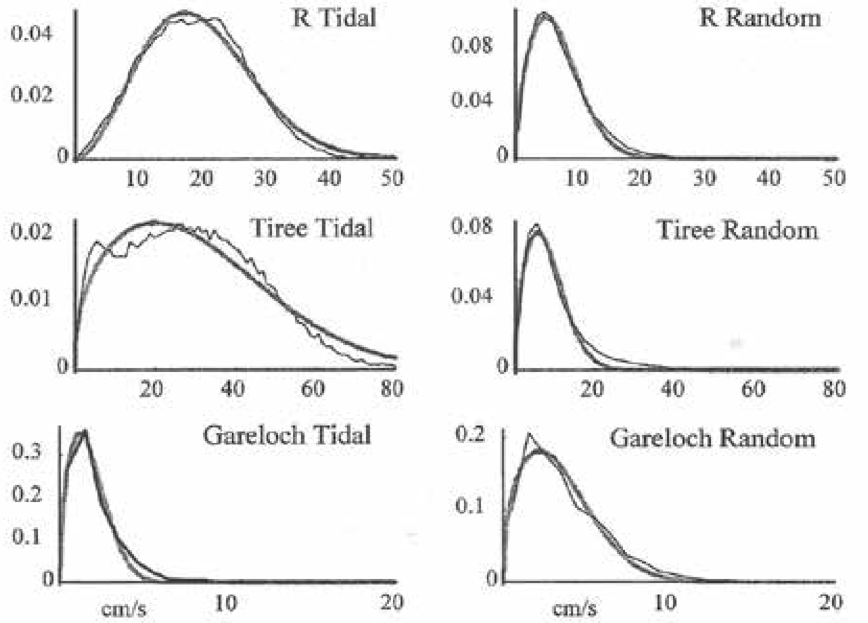


Figure 7: Station R, Tiree Passage and the Gareloch: derived speed distributions and the best nonlinear fits to the Generalised Maxwell-Boltzmann distribution {9}.

The dominance of tidal flows is clear in the open sites. More detailed analysis of the kinetic energy at these sites is shown in **Table 2**.

Table 2: Comparison of current measurement sites in the West of Scotland

Site	Kinetic energy ratio Tidal/ Random	r.m.s tidal speed $cm.s^{-1}$	r.m.s random speed $cm.s^{-1}$	Nature	Dimensionality *n* of random part
Station R	5.8	20.1	9.5	open sea	1.65
Tiree	6.54	33.5	13.1	a strait	1.52
Gareloch	0.26	2.4	4.6	inlet head	1.39

The ratio of tidal to random kinetic energy is around six in the open sites and merely a quarter in the Gareloch.

From these comparisons, it is clear that the Gareloch (and by implication, many other lochs) is not typical of more open sites.

A formal distinction between strongly and weakly tidal may be made by comparing the ratio of tidal to random kinetic energy in records. If the ratio exceeds one, the site is more tidal than random; if it is less than one, it is weakly tidal. To do this requires tidal analysis of the deterministic part of records, the remainder being the random part.

2.2 Derivation of a factor at open sites

On present information, little more can be said here about station R. To examine such shelf sites, access to and analysis of various series of measurements are needed.

A crude analysis of the Sound of Sleat data used by Edwards et al (1996) is possible. **Figure 2** shows the distribution of speeds without any separation into random and tidal parts. Two fits of a Weibull model were made to these data and the equations shown in **Figure 2** may be used to estimate the return periods of various speeds.

Table 3: Factors relating the extreme speed in various periods to the extreme in 3 months; 2-and 3-parameter models of distribution

Sound of Sleat	**2-parameter model**		**3-parameter model**	
Years	**Speed (S), $cm.s^{-1}$**	**Factor $S/S_{(0.25)}$**	**Speed (S), $cm.s^{-1}$**	**Factor $S/S_{(0.25)}$**
0.25	22	1.00	0.25	1.00
0.525	23	1.05	0.85	1.08
1.275	24	1.09	1.65	1.12
3.1	25	1.14	3.35	1.16
7.5	26	1.18	6.5	1.20
17	27	1.23	20	1.28
32.5	28	1.27	30	1.32
47.5	29	1.32	42.5	1.40

The values of speed modelled in this table are different because of the differences of the two models at various speeds. No further distinction can be made here but nevertheless this table shows factors that relate the predicted extremes to the measured three-month extreme. For example, to predict the fifty-year extreme, a factor of about 1.4 x three-month extreme might be expected.

3 WEAKLY AND STRONGLY TIDAL SITES

The foregoing sections point to the importance of distinguishing sites that are weakly tidal from strongly tidal. It may be at present neither desirable nor practical to place the burden of tidal analysis on the industry. Nevertheless, some insight has been gained here by considering existing records from Scottish farm sites.

3.1 A Controlled Activities Regulations (CAR) Dataset

Fish farmers collect 15-day current records to support their applications to SEPA for a site licence under the Controlled Activities Regulations (CAR). Such short records are not suitable for probabilistic analysis and prediction of extremes according to the methods of earlier sections. The records are publicly available and a selection has been analysed in what follows. Site anonymity has been retained and each site is merely referred to by a number (1 to 111).

The chosen CAR records are those containing measurements at 20 minute intervals. 111 records each of 1080 measurements from near surface have been analysed roughly so as to distinguish the tidal part from the non-deterministic (hereafter called "random") part. It is significant that, for its modelling purposes, SEPA requires these records to be obtained in the absence of too much strong wind.

3.2 Tidal analysis of 111 CAR records

Tidal motions comprise a large number of harmonic components of various amplitudes, frequencies and phases determined by astronomical tidal forces and modified by the ocean's topography.

For a rough analysis, the principal harmonic components of the tide at any of the CAR sites were assumed to be as in **Table 4**.

Table 4: Principal tidal constituents

Origin	Symbol	Period (day)
Principal lunar	O_1	1.076
Principal solar	P_1	1.003
Principal lunar and solar	K_1	0.997
Principal lunar	M_2	0.518
Principal solar	S_2	0.5
Declinational lunar and solar	K_2	0.499
From Pugh (2004)		

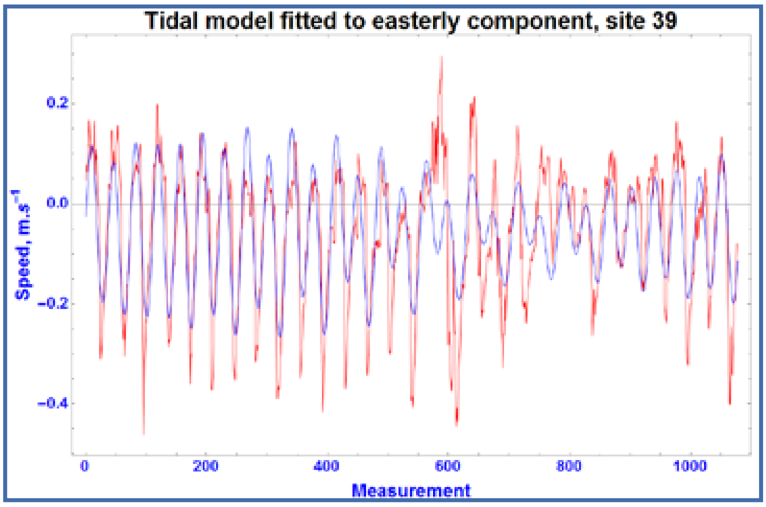
At each site, the current was resolved into the easterly and northerly components. Each component was fitted (Mathematica, 2014: *NonLinearModelFit* routines) to a model composed of a constant a_0 and the above six harmonics each with unknown amplitude (a_i) and phase (f_i):

Speed $U(t) = a_0 + \sum_1^6 a_i \, Sin(w_i \, t + f_i)$ where t is time and $w_i = 2\,\pi / Period$

3.2.1 A moderately tidal example from site 39

An example of the tidal analysis is shown in **Figure 8**. Measurements of the northerly component of current are shown in red; the best fit model is shown in blue.

Figure 8: A 6-harmonic tidal model of northerly current at site 39, 15 days, 1080 measurements



Similar analysis was done for the easterly component. Combination of` the easterly and northerly variances of these components (proportional to their kinetic energy) then gives a picture of the overall balance between tidal and random parts. In this example from CAR site 39, the total variances may be compared as in **Table 5**.

Table 5: Variances of current and tidal model at CAR Site 39

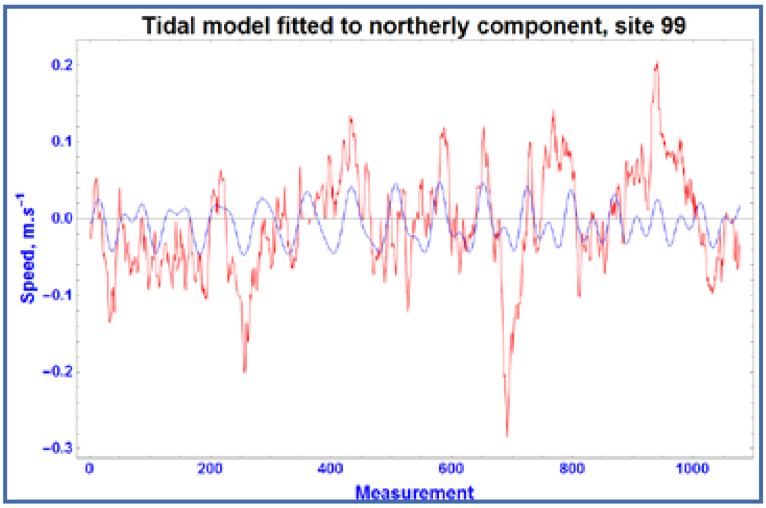
Site 39: Combined Variances	**Variance, $m^2.s^{-2}$**
Total	0.020
Tidal Model	0.011
Random	0.009
Tidal/Random Ratio	1.19

It is clear in this case that the record is mainly tidal with lesser random embellishment.

3.2.2 A weakly tidal site: site 99

On visual inspection, the northerly component (**Figure 9**, red) from site 99 is not obviously tidal. The motions at this site are largely random and the modelled part (**Figure 9**, blue) is relatively small.

Figure 9: A 6-harmonic tidal model of northerly current at site 99, 15 days, 1080 measurements



This visual impression of the record at this site is confirmed by the analysis of the total variance shown in Table 6.

Table 6: Variances of current and tidal model at CAR site 99

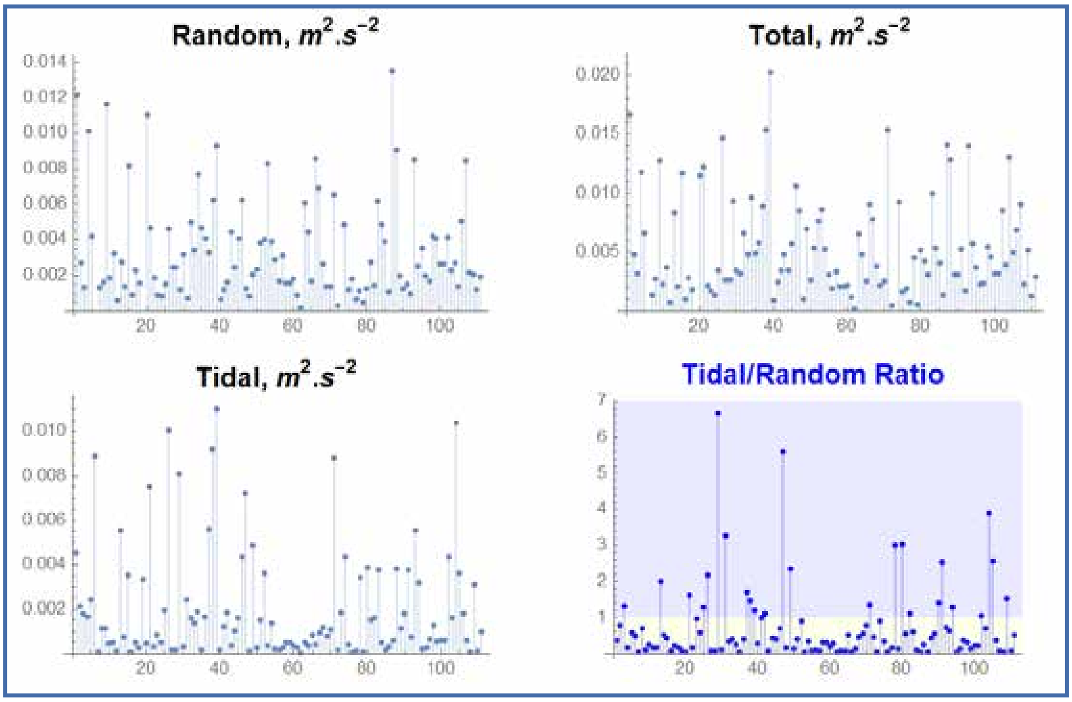
Site 99: Combined Variances	Variance, $m^2.s^{-2}$
Total	0.0467
Tidal Model	0.0006
Random	0.0041
Tidal/Random Ratio	0.14

This site is therefore weakly tidal, similar to the Gareloch (ratio ~ 0.26), and is dominated by turbulence, wind-driven and other currents of non-tidal origin.

3.3 Variance analysis of the CAR sites

The analysis of sections 3.2 has been applied to all 111 CAR sites. Figure 10 shows (with a small number of outliers omitted) the total, random and modelled tidal variances at all sites, together with the tidal/random ratios. Stronger tidal sites lie in the blue region of the figure (ratio>1); weaker tidal (ratio<1) are in the yellow region.

Figure 10: Variance Analysis of 111 sites

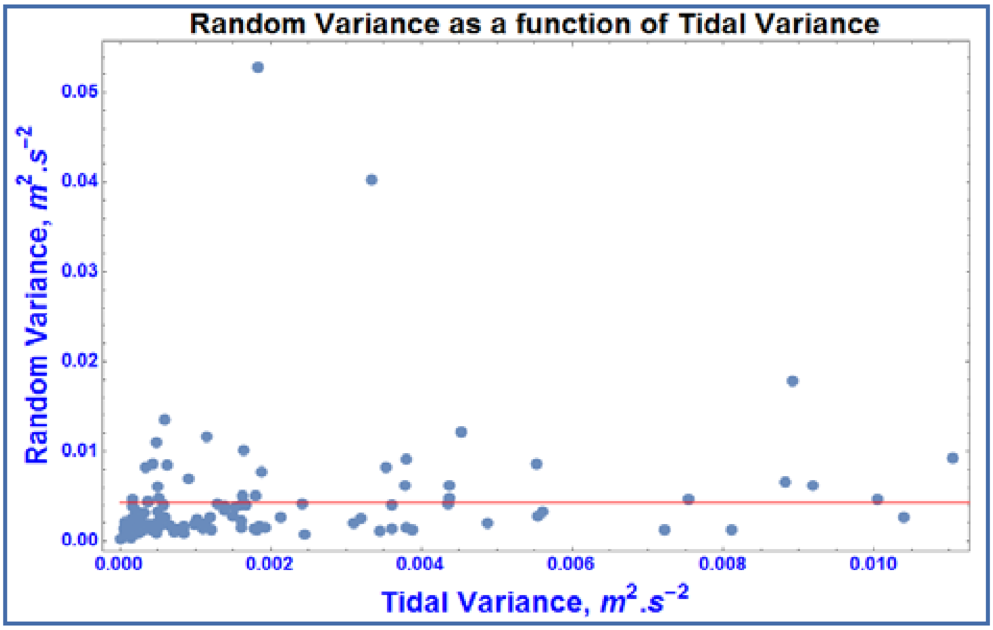


It is interesting to see how random variance depends on the tidal variance. Figure 11 shows the dependence across all sites.

There is no obvious correlation in Figure 11, the random variance trending largely constant around the mean value (shown in red) of 0.0045 $m^2.s^{-2}$ across the range of tidal conditions.

This is consistent with the most of the sites enjoying similar disturbances associated with wind, turbulence and other forcings, no matter what the tidal strength is.

Figure 11: Random variance as a function of modelled tidal variance

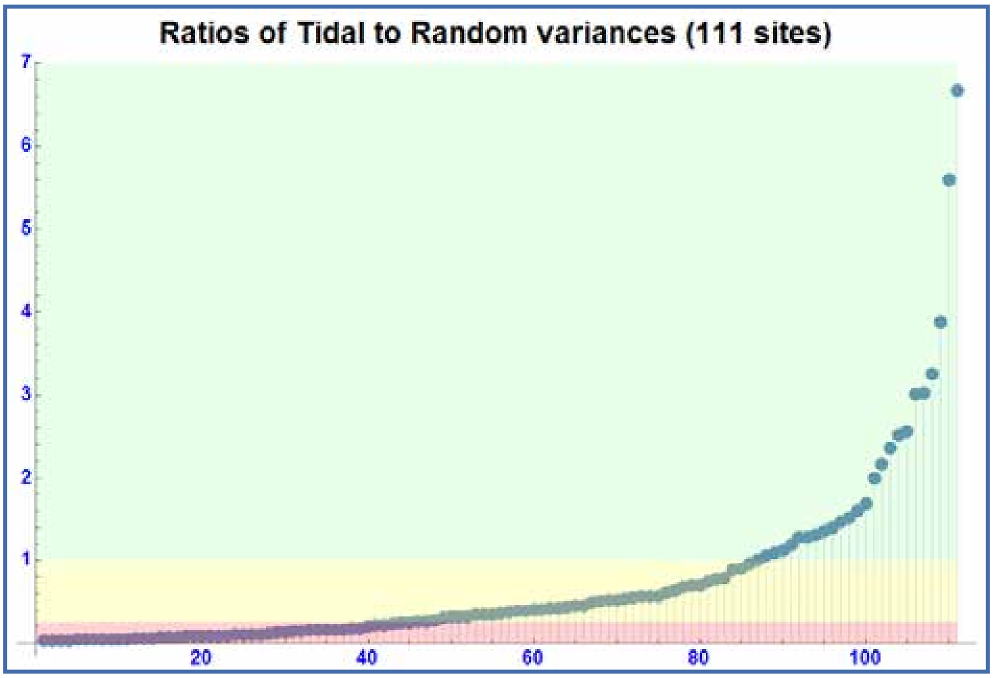


Corresponding to this mean random variance, the typical size of random currents is $(0.045\ m^2.s^{-2})^{0.5}$, or about 7 $cm.s^{-1}$. If near surface currents are imagined to be about 3% of wind speed, this is consistent with typical winds about 2 $m.s^{-1}$ or 5 knots. This in itself seems consistent with the constraints placed by SEPA on the maximum acceptable winds during a record deemed valid for regulatory purposes.

3.3.1 Distribution of weakly and strongly tidal sites

Figure 12 shows a sorted list of the tidal/random variance ratios in the CAR sites.

Figure 12: The distribution of tidal/random variance ratios across the CAR sites



About 35% (red) of these CAR sites are less tidal than Gareloch; about 40% (yellow) are more tidal but nevertheless dominated by random motions; about 25% (green) are predominantly tidal and a handful of these reach the tidal dominance of station R. Tiree Passage and the Sound of Sleat.

Most of this range of variance ratios in the CAR sites lies in range covered by, for example, Table 2. The values of the ratios therefore shed light on the same type of circumstances as were examined in earlier sections.

3.3.2 Distinction between weakly and strongly tidal sites

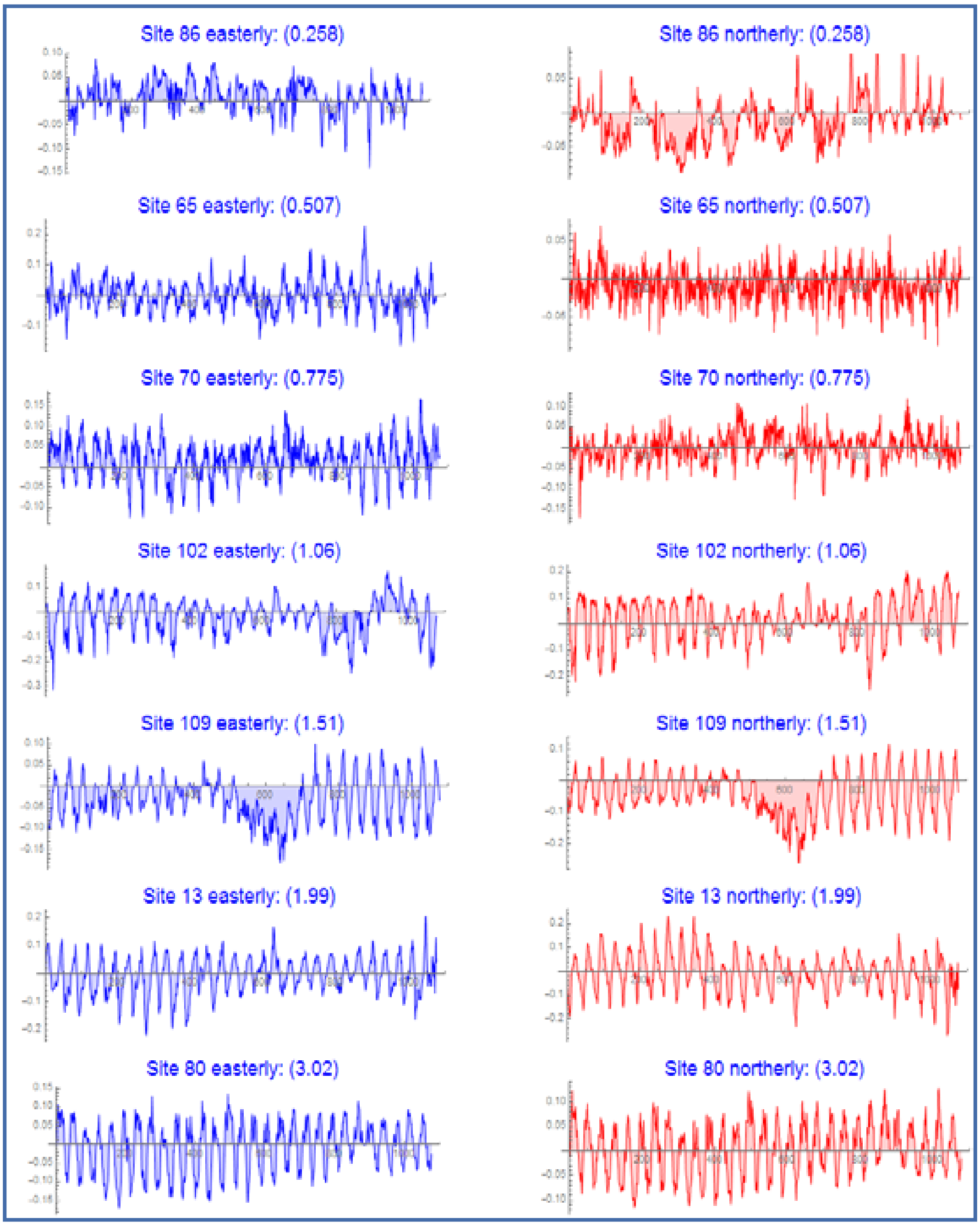
Figure 13 shows a few records from the CAR sites, selected to show the different visual nature of records as the ratio of tidal to random variance increases.

When the ratio of tidal to random variance exceeds unity the visual nature is clearly tidal, with a deal of semidiurnal oscillation (period around 12.5 hours).

When the ratio is less than about 0.5, it is difficult to see the tidal signal. This suggests that, in the first instance, visual inspection may be sufficient to classify a site as weakly or strongly tidal.

It is important to bear in mind that the CAR data sets are collected under SEPA's restrictive conditions that there be no extreme meteorological events. Real site records may therefore be expected to contain more random content than these CAR records, biasing the (fifty-year extreme from three-month extreme) factor higher.

Figure 13: Easterly and northerly currents at sites according to tidal/random variance ratios (in parentheses)



4 THE PERIOD OF MEASUREMENT

In view of the effort and high cost of obtaining long series of measurements from which to predict extremes, the question arises: what is a suitable length of record?

A definitive or universal answer to this question is not possible here but some understanding comes from the probabilities associated with the Weibull Distribution.

4.1 Sampling a Weibull Distribution

If a sample (i.e. a measurement) is drawn at random from any distribution, the probability of its not exceeding the median of the distribution is 0.5 (by definition).

Consider drawing samples from a simple 2-parameter Weibull describing the probability P of a speed u (**Figure 14**):

$$P(u) = 0.5\, e^{-(\frac{u^2}{4})}$$

The corresponding probability of drawing a sample below some speed **U** is:

$$Q(\mathbf{U}) = \int_0^{\mathbf{U}} P(u).du$$

And the probability of not drawing it is:

$$R(\mathbf{U}) = 1 - Q(\mathbf{U})$$

Consider three particular examples of sampling:

A single sample

As a trivial case shown in **Figure 14** (left), one sample drawn from this distribution has a 50% chance of being less than the median speed **M** (red) and therefore of not coming from the (orange) tail of extremes above **U** which, in this case is – by definition - the median **M**.

Two samples

If two independent samples are drawn, we have three exhaustive probabilities:

of both slower:	Q^2
of one slower, one faster:	$2.Q.R$
of both faster:	R^2

With a total probability of $Q^2 + 2.Q.R + R^2 = (Q + R)^2 = 1$

This is a simple binomial expansion of the possible outcomes.

To find the 50% chance that no sample comes from the orange tail (Figure 14, centre) of extremes, we require $Q^2 = 0.5$, or

$$(\int_0^{\mathbf{U}} P(u).du)^2 = 0.5,$$

the 2 in the exponent corresponding to the number of samples in this case,
giving **U** = 1.33 **M**.

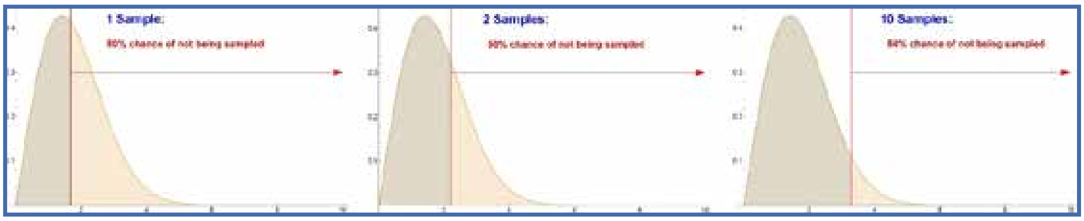
10 samples

If ten independent samples are drawn,

$$(\int_0^U P(u).du)^{10} = 0.5$$

The consequent group of samples has a 50% chance that none comes from the (orange) tail of extremes (**Figure 14**, right) if, in this case, **U** = 1.97 **M**.

Figure 14: The Weibull tail that has a 50% chance of not being sampled with 1, 2 & 10 samples



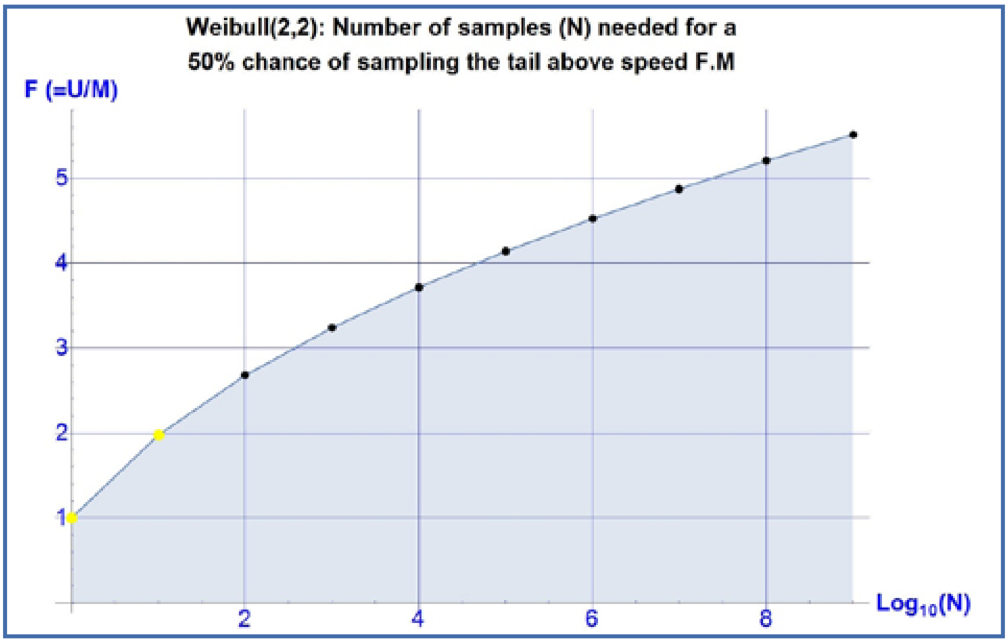
N samples

More generally, if **N** independent samples are drawn, the speed **U** at which there is a 50% chance of all these samples being less than **U** is given by:

$$(\int_0^U P(u).du)^N = 0.5$$

This equation has been solved numerically for any number of samples and the results are shown in **Figure 15**. **F** is the ratio of **U** to the median speed **M**. Two of the cases examined above are shown in yellow (for one and ten samples).

Figure 15: A Weibull(2,2) Distribution. Number (N) of samples needed for 50% chance of measuring in the tail above a speed U (=F x median speed).



It is interesting to consider sampling strategy in relation to such a diagram.

If for example, ten thousand measurements were taken, there is 50% chance that all would lie below about 3.7 x median speed. Ten thousand measurements might represent about ten weeks at 10 minutes interval. If fifty weeks of record were obtained, the 50% chance speed threshold would increase only to 4 x median speed, an increase of only 10%. As another example, if ten thousand independent measurements were taken so as to determine a measured maximum speed of 3.7 x median speed, 10^8 measurements would be needed to measure a maximum only 1.4 times as high, at 5.1 x median speed.

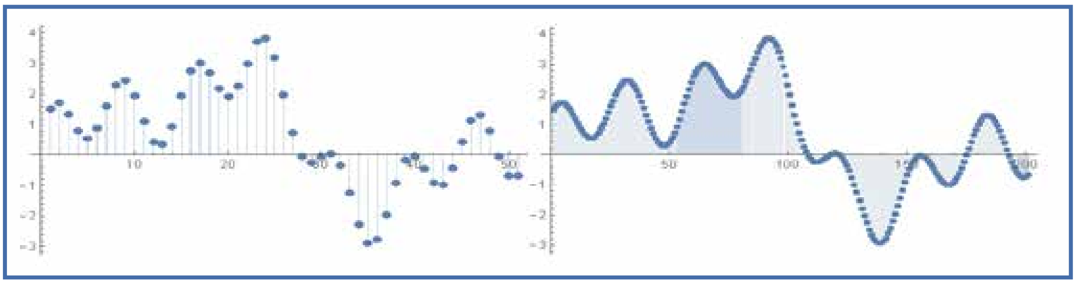
These modest increases in likely measured maximum for large increases in the measurement effort make clear the diminishing returns to be gained from increasing sampling effort. In particular, the increase in maximum value by only 10% as sampling period goes from ten weeks to a year is small in comparison to factors of 1.5 or more. The increase of 10% is also comparable with the uncertainty implicit in **Table 1** and **Table 3**. There is therefore little point in the extra effort (see section 6).

4.2 Independence of samples

It is important to note that the argument of section 4.1 applies only if the samples are independent – that is, if a measured speed is not correlated with other nearby measurements. This is not true of most records, where the sampling interval is of order seconds or minutes and sequences of measurements are therefore auto-correlated because of being taken from tidal movement on the scale of hours, wave motion on the scale of ten seconds or so, turbulent eddies on many time scales, and wind driven currents.

Figure 16 is a cartoon to emphasise this point: no more information about extremes is to be obtained by the more frequent sampling on the right than is known from the sparse sampling on the left.

Figure 16: Sampling an auto-correlated series at different intervals



It is outside the scope of this note to generalise quantitatively about the degree of independence of measurements. In coastal and oceanic sites, ten minute measurements are clearly not independent. The relevant time scales are:

- waves – a few to 20 seconds
- tidal – tidal cycles are dominantly semidiurnal or diurnal on the scale of many hours
- wind – Atlantic depressions are on the scale of days
- turbulent eddies – on many time (& length) scales from seconds to hours or days

The balance of these processes varies from in space and time. Nevertheless, in the light of the process time scales, independence in the coastal sea might be imagined to be small on time scales of minutes and to increase significantly when measurements are separated by a matter of hours rather than minutes.

For the purpose of argument, assume that independence is largely achieved on a separation of three hours and that ten-minute measurements are made for a period of 90 days. The notional number of independent samples is then of order a thousand rather than the ten thousand or so actually made.

For a thousand samples, the 50% chance speed is about 3.2 x median. If a period of a year were used, the 50% chance speed would increase only to about 3.5 x median, an increase of 10%. From this somewhat hypothetical viewpoint and a pessimistic view of independence, the increase from three months to a year in the likely measured extreme remains small (as in section 4.1), about 10%.

This increase is small in comparison to factors of 1.5 or more. The increase of 10% is also comparable with the uncertainty implicit in

Table 1 and Table 3. There is therefore little point in the extra effort (see section 6) of increasing measurement periods from three months to a year.

4.3 Tidal considerations

One caveat to the conclusions of section 4.2 is that there are long-term tidal variations on a scale of a year or more, particularly associated with increased tidal range around the equinoxes. Measurement at such times may be optimal although not necessarily essential. Much depends on the length of the sampling period.

4.3.1 An example: tides at Ullapool

Figure 17 shows an example of the predicted tidal range at Ullapool (from Admiralty Tide Tables). Spring–neap variation is clear, as is a slight increase in range near the spring and autumn equinoxes.

If it is assumed that tidal currents scale roughly according to tidal range, the figure shows the importance of spring tides in contributing to the production of extremes.

Figure 17: Tidal range at Ullapool, 2000

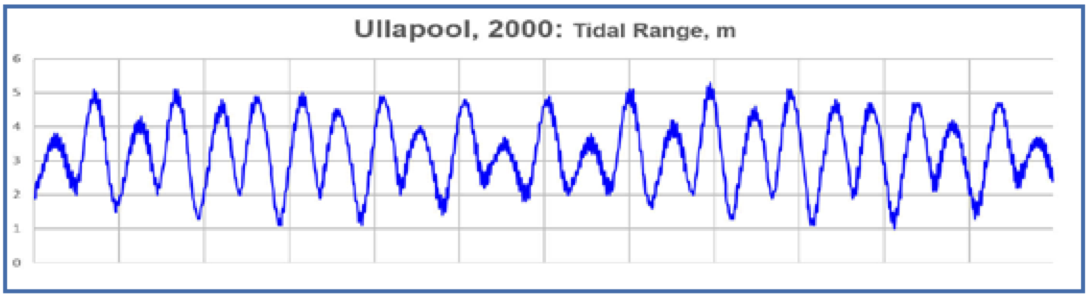


Figure 18 shows the same predictions, as a running mean over 30 days. The figure also shows the maximum predicted range within 30 days. Although the mean range is almost invariant, it is clear that this period of 30 days may miss significant maxima. With such a sampling period, significant tidal extremes may be missed.

Figure 18: Ullapool, 2000, running mean range and maximum range over 30 days

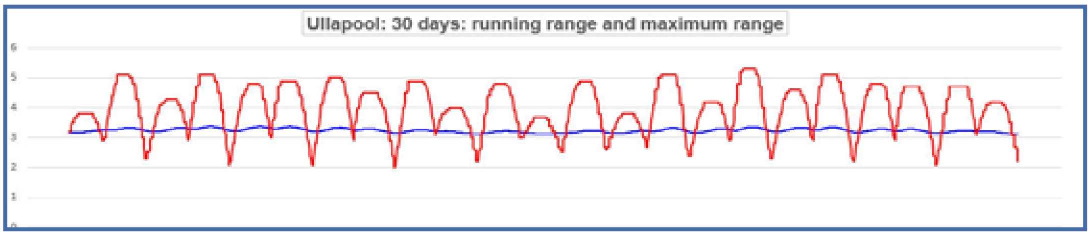
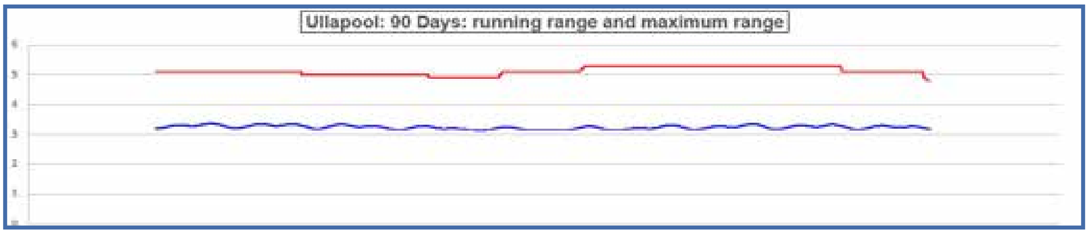


Figure 19 shows the same predictions, as a running mean range and a maximum range over 90 days. Both statistics are almost invariant, suggesting no particular advantage or drawback to choosing the 90 days from any particular time of year.

Figure 19: Ullapool, 2000, running mean range and maximum range over 90 days



From this analysis, it may be recommended that a sampling period should not be as small as 30 days, and that 90 days may be a practical expedient that suffices to include maximal ranges from 4.9 to 5.3 metres.

Similar considerations may apply to other west Scottish sites but their tidal predictions have not been analysed here and the assumption remains untested.

4.3.2 Scaling up measurements to equinoctial conditions

Tidal variations might be allowed for by the simple scaling up of measurements according to the ratio of the predicted tidal ranges to values during the period of measurement.

For example, the highest tides of the year at Ullapool (**Figure 17**) occur during the three months around the equinoxes. From the Ullapool analysis of section 4.3.1, scaling up of the lowest predicted maximum (4.9 m) over 90 days to the highest predicted maximum (5.3 m) may be about 10% – a scaling of 1.1.

More generally, the National Tides and Sea Level Service (http://www.ntslf.org/tides/hilo) quotes equinoctial ranges at West Scottish ports that are typically 10 to 20% above mean spring tidal ranges. Such scaling up of tidal currents is therefore likely to be with a multiplier around 1.1 to 1.2.

Because scaling would apply to the random parts of the current record as well as to the deterministic tidal currents, it would (prudently) over-inflate the predicted extremes.

From this viewpoint, there is no strong need to select a 90-day measurement period that encompasses an equinoctial period. Periods of lower tidal range may be used and scaled up before any estimation of longer period extremes.

4.4 Frequency of measurement

It does not follow from any of the foregoing (see for instance section 4.2) that samples every few hours would suffice. There are many short-term processes at work that demand as high a sampling frequency as expedient. This is not an onerous restriction: rapid sampling is unlikely to pose great difficulty or cost, given the nature, data storage capacity and battery life of modern current meters. Every advantage should be taken of contemporary technology to sample as frequently as possible within the constraints of cost and mooring maintenance.

5 MEASUREMENT STRATEGY

From the previous sections, measurement strategy becomes clearer.

- On the limited analysis of 4.1, and considering costs of deployment, there is little advantage to measuring over a year rather than over three months.
- Even if samples are not independent and there is 90% redundancy in the measurements, as in section 4.2, there is little advantage to taking measurements over a year rather than over three months.
- Measurement periods of less than three months do not cover more than a few spring-neap cycles, are likely to miss tidal extremes (section 4.3.1), and may miss energetic periods of atmospheric cyclonic activity that produces non-predictable currents additional to the tides. They cannot be recommended.
- If a three-month period of observation lies outwith the period of three-month highest tidal range the measurements may be scaled upwards by about 1.1 so as to mimic currents at the highest tidal ranges (section 4.3.2). This procedure also increases the random components of the record, leading to a small but prudent over-estimate of the record's extreme currents.
- It is recommended (section 4.4) that sampling frequency be as high as economical use of the current measuring equipment permits, with a sampling interval of at most a few minutes.
- The probabilistic analysis does not depend on detailed knowledge of the tidal components, and there therefore is no need for the 90 days to be continuous (as might be needed for tidal frequency analysis).
- Nevertheless, if a 90-day record is split, it is important to ensure equitable cover of spring-neap, diurnal and semi-diurnal components. Care should be taken not to exclude any or many of the highest predicted maxima (in the light of section 4.3). On the assumption that most sites will be west-coast tidal in nature, with marked spring-neap variation, it is recommended that the 90 days be composed of periods at least 15 days (apart from odd short-term data drop-outs over periods of less than a few hours).
- The depth of measurement is difficult to specify, given that varying wave action of presently unknown wavelength declines with depth, and because of the various difficulties of measuring near-surface. Waves much shorter than the structures are likely to be less important than those with wavelength similar to the scale of the structures; these latter are likely to interact strongly. As a general rule, the record should be obtained from depths representative of cage depths, and as close to the surface as practicable. This will not pick up short wave length wave action, whose currents diminish rapidly with depth. However, it will pick up some of the longer period wave action (if it is present), which penetrates deeper, thereby prudently biasing measurements overall towards higher speeds.

6 A DEFAULT FACTOR

Sections 1.4 to 2.2 suggest tentatively that the measured extreme in a period of three months may be scaled up to longer periods such as fifty years by a factor that is greater in weakly tidal sites because of the relative importance of random motions, and is less in strongly tidal sites because of the dominance of deterministic and quasi-repetitive motions, whose near-extremes occur even in short records, and which dominate the random motions. The examples show that, for a fifty-year prediction period, it may be appropriate to adopt a factor of about 1.4 (more tidal) to 1.7 (less tidal).

Section 3 presents a rough analysis of the balance of tidal and random motion over 111 CAR fish farm sites (20-minute sampling) taken from the regulatory records. From this perspective, it seems that present licenced sites probably cover a range from weakly tidal to strongly tidal.

About 75% of these consented CAR sites are weakly tidal (**Figure 12**, tidal/random variance ratio <1) and 25% are strongly tidal (**Figure 12**, tidal/random variance ratio >1). It therefore seems inappropriately restrictive to adopt a single factor of 1.7 (weakly tidal) and overly lax to adopt a single factor of 1.4 (strongly tidal).

Section 3 also argues that there may be a convenient visual basis for distinguishing weakly and strongly tidal sites.

The CAR records comprise most of the 20-minute records submitted by farmers across west Scotland. They were taken from the very much larger SEPA database, which contains many more 10-minute records.

On the assumption that the 20-minute sites are representative of all records, it is clear that one factor is too simple a representation of the sites. It seems reasonable to retain at least two factors: 1.4 for strongly tidal and 1.7 for weakly tidal.

It is particularly noteworthy that the CAR records were collected – by regulatory definition – in periods without extreme winds. Future records collected for design purposes may therefore contain more random motion, skewing the site diagnosis towards weakly tidal nature and higher factors. On the other hand, future records may come from more open and more tidal sites, skewing the other way. Refinement or simplification of these factors may therefore best wait until new records are obtained from sites that are subject to the new guidance.

Sections 4.3 and 5 draw attention to uncertainties in the application of these analyses to real sites. A particular issue arises: if measurements are made in three months of lowest maximum tidal range in the year it is prudent to scale them up by about 10% (multiplier 1.1, section 4.3.2) so as to mimic the periods of highest tidal ranges. Such a procedure and the value of the multiplier should be based on the relevant tidal predictions for the year. This is a prudent procedure that also scales up the random currents.

6.1 Possible redundancy of the factor

In future the magnitude and variability of the (three-month to fifty-year) factor may not matter very much: if the recommendation in section 7.3 were to be adopted, the factor would become redundant as a predictor, retaining little significance other than as a descriptive parameter of the probability distributions of the measurement records.

7 SUMMARY

7.1 Introduction

This note offers a brief summary of an analytic approach to estimating extreme values over a long period from a series of measurements over a short period. It offers the prospect of reasonable estimation, albeit with decreasing confidence as the extrapolation goes to longer periods of time and higher speeds.

The probabilistic analysis has been based on only four sites. Much remains to be validated but, before embarking on long observation programmes:

- It would be useful to apply the technique to a relevant long data set to judge the confidence of the extrapolations that could be made from shorter subsets of it. This is particularly needed for more open farm sites than are presently used.
- It seems essential to consider the confidence of such extrapolations, what confidence is needed for engineering purposes, and the extent to which they relate.

7.2 Main conclusions

The principal conclusions are:

1. Techniques exist for estimating long-term extremes from short-term records; examples have been given for the fifty-year extremes. In principle, longer terms may be considered
2. The confidence of extreme current estimation increases with longer measurement periods and decreases as longer prediction periods are imagined
3. The minimum recommended period of measurement on the Scottish west coast is three months
4. The extra effort and cost of measuring for a year is unlikely to be justified by the small increase in confidence of the fifty-year long-term estimate
5. Measurements made in periods outwith the highest tidal ranges might expediently be scaled up in proportion to tidal range so as to simulate periods of the highest tidal ranges. The relevant multiplier will probably be around 1 to 1.2 in many places but should be determined locally.

Secondary conclusions are:

6. A first estimate of fifty-year extremes at weakly tidal sites may be about 1.7 x three-month extreme
7. A first estimate of fifty-year extremes at strongly tidal sites may be about 1.4 x three-month extreme
8. Three quarters of a selection of 111 20-minute fish farm CAR records held in the SEPA database are weakly tidal; one quarter is strongly tidal.

7.3 A recommendation

7.3.1 The principal conclusions

The principal points **1** to **5** in section 7.2 relate to the development of a feasible Technical Standard that does not demand excessively long and expensive current measurements.

7.3.2 The secondary conclusions

The secondary points **6** to **8** of section 7.2 deal with a different and more specific problem: how to make a first (or preliminary) estimation of the fifty-year extreme by applying a factor to the measured three-month extreme.

These factors have been tentatively derived in section 1.4 and section 2 from probabilistic analysis. The factor may be useful in quick assessment of a record. It is also a convenient descriptive parameter of the probability distribution of the record.

7.3.3 The recommendation

In view of the effort and expense of obtaining three-month records, it is strongly recommended that their probabilistic analysis (as outlined in section 1) should be used to estimate the corresponding fifty-year extreme (or indeed any other period of interest), rather than using the factor.

Such an analysis would represent only very small additional cost above the measurement effort and would deliver a site-specific prediction that could, firstly, be viewed critically in the context of the general west-coast picture and, secondly, would help build that picture.

The procedures and standards for such a probabilistic analysis might be handled initially by a service point operating to – and developing – consistent standards.

As happened with development of the Depomod fish farm benthic impact tool, this stage might best be followed by development of open-platform software (available to all).

Once either of these approaches had been implemented, the marginal cost of a fifty-year estimate from a three-month record would be trivial.

The accumulation of such analyses would help build a reliable picture of this issue, superior to the first estimates made by applying a factor based on the few cases examined in this note.

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ANNEX 7 Wind Induced Wave Parameters Calculations

The following process shall be followed:

a) Determine the effective fetch length.

   i) The effective fetch length shall be determined for eight concurrent directions, aligned to include the longest fetch for the site. This will be based on measurements taken from an appropriate marine chart; for freshwater sites, a navigational chart should be used if available or, if not, an Ordnance Survey map.

   ii) The fetch length will be measured at each of the eight directions at 1° intervals across an opening of ±12°. The effective fetch shall be taken as the median value of each set of 25 measurements for each of the eight directions.

b) Calculate the adjusted wind velocity using the following equation:

$U_A = 0.71 \times U_{10}^{1.23}$

Where U_A is the adjusted wind velocity and U_{10} the wind velocity

c) Determine the significant wave heights and equivalent peak periods for each of the eight effective fetch lengths for both the 10 and 50 year return periods using the 10 year and 50 year wind velocities and the following equations:

$H_S = 5.112 \times 10^{-4} \times U_A \times F_e^{1/2}$
$T_P = 6.238 \times 10^{-2} \times (U_A \times F_e)^{1/3}$

Where H_S is significant wave height, TP is the equivalent peak period, UA is the adjusted wind velocity and F_e is the effective fetch length.

d) The significant wave heights and equivalent peak periods determined above will be further processed using either the irregular or regular sea approach as below; the rationale for deciding which approach to use shall be documented.

   i) For an irregular sea, the JONSWAP spectrum shall be used (using $_Y = 2.5$ for wind sea and $_Y = 6.0$ for swells). In lochs or partly sheltered sites, however, a 2-paramater Pierson Moskowitz spectrum can be used instead. In both approaches, a fully developed sea state shall be assumed.

   ii) For a regular sea, a regular wave height shall be assumed, which is equal to:

$H = H_{max} = (1.9)Hs$

The regular wave period shall be defined as the peak period.

ANNEX 8 Product Specification Sheets

Product specification sheets shall be provided by the relevant manufacturer for primary equipment. They shall include the following:

a) Confirmation of the environmental parameters for which the equipment has been designed, including nature of environment (sea water or freshwater) maximum current, significant wave height and peak wave period.

b) A diagram of the equipment with all relevant dimensions and, where appropriate, showing the three dimensional manner in which it should be installed.

c) The specification of all materials (including material type and capacity).

d) Identification of the location, material, intended use of and maximum load (with any constraints on the direction of load application) for all attachment points.

e) Details of any redundancy built in to the design.

f) Confirmation as to whether or not the mooring system and/or pen has been designed to accommodate the mooring of boats, rafts, barges and/or any secondary equipment and, if so, the location of mooring points, the maximum sizes that can be accommodated and any restrictions that may apply (including environmental conditions and/or operations).

g) Any requirement for the tensioning/pre-tensioning of the pen.

h) Chemical treatments – specifically anti-fouling or other paints/surface treatments.

i) Confirmation of the maximum weights of plant, equipment and/or consumables that can be stored and used on the pen, or areas thereof.

j) Confirmation of any specific types of secondary equipment for which the net may have been designed to be used with (e.g. mortality collection systems).

k) Confirmation of whether any specific plant or equipment can (or cannot) be attached to the pen and net, if so, what, how and where.

l) Confirmation of the manufactured weight of the completed pen and net.

m) Details of any weighting system for which the pen and net have been designed, if relevant.

n) Details of any requirements for how the pen shall be positioned within the mooring system and associated tolerances.

o) For freshwater pen sites, a summary of the icing assessment undertaken.

p) Details of any assumptions used in the design.

q) Confirmation that all equipment has been designed and will be manufactured in accordance with this Standard.

ANNEX 9 Types of Loads

The loads which should be considered during dimensioning shall include, but not be limited to, those listed in Table 3 below.

Table 3: Types of loads

Permanent loads: loads present throughout the working life of the equipment	
Including:	– The weight of the fish farm in air. – The weight of fixed equipment. – Static buoyancy forces.
Variable function loads: loads which can be moved on the site or removed from it.	
Including:	– Mechanical equipment. – Personnel. – Consumables. – Variable ballast. – Mutual load between primary equipment and, if relevant, secondary equipment. – Routine boat impact. – Fendering or mooring of boats, including feed boats, well boats, personnel boats, work boats and boats used to remove mortalities – Fendering and mooring of other floating equipment. – Any extra loads applied as a result of particular work operations.
Deformation loads	
Including	– Pre-tensioning. – Mooring. – Temperature.
Environmental loads	
Including	– Wind. – Waves* – Current
Accidental loads	
Including	– Breaks in mooring lines – Breaks in connectors – Puncturing or loss of floating parts

*Note: the *consideration of waves is not required in static analysis - although it is recommended.* Waves shall be considered for sites affected by ocean swells.

ANNEX 10 Material Factors and Load Factors

Annex 10 presents the material factors and load factors to be used in the partial co-efficient analysis (see Annex 12).

Table A10.1: Material factors for mooring lines

Type	Material factor
Synthetic rope	3.0
Synthetic rope with knots	5.0
Ground and mooring chain	3.0
Other Chains, including bridles, and chain components	3
Used chains	5.0
Coupling discs and other connecting points of steel*	5
Shackles	4
Rock bolts and other bottom attachments	3.0
Anchors	3

Notes:

* First yield

i) Should the relevant component not be included in the table above, the mooring supplier shall source and document the material factor.

ii) Material factors assume that the component is used as intended in the manufacturer's/supplier's instructions. This includes, but is not limited to, a mooring component used/attached at a different angle to that specified; in such cases, a different material factor shall be used in consultation with the manufacturer – the chosen factor and all associated correspondence shall be documented.

Table A10.2: Load factors for mooring lines

Type	Load factor
Static analysis	1.6
Quasi-static analysis	1.15 x DAF*
Dynamic analysis	1.15
Accident limit (break in mooring line)	1.0
Spring tide	1.0

Notes:

* DAF shall be set at ≥ 1.0 – the actual value used shall be documented and justified.

Table A10.3: Load factors for steel and plastic pens in different limit states

Dimensioning situation	Permanent load	Variable function load	Deformation load	Environmental load
Establishment of capacity	1.0	1.0	1.0	1.3
Accident situation – damaged condition***	1.0	1.0	1.0	1.0

Notes:
*** Applies to breaks in mooring lines, puncturing and ice and snow.

Table A10.4 Material factors for steel installations

Limit states	Parameters	Material factor
Breaking strength	Cross-section capacity	1.1
Breaking strength	Screw, bolt, friction and welding connections	1.25
Fatigue limit	All material factors	1.0
Accident limit	All material factors	1.0

ANNEX 11 Example Force Equation

The following equation may be used to determine the forces on a mooring system:

$F = 0.5\rho CDAV^2$

Where:

- F is the force, ρ is the density of the fluid, C_D is the drag coefficient, A is the area upon which the force is acting and V is the current velocity.
- All factors shall be documented and justified.
- A shall meet the fouling requirements in Section 3.3.1

Further information on the forces that mooring systems may be subject to are presented in a wide range of publications which include those listed below.

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ANNEX 12 Partial Co-efficient Analysis

Where partial co-efficient analysis is required in this Standard, this shall be undertaken such that the following expression is fulfilled:

$$S_f \leq \frac{R}{\gamma_m}$$

Where: S_f is the design load multiplied by the load factor(s).

R is the capacity of the equipment.

γ_m is the material factor.

ANNEX 13 Manufacturer's Instructions

Introduction

All primary equipment and certain secondary equipment[6] shall be accompanied by manufacturer's[7] instructions designed as a reference for fish farmers on-site. It should provide key information about the use of the relevant equipment to help prevent escapes.

The manufacturer's instructions shall be followed for all aspects of the use of the equipment as detailed in section 10.

The manufacturer's instructions shall include as a minimum the relevant requirements listed below.

Background information

a) Manufacturer's name and place of business;
b) Manufacturer's contact details;
c) For imported equipment, the contact details of a UK representative if appropriate; and,
d) Product reference number/descriptor if relevant.

Generic requirements

a) A copy of the final product specification sheet for primary equipment – and all key dimensions and characteristics for secondary equipment.
b) Any measures to prevent damage during handling and installation.
c) Any measures to ensure correct installation.
d) Preventative maintenance requirements, including an inspection regime with maximum intervals and indicators for replacement.
e) The maintenance regime shall include an inspection regime in regard to metal fatigue where appropriate.
f) Reactive maintenance regime to include how components subject to wear and tear should be replaced.
g) The specifications and any other useful info to facilitate traceability of individual components and parts.
h) Where required, any specific qualifications, experience, training and/or competencies for specific tasks shall be identified.
i) For freshwater pen sites, a summary of the icing assessment undertaken.

Towing and Pushing

a) The location of towing and pushing points.
b) The approach for attaching towing or pushing equipment.
c) Any measure required to prevent damage to the pen whilst being towed or pushed.
d) The maximum towing or pushing velocity (expressed as speed through the water) and any other restrictions on the environmental conditions that can be experienced during towing or pushing.
e) Requirements for inspection and maintenance during and after towing or pushing.

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6 Manufacturer's instructions are required for secondary equipment where this relates to purchased systems, rather than those assembled by or on behalf of the fish farmer.

7 In the case of systems such as mooring systems, weighting systems, the instructions shall be provided by the designer of the system – in the case that an aquaculture production business was the designer rather than the manufacturer, it shall provide instructions as if it were the manufacturer.

Mooring system

a) Instructions as to how to lay or install each type of anchor, rock bolt, dead weight mooring or other form of anchoring system being used.

b) Requirements for how to load each mooring line to ensure that each anchor is firmly embedded into the substrate, taking in to account the requirements of section 3 of this Standard and a statement when an anchor shall be installed again.

c) The length of all mooring lines – and the associated scope of mooring lines for those attached to anchors/drag anchors.

d) The tolerances for the adjustment of all relevant elements of the mooring system, including mooring lines, grid ropes and bridles. This shall clearly state the maximum adjustments that can be made (i.e. corresponding to the minimum length of each element that is acceptable from the perspective of maintaining the integrity of the mooring system).

e) Any measures required to ensure that the geometry of the mooring system is maintained during installation.

Pens

a) Instructions as to how to connect pen(s) to the mooring system.

b) Any measures required to ensure that the location of the pen within the mooring system is maintained as required.

c) The approach to lifting pens, which shall include lifting circular pens afloat for cleaning purposes – this shall state the maximum height that one point of a circular pen can be lifted in relation to the rest of the pen;

Nets and weighting systems

a) Details of any net treatments used.

b) Mesh strength and rope strength.

c) The maximum weights that can be attached to down ropes.

d) The method for attaching the net to the pen and any stipulations about how the net should not be attached.

e) The method for attaching the net to the weighting system and any stipulations about how the net should not be attached and how the weighting system should be used, including the maximum distance that ropes supporting the weighting systems can be lifted/dropped in any one lift/drop where relevant.

f) Instructions as to how the net can be tensioned/weighted without risking chafing or other damage and the predicted net deflection.

g) Any key information about how the net shall be lifted/dropped, including the maximum distance that down ropes can be lifted/dropped in any one lift/drop.

h) How the net shall be hung when raised/partially raised and what parts of the net can be used for supporting the weight of the net during such operations.

i) Confirmation of any specific types of secondary equipment for which the net may have been designed to be used with (e.g. mortality collection systems).

j) A statement that the net should be suitable for the pen and properly fit the pen.

k) Whether the netting or ropes can be used to take the weight of any pieces of equipment and, if so, to specify how and what.

l) The number and location of pen attachment points.

m) The number and location of down ropes.

n) The height of the jump net.

o) Parameters for net washing operations *in situ* and at dedicated stations

ANNEX 14 method to determine the half-mesh measurement on netting

Half mesh measurement for nylon and other material nets with a square mesh

The methodology for determining the half-mesh size for nylon and other material nets with a square mesh shall be undertaken as described below.

a) Netting shall be pulled tight so as to distort the square mesh into a narrow diamond.
b) The measurement shall be made across the length of the diamonds (i.e. across the narrow aperture rather than along the twine);
c) The measurement shall be made between either a) the centres of the twine joins, b) the inside edge to the outside edge of the twine join or c) from the outside edge to the inside edge of the twine join.
d) The measurement shall be made across a minimum of ten meshes and divided by the number of meshes measured and the answer then further divided by two to give a single half mesh measurement.
e) A tolerance of ≤ 5% is acceptable.

Half mesh measurement for nylon nets with a hexagonal mesh

The half mesh size of net mesh for nylon nets with a hexagonal mesh shall be undertaken as described below:

a) Identify the corresponding square mesh side measurement by reference to Annex J in NS9415.
b) Use the square mesh side measurement by following the methodology above to identify the half-mesh measurement

Half mesh measurements for other products

This standard does not include a method of measurement for nets constructed of materials other than nylon and or HDPE. Should it be necessary to measure other such materials, a satisfactory approach shall be developed which addresses the following principles:

a) The measurement shall correspond to a half-mesh measurement;
b) The measurement shall be from two corresponding points on the netting;
c) The measurement shall not describe the net aperture;
d) The measurement shall be averaged over a minimum of ten meshes, and more if required to gain a representative result;
e) The measurement shall be undertaken in such a way as to ensure consistent results when repeated;
f) The measurement shall be documented; and,
g) The maximum tolerance shall be recorded.

ANNEX 15 Twine Surface Area

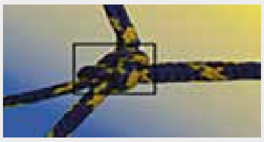
CALCULATIONS FOR COVERED / UNCOVERED AREA IN AQUACULTURE **KNOTLESS** NETTING

Notes:
1. The calculations are done on the basis of inside mesh opening and twine size.
2. The inside mesh opening area indicates the uncovered area.
3. The area occupied by the “joints” is assumed less significant as compared to the twine area.
4. The ‘weave’ of the netting construction is not incorporated in the calculations.
5. A loose weave may provide a more effective area for algae to bind to the net.

Sr No	Construction	Mesh BS (kgf)	Knot type	Mesh size (mmsq)	Twine diameter (mm)	Inside Mesh size (mm)	Area of inside mesh - (sq.mm) (A)	No of meshes in 1 (sq.m) (B)	Total uncovered area - (sq.mm) (AxB)	Covered area - (sq.mm)	Total area - (sq.mm)	% of Uncovered area	% of Covered area
1	210D/42S(48Ply)	60	Normal knot	15	1.9	13.1	171.6	4,444	762,711	237,289	1,000,000	76	24
2	210D/48S(54Ply)	66	Normal knot	15	2.1	12.9	166.4	4,444	739,600	260,400	1,000,000	74	26
3	210D/60S(64Ply)	78	Normal knot	18	2.3	15.7	246.5	3,086	760,772	239,228	1,000,000	76	24
4	210D/60S(64Ply)	78	Normal knot	25	2.3	22.7	515.3	1,600	824,464	175,536	1,000,000	82	18
5	210D/90S(96Ply)	106	Normal knot	18	2.4	15.6	243.4	3,086	751,111	248,889	1,000,000	75	25
6	210D/60Ply	89	Super knot	15	2.1	12.9	166.4	4,444	739,600	260,400	1,000,000	74	26
7	210D/96Ply	118	Super knot	18	2.4	15.6	243.4	3,086	751,111	248,889	1,000,000	75	25
8	210D/108Ply	133	Super knot	25	2.5	22.5	506.3	1,600	810,000	190,000	1,000,000	81	19
9	HDPE/264 Ply/25 mmim	89	Normal knot	17.5	3.4	14.1	198.8	3,265	649,176	350,824	1,000,000	65	35
10	HDPE/264 Ply/36 mmim	89	Normal knot	23	3.4	19.6	384.2	1,890	726,200	273,800	1,000,000	73	27
11	HDPE/274 Ply/30 mmim	99	Normal knot	20	3.6	16.4	269	2,500	672,400	327,600	1,000,000	67	33
12	HDPE/312 Ply/45 mmim	106	Normal knot	27.5	3.9	23.6	557	1,322	736,476	263,524	1,000,000	74	26
13	UHDPE/1600D/2Ply/2bar	73	Normal knot	15	1.2	13.8	190.4	4,444	846,400	153,600	1,000,000	85	15
14	UHDPE/1600D/6Ply/6bar	103	Normal knot	33.5	1.8	31.7	1004.9	891	895,424	104,576	1,000,000	90	10
15	UHDPE/2400D/6Ply/6bar	152	Normal knot	30	2.1	27.9	778.4	1,111	864,900	135,100	1,000,000	86	24

CALCULATIONS FOR COVERED / UNCOVERED AREA IN AQUACULTURE **KNOTTED** NETTING

Notes:
1. The calculations are done on the basis of inside mesh opening and twine size.
2. The inside mesh opening area indicates the uncovered area.
3. The area occupied by the ‘knots’ is calculated separately - assuming that each mesh will occupy one square area of dimension - ‘2 x twine dia. +1’



Sr No	Construction	Knot type	Twine BS (kgf)	Twine KBS (kgf)	Mesh size (mmsq)	Twine diameter (mm)	Inside mesh size (mm)	Area of inside mesh (sq.mm) (A)	No of meshes in one sq.m. (B)	Theoretical area of one knot (sq. mm)	Total knot area in one sq.m (sq. mm) (C)	Total uncovered area (sq.mm) (AxB) - C	Covered area (sq.mm)	Total area (sq.mm)	% of Uncovered area	% of Covered area
1	Braided knotted HDPE/ 2.1mm/18hm	Knotted	115	135	18	2.1	15.9	252.8	3,086	27	83,457	696,821	303,179	1,000,000	70	30
2	Braided knotted HDPE/ 3.1mm/80hm	Knotted	195	275	80	3.1	76.9	5,913.6	156	52	8,100	915,902	84,098	1,000,000	92	8
3	Braided knotted HDPE/ 3.5mm/100hm	Knotted	295	345	100	3.5	96.5	9,312.3	100	64	6,400	924,825	75,175	1,000,000	92	8
4	Braided knotted HDPE/ 4.2mm/80hm	Knotted	380	510	80	4.2	75.8	5,745.6	156	88	13,806	883,950	116,050	1,000,000	88	12
5	Braided knotted HDPE/ 3.1mm/80hm	Knotted	190	285	80	3.1	76.9	5,913.6	156	52	8,100	915,902	84,098	1,000,000	92	8
6	Braided knotted HDPE/ 3.1mm/150mmkk	Knotted	190	285	75	3.1	71.9	5,169.6	178	52	9,216	909,826	90,174	1,000,000	91	9

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