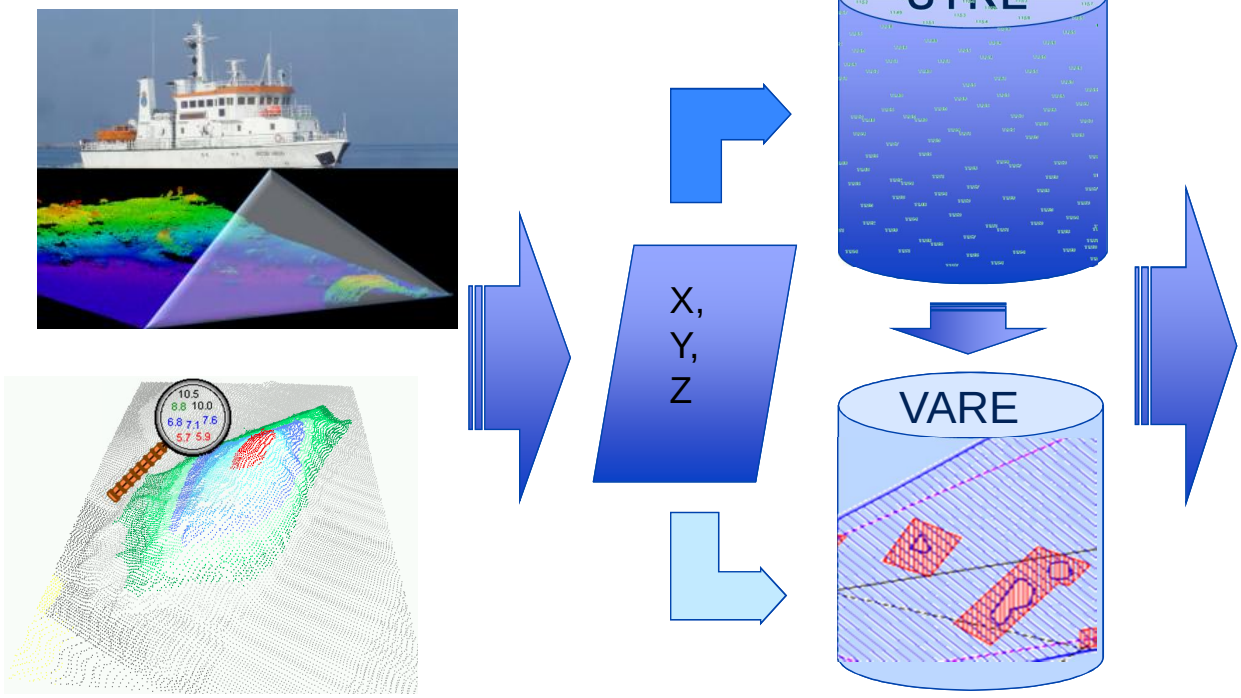
# TuAMK väyläsuunnittelu Merenmittaustietojen tilaus ja vastaanotto

Seppo H Mäkinen
3.2.2015



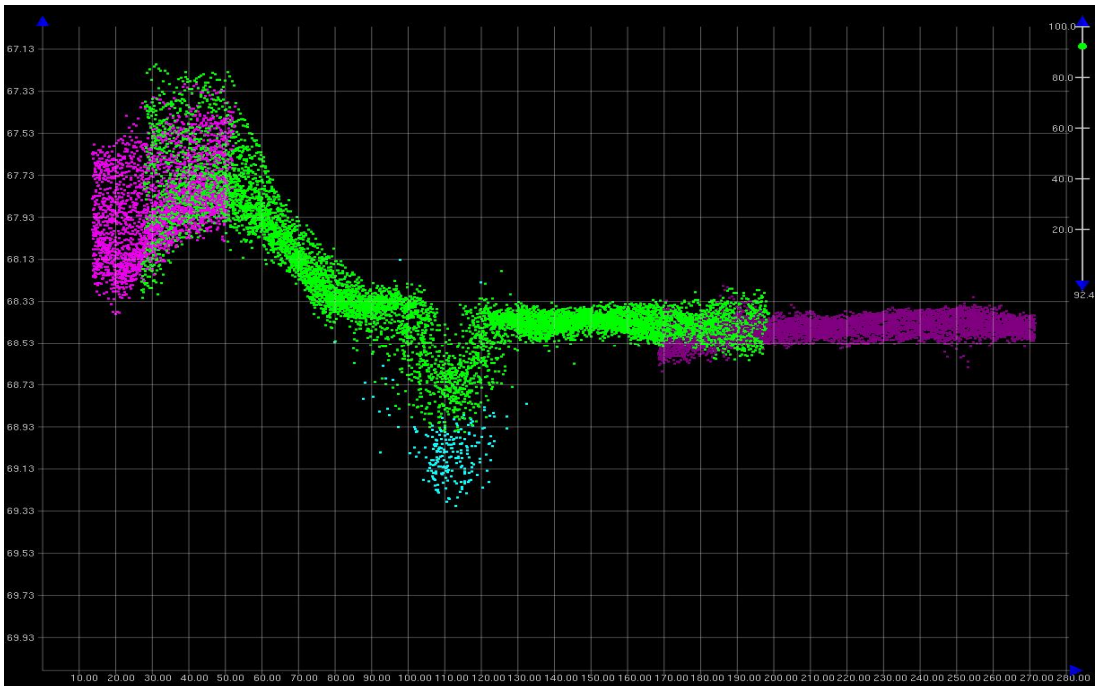

***Merenmittauspaikkatiedot -> tuotteille ja asiakkaille***

# Merenmittausaineistojen vastaanotto

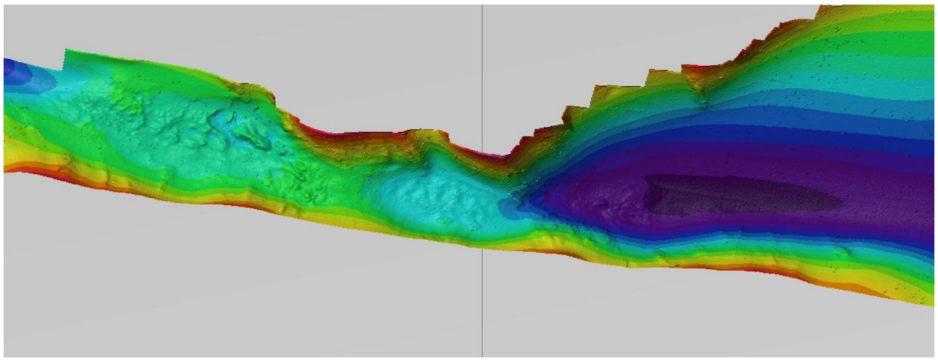
- Aineistojen vastaanotossa tarkastellaan tarjouspyynnössä edellytetyt asiat
  - Aineistot vaaditussa formaatissa ja kansiorakenteessa, tiedostot nimetty vaaditulla tavalla;
  - Sensorikohtaiset raakadatat, käsitellyt aineistot, mittauspöytäkirjat, muut luettelot;
  - Kaikki aineisto vaaditaan, myös ”poistettavaksi” merkityt havainnot käsitellyn aineiston mukana;
- Vastaanottotarkastuksessa käytetään osin samoja ohjelmistoja kuin merenmittauspalvelujen tuottajat käyttävät itse mittauksissa ja jälkikäsittelyssä:
  - Päätyökaluna Fledermaus;
  - peittävyys, pistetiheys, tasalaatuisuus, syvyystasojen vertailu, outliers (havaintopoikkeamat), lohkareet;
  - Syvyyspistetarkastelu, ristiin ajetut linjat, tilastollinen tarkastelu: keskihajonta;
- Vastaanottotarkastus on tehtävä huolella, koska Liikennevirastolla on vastuu merikartan tiedoista ja ankara vastuu väylätietojen oikeellisuudesta.
  - Tyypillisimmät ongelmat ovat äänennopeudesta johtuvia;

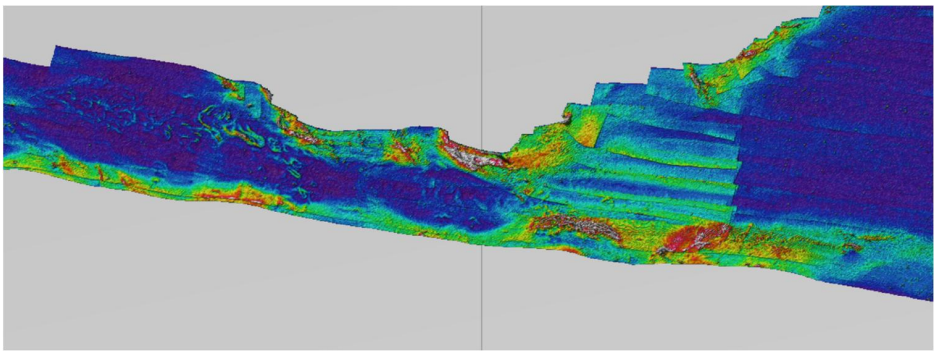


# Merenmittausaineistojen vastaanotto



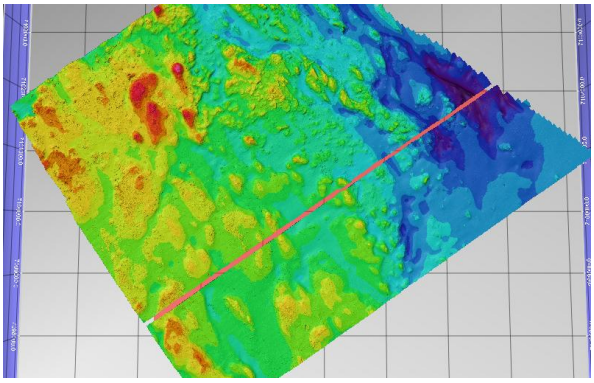
# Merenmittausaineistojen vastaanotto

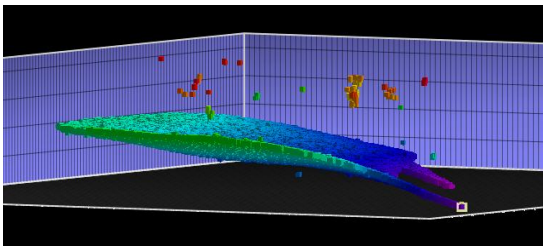


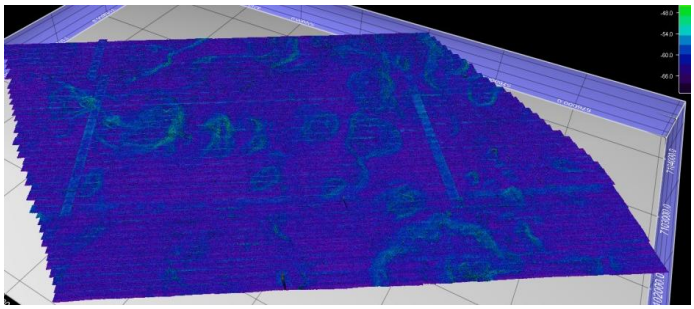


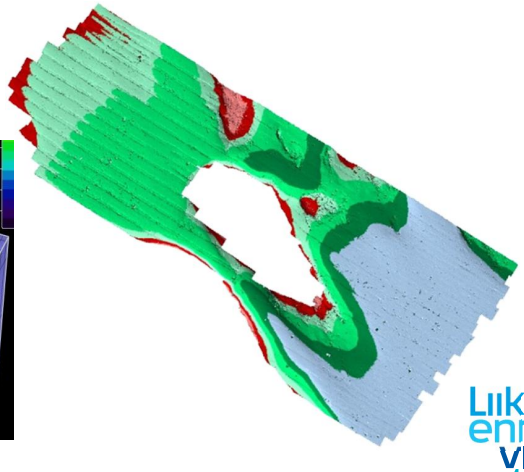


# Merenmittausaineistojen vastaanotto







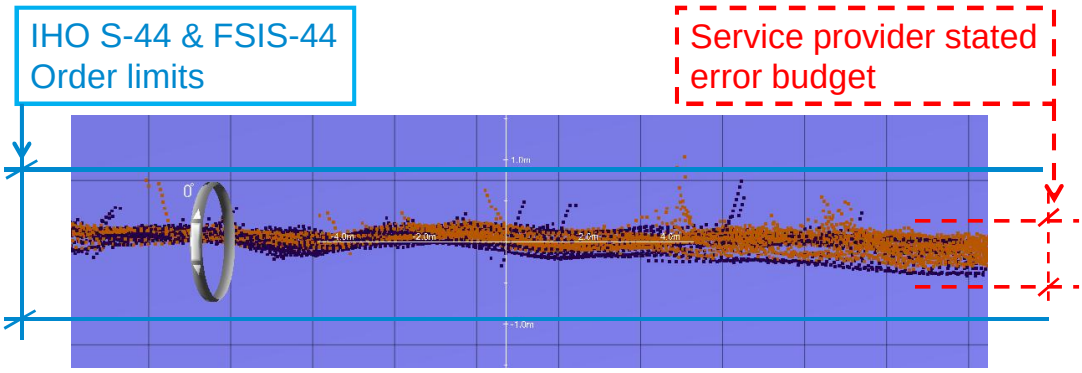


# Merenmittausaineistojen vastaanotto

Quality issue (referred to invitation to tender chapter 4.6.8), FTA request:

- All systematic errors and effects shall be detected with post-processing software;
- Outliers, below and above the expected bottom surface, shall be flagged as rejected;
- All observations greater than contractor stated error budgets (but may be within contract defined IHO S-44 & FSIS-44 order specifications) shall be observed as suspicious observations and further analysed and minimized.

➢ All observed systematic errors and effects shall be detected and removed;
➢ Data quality shall be noted throughout the entire hydrographic survey process;






# Merenmittausaineistojen vastaanotto

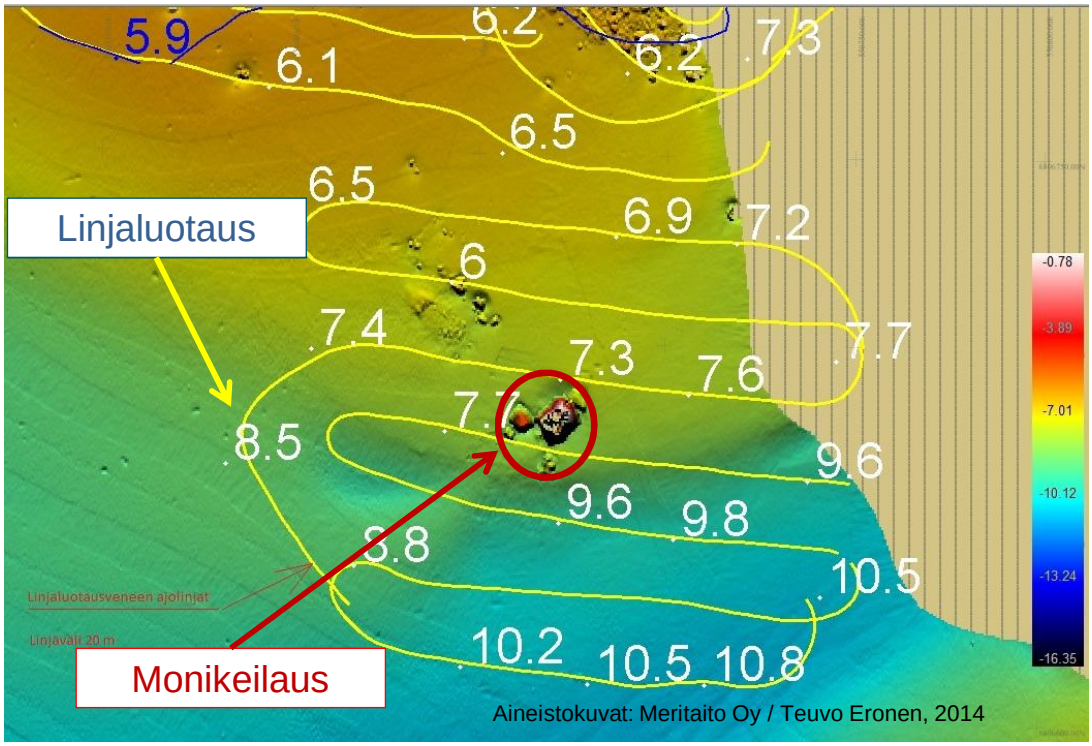
## Aluemittausten peittävyyden ja kohteiden havaitsemisen tarkastelukriteereistä;

| Rivi | KA | Mittauslaji | Syvyys-alue (m) | Hyväksyttyjä pisteitä / pinta-alayksikkö | Kohteen min.koko | Tarkk.-vaat. | Huom |
|---|---|---|---|---|---|---|---|
| 1 | II | Aluemittaus | < 6 | Erillisohje | Erillisohje | Erillisohje | Ks.sel. |
| 2 | II | | 6 – 18 | 9 / 1mx1m | 6 / 0.5m<br>9 / 1m<br>18 / 1.5m | S-44 Order1a | |
| 3 | II | | 18 – 23 | 3 sweepin suunnassa ja 3 ajosuunnassa / 1mx1m | 2mx2m | S-44 Order1a | |
| 4 | II | | 23 - 27 | 3 sweepin suunnassa ja 3 ajosuunnassa / 2mx2m | 2mx2m | S-44 Order1a | |
| 5 | II | | 27- 40 | 2 / 2mx2m | 10% sy-vyydestä | | |
| 6 | II | | 40 - | full sea floor search (at – 3dB) | 10% sy-vyydestä | | |

# Merenmittausaineistojen vastaanotto

- Aineistojen vastaanottoon on nykyisissä sopimuksissa varattu 30 vrk, viivästystapauksissa (sekä joulun ja heinäkuun aikana) 45 vrk:
  - Vastanottoaika keskeytyy selvityspyynnön ja reklamaation ajaksi;
  - Aineistoerän koko rajoitettu;
- Aineistoerätoimituksen maksatus vasta hyväksytyn vastaanottotarkastuksen jälkeen:
  - Kaikista vastaanotoista annetaan kirjallinen raporttikooste;
- Aineistot viedään syvyyspaikkatietorekistereihin viiveellä, ei ihan heti käytettävissä;
- Loppuraportti sisältää kaikki työhön liittyvät tiedot






Aineistokuvat: Meritaito Oy / Teuvo Eronen, 2014

# General and Technical Specification for Surveying in Finnish areas in the Baltic Sea

## 3 Part Two – The Work and Technical specification

### 3.1 The work-overview

The hydrographic survey work is to be performed according to the hydrographic survey specifications based on the IHO S-44 ed. 5 standard and the buyer's implementation of it, named FSIS-44. The implementation specifies different accuracy requirements (Orders) at intervals of depths for "fairway areas" and "other depth areas" according to their importance for the safety of navigation, for more information see Attachment 2.

Systematic effects/errors shall be minimized prior the survey and shall be limited to equal or less than the magnitude of the random errors for the specific system. If effects/errors are found, further investigations will carry on trying to identify the source and amount of error which shall not exceed the values given in the error budget calculations. Corrective measures shall be carried on to remove or minimize the errors.

*Note that the requirement for bar-sweeping in FSIS is not to be considered in this Project.*

In this project required survey depth ranges are following:

<u>Other depth areas</u>

- Areal surveys in depth range 5,5 m - 100 m shall fulfill FSIS-44 order 1a requirements
    - open sea shoals within depth range 5,5 m- 20 m are considered as fairway areas and shall fulfill FSIS-44 Special Order requirements.
- *Areal surveys in depth range 2,5 m - 5,5 m towards shore line shall fulfill FSIS-44 order 1a accuracy requirements, but no full sea floor search is required. Not expected to be applicable in this work.*
- *Areal surveys of shoals within depth range 2,5 m - 5,5 m shall fulfill FSIS order 1a accuracy requirements, but no full sea floor search or ± 65° MBES swath width is required. The purpose is to detect the least depth within this depth range with best possible accuracy. Not expected to be applicable in this work.*

Fairway areas

- Fairway surveys in depth range 4 m - 20 m shall fulfill FSIS-44 Special Order requirements.
- Fairway surveys in depth range 20 m - 100 m shall fulfill FSIS-44 Order 1a requirements.

Note that all MBES survey vessels and equipment shall be capable to Special Order survey. It is the requirement of the buyer that the carefulness of the surveyor and the reliable operation of the equipment shall not be degraded in areas which are surveyed to Order 1a, although the geometric accuracy requirements are significantly lower. On other words, systematic errors and operator related blunders are not allowed although the order of the survey is lower.

The MBES shall be permanently hull mounted on the survey vessel(s). Surface sound velocity observations shall be taken from a hull mounted system and be applied to the real-time data collection system.

Calibration and verification procedures prior to survey and in case of any change in the survey system during the work are defined in the chapter *4.12. Controls and calibrations.*

Bathymetric data processing, quality control and delivery as well as metadata delivery is to be performed according to these specifications and the contract. The resulting deliveries are listed in chapter 4.14.3.

Into account shall be taken of the effect of a rough sea state on the quality of the data being collected. Survey work shall not continue if frequent gaps or interference are created in the data because of operation in inappropriate sea states or if the sounding accuracy by any other cause cannot be met.

## 3.2 Areas

The survey areas are available as a downloadable shape file. Overviews as chartlets of the specified areas are to be found in Attachment 1. The survey areas are within Finnish waters.

The borders of the areas as described in the shape-file are straight lines in the used map projection (see chapter *4.7 Geodesy*).

***No surveying is allowed to be performed in territorial waters outside the specified survey areas.***

The Buyer requests the contractor to perform a control survey on a test plate on the coast of the Bothnian Sea, in the approaches to the port of Tahkoluoto (Pori). If the contractor wants to perform any control survey or multibeam calibration within other areas of the territorial waters, this has to be agreed with the Buyer.

## 3.3 Environmental information

### *3.3.1 Salinity, water level fluctuation and sound velocity*

The Baltic Sea water is brackish with salinity between 2-8 ppm. Actual tide does not exist, but a diurnal tidal wave, in the magnitude of 5-20 cm is passing back and forth within the closed basins, but this tidal wave is not modelled. Due to the prevailing winds and weather, the long term fluctuation on the water level varies typically between ± 50 cm.

<u>Temperature and therefore the sound velocity in water media plays an important factor in successful hydrographic survey work.</u>

Due to the environmental conditions the sound velocity will vary locally and this will have large effect on the operation of a MBES system, swath width being used and the quality of the data.

### *3.3.2 Topography*

The different survey areas are basically open sea areas having very varying bottom topography. Typically depths are 3 – 50 metres, often can be less than 3 m of water depth.

The present surveys in the areas are somewhat old and consists mainly of single beam soundings with about 40 m line spacing.

For information about the topography see the raster charts (Geo-Tiff) downloadable as separate files Attachment 1. *Charts available from other sources is known by the buyer sometimes to show different depths than the Finnish nautical charts.*

## 3.4 Mission support

The Contractor shall organize the support services to their survey vessel(s) as they see fit.

The Contractor shall be responsible for arranging and to obtain all permits, permissions and licenses for flight, access and radio frequency clearance for all survey operations whether ashore, afloat or in the air.

An FTA Overseer will be appointed as a representative of FTA.

### *3.4.1 Meteorological information*

The expected sea state conditions and weather forecasts for the survey area are available from:

The Finnish Meteorological Institute (also in English) at the following address www.fmi.fi

It is to be noted that in winter time the work areas will be covered with ice. Information is available from the above mentioned services.

### *3.4.2 Navigational warnings*

The Contractor shall take note of the sometimes dense traffic in the survey areas.

The Contractor has to arrange for Maritime Safety Information to be broadcasted by Radio and Navtex services as they see fit.

For Finland information can be found on the following homepage: http://portal.liikennevirasto.fi/sivu/www/e/professionals/vts/turku_radio

### *3.4.3 Offshore operators liaison/dispute resolution*

The Contractor is responsible for deciding if naval or military firing and exercise areas will affect the survey and for liaising with the appropriate authority in each case to avoid mutual interference. The responsibility for resolving disputes with these, or any other offshore operators who may restrict survey operations, rests solely with the Contractor.

### *3.4.4 Fishing industry liaison/compensation*

Liaison with, and compensation to, fishermen for loss/damage to fishing gear are matters which rest entirely with the Contractor.

The Finnish fishermen do not report their activity to the authorities in advance.

Some information of fishing administration concerning survey areas in Finland can be found in Finnish and in Swedish language on the web-page of Centre for Economic Development, Transport and the Environment: http://www.ely-keskus.fi/en/web/ely-en/ .

### *3.4.5 Information to the Coast Guard*

FTA will inform the Finnish Coast / Border Guard that the Contractor will perform surveys in the area. Operational contacts with the Coast Guard are to be handled by the Contractor.

Links to:

The Finnish Coast / Border Guard
http://www.raja.fi/rvl/home.nsf/pages/index_eng

## 3.5 Data handling

### *3.5.1 Naming convention*

The folder and file naming convention used shall be clear and unambiguous.

The points below are to be agreed upon at a project meeting before the survey work starts.

- Survey file folder structure and naming convention.
- Survey line naming convention.

A digital survey line log shall be used in which all runlines are entered with name, date, purpose (if a runline is a cross line, for object investigation etc.) and processing events (if data has been waterlevel reduced etc.).

### *3.5.2 Data transmission*

Whenever survey data, records or similar material are transferred between the two parties, proper measures shall be taken to ensure safe and secure transfer.

Documents, data, information etc. to be exchanged between the parties under this Project, should be enclosed a transmittal note when passing to the other party. The documents etc. shall be deemed delivered to the other part by signing of the enclosed transmittal note or by an email confirming the reception of the delivery.

The data transmission procedures and persons responsible are to be agreed upon at project meeting before the survey work starts.

### *3.5.3 FTA copyright*

Data, accompanying documents and records originating from the survey become the property of the FTA for all work performed in Finnish Waters and shall be handed over, latest at the date of the final Contract payment. Where appropriate, they shall carry the following markings:

© FTA COPYRIGHT (2015) FOR INTERNAL USE ONLY

### *3.5.4 Disclosure*

The Contractor has no right to use, for marketing purposes or disclosures to third party any information retrieved by this Contract without written permission given by FTA.

### *3.5.5 Disposal of data*

All raw and processed digital records shall be retained and maintained by the Contractor until the date of the final Contract payment. Thereafter it shall be disposed within one (1) month.

In the event of termination of the agreement, data is to be disposed within two (2) months after the notification hereof is received.

## 3.6 Bathymetry

### *3.6.1 Depth accuracy*

Depth accuracy shall be in accordance with FSIS-44. Depth data shall be recorded in meters, with a precision of at least centimetres. This precision shall be maintained in the delivered digital data.

### *3.6.2 Object detection*

For all parts of the survey area where full sea floor search is required, the minimum size of objects required to be detected shall be in accordance with FSIS-44.

Each object, as stated above, shall be detected by at least three (3) valid multibeam pings in the along-track direction and three (3) valid “strikes” in the across-track direction.

For an object appearing in areas to meet Special Order requirements, where underkeel clearance is critical, the object shall be possible to be detected within a swath width of ±45º from at least one (1) survey line. It means that the line spacing needs to be calculated based on using ±45º swath.

During surveying, filtering or flagging of data, based on quality parameters given from the MBES such as collinearity and brightness filters, is to be done with great care to ensure that objects on the seafloor will not be accidentally rejected.

### *3.6.3 Area planning*

The survey area shall be divided into smaller parts to which the data files are kept in corresponding folders. The divided survey areas shall be in such way that adjacent survey lines will compose logically coherent blocks.

Sizes of the survey blocks are to be agreed upon at a project start-up meeting before the survey starts. There is no connection between the area division used in the tendering process and the one actually used by the Contractor for survey planning and execution purpose. The contractor shall plan the survey area to be surveyed as efficient as possible.

### *3.6.4 Line planning*

The Contractor shall plan and operate the survey in such a manner that the requirements in this specification of invitation to tender and the contract are met and documented. The demands in chapter 4.6.2 *(Object detection)* shall specially be noted when calculating survey speed, especially if the tenderer plans to use a dual head multibeam system that does not ping simultaneously.

**The MBES shall not be operated at a larger swath width than ±65º from nadir**, noting also chapter 4.6.2 *(Object detection)* and objects.

Straight survey lines shall be run wherever possible. Data logging shall be stopped before turning and is not to be restarted until the survey system is stabilized again.

In general, line spacing shall be such that full bottom coverage is achieved with sufficient overlap and requirements of depth accuracy, object detection and sounding density are met. Any gaps between lines shall be covered by additional surveying. The Contractor shall at all times take note of any degradation/rejection of the outer beams of the MBES.

It is required to add survey lines over doubtful features, where necessary, in order to try to prove or disprove their existence.

### *3.6.5 Infill lines*

Re-surveying shall take place in areas where rejection of data results in clusters of empty bin cells or systematic distributed empty bin cells. Bear in mind that normal surveying procedure shall apply also for re-surveying (for example stabilization of motion sensor, appropriate SVP's etc.). Infill lines are to be done with the same vessel and MBES system as the area itself, which is to be filled in.

### *3.6.6 Cross lines*

Cross lines shall be run perpendicular to the main survey lines at intervals of approximately 20 times the mean survey line spacing in order to conduct cross line comparisons. All main survey lines shall have at least two (2) cross lines. In shallow areas this is negotiable, but to be agreed.

Cross lines shall be incorporated into the main data set and named specifically so they easily can be used for later analyses.

### *3.6.7 Backscatter*

Geo-referenced multibeam backscatter data shall be recorded. The data is to be used to provide a general determination of the nature of the seabed.

If a dual head multibeam system is used the contractor has to prove that the average recorded amplitude from both heads/systems gives the same signal strength. Any differences shall be calibrated or compensated.

### *3.6.8 Data cleaning*

Bathymetric data and data from all sensors shall be analysed, edited and cleaned according to these principles:

- Processed data files shall contain all collected data points, flagged as accepted or rejected.
- In the processing of raw positioning and motion sensor information, all outliers shall be deleted or flagged as rejected.
- Shallowest detected valid data point for objects and shoals shall remain in the accepted data set as well as the surrounding valid data points helping to confirm the case.
- Outliers, below and above the expected bottom surface, shall be flagged as rejected.
- All observations greater than contractor provided error budgets (but may be within contract specifications) shall be observed as suspicious observations and further analysed and minimized.
- Accepted automatic methods to flag data points as rejected are by “restricted swath angle” or “maximum and/or minimum depth thresholds” only.
- Flagging data as rejected by means of statistical methods solely employing a magnitude of the grid cells standard deviation as a limit is not accepted.
- Statistical algorithms employed for detecting erroneous and/or doubtful data shall be documented and adequately tested to prove their suitability.
- All systematic errors and effects shall be detected with post-processing software and removed;
- Outliers, below and above the expected bottom surface, shall be flagged as rejected;
- All observations greater than contractor stated error budgets (but may be within contract defined IHO S-44 & FSIS-44 order specifications) shall be observed as suspicious observations and further analysed and minimized.

### *3.6.9 Quality control*

The Contractor must perform quality analysis on the post processed data according to the survey manual in order to verify that the data is of the desired quality and fulfils the specification. Quality analysis and respective reporting shall minimum include control of statistical values, min-max and difference surface analyse, discrepancies, crosscheck analyse and be well documented and submitted together with the data delivery. The Buyer will perform a similar quality analyse, according to Part Three, to be able to verify acceptance of the data.

### *3.6.10 Single beam surveys*

In areas in depth range 6 – 2,5 m, where MBES surveys can not be carried out and full sea floor search is not required can be use single beam launch.

Straight and regular survey lines shall be run whenever possible. It is difficult to name exact line spacing. On rocky abrupt shores minimum of two lines following the course of shoreline will be enough. On smooth and sandy bottom a regular survey with 15-20 meter line spacing is recommended. It is essential to try to find the shallowest bottom forms.

SBES surveys shall be agreed separately.

## 3.7 Geodesy

The survey shall be processed and rendered using the following geodetic parameters:

**Reference System:** EUREF89.

EUREF-89 is represented in Finland of EUREF-FI.

**Reference Ellipsoid:** GRS 80.

**Map Projection:** UTM zone 34, Central meridian 21 degrees East.

- The central meridian shall remain the same for the whole survey.

**Survey Datum:** European vertical reference frame (EVRF) represented in Finland by N2000.

Information regarding map projection, horizontal reference system and reference frame, vertical (height) reference system and frame, transformation parameters and methods including check calculations will be agreed in the project meeting.

All rendered positions shall be quoted as geographical coordinates (i.e. in terms of latitude and longitude) as degrees and decimal minutes (DDº MM.mmmmm'), or in UTM projection described above as meters (with a precision of at least centimetres).

Where necessary, change of geodetic reference system shall be performed by 7-parameter transformation and be verified by control conversions on fixed reference points provided by FTA prior to the survey.

## 3.8 Positioning and Vessel reference frame

### *3.8.1 Vessel reference frame and sensor alignment*

Internal coordinate system with fixed mounted sensors shall be surveyed within acceptable accuracy. MBES, MRU/IMU, GNSS antennas, draft marks or draft sensor, offset points, etc.

Motion sensor(s) shall be aligned with the internal coordinate system three axis within acceptable accuracy.

Heading sensor shall be aligned with the vessel internal coordinate system along ship axis within acceptable accuracy.

### *3.8.2 Not applicable*

### *3.8.3 Primary positioning system*

Positioning shall be provided by a system capable of providing an overall positioning solution so that the accepted uncertainty limits specified in FSIS-44 can be fulfilled.

The differential GNSS correction service, broadcasted on the FM radio networks RDS transmissions, is by the Buyer considered to be so unreliable in the areas that the demands for positioning cannot be met and hence will not be accepted.

### *3.8.4 Secondary positioning system (not in SBES system)*

Positioning shall be provided by a secondary system capable of providing an overall positioning solution so that the accepted uncertainty limits specified in FSIS-44 can be fulfilled.

The secondary system used can be identical to the primary system but in the case of GNSS they are not allowed to use the same correction system. This is to ensure the correction integrity and quality.

The secondary positioning system shall be integrated into the survey system and be used for comparisons to prove that the primary positioning system gives reliable data for the survey.

### 3.8.5 *Positioning control*

The positioning system shall at all times provide:

- Position accuracy or uncertainty estimate. If the receivers don't provide accuracy or uncertainty estimates the control can either be performed based on standard deviation of a weighted position or by difference comparisons, between the two systems.

- In the case of GNSS following information shall be provided by the positioning system:
    - Number of satellites.
    - DOP-values.
    - GNSS height information, if applicable, for identifying sudden changes and thus uncertain or unrealistic positioning results.
    - RAW-GNSS positioning data (in RINEX-format)

These values shall have a user defined alarm limit and be monitored at all times. Note that change of differential correction service source on the fly shall alarm.

In the case other than GNSS system is used they should deliver similar data.

### 3.8.6 *Position verification with objects*

Existing objects appearing in two adjacent survey lines should be checked for position consistency.

If an inconsistency is found the difference in positions of such objects shall be analysed and any error sources and affected data shall be identified and rectified or rejected.

### 3.8.7 *GNSS limits*

In all cases at least 5 GPS satellites must be included in the positioning solutions. Satellite height shall all the time be more than 10 degrees above horizon.

Positions with PDOP values higher than 4 are not allowed.

### 3.8.8 *Time synchronization*

A common time reference system shall be used throughout the survey. The use of GPS based UTC-time is acceptable and all survey systems and equipment (where possible) shall be synchronized by the use of PPS pulse.

## 3.9 Sound velocity

The Contractor shall collect sound velocity profiles at a sufficient interval to ensure that the FSIS-44 demands are met, but with a maximum spatial interval described in 4.9.1.

The primary instrumentation for sound velocity profile measurements shall be of sound velocimeter type. During the survey this instrument shall be compared to another instrument with similar or different operation principle at least every 14$^{th}$ day. These comparisons shall be documented among other survey documentation. If an unacceptable deviation is observed in comparison of instruments the problem has to be solved before the survey continues.

The water in the area is brackish, and the average salinity is typically in the magnitude of 2-8 ‰. The salinity is normally higher on the bottom with less saline water in the top layers. The sound velocity profiles are known to vary a lot even within small distances and during the summer period significant daily temperature rising can be observed down to 10 m of depth. A sample profile can be seen in the good to know attachments.

Surface sound velocity observations shall be taken from a hullmounted system next to the MBES transducer and be applied to the real-time data collection system.

The difference between the surface (transducer depth) sound velocity and the sound velocity profile (SVP) value for the same depth is not allowed to diverge more than 3 m/s. If there is a fixed difference between the sensors this shall be considered at the comparison.

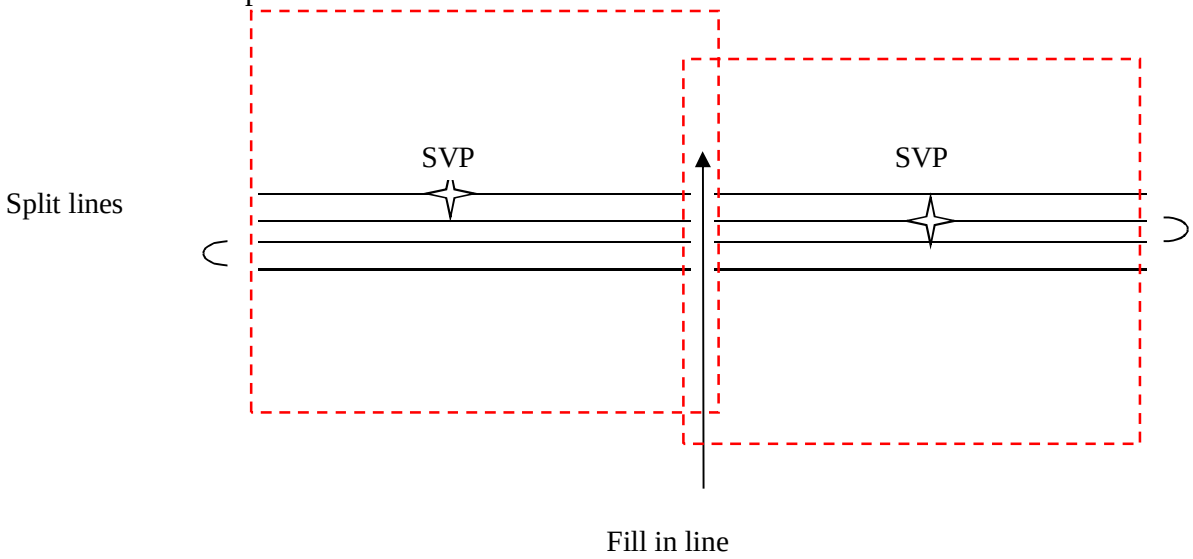
### *3.9.1 Validity*

Due to the very varying sound velocities in the Baltic Sea, special care shall be taken to the sound velocity.

A single SVP is allowed to have validity inside a square box of maximum 5000 x 5000 m with the position of the profile in the centre of the box. To run longer runlines, the Contractor can select to measure two or more profiles maximum 5000 m apart and switch between them at the same time as the raw data file is restarted. If there becomes a gap in the line collection, fill in lines may be run across the gaps, see example below. The “fill in lines” is not to be considered as crosscheck lines. As a better alternative, several SVP could be applied to the survey lines in post processing by nearest in distance or time or by interpolation.

In areas with depths greater than 100m the size of the box, described above, is allowed to be extended to 10000 x 10000 m, provided that the application of SVP is satisfactory.

Example:




### *3.9.2 Sound velocity modelling or interpolation*

If the Contractor wants to use sound velocity modelling or interpolation, in combination with traditional single dip sound velocity profiling, in order to be able to run longer continuous survey lines the method shall be described in the Tender documents and approved by the Buyer for use in the Field Work.

### *3.9.3 Handling of sound velocity data*

No editing of the taken profiles is allowed except for obvious spikes or deletions of the last samples (if the profiler gets into the mud layers causing erroneous measurements) or software dependant extensions in depth. If editing has been performed the original file shall be kept and the edited file is to be given an extension to the filename that clearly mark that the file has been edited.

All taken profiles shall be stored with its position and time.

All sound velocity samples shall be delivered both in raw sensor format and in readable ASCII format containing position, date, time, followed by depth, sound velocity and temperature (if available). Storing of the sound velocities shall be done either in the data directories or in separate directories.

### *3.9.4 Distribution of Sound Velocity data*

All measured profiles shall be marked with a header containing the position of the profile. The resolution of the position is to be within 200m.

### *3.9.5 Moving Vessel Profiler*

A sound velocity profiling system such as a moving vessel profiler (MVP) is allowed to be used in the Field. What is written above regarding validity of a SVP and handling of sound velocity data applies also to this case.

## 3.10 Waterlevels, heights and draft

The waterlevel variations in the Baltic Sea are mainly caused by meteorological pressure and wind. The influences by celestial bodies are negligent.

A diurnal standing wave, caused by wind pressure, may occur across the Baltic Sea with a magnitude of approximately 5-20 cm.

Even that the waterlevel variations normally are within ±50 cm, extreme values of ±100 cm and higher might occur. The waterlevel change may come fast, with differences of >30 cm during 30 minutes, as different pressure systems moves across the Baltic.

### *3.10.1 Waterlevel Reduction of soundings*

Soundings shall be reduced for waterlevels. All soundings shall be presented as depths below Survey Datum.

Waterlevels used in reduction of soundings shall be acquired from the waterlevel stations (mareographs) operated by Finnish Meteorological Institute.

The Tenderer shall demonstrate that the method chosen for waterlevel reduction results in the overall depth accuracy requirements being met (see 4.6.1).

It is the Contractor's responsibility to ensure that the waterlevel data is of suitable quality.

### *3.10.2 External waterlevel information*

The Swedish Meteorological and Hydrological Institute (SMHI) and the Finnish Meteorological Institute (FMI) operate a number of waterlevel stations (mareographs) around the Bothnian Sea and the Bay of Bothnia and data can be obtained on an hourly basis.

FTA will provide information on a daily (weekdays only) basis from FMI water level stations, for more information see: http://www.boos.org/index.php?id=22

and http://en.ilmatieteenlaitos.fi/marine-weather-and-baltic-sea

### *3.10.3 Establishment of on shore waterlevel stations and vertical control*

The Contractor shall provide a plan for waterlevel measurements including time interval for the measurements, if necessary.

FTA will allow the Contractor to access the geodetic reference mark register to retrieve waterlevel reference marks at nominal cost, if so needed.

### *3.10.4 Levelling of waterlevel stations*

The Contractor shall make long time levelling of all new stations including offshore gauges with a minimum averaging period of 4 weeks. Comparisons shall be made to the SMHI and FMI mareographs. Levelling diagrams and spreadsheets shall be delivered together with the waterlevel data.

### *3.10.5 Sinkage and squat table*

The dynamic draft of a vessel includes static draft, sinkage and squat. To be able to find the dynamic draft, a table with draft increase versus vessel speed and current depth below the keel must be developed taken into consideration the sinkage. The speed range must be within the range of the survey speeds used in the survey and the depth range must be within the expected depths in the survey area. Note that larger depths than about 7 times the vessel draft will not give any difference in squat hence maximum depth in the table may be 7 times the vessel draft. See an example of a squat result in attachment 8.

### *3.10.6 GNSS heights*

The Contractor may use GNSS heights only to quality control / verify their own work. GNSS raw data shall be stored and part of the delivery.

Upon comparison of the derived height towards waterlevel, dynamic draft of the vessels needs to be taken into account.

### *3.10.7 Spike filtering of water level information*

Waterlevel information shall be quality controlled before it is used for waterlevel reduction. Quality control shall be done by comparing the used water level station information to the nearest water level stations (mareographs).

If the Contractor observes spurious spikes in the collected waterlevel information the spikes shall be removed and an interpolated value inserted may be used for single observations.

If any filtering or editing of waterlevel information is performed, the raw collected sensor data shall be preserved and the filtered information be put in a filtered waterlevel file. Both files shall accompany the data deliveries and shall be possible to identify either by directory name or the filenames.

#### *3.10.8 Smoothing of waterlevel observations*

If waterlevel data is planned to be smoothed the suggested method shall be described in the Tender to be approved or disapproved by the Byer. Spikes shall always be removed from the dataset before smoothing is applied.

If any smoothing of waterlevel information is performed, the raw collected sensor data shall be preserved and the smoothed information be put in a smoothed waterlevel file. Both files shall accompany the data deliveries and shall be possible to identify either by directory name or the filenames.

Smoothing should normally not be necessary to perform.

#### *3.10.9 Waterlevel comparison*

Analysis should be performed on collected waterlevel series. All series must be compared to the nearest tide gauge water level series and evaluated to be valid and realistic in a diagram. Significant differences between the series must be documented and if possible corrected.

A documentation of which individual waterlevel series is used for correcting the depths in the different survey areas must be submitted.

#### *3.10.10 Static and dynamic draft*

The dynamic draft, including static draft, squat and sinkage (load), of the survey vessel shall be applied to correct the soundings to the actual water level on a daily basis. The method used shall be described and approved by the Buyer before the start of survey.

The static draft shall be recorded regularly, at least once a day and whenever the load of the vessel changes. This information shall be included in the data deliveries.

Readings of the draft is to be made directly against the waterlevel either by using draft scales on the hull or by levelling glasses mounted close to the reference point whenever the weather permits but always entering and leaving port.

### 3.11 Wrecks, objects and shoals

There exist known wrecks in the area. Wreck positions given by the Buyer shall be treated as approximate (PA) or very uncertain. The probable existence of previously not discovered/registered wrecks is very high, approximately 10 - 30 wrecks.

Wreck, object and shoal investigation survey lines shall be incorporated into the main data set.

### *3.11.1 Wreck reporting*

Any wrecks, suspected wrecks or similar objects found during surveying or post processing shall be registered in a wreck register. For all wrecks, the position, shallowest depth, height above the seabed, dimensions and orientation must be determined and reported upon, together with an opinion of its nature.

An Excel document will be provided to the Contractor and shall be filled in with the appropriate information. Naming of the wrecks shall be "*[abbreviation of the project name] #*" where # is a consecutive number for this survey.

### *3.11.2 Wreck investigations*

In order to enhance the depth resolution and information about the wrecks, at least one survey line shall be run on each side of the wreck with the wreck well within the swath width. Also one extra survey line shall be run centred over the wreck, if no risk of grounding exists. The speed during these extra lines shall not exceed 4 knots and the MBES ping rate and resolution shall be set to highest possible.

Where a wreck, suspected wreck or similar target is found the shallowest detected point (by the MBES) shall always be kept undeleted in the dataset.

For each target, at least one snapshot shall be delivered as Geo-Tiff or Tiff file showing the sidescan imagery collected by the MBES system as well as one snapshot, taken from the DTM created in post processing, showing the target in plan view and one in 3D. The filenames of the snapshots shall start with the "*[abbreviation of the project name] #*" followed by sidescan, plan or 3d. If more screenshots are delivered a consecutive number is given to the following files.

### *3.11.3 Shoals (this item not applicable to the BBROK2015)*

*In areal survey areas (not limiting to shoreline) where the depth is shallower than 20 m up to 5,5 m, shoal survey shall fulfil FSIS-44 Special Order requirements. In depth range 5,5 – 2,5 m FSIS-44 Order 1a is the requirement.*

*There are also other shallow areas < 20 m, where the principle described in chapter 4.1. (The work overview) shall be followed, but it is not required to use limited maximum ± 45º beamwidth unless there exists an object to survey. Care shall specifically be taken to ensure full bathymetric coverage over all shoals in order to give correct information about the minimum depth. Extra care is required in case when sudden sharp peak is located on a deeper sea bottom. The minimum depth shall be surveyed carefully, however without endangering the survey vessel herself, and such shoals shall be treated as navigational hazards.*

### *3.11.4 Navigational hazards*

Navigational hazards such as, but not limited to, uncharted shoals or other obstructions of less than 20 m depth, shall be reported (with respect to position, extent and least depth) immediately to the FTA Overseer.

## 3.12 Control and Calibrations

Before the survey all the sensors in the survey system shall be calibrated and adjusted or have correction values applied in data collection or in post processing. The systematic errors shall be minimized and be within the uncertainty of the individual sensors.

Calibrations shall not be older than 6 months prior to the start of the survey work.

The complete survey system shall be checked to verify that horizontal and vertical uncertainty fulfils the FSIS-44.

All verifications and calibrations shall be approved by the Buyer and described and documented in a calibration report which is to be sent to the Buyer before start of survey.

If at any time during the survey any significant changes are made to the survey system, sensors or software, the Buyer shall be notified and the calibrations and controls shall be repeated. In such case a revised calibration and control report is to be sent to the Buyer.

### *3.12.1 Patch test*

A full patch test shall be performed prior to commencing to the Field Work. If the system setup or in case any sensor is changed during the survey a patch test including all relevant tests shall be performed.

A full patch test shall minimum include the following determinations:

- Latency bias.
- Pitch bias.
- Roll bias.
- Yaw bias.
- Optimum heave period for the MRU.
- Stabilisation period of the MRU after rapid manoeuvres (e.g. survey vessel turns).

Patch test methods shall be approved by the Buyer and the results (including raw and processed data) shall be delivered to the Buyer within one week after the test is performed.

Any individual biases must not be determined by only one set of survey lines. An average bias shall be calculated from several samples, which are not too much divergent, on at least two sets of survey lines. A final set of survey lines must be performed to verify that all biases has been removed.

#### *3.12.2 Dynamic accuracy control using a reference object (manmade object)*

Before the survey is started the survey ships shall perform a test at a reference object (manmade object) at the seabed.

At present moment such reference objects are located outside Hanko and Pori in Finnish Territorial Waters. This will require a permission from Finnish authorities.

The Contractor shall by this survey proof that the system setup is correct and that the complete system is proved to be within the values used in the delivered error budget and fulfils the demands for the survey project. If the result is unsatisfactory corrective actions have to be taken and a new check is to be performed.

The buyer overseer will be present during the survey. The data shall be analyzed right after the survey has been performed.

Validation report is to be sent to the Buyer.

#### *3.12.3 Static and internal position transformation verification*

A static position validation shall be carried out minimum before and after the survey.

Verification of the vessel absolute position shall be performed using a geodetic bench mark ashore which coordinates are provided in defined coordinate system (see chapter *4.7 Geodesy*). As a verification survey system can be used an independent GNSS equipment providing RTK or PPK solution.

Position from the primary and secondary position system in surveyed offset points within the internal coordinate system shall be compared to the position of a geodetic fix point or independent GNSS equipment.

Reports shall be sent to the Buyer.

#### *3.12.4 Test area*

A verification of the last performed calibration shall be performed in the test area in the work area during the first days of survey. The result of the

verification together with the last calibration report shall be delivered to the Buyer.

If the verification indicates errors out of the sensor specifications a full Calibration shall be performed.

The results of the calibration verification (including raw and processed data) shall be delivered to the Buyer within one week after the verification is performed.

A test area shall be selected and surveyed on a suitably similar seafloor around depth range of 20-30 m. *There is no need to do this prior to the start of surveying. The thought is to select an area based on the survey result achieved during the first survey days.*

Minimum 3 parallel lines with > 100 % overlap shall be run. Thereafter shall also minimum 2 parallel lines perpendicular to previous lines be run. All lines shall be surveyed in both directions. Sound velocity profile shall be taken in the centre of the test area. Data logging shall be stopped before turning and is not to be restarted until the survey system is stabilized again.

The test areas shall be included in the first data delivery for FTA according to 4.14.2 *(Delivery schedule)*, to the Buyer for analysis.

The test area shall also be surveyed once more close to the end of surveying and delivered together with the final data delivery. If the Contractor temporarily leaves the area for other reasons than weather standby or crew change a survey of the test area is required at both leaving and returning. Resurvey of the test areas shall also be made if the contractor changes firmware or upgrades the MBES collection software and if any other significant changes are made to the survey system during the project.

Test area outside port of Pori will be used for reference, only with Buyer's representative on board

## 3.13 Miscellaneous requirements

### *3.13.1 Bottom sampling*

Bottom samplings are not required.

### *3.13.2 Fixed and floating aids to navigation*

The positions of fixed and floating aids to navigation are not to be determined.

### *3.13.3 Light characteristics*

Light characteristics and sectors are not to be checked in the field against the chart.

#### *3.13.4 Seabed classification*

No geological interpretation of the multibeam backscatter data shall be carried out.

#### *3.13.5 Sidescan sonar*

Sidescan sonar for object detection is not required. If sidescan sonar is towed on wreck sites images shall be delivered together with the wreck report.

#### *3.13.6 Bar or wire-sweeping*

Bar or wire-sweeping is not to be carried out during this mission.

### 3.14 Product delivery

All data shall be cleaned and quality controlled, ready to be inserted into the national depth databases.

Every delivery must be certified by the Contractor as having passed the internal quality control prior to delivery.

#### *3.14.1 Test delivery*

A sample of processed data shall be delivered to the Buyer soon after the award of Contract in order to test data formats and data transfer between the Contractor and the Buyer. This data may be from any surveyed area with the proposed systems.

#### *3.14.2 Delivery schedule*

The data deliveries shall be of homogeneous survey blocks. The first delivered survey block shall be approximately 20 $km^2$ and the following blocks shall be delivered at an interval of approximately 14 - 28 days. If a delivery contains more than 21 days of ship time or equivalent amount of data from more than one vessel the Buyer will be allowed to an extended evaluation period compared to what is stated in 4.14.8. Before any new data delivery takes place the previous delivery shall have been accepted by the Buyer, see 4.14.8. Detailed delivery schedule will be agreed in the project start-up meeting. This shall be noted in the contract Art. 6 E.

- Data delivery 1:
    - Containing the “Test area” together with the first completed survey block.

- Data delivery 2:
    - Containing the second completed survey block.
- Data delivery 3-n:
    - Further deliveries of completed survey blocks
- Final data delivery:
    - Containing the last completed survey block together with a second survey of the “Test area”. The acceptance from the Buyer of the final data delivery results into completion of Field Work.
- Final delivery:
    - A final survey report and miscellaneous data shall be delivered within 15 working days after final data delivery acceptance. The acceptance from the Buyer of the final delivery results into completion of the Project.
- Other deliveries:
    - Deliveries according to 4.12, prior to start of survey or as complementary report.
- Delivery schedule
    - ⅓ deliveries during 2015.
    - stated timetable when ½ deliveries are made
    - stated timetable when ¾ deliveries are made

### *3.14.3 Data delivery*

The following records shall be rendered for each data delivery in accordance with these instructions:

- Processed survey data.
- Raw survey data (proprietary system format), including backscatter data.
- Digital report of survey accompanied with a small chartlet indicating the surveyed area (details of contents to be decided at the Contract).
- Documented result of quality analysis of post processed data according to 4.6.9.
- Drawing / index of which survey lines are within which cell.
- Sound velocity profiles according to 4.9.3.

- Waterlevel records according to 4.10.
- Wreck records according to 4.11.1.
- Reports of navigational hazards according to 4.11.4.
- Draft records and if occurring, complementary report according to 4.10.10.
- Miscellaneous observations records.
- Backscatter mosaics in high resolution Geo-Tiff format (minimum pixel size corresponding to the cell size of table 1.1 of Attachment 5).
- RAW-GNSS positioning data (in RINEX-format)

#### *3.14.4 Weekly report*

A weekly status report starting at the date of mobilisation, shall be delivered by e-mail, every Monday before 07:00 UTC to the Buyer with a summary of the operation, a chartlet depicting the completed area of the survey and state any weather or equipment down-time.

If Daily or similar reporting normally is used internally by the survey company these as well shall be sent to the Buyer.

#### *3.14.5 Final delivery*

The following records shall be rendered at the final delivery in accordance with these instructions:

- Digital final survey report of containing full documentation of the Project (details of contents to be decided at a project meeting).
- Miscellaneous data that has been complete collected after the end of the survey.

#### *3.14.6 Format of bathymetric data*

Processed survey data can be delivered in any of the following alternatives and will be agreed in the Contract:

- Binary FAU-format, line by line. Specification of the format, see Attachment 6. All fields in the FAU format shall be populated included the amplitude value.
- Some other file format, approved by the Buyer. Minimum required information for each data point is time, depth, position, beam angle, amplitude, roll, pitch, heave and reject flag.

### *3.14.7 Digital data media*

All data shall be delivered on USB 2.0 removable Hard Drives (Win XP compatible). All delivered digital media included in this Project becomes the property of the Buyer.

### *3.14.8 Quality control of delivered data*

Each delivery of survey blocks will be tested to ensure it meets the demands of the contract and attachments specifications.

For information of quality control methods, see “Part Three – Evaluation of survey data”.

Each testing will commence on the first working day after the date of reception of data.

The Contractor will receive a quality acceptance report within 30 Calendar days, stating the delivery as accepted or rejected. The period of 45 Calendar days will be used in deliveries taking place between Finnish midsummer and end of July or in December. If the Contractor fails to deliver the area within the time specified in the contract or in the start-up meeting, the validation time for the Buyer will be extended to 45 Calendar days.

### *3.14.9 Quality control failure procedure*

If any data delivery is rejected following the Buyer Quality Control, the Contractor will be required to re-supply conformant data at his own expense. The Contractor will from the quality acceptance report be informed of the non-conformities.

After a new delivery another 30 Calendar day acceptance test follows.

### *3.14.10 Acceptance of final delivery*

The Contractor will receive an acceptance report within 30 calendar days, stating delivery as accepted or rejected. If rejected, the Contractor shall submit a new version with additions according to the Buyer demands.

# 4 Part Three – Evaluation of delivered survey data

Delivered survey data will undergo quality control at the Buyer with the object to check that data has obtained the desired quality. The quality of the data shall be in accordance to what has been stated in the Contract and attachments specification. The data will be controlled by the steps described below.

Tables referred to in this chapter are to be found in Attachment 5.

## 4.1 Complete delivery of data

- Check that the surveyed area is homogeneous.
- Check that all data files have been delivered.
- Check for full coverage towards adjacent areas from earlier deliveries.

## 4.2 Full bottom search and sounding density

Full bottom search is required for the entire survey area. Sounding density shall be adequate to ensure an acceptable probability to detect and identify objects in the surveyed area. The control will be based on areas represented by gridded survey data created according to table 1.1 in attachment 5. The individual DTM-cells shall for the proper bin size at a certain depth interval be populated by ≥ 5 accepted data points.

Objects and shallow areas will be checked more carefully by viewing sub-sets of data points. Shoals and shallow areas shall always have full (100 %) coverage as well as areas represented by soundings in the chart.

After post-processing, random distributed bin cells may exist that do not fulfil the requirement, but shall not exceed 1 % of the total amount of cells. Not more than 0.1 % of the bin cells may be empty.

## 4.3 Systematic effects/errors

The analysis will be based of surfaces represented by the minimum, mean and maximum depth. The DTM's shall be created according to table 1.1 in attachment 5, with the individual bin-cells holding at least 5 accepted data points (to ensure statistical stability).

An analyse will be made based on the standard deviation of the bin-cells in the created DTM's in order to find anomalies and other problems such as sound velocity issues.

The DTM's shall be sun-illuminated from orthogonal directions with one shading direction perpendicular to the main survey lines. The object is to control any existence of systematic anomalies.

Systematic effects/errors shall be minimized prior the survey and shall be limited to equal or less than the magnitude of the random errors for the specific system. If effects/errors are found, further investigations will carry on trying to identify the source and amount of error which shall not exceed the values given in the error budget calculations.

## 4.4 Cross-line comparisons

Check that the cross-line spacing is accordingly to 4.6.6.

For the further analyse the Fledermaus software with its Cross-check Tool will be used.

A depth reference surface will be created by cross line data and accepted production survey data will be compared against it. The analysis shall pass the requirements of contract and attachments specifications Order tests.

## 4.5 Surface difference

- The differences between the minimum depth and maximum depth surfaces of accepted data will be analysed. The delivered area can be divided in sub-areas down to minimum 7 km². The standard deviation of the differences between the surfaces will be calculated and converted to the 95 % confidence level for each area/subarea. The resulting values must be within the contract specification.
- The individual minimum and maximum surfaces of accepted data will be checked for remaining spikes in the data.

## 4.6 Data handling

- Spot areas with all data points (flagged as accepted as well as rejected) will be analysed in order to check if valid data or objects have been erroneously flagged as rejected.