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On

The Use of Aids to Navigation in the Design of Fairways and Waterways

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International Association of Marine Aids to Navigation and Lighthouse Authorities

IALA

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1 INTRODUCTION

The purpose of this Guideline is to provide guidance for Aids to Navigation Authorities on the

- use of AtoN in the design of fairways/waterways including dredged channels and canals.
- new design or review of existing AtoN for fairways and waterways.

The objective is to define a level of deployment of AtoN which enables safe and efficient vessel traffic in a cost effective way for the AtoN Authorities.

This Guideline shall be used for a general overview. For detailed AtoN planning it is necessary to use it in conjunction with other IALA Recommendations and Guidelines.

1.1 Background

The art of navigation has evolved over many years, as well as the properties of ships, vessels and various other craft.

In principle navigation comprises:

- Planning a safe track / passage for a ship by the use of a nautical chart and relevant publications;

- Monitoring or establishing the ships position or advance along a predetermined track / passage;

- Control of the ship, e.g. to ensure that it follows a predetermined track / passage.

The navigation process is normally performed by the navigator integrating the chart, navigational information and control of the ship. In some ships this process is fully automated, using electronic tools. This places a demand on accuracy of the chart, the navigation system and the control system, that cannot be fulfilled under all circumstances today. In general, it is considered that proper marking of waterways/fairways, dredged channels and canals by visual and radar aids is important to reduce the risk posed by the waterway and the traffic.

Until recently, mariners have used the radio aids to navigation systems (also referred as electronic aids to navigation) and short range visual systems in two distinct geographic areas. The short range system was mostly used close to shore and in restricted waterways. Alternatively, vessels were able to navigate offshore safely using less accurate radionavigation systems.

However, considering the availability, reliability and relatively low cost of high precision electronic position fixing systems (e.g. GPS/DGPS and electronic charting programs) available today, these two areas of navigation are overlapping nowadays. This is especially true in those transitional areas where mariners shift from the low accuracy requirements of ocean navigation to the high accuracy needs of coastal and inshore piloting. As electronic aids continue to improve, their use will increase in areas where previously short range aids predominantly were used. This evolutionary change must be recognized and accounted for when conducting waterway analyses and designing AtoN systems for fairways.

1.2 Future Development

In future e-Navigation will have a considerable impact on the mix of AtoN for an existing or a planned channel. e-Navigation will help to improve the efficiency of fairway marking with AtoN by integrating the elements of information. Further on it will provide:

- Improved safety, through promotion of standards in safe navigation;
- Better protection of the marine environment;

- Potential for higher efficiency and reduced costs;
- Potential reduction in bureaucracy - e.g. standardised reporting requirements;
- Improved human resource management by enhancing the experience and status of the bridge team.

Elements of e-navigation, which are currently limited by availability of equipment and training of personnel, will be available for most of the users in the future. Issues relating to the presentation of information need to be addressed.

2 USER REQUIREMENTS

2.1 General

According to SOLAS, Chapter V, regulation 13, each of the Contracting Governments has to provide, as it deems practical and necessary, Aids to Navigation as density of traffic and the level of risk requires. IMO member states commit themselves to take into account international recommendations and guidelines when establishing such aids.

2.2 Accuracy

The required navigation accuracy for a vessel depends on the beam of the vessel, the draft of the vessel, the under keel clearance and the bathymetry and many other factors in the waterway. The position accuracy of the vessel should meet the required navigation accuracy. However, as there are many relevant properties of vessel and waterway, there will be a level, where the navigation accuracy cannot be improved further by improving the position accuracy.

For the mariner it is relevant to know exactly the distance from the vessel to a certain point or line, like a critical hazard or the limitation of a fairway. The distance can be found as the difference between two absolute positions. Then it is determined by the absolute accuracies of both positions. The distance can also be found directly, if there is a visual aid or a radar target or any other device showing directly the relevant point or line. This is described by the relative accuracy.

The principle of relative accuracy is often used for the layout of visual AtoN systems.

Leading lines and very precise buoyage systems are – in many cases – designed for an accuracy of 1/6 of the width of the channel.

The general requirement for the position accuracy for Radionavigation systems for general navigation is 10 m for most of the different types of waterways. This is an absolute accuracy. It is indicated in IMO Resolution A.915(22) “Revised Maritime Policy and Requirements for a Future Global Navigation Satellite System (GNSS)”, adopted on 29 November 2001 and A.953(23), “World-Wide Radionavigation System”, adopted on 5 December 2003.

The position of the aids to navigation itself should be accurate and at least in accordance with IHO standards so that a ship can establish its position sufficiently and follow a track in the fairway by visual means, radar or Radionavigation. Generally the mariner will determine the position for the location of AtoN first on the nautical chart. This may be different for direct local positioning of a small buoy, beacon or a withy.

The aids to navigation should be surveyed and positioned with at least the same accuracy as the nautical chart. This is given by the IHO Standards for Hydrographic Surveys (S-44) 5th Edition February 2008 with

2 m for fixed aids (5 m when water depth more than 100 m) and

10 m for floating aids (20 m when water depth more than 100 m).

In many cases of fairway or channel design a better accuracy for the positioning of the buoy will be required resulting from the specific layout of the system and its components.

2.3 Reliability

The Reliability includes issues of Integrity Availability, Continuity and mean time to repair (MTTR).

The level of Reliability is dependent upon the threats and risks, to the mariner, the ship and/or the marine environment, that are mitigated through the use of a particular aid to navigation. In those areas in which the level of risk has been determined to be high, the use of certain types of aids to navigation may prove to provide greater risk mitigations.

However, the planner must also consider the higher availability objectives that may be required. Authorities should refer to IALA Recommendation O-130 on Categorisation and Availability Objectives for Short Range Aids to Navigation for additional information related to the categorization of individual aids to navigation, the calculation of availability targets, and recommended availability objectives.

If used for defining the requirements for a specific system, the Continuity has to be calculated for the time, that a vessel needs for a passage of fairway or area, where no return or stop is possible.

2.4 Special Requirements for different user groups

The level of on-board navigational equipment is the different on different types of ships. *Certified Commercial vessels* are equipped with certified on-board navigational equipment suitable also to support long-range and/or low visibility navigation. These vessels are operated by professionally trained and certified personnel. For these ships the visual AtoN are a back-up-system in case of failure of Radionavigation systems or on-board equipment. However, in practical navigation, mariners on these ships will use the visual AtoN.

2.4.1 High speed craft (HSC)

According to the definition of the International Maritime Organization (IMO) HSC are defined as:

"*craft capable of maximum speed, in metres per second (m/s), equal to or exceeding:*

$3.7\,\nabla^{0.1667}$

where:

- ∇ = volume of displacement corresponding to the design waterline (m^3)

excluding craft the hull of which is supported completely clear above the water surface in non-displacement mode by aerodynamic forces generated by ground effect."

In coastal areas, if the HSC use the visual AtoN for a safe passage in harbours, port approaches, channel or inter-island navigation, the speed of these vessels can be the driving factor for the AtoN system. The time for reaction is short, so the information provided by AtoN has to be quick and has to avoid any ambiguity.

IALA Guideline No. 1033 "on the provision of aids to navigation for different classes of vessels, including high speed craft" addresses the specific AtoN requirements of HSC, e. g.:

- For coastal passages:

- Consider shortening the period of and increasing the flash length of AtoN lights, and the use of floodlighting (IALA Guideline No. 1061 on Light applications on the illumination of structures);

- For coastal passages and port approaches:

- Consider the provision of AIS (Automatic Identification System) on buoys and beacons that makes available additional information such as meteorological and hydrological data that can be particularly important for HSC;

- For harbours and port approaches:

- AtoN lights should have a multiple flash character rather than a single flash, for example, Fl (3) 15 sec rather than Fl 15 sec., for more rapid identification;

- For channels without turns or bends:

- Consider the synchronisation or sequential flashing of AtoN lights.

- Consider the vertical divergence or of lights. (For example, there may be difficulty in seeing an LED buoy light or beacon that is fitted with a solar panel on top when in close proximity and when viewed from above);

- In channel or inter-island navigation:

- Indirect lighting of beacons may be particularly effective. (IALA Guideline No. 1061 on Light applications on the illumination of structures.)

2.4.2 Pleasure Craft and Uncertified Commercial vessels

For these vessels the above-mentioned regulations in terms of requirement for on-board navigational aids do not completely apply. Such vessels operate with charts and are normally equipped with a compass and timepiece suitable only for short range navigation. These vessels are normally equipped with a searchlight where night-time use of reflective short range marine aids is necessary. They are operated by personnel who may or may not have a certificate.

Mariners on these boats there might have a considerable local knowledge to navigate safely.

For these boats and ships the visual AtoN are the basic system for navigation in coastal areas, channels, harbour approaches and for landfall.

3 PERFORMANCE PARAMETERS/LEVEL OF SERVICE

3.1 Accuracy

3.1.1 GNSS

The position accuracy (95 %) for a vessel using Radionavigation systems – augmented by differential systems where appropiate – can be assumed to be 10 m (IMO Resolution A.915(22) and A.953(23). This is an a*bsolute accuracy* (geodetic or geographic accuracy) and a absolute position information which has to be used in conjunction with sea-chart information. The accuracy of the objects in the sea-chart has to be taken into account.

3.1.2 Visual AtoN

They do – in most of the cases – not provide accuracies of 10 m or less. But they provide a good *relative accuracy*. Thus the can determine the position relative to relevant objects like fairway boundaries and hazards.

For some specific visual AtoN systems like leading lines and high precise buoyage the design and layout can be calculated according to the requirements.

The position of the aids to navigation should be accurate and at least in accordance with IHO standards so that a ship can establish its position sufficiently and follow a track in the fairway by visual means, radar or Radionavigation. Generally the position for the location of AtoN should be first determined on the nautical chart. This may be different for direct local positioning of a small buoy, beacon or a withy.

3.1.3 Drift Detection

Yet there isn't a method of calculation of the positioning accuracy in a fairway with buoys and other means which could be considered as internationally agreed.

A new method for drift detection for a ship in a channel by means of buoys, ship radar and (D)GPS has been developed in Japan. It could be a good method for calculating the achievable accuracy for the position of a ship in a channel and also for optimizing the AtoN system. It was presented in a PIANC WG on 'Approach Channels – A Guide for Design' to optimize channel width by employing efficient AtoN. The basic principle and algorithms of this method can be found in ANNEX 2 of this Guideline.

3.1.4 Positioning Accuracy of the AtoN

Due to the different mooring arrangements the position and therefore the navigation accuracy of floating short range aids to navigation is sometimes difficult to define. Floating aids to navigation are subject to a great degree of variation due to water level, tides and current, to the capabilities of the servicing vessel.

If precise surveying systems like DGPS or precise DGPS are available and the floating aids are easy accessible by the service vessel the positioning accuracy should be as accurate as possible.

But there will still be some inaccuracy of the position of the floating aid because it will have a swinging circle radius, depending on the chain length, ground chain, thrash and riding chain and the water depth at low water and high water. If the swinging circle radius is bigger than the desired positioning tolerance, elastic moorings or resilient and hinged beacons or beacons should be considered as an option.

3.2 Reliability

Reliance upon a single aid to navigation may result in a higher availability requirement which may prove difficult for the National Authority to meet. If this is the case, the implementation of multiple aids may be used to provide redundancy during periods of unavailability of certain aids.

Duplication in function of an AtoN may be appropriate and necessary to provide a degree of safety in the event of a discrepancy and to avoid excessive costs of emergency repairs. Moreover temporary duplication may be provided when new or alternative types of aids are being introduced in order to allow a safe transitional period.

3.3 Perception of AtoN

3.3.1 General

To plan the AtoN for a certain part of the waterway, e. g. a channel, the distance, from which the AtoN can be seen and identified by the mariner, is an important parameter. For the visual perception this can be called the “useful range”. This is the practical convenient range for a mariner to identify an AtoN.

The useful range does not only depend on the properties of the AtoN itself. The properties of the atmosphere and the human eye are the other determining factors. So, it range can be calculated using scientific knowledge about the light, the atmosphere and the human eye, also using mariners experience with AtoN.

The IALA expertise on this issue is laid down in certain IALA documents which will be referenced in the relevant sections of this Guideline.

Generally there are different qualities of visual perception:

- The object is visible (Pure visibility). The aid can be seen but appears still too small to be recognized as a certain type of AtoN according to IALA buoyage system;
- When the daymark is visible and its shape and outline can be seen, but the colour remains unclear – object is partly recognizable;
- The object can be identified (identification): The aid can be identified, e. g. as a certain type of buoy of the IALA buoyage system. Usually this will be the quality of perception which is needed for a practical use of the AtoN for the navigator. Therefore this quality will determine the useful range.

In some cases the conspicuity of an object is relevant or limited in its visibility and particularly for its identification and use by the navigator. An object is conspicuous if it appears outstanding in a complex visual scene.

In every case it is necessary that the visual information, provided by the AtoN, is confirmed (Confirmation, Verification). This process can take time and could thus be a limiting factor, if the visual information emitted from the aid is influenced or interrupted by intermittent influences like movement of a floating aid by waves.

However, this process can also provide a level of redundancy, which means an increase in the safety of the use of the aid. The AtoN sends out its information in different ways (light, shape, colours, marking by letters and numbers, other means). As long as the information from one aid, received by different means, is conflicting, there is no confirmation of the information from the aid.

The conditions of perception can be different in:

- Good visibility at daytime;
- Good visibility at night;
- Poor visibility.

3.3.2 Lights

A parameter to define the performance for a light is the luminous range. This is the distance from which – under defined conditions - the user can identify the light.

The identification and confirmation of a light includes also its colour and character.

The parameter to describe the light itself is the intensity, the colour and the distribution of the light. The IALA-Recommendations of the E-200 series provide methods on how to calculate the luminous range which can be obtained when observing a light with a given intensity.

The calculation includes the following factors:

- Intensity and vertical divergence profile;
- Light character;

- Colour;
- Transmissivity of the atmosphere;
- Daytime / night time;
- Background illumination / light pollution.

The conspicuity in the specific situation must be considered.

The prevailing visibility conditions will vary over different geographical locations. Therefore, when selecting a light, this should be taken into account. Selection and calculation of the useful range should be based on a practical luminous range value and not on nominal range.

However, the luminous range will be promulgated in nautical charts and publications for mariners, lists of lights etc.

3.3.3 Daymarks

The distance at which a daymark can be identified depends on:

- Size;
- Shape;
- Colours (one or more on one aid);
- Geographical range.

A simple rule for the estimation of the distance in which a daymark of a simple shape can be identified – provided the contrast to the background is sufficient - is as follows:

The object can be normally identified when it appears at the eye of the user under an angle of more than 3' (three minutes). This means that the arctan of the quotient 'main dimension of the object / distance of the object' must be more than 3'.

Other distances can be defined for identification of topmarks and identification of numbers.

The contrast to the background and the identification of the colours depends on the:

- Chromaticity of the paint of the aid, the specific meteorological visibility in the area;
- Colour and illumination of the background;
- Conspicuity.

It has to be considered that there is poor visual perception of unlighted AtoN at night. There are some tools that assist navigation using unlighted AtoN at night time:

- Searchlight onboard illuminating the aid;
- Reflective sheets / retro-reflective material on the aid (buoy, beacon, withy);
- Shipborne radar.

3.3.4 Radar

The Perception with shipborne radar is determined by the

- Height of the ship's radar;
- Observation area chosen by the mariner on the radar screen;

- Size and the shape of the AtoN;
- current/sea state
- existence of radar reflectors and their performance parameters
- RACONs on the AtoN

3.3.5 Electronic devices on AtoN

The perception can be improved by means of additional electronic devices on AtoN, provided the on-board equipment allows receiving and presenting the information ("e-Navigation").

The benefits – for example of AIS on aids to navigation – are:

- unambiguous indication of the identity of the AtoN, by carrying the AtoN name within the AIS message data;
- day and night operation and also in conditions of impaired visibility when visual AtoN signals may not be seen;
- greater range than daytime visual signals and visual signals from floating AtoN;
- enhanced accuracy, because it shows the accurate position on the electronic chart or on a modern radar screen;
- Verification of the integrity of the aid, including Off-Position and operational status indication / malfunction alert to the mariner;
- additional broadcast of meteorological and hydrological data and safety related information in real time.

More Details can be found in IALA Recommendation A-126 on the use of AIS in Marine Aids to Navigation Services.

4 LAYOUT OF SYSTEMS FOR MARKING A FAIRWAY

4.1 General

The IALA Maritime Buoyage System (IALA MBS; set in force by IMO) must be observed. The newest version dates from 2010.

However, for the inland waterways, there might be different legislation, other rules and other marking systems established by national authorities, for example SIGNI (Signs and Signals on Inland Waterways, Revision 1, from 2005, New York and Geneva, worked out by the Working Group on Inland Water Transport of the Inland Transport Committee of the Economic Commission for Europe of the United Nations).

It is essential, that relevant Aids to Navigation are identified and marked on nautical charts (ENC, paper chart, synthetic radar screen). References to IMO- and IHO-requirements, described in following sections of this Guideline, are also essential.

In narrow or winding passages it may be difficult for mariners to correlate the vessel's position with chart information in a timely manner. Therefore the navigational marks should be explicit and clear so that navigational decisions can be made directly by using visual and/or radar information.

The delineation of a fairway indicates in general, the area of navigable waters and the general track for the vessels in this area. Additional short range aids to navigation and electronic aids to navigation may be used in the right mix to indicate:

- Critical points;
- The (middle) of the fairway;
- Change of direction;
- Marking of different dangers;
- Marking of different areas.

The following marks can be used:

- Lateral, cardinal or safe water marks, which are physically deployed directly in the fairway or on the point they indicate - or as close as possible to it;

These can be floating (buoys) or fixed (beacons) aids;

- Single markers for warning purposes, curve turning points and longitudinal positioning;
- Paired markers for both longitudinal and lateral positioning; One advantage of this type of mark is that they are clearly visible on shipborne radar. One disadvantage of this type of mark is that they can be displaced / damaged by ice, severe weather or collision.
- Leading marks, which are not physically in the place they indicate, especially leading lines along the centre line of the fairway, act as a powerful tool for lateral positioning in the fairway;
- Sector lights as a tool for lateral positioning in the fairway (direction lights) including port entry lights (PEL);
- Sector lights with oscillating boundary are a powerful tool for lateral positioning in the fairway;
- Sector lights abeam or leading lines crossing the fairway at turning points or other relevant positions (longitudinal positioning in the fairway);
- Other aids to navigation including radio aids;
- Automatic Identification System (AIS).

4.2 Buoys and beacons on the fairway

A fairway shall be marked in principle by lateral marks.

There shall be buoys or beacons at least at bends and junctions of the fairway.

Light buoys or beacons should be generally used for:

- Approaches;
- First and last pair of buoys;
- Changes of direction;
- Dangers or hazards for shipping;
- Special marks (for example, measuring instruments in the field of shipping routes).

The sections between the bends and junctions should be divided into the same distances between buoys.

In general, the useful range (identification) of buoys at daytime and night time should be greater than the distance between the buoys. Their appearance on the on-board-radar screen should also be considered.

The most-used range on shipborne radar is 3 nautical miles in fairways and channels. So, the buoy to buoy distance of continuous buoyage should not exceed 3 nautical miles.

Simulation tests for lighted buoys in narrow waters with 150 m to 600 m width have shown buoy separation distances of 1 - 1.5 nautical miles as the best for navigation.

The distances between unlighted buoys are based on their size and daytime visibility.

In general, the buoys or beacons of one fairway section should have the same distance from the axis (centre) of the channel.

Generally the buoys marking a fairway shall be established as pairs ("gates"), especially if high navigation accuracy or a very clearly distinct channel with continuous buoyage is required.

The design of continuous buoyage marking a fairway which is formed by straight lines and bends can be done in three steps:

1 Establish a conspicuous buoy or pair of buoys for the point where the fairway starts.

2 Place buoys on points.

 a Where ships have to alter their course; or

 b Where the fairway boundary line or the middle line has a bend or curve; or

 c Where critical shallows and rocks or other hazards form the boundary of the fairway or channel; and

 d At Fairway / channel intersections.

3 Distribute buoys between these points with regard to the distance, at which they can be detected and identified (section on perception of AtoN in this Guideline and other relevant IALA documents).

 The distance, at which the marks should be detected and identified, may be different in relation to the length of the fairway section for different cases as follows:

 The buoy separation distance should be chosen in such way that the next one or two buoys are recognized approximately 100 m or more before the nearest one has been passed or in other cases approximately 100 m before the last buoy can no longer be detected and identified.

 Examples:

 (D is the buoy separation distance, L is the distance, at which the marks can be detected and identified)

 $D < L / 2$, if high navigation accuracy or a very clear and continuous buoyage is required

 $D < L$, "normal" for fairways

 $D < 2L$ for some purposes in the open sea, e. g. for a Ship Routeing System

If a certain buoy separation distance is desired, the appropriate mark has to be established.

If a certain type of marks is desired, the separation distance has to be determined.

Usually, this will be an iterative process. More than one option should be examined and assessed against the level of risk, from the nautical, economical and technical point of view.

In general a high density of fairway or channel markers enforces an easy and more accurate level of navigation. However, there is a saturation point where adding AtoN does not help positioning of vessels any further. Too many marks may be confusing and weaken the result. To find this point, simulation and risk assessment will be necessary or at least very useful in the detailed design phase.

To make the design process easier and to make the AtoN economically more efficient, it can be a good option for the service provider to define a restricted number of various types and classes of buoys (by size and shape) with certain identification distance and useful range of the light. Thus, the best buoy can be chosen from this 'toolbox' instead of designing a new one for each case.

4.3 Fixed visual AtoN

4.3.1 Leading lines

Leading lines (lighted or unlighted) generally provide high accuracy for the middle of the channel. They can be established if there are stretches in a fairway or in the channel that form a straight line. Leading lines should be established if:

- the middle of a fairway has to be indicated;
- the buoyage could be affected by ice or severe weather or tide;
- there is a channel inside the fairway, which has to be used by ships with deeper draft;
- strong cross currents occur (harbour entrances);
- They can also be used to show boundaries of a navigable area, provided this function is clearly shown in the relevant nautical publication.

The preliminary decision in designing a leading line is to specify the segment of water to be defined by the leading line. Generally, it is costly to build a leading line to serve a long channel, as the rear leading light must be of sufficient height to be clearly visible above the front structure. Leading marks must also be large enough to be visible from the far end of the channel. Both of these conditions result in increases to the required height of the rear structure marking a long channel. The structures must also be sturdy enough to support the leading mark under maximum expected wind loads. The use of other aids (fixed beacons or buoys) may reduce the overall cost of marking the waterway by reducing that portion of the channel marked by the leading line.

More Details can be found in IALA Guideline No. 1023 for the design of leading lines.

4.3.2 Sector lights

A sector light is an aid to navigation that displays different colours and/or rhythms over designated arcs. The colour of the light provides directional / positional information to the mariner.

A sector or a limit between two sectors may indicate a fairway, a turning point, a junction with other channels, a hazard or something else of importance for the navigator.

When a fairway is covered by a white sector, the convention to a vessel approaching the light is a green sector to starboard and a red sector to port (IALA Maritime Buoyage System colour convention for Region A, for Region B the colours are reversed). The white sector indicates safe passage, however this does not always hold true in the entire radial length of the sector.

A sector light may indicate one or more of the following boundaries and aspects of a navigable waterway or channel, for example:

- Position at which change of course should be made;
- Location of shoals, banks, etc.;

- An area or position (e.g. an anchorage);
- The deepest part of a waterway.

More details can be found in IALA Guideline No. 1041 on Sector Lights.

New developments in optimizing sector have taken place. Precise direction lights provide very high accuracy. Considerations for their use can be found in the IALA NAVGUIDE.

4.3.3 Examples of Marking of fairways

Some examples for the marking of fairways are given in ANNEX 3 to ANNEX 7.

5 METHODOLOGY/PROCEDURE

5.1 Risk assessment

"Risk management involves the analysis of scenarios about future events, their likelihood, impact and acceptability to stakeholders. This information is critical to issues such as the balancing of "program integrity" and "limited resources." Simply put, limitations on resources can adversely affect program integrity that involves the ability of organizations to ensure the continued achievement of results consistent with priorities. Organizations need modern management approaches including risk management to make judgments about maintaining program integrity. Competency in conducting intuitive and systematic analyses of the level of risk involved in organizational transition and new opportunities will support timely decision making and demonstrate due diligence across and down the organization. "(IALA Guideline 1018, Annex IV)

The elements that can be taken into consideration include those relating to vessel conditions, traffic conditions, navigational conditions, AtoN conditions, waterway conditions, immediate consequences and subsequent consequences.

The risk management process as described in the IALA Guideline 1018 comprises five steps that follow a standardized management or systems analysis approach:

1. Identify hazards;
2. Assess risks;
3. Specify risk control options;
4. Make a decision; and
5. Take action.

With this Guideline 1018 and the Rec. O-134, IALA outline a general description on risk management methodology and tools to assessing the risk in ports or restricted waterways, for marine Aids to Navigation (AtoN) including Vessel Traffic Services (VTS), compared with the risk level considered by administrations and stakeholders to be acceptable, so that all types of risks are effectively managed by AtoN authorities.

5.2 Simulation

Prior to implementing a new AtoN system or changing an existing one, Competent Authorities can use simulation techniques to assess the overall safety and effectiveness of these changes. The use of Geographic Information System (GIS) technology can improve efficiency of AtoN deployment and waterway layout which, with volume of traffic overlaid (e.g. taken from AIS data), can be used to assess risks and plan the disposition and type of AtoN to mitigate such risks and improve the provision of AtoN for all users. Having planned aids to navigation in this manner, the authority can use modern simulation tools where passage and combinations of various types of vessels can be simulated, in order to conduct a validation process, in consultation with appropriate stakeholders. To achieve a high level of realism in the simulations, GIS data can be integrated to the waterway models used in the simulator.

One of the purposes of simulation in relation to waterway design is to evaluate planning of placement and design of AtoN in a specific waterway, channel or port area. Other purposes could be e.g. ensuring sufficient channel width, channel depth, and optimal orientation and design of breakwaters as well as ensuring that the lay-out of a channel and port is suitable seen from a manoeuvring point of view.

Simulation offers a method to help ensure that AtoN are appropriate and cost effective. Sophisticated computer simulation techniques are becoming increasingly available, and they provide an excellent mechanism for decision making as follows:

- Generating 'what if' scenarios – feasibility studies;
- Obtain input to placement and design in consultation with stakeholders;
- Validation of final design and lay-out;
- Training in a variety of areas.

Simulating the placement and operation of AtoN by day and night, and under various conditions of visibility assists in ensuring that AtoN are effective and provided in a cost effective manner that suits the purpose of providing a predetermined level of safety. This is particularly important as aids to navigation become more sophisticated (synchronised and sequential lights, LED with flicker, and other new light characteristics).

Please see IALA Recommendation O-138 "on the Use of GIS and Simulation by Aids to Navigation Authorities" for further discussion on the use of simulation in waterway design and placement of AtoN. The recommendation includes a reference to a Guideline that amongst other outlines how to select the right simulation tool in relation to the objectives and expected outcome of the simulations.

5.3 Channel design - the hydraulic engineering aspect

Waterways planners, for instance hydraulic engineers and mariners, in the port and waterways authorities should consider the option of a significant contribution to the efficiency of major dredging projects and waterways maintenance by improving positioning accuracy and navigational accuracy due to proper use of Aids to Navigation. Thus in some cases the required channel width could be reduced and also the costs for major and maintenance dredging. There can be found some ideas regarding this issue in the PIANC Guide 'Approach Channels'.

Simulation can also be used - in interaction with AtoN planning - for waterway planning, to examine options for channel width, channel depth, orientation and design of breakwaters, lay-out of a channel and port, manoeuvring.

6 CONCLUSION

For the design of an AtoN system for an existing or a new designed fairway or channel, many considerations are necessary. The requirements can be defined in parameters as accuracy and reliability. They vary depending on the type of waterway, on the vessel traffic and on other risk factors. The design must be carried out regarding general requirements from different international bodies such as the IMO and IHO and under consideration of IALA documentation.

e-Navigation will in future integrate the information on visual AtoN for a fairway or a channel into the whole information available on the bridge of a ship and thus contribute to their optimized use. The efficiency of marking might increase and allow some optimization of the AtoN. However, this is subject to further development, because nowadays there are not so many ships with are equipped for the use of e-Navigation applications. The systematic approach for the design of AtoN systems is a first step in the direction towards integration in e-Navigation.

Continuous improvement of the marking principles and the available technology will help to save money and to protect the environment, e.g. by savings in energy consumption for operation and maintenance of AtoN.

In this Guideline some general knowledge on the perception of AtoN and general rules and procedures for AtoN design are given. It is shown that the interaction between buoy distance and size of the buoys must be observed. When regarding the achievable positioning accuracy of a ship in a fairway by means of buoys or (D)GNSS a reference to a new Japanese method can be used. However, also in this case, the practical experience of mariners and engineers with AtoN should not be neglected.

When planning the AtoN, in the framework of a bigger project, detailed risk assessment and simulation should be used.

IALA documentation is extensive and can provide considerable guidance and should especially be considered regarding the use of specific technologies, e.g. the use of marine lights.

ANNEX 1 RELEVANT IALA DOCUMENTATION

1 IALA AIDS TO NAVIGATION GUIDE (“NAVGUIDE”)

This document provides overall guidance, in particular chapters on AtoN and Risk Management

2 IALA RECOMMENDATIONS

- R 101 on Maritime Radar Beacons
- E-105 On the need to follow national and international standards
- E-110 for the Rhythmic Characters of Lights on Aids to Navigation
- E-111 for Port Traffic Signals
- E-112 for Leading Lights
- O-113 for the Marking of fixed bridges over navigable waters
- A-126 on the use of AIS in Marine Aids to Navigation Services
- O-130 on categorization and availability objectives for short range aids to navigation
- O-133 on Emergency Wreck Marking Buoy
- O-138 on the Use of GIS and Simulation by Aids to Navigation Authorities
- E-200-0 on Marine Signal Lights - Overview
- E-200-1 on Marine Signal Lights - Colours
- E-200-2 on Marine Signal Lights - Calculation, Definition and Notation of Luminous Range
- E-200-4 on Marine Signal Lights - Determination and Calculation of Effective Intensity
- E-200-5 on Marine Signal Lights - Estimation of the Performance of Optical Apparatus

3 IALA GUIDELINES

- 1010 on Racon range performance
- 1018 on Risk Management
- 1023 for the Design of Leading Lines
- 1033 on the Provision of Aids to Navigation for different classes of vessels, including high speed craft
- 1041 on Sector Lights
- 1046 on a Response Plan for the Marking of New Wrecks
- 1051 on the Provision of Aids to Navigation in Built-up Areas
- 1058 on the Use of Simulation as a Tool for Waterway Design and Aids to Navigation Planning
- 1061 on Light Application – Illumination of Structures

Other IALA Recommendations and Guidelines on VTS, AIS, Racons and DGPS should also be considered.

ANNEX 2 DRIFT DETECTION – JAPANESE METHOD

Extract from Japanese Method (contribution to Section 5 "Fairway Layout and Channel Width" to the Draft of the report of PIANC MARCOM Working Group 49 "Horizontal and vertical dimensions of channels").

5.3.2 Channel Classification and Channel Width Elements

Channel width can generally be assumed to consist of the following fundamental elements.

- Width of basic maneuvering lane: W_{mi} $\left(=W_m(\beta)+W_{my}+W_m(S)\right)$

where

$W_m(\beta)$: width needed against wind and current forces

W_{my} : width needed against yawing motion

$W_m(S)$: width needed for drift detection.

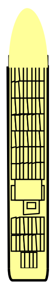
- Additional width needed against bank effect forces: W_{bi}
- Additional width needed against two-ship interaction forces in passing condition: W_c
- Additional width needed against two-ship interaction forces in overtaking condition: W_{ov}

It is noted that the total channel width may be obtained by summing up necessary elements mentioned above, not necessarily all, according to design purposes and detailed conditions for the subject channel.

5.3.1.3 Equipment and Systems of Navigation Aids

A ship sailing in a channel usually makes some amount of drift from its course line due to various causes together with external forces even if a ship handler does believe that his ship is running on the right way. Drift detection may be impossible when the drifting amount is small, but a ship handler can recognize a drift when a ship makes some considerable amount of lateral deviation from its course line as shown in **Fig.5.3.6**. The drifting amount which a ship handler can detect depends on the type of equipment and systems of navigation aids together with the way in which they are utilized. It should be noted that the drifting quantity to be detected plays an important role in the design of channel width. A narrower width may generally be adopted for a channel with a higher level of equipment and systems where the drift detection can be made more easily. Moreover a ship of larger size may be allowed to sail by installing higher level of equipment and systems even in an existing channel which can not be widened due to some topographical limitations.

Figure 5.3.6 Undetectable zone



As for the drift detection, in general, three types of equipment and systems of navigation aids are available as follows.

- Drift detection by observing light buoys ahead on both sides of channel with the naked eye.
- Drift detection by observing light buoys ahead on both sides of channel with RADAR.

- Drift detection by GPS or D-GPS.

The channel width needed for the drift detection can be estimated with a detectable deviation from a course line with the use of the equipment and systems of navigation aids as the above in each channel to be designed.

5.3.5 Width Needed for Drift Detection

As for the drift detection means by observing light buoys ahead on both sides of channel either with the naked eye or with RADAR, the channel width needed for the drift detection may be estimated on the basis of an angle made by two lines from a ship to two buoys ahead on both sides θ shown in **Fig.5.3.12**, which is defined as

$$\theta = 2\arctan\left(\frac{W_{buoy}}{2L_F}\right) \qquad (5.3.7)$$

where

W_{buoy} : clearance between two buoys

L_F : distance along channel center line form ship to light buoys ahead.

In Eq.(5.3.7), amounts of W_{buoy} and L_F are given in the following manner according to the subject channel of a newly designed channel or an existing channel.

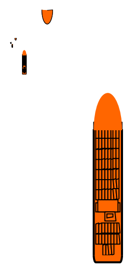


Figure 5.3.12 Detectable manoeuvring lane for light buoys on the both sides of fairway

1) Newly designed channel
In this case, W_{buoy} is to be the channel width finally determined which is unknown in the beginning of channel width design. Therefore an iteration technique as described in 5.3.6 is employed where assuming some amount of W_{buoy} iterations are made until computed value is to be finally identical to the assumed one. Amounts of L_F may be set empirically to be $7L_{OA}$ for a one-way channel and $(3.5-7)L_{OA}$ for a both-way channel. Moreover, L_F may be set with a value of $(0.5-1.0)$ times of the distance between two successive buoys along a channel when buoy locations are given.

2) Existing channel

W_{buoy} is set with a clearance between two buoys on both sides of the channel, and L_F is set with a distance between two successive buoys along a channel. However, when the distance between two successive buoys is thought to be somewhat long or more, L_F may be set, in a similar way to the case of newly designed channel, to be $7L_{OA}$ for a one-way channel and $(3.5-7)L_{OA}$ for a both-way channel.

5.3.5.1 Drift Detection by Observing Light Buoys with Naked Eyes

As shown in **Fig.5.3.12**, an angle made by two lines of a channel center line and a line from a ship to a midpoint of two buoys is denoted with α. A concept of the maximum deviation is introduced which is defined that almost all ship handlers are able to recognize a drift from its course line. Corresponding to this maximum deviation, the angle of α is denoted with $\alpha_{\max}$ as shown in **Fig.5.3.12**. Making use of the above concept of $\alpha_{\max}$, the channel width needed for the drift detection by observing light buoys with the naked eye can be calculated by

$$W_m(\alpha) = L_F \tan(\alpha_{\max}) \qquad (5.3.8)$$

where $\alpha_{\max}$ may practically be estimated with an empirical formula developed on the basis of statistical data by full scale experiments, which is given by

$$\alpha_{\max} = 0.00176\theta^2 + 0.008\theta + 2.21372. \qquad (5.3.9)$$

5.3.5.2 Drift Detection by Observing Light Buoys with RADAR

The channel width needed for the drift detection by observing light buoys with RADAR can be calculated by

$$W_m(R) = \frac{W_{buoy}}{\sin\theta}\sin\gamma \qquad (5.3.10)$$

where

γ : error of direction observation by RADAR.

The following expressions are easily written from Eq.(5.3.10) for two cases of γ = 2deg. and 1 deg. respectively.

$$W_m(R) = 0.0349\frac{W_{buoy}}{\sin\theta} \quad (\gamma : 2 \text{ deg.}) \qquad (5.3.11)$$

$$W_m(R) = 0.0175\frac{W_{buoy}}{\sin\theta} \quad (\gamma : 1 \text{ deg.}). \qquad (5.3.12)$$

5.3.5.3 Drift Detection by GPS

In ship maneuvering operation with the utilization of GPS, a ship handler may judge and recognize the ship position by an image of GPS information displayed on an electric chart. Although image information on the electric chart is sufficiently accurate, the drift detection is made solely by perceiving a ship movement on the display with the naked eye, and some amount of perception error should be taken into account. As for the drift detection means by GPS, an assumption is made for the above perception error to be a half of ship breadth. In addition, the margin of error for GPS information error is assumed to be 30 meters for a usual GPS and none for a D-GPS. Therefore the channel width needed for the drift detection by GPS and G-DPS can be calculated by the following equations respectively.

$$W_m(GPS) = 0.5B + 30 \quad \text{(unit: meter)} \qquad (5.3.13)$$

$$W_m(D - GPS) = 0.5B \quad \text{(unit: meter).} \qquad (5.3.14)$$

In addition, it is noted that the channel width for GPS should be designed by carefully taking trouble risks on GPS itself and GPS-related equipment as well into consideration.

References:

[1] Ohtsu,K., Yoshimura,Y., Hirano,M., Tsugane,M.and Takahashi,H.: Design standard for fairway in next generation. Asia Navigation Conference 2006, No.26, 2006.

[2] The Japan Port and Harbour Association: Technical Standards and Commentaries of Port and Harbour Facilities in Japan,2007.(in Japanese)

ANNEX 3 AtoN DESIGN FOR THE RIO DE LA PLATA NAVIGATION CHANNEL

The Rio de La Plata Navigation Channel is a partly straight and partly curved channel with buoys from a position of 129.1 miles seawards of the harbour entrance of Buenos Aires.

More data can be seen on the following chart.

1 SOME BASIC DATA

Waterway in analysis	
Length:	63.8 M
Width:	100 m (one way channel) (there is a two way channel sector of 160 m)
Design Depth:	34 feet
Tidal range	0,60 m

2 THE VESSEL TRAFFIC

Total Traffic in the Area in 2006: including	7.760 vessels
Containerships:	1.726
Bulk Carriers:	3.134
General cargo:	962
Oil Tanker:	1.386
Other:	552

3 MAXIMUM SIZE OF VESSELS DIMENSIONS:

	Length BP	Beam	Design Draught
Containership	261 m	40 m	41 feet
Bulkcarrier	260 m	42 m	42 feet
Tanker	241 m	32,2 m	49 feet

4 AIDS TO NAVIGATION

The buoyage system is designed as “paired buoys” with the following parameters:

Buoy separation distance	average 3000 m (max 5.000 m, min 1.100 m)
Buoy types	Floating buoys and Spar Buoys
Floating Buoy size above water level	4 m
Spar Buoys size above water level:	8 m

Additionally there are the following AtoN:

DGPS coverage (on demand- private service)

VTS and AIS control by Prefectura Naval Argentina (National Coast Guard)

Mandatory Pilotage services

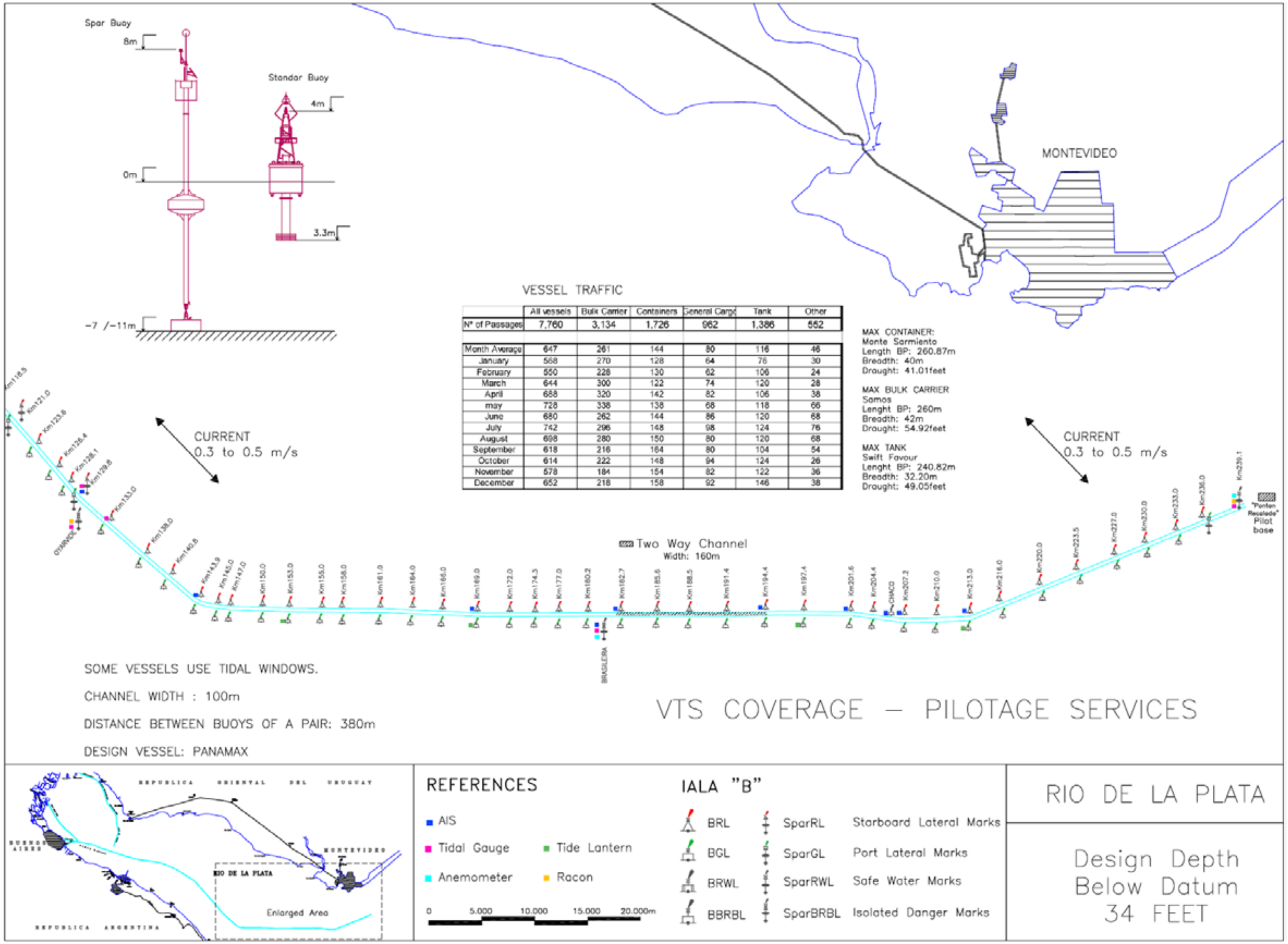


Figure 1   AtoN design on the Rio de la Plata

ANNEX 4 ATON DESIGN FINLAND

1 MUSSALO

FAIRWAY DATA Alignment and buoyage: The channel starts SW of Kotka Lighthouse and runs in a NE direction. E of the edge mark Kaakkoniemi it turns northwards towards the Deep Harbour of Kotka. Length 51 km/28 nm. 5 navigation lines, marked by boards and sector lights. Cardinal marks in the channel, lateral marks in the harbour. Lit. Dimensions: Design vessel: bulk carrier 125 000 DWT, l = 300 m, b = 48 m, t = 15.3 m. Authorised draught 15.3 m, safe clearance depths (MW 90) 18.4 m, along the navigation line in the harbour 17.5 m. Minimum width 200 m. Anchorage areas etc.: Anchorage NE of Kaunissaari, close to crossroads. Safe clearance depth - 18.4 m.
NAVIGABILITY Navigational conditions: The approach as far as the island Viikarinsaari consists of open sea, unsheltered against E–S–SW winds. Navigation may be hampered by strong winds and sea state. The channel is at its narrowest at the edge mark Elo 2, where it is only 510 m wide. Along the navigation line in the harbour the width is 200 m. RECOMMENDATIONS (channel) Speed: Ships sailing at maximum draught should take the squat effect into account; design speed 16.5 knots (Sc 18.4) in the approach, 13 knots (Sc 17.5 m) in the harbour.
TRAFFIC SERVICE Pilotage: Pilot order, tel. +358 204 48 5604. Pilot boarding position 60°07.49\, 26°29.65\. Pilotage distance 25 nm. VTS: Kotka VTS, VHF Channel 67. Tugs: Provided by Alfons Håkans Ltd. Ordered by pilot, if required.
PORT Quays: A Quay: length 609 m, safe clearance depth 15.0..17.5 m; B Quay: length 500 m, safe clearance depth 11.7 m; C Quay: length 936 m, safe clearance depth 11.7 m; Liquid Bulk Terminal, berth N 1: length 69 m, safe clearance depth 15.0 m; Liquid Bulk Terminal, berth N 2: length 60 m, safe clearance depth 11.5 m. Cargo handling: A Quay – four cranes (40 t), B Quay – two cranes (40 t) and a mobile crane, C Quay – four cranes (50 t). Harbour basin: Speed of vessel to be regulated to ensure that no harm or damage is caused.
CONTACTS VTS: Kotka VTS tel. +358 204 48 5604 fax +358 204 48 5600 Port: Port of Kotka tel. +358 5 2344 280 fax +358 5 2181 375

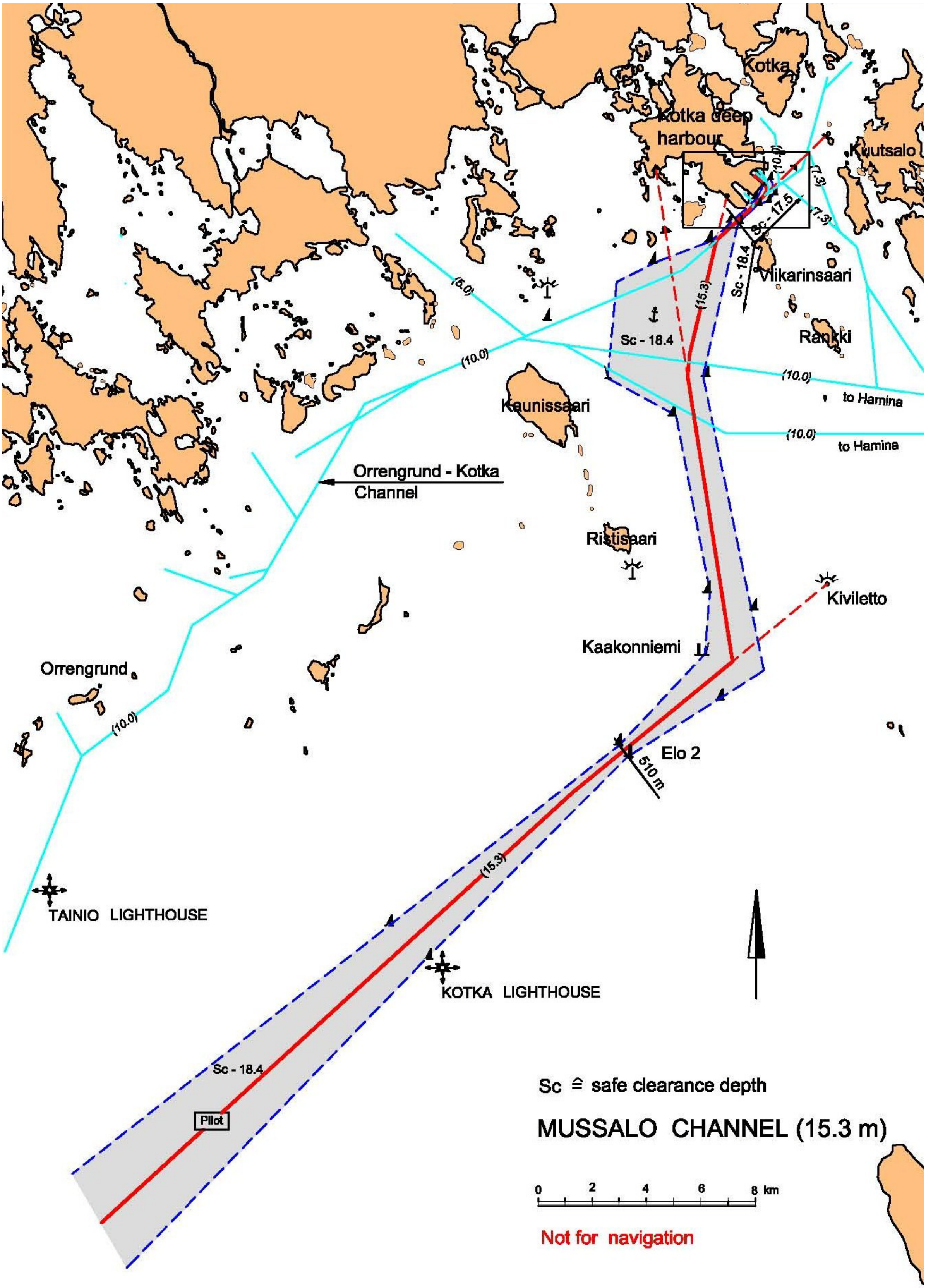


Figure 2 Mussalo Channel

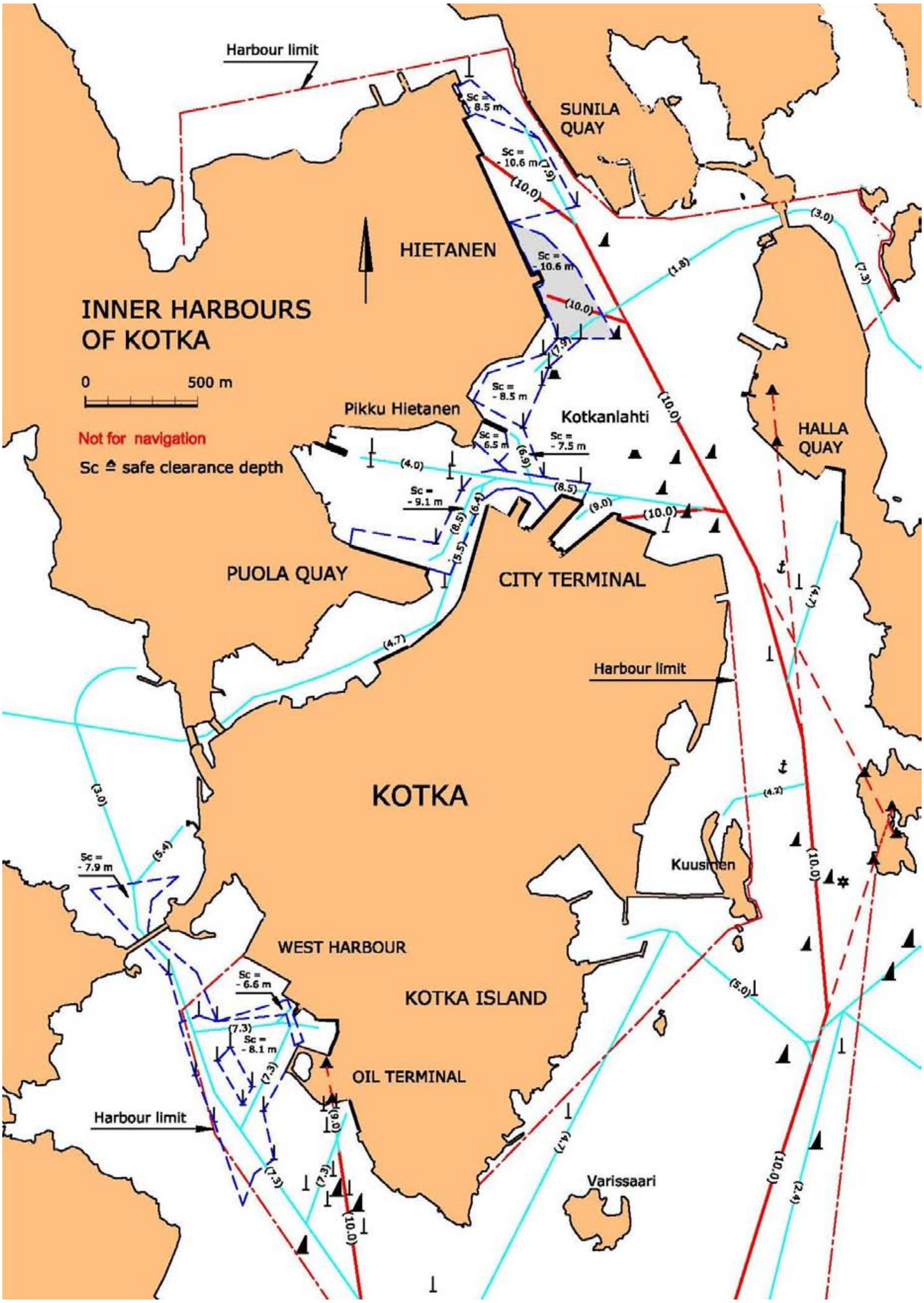


Figure 3 Kotka inner harbours

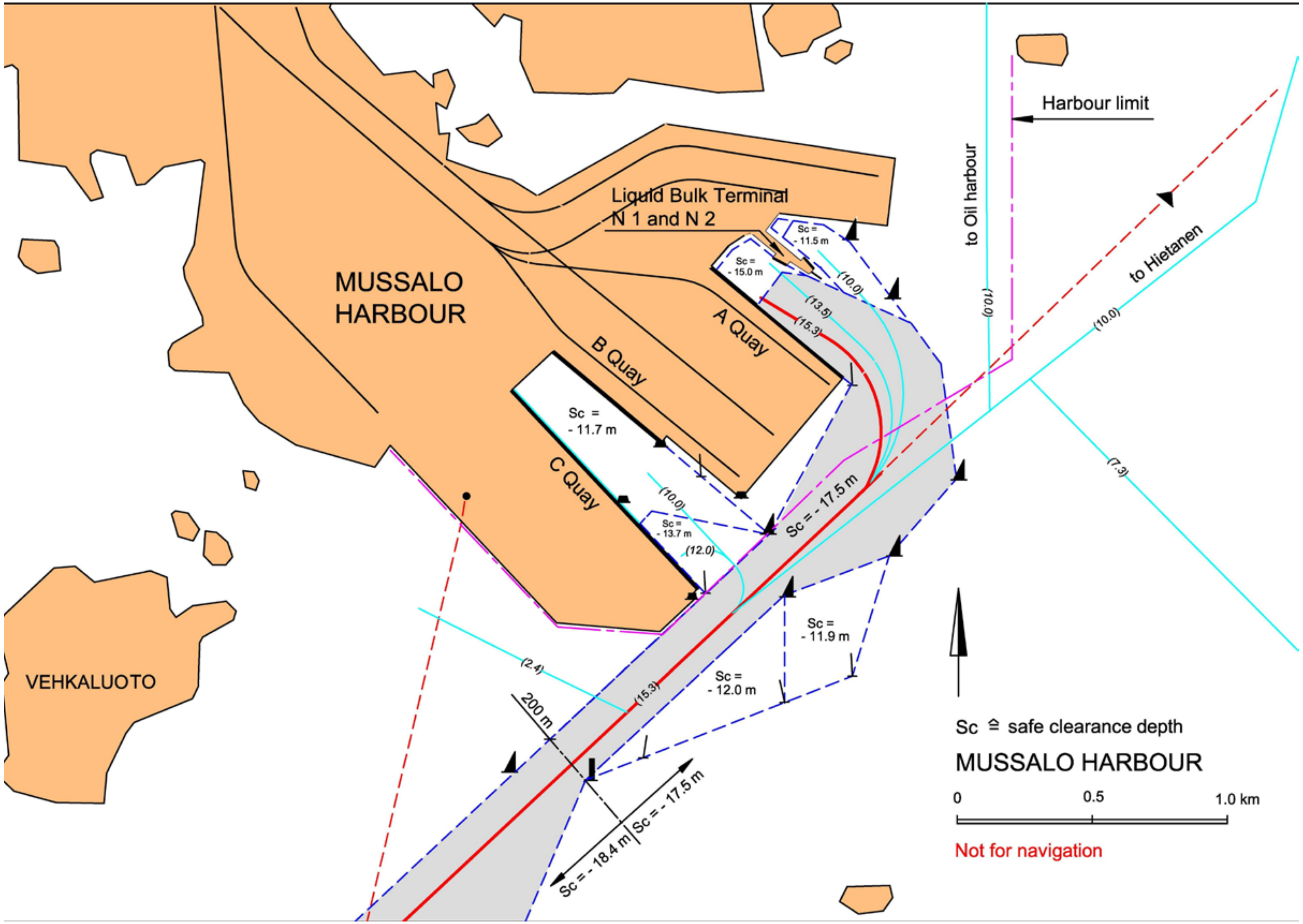


Figure 4 Mussalo Harbour

2 RAUMA

2.1 Rauma Channel

CHANNEL DATA

Alignment and buoyage: V of Rauma Lighthouse – port. Four lines. Length approx. 26 km/14 nautical miles. Lateral marks. Lit.

Dimensions: Design ship: Ro-Ro ship, L = 210 m, B = 30 m, T = 10.0 m. Maximum authorised draught 10.0 m, safe clearance depth (MW95) in the outer channel -12.0 m, in the inner channel -11.5 m. Minimum width 120 m, in the passage of Kovankivet 160 m; minimum bend radius 1000 m; design speed in dredged passages 12 knots.

Anchorage and other special areas: In the outer channel, anchorage W of Rauma Lighthouse; beware of cable S of lighthouse. In the inner channel, anchorage and passage either in the widened area N of Rihtniemi or SW of Iso Järviluoto, approx. 1.5 km before arrival into port.

NAVIGABILITY

Navigational conditions: The outer channel to Rihtniemi is unsheltered and open to S-W-N winds. From Rihtniemi on, the channel continues as a narrow and densely marked channel, sheltered by isles, islands and mainland. Cross currents, which make the manoeuvring of large vessels more difficult, may occur when navigating the Urmluoto line in the passage of Kovankivet. Strong side winds also aggravate the side drift.

Ice conditions: In winter ice fields tend to move in the channel, outside Hylkikarta. Ice movement may cause buoys to be pressed beneath the surface and their lighting devices may be damaged.

OPERATIONAL RECOMMENDATIONS (channel and harbour)

Wind: Max. speed of drifting wind gusts 18 m/s in daytime and 15 m/s at night. Limits lower for Ro-Ro ships and ships in ballast. Max. wind gusts 11 m/s for ships in ballast, larger than the design ship. Drifting wind means a wind which differs from the Urmluoto line by more than 30°. Pilotage is discontinued when the wind speed exceeds 20 m/s.

Visibility: The Urmluoto lines should be visible at night.

Ship-specific recommendations: Vessels larger than the design ship and vessels with poor manoeuvrability are piloted only in daytime.

New authorised channel draught practice applied in the channel as from July 15th, 2005 (NtM 17/2005, 20.6.2005).

TRAFFIC SERVICE

Pilotage: Pilot order, tel. +358 204 48 6645. Pilot boarding position 61°07,5', 21°10,4'. Pilotage distance 10 nautical miles.

VTS: West Coast VTS, Channel 67

PORT

Quays: Petäjäs: length 445 m, safe clearance depth -11.0 m; Iso-Hakuni: 6 berths alongside/Ro-Ro berths, safe clearance depth -11.0 m; Oil harbour: safe clearance depth -9.15 m; Central harbour: length 665 m, Ro-Ro berth, safe clearance depth -6.70..-7.30 m; Laitsaari: length 246 m, safe clearance depth - 9.05 m; Inner harbour: 2 chemical piers, safe clearance depth -5.10..-7.05 m.

Cargo handling: Petäjäs: cranes 40 t, 45 t and 16 t, pneumatic grain suction device; Iso-Hakuni: cranes and reach stackers; Oil harbour: piping, pumping power 1000 t; Central harbour: crane 6 t. Vehicle mounted cranes (50 and 100 t) used in all parts of the port.

CONTACT INFORMATION

VTS: West Coast VTS, Pori	Tel. +358 204 48 6645 Fax +358 204 48 6646
Port: Port of Rauma, Rauma	Tel. +358 2 83 44 710 Fax +358 2 822 63 69 Port Director Hannu Asumalahti

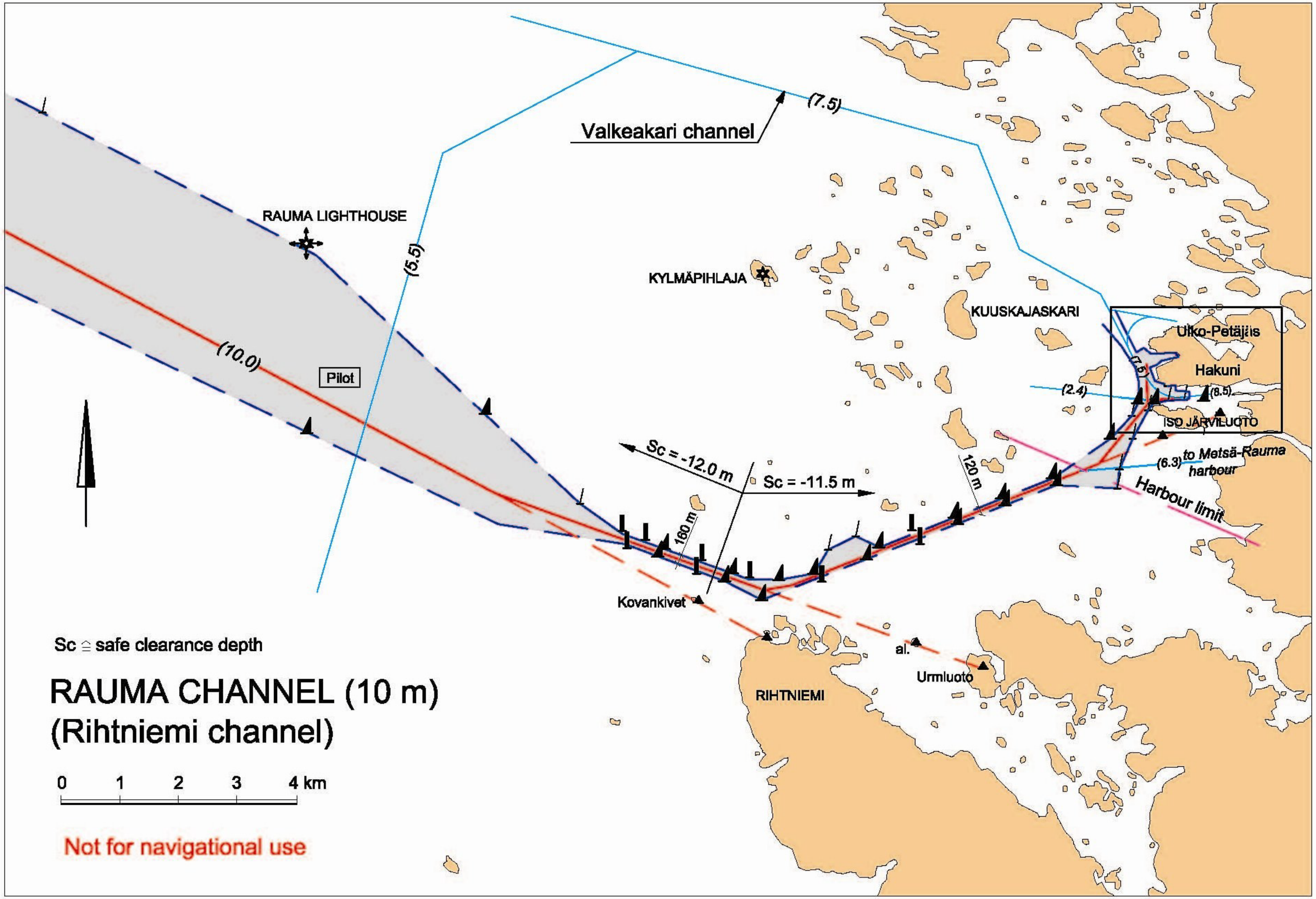


Figure 5 Rauma Channel

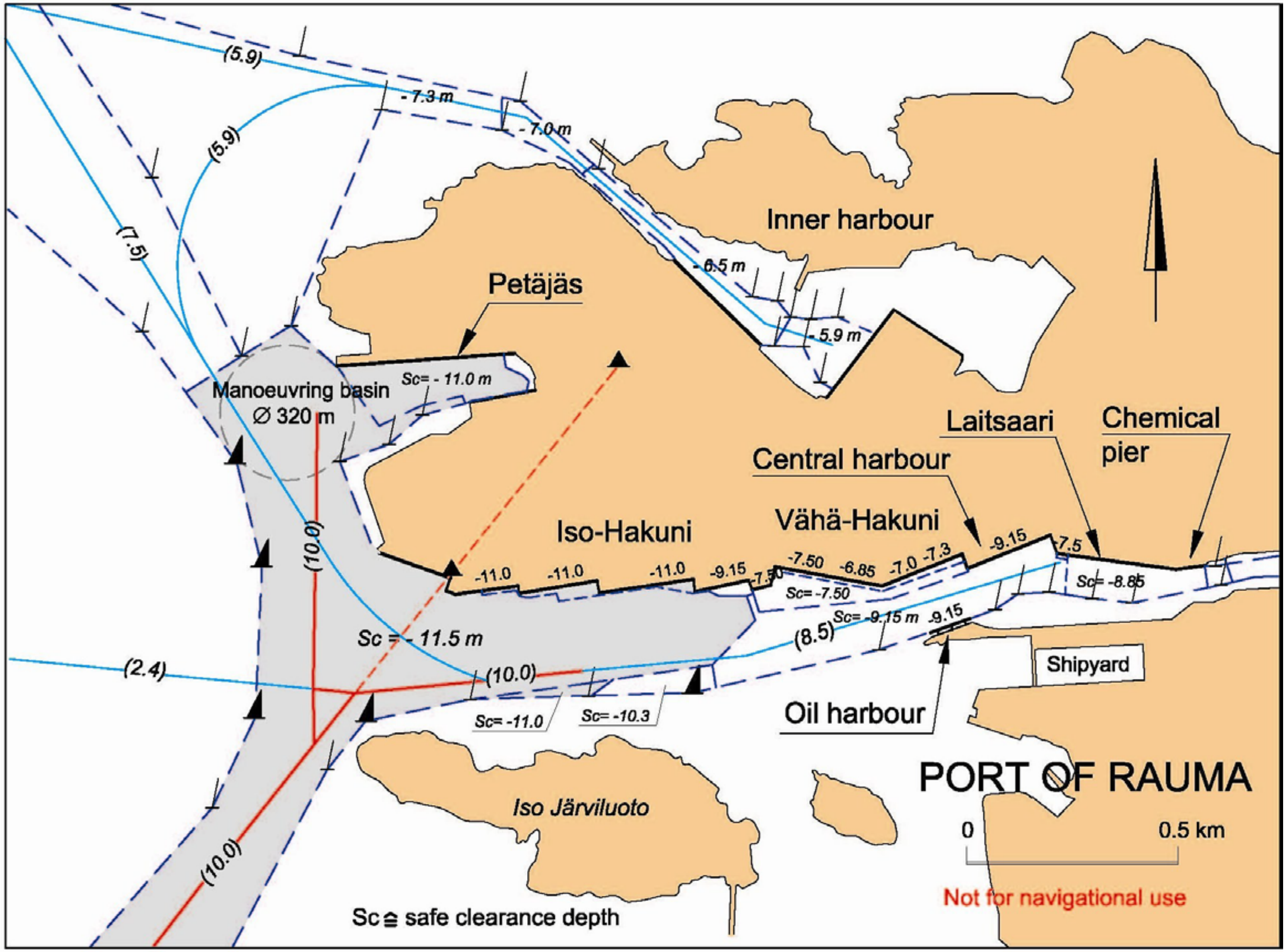


Figure 6 Port of Rauma

ANNEX 5 ATON DESIGN FOR LE HAVRE AND PORT 2000, FRANCE

Le Havre (1st port in France) is a deep-water port with day and night access for the largest container carriers (10,000 TEUs and more),

Located at the south end of the port, the facilities of the Le Havre oil port are made up of 8 specialised berths, including two for the reception of 230- 280,000dwt tankers.

Recently, a new external port (Port 2000 terminals) able to welcome and rapidly handle the largest container carriers in the world in optimal logistic and nautical conditions has been created.

The area is also one of the major places for pleasure and fishing craft in the region.

1 THE VESSEL TRAFFIC (PER YEAR)

Total traffic flow:	80 million tons
Container traffic flow:	2.5 million TEUs
Oil:	40 millions tons
Roll-on/roll-off services:	472 000 vehicles
Passengers:	355 000
About 7 500 vessel calls	

2 MAIN WATERWAY IN ANALYSIS

Length:	12 nautical milles from the landfall buoy to the main entrance
Width:	450 metres (two-ways channel)

3 PORT 2000 WATERWAY

Lenght:	3 nautical milles
Width:	350 metres (two-ways channel for vessels up to 55 m beam)
Design Depth:	15 meters + tide
Tidal range:	8,00 metres

4 AIDS TO NAVIGATION

The buoyage system is designed as “paired buoys” with the following parameters:

- Buoy separation distance average 1400 m (max 2 000 m in the entrance , minimum 1.000 m at Port 2000);
- Buoy types: 18 Floating buoys and 3 fixed beacons (LH 17, 18 & 21) for the marking of the effective width of the fairway (EWF);
- Floating Buoy size above water level: 3,5 m with a luminous range of 3 miles by night;
- Beacons size above the highest water level: 5 m.

All the lights are synchronised by paired buoys and sequenced (timing method GPS)

Additionally there are the following AtoN:

- Leading lines covering the main channel up to the landfall buoy (front light height 36 meters and range 25 Miles by night rear light height 78meters and range 25 miles by night) operated night and day;
- A very precise PEL Sector light with oscillating boundary for the Port 2000 channel (5 sectors in 5°) operated night and day;
- Various Sector lights in the port;
- DGPS coverage;

- VTS and AIS control by The port of Le Havre Authority;
- AIS Aton on the landfall buoy;
- Mandatory pilotage services.

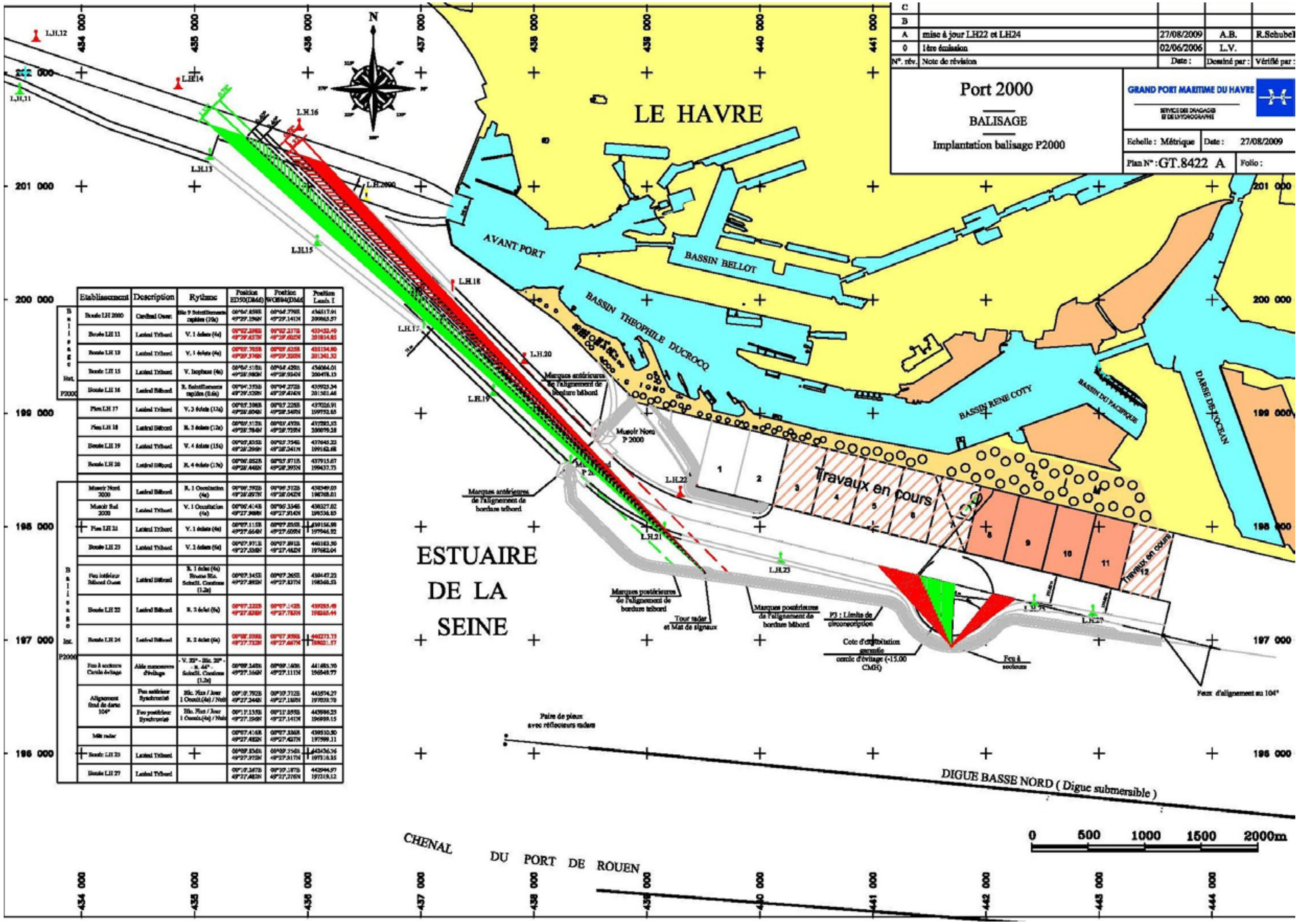


Figure 7 Port of Le Havre

ANNEX 6 ATON DESIGN FOR THE 'SEEKANAL ROSTOCK'

The Seekanal Rostock is a straight channel with buoys from a position 6 miles seawards of the harbour entrance of Rostock/ Warnemünde leading into the mouth of the river Warnow with following design data:

1 WATERWAY

Outer part:

Length:	5.7 M
Width:	225 … 120 m
Depth:	≥ 14,5 m

Inner part:

Length:	1.5 M
Width:	120 m
Depth:	≥ 14,5 m

2 VESSEL TRAFFIC

Total Traffic in the Area in 2006: including	25.200 vessels
Passenger- and Ro/Ro Ferries:	13.000
Cargo vessels:	4.500
Oil Tanker:	1.800

The area is also one of the major places for pleasure and fishing craft in the region.

3 VESSELS DIMENSIONS

Terms for two lane traffic passing 120 m width area:

1 Beam < 40 m – sum of both passing vessels and

Draught < 8.5 m

2 If wind < 6 Bft and both captains accept a two lane traffic passing and

Beam < 60 m – sum of both passing vessels beams and

Draught < 8.5 m

3 vessel with draft > 8,5 m and using the leading line

X = 60 m – 0.5 * beam of this vessel

MAX beam of the meeting vessel X/5 (opposite direction)

All other vessels have to pass by "one lane traffic" under the responsibility of the captain with assistance of VTS.

4 MAXIMUM SIZE OF VESSEL IN 'SEEKANAL ROSTOCK'

Length	296 m
Beam	32 m
Draft	10.5 m

The channel is narrow in relation to the vessels dimensions.

5 AIDS TO NAVIGATION

The buoyage system is designed as “paired buoys” with the following parameters:

Buoy separation distance	Outer Part	1500 … 1000 m
	Inner Part	600 m

Buoy type Outer Part: deep water light buoy ‘LT 81’, steel mooring chains

Inner Part: hinge beacon with steel tube, with a minimal swinging circle radius, synchronised lights

Buoy size above water level	Outer Part:	2.5 x 5 m
	Inner Part:	1 x 4 m

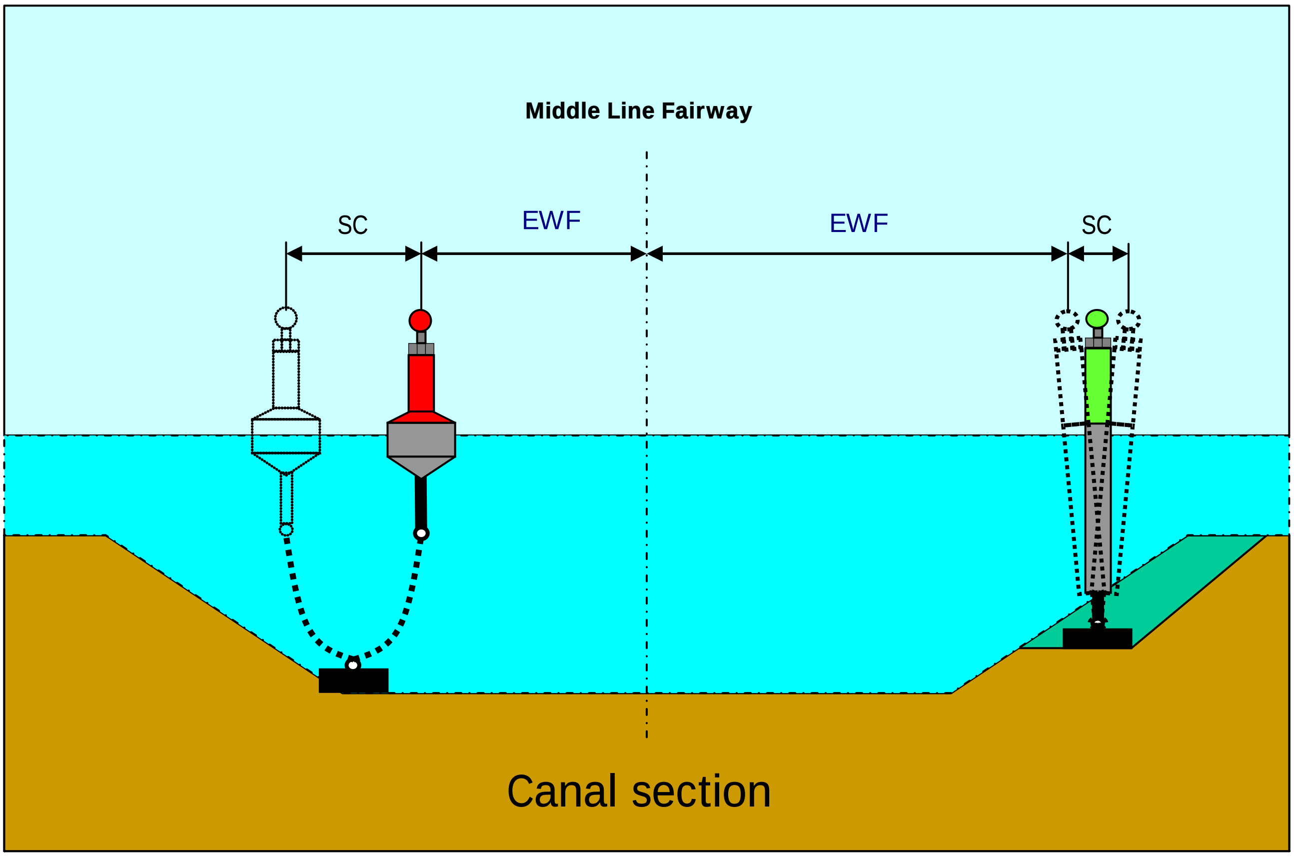


Figure 8 Example for different types of floating aids on the same fairway : Deep Water Buoy and hinged Beacon

Notes

1 EWF = effective width of fairway

2 SC = swinging circle

The inner part of the canal is designed with Hinge Beacons because they have a smaller swinging circle and thus cause less reduction of the effective width of fairway.

Additionally there are the following AtoN:

- Leading Light over 4 miles, DGPS coverage, VTS coverage, AIS coverage;
- The Leading Lights are synchronized (same character for front light and rear light).

To avoid misleading information in case of failure of one of the lights by mirroring a light with the same character on the water surface and be interpreted as a front light in the wrong place, in case of failure of either the front light or the rear light the other one will also be switched off. This is ensured by connecting the remote control devices of the front light and the rear light.

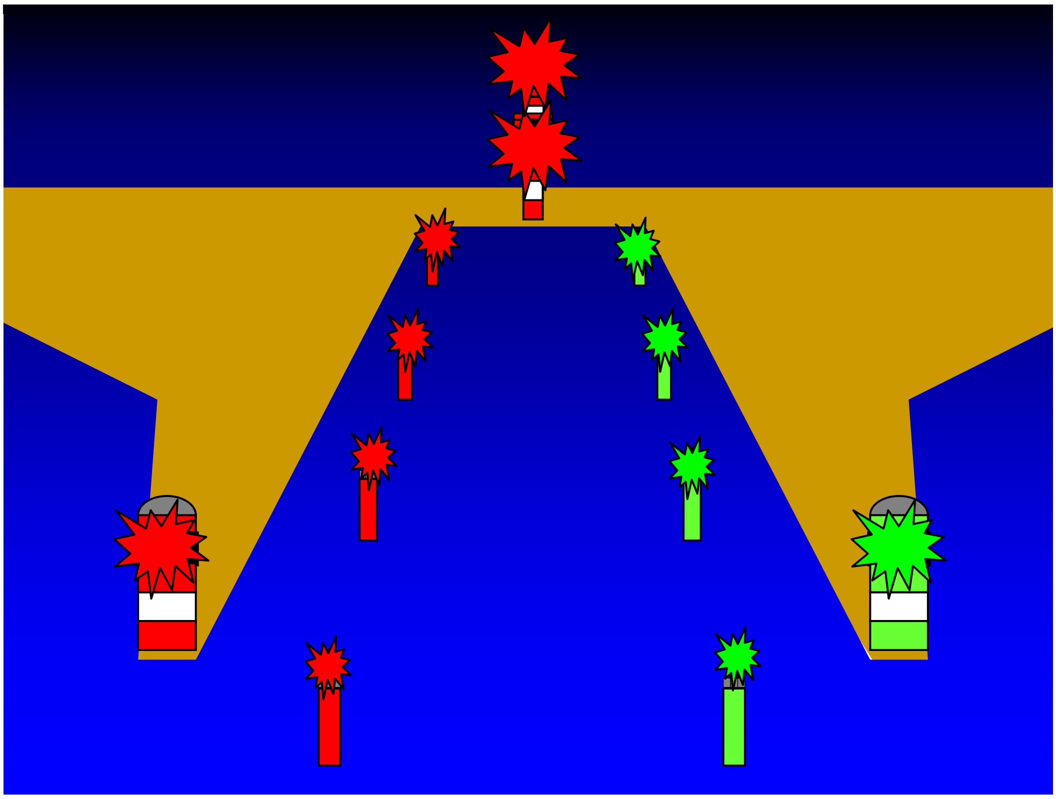


Figure 9 Example for synchronized AtoN : Inner part of 'Seekanal Rostock'

The Leading Lights are synchronized with the mole lights and the buoys as shown in Table 1.

Table 1 Synchronization of AtoN

	1s	2s	3s	4s	Flash code
Leading lights	X	On	On	On	Occ. 4s
Mole lights at canal entrance	X	X	On	On	Iso. 4s
Articulated lights on buoys	X	X	X	On	Fl. 4s

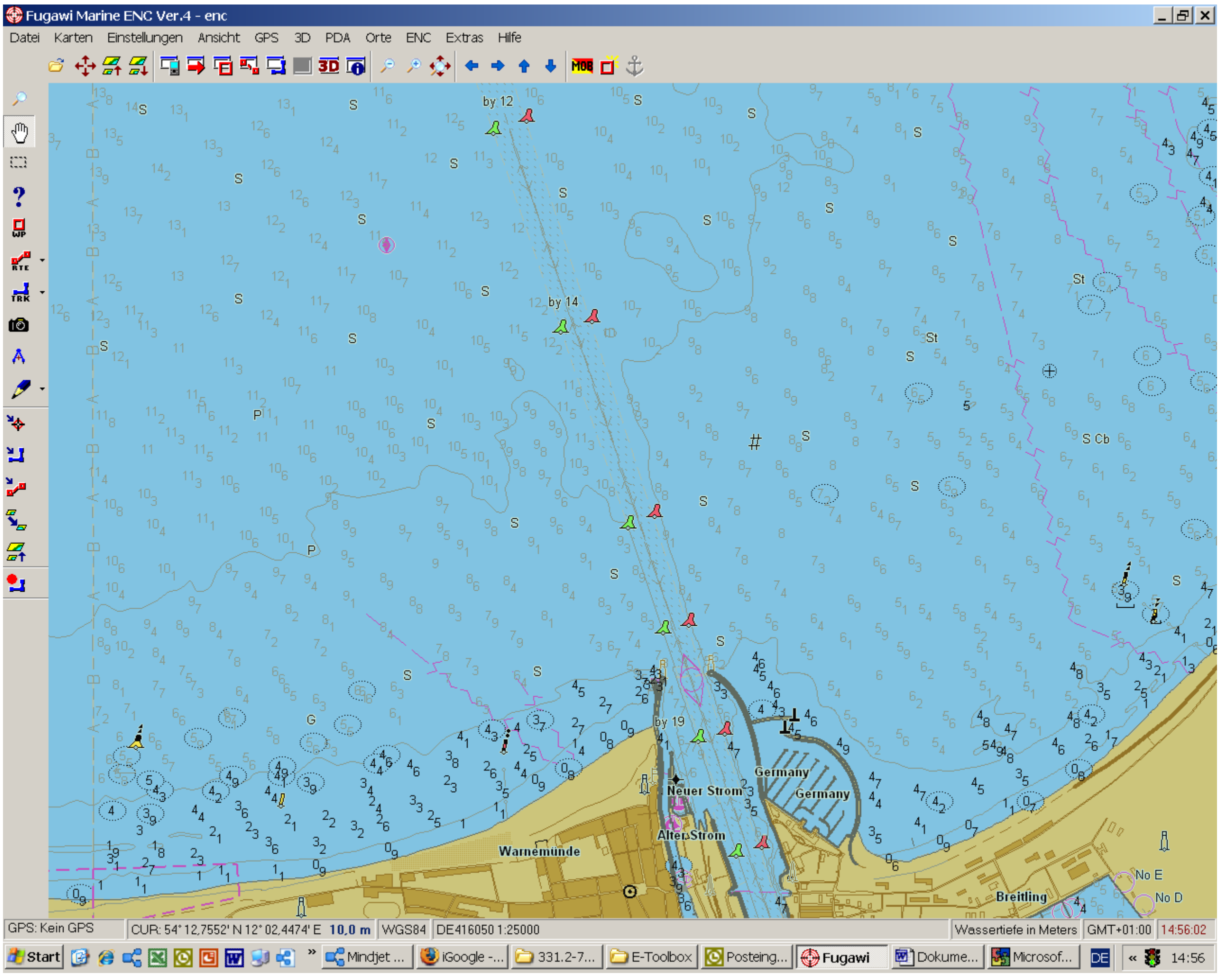


Figure 10 Sea Chart of a part of the outer and inner channel 'Seekanal Rostock'

ANNEX 7 ATON DESIGN FOR THE APPROACH TO MALMÖ, SWEDEN

The Port of Malmö is located on the west coast of the southern part of Sweden. The port is approached from the sea through a channel marked by buoys, light buoys, lights, and beacon, on the alignment of leading lights. The channel layout is based on a simulation that was carried out in November 2006 in order to evaluate risk and conditions in terms of ships types and sizes, tug capacity, port and channel layout.

Waterway

Outer part
Length: 3,9 nm
Width: The channel has been widened to 162 m in full length.
Depth: 13,5 m

Inner part
Length: 0,6 nm
Width:
Depth: 13,5 m

Vessel Traffic
Total Traffic in 2008: 1102 arr/dep

Vessel Dimensions: 260 x 40 x 12,5 m

Aids to Navigation

The buoyage system is designed as “paired buoys”.

Buoy separation distance Outer part: 0,3 nm
Inner part: 0,1 nm

All buoys in the channel have synchronized lights with the same frequency at the same time. The light rhythm for the buoys in the channel is Q (0,2s + (0,8s) = 1s) on both sides of the channel. The buoys are of type “S-7” (light is 4 m above surface of water). The placement and the synchronised flash on the buoys in the layout is an advantage for safe navigation during darkness as it is much easier to see as the darkness period is very short.

The position of the leading light has been optimized according to new channel layout and the blink rate has changed to Oc 6s. There are two lights in line, marking the sides of the channel with the light rhythm Q. The quality of the centre line has improved with a modern high visible light. This improves safety for navigation in restricted visibility.

These improvements have made navigation in darkness much safer.

Additionally

DGPS coverage, VTS, Mandatory pilotage services etc.

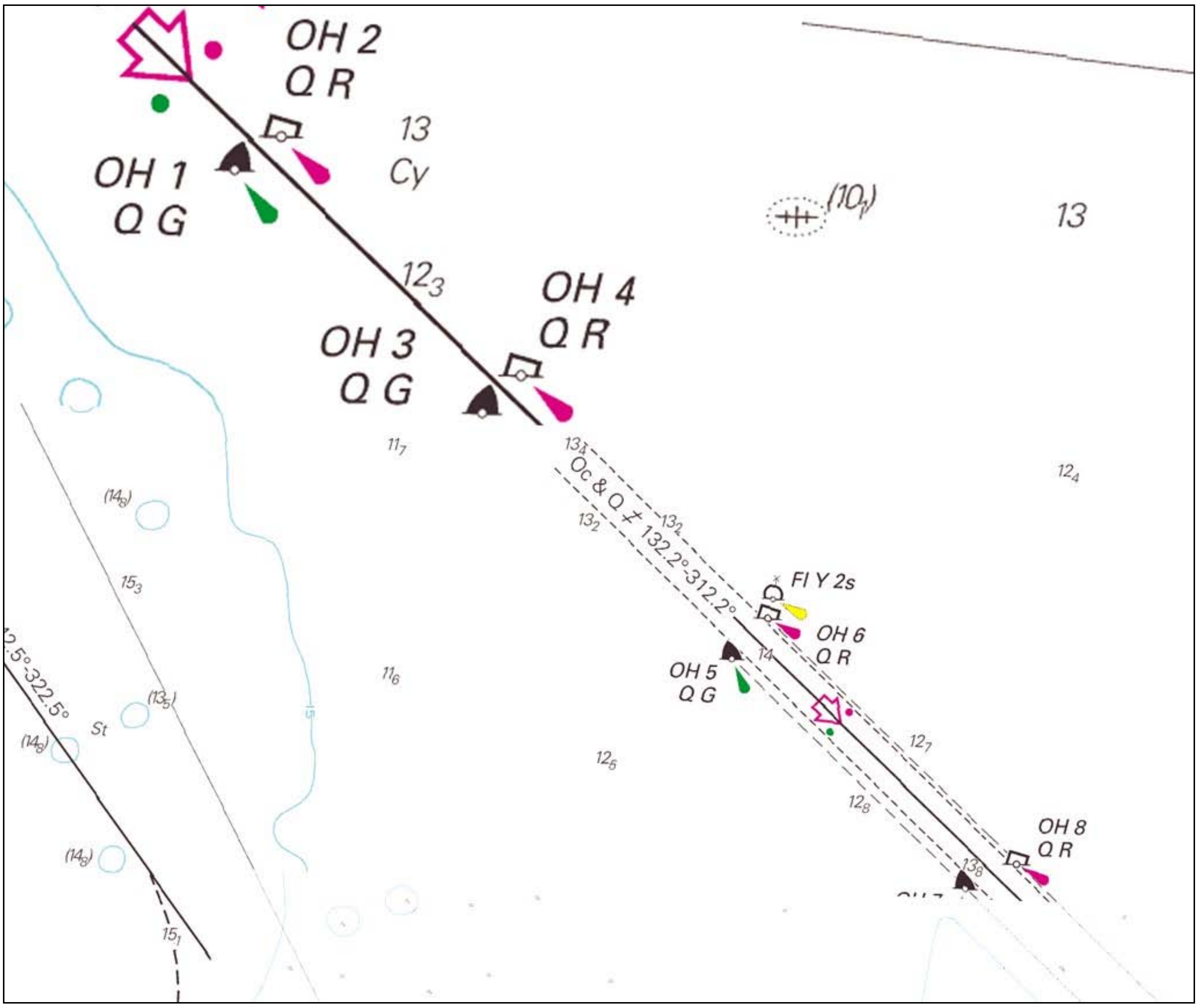


Figure 11 Outer part of channel - Malmo

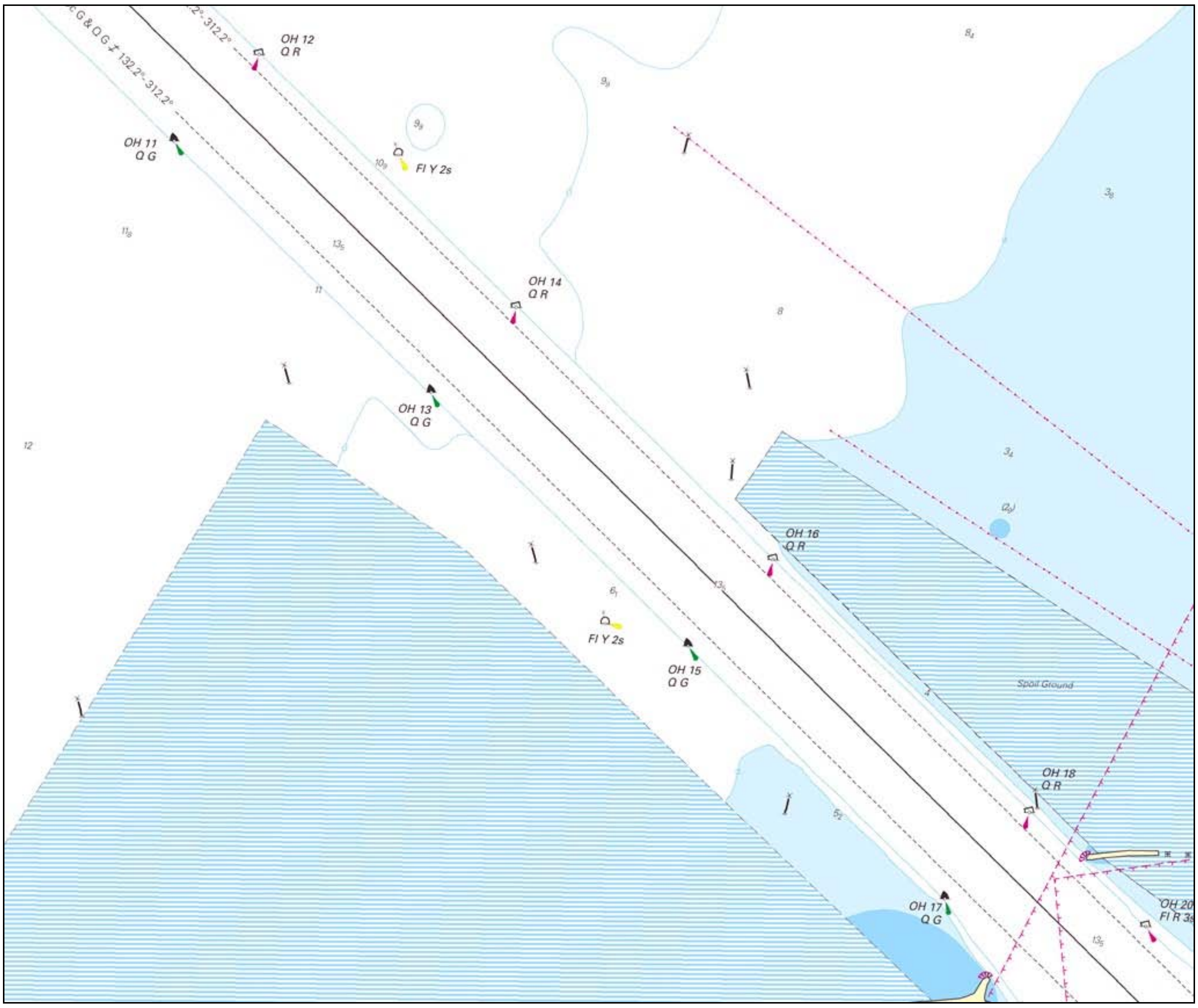


Figure 12 Inner part of channel - Malmo

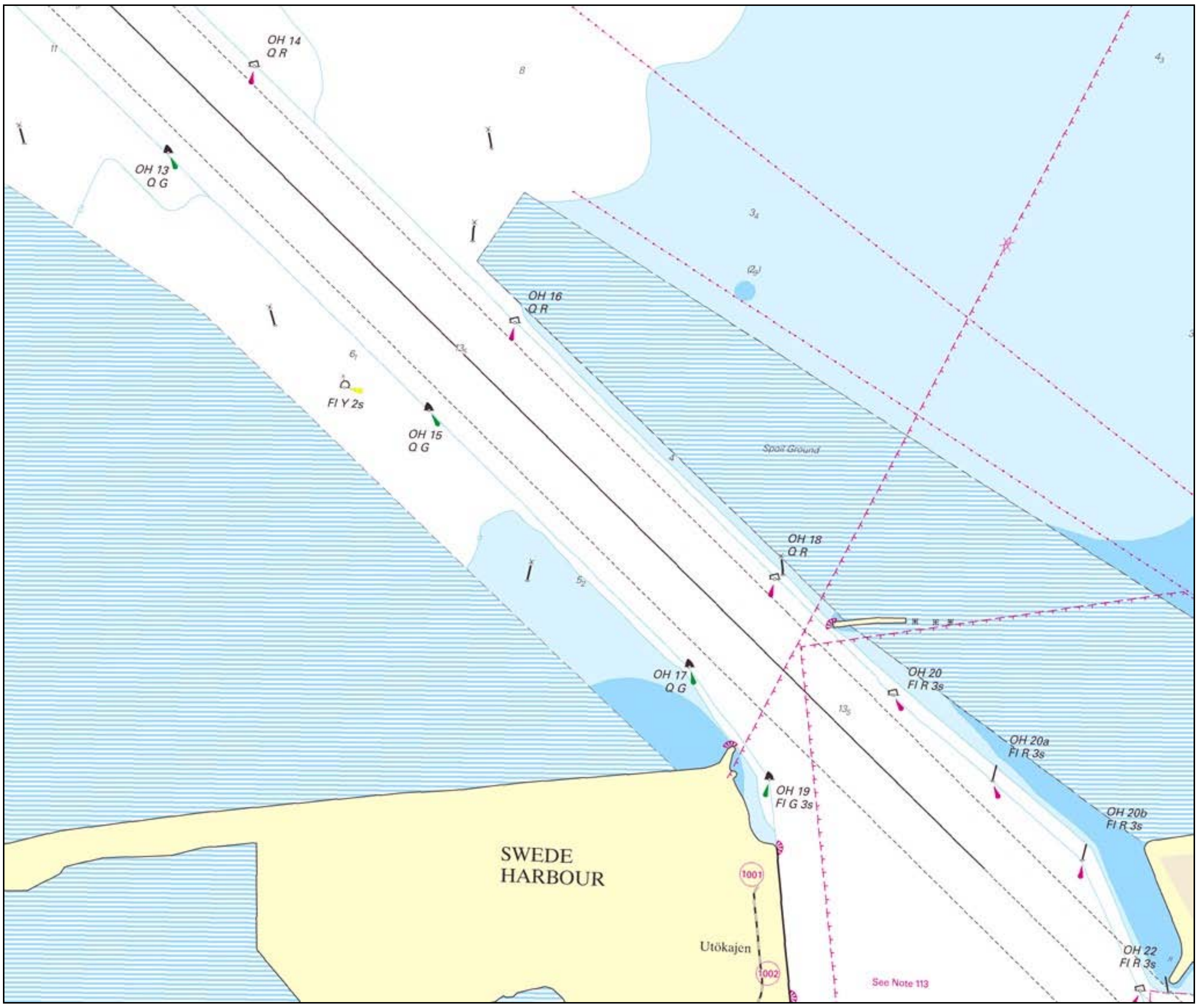


Figure 13 Entrance to Malmo Harbour

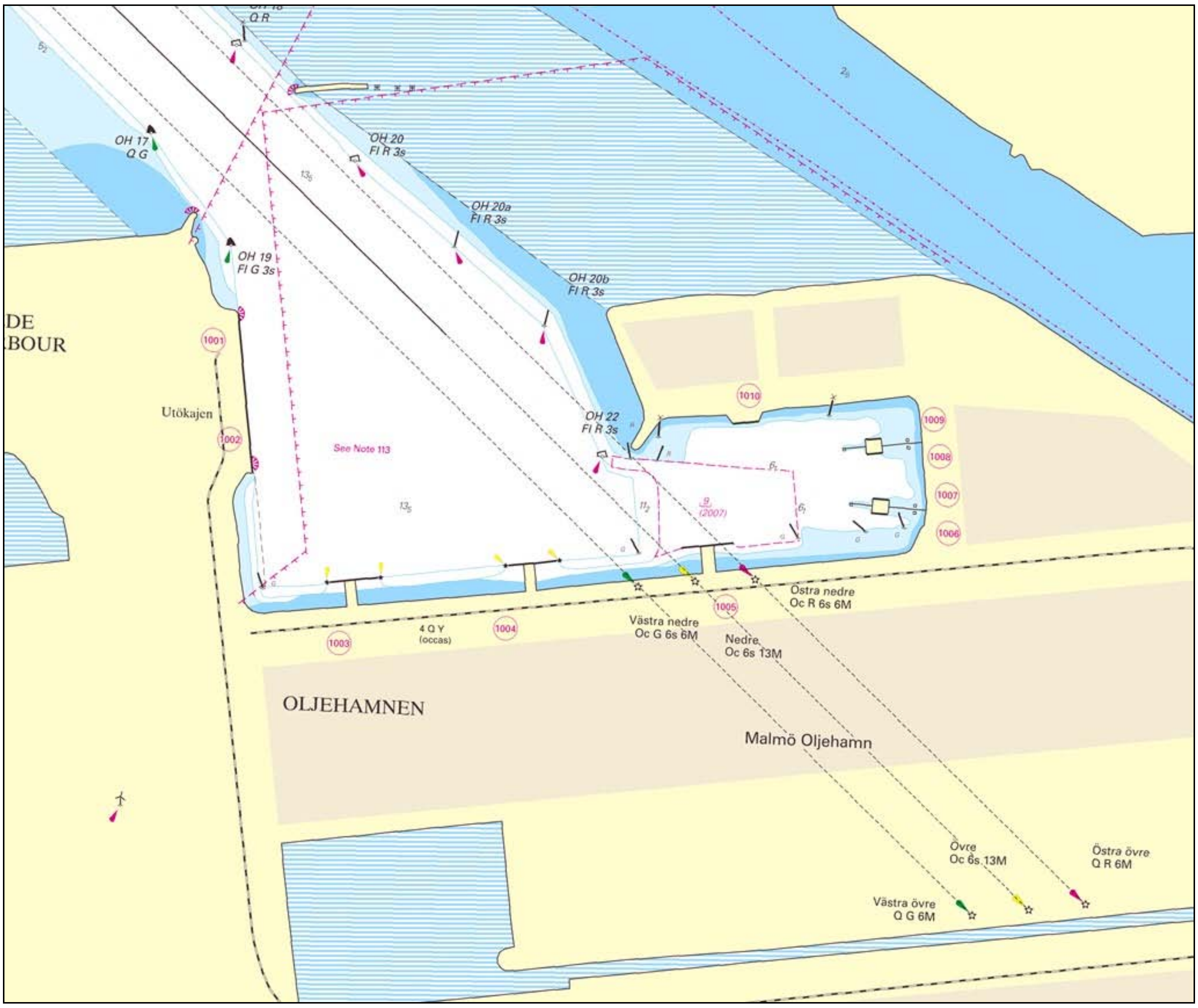


Figure 14 Malmo Harbour