IALA

IALA GUIDELINE

G1078
THE USE OF AtoN IN THE DESIGN OF FAIRWAYS AND CHANNELS

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1. INTRODUCTION

The purpose of this Guideline is to give guidance to Marine Aids to Navigation (AtoN) providers and competent authorities on the:

- use of AtoN in the design of fairways and channels; and
- review of existing AtoN for fairways and channels.

The objective is to define a suitable AtoN mix that enables safe and efficient vessel passage in the most cost-effective way for AtoN providers.

This Guideline shall be used as a general overview. For more detailed AtoN planning, this document should be used in conjunction with other IALA documentation, especially the *IALA Maritime Buoyage System (MBS)*.

1.1. BACKGROUND

The art of navigation has evolved over many hundreds of years, as well as the design of vessels. For instance, vessels are bigger and faster, and vessel equipment has become much more complex.

In principle, navigation comprises:

- planning a safe passage for a vessel, through the use of nautical charts and relevant publications;
- monitoring or establishing a vessel's position or movement along a planned passage; and
- controlling a vessel, to ensure that it follows a planned passage.

The navigator will combine various tools providing navigational information to control the vessel. This places great demand on the accuracy of the chart, the navigation system and the vessel's control systems.

The availability, reliability and relatively low cost of high precision electronic position fixing systems provide the modern mariner with accurate real time positioning from open ocean into restricted waterways. Modern electronic AtoN, such as AIS AtoN, continue to become more available and, along with traditional physical AtoN, give the modern AtoN manager even more tools in designing and deploying AtoN systems for fairways and channels. Even as electronic aids evolve and improve, physical AtoN will continue to be the essential component of every waterway.

1.2. E-NAVIGATION

e-Navigation now has a considerable impact on the mix of AtoN for an existing or a planned fairway and channels. e-Navigation will help to improve the efficiency of fairway / channel marking with AtoN, providing:

- improved safety through promotion of standards for technology development;
- better protection of the marine environment;
- the potential for higher efficiency and reduced costs; and
- a potential reduction in bureaucracy - e.g., standardized reporting requirements.

Issues relating to the presentation/promulgation of e-Navigation information are still being developed.

2. USER REQUIREMENTS

2.1. GENERAL

According to SOLAS, Chapter V, Regulation 13, each of the Contracting Governments is required to provide, as it deems practical and necessary, AtoN, as the density of traffic and the level of risk requires. IMO Member States commit themselves to taking into account international recommendations and guidelines when establishing such aids.

2.2. ACCURACY

The assigned position of the AtoN should be accurate and in accordance with International Hydrographic Organization (IHO) standards, in order that a vessel can establish its position sufficiently and follow a route in the fairway /channel by visual or radionavigation means.

The AtoN should be surveyed and positioned with at least the same accuracy as the nautical chart. This is determined in the IHO *Standards for Hydrographic Surveys (S-44) 6th Edition September 2020* with accuracies of:

- 1-5 for fixed aids
- 5-20 m for floating aids

In many cases, such as leading lights, these minimum IHO requirements are not accurate enough.

2.3. RELIABILITY

In determining AtoN Reliability, such issues as integrity, availability, continuity and mean time to repair (MTTR) need to be taken into account.

The required level of AtoN reliability is determined by the level of risks to the mariner, the vessel and the marine environment that are mitigated through the use of a particular AtoN. In those areas in which the level of risk has been determined to be high, the use of certain types of AtoN may prove to provide greater risk mitigation.

The planner must consider availability objectives. AtoN providers should refer to IALA Recommendation *R0130 The Categorization and Availability Objectives for Short Range AtoN,* for additional information related to the categorization of individual AtoN, the calculation of availability targets, and recommended availability objectives.

If continuity is used for defining the requirements for a specific system, it has to be calculated for the time that a vessel takes to pass through the fairway, channel, or area.

2.4. SPECIAL REQUIREMENTS FOR DIFFERENT USER GROUPS

The level of on-board navigational equipment can vary significantly on different types of vessels. SOLAS vessels are equipped with certified on-board navigational equipment. This is suitable to support long-range and/or low visibility navigation. These vessels are operated by professionally trained and certified personnel. For these vessels, visual AtoNs are used to enhance navigation and as a valuable way to verify the vessel's position, thus providing essential redundancy to electronic navigation systems. It is recommended that whenever possible, the reliance on a single method of determining position be avoided. However, for vessels that are not SOLAS equipped[1], visual AtoNs are even more essential.

[1] For instance, fishing vessels and leisure craft

For example, high speed craft (HSC) and other fast vessels in coastal areas, using visual AtoN for a safe passage, the speed of these vessels can be the defining factor for the AtoN system[2].

2.5. USER ENGAGEMENTS

User consultation is an integral part of all AtoN planning and also applies to the use of AtoN in the design of fairways and channels. Refer to Guideline *G1079 Establishing and Conducting User Consultancy by Marine Aids to Navigation Authorities* for guidance.

3. CONSIDERATIONS

When the use of AtoN in the design of fairways / channels are considered, or reviewed, the following should be taken into account:

(a) Approach to and exiting from a Port or Harbour

Port and Harbour AtoN should comply with the MBS wherever possible, in order that mariners can achieve a seamless transition between different areas.

(b) Through an area with specific features, e.g.:

(i) Depths of water, or lack thereof in certain areas and vessel under keel clearance

This would have an influence on the size of vessels that would be able to safely navigate the fairway / channel, and subsequently the type of floating AtoN (normal buoy, resilient/elastic type, focal height, draft, diameter, with, or without a tail) to be made provision for, the swinging circle, the type of mooring (traditional or elastic) and the divergence of the buoy lanterns.

(ii) Underwater- or above water obstructions, such as fully/partly submerged breakwaters, isolated dangers, wrecks, that would require to be marked accordingly.

(iii) Special Mark applications (Ocean Data Acquisition Systems (ODAS)) marks, traffic separation marks, spoil ground marks, military exercise zone marks, cable or pipeline marks, recreation zone marks, boundaries of anchorage areas, structures such as offshore renewable energy installations, aquaculture and mooring buoys.

(c) Fairway / channel cutting across a fishing, environmental and / or protected area (including dynamic marine mammal protected areas).

When it is necessary to create a throughway across a fishing, protected, or another restricted area to reach e.g. a slipway, beach, or any other destination for mariners, the implementation of a fairway / channel and AtoN should be taken into consideration.

In the case of a mammal (whales) protected area, it should be noted that these areas may change due to the natural movement of the mammals, and amendments to the layout of the fairway / channel could be considered (maybe very expensive or impractical), or safety precautions taken through the promulgation of relevant Maritime Safety Information (MSI) messages.

[2] IALA Guideline *G1033 The Provision of AtoN for Different Classes of Vessels, including High Speed Craft* addresses the specific AtoN requirements of HSC.

(d) Zoning

Special Marks with relevant pictograms should be considered to identify the zoning area, as well as the IALA Recommendation *R0139 Marking of Man-Made Offshore Structures,* should be consulted as to the marking of such areas.

(e) Split in fairway / channel

In the design of a fairway / channel, and where a split is required, e.g., a preferred channel, the following should be taken into consideration.

A split in a fairway / channel can be identified by:

(i) A traffic separation scheme

(ii) Preferred channel marking

(iii) Incoming traffic from a different channel with mandatory obligations to choose one direction ("T" connection)

(iv) Fairways Intersect

Note: A split in a fairway / channel should only be established when safety of navigation in the area can thereby be clearly improved (IMO Resolution *A.572(14)*).

(f) Limited width of Fairway / channel (swinging circle / Resilient/elastic type)

In a fairway / channel with limited width, consideration should be taken that floating AtoN positions might be subjected to variations (swinging circle) because of depth, tides, current and mooring types. The mooring system must be able to maintain the floating aid in a sufficiently accurate position for it to perform its function as an AtoN in order to ensure that the effective width of the fairway / channel is not reduced. The use of resilient / elastic buoys is particularly suitable in fairways / channels where the swinging radius is limited by the width of the fairway / channel and heavy vessel traffic.

(g) IMO International Regulations for Preventing Collisions at Sea 1972 (COLREGS)

COLREGS apply to all vessels upon the high seas and in all waters connected therewith navigable by seagoing vessels.

Narrow and shallow waters in waterways such as channels and fairways impose on a vessel's ability to manoeuvre depending on the nature and type of the vessel or its draught in relation to the available depth and width of navigable water which may severely restrict its ability to deviate from the course it is following. Also, ship-to-ship interaction can cause vessels to drift toward each other, resulting in a risk of collision.

The design of the fairway / channel should ensure ship's safe manoeuvring and assess the navigational risk to improve the safety of ship underway.

The following are some examples of the COLREGS rules that an AtoN competent authority may have to consider when designing a fairway / channel:

Rule 1 Nothing in these rules shall interfere with the operation of special rules made by an appropriate authority for roadsteads, harbours, rivers, lakes or inland waterways connected with the high seas and navigable by seagoing vessels.

Rule 6 Safe speed. Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstance and conditions, taken into account the draught in relation to the available depth of water.

Rule 9 Narrow channels - Vessels less than 20 meters or sailing vessel shall not impede a vessel which can safely navigate within a narrow channel. Fishing vessels shall not impede. Vessels shall avoid anchoring. Consider options for smaller vessels, fishing vessels, emergency anchorages, etc.

A vessel nearing a bend or an area of a narrow channel or fairway where other vessels may be obscured by an intervening obstruction, shall navigate with particular alertness and caution and shall sound the appropriate signal.

Rule 10 Traffic Separation Schemes – multiple lanes, higher risks at entrance and terminus, mandatory usage by certain vessel types/sizes.

Rule 18 Responsibilities between vessels - any vessel other than a vessel not under command or a vessel restricted in her ability to manoeuvre shall, if the circumstances of the case admit, avoid impeding the safe passage of a vessel constrained by her draught exhibiting the signals.

Rule 28 Vessels constrained by their draught – must navigate in the channel.

(h) Audible signals

If the conditions include limited visibility (e.g., 10 days of visibility under 1 nautical mile (NM) per year)) installation of an audible, or sound signal may be justified.

(i) Background environment (height & colour of buildings, etc.)

The visibility of a visual AtoN may be affected during day-and night-time by the type of background such as lighting, vegetation, snow, buildings (height & colour), etc. and should be considered in the design of a fairway / channel. Refer to the *IALA NAVGUIDE* and relevant IALA recommendations and guidelines in this regard.

(j) Nature of Seabed

The nature of the seabed may have an influence on the type of mooring lines and components, including the sinkers of buoys to be deployed. Seabed composition can additionally have an influence on the designed positioning when laying the anchors / sinkers.

In areas with dynamic sediments, studies should be considered in the design of AtoN.

(k) Two-way traffic

Should marking be required to indicate two-way traffic areas on a fairway / channel, appropriate AtoN are to be used to avoid misunderstanding by the users, noting that there are no specific AtoN relating to two-way traffic.

(l) Other local inland navigation rules or instructions, e.g., the European Code for Signs and Signals on Inland Waterways (SIGNI)

Refer to point 6.1.

4. PERFORMANCE PARAMETERS OF ATON SYSTEMS

4.1. POSITIONING ACCURACY

4.1.1. RADIONAVIGATION SYSTEMS

The position accuracy for a vessel using radionavigation systems can be assumed to be 10m (95%) or better; therefore, the accuracy of the chart has to be taken into account when using radionavigation systems.

4.1.2. VISUAL ATON

Generally, visual AtoN are not used to provide absolute accuracies, however, and importantly, they provide a good relative accuracy. Thus, they are a good tool to determine the vessel's position relative to relevant objects, such as fairway / channel boundaries and hazards.

Due to differing mooring arrangements, the position accuracy of floating short range AtoN is sometimes difficult to define. Floating AtoN positions are subject to variation because of water depth, tides, current, mooring type, and the capabilities of the servicing vessel in positioning the AtoN anchoring device.

4.2. REDUNDANCY

Reliance upon a single AtoN may result in a higher availability requirement which may prove difficult for the provider to meet. Therefore, the implementation of multiple AtoN should be considered to provide redundancy and reduce risk.

Duplication of the navigational functions of a single AtoN may be appropriate to provide a degree of redundancy to avoid the excessive cost 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 transition period.

4.3. PERCEPTION

4.3.1. GENERAL

When designing a fairway / channel, the distance from which the AtoN can be detected, recognized and identified by the mariner, is a critical consideration. For visual perception, this is called the useful range.

The useful range does not only depend upon the properties of the AtoN itself. The atmosphere and the human eye are the other determining factors. Therefore, useful range can be calculated using characteristics of the AtoN, atmosphere and the human eye (this is further determined by the experience of the observer). The conspicuity of an object is also relevant. An object is conspicuous if it appears outstanding in a complex visual scene.

To identify an AtoN, it is important that the visual information provided by the AtoN is verified. The mariner achieves this task by comparing the characteristics of the AtoN (e.g., shape, colour, daymark, lettering and light character). This process can take time due to interference by intermittent influences such as wave movement and visibility.

Audible signals, also referred to as sound signals, should only be used as a hazard warning. These hazards refer to certain man-made structures such as offshore structures, renewable energy infrastructure, bridges, breakwaters, and isolated AtoN. The competent authority shall determine whether a hazard requires an audible signal. Where provided, audible signals for navigation hazards should have a nominal range of at least 1 NM. (Refer to Recommendation *R0109* and Guideline *G1090 The Use of Audible Signal*s).

4.3.2. LIGHTS

An AtoN light can be defined by its intensity, colour and divergence. When this light is measured in its practical application, a further parameter is derived; the luminous range. The luminous range is the distance from which, under defined conditions, the user can identify the light. To identify the light, the mariner must be able to confirm its colour and character.

The prevailing visibility conditions will vary for different geographical locations. Therefore, when selecting an AtoN light, these conditions should be taken into consideration. The nominal range will be promulgated in nautical charts and publications for mariners, lists of lights etc.

The IALA R0200 series of recommendations provides further information on the determination and measurement of marine signal lights.

4.3.3. DAYMARKS

The distance at which a daymark can be identified depends on size, shape, colour, contrast to the background, environmental conditions, background and geographical range. The object can be normally identified when it subtends, at the eye, an angle of more than 3’ (three minutes of arc).

The contrast between the background and the AtoN depends on the:

- chromaticity of the paint of the AtoN;
- specific meteorological visibility in the area;
- colour and illumination of the background; and
- conspicuity.

Reflective sheets / retro-reflective material on the aid can be used at night to enhance the daymark in low visibility conditions.

4.3.4. RADAR

The perception of an AtoN by a vessel borne radar is determined by the:

- height of the vessel's radar;
- height of AtoN above actual sea level;
- radar cross section of the AtoN (including any radar reflector);
- environmental conditions:
  - radar clutter due to sea state and weather; and
  - movement of AtoN due to environmental conditions; and
- active radar devices on the AtoN.

4.3.5. AUTOMATIC IDENTIFICATION SYSTEM (AIS)

Perception can be improved by means of AIS on AtoN, provided that the vessel's on-board equipment allows the presentation of such information.

Some of the benefits of AIS include:

- Unambiguous indication of AtoN identity
- Day/night and all-weather operation
- Greater range than most visual signals
- Enhanced perception, showing the position on the vessel's electronic chart (if the AIS and the electronic chart is interconnected)
- Verification of the integrity of the aid, including Off-Position and operational status indication / malfunction alert to the mariner and AtoN provider
- Additional broadcast of meteorological and hydrological data and safety related information in real time if suitable equipment is fitted to the AtoN

More details on AIS and its implementation as an AtoN can be found in IALA Recommendation *R0126 The use of AIS in Marine AtoN Services*.

5. LAYOUT OF AtoN FOR MARKING A FAIRWAY / CHANNEL

5.1. GENERAL

When considering the design of a system of AtoN, the MBS must be adhered to. However, for inland waterways, there may be different legislation, rules and marking systems established by national authorities; for example, SIGNI. Any risk of conflict or confusion between the two systems (*IALA MBS* and that of the inland waterway) should be avoided as far as possible.

The Hydrographic Office is responsible for marking AtoN on nautical charts (ENC and paper charts), whilst the AtoN provider is responsible for verifying that AtoN are identified and marked on these charts.

In narrow, winding or meandering passages, it may be difficult for mariners to correlate the vessel's position with chart information in a timely manner. In these circumstances, visual AtoN will be the primary means of navigation.

5.2. AtoN MARKING THE FAIRWAY /CHANNEL BOUNDARIES

The following general principles apply to the design of fairways:

1 A fairway / channel shall be marked by lateral and cardinal marks.

2 There shall be AtoN at least at bends and junctions of the fairway / channel.

3 Lit AtoN should be generally used for:

- the beginning and end of the fairway / channel; and
- changes of direction.

4 AtoN should be spaced evenly along the fairway / channel, where practicable.

5 In general, the useful range of buoys at day and night should be greater than the distance between the buoys. The AtoN appearance on the vessel's radar screen should also be considered.

6 The distances between unlit AtoN are based on their size and daytime visibility.

7 The AtoN on one or both sides of the fairway / channel, should be positioned equal distance from the central axis of the fairway / channel, where practicable.

8 The use of synchronized and sequential lights should be considered[3].

9 If high navigational accuracy or a very clearly distinct fairway / channel with continuous buoyage is required, ideally, the AtoN marking the fairway / channel shall be established as pairs ("gates"); however, if this degree of accuracy is not required, then a "staggered" arrangement of AtoN could be considered. Moreover, AtoN could be positioned to one side of the fairway / channel only, or where relevant, marking the deepest part of the fairway / channel with safe water marks.

10 If a fixed AtoN separation distance is required, then the appropriate mark and size has to be established. If a certain type of mark/size of AtoN is preferred for a particular purpose, then the separation distance of the AtoN 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 navigational, economical, technical and operational perspectives.

11 In general, a high density of fairway / channel AtoN ensures an easy and more accurate level of navigation. However, there is a saturation point where adding AtoN does not help positioning any further. To find the ideal AtoN density, simulation and risk assessment will be necessary, or at least very useful in fairway / channel design.

12 To make AtoN service provision more economical, providers should consider defining a restricted number of various types and classes of AtoN (by size and shape) with certain identification distances and N can be chosen from this "toolbox" instead of designing a new one for each case.

[3] IALA Guideline *G1116*

5.3. OTHER AtoN MARKS IN THE APPROACH TO OR IN THE FAIRWAY / CHANNEL

In addition to marking the boundaries of the fairway / channel, short range AtoN and electronic AtoN may be used in the right mix to indicate:

- critical points, such as ferry crossings;
- temporary operations, such as areas being dredged and under construction;
- the centre of the fairway / channel;
- change of direction;
- marking of isolated dangers;
- marking of different areas;
- marking specific type of objects, e.g., Ocean Data Acquisition Systems (ODAS) and wrecks (fixed and / or moving); and
- transit- corridors and routes through man-made off-shore structure arrays.

The following marks can be used:

- Lateral, cardinal or safe water marks, which are physically deployed directly in the fairway / channel, or on the point they indicate (or as close as possible to it).
- Special Mark applications, both in the approach to, and / or in the fairway / channel – refer to the MBS for the Special Mark applications.

Above mentioned AtoN can be floating (buoys) or fixed (beacons) AtoN.

5.3.1. APPROACH TO A FAIRWAY / CHANNEL

The phase of navigation called *restricted waters,* relates to the approach to a harbour, restricted waters, or a fairway / channel, noting that although the harbour approach is an aspect of the restricted waters phase, it is treated separately as its own phase. Consideration could be given to position a safe water mark in an appropriate position to indicate the approach to a fairway / channel.

5.3.2. AUDIBLE SIGNALS

Audible signals may also be used to augment the AtoN identification, both lighted and unlighted, to enhance their effectiveness to the mariner in reduced visibility. Audible signals on buoys should be used to warn mariners of a particular hazard, such as proximity to shoals, rocks or other hazards; or to alert the mariner to a change in navigational requirements, such as the entrance to a restricted channel. Where electronic audible signals are used to augment buoys, they should have a nominal range of 0.25 to 0.5NM (refer to Guideline *G1090 The Use of Audible Signals*).

5.3.3. RADAR BEACONS AND AIS

The use of radar beacons (racons) and/or AIS could be considered as these add value to the mariner. Placing a racon and/or AIS in the approach to a fairway / channel, and / or bends and junctions of the fairway / channel could be considered, noting that racons and/or AIS are not limited to be placed on buoys only.

5.3.4. MATON

MAtoN shall not be a permanent part of a marked fairway / channel. It should only be used to mark moving / drifting hazards following the completion of a fairway / channel design.

Refer to IALA Guideline *G1154 Use of Mobile Aids to Navigation.*

5.3.5. TIDE LANTERNS

Although a tide lantern is not an AtoN, it provides information to the mariner on the direction of the tide, e.g., on estuaries and may be a consideration - refer to appendix 1.

5.3.6. TRAFFIC SEPARATION SCHEME (TSS)

A Traffic Separation Scheme (TSS) is a routeing measure aimed at the separation of opposing streams of traffic by appropriate means and by the establishment of traffic lanes. A TSS is an important instrument for managing shipping traffic and is intended to achieve the most unambiguous traffic flow possible. In a TSS, shipping traffic in the opposite direction each has its own waterway. This principle is applied in busy sea areas and ensures fewer intersecting movements and thus a clearer and safer traffic image. The connecting lines between TSS form a route structure which is followed by the majority of ships. In practice, mainly large ships make use of a TSS at it provides for a safe structure to their sea voyage. TSS are less suitable for small recreational craft.

A TSS is usually marked with safe water and / or lateral marking, unless the use of conventional channel marking may cause confusion, in which case Special Marks are used.

5.3.7. BRIDGES, OVERHEAD CABLES, ETC.

Fixed bridges and other structures, including floating bridges, overhead pipelines as well as structures under construction that cross fairways / channels should be marked to ensure their safety and that of vessels navigating beneath them, for example by reason of limited clearance (air draught), water depth or the possibility of collision.

IALA Recommendation *R0113 Marking of Fixed Bridges over Navigable Wa*ters provides further guidance on the marking of fixed bridges and other structures over navigable waters.

5.3.8. BREAKWATERS, SUBMERGED BREAKWATERS AND BARRIERS

Fairways and / or channels in many cases provide safe passage to vessels entering and exiting a port or harbour. It is therefore necessary to also take the following into consideration in the design thereof. Breakwaters are usually marked using a combination of lateral marks to assist approaching vessels in navigating between breakwaters. In those instances where both “above water”, partially or wholly submerged breakwaters present a hazard to navigation**,** a small network of special marks (fixed and/or floating) spaced at an equal distance apart could provide an appropriate and recognized means of marking these hazards.

The unlit portion of the breakwater (in between AtoN) could present a hazard to navigation for mariners. Pathway, or street lighting could be considered to provide a non-conventional means to maximize the area illuminated of a breakwater, thus increasing safety for the mariner.

More detail can be found in IALA Guideline *G1163, The Marking of Breakwaters and Barriers*.

5.3.9. OTHER BOUNDARY AREAS

Other boundary areas adjacent, or close to a fairway / channel, e.g., where dredging material is deposited, an anchorage area, offshore renewable energy fields, waiting and manoeuvring areas, etc. and which are usually marked by Special Marks, would need to be taken into consideration to ensure that there is no interference or ambiguity between those markings and that of the fairway / channel.

5.4. AtoN AND OTHER AIDS OUTSIDE THE FAIRWAY / CHANNEL

5.4.1. LEADING AND TRANSIT LINES

Leading lines (lit or unlit) generally provide high accuracy for the middle of the fairway / channel and or they can be established when there are straight stretches in the fairway / channel, or if:

- the middle of a fairway / channel needs to be indicated;
- their deployment may reduce the need for physical AtoN;

- other AtoN could be affected by ice, severe weather or tide;
- there is a channel inside the fairway / channel, which has to be used by vessels with deep drafts;
- strong cross currents occur (for instance in harbour entrances); or
- leading and / or transit lines can also be used to mark the boundaries of the fairway / channel, provided this function is clearly shown in the relevant charts (see example in Appendix 6).

The preliminary decision in designing a leading and / or transit line is to define length and breadth of the section of fairway / channel to be defined by the 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 should also be large enough to be visible from the far end of the section of fairway / channel marked. Both these conditions result in increases to the required height of the rear structure marking a long channel.

More details can be found in IALA Recommendation *R0112 Leading Lights*, *R0112-1 Leading Lights Design Programme* and in the *IALA NAVGUIDE.*

5.4.2. SECTOR LIGHTS

A sector light is an AtoN 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 / channel, a turning point, a junction with other fairways / channels, a hazard or something else of importance for the navigator.

When a fairway / channel is covered by a sector light, colours indicating safe passage and danger areas are defined in the MBS.

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

- Position at which a change of the course should be made
- Location of shoals, banks, etc.
- An area or position (e.g., an anchorage)
- The deepest part of a fairway / channel

More details can be found in IALA Guideline *G1041 Sector Lights*.

5.4.3. MAJOR FLOATING ATON

Major floating aids include light vessels, light floats and large navigational buoys.

Consideration could be given to deploying major floating aids. Such aids are generally deployed at critical locations, intended to mark approaches from offshore areas, where shipping traffic concentrations are high. They may provide a platform for other AtoN such as racons and / or AIS AtoN.

5.4.4. POSITION, NAVIGATION AND TIMING (PNT) AND DIFFERENTIAL SYSTEMS

Position, navigation and timing (PNT) and Differential Global Navigation Satellite System (DGNSS) are widely used both for navigation and as an AtoN. The availability and type of positioning fixing system in a particular area should be considered.

5.4.5. VESSEL TRAFFIC SERVICES

Vessel traffic services (VTS) managing traffic volume and density in a fairway / channel may mitigate some of the risk and therefore may influence the type and amount of AtoN to be deployed.

5.4.6. PILOTAGE

Pilotage is a specialized service to navigation, specifically in restricted and / or navigationally challenging waters. The pilot draws on local knowledge related to geographic and hydrographic points of interest. Deployment of AtoN may be designed considering pilots' knowledge or requirements.

6. DESIGN METHODOLOGY/PROCEDURE

6.1. A SIMPLE PROCEDURE FOR THE ESTABLISHMENT OF A MARKED FAIRWAY / CHANNEL

The design of AtoN marking a fairway / channel which is formed by straight lines and bends can be undertaken considering the following:

1 Establish a conspicuous AtoN, or pair of AtoN, at the beginning of the fairway / channel.

2 Place AtoN at points where:

   (a) vessels have to alter their course;

   (b) the fairway / channel boundary line or the middle line has a bend or curve;

   (c) critical shallows and rocks, or other hazards, form the boundary of the fairway / channel; and

   (d) fairway and channel intersect or split.

3 Distribute AtoN between these points with regard to the distance at which they can be detected and identified (refer to the section on perception of AtoN in this Guideline (section 4.3) and other relevant IALA documents).

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

- After the initial assumption of requirements made from section 4.3, the AtoN separation distance should now be chosen that when the nearest AtoN is being approached, the mariner should be able to see at least the next AtoN along the fairway (the next two AtoN in more accurate applications).

6.2. CHANNEL DESIGN AND MAINTENANCE

Fairway / channel planners in the relevant authorities should consider AtoN solutions to minimize the amount of dredging and surveying that is required in fairway / channel construction and maintenance. Further details on these matters can be found in the PIANC "*Report WG 121- 2014, Harbour Approach Channels Design Guideline*".

6.3. RISK ASSESSMENT

Advice on risk assessment and risk management can be found in the IALA Guidelines *G1018 Risk Management*, *G1123 The Use of IALA Waterway Risk Assessment Programme (IWRAP MkII), G1124 The Use of Ports and Waterways Safety Assessment (PAWSA) MkII Tool* and *G1138 The Use of the Simplified IALA Risk Assessment Method (SIRA).*

6.4. SIMULATION

Simulation can be used as a tool in the design and planning of fairways / channels. Refer to IALA Recommendation *R0138 The Use of GIS and Simulation by AtoN Authorities* and IALA Guideline *G1058 The Use of Simulation as Tool for Waterway Design and AtoN Planning*, for discussions on the use of simulation in fairway / channel design and placement of AtoN.

7. EXAMPLES OF MARKING OF FAIRWAYS / CHANNELS

Some examples for the marking of fairways / channels are given in appendices 1 to 7.

8. CONCLUSION

When designing an AtoN system for a fairway / channel, many considerations are necessary. The requirements can be defined in parameters such as accuracy, reliability, conspicuity, etc. The parameters vary depending on the type of fairway / channel, the vessel traffic and on other factors such as risks. The design must include the considerations and requirements of international bodies such as the IMO, IHO, PIANC and IALA.

As e-Navigation progresses further and future carriage requirements (from SOLAS and the coming IHO S-100 standards) are implemented, future benefits in situational awareness may result in need for revised approaches to the design of fairways and channels.

Nevertheless, Competent Authorities should strive for continuous improvement of marking principles and AtoN positioning that will optimize the fairway / channel design, drive efficiencies and protect the marine environment.

9. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) at http://www.iala-aism.org/wiki/dictionary and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

In addition, for this document, the following definitions are relevant:

Absolute Accuracy	The accuracy of a position estimate with respect to the geographic or geodetic co-ordinates of the Earth
AtoN Provider	Any organization, public or private, which is required to deploy AtoN as part of its duties
Availability	The probability that an AtoN or system of AtoN, as defined by the ompetent authority, is performing its specified function at any randomly chosen time. This is expressed as a percentage of total time that an AtoN or system of AtoN should be performing their specified function
Canal	A narrow stretch of waterway created artificially to serve navigation
Channel	A channel is a natural or dredged lane having sufficient depth, usually restricted on either side by shallow water and designated or customarily use for vessels. The borders of a channel may be defined by natural or artificial banks and is nearly always marked by AtoN
Conspicuity	The ability of an object to stand out from its surroundings
Continuity	The probability that, assuming a fault-free receiver, a user will be able to determine position with specified accuracy and is able to monitor the integrity of the determined position over the (short) time interval applicable for a particular operation within a limited part of the coverage area
e-Navigation	The harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment

Fairway	A charted waterway
High speed craft (HSC)	Craft capable of maximum speed equal to or exceeding $3.7\nabla^{0.1667}$ ms^{-1} where: ∇ = volume of displacement corresponding to the design waterline (m^3) This excludes WIG vessels
Integrity	The ability to provide users with warnings within a specified time when a system should not be used for navigation
Luminous range (of a light)	The maximum distance at which a light can be seen, as determined by the luminous intensity of the light, the atmospheric transmission factor and the threshold of illuminance on the eye of the observer
Nominal range	The nominal range of a light used as a marine aid to navigation is its luminous range in a homogeneous atmosphere in which the meteorological visibility is 10 NM
Radionavigation	Radiodetermination used for the purpose of navigation, including obstruction warning
Radionavigation system	Navigational system that uses radio frequencies to determine a position
Relative Accuracy	The accuracy with which a user can determine position relative to that of another user of the same navigation system at the same time
Reliability	Ability of a device, or system, to satisfy the requirements of its intended use within defined limits, and for a stated period of time
Sound (Geographical Term)	Often used interchangeably with other geographic terms, such as a bay or fjord. A sound may be formed when a river valley is flooded by seawater or as the result of glacial erosion
Useful range	The practical convenient range for a mariner to identify an AtoN
Waterway	A waterway defines a coastal region, sound, strait, harbour, bay, channel, fairway, river, canal, or a geographically shared series of any or all. It can consist of natural or manmade passages, which may or may not restrict vessel traffic within its boundaries, marked or not marked by AtoN, that allows for the transit of vessels

10. ABBREVIATIONS

AIS	Automatic Identification System
AtoN	Marine Aid(s) to Navigation
COLREGS	IMO International Regulations for Preventing Collisions at Sea
DGPS	Differential Global Positioning System
DGNSS	Differential Global Navigation Satellite System
DWT	Deadweight tonnage
ENC	Electronic navigation chart
EWF	Effective Width of the Fairway
GIS	Geographic Information System
GPS	Global Positioning System
HSC	High speed craft
IHO	International Hydrographic Organization
IMO	International Maritime Organization (Acronym style)

MARCOM	A PIANC technical working group
MAtoN	Mobile AtoN
MBS	IALA Maritime Buoyage System
MSI	Maritime Safety Information
MTTR	Mean Time to Repair
NM	Nautical mile(s)
ODAS	Ocean Data Acquisition Systems
PEL	Port entry light
PIANC	The World Association for Waterborne Transport Infrastructure
PNT	Positioning, Navigation and Timing
Racon	Type of radar beacon
SC	Swinging Circle
SIGNI	Signs and Signals on Inland Waterways, United Nations Economic Commission for Europe (UNECE) Resolution No 90
SOLAS	International Convention for the Safety of Life at Sea
S-44	Standards for Hydrographic Surveys (IHO)
TEU	Twenty-foot equivalent unit
TSS	Traffic Separation Scheme
VTS	Vessel Traffic Service(s)
WIG	Wing in Ground

11. REFERENCES

[1] IALA. standards S1010

[2] IALA. NAVGUIDE

[3] IALA. Recommendation R0101 Maritime Radar Beacons

[4] IALA. Recommendation R0110 The Rhythmic Characters of Lights on AtoN

[5] IALA. Recommendation R0111 Port Traffic Signals

[6] IALA. Recommendation R0112 Leading Lights

[7] IALA. Recommendation R0112-1 Leading Lights Design Programme

[8] IALA. Recommendation R0113 The Marking of fixed bridges over navigable waters

[9] IALA. Recommendation R0126 The Use of AIS in Marine AtoN Services

[10] IALA. Recommendation R0130 Categorization and availability objectives for short range AtoN

[11] IALA. Recommendation R0138 The Use of GIS and Simulation by AtoN Authorities

[12] IALA. Recommendation R0139 Marking of Man-Made Offshore Structures

[13] IALA. Recommendation R0200 Marine Signal Lights – Overview

[14] IALA. Recommendation R0201 Marine Signal Lights-Colours

[15] IALA. Recommendation R0202 Marine Signal Lights-Calculation, Definition and Notation of Luminous Range

[16] IALA. Recommendation R0204 Marine Signal Lights – Determination and Calculation of Effective Intensity

[17] IALA. Recommendation R0205 Marine Signal Lights – Estimation of the Performance of Optical Apparatus

[18] IALA. Guideline G1010 Racon range performance

[19] IALA. Guideline G1018 Risk Management

[20] IALA. Guideline G1033 The Provision of AtoN for different classes of vessels, including high speed craft

[21] IALA. Guideline G1041 Sector Lights

[22] IALA. Guideline G1046 Response Plan for the Marking of New Wrecks

[23] IALA. Guideline G1051 The Provision of AtoN in Built-up Areas

[24] IALA. Guideline G1058 The Use of Simulation as a Tool for Waterway Design and AtoN Planning

[25] IALA. Guideline G1061 Light Application – Illumination of Structures

[26] IALA. Guideline G1163 The Marking of Breakwaters and Barriers.

APPENDIX 1 ATON DESIGN - THE RIO DE LA PLATA NAVIGATION CHANNEL - ARGENTINA

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.

1.1. SOME BASIC DATA

Waterway in analysis	
Length:	63.8 NM
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

1.2. THE VESSEL TRAFFIC

Total Traffic in the Area in 2006:	7.760 vessels
including	
Container vessels:	1,726
Bulk Carriers:	3,134
General cargo:	962
Oil Tanker:	1,386
Other:	552

1.3. MAXIMUM SIZE OF VESSELS DIMENSIONS

	Length BP	Beam	Design Draught
Container vessel	261 m	40 m	41 feet
Bulk carrier	260 m	42 m	42 feet
Tanker	241 m	32.2 m	49 feet

1.4. AtoN

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:

1 DGPS coverage (on demand- private service)

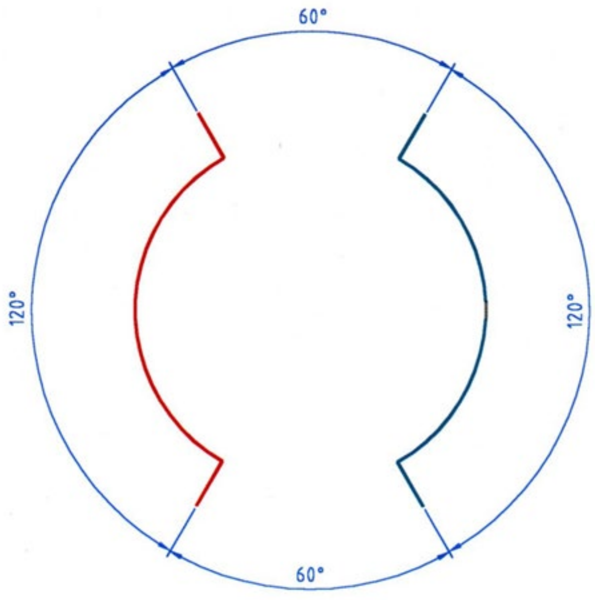
2 VTS and AIS control by Prefectura Naval Argentina (National Coast Guard)

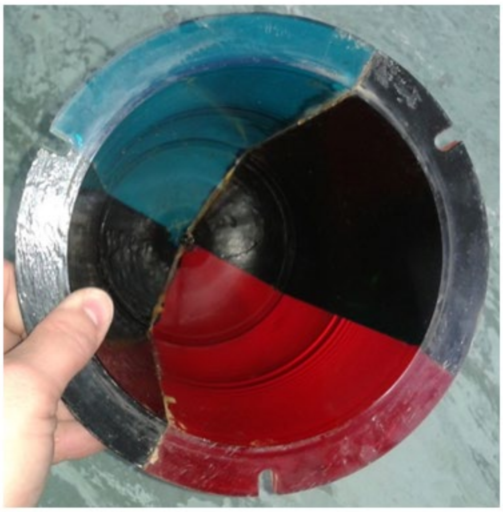
3 Mandatory Pilotage services

Tide Lanterns

Tide lanterns are deployed in 10 buoys; 9 on Port Hand buoys, and one on a Safe Water Mark buoy and provide information to the mariner on the direction of the tide. The buoys are equipped with a rudder and change position when the flow of the tide changes, displaying a fixed, low intensity green light to vessels transiting from the open seaside when the current direction is "going out of the estuary" and vice versa a red light when the current direction is "coming into the estuary"

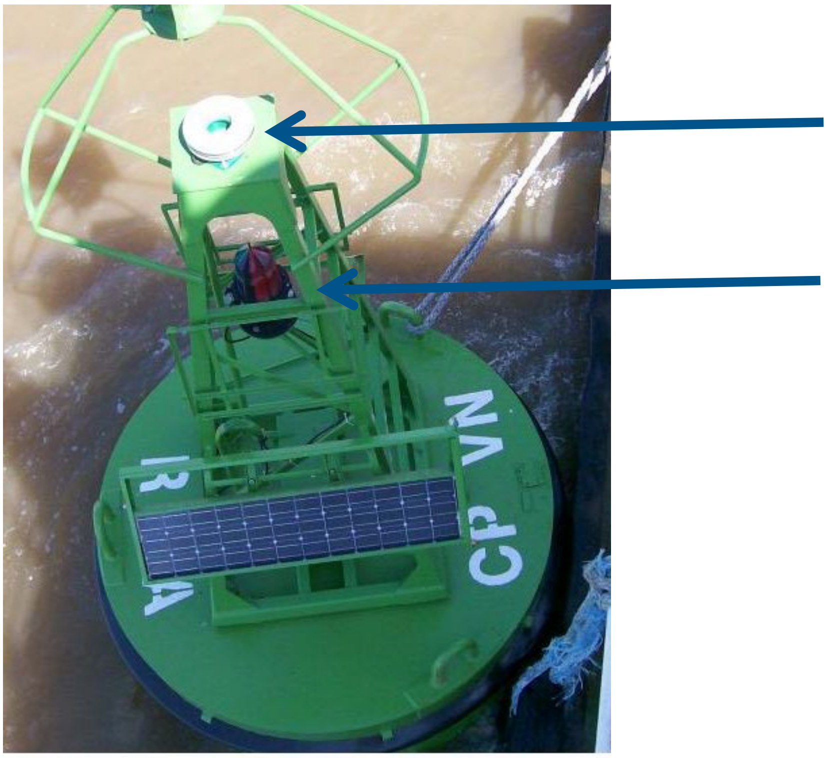
The lens of the lantern has two 60 degrees (one green and other red) and two 120 degrees dark sectors





The green and red sectors need to be aligned with the buoy rudder.

Tide lanterns are placed in the middle of the buoy super structure to ensure that there is no interference with the main lantern.


Main lantern /flash)
Tide Lantern (fixed, low intensity light)

APPENDIX 2 DRIFT DETECTION – JAPANESE METHOD

Extract from Japanese Method (contribution to Section 6 "Fairway Layout and Channel Width" to the Draft of the report of PIANC MARCOM Working Group 49 "*Horizontal and vertical dimensions of channels*").

1.1. CHANNEL CLASSIFICATION AND CHANNEL WIDTH ELEMENTS

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

$$W_{mi} = \left(W_m(\beta) + W_{my} + W_m(S)\right)$$

Equation 1 Width of basic manoeuvring lane:

where:

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

W_{my} is thewidth needed against yawing motion

$W_m(S)$ is thewidth needed for drift detection.

Additional width needed against bank effect forces: W_{bi};

Additional width needed against two-vessel interaction forces in passing condition: W_c;

Additional width needed against two-vessel 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.

1.2. EQUIPMENT AND SYSTEMS OF NAVIGATION AIDS

A vessel 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 vessel handler does believe that his vessel is running "on track". Drift detection may be impossible when the drift amount is small, but a vessel handler can recognize a drift when a vessel makes some considerable amount of lateral deviation from its course line as shown in Figure 1. The drift amount which a vessel 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 drift 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 vessel of larger size may be allowed to sail by installing a higher level of equipment and systems even in an existing channel which cannot be widened due to some topographical limitations.

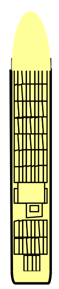


Figure 1 Undetectable zone

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 DGPS.

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 above, in each channel to be designed.

1.3. 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 vessel to two buoys ahead on both sides θ shown in Figure 2, which is defined as:

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

Equation 2 Channel width required for drift detection using the naked eye or radar

where:

W_{buoy} is the clearance between two buoys

L_F is the distance along channel centre line from vessel to light buoys ahead.

In **Error! Reference source not found.**, 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.

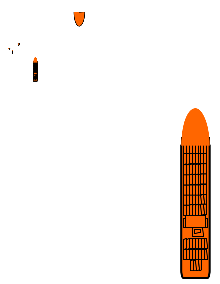


Figure 2 Detectable manoeuvring lane for light buoys on the both sides of fairway

1.4. 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 section 6.1 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.

1.5. 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.

1.6. DRIFT DETECTION BY OBSERVING LIGHT BUOYS WITH NAKED EYES

As shown in Figure 2, an angle made by two lines of a channel centre line and a line from a vessel to a midpoint of two buoys is denoted with α. A concept of the maximum deviation is introduced which is defined that almost all vessel handlers are able to recognize a drift from its course line. Corresponding to this maximum deviation, the angle of α is denoted with α_{max} as shown in Figure 2. Making use of the above concept of α_{max}, the channel width needed for the drift detection by observing light buoys with the naked eye can be calculated by:

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

Equation 3 Channel width needed for drift detection by observing light buoys with the naked eye

Where α_{max} may practically be estimated with an empirical formula developed on the basis of statistical data by full scale experiments, which is given by:

$$\alpha_{max} = 0.00176\theta^2 + 0.008\theta + 2.21372$$

Equation 4 Definition of α_{max}

1.7. 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:

$$W_m(R) = \left(\frac{W_{buoy}}{\sin\theta}\right)\sin\gamma$$

Equation 5 Channel width needed for drift detection by observing light buoys with radar

where:

γ is the error of direction observation by radar

The following expressions are easily written from Equation 5 for two cases of γ = 2deg. and 1 deg. respectively.

$$W_m(R) = 0.0349\left(\frac{W_{buoy}}{\sin\theta}\right)$$

Equation 6 Channel width needed with error of direction of 2 degrees

$$W_m(R) = 0.0175\left(\frac{W_{buoy}}{\sin\theta}\right)$$

Equation 7 Channel width needed with error of direction of 1 degree

1.8. DRIFT DETECTION BY GPS

In vessel manoeuvring operations with the utilization of GPS, a vessel handler may judge and recognize the vessel 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 vessel movement on the display with the naked eye, and some amount of perception error should be taken into account. As for drift detection by means of GPS, an assumption is made for the above perception error to be a half of the vessel's breadth. In addition, the margin of error for GPS information error is assumed to be 30 metres for a standard GPS and none for a DGPS. Therefore, the channel width needed for drift detection by GPS and DGPS can be calculated by the following equations, respectively:

$$W_m(GPS) = 0.5B + 30\ (unit{:}\, metre)$$

Equation 8 Channel width required with drift detection by GPS

$$W_m(DGPS) = 0.5B\ (unit{:}\, metre)$$

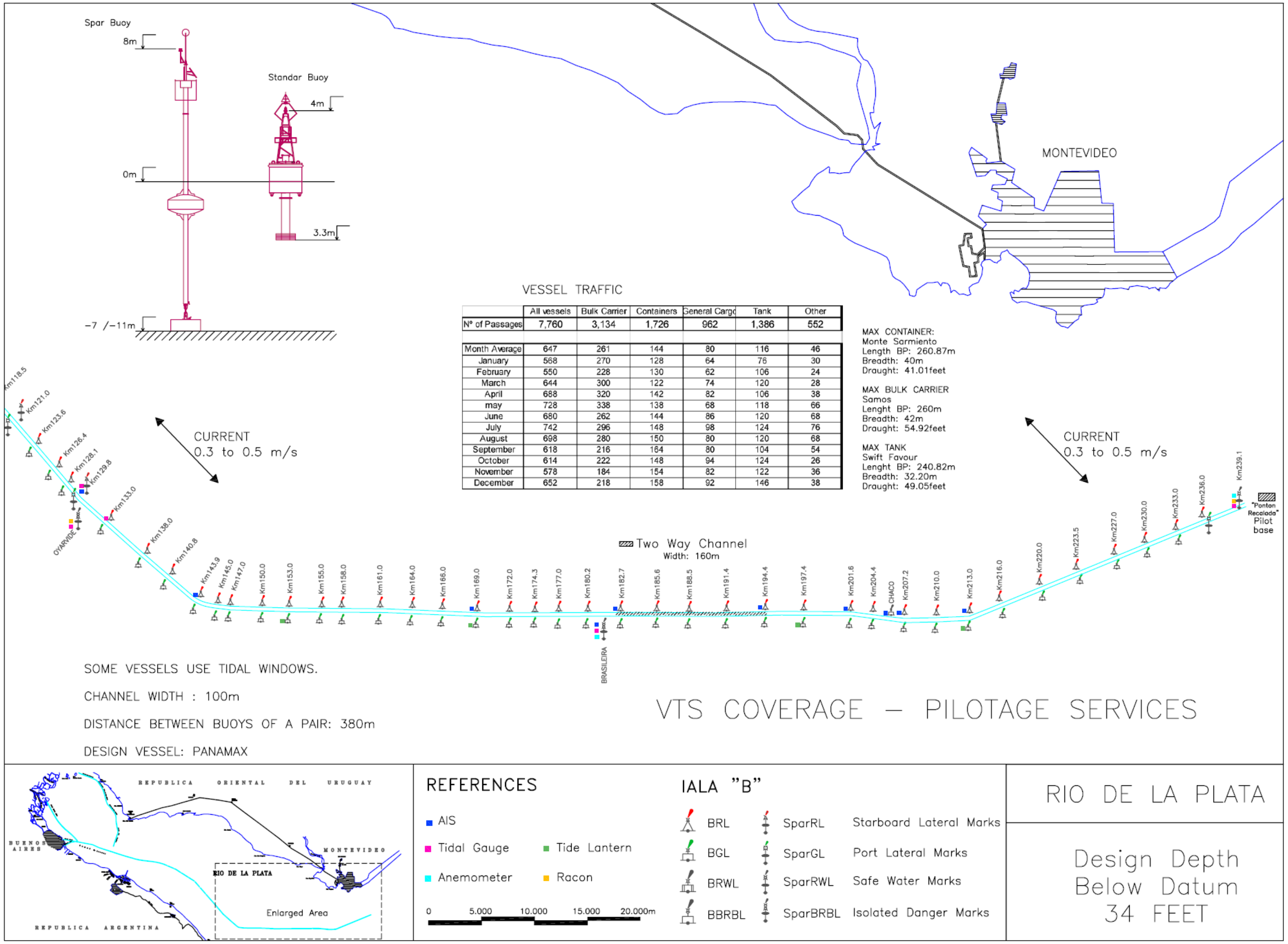
Equation 9 Channel width required with drift detection by DGPS

In addition, it is noted that the channel width needed for drift detection by GPS should be designed with careful consideration of the risks involved in using GPS and GPS-related equipment.

1.9. 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)



	All vessels	Bulk Carrier	Containers	General Cargo	Tank	Other
N° of Passages	7,760	3,134	1,726	962	1,386	552
Month Average	647	261	144	80	116	46
January	568	270	128	64	76	30
February	550	228	130	62	106	24
March	644	300	122	74	120	28
April	688	320	142	82	106	38
may	728	338	138	68	118	66
June	680	262	144	86	120	68
July	742	296	148	98	124	76
August	698	280	150	80	120	68
September	618	216	164	80	104	54
October	614	222	148	94	124	26
November	578	184	154	82	122	36
December	652	218	158	92	146	38

Figure 3 AtoN design on the Rio de la Plata

APPENDIX 3 ATON DESIGN - FINLAND

1.1. MUSSALO CHANNEL (15.3 m)

16.6.2021

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. Overall length 67 km/ 36 M, length from Kotka Lighthouse to the harbour 35.5 km/ 19 M. 4 navigation lines, marked by leading beacons, direction 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 -18.4 m and -17.5 m (MW2005). Minimum width 182 m (in Viikarinsalmi at the port entrance). The channel approach is at its narrowest, 479 m, at the edge mark Elo 2.

Anchorage areas etc.: Anchorage NE of Kaunissaari, where the channels are crossing (safe clearance depth
-18.4 m, MW2005) and anchorage SW of Kotka Lighthouse (safe clearance depth - 19 m, MW2005).

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.

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, 12.5 knots (Sc -17.5 m) in the harbour.

TRAFFIC SERVICE

Pilotage: e-mail pilotorder.east@finnpilot.fi. Order form www.pilotonline.fi. Tel.: +358 (0) 400 907 978, fax.
+358 (0) 29 52 53011. Pilot boarding position 60°10,00' N, 26°36,20' E. Pilotage distance 20 M.

VTS: Kotka VTS, VHF Channel 67.
Gulf of Finland Vessel Traffic Centre, phone +358 204 48 5391, E-mail: kotka.vts(at)fintraffic.fi and supervisors.hki(at)fintraffic.fi..

Tugs: Provided by Alfons Håkans Ltd. Pilots can assist in ordering the service, if required.

PORT

Quays: A Quay: length 609 m, safe clearance depth -14.5..-17.3 m; B Quay: length 856 m, safe clearance depth -11.5 m..-13.7 m; C Quay: length 936 m, safe clearance depth -11.5 m…-13,7 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 – three cranes (40 t), B Quay – one crane (40/50 t) and a mobile crane, C Quay –
five cranes (40/50 t).

Harbour basin: Speed of vessel to be adjusted to ensure that no harm, damage or danger is caused.

Port: Port of HaminaKotka Ltd tel. +358 (0) 20 790 8800, Ship service (24h) +358 (0)20 790 8840

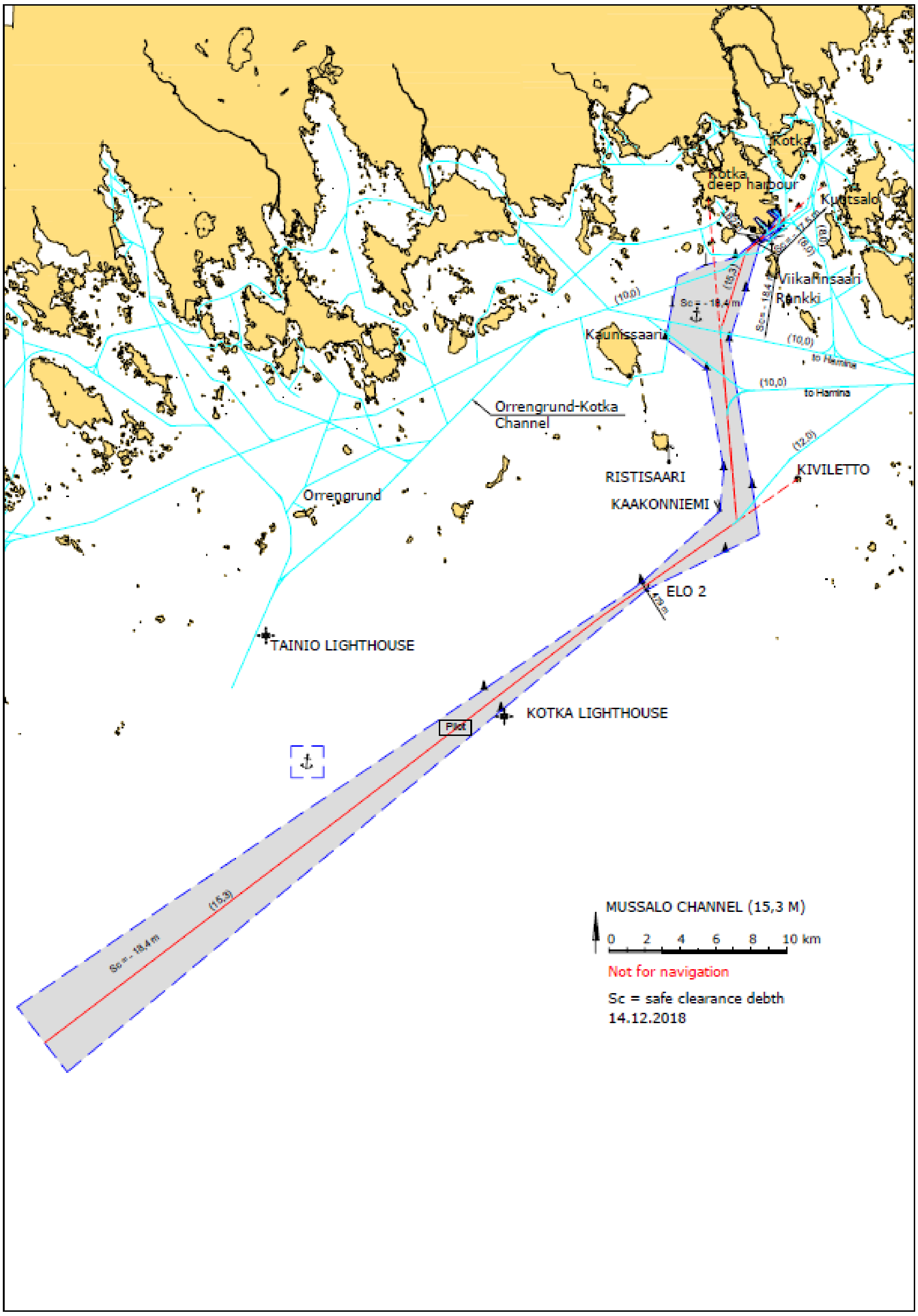


Figure 4 Mussalo Channel

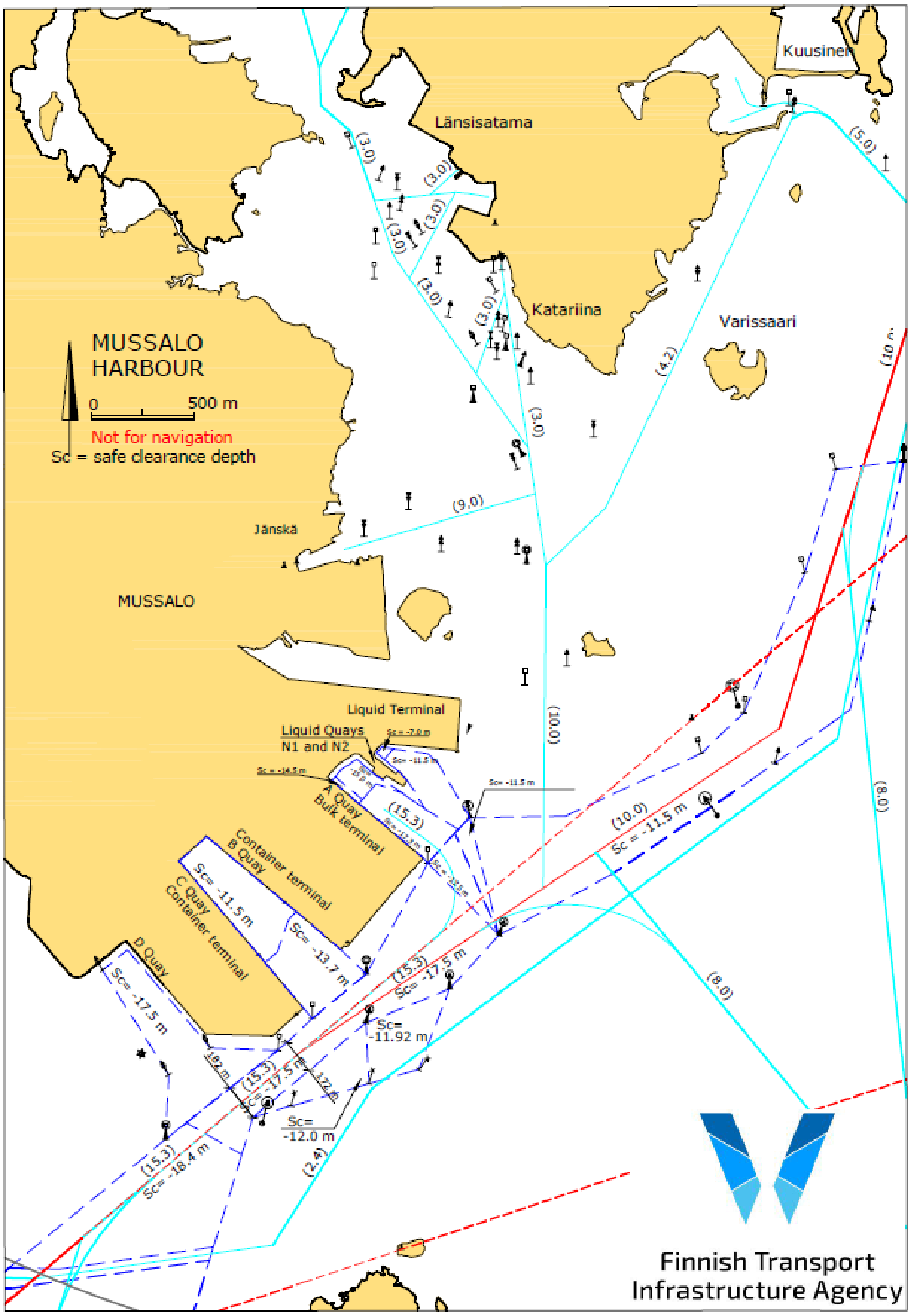


Figure 5 Mussalo Harbour and Approach

1.2. RAUMA CHANNEL (12.0 m)

1.7.2021

CHANNEL DATA

Alignment and buoyage: The channel starts W of Rauma Lighthouse and continues to the Port of Rauma. Four lines.
Length approx. 26 km/14 nm. Lateral marking. Lit.

Dimensions: Design ship: ro-ro vessel, l = 255 m, b = 32.2 m, t = 12.0 m. Maximum authorised draught 12.0 m, safe clearance depth in the outer channel -14.1 m MW2017 / -14.0 N2000, and in the inner channel -13.6 MW2017 / -13.5 m N2000. Minimum width 144 m, in the Kovankivet passage 158 m; minimum bend radius 1,275 m; in the port 400 m; de- sign speed in the outer channel (safe clearance depth=14.1 m) 12 knots and in the inner channel 10 knots (safe clearance depth 13.6 m).

Anchorage areas etc.: Anchorage SW of Rauma Lighthouse in the outer channel; take caution to avoid the cable situated S of the lighthouse.

NAVIGABILITY

Navigational conditions: The outer channel until Rihtniemi consists of open sea and is unsheltered against S-W-N winds. From Rihtniemi, the channel continues sheltered by skerries, islands and mainland and densely marked with edge marks to the Port of Rauma. On the Urmluoto line, in the Kovankivet passage, the manoeuvrability of large vessels may be restricted by cross currents. Strong side winds increase drift.

Ice conditions: In winter, there may be moving ice fields in the area off Hylkikarta. Moving ice may cause buoys to be pressed beneath the surface and their lighting devices may be damaged.

OPERATIONAL RECOMMENDATIONS (channel and harbour)

Wind: Vessels with a length under 210 m; maximum speed of drift-inducing wind gusts 18 m/s in daytime and 15 m/s at night. Vessels with a length over 210 m; maximum speed of drift-inducing wind gusts 15 m/s in the daytime and 12 m/s at night. Lower limits for ro-ro vessels and ships in ballast. Drift-inducing wind refers to wind which deviates from the Urmluoto line by more than 30°. Pilotage is discontinued when the wind speed exceeds 20 m/s.

Visibility: The Urmluoto lines shall be visible at night.

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

TRAFFIC SERVICES

Pilot order: Email: pilotorder.west@finnpilot.fi. Web-based pilot order form www.pilotorder.fi. Phone: +358 (0) 400 907979, fax: +358 (0) 29 5253012.
Pilot boarding position 61°07.5’, 21°10.4’. Pilotage distance 10 nautical miles.

VTS: West Coast VTS, VHF channel 9; phone +358 (0) 20 448 6645; email: westcoast.vts@fintraffic.fi

Tugs: Alfons Håkans’ tugs (ASD and conventional), phone +358 400 521 854 /24h. Tugs shall be ordered at least 2 h in advance.

PORT

Quays: Petäjäs: length 495 m, safe clearance depth -11.0 m; Konttilaituri (old), length 160 m, safe clearance depth -11.0 m; Konttilaituri (new) length 350 m, safe clearance depth -13.6 m; Iso-Hakuni: 5 side/stern ramp berths, safe clearance depth -11.0 m; Oil Harbour: safe clearance depth -9.15 m; Central Harbour: length 605 m, stern ramp berth, safe clearance depths -6.70...-7.50 m; Laitsaari and chemical quay: total length 347 m, safe clearance depth -8.85 m.

Cargo handling: http://www.portofrauma.com/

CONTACT INFORMATION

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Managing Director Hannu Asumalahti phone +358(0)50 3039700
Port Control phone +358(0)500 597 579, satamavalvonta@portofrauma.com

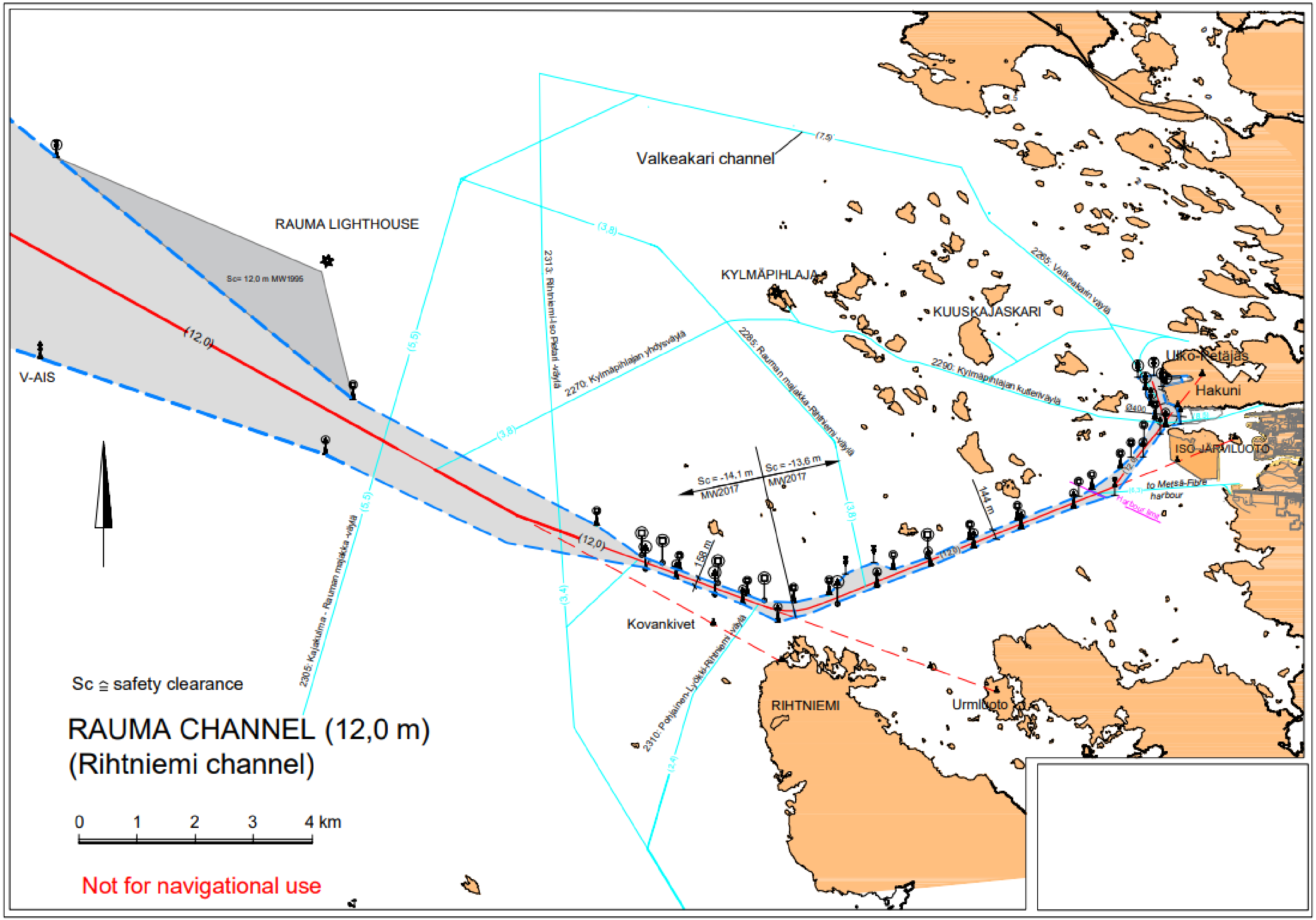


Figure 6 Rauma Channel

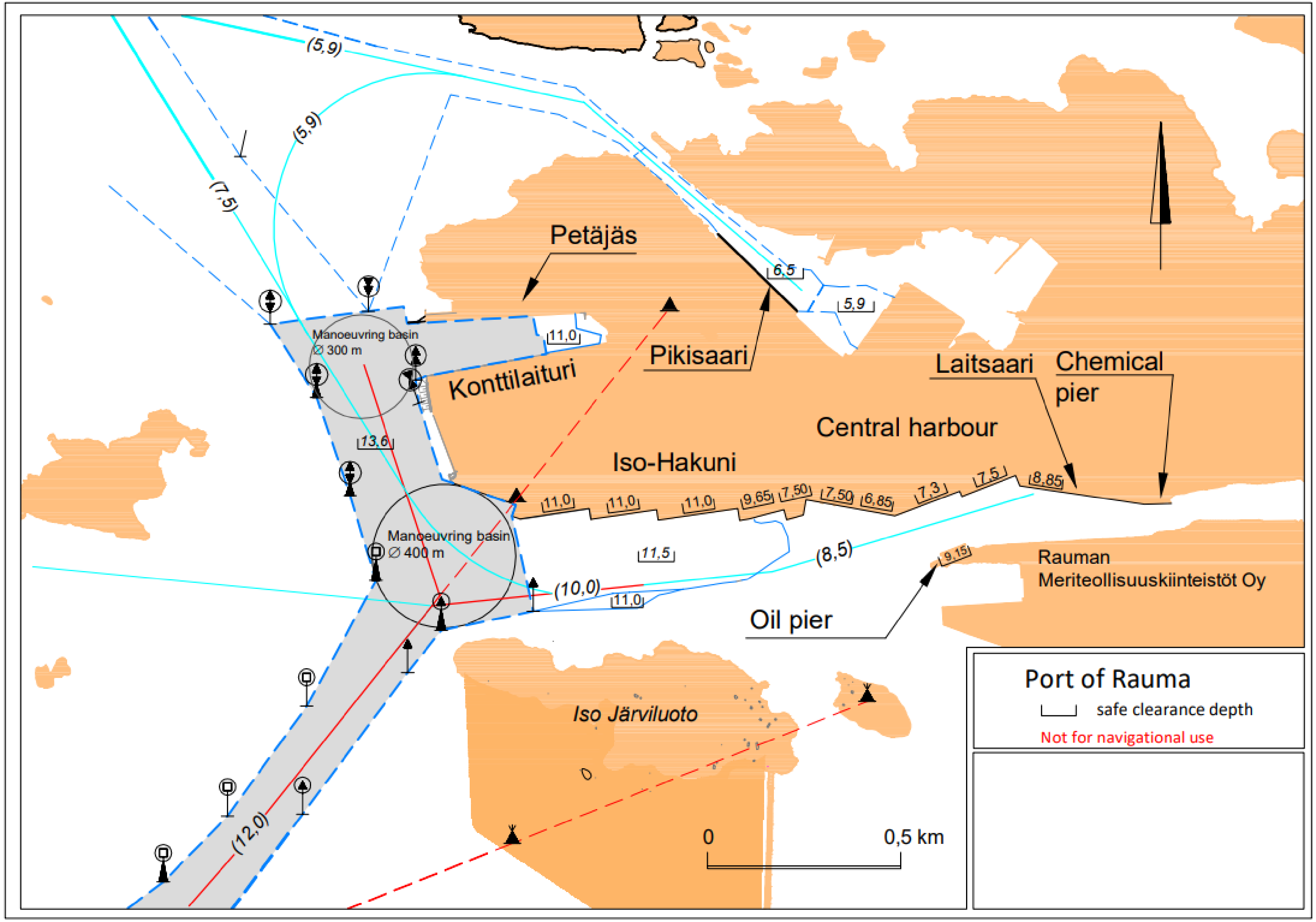


Figure 7 Port of Rauma

APPENDIX 4 ATON DESIGN - 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 specialized berths, including two for the reception of 230- 280,000 DWT tankers.

Recently, an 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.

1.1. THE VESSEL TRAFFIC (PER YEAR)

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

About 7 500 vessel calls

1.2. MAIN WATERWAY IN ANALYSIS

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

1.3. PORT 2000 WATERWAY

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

1.4. AtoN

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 synchronized 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 78 meters 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

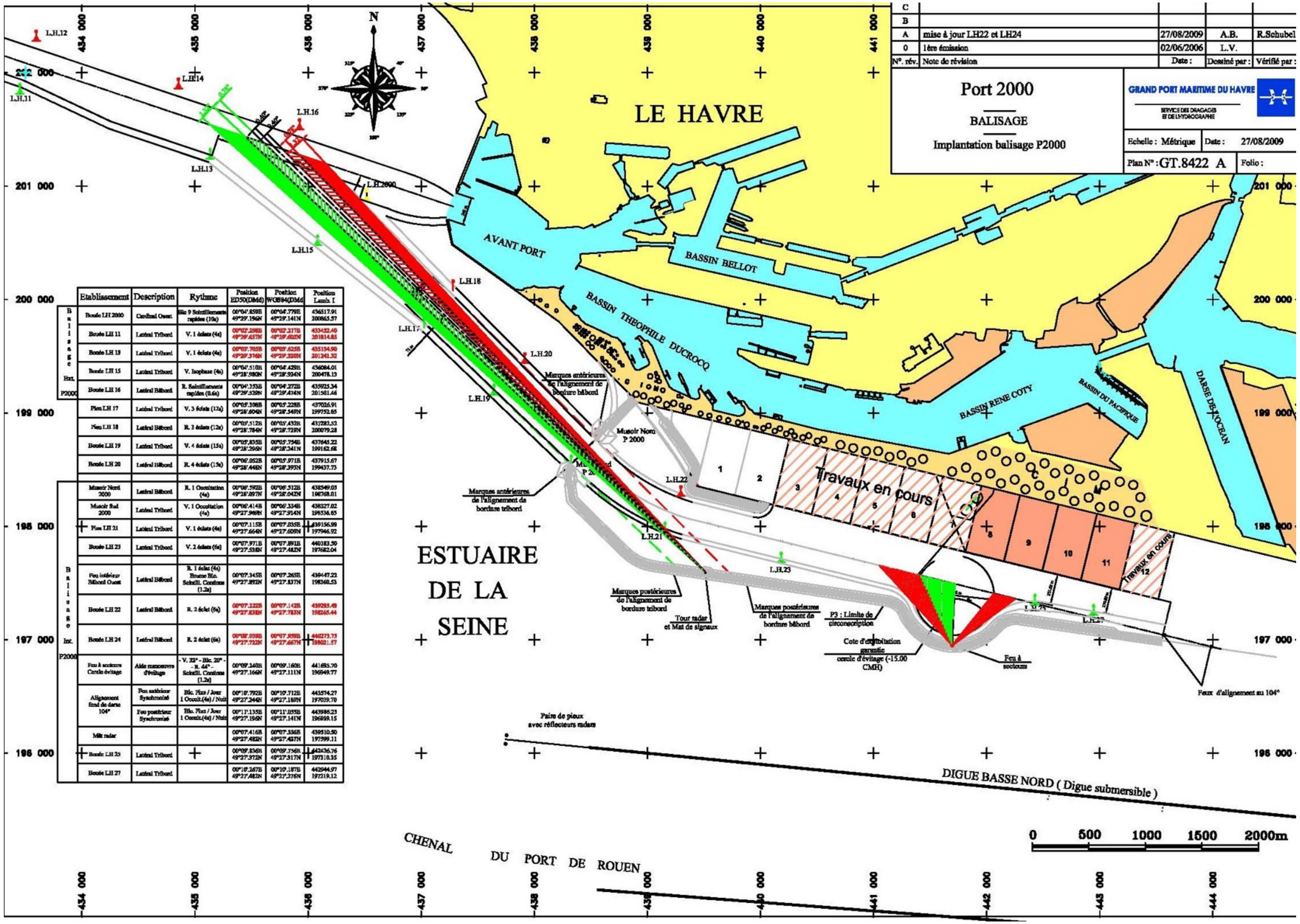


Figure 8 Port of Le Havre

APPENDIX 5 ATON DESIGN - THE “SEEKANAL ROSTOCK” – GERMANY

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:

1.1. WATERWAY

Outer part:

Length: 5.7 NM

Width: 225 … 120 m

Depth: ≥ 14.5 m

Inner part:

Length: 1.5 NM

Width: 120 m

Depth: ≥ 14.5 m

1.2. VESSEL TRAFFIC

Total Traffic in the Area in 2006: 25.200 vessels including:

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.

1.3. VESSELS DIMENSIONS

Terms for two lane traffic passing 120 m width area:

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

Draught < 8.5 m

5 If wind < Force 6 and both masters accept a two lane traffic passing and

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

Draught < 8.5 m

6 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.

1.4. MAXIMUM SIZE OF VESSEL IN “SEEKANAL ROSTOCK”

Length	296.0 m
Beam	32.0 m
Draft	10.5 m

The channel is narrow in relation to the vessels dimensions.

1.5. AtoN

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, synchronized lights

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

Notes

1. EWF = effective width of fairway

   SC = swinging circle

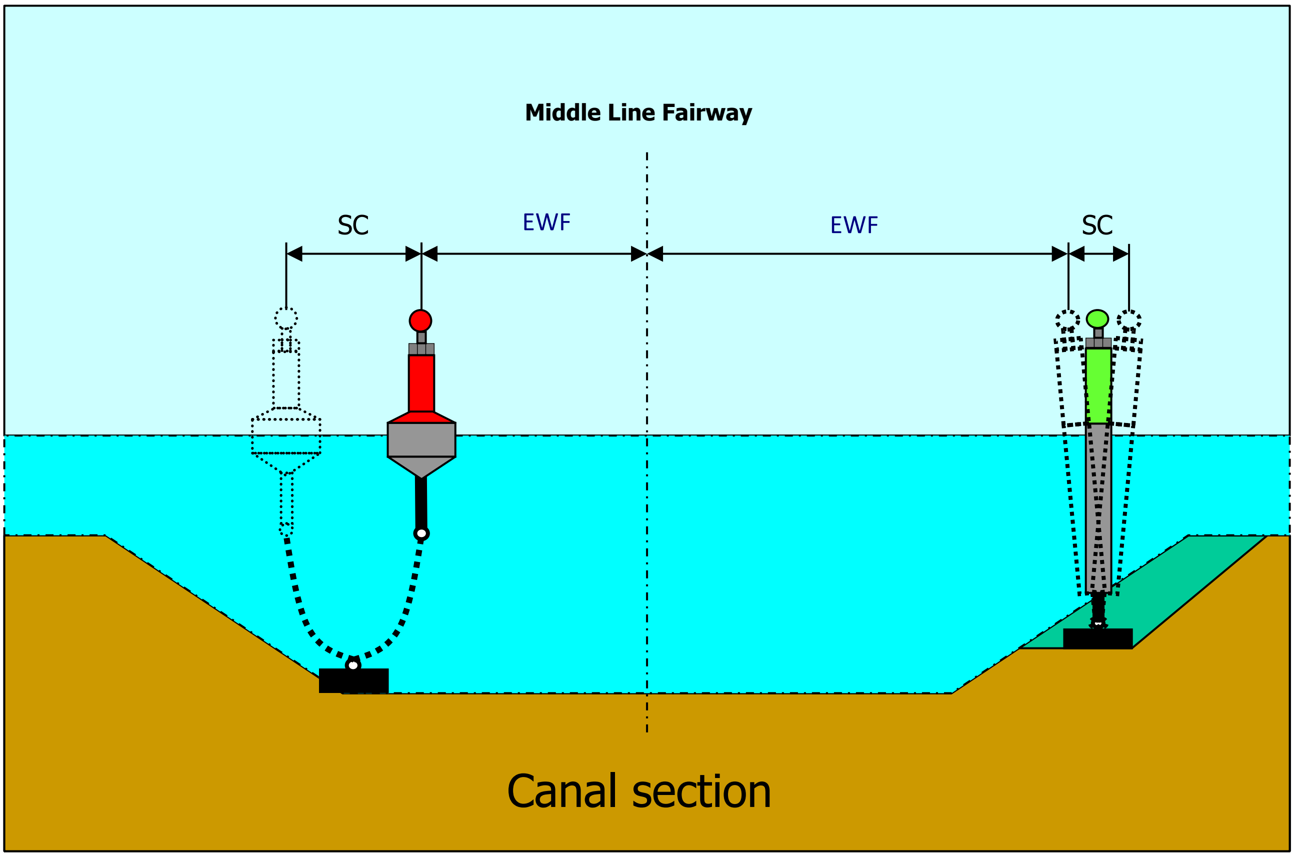


Figure 9 Seekanal Rostock – canal section

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 Lights over 4 NM, 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.

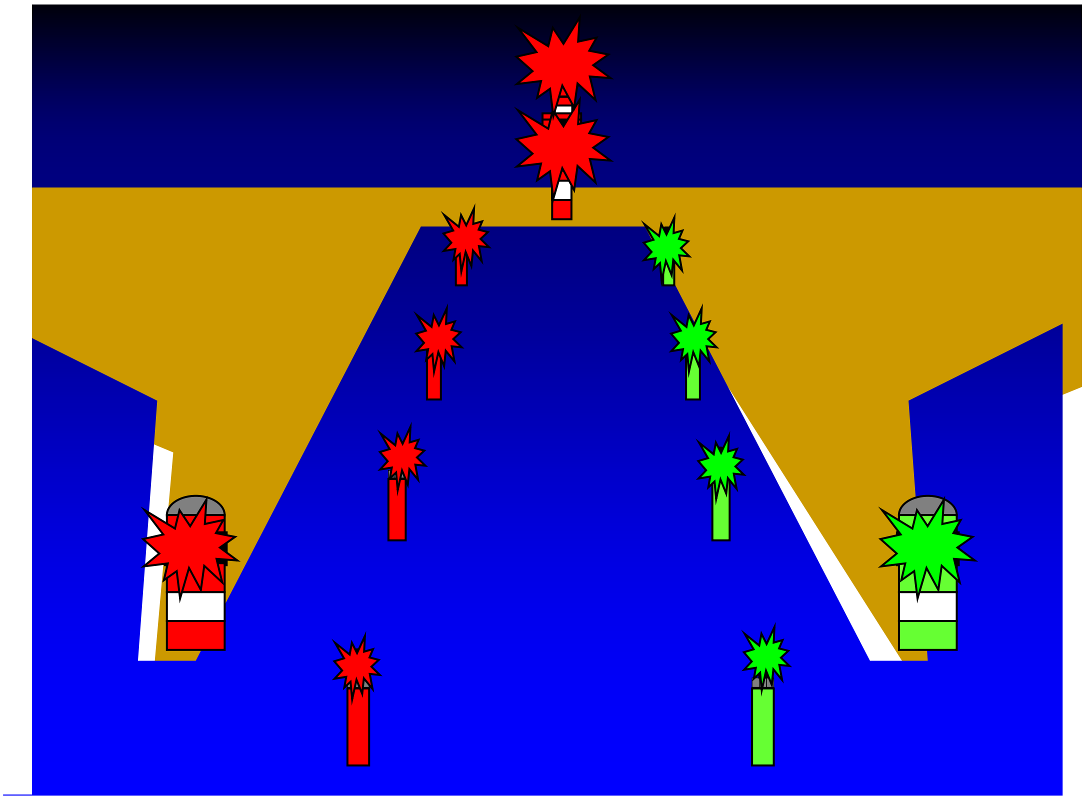


Figure 10 Example for synchronized AtoN: Inner part of "Seekanal Rostock"

The Leading Lights are synchronized with the mole lights and the buoys as shown in Table 2.

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

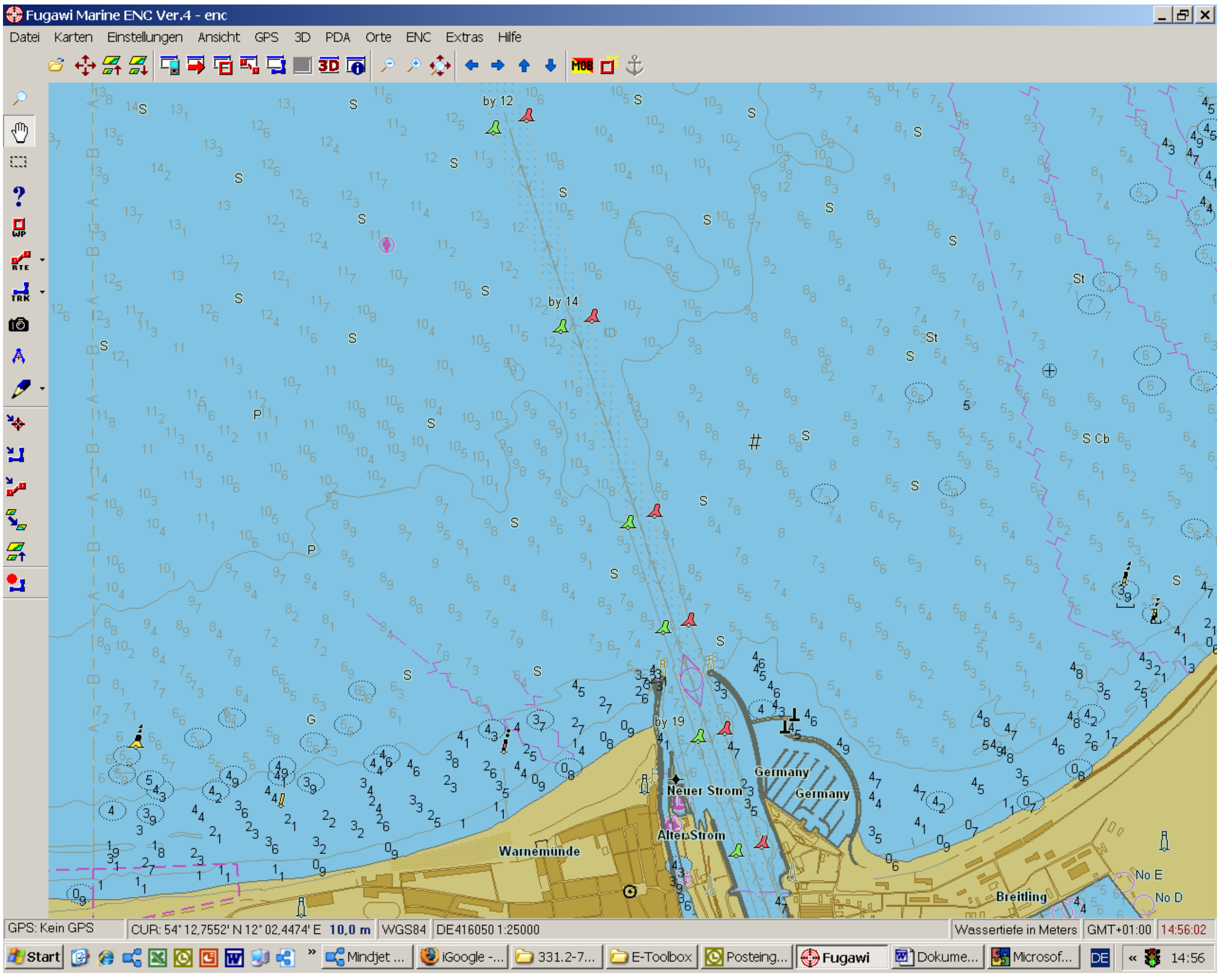


Figure 11 Sea Chart of a part of the outer and inner channel "Seekanal Rostock"

APPENDIX 6 ATON DESIGN - 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 vessels types and sizes, tug capacity, port and channel layout.

1.1. WATERWAY

1.2. OUTER PART

Length: 3.9 NM

Width: The channel has been widened to 162 m for its full length.

Depth: 13.5 m

1.3. INNER PART

Length: 0.6 NM

Width:

Depth: 13.5 m

1.4. VESSEL TRAFFIC

Total Traffic in 2008: 1102 arr/dep

Vessel Dimensions: 260 x 40 x 12.5 m

1.5. AtoN

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 synchronized 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.

1.6. ADDITIONALLY

DGPS coverage, VTS, Mandatory pilotage services etc.

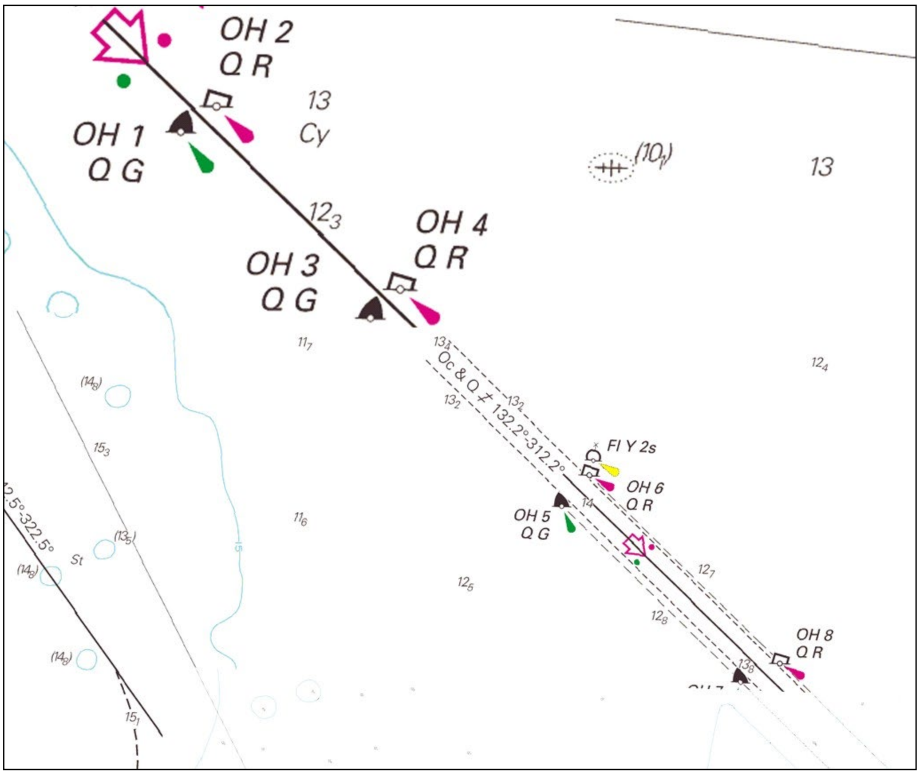


Figure 12 Outer part of channel - Malmo

Figure 13 Inner part of channel - Malmo

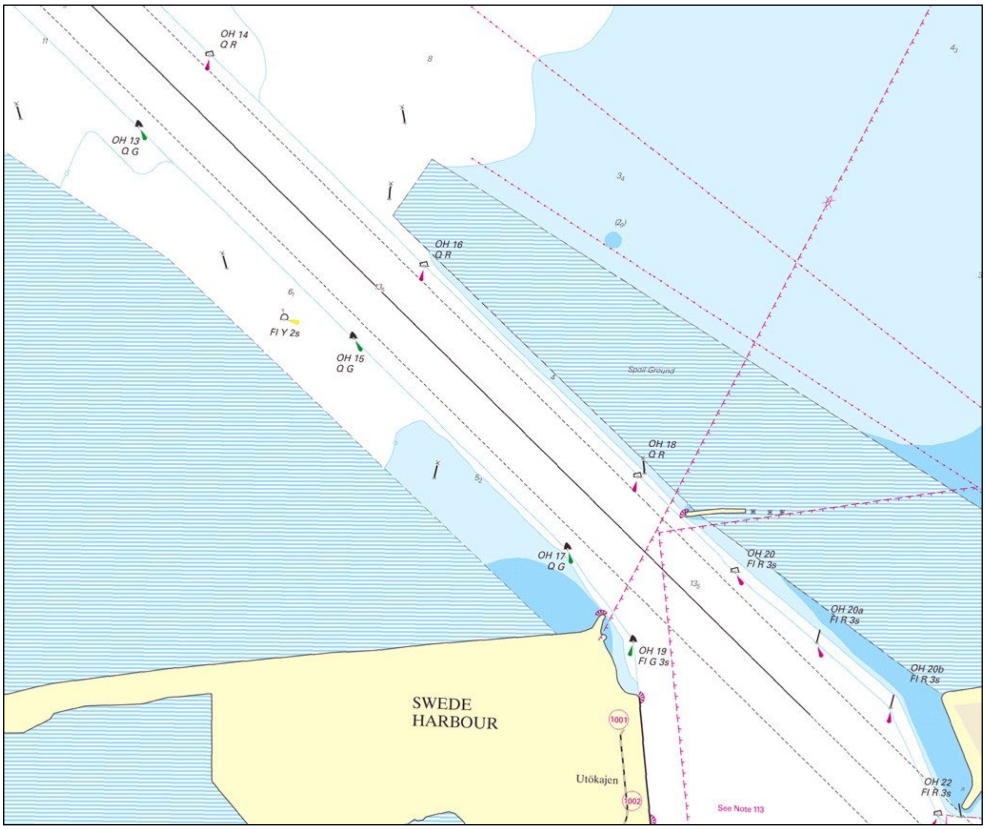


Figure 14 Entrance to Malmo Harbour

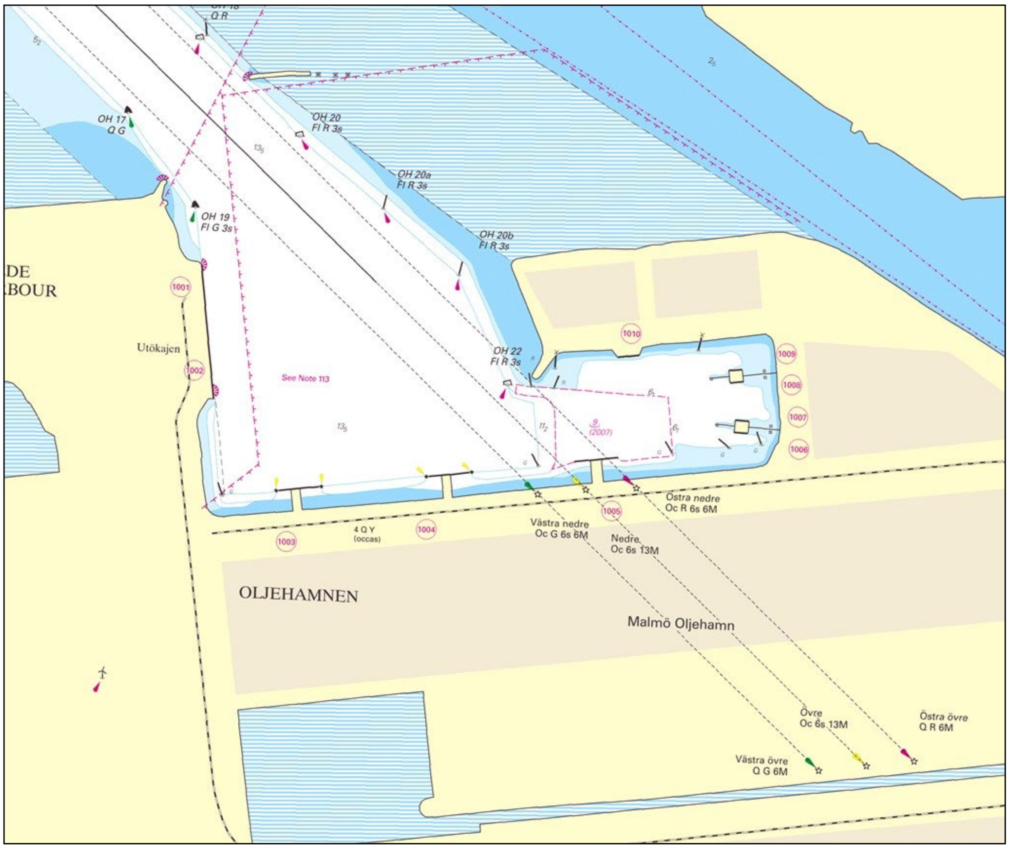


Figure 15 Malmo Harbour

APPENDIX 7 ATON DESIGN - NETHERLANDS PORTS

1.1. INTRODUCTION

The Port of Rotterdam is by far the largest seaport in the Netherlands. Other important seaports are Port of Amsterdam, Zeeland Seaports and Groningen Seaports.

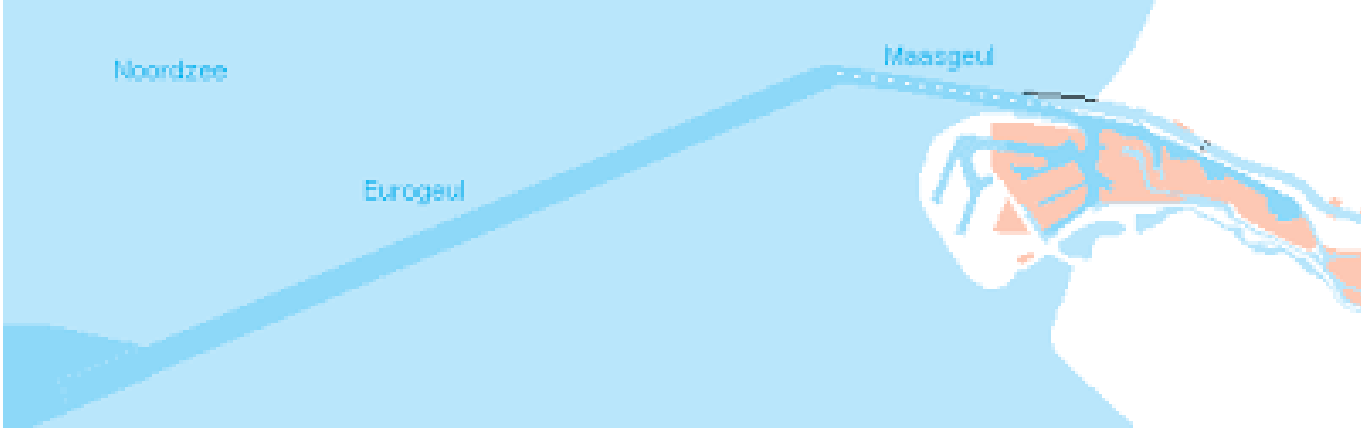
Every year, approximately 95,000 seagoing vessels visit the ports of the Netherlands. The lengths of these ships vary between about 70 and almost 400 meters. Small ships with a shallow draft call at the ports of Rotterdam, but also very deep-draft ships with specialized cargoes visit specially constructed ports. However, the North Sea off the Dutch coast is not deep enough to allow such deep-draft vessels to navigate safely. Deep channels have been constructed off the Dutch coast, especially for these ships so that these ships can still reach the ports intended for them.

- Off the coast of Hoek van Holland (approach Port of Rotterdam) this channel is called the Eurogeul/Maasgeul (Euro channel / Maas channel).
- A comparative channel has been constructed off the coast of IJmuiden (approach Port of Amsterdam). This is called the IJgeul (IJ channel).

	IJ channel (to Port of Amsterdam)	**Euro-Maas channel (to Port of Rotterdam)**
Depth (average)	21 m	26 m
Width	450-600 m	600-1,200 m
Length	43 km	57 km
Maximum draft	17,80 m	22,85 m

1.2. PORT OF ROTTERDAM

The Euro channel or Euromaas channel is a channel dug in the North Sea in conjunction with the Port of Rotterdam. It has a length of 57 km and a depth of 23 meters



The Euro channel is a so-called *deep water route* in the *Traffic Separation Schemes* of the Southern part of the North Sea and the English Channel. Ships with a draft between 14 and 20 meters only need to use the last part of the Euro channel; the Maas channel. Ships with a depth of 20 meters or more need to use the entire length of the Euro channel and will get a pilot on board before entering the Euro channel. The smaller ships will normally receive their pilot near the pilot station at Maas Center buoy.

The Euro channel allows deep-water sea access to the Port of Rotterdam. At high tide it allows large containerships and large ore carriers like the MS *Berge Stahl* or MV *Vale Rio de Janeiro* to enter Rotterdam. The VLOC *Berge Stahl* operates a frequent service between Brazil and Rotterdam to supply iron ore for the German steel industry.

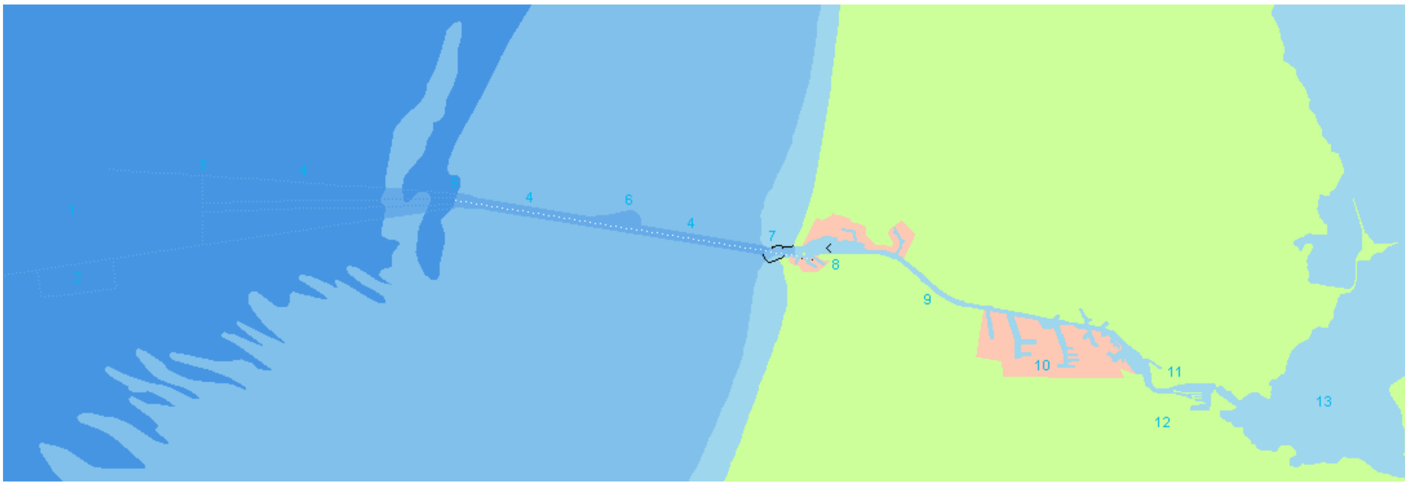
Maas channel

The last 14 km section of the Euro channel before approaching the coastline is called the *Maas channel*. Seagoing vessels with a draft of over 20 meters must utilize the Euro channel. Other ships can take the Maas channel directly. The navigation is strictly regulated. Attendance is about one ship per day (357 for the latest year available). The channel must be dredged and maintained. Every year 5 to 7 million tons of sand are recovered. In 2008 the Euro channel was expanded to an overall width of 600 meters.

In 2012 the Maas channel was widened to 830 meters, in order to accommodate larger ships. The work was completed in time for the opening of the new Maasvlakte, the Maasvlakte 2.

1.3. PORT OF AMSTERDAM

The IJ channel or IJ channel is a man-made excavation on the bottom of the North Sea, off the coast of IJmuiden, which provides access to large vessels with deep drafts to the port of IJmuiden, and also via the North Sea Canal, to the port of Amsterdam (just like the Euro channel for the port of Rotterdam).



When the IJ channel opened in 1982, the maximum draft was at 16.5 meters. In 2006, the Minister of Transport decided to deepen and extend the IJ channel. Public works have dredged the channel to 17.8 meters. In addition, the IJ channel was extended in length from 23 to 43 kilometres.

Traffic is strictly regulated; vessels must follow the leading lights over the last 23 km, which are formed by the Hoge lighthouse of IJmuiden and the Lage lighthouse of IJmuiden. 18 km from the coast, a space was created so that in case of problems, it is possible for vessels to turn back.

1.4. AtoN IN THE EURO CHANNEL / MAAS CHANNEL AND IJ CHANNEL

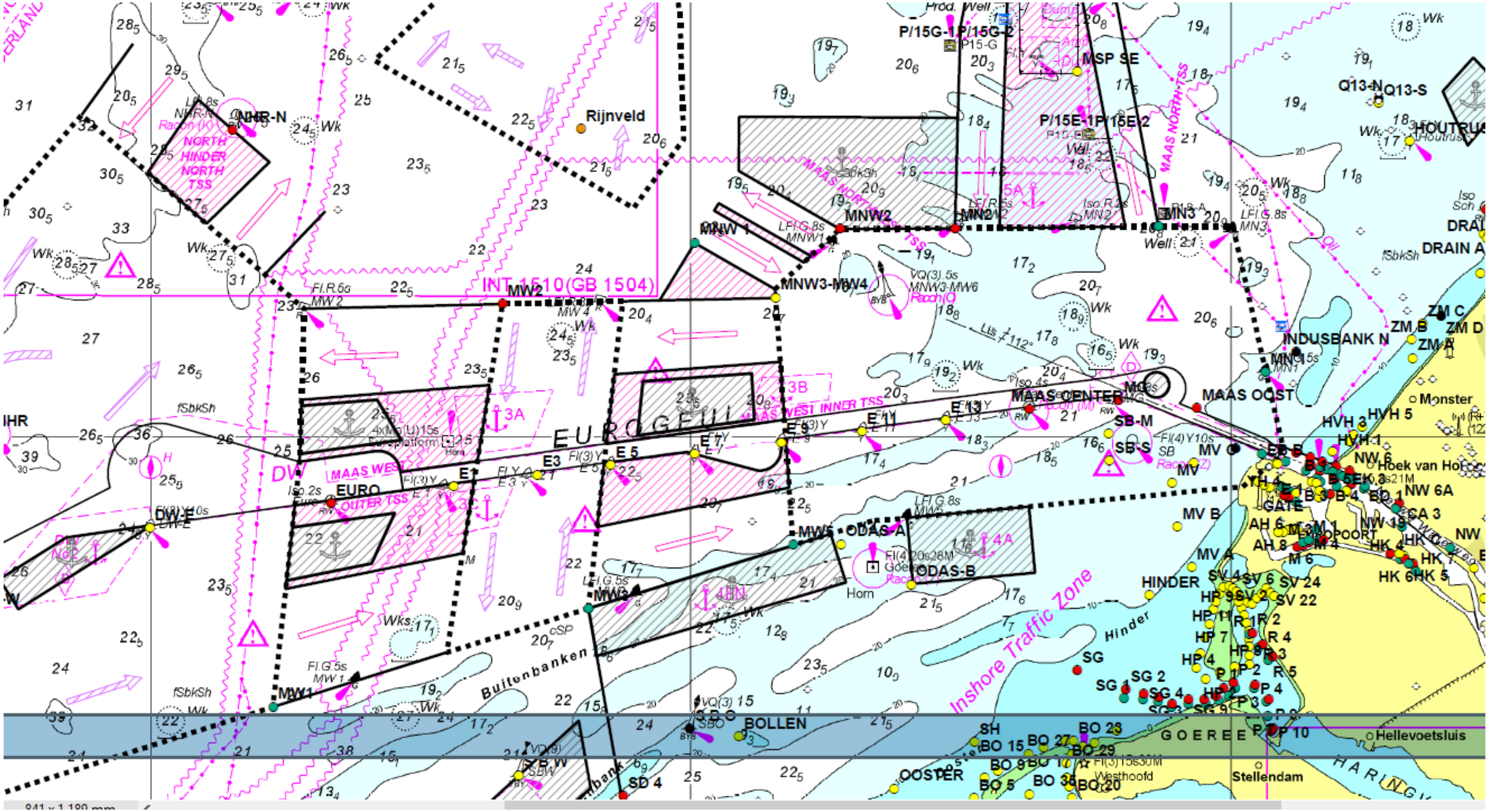
Both approaches of the channels are similarly marked: halfway through the North Sea is a large safe water mark. This buoy marks the approach to the channels.

It is not visible from the water surface where the channels are located. That is why these channels are marked with light buoys at certain distances from each other. Seen from the sea, there are large yellow light buoys with odd numbers in the direction of the Dutch coast. These yellow light buoys are located at a mutual distance of about 3 nautical miles (about 5.5 km). apart. Passing ships keep these yellow buoys to their starboard or right side as they sail towards the coast of the Netherlands.

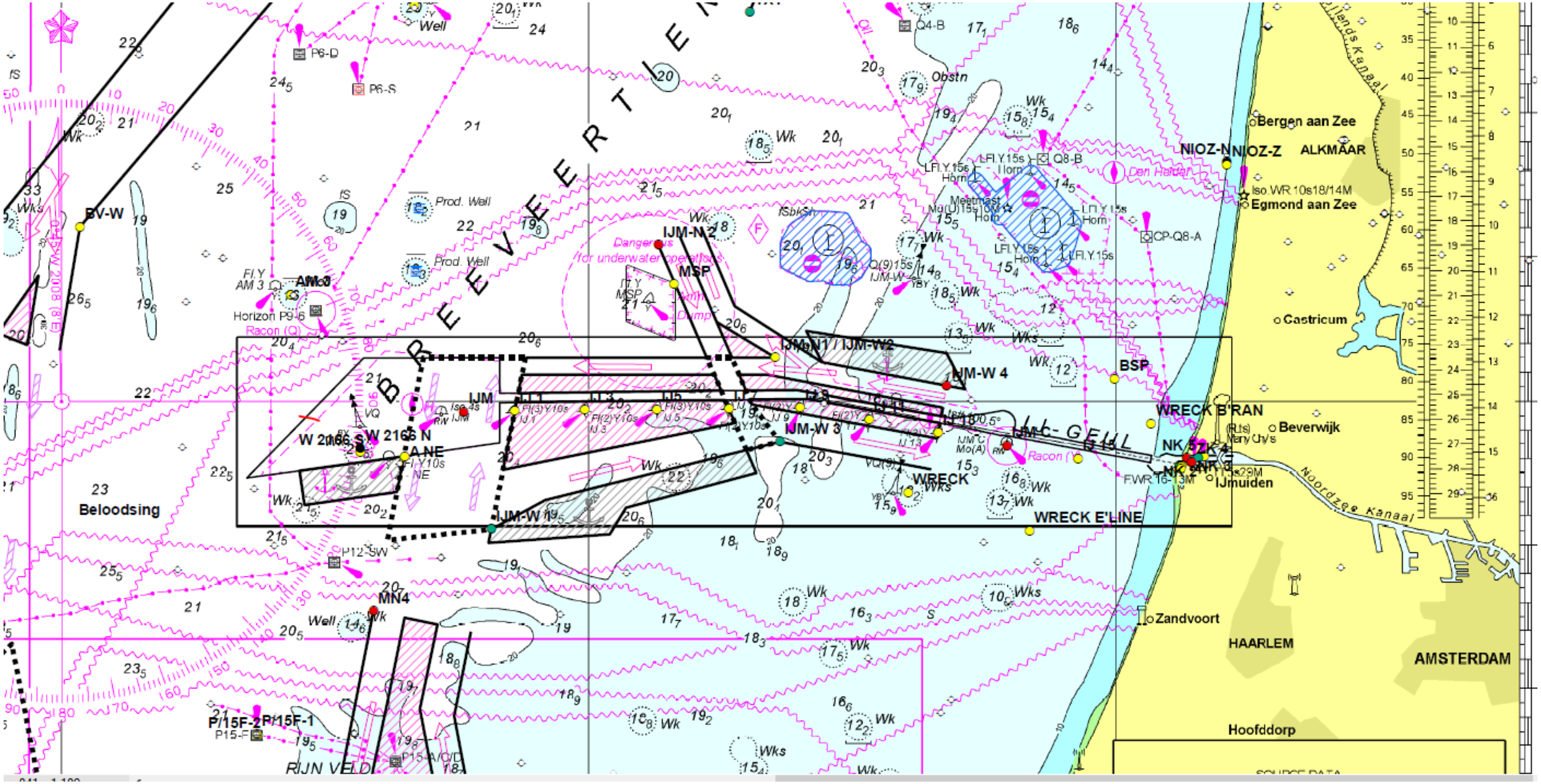
After the yellow buoys there is a safe water mark which stands for Maas Center and Ijmuiden Center. This buoy marks respectively the approach to Hoek van Holland (Rotterdam) and IJmuiden (Amsterdam).

1.4.1. AtoN Euro channel / Maas channel

1.4.1.1. AtoN Euro channel



1.4.2. ATON IJ CHANNEL



1.5. ZEELAND SEAPORTS / NORTH SEA PORT

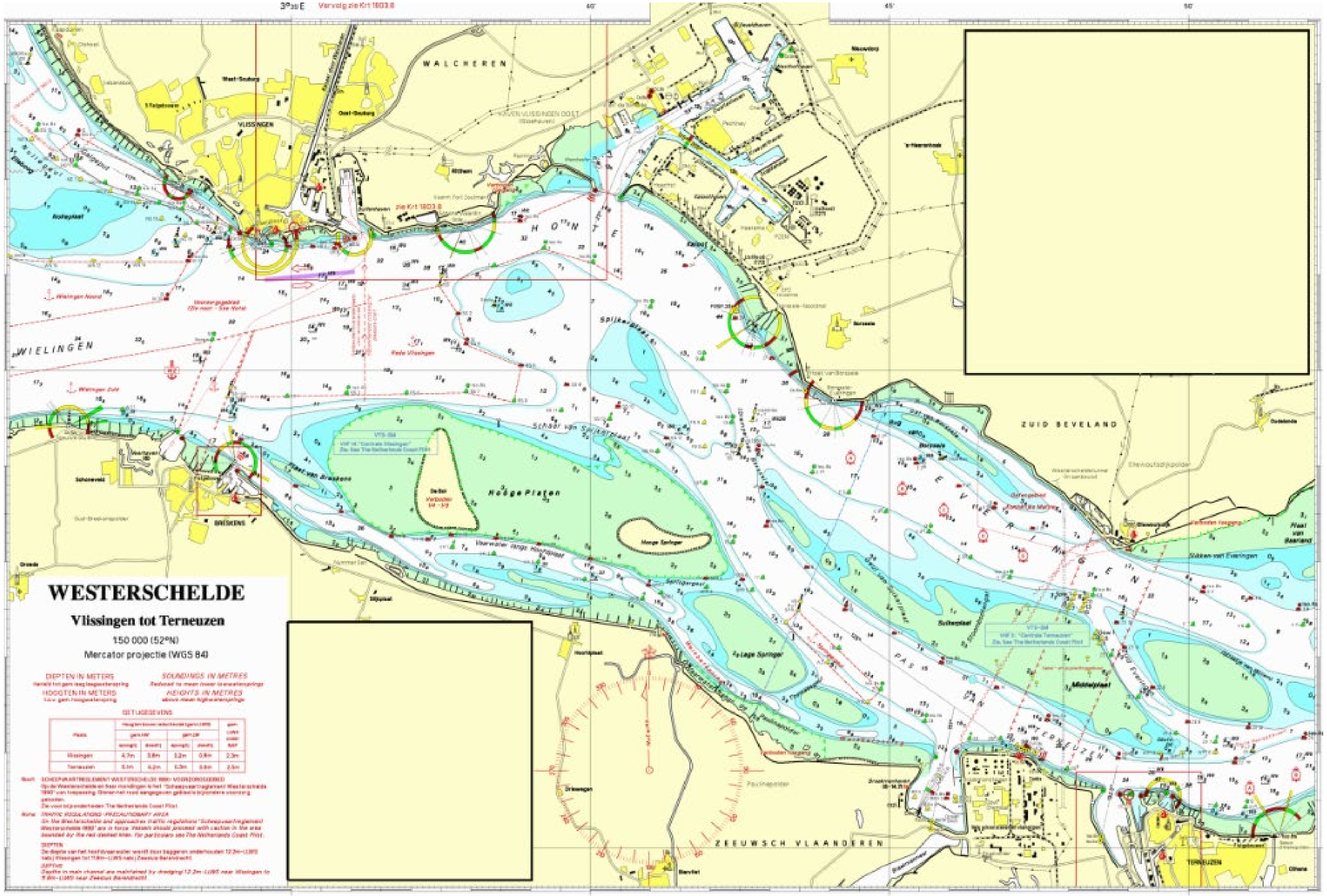
(The cross-border port of North Sea Port has been in existence since 1 January 2018 and arose from the merger of the Dutch Zeeland Seaports (Vlissingen and Terneuzen) and the Flemish/Belgian Ghent Port Company.

North Sea Port, located along both banks of the Western Scheldt, is accessible to global shipping via the North Sea. The Western Scheldt provides an open connection to the North Sea and is close to international routes. Thanks to the maximum depth of 17 metres, the largest seagoing vessels can reach the port.

Terneuzen and Gent can be reached by seagoing and inland vessels via the lock complex at Terneuzen, which lies at the head of the Gent-Terneuzen Canal. This straight and wide canal offers shipping traffic smooth and rapid nautical access to Terneuzen and all the way to Gent, at North Sea Port's southern limit.

The non-tidal Gent-Terneuzen Canal is accessible to ships with a maximum draught of 12.5 metres. The Western Lock in Terneuzen can accommodate ships of up to 92,000 DWT ("deadweight tonnage" or carrying capacity), with a maximum length of 265 metres, a width of 37 metres and a draught of 12.50 metres. By 2022, a new lock will be finished that will replace the middle of the three existing locks. This will prepare North Sea Port for the future, to properly welcome the ships that are always increasing in size.

1.6. AtoN WESTERSCHELDE



1.7. GRONINGEN SEAPORTS

Groningen Seaports (GSP), known as the Delfzijl Port Authority from the 1950s to 1997, is the organization that manages two seaports in the Dutch province of Groningen: the Port of Delfzijl and the Eemshaven, with the adjacent industrial areas.

The Groningen Seaports are located at the mouth of the River Ems and near the main North Sea shipping route in the Le Havre-Hamburg Range.

Delfzijl: Latitude 53°20’N, Longitude 06°56’E.

Eemshaven: Latitude 53°27’N, longitude 06°50’E.

- From Delfzijl to Emden is 10 nautical miles via Paapsand-Süd.
- From Delfzijl harbour to the pilot station is 37 nautical miles via Paapsand-Süd.
- From Delfzijl harbour to Eemshaven is 15 nautical miles via Paapsand-Süd.
- From Eemshaven quays to the pilot station is 23 nautical miles via Westereems.

Approach

From the pilot station at Westereems fairway buoy, vessels bound for Delfzijl sail via Westereems, Ranselgat, Doekegat and Oost Friesche Gaatje to the entrance near Oterdum. Vessels bound for Eemshaven sail via Westereems, Ranselgat and Doekegat to the entrance of Eemshaven.

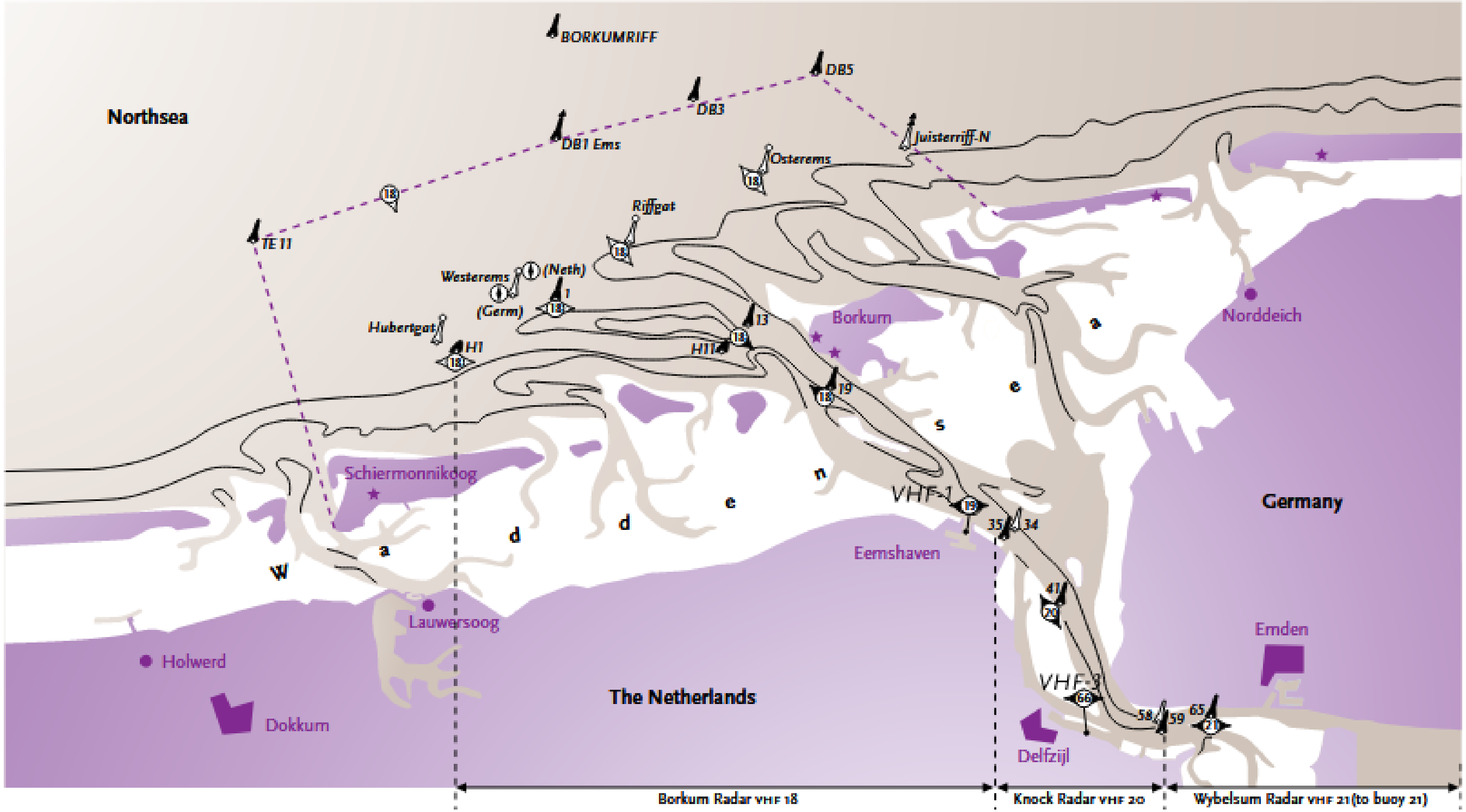
- Distance from pilot station to Delfzijl quay: 37 nautical miles.
- Distance from pilot station to Eemshaven quay: 23 nautical miles.

The Zeehavenkanaal in Delfzijl offers vessels an operational draught of about 9.0 metres under mean HW conditions. At present, Eemshaven offers an operational draught of about 14 metres under mean HW conditions. With respect to the operational draught for both the ports, a keel clearance of 10 per cent of the draught is applicable.

Anchorage at Delfzijl: vessels up to 100 metres long which have to anchor outside the piers can anchor on the Oterdum roads north-east of the harbour entrance.

Larger vessels or vessels carrying dangerous cargo should anchor in the Doekegat or Oude Westereems near Eemshaven.

Request for anchorage should be applied at the Vessel Traffic Centre Ems, VHF Channel 74. Anchorage is forbidden in the ports of Delfzijl and Eemshaven



River Ems and Estuary

Sailing Report Position Report Lighthouse Buoy lit Buoy unlit

1.8. AtoN EEMS AND ESTUARY