



Site selection and design of marine terminals

Fecha de entrega: 28 de Abril 2009
Fecha de aceptación: 2 de Junio 2009

Colin Skipper¹ and Stephen Gyi²

¹HR Wallingford Ltd, Howbery Park, Wallingford, Oxfordshire OX10 8BA, UK, c.skipper@hrwallingford.co.uk

²Ultimate Marine Consultants Ltd, 98 Luscinia View, Napier Road, Reading RG1 8AE, UK, stephen.gyi@ultmar.com

This paper considers the site selection and design issues associated with the development of a new marine terminal, develops a methodology to address the issues, and examines traditional and new hydraulic design techniques and technologies that are used as tools in the design process.

Keywords: design, marine terminal, operability, navigation, dredging, breakwaters and mooring

Este artículo considera la elección de la ubicación y aspectos de diseño asociados con la construcción de un nuevo terminal marítimo. Se presenta una metodología para abordar estos aspectos y se examinan técnicas de diseño hidráulicas tradicionales y nuevas. Además se presentan tecnologías que son usadas como herramientas en los procesos de diseño.

Palabras clave: diseño, terminal marítimo, operabilidad, navegación, dragado, rompeolas y atraque

INTRODUCTION

Marine terminals may be situated in remote locations and dedicated to handling a single product, or they may be located inside an existing multi-purpose port and handle multiple products. The issues are very different; however the requirements are always the same:

- a) located close to source of supply/delivery
- b) located in an area that is not environmentally sensitive
- c) suitable onshore areas for storage and process plant
- d) berth(s) located close to the onshore facilities, preferably in naturally deep water and a sheltered environment with high berth availability
- e) safe marine access to the berth(s)

It is not always possible to meet all these criteria in the natural environment, in which case there will be a need to create them by the dredging of approach channels and manoeuvring areas for marine access, creating protection to the berth by use of breakwaters, or even moving the plant and storage offshore. Examples of the issues and the challenges faced by the designer will be provided based on the authors' extensive project experiences in the international oil and gas industry.

METHODOLOGY

Key drivers in the design process are:

- a) operability
- b) cost (Capital Expenditure CAPEX and Operational Expenditure OPEX)
- c) schedule
- d) Health, Safety, Security, and Environmental risks HSSE
- e) impact on / threats from other users of the area

Paying due attention to the above should deliver a marine terminal with the level of performance required, at lowest cost, as quickly as possible, and with minimal impacts and risks.

The golden rule in marine facility design is to select a site and develop the design of a marine terminal based around the shipping operations. Too often in the past has a terminal been located and designed by an engineer without marine operational experience, and then handed over to an operator who has to work out "how to operate it". The methodology presented is an integrated one that puts marine operations at the heart of every design decision.



The key objectives early in the process are to define the functional requirements and operational needs, and in parallel, to develop an understanding of the environment in which the terminal may be located. As the project evolves the Design Basis needs be refined as new information becomes available and become more detailed as the level of design definition increases. Having identified the Design Basis the Design Development process can proceed and the Design of the marine terminal developed. This involves holistic consideration of a wide variety of different factors such as navigation to/from the berth(s), the need to create access by dredging (both capital and maintenance), the mooring and loading of the vessels and the need for breakwater protection, and how to convey the cargo to/from the storage area to the berth. In parallel constructability, cost and schedule and HSSE impacts and risks need to be considered.

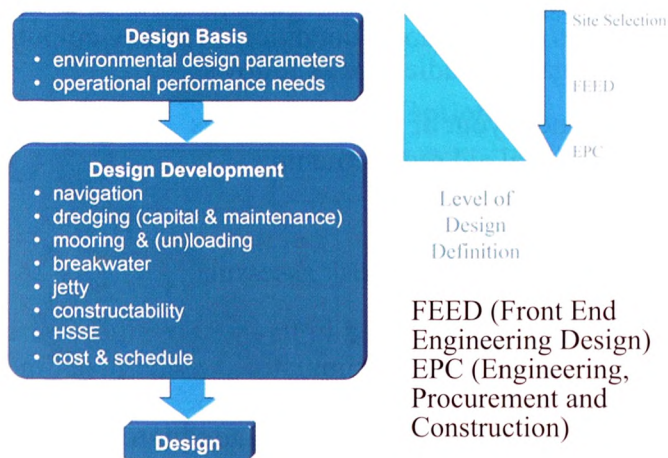


Figure 1: Site selection and design framework

In order to address all the interactions between these different considerations it is normal to approach the task in a phased manner; starting at a high level (conceptual) and then increasing the level of design definition as the project matures. It is vital that appropriate expertise, techniques and experience is applied in throughout the process; but particularly at the front of the project when fundamental decisions are made to the location of the site and the layout of the facilities. Poor judgements at this time can lead to the project taking a sub optimal direction, and it can be costly and time consuming to correct.

TECHNIQUES AND TECHNOLOGIES

There are a wide range of techniques and technologies that are used in the design process described above.

These are presented below within above framework (Figure 1). Discussion on topics such as techniques for the structural engineering of piled structures is outside the scope of this paper, as are construction techniques and methodologies, environmental, health, safety and security, and cost and scheduling estimating.

Environmental design parameters

The site selection and design of marine facilities must take into consideration a wide range of environmental parameters including bathymetry/topography, land/sea use, geology, seismicity, wind and wave climate, water levels, currents, visibility, sediment transport, morphology (shoreline and seabed) and environmental/ecological sensitivities.

During the early phases of a project site specific data are often limited. Key tools to gain an initial appreciation of the site are “the designers eyes” and access to regional data. In the case of metocean conditions, for example, there are a large number of regional models generally available that are used for weather forecasting purposes. Although these models are not accurate in shallow water areas (because of the regional nature of the model and hence its resolution and limited representation of shallow water processes) information can be abstracted at points in deepwater and then, by the use of transformation models that represent the important physical processes, site specific climate and extreme data can be rapidly developed.

As the project moves forward it is important to have the required level of data available to support the decisions to be made and the level of design definition required. It is important that site specific data collection programmes are commenced early in a project. In order to best target and focus these it is important that location and layout decisions (or decision envelopes) are also made early. It is frequently necessary to deploy specialist recording equipment at the sites as early as possible to ensure a reasonable time of recording. Such equipment may include tide gauges, current meters and wave rider buoys, which should ideally be deployed for at least twelve months, or longer, to cover the full seasonal variations. Clearly this has implications in terms of the time required for the design process and thus the requirement for comprehensive data collection should not be overlooked in the overall planning of new facilities. That said, it should also be noted that a combination of a short period of data used to validate

models can be used to rapidly improve the level of confidence in the design dataset (and reduce the range of uncertainties).

It is also worth noting that if the project modifies the environmental conditions, the only way to understand this interaction is by the use of models.

Operational Performance

The key operational performance requirements are usually framed in terms of:

- a) products and production rates
- b) vessels and parcel size
- c) ship scheduling, downtime and storage requirements

Although high level needs can usually be identified (or bounded) at the outset of the project (*e.g.* X tonnes of cargo to be lifted per annum by ships ranging from Panamax to Cape Class bulk carriers), it is another matter to develop detailed performance requirements and to assess that these are being met by the design. The issue is often one of identifying the economically acceptable level of performance (*e.g.* 100% berth availability is very expensive to achieve, can the project accept 90%?).

A key tool to assess the operational performance of the design (drawing on information from the design process below) is a terminal simulation model. At its simplest level this takes a shipping schedule and simulates all the steps through logistics chain, evaluates delays at each step, and assesses the ability to lift (or unload) the required cargo volumes without causing the available storage to be exceeded (and hence shut down any production processes). This model needs to include the following types of delay:

- a) weather (vessel, tug and (un) loading operational thresholds)
- b) tug and pilot availability
- c) berth availability
- d) traffic conflicts

The model can also include production and storage, and even the complete logistics chain (Figure 2).

Using such tools (in conjunction with marketing department inputs and design data) the operational performance of a design can be evaluated and economically realistic levels of performance set for the next step in the design evolution.

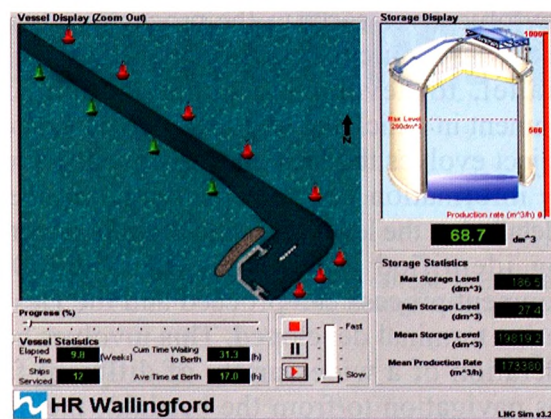


Figure 2: Terminal operation simulation

Navigation

The key inputs to the navigation task are a selection of design vessels (from Operational Performance needs) and the Environmental Design parameters, noting that the focus is on operational conditions. The key outputs from navigation studies are as follows:

- a) depth and layout of navigation areas
- b) navigational aid requirements
- c) tug requirements
- d) safe operating limits
- e) hazard identification / risk assessment

The key technologies used in navigation studies are desk assessment and ship simulator systems (fast time and real time). HR Wallingford's experience is that desk assessments are generally adequate for site selection purposes and initial concept development, but prior to layouts being fixed it is generally advisable to perform real time navigation simulation (Figure 3).

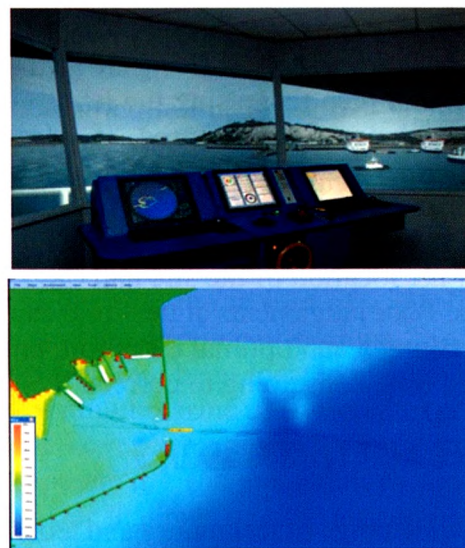


Figure 3: Ship simulator system

Dredging and disposal

The key inputs to design of capital and maintenance dredging and disposal operations are:

- a) depth and layout of navigation areas (from Navigation task)
- b) nature of dredged material, nature of seabed and sediment transport (from Environmental Design parameters)
- c) metocean conditions (from Environmental Design parameters)

The key outputs are:

- a) capital works design (dredging and disposal plans)
- b) assessment of sediment infill
- c) maintenance dredging and disposal plan

Key tools in developing these outputs are desk assessment and sediment transport models (Figure 4).

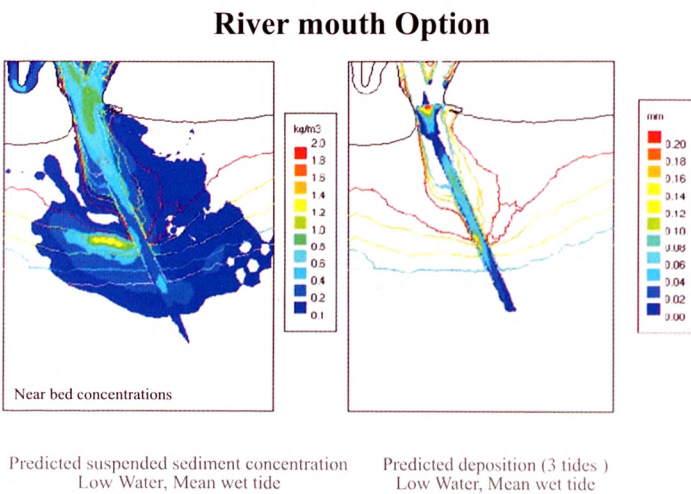


Figure 4: Modelling sediment transport

Key tools to develop these outputs are (Figure 5):

- a) desk assessment
- b) static mooring analysis
- c) fully dynamic mooring analysis
- d) physical models

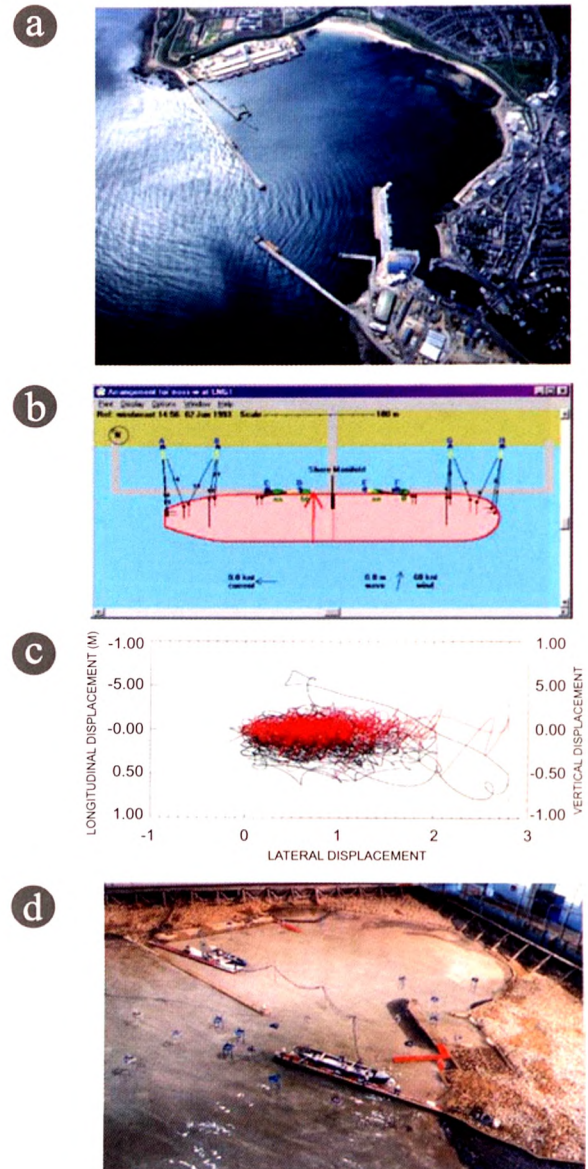


Figure 5: (a) Desk assessment showing wave disturbance, (b) static mooring and loading analysis, (c) fully dynamic mooring and (d) physical model to study wave disturbance shown in (a)

Breakwater

The key inputs to design a breakwater are the Operational Performance needs, the outputs from the mooring and loading task, the Environmental Design parameters; both operational conditions and extreme conditions, together with and geology and seismicity data. The key inputs to outputs are as follows:

- a) layout (plan and elevation) of dolphins
- b) mooring equipment (hooks and fenders)
- c) depth of berthing areas
- d) loading system envelope
- e) gangway envelope
- f) operational thresholds



- a) breakwater length and height to provide adequate shelter
- b) identification and development of breakwater concept
- d) design of concept

The key tools to develop these outputs are (Figure 6):

- a) desk assessment
- b) computational wave disturbance models
- c) physical models (2D flumes and 3D wave basins)

It should be noted that constructability also has a key influence on the selection of the breakwater concept.

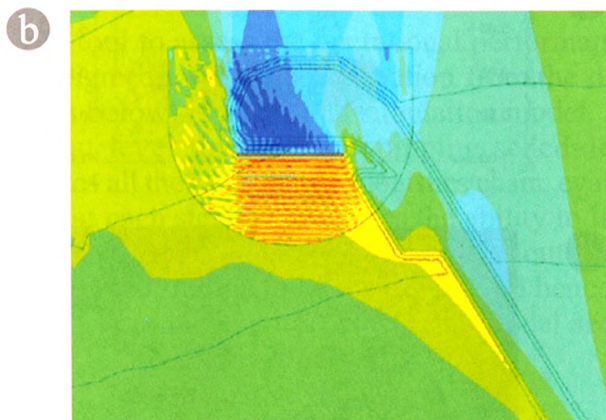


Figure 6: Breakwaters a) desk assessments, b) computational wave disturbance model and c) physical model

Access trestles, platforms, quay walls

Excluding the topsides (piping and process, mechanical and electrical equipment, and roadway) the final design item are the civil structures that convey the topsides from shore to the ship at berth. These may comprise:

- a) loading platform(s) or quay walls
- b) berthing/mooring structures
- c) walkways
- d) access trestle
- e) tug berth

Depending on the nature and purpose of the terminal, there may be additional items that need to be included in the above list or deletions from the above list. Discussion on the structural engineering techniques and technologies is outside the scope of this paper.

CONCLUSIONS

The paper has presented an overview of the site selection and design issues associated with the development of a new marine terminal; developed a methodology to address the issues, and examined hydraulic design techniques and technologies that are used as tools in the design process.

There are a wide range of techniques and technologies that are used in the design process. It is important that the strengths and weaknesses of these are understood by the design team and that the appropriate technique is applied at the appropriate design phase. In selecting what is an “appropriate” technique due consideration needs to be given to:

- a) the level of confidence in the input information / data available (and hence uncertainties)
- b) the important processes that need to be represented
- c) the level of design definition required and the decisions that need be made based on this information

It is impossible to be prescriptive, every project is different. One useful technique, however, when a critical decision is to be made on limited information is to assess the impact of uncertainty on the decision. For example, develop P10 case (optimistic), P50 case (best estimate) and P90 case (pessimistic – 90% chance the number will not be worse than predicted) and assess how this range of outcomes impacts on the decision to be made. In addition to helping to formulate the decision it is also a useful technique to gain insight as to how important a parameter is influencing the outcome; and hence how much effort (cost and time) should be spent on refining the parameter.