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Extension of Muuga Port, Tallinn / Estonia

1 Introduction

Muuga Harbour is among the deepest and most modern ports in the Baltic Sea region. Located 17 kilometers east of the city of Tallinn with good hinterland connections it has a major role in the transit trade of Estonia. Nearly ¾ of cargo loaded in Muuga Harbour include crude oil and oil products, but the harbour also serves as a major harbour in the Port of Tallinn in terms of dry bulk (mostly fertilizers, grain and coal).

The port serves major shippers from Russia and CIS offering fast terminals and deep-water berths. It also serves major Western European ports as a connection point to the Baltic, Russian, CIS and Scandinavian market providing fast service for short sea shipping lines. A full range of services is offered, including shipping agencies, chartering of ships, freight forwarding, customs clearance and insurance services. Loading and discharging services are offered 24 hours a day.

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Muuga Harbour has a territory of almost 450 ha and an aquatory of more than 750 ha. The total number of existent berths reaches 26. The overall length of all 26 berths results in 5.5 km. The maximum depth at the berths is up to 18 m. As landside access Muuga Harbour is connected to the Estonian road network and rail system. Domestic transport is dominated by road transport. More than 90 percent of the freight transit through Estonia is by rail.

In order to improve the operational efficiency of the harbour an expansion of the eastern part of Muuga Harbour is planned.

2 Port Developmend

2.1 Port extension requirements

According to the general tendency of an enormous increase of cargo handling via sea-

Abstract

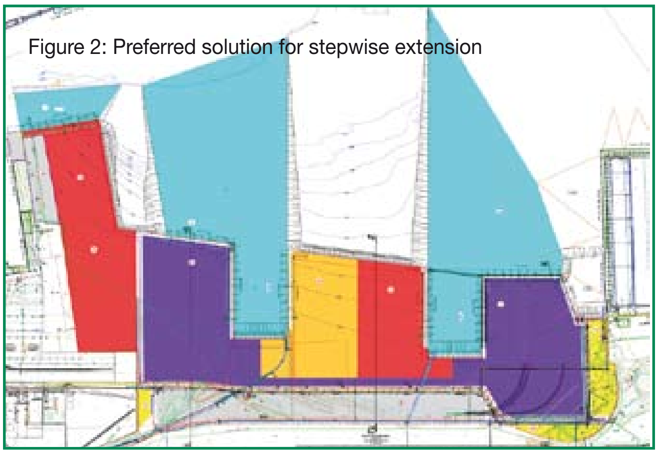
In order to fit effectively into the competitive environment the Port of Tallinn has undergone a complete restructuring in the mid 1990s by developing from a service port into a port of landlord type. To improve the harbour's operational efficiency, a stepwise expansion of the eastern part by approximately 130 ha by the year 2025 is planned. This development will be realised in connection and interconnection with the Trans-European Network.

The technical and economic feasibility of the port extension was investigated and the necessary scope of planning incl. elaboration of plan identification and tender documents were carried out. To determine the most appropriate port extension, different development solutions were investigated supported by wave modelling of the affected new and old harbour territory. For the purpose of financing this project an application for funding by the Cohesion Fund of the EU was elaborated.
The construction measures for the port extension embraced:

- Dredging / dumping – approx. 6.9 million m^3
- Land filling – approx. 5 million m^3
- Use of appropriate dredging material for land filling
- Consolidation of soft layers by installation of vertical drains (approx. 2,000 km) and extra loads
- Approx. 2,000 m quay for various purposes
- Slope protection
- Road and rail access
- Infrastructural development (electric current, water and waste water, communication)

Figure 1: Overview Muuga Port

Figure 2: Preferred solution for stepwise extension



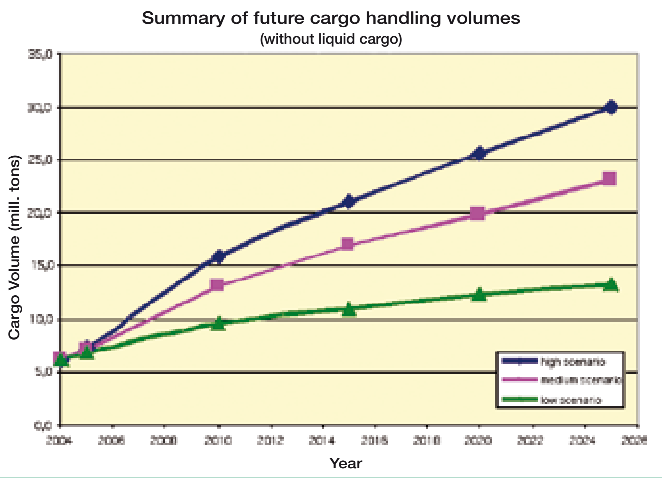


Table 1: Traffic forecast Muuga Port (without liquid cargo)

ports the traffic forecast for Muuga Port in Table 1 shows the same development.

The potential development of future traffic volumes is given in three different development scenarios, i.e. low, medium, high, covering the time period from the year 2005 to the year 2025.

Individual growth rates are assumed for the various commodity groups within the different scenarios. It was decided to adopt the medium scenario for the port extension.

Based on these scenarios and under consideration of the capacities of the existent berth facilities, the berth requirements in chart 2 were being determined, which will be needed to meet and handle the expected increases in the cargo volumes of the port.

As the first step of the extension development the port has concentrated on the estimated requirements up to the year 2015. The berth requirements up to year 2015 are compiled in Table 3.

Analog to the determination of the required berth facilities the terminal area needed for the annual cargo volume handled by the terminal, the average storage of the cargo and the resulting average stock allowances to be made for the railway facilities as well as for the traffic and ancillary areas were being investigated and confirmed with the port operators.

Table 4 shows the calculation for the required area for the intended metal terminal.

Of course, general port development requirements for example sufficient and commodity tailored handling and storage capacities, flexibility with regard to changes in the commodity structure or modes of transport and adequate quay and traffic areas close to the berths to secure high cargo handling rates overall have been implemented to render efficient, cost effective and competitive port and cargo handling services to the satisfaction of the port industry.

2.2 Design Characteristics

For the design of the infrastructure and the port handling equipment as well for sea side and landside connection the prevailing climatic conditions must be taken into consideration.

The climatic conditions are characterized as moderate cold winters, relatively dry and cool springs, moderate warm summers, relatively dry in the beginning and rainy in the second half, and long and warm autumns. The Atlantic cyclones have a strong influence, especially in the cold period when they snow and thaw. During the warm season the cool breezes often cause rain. The region is influenced by cyclones 200 days a year, by anticyclones 165 days, mainly from March to May and in September. The high-pressure brings sunshine in spring together with late night frost, in the autumn with early night frost. Sometimes durable frost occurs during winter.

The average annual temperature is 4.7 °C, the warmest month is July (16.6 °C), the coldest February (-6,0 °C). The absolute maximum and minimum temperatures registered were +32.3 °C and -34.4 °C. It is considered that about 52 % of the annual wind fields offshore are generating waves which are approaching Muuga Bay. Due to the geographical location of Muuga the most frequent wind directions S and SW are without impact. The main relevant winds occur between 270° and 90° north. Although Muuga Bay is largely protected from western winds by Viimsi peninsula, the offshore waves are refracted and follow the coastline more or

Traffic forecast scenario	Berths estimated up to year 2025
»Medium«	1 berth for containers 4 berths for metals 1 berth for other general cargo 1 berth for fertilizers in bulk **7 berths in total**

Table 2: Berth requirements

Five years interval	Required berths
Up to 2010	1 berth for metals 1 berth for fertilizers in bulk
Additional in 2015	1 berth for metals
Total up to 2015	2 berths for metals 1 berth for fertilizers in bulk 3 berths in total

Table 3: Berth requirements up to the year 2015

Design Parameter	Open Storage
Berth throughput capacity (average 3 berths)	2,100,000 tpa
Commodity group	Metals
Estimated percentage of indirect operation	90 %
Throughput via storage area	1,900,000 tpa
Average storage period (2–4 weeks)	21 days
Turnover of stock per year (basis of 350 port operational days)	17 x
Average stock	112,000 t
Approximate peak ratio	1.33
Maximum Stock	149,000 t
Average utilization per net area (maximum utilization 20 t/m²)	4.0 t/m²
Effective use ratio / broken stowage allowance	0.60
Required storage area	62,000 m²
Allowance for railway lines (depending on layout; about 150 %)	93,000 m²
Allowance for quay area and terminal roads (about 40 % depending on layout)	25,000 m²
Allowance for ancillary areas (gear shed, workshop, vehicle and rolling transport equipment; 15 % depending on layout)	9,000 m²
Contingency	11,000 m²
Approximate terminal area demand	200,000 m²

Table 4: Outline of area demand for Metal Terminal (for a berthing length of 2 x 250 m allowing 2 to 4 vessels to moor)

Harbour depths Resulting design figures	
Nominal depth of container terminal harbour bottom	14,5 m
Nominal depth of bulk terminal harbour bottom	16 m
Nominal depth of general cargo terminal harbour bottom	12,0 m

Table 5: Berth depths

less parallel, continuously loosing energy along the more shallow waters on their way towards the port. The water level in the harbour area depends on the wind direction. Storms in 2001 from W caused levels from 50 to 100 cm over Kronstadt's zero. The average ice thickness is (by EMI) 35 cm, maximum measured 73 cm. The average ice period in Muuga Bay is considered as 70 to 80 days annually.

As a general basis for the port extension the following design vessels were aligned:

container ship
50,000 DWT (266 m x 32.3 m x – 13.3 m);

bulk carrier
100,000 DWT (248 m x 37.9 m x –14.8 m);

general cargo ship
20,000 DWT (170 m x 24.9 m x –10.4 m)

According to the design vessels the required berth depths are listed in Table 5.

The listed berth depths were determined according to the design ship draughts, the mean low water level of Muuga Harbour and the required under keel clearance. Under consideration of the maintenance dredging zone, dredging tolerances and the future possibility to dispatch the biggest design ship in all terminals, the design depth for all quay structures was defined with 17 m below the main sea level.

Finally, to ensure safe port operations and to connect the new terminal areas with the existing ones at the same altitude due to proper interconnections an elevation of the berth of +3.00 m and of the terminals of +2.70 m was chosen.

2.3 Layout alternatives for port extension

Within the elaboration of the design works for the overall port extension mainly two layout alternatives were investigated.

The layout alternative 1 shown in Fig. 3 is based on a linear quay line from the south-western to the north-eastern part of the extension area and will provide six berths for cargo handling on this line. In front of this quay line an approach channel and place for moored vessels with a width of 250 m will be dredged in the harbour basin. A turning circle with a diameter of 550 m will be placed on the eastern side of the harbour. It guarantees the safe access of the vessels to the new berths. At the eastern side, rectangular to the quay line, an auxiliary quay with a length of 130 m to be used for tug boats and fire fighting boats will be implemented.

This alternative distinguishes itself by a high degree of flexibility in using the berth capacities and their directly connected terminal areas. The linear berth lengths of about 1600 m with unlimited single berth length can be used by small and large vessels alike without remaining unusable berthing places. If required the dedicated terminal areas for the operators can as well be shifted in small steps to meet their area requirements right to the point.

Apart from these advantages this solution could probably cause problems with occurring wave conditions by unfavorable weather conditions for safe mooring and cargo handling operations in this harbour area which is not protected by a breakwater.

The Alternative 2 according to Fig. 4 is based on the assumption that the unfavorable wave conditions cause severe problems to implement a linear quay line as anticipated

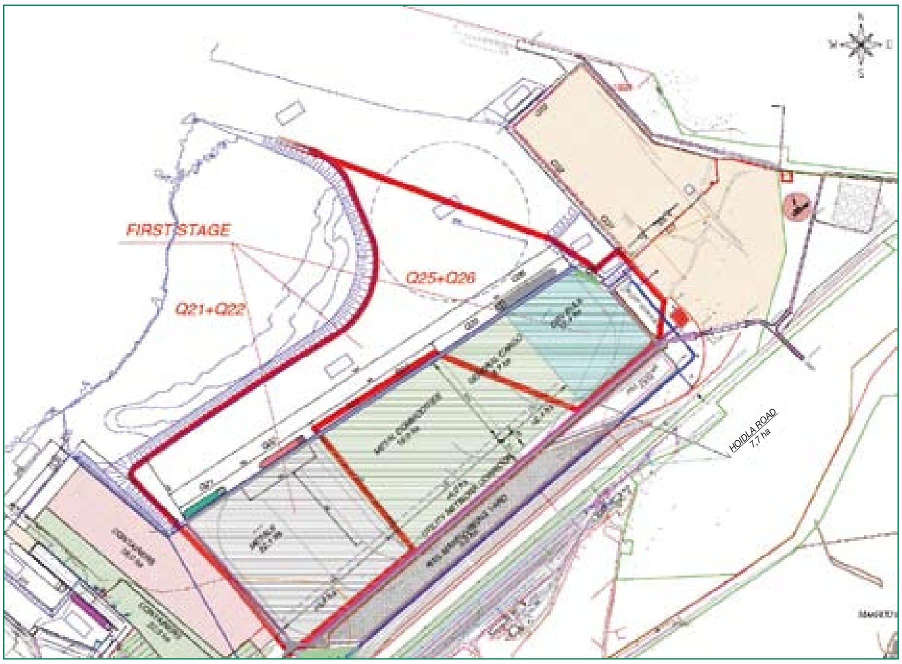


Figure 3: Layout Alternative 1

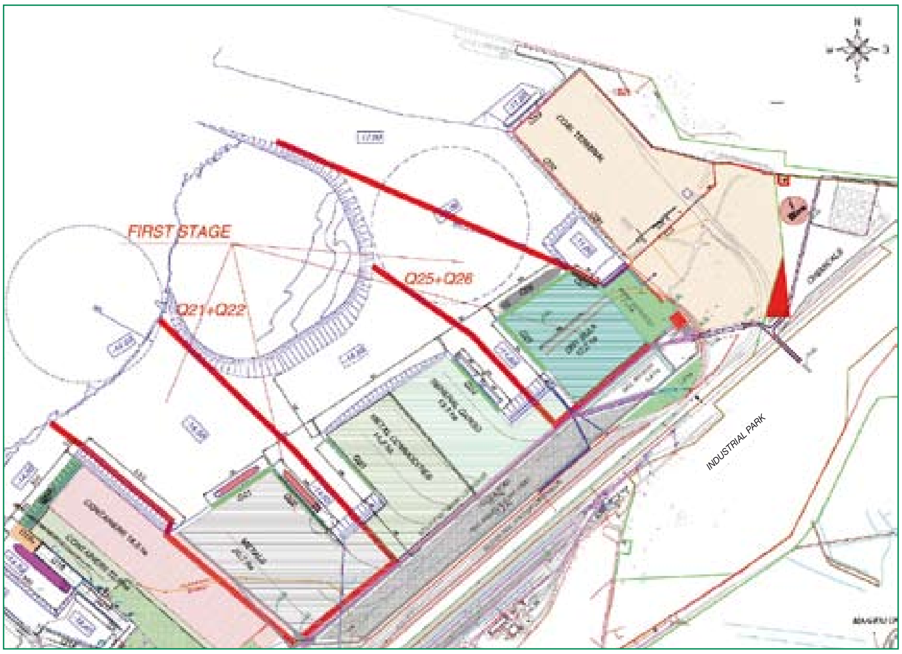


Figure 4: Layout Alternative 2 – chosen for implementation

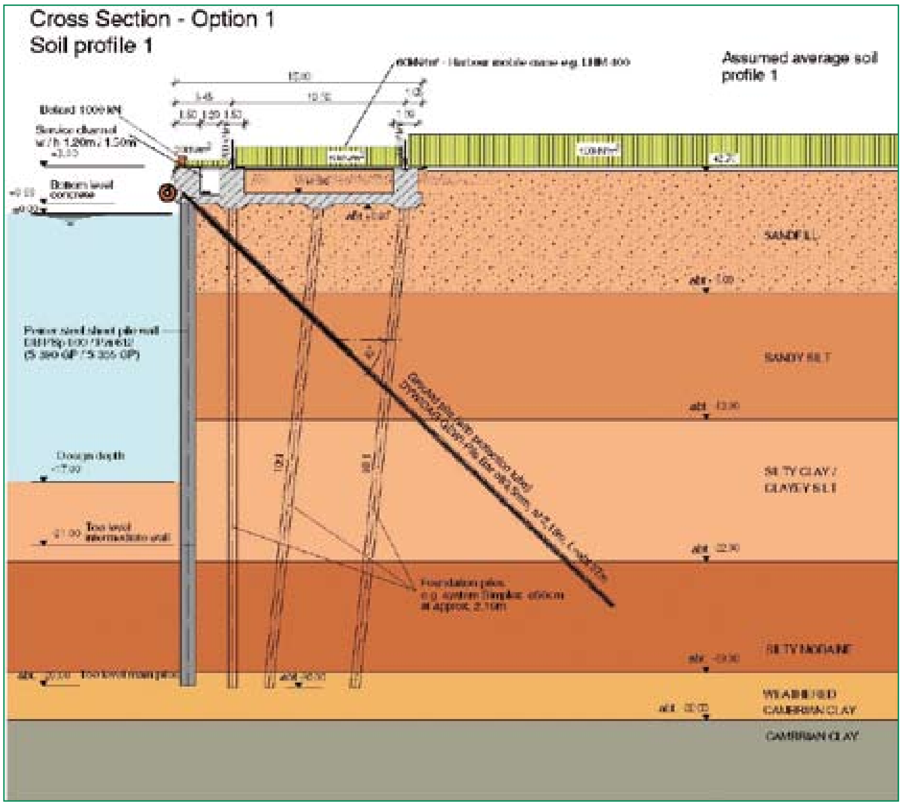


Figure 5: Quay cross section – chosen for implementation

in Alternative 1 and the future execution of a breakwater that will protect the whole Muuga Harbour may not be built so soon.

A linear quay line with a length of 310 m and an auxiliary quay with a length of 130 m will be built in the north-eastern part of the harbour extension area. This part of the harbour is still protected against unfavorable wave conditions by a new build coal terminal on the north-eastern side.

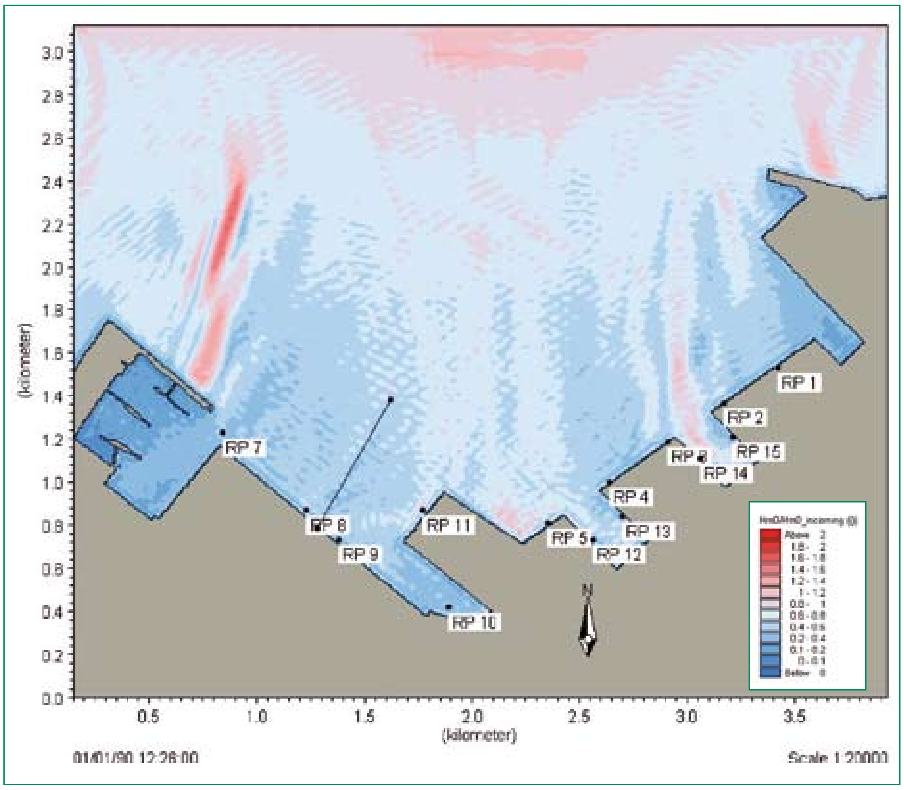


Figure 6: Results of Bousinesq model showing relative wave heights Hm0/Hm0,i (equal to Hs/Hs,i) for waves approaching from north (0°) and reference points used.

At the south-western end of the linear 310 m quay line a right angle basin will be dredged having a length of 300 m, a width of 200 m and a depth down to -14.5 m. The landside basin end is aligned parallel to the Muuga Rail Station. The basin accommodates two berths.

At the other, i.e. the south-western end of the extension area another linear quay line of a length of 300 m will be implemented and similarly located and aligned in Alternative 1 but followed by a basin at the north-eastern end having the same dimensions and direction as the other basin. This basin provides two berths. The waterside face of the reclaimed area between the two basins is sloped and will get a permeable revetment protection. Berths could be provided at this location, if future port development should require so.

As the preferred alternative for the quay construction a fully backfilled anchored steel sheet pile wall according to Fig. 5 was chosen. All components of this structure are already approved successfully in other quay structures in the Muuga Harbour and provide a sustainable structure at reasonable costs.

As described the prevailing wave conditions in the extension area were crucial to the choice of the most appropriate layout alternative to be implemented.

To assess the near shore wave climate for the eastern part of Muuga Bay a numerical model has been set up, which is capable of transforming offshore wind and wave conditions towards shallow water.

An example plot of the wave modelling investigations is shown in Fig. 6 depicting the amplification factor $H_{m0}/H_{m0,i}$ (equal to $H_s/H_{s,i}$), i.e. the increase of the incident wave height due to reflection, diffraction and other processes in Muuga Bay.

The determination of the exceedance probabilities for wave conditions in Alternative 1 and 2 as shown in chart 6 lead to the decision that the down times for loading and unloading ship operations caused by unfavourable to critical wave agitation will be unacceptable in Alternative 1.

2.4 Land reclamation

To get appropriate terminal areas for cargo handling, land has to be reclaimed. The reclamation fill has to be dredged and imported from an offshore borrow site within a distance of approx. 45 km and in small amounts from the dredging works in the harbour basin. As reclamation fill non-cohesive and compactable subsoil will be used.

Due to the soft to very soft soil in the subground, the filling under the expected live load will suffer high settlements. To reduce the settlement to an acceptable extent for port handling (20 cm settlements within five years by expecting 60 kN/m^2 permanent live loads were agreed with the port and operators) consolidating measures will have to be carried out. With the construction of vertical drains (distance every 2.5 m x 2.5 m down to the bearing soil layers e.g. moraine) combined with overloading of the reclamation area (up to a high of +6.5 m for approx. three months) the settlement process will be accelerated to the needed demands during the construction works.

As a measure of soil management with a phase-wise filling process of dredged sea material and a shifting of fill for overloads to be placed where already subsoil is needed, suitable dredged material will be used for land reclamation and does not have to be disposed.

2.5 Road and rail access, utility network requirements

A new road and rail access will be built as an efficient site utilization. The main route is located side by side with a new rail-manoeuvering yard from that the rail access to each terminal will enveloped.

The total road area's width is 30.0 m and will be divided as follows:

• Road asphalt pavement between curbs	8.00 m;
• Greenery from curbstone to walkway	-3.00 m;
• Cycling/walkway on one side	3.00 m;
• Greenery from walkway to borderline	4.00 m;
• Utility networks' corridor on other side	12.00 m.

The road is classified as cargo traffic street with speed limit of 50 km/h. Separate walkways or cycling roads are required and the road meets (Fair) the traffic content of two trucks at the time.

For the port extension water supply, fire water, sanitary sewage, storm water sewerage, system electrical power supply and telecommunication systems will be established.

	NSW model		Bousinesq model			
	Reference case		Alternative 1		Alternative 2	
Reference	Wave height $H_{s,i}$ *)		Wave height $H_{s,i+r}$		Wave height $H_{s,i+r}$	
Point	0.3	0.6	0.6	1.2	0.6	1.2
1	20	8.5	13.2	7.5	11.3	4.7
2	28.5	15.2	17.8	6.8	13.7	8.4
3	27.7	17.6	17	8	7.7	0.4
4	23.2	17.8	15.1	9.1	11.4	2.4
5	23.3	15.9	23.1	12.8	14.7	3.1
6	23	20.8	-	-	-	-
7	21.5	10.5	12.8	2.6	10.3	1.2
8	22.8	12.4	20	9.8	17.5	5.9
9	21.3	9.9	18.4	7.6	13.9	2.4
10	8.6	0.1	7.9	2.3	2.3	0.1
11	-	-	17.6	10	11.4	3.8
12	-	-	-	-	13.4	4.6
13	-	-	-	-	6.1	0.4
14					10.7	4.3
15	-	-	-	-	6.5	0.9

* Remark: for the NSW model the total wave height Hs, i+r has been derived by 2* Hs to simulate full reflection from the vertical quay wall.

Table 6: Exceedance probabilities for wave conditions at the reference points analysed at Muuga Port

The following assumptions must be taken into account for the design of the required utility network.

Water Supply

• Container Terminal	14.0 m^3/dy;
• Metals Terminal	12.0 m^3/dy;
• General Cargo Terminal	4.0 m^3/dy;
• Dry Bulk Terminal	8.0 m^3/dy;
• Muuga Coal Terminal	12.0 m^3/dy;
• Other territories (incl. Chemicals)	30.0 m^3/dy;
• Vessel bunkering	120.0 m^3/dy;
TOTAL	200.0 m^3/dy;

The reserve for buildings' internal fire extinguishing water will be stored in special tanks installed at the new pumping station.

Fire Water (External Extinguishing)

• Container Terminal	40.0 l/sec;
• Metals' Terminal	40.0 l/sec;
• General Cargo Terminal	40.0 l/sec;
• Dry Bulk Terminal	50.0 l/sec;
• Muuga Coal Terminal	65.0 l/sec;
• Chemicals' terminal	150.0 l/sec;
• Rail maneuvering yard & rail station	195.0 l/sec;
• Other territories	20.0 l/sec;

The fire fighting water pipeline network should be circular, the circles will be installed according to the construction stages and will be equipped with hydrants.

Sanitary Sewage

• Container Terminal	14.0 m^3/dy;
• Metals Terminal	12.0 m^3/dy;
• General Cargo Terminal	4.0 m^3/dy;
• Dry Bulk Terminal	8.0 m^3/dy;
• Muuga Coal Terminal	12.0 m^3/dy;
• Other territories (incl. Chemicals)	30.0 m^3/dy;
TOTAL	80.0 m^3/dy;

The wastewater will be led into the pumping stations from where the waste water will be pumped into the Maardu City purification facilities which has enough capacity to handle these volumes. The existing purification plant consists of two blocks with capacities of 3000 and 2000 m^3/day accordingly.

Storm Water Sewerage System

The rain water systems will be installed on the new terminals' area considering the collector wells and purification facilities. Outlet from purification facilities into the sea should not contain floating particles of more than 40 mg/litre and oil products of not more than 5 mg/litre.

Electrical Power Supply

• Container Terminal	1,5 MVA;
• Metals Terminal	3,0 MVA;
• General Cargo Terminal	1,5 MVA;
• Dry Bulk Terminal	4,0 MVA;
• Muuga Coal Terminal	5,5 MVA;
• Other eastern territories (incl. Chemicals)	3,0 MVA;
• Other western territories	1,5 MVA;
• Quay infrastructures	2,0 MVA;
• Rail maneuvering yard	0,5 MVA
TOTAL	22,5 MVA

3 Conclusion

In the framework of the »Trans European Network« Muuga Harbour will be extended with new berths and terminal areas stepwise by approx. 130 ha within a time span of ca. 20 years.

In order to guarantee a sustainable and successful port development the planning and implementation of the port extension is based on a detailed traffic prognosis and embracing alternative and cost-benefit analyses.

The chosen development alternative includes terminals for container, metal and bulk cargo handling and is adapted to the requirements of efficient cargo handling with respect to the competition with other Baltic Sea ports. □