Polder Container Terminal

Ir. J.F. van Beemen
Royal Haskoning
j.vanbeemen@royalhaskoning.com

New ports are mostly constructed on low lying coastal land or in shallow coastal waters. The surface level of the land for port facilities is then raised to a level well above the highest water mark. This requires vast volumes of good quality fill material often dredged from the sea. Besides the cost of dredging, there is the environmental impact of dredging.

Container terminal operators generally ask for sites which are well above the highest water level. Is this justified, and is there a way of constructing safe terminals with smaller volumes of dredged material and thus lower environmental impact?

Royal Haskoning explored the possibilities of a container terminal with a "polder yard". The yard would lie below high water level and would be surrounded by an embankment keeping the water out. Part of the embankment would have the form of a quay wall with apron for vessel berthing.

A polder needs storage capacity for rain and seepage water plus a system for discharging the water. This storage can have different forms, such as storage in gravel beds or surface water. Often new port development requires compensation in the form of development of nature elsewhere. If the polder surface water is developed as wetland area inside the polder terminal, nature may be compensated for within the port.

This paper explores the possibilities of the polder container terminal, concept solutions for layout, the embankment type quay and how to overcome level difference between yard and apron.

1 Port construction

1.1 Land reclamation

Because of urban and industrial development, most ports in the world have no possibilities for onshore expansion. Therefore port expansion plans mostly look seawards. For port expansion projects large areas of low lying coastal land or shallow coastal water are raised or reclaimed to the required level, by filling with dredged material. In between the reclaimed land areas, harbour basins and access channels are dredged to the required depth.
If the dredged material from the basins and access channels is of sufficient quality, it is generally used for raising the dry areas. Often this volume is not sufficient and considerable additional volumes of suitable fill need to be dredged from offshore locations. For large expansions, or second or third seaward expansions, even more fill needs to be brought in, because further out the water is generally deeper. Often suitable material cannot be obtained close by and needs to be transported over considerable distances.
Although dredging is by far the most economical technique for obtaining, transporting and placing large volumes of fill material, the financial cost and environmental impact

are high, especially when reclaiming in deeper water and obtaining fill from more distant borrow areas.

1.2 Environmental impact

The low lying coastal lands and shallow coastal waters, where many port expansion projects take place, are often of great ecological importance. Wetlands are often feeding grounds for migratory birds and shallow seas are breeding grounds for fish and other sea life. Obviously, wildlife in such areas will suffer from port construction. Apart from that there is also the environmental cost of dredging itself. Dredging severely impacts life on the sea bottom from where fill material is taken. The dredging process increases water turbidity which may affect marine life over a much wider area. Moreover, at the site of reclamation, life on the sea bottom is totally destroyed and again turbidity may affect marine life over a much wider area.
In the evaluation of port project proposals, environmental issues play an increasingly important role. If it concerns areas of ecological importance, in some cases, costly nature compensation elsewhere is required.

1.3 Reclamation level

Most modern deep-sea ports are directly accessible from the open sea and are located outside the protection of any dikes and flood barriers. Therefore the land areas are raised to a level high enough to provide a high degree of protection against flooding. For Maasvlakte 2 for instance, the reclamation level is +5m CD.
Apart from cargo handling terminals, deep-sea ports also attract industries relying on sea transport for raw materials and finished products. The investment in the industrial installations itself is often of a different order than the cost of land. Such industries are often part of international conglomerates and are not familiar with polders. They therefore mostly demand a surface level for the reclamation, well above any flooding risk level, and are rarely willing considering anything else.
As large scale port expansion projects generally have one overall reclamation surface level, container terminals and other cargo handling terminals are also constructed at the same high level. This level, which is a major cost determining factor, is generally determined after extensive risk analysis on the basis of historic data and modelling of the future situation.
The question remains whether all of the reclaimed land should be raised to the same level? If this option is considered, the question is what the optimal solution would be?

1.4 Soil settlement

Many flatlands in coastal areas and many shallow water bottoms have very soft soils. Especially in river estuaries and delta areas one often finds tens of meters of soft and wet material. If such areas are raised with sand, the water is slowly pressed out of the original material resulting in considerable subsidence. This process may take many years or even decades before stabilising. If the subsoil has an irregular structure, differential settlement will occur, making things even worse.
A multitude of soil improvement techniques have been developed. If applied over large areas and especially if applied to greater depth, these measures can be very costly.
Part of the settlement is caused by buildings, installations and cargo, but most of the settlement is caused by the weight of the fill material used to raise the site. So if the reclamation level can be reduced, also cost savings with regard to soil improvement can be made.

2 Polder terminal

2.1 Concept

The idea of a polder terminal was triggered by a Royal Haskoning container terminal study in Southeast Asia. The site was a tidal wetland along a river. The soil consisted of tens of meters of mud. The site would have needed to be raised considerably and would have required extensive and complex soil improvement. This would have been very costly. Royal Haskoning then looked at the option of not raising the site, but construct a dike around it instead. Without raising the site, soil improvement requirements would be much less. There would be cost savings on both raising the site plus soil improvement, but there would be additional cost for dike construction and a water management system. Furthermore, the level difference between quay plus apron and the yard would need to be resolved in a way enabling smooth operations.

2.2 Bangkok International Airport

The concept of a small special purpose polder is not entirely new. In 1993 De Weger, an architects and engineering consultancy firm, now fully integrated in Royal Haskoning, designed a flood protection system for the Suvamabhumi International Airport in Bangkok, in the form of a polder (see Figure 1).
The low lying lands in the Bangkok area are prone to flooding because of regular high water levels in the rivers, high sea water levels and land subsidence resulting from ground water extraction. The new airport is located in this area. Economically and technically it was not attractive to raise the site by 2.5m above the original level. Raising the site would cause considerable subsidence due to a 20m soft clay layer.

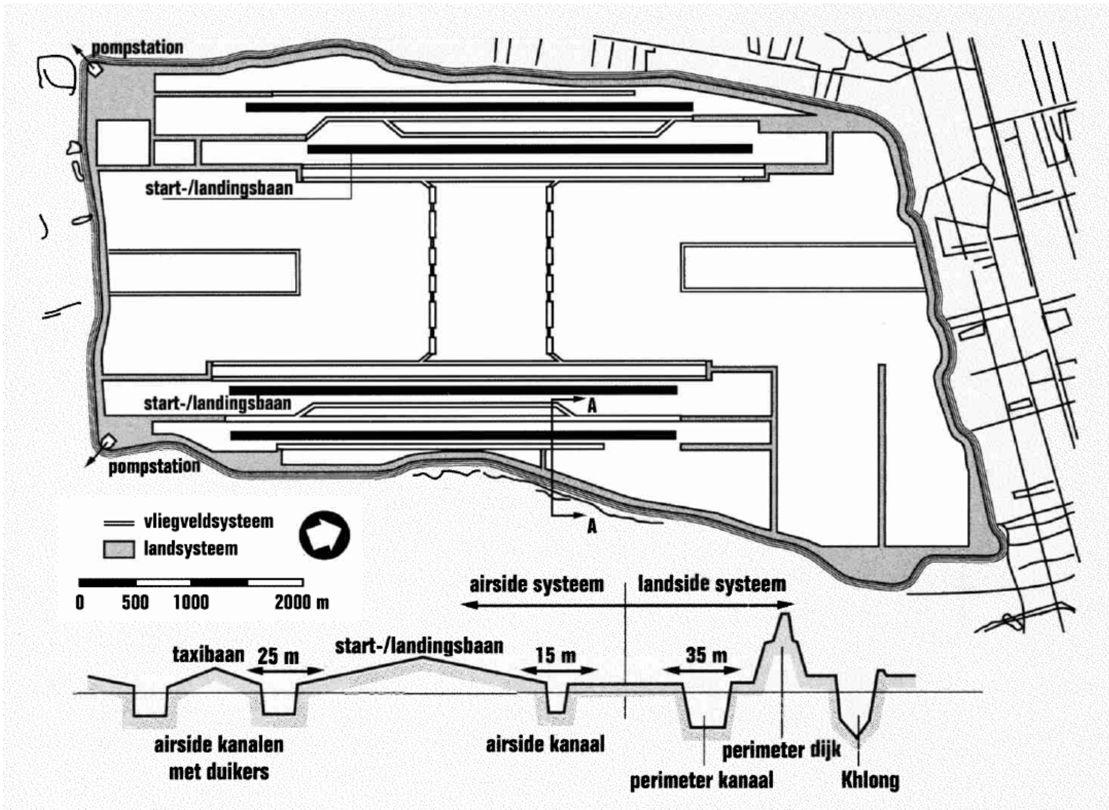

Figure 1 – Suvamabhumi International Airport Polder, Bangkok (© Royal Haskoning)

De Weger designed a 32km^2 polder with a ring dike and a canal system for water collection. Two pumping stations, with a joint capacity of 12m^3/s, discharge the water to surrounding watercourses. The rainfall of 1,500mm annually is, in itself, not excessive, but 85% of the annual precipitation falls during the south-west monsoon and the rain intensity during first monsoon days can be considerable. A starting point was that the runways would not flood more often than once every ten years. A constraint was that the polder would not discharge any water on the adjacent natural watercourses during high water. This would worsen the situation in less well-protected areas elsewhere. Therefore the airport polder has a considerable water storage capacity.
The Suvamabhumi International Airport has been constructed this way and the approach proved to be a satisfactory solution.

3 Polder terminal operations

3.1 Container terminal operations

Virtually all container terminals in the world have a quay plus apron on the same level as the container yard, so horizontal transport can easily take the containers from under the ship to shore crane to the stack and vice versa. Also the earlier automated container terminals operate this way (see Figure 2). Hatch covers are stored in the back reach of the cranes. The exchange of all containers, including out of gauge containers, between the ship to shore crane and horizontal transport vehicles, takes place within the gantry of the crane. Service traffic also takes place within the gantry, or in some cases on a service road, just waterside of the waterside rail.
At a polder container terminal the quay plus apron must be well above high water level while the yard may lie considerably lower, so a solution must be found where and how to make this transition.

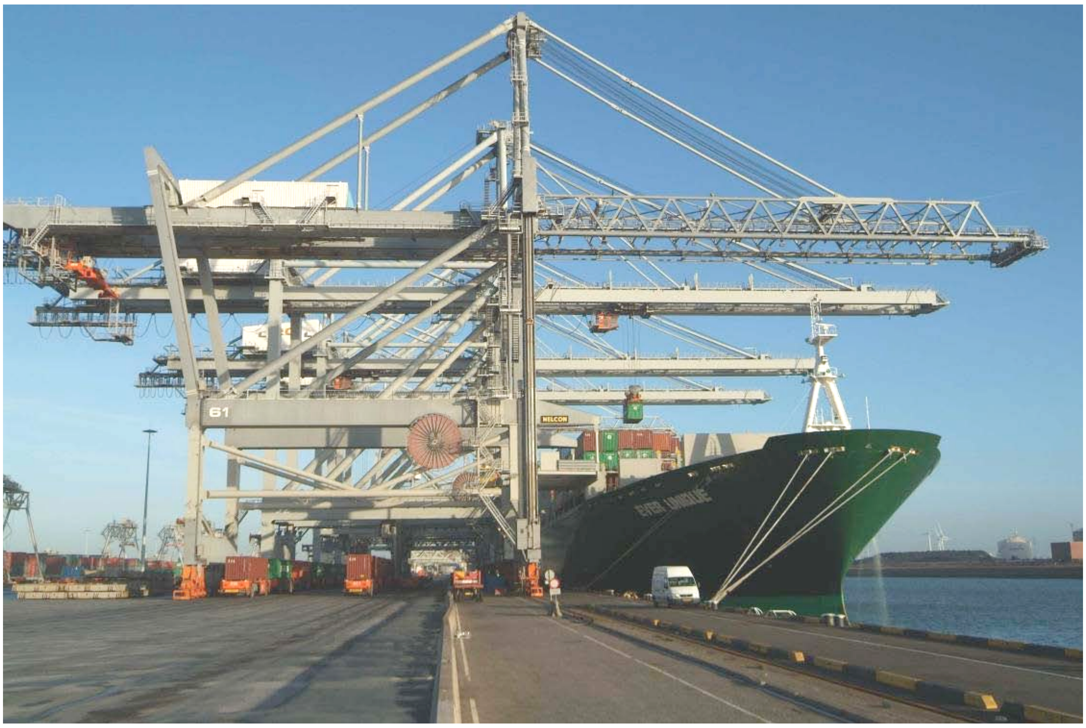

Figure 2 – Apron of an early automated container terminal (photo ECT)

Euromax in Rotterdam and Altenwerder in Hamburg are two of the most modern container terminals in the world. Both automated terminals deploy cranes with a

second trolley (see Figure 3). The general trend in ship to shore container cranes for large container terminals is a development towards second trolley cranes, and in the more distant future multi trolley cranes.
When unloading the vessel, the first trolley, operated by the crane driver, takes the container from the vessel to a platform in the crane. From there the crane driver takes the first trolley back to the vessel for picking up the next container. On the platform, any automatic twist locks are removed and the second trolley, which is automated, takes the container into the back reach of the crane and places it on an automatically guided vehicle. The automatically guided vehicle takes the container to the stack.
Hatch cover storage, out of gauge container handling and service traffic access; all take place between the crane rails.
Between the automatically guided vehicle area, in the back reach, and the area between the crane rails, is a barrier (see Figure 3). In the area waterside of the barrier, manual operations take place. In the area landside of the barrier, no staff are allowed, because of the dangers posed by fully automated operations. The line of this barrier is not to be crossed by any vehicle or person. So this seems to be the ideal line for the level transition between quay plus apron and yard.

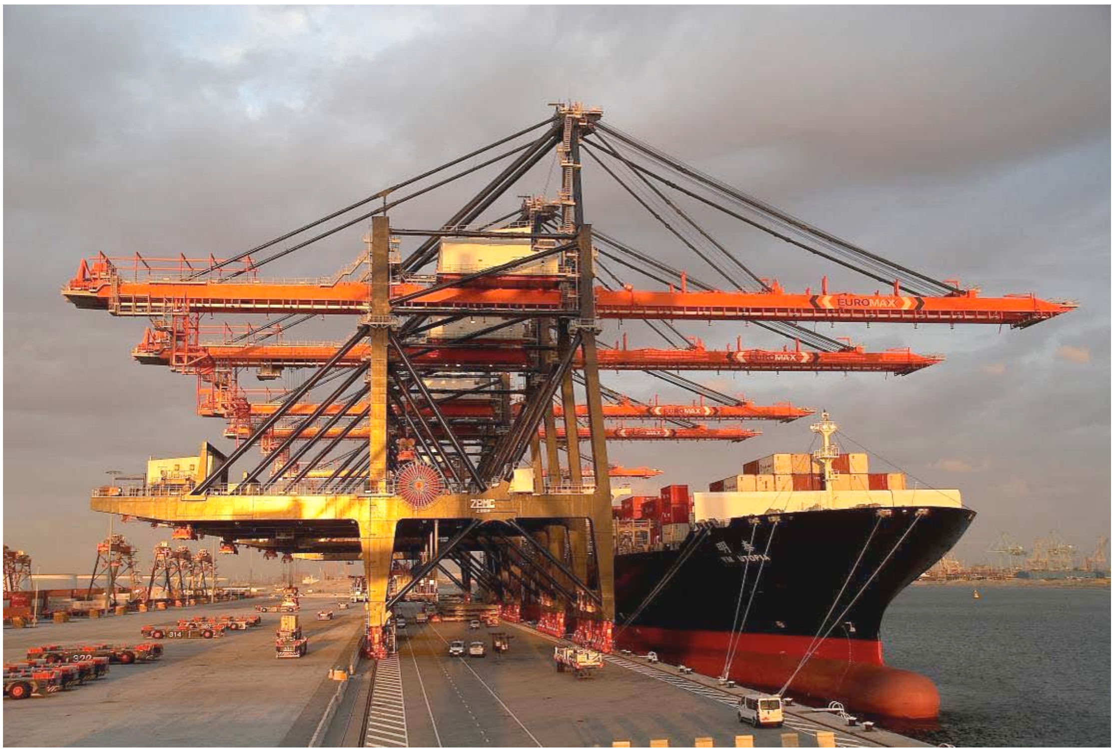

Figure 3 – Apron of Euromax, one of the most modern automated container terminals (photo ECT)

Figure 4 shows a section of the polder container terminal. The level transition between quay plus apron and yard is clearly indicated. Just landside of the landside crane rail is a retaining wall. In this example the yard level is approximately the same as mean sea level, some 5m lower than the apron level. But yard levels could be considerably lower, possibly down to -5m CD, which would be around 10m below apron level, all depending on the original level of the site (low lying land or shallow sea). By having the level transition here, the automated container operations would not be affected at all (see Figure 5).

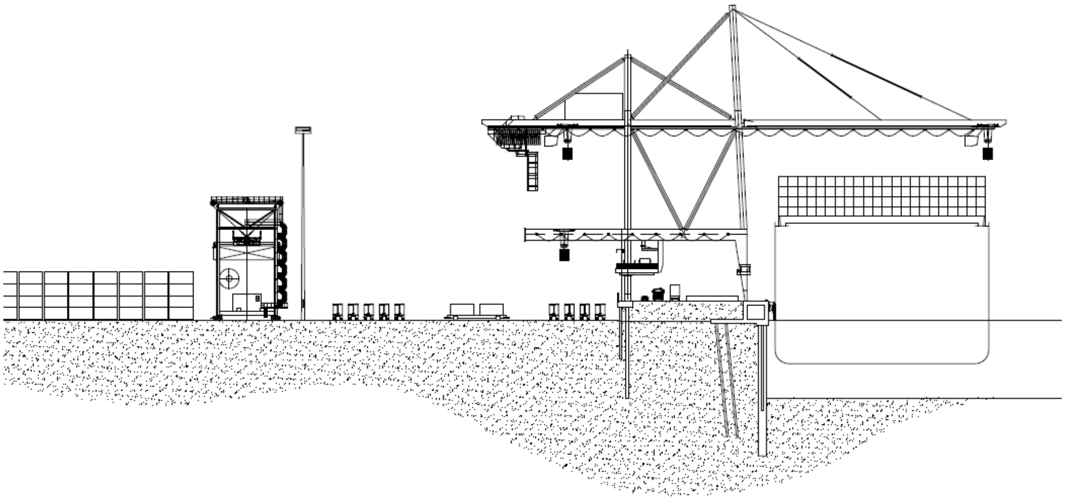

Figure 4 – Section across quay, apron and waterside horizontal transport area of the polder terminal (© Royal Haskoning)

Quay and apron would be of sufficient height preventing any flooding. Second trolley cranes would operate on this raised strip with an approximate width of about 40m. Also hatch covers are stored in this area. Quay wall structure plus apron plus landside retaining wall, in fact form a dike with vertical sides.
For out of gauge container operations and service traffic, there would be a ramp from yard level to the apron level, very much the same arrangement as in similar non-polder terminals.

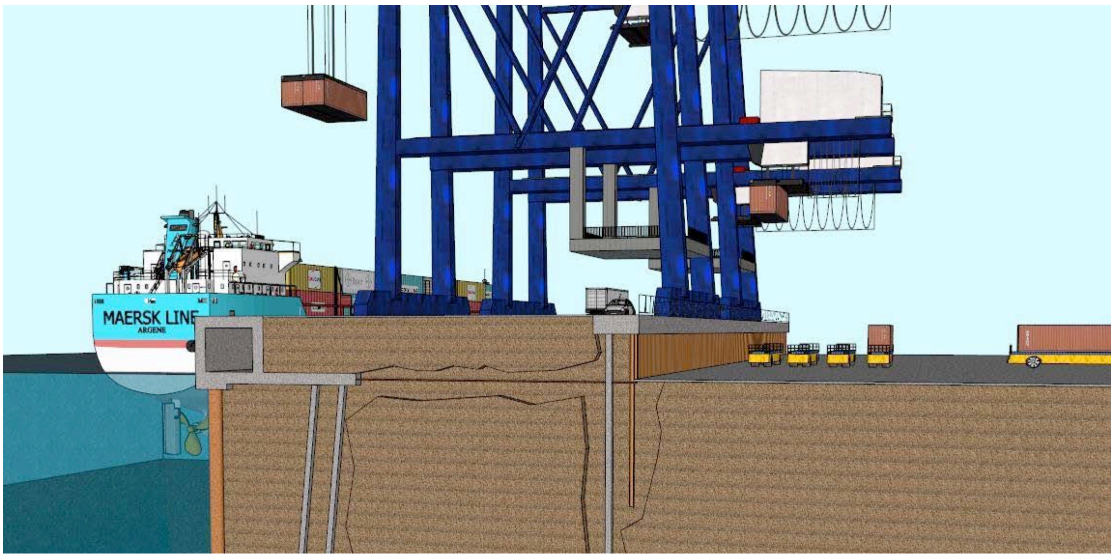

Figure 5 – Level transition between apron and yard, just landside of the landside crane rail (© Royal Haskoning)

3.2 Other polder terminals

The polder terminal approach may also be suitable for car, dry bulk and wet bulk terminals.
For car terminals more ramps between apron and yard would be required, but they could easily be integrated into the typical layout of a car terminal.
Dry bulk terminals make extensive use of conveyor belts, often partially elevated. Conveyor belts can easily bridge level differences.

On wet bulk terminals often no quay wall is required. A more conventional dike can then be used with a jetty in front of it. On wet bulk terminals the cargo is pumped between vessels and tanks and level differences will cause no problem at all.

4 Polder container terminal quay structure

Figure 6 shows the polder terminal quay wall and apron structure. In sandy soils the quay wall itself could have very much the same structure as those normally used for sandy soils. The retaining wall would be a steel combi-wall or a concrete deep-wall with a concrete top structure and relief platform. This structure would provide the foundation for the waterside crane rail, and the combi-wall or deep-wall would have the additional function of a seepage screen, thus reducing seepage into the polder. On the landside there would be a steel retaining wall for the level transition. This retaining wall would be tied with steel rods to the quay wall, thus acting as an anchor wall to the quay wall. Also the other way round, the quay wall structure would act as an anchor wall to the landside retaining wall.

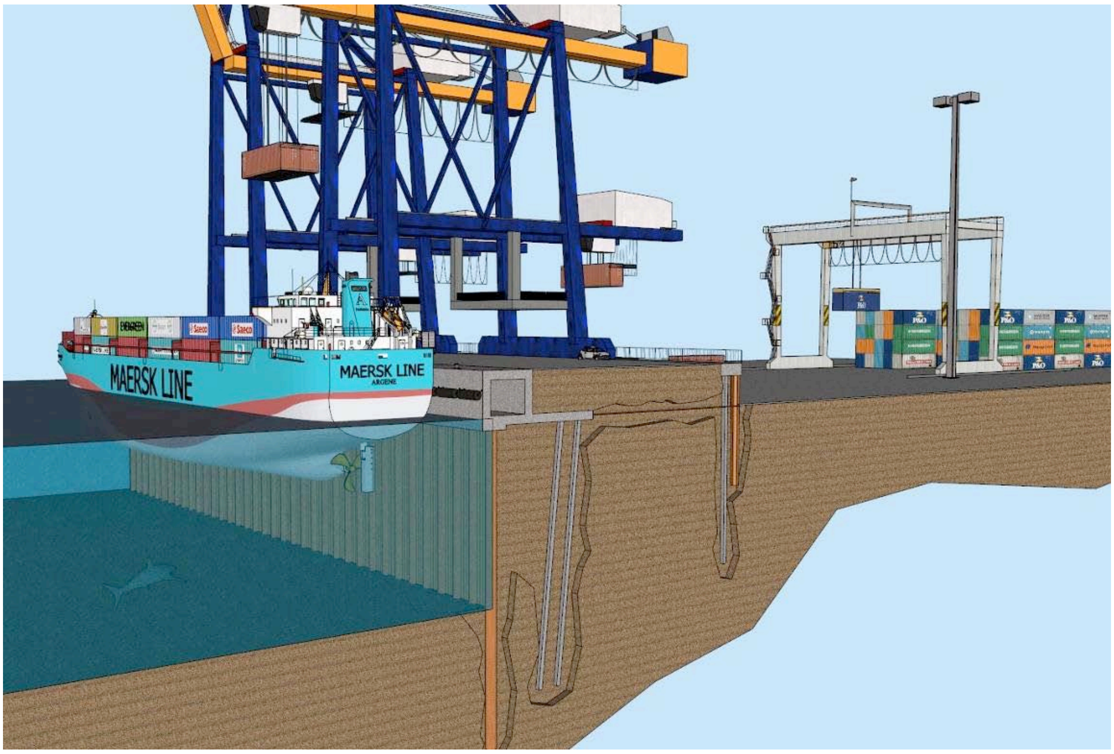

Figure 6 – Polder terminal quay wall structure (© Royal Haskoning)

The landside retaining wall would be capped with a concrete beam, which would also be the foundation beam for the landside crane rail. The vertical forces on this beam would be carried by a row of concrete foundation piles.
The electric cables for the cranes would be just landside of the landside crane rail. In this area there would be no traffic, so the cables would not require expensive protection measures. Furthermore cable turnover pits can be constructed more easily and more economically on the landside.

5 Water management

5.1 General

Depending on rainfall, seepage and evaporation, the ground water in the polder would be fresh to brackish. In this special purpose polder would be neither agriculture

nor any historic buildings on wooden pile foundations. Hence this would allow a lot of freedom with regard to salinity and ground water level.
The upper limit of the ground water level would be the highest level which would not cause any hindrance to operations or any damage to structures, including pavement, and cargo. The lower limit would be determined by prevention of subsidence of the ground. If there is surface water inside the polder with a nature function, additional requirements would need to be met.

5.2 Water collection and storage system

A polder needs a collection system for rain and seepage water, and water storage capacity, and a system for draining or pumping the water out of the polder.
Rain water would be collected by a storm water system consisting of gullies and drain pipes as on any other terminal. Seepage water would be collected by agricultural type drains and ditches.
Water storage is required as a buffer in periods of high influx of water, higher than the discharge capacity of the system. The larger the storage capacity, the smaller the required discharge capacity may be.
At a polder terminal, this water storage can take on different forms. Gravel beds are often used in automated container yards and are also most suitable for water storage. Surface water offers most storage capacity, but requires more space. If surface water is the main form of water storage, about 5-10% of the polder area would be required for surface water.
A system of interconnected ponds inside the polder would offer additional value. The ponds could be used for wetland nature development, or fish or algae farming. Often new port developments require compensation in the form of development of nature elsewhere. With wetland development inside the polder terminal, nature is compensated for within the port.
It is believed that wetland development inside a container terminal offers unique opportunities. On container terminals there are few human beings and no cats and dogs threatening wildlife. Water management within the polder terminal allows a considerable range in water level and salinity, resembling much of the environmental conditions of coastal wetlands.

5.3 Water discharge

The short ends of container terminals generally require no quay. Here the embankment would have the form of a conventional dike. Behind the dike would be a large collecting pond and from this pond pumping stations would pump out the water into the harbour basin. On this dike there would be windmills generating electric power for the pumping stations. When there is no need for pumping, electric power would be provided to the terminal or the grid. Because the water level inside the polder is not that critical, most of the discharge can take place when ample renewable power is available.

6 Conclusions

A polder container terminal would have the following advantages:

- All design and construction methods for a polder terminal are proven technology;
- The polder terminal concept combines two fields of Dutch expertise;
- The polder terminal concept can be applied not only in the Netherlands, but also in any low lying area in the world;
- The polder terminal concept has considerable export potential;
- The polder terminal requires less fill volume, resulting in lower dredging cost and will have less environmental impact as a result;

- Because the yard is not raised, less settlement of the subsoil will occur. This is especially attractive for soft soil types as often found in river deltas. This way, expensive soil improvement can be avoided or reduced;
- The level transition just landside of the landside crane rail is fully compatible with layout requirements for modern second trolley ship to shore gantry cranes;
- The dike like quay wall plus apron structure can be constructed with existing quay wall construction methods and is only marginally more expensive than a conventional quay wall plus crane rail foundations;
- The visual impact of the container terminal yard is less because the ground level is lower;
- Wetland nature area may be created inside the port instead of compensation for nature elsewhere;
- If the sea level rises faster than forecasted, only the apron dike would need to be raised and the water discharge capacity would need to be increased. There would be no need to raise the entire terminal. This would be more economical and would cause fewer disturbances to operations.

On the other hand a polder container terminal would have the following disadvantages:

- Savings on fill are partially offset by the extra cost for a water level control system;
- If surface water is used for water storage, the total terminal area would be larger than without it;
- The chance of flooding is marginally larger than for a fully raised terminal. However, this risk could be compensated for by making the quay plus apron structure slightly higher at marginally more cost.

A polder container terminal seems to be a feasible option, with likely lower construction cost, with environmental advantages and with no operational limitations, and little or no additional flooding risk.
