A NEW SEA LOCK IN TERNEUZEN WITH EQUAL DIMENSIONS AS THE PANAMA CANAL EXPANSION PROJECT

Koen Van Doorslaer[1], Marc Bool[2], Wim De Cock[3], Harm Verbeek[4]

ABSTRACT

The construction has started for a New Lock in the lock complex of Terneuzen. By 2022 this lock, in the middle of a continuous operational lock complex, will be finished. With a lock chamber of 427m x 55m x NAP -16.44m, the New Lock in Terneuzen will have the same dimensions as the Panama Canal Expansion Project. This paper, a joint paper by Contractor and Client, describes the tender procedure and goes into detail on the project phasing and highlights the strong points of this project. By means of a temporary navigation channel around the construction area, the lock complex maintains its current three lock capacity for most of the construction period. The New Lock is built by a combined dry-wet construction methodology: building the contours from water, reclaiming the land in between, and continuing all civil works from land, this to keep the construction area as economical as possible. Due to the challenging geo-hydrology of the area, there is a risk of influencing the ground water level outside the project area and affecting the city of Terneuzen. This is solved by means of deep diaphragm walls up to a level of about NAP -45m for the lock head walls. Besides the New Lock, the project scope also requires new mooring and berthing facilities, deepening the inner and outer harbor and modifying the Flood Defense Line to guarantee safety against superstorms.

1. INTRODUCTION

The Rotterdam-Paris inland waterway route (Figure 1) is an important connection for the economy of France, Belgium, The Netherlands and other neighboring countries. This route however has some major bottlenecks. Most of them are or will be tackled in the Seine-Scheldt project, a joint plan between France, Wallonia and Flanders (the 2 Belgian regions). A last bottleneck is the Terneuzen lock complex in The Netherlands. This bottleneck and its renewed solution are the topic of the current publication.

Terneuzen, a city in the Netherlands with a little over 55.000 inhabitants, is housing a lock complex with three sea locks connecting the Ghent-Terneuzen Canal (BE) to the river “Westerschelde” (NL/BE). The Ghent-Terneuzen Canal is the main waterway to/from the Port of Ghent (BE) and is a part of the Rotterdam-Paris inland waterway route. Coming from this canal, the Terneuzen lock complex is the gate to the Westerschelde, the North Sea, the port of Antwerp, and gives via Hansweert also connection to the port of Rotterdam, see Figure 2.

[1] DEME nv, Dredging International nv (part of Joint Venture Sassevaart), Zwijndrecht, Belgium. van.doorslaer.koen@deme-group.com
[2] BAM (part of Joint Venture Sassevaart), Gouda, The Netherlands. marc.bool@bam.com
[3] Flemish Government, Department Mobility and Public Works, Division Maritime Access (part of client VNSC). Antwerp, Belgium. Wim.De.Cock@mow.vlaanderen.be
[4] Rijkswaterstaat (part of client VNSC), Terneuzen, The Netherlands. Harm.verbeek@vnsc.eu

Figure 1. The Paris-Rotterdam Waterways, with the location of the New Lock Terneuzen

Figure 2. Ghent-Terneuzen Canal gives access to the Westerschelde, the North Sea, Rotterdam and Antwerp

The current lock complex is showing long waiting times for inland navigation and is since some time at its maximum capacity. Besides this discomfort, the existing locks in the lock complex are old and limited in dimensions:

- the Eastern Lock (1963) has dimensions of 280m x 24m, for inland waterway only;
- the Middle Lock (1910) is 140m long by 18m wide, for inland waterway and sea going vessels with a draught up to 7.2m;
- the Western Lock (1968) has dimensions 290m x 40m, for inland waterway and sea going vessels with a draught up to 12.5m;

Therefore, the Flemish (BE) and Dutch (NL) government have decided to replace the Middle Lock for a new and bigger sea lock in Terneuzen. With a lock chamber of 427m by 55m, the New Lock in Terneuzen will have the same size lock chamber as the Panama Canal Expansion Project that became operational in June 2016. Terneuzen's New Lock will be operational by mid-2022, after a construction period of 5 years. During all this time, the existing lock complex has to remain operational.

2. TIMELINE AND TENDER PROCEDURE

2.1 Timeline

The project New Lock Terneuzen is a binational Flemish (BE) - Dutch (BL) cooperation, both for the Client (VNSC, see section 2.5) and for the Contractor (Sassevaart, see section 2.6). In this section, an overview of the different phases is given starting from the first idea until the operational New Lock.

In 2006, first studies were started to evaluate the effect of the increasing traffic and ship sizes to the economy in the Ghent-Terneuzen Canal area. It showed that the lock complex in Terneuzen is a bottleneck and a hazard for economic growth. From 2007 on, cost-benefit analysis took place, proposing different solutions and investigating all of their possible aspects such as nautical safety, environment, traffic, stakeholders, …

On March 19 2012 the Flemish minister of Transportation and Public Works, and her Dutch colleague minister of Infrastructure and Environment, announced that a new Lock will be built in Terneuzen. The technical and functional requirements, the location of the lock, its geometry and other characteristics were not yet fixed at that moment, but should be the result of the plan study that both governments ordered in 2012. Between 2012 and 2015 this plan study took place, leading to two important documents:

- an EIA (environmental impact assessment) in which all different alternative solutions and their effect on different environmental aspects such as water, noise, air quality, nature, traffic and flood risk were studied.
- An OTB (Ontwerp Tracé Besluit, Dutch for "draft planning decision"), in which the choice between the different alternatives is made, thereby proposing a fixed location and geometry for the lock, the layout of roads and lock facilities. Also the legal framework for the project is given, which laws to obey, how to deal with topics such as air quality, traffic, archaeology, landscape, nuisance (noise, vibrations, …) for local residents, hinder for navigation (obstructions due to the works), …

Both the EIA and the OTB were published mid-2015 and open to the public for 6 weeks to file comments or complaints. After a period (+/- 1 year) of thorough investigation by the administrations of The Netherlands and Flanders, the comments and/or complaints led to the improved and official document, called "Tracébesluit" (Dutch for "final planning decision"), published on March 14 2016. This document gives a detailed description of the project, where the exact location of the lock is decided by both administrations. After again six weeks for comments or complaints by the public, a European tender was initiated on May 25 2016 for this Design, Construct and Maintain project.

2.2 Project details

The project that was put to the market is summarized in the following assignments:

- Design and construction of the New Lock with dimensions 427m x 55m x NAP - 16.44m within the existing lock complex of Terneuzen; NAP is the Dutch reference level.
- Realising the local operation and control of the New Lock and preparing for remote operation;
- The construction of four lock doors and two bascule bridges;
- Adapting the Flood Defence Line;

- The construction of a tugboat harbour and warehouse;
- Demolishing of the existing Middle Lock and houses on the lock complex;
- Adapting the lock infrastructure and terrains;
- Adapting the roadway infrastructure on the lock complex;
- Deepening the navigation channels and maintaining the nautical depth during the works;
- Maintenance for two years after commissioning, with the exclusion of the dredging works.

In Figure 3, the project area is shown. In transparent, the scope to be removed is shown. In black, the new constructions are shown. This project is more than building a New Lock. Also the dikes, mooring and berthing facilities for navigation and different quays are renewed within this project.

The Ghent-Terneuzen Canal has its still water level at +2.13m NAP, whereas the Scheldt River fluctuates between -1.89m NAP and 2.29m NAP in daily situation.

The New Lock will allow passage for large seaworthy vessels of 366m long, 49m wide and a draught of 14,5m.

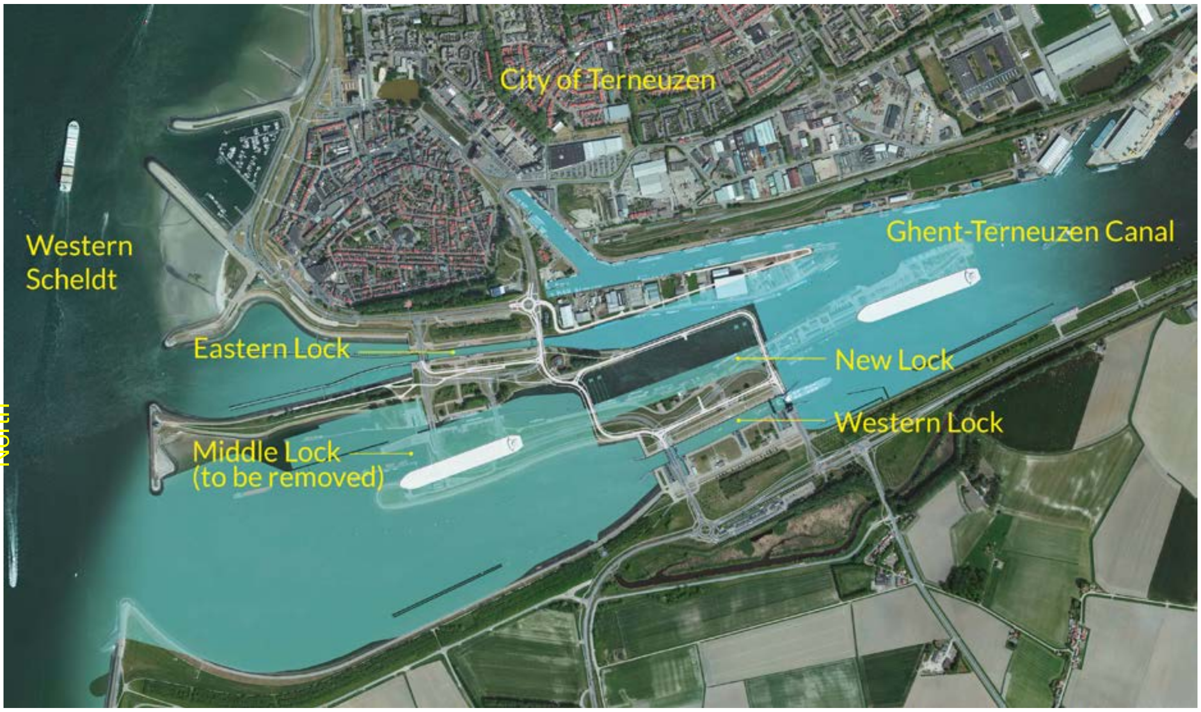

Figure 3. Project New Lock Terneuzen, with indication of the existing locks, the new constructions (black) and constructions to be removed (transparent)

2.3 Tender Procedure

The winning Contractor/Joint Venture (JV) is chosen based on the Dutch EMVI principle, where EMVI is the Dutch abbreviation for 'Economical Most Valued Offer'. This means that besides pricing, also other criteria are valued in awarding the tender to the winning JV.

Just like any other tender, the tender started with a selection phase to select X participants by July 8 2017. Three Joint Ventures were selected for participation.

The 2nd step in the tender procedure was to go from X selected Contractors/joint ventures to a maximum of three by November 2016, by means of a risk management plan. Despite X was equal to three from the beginning, the selection procedure was maintained but no participants were excluded from continuing the tender procedures at the end of this step.

The 3rd phase of the tender was an individual dialogue phase between each JV and the Client, to discuss critical design scope and the EMVI-criteria. This dialogue finished end of March 2017, and the tender had to be submitted by all JV's on May 4 2017.

After a review period by the Client and their advisors, the Project was awarded to the winning JV Sassevaart in September 2017.

The project will be finished by August 2022, after which a two year maintenance period of the New Lock and all new constructions with the exclusion of the maintenance dredging starts.

2.4 EMVI criteria

As stated earlier, the price was not the only criterion for selecting the winning JV. In The Netherlands this is known as an EMVI-procedure (Dutch: Economisch Meest Voordeling Inschrijving. English: Economical Most Valued Offer).

The first EMVI-criterion was to submit a Risk Management Plan (RMP) for 7 pre-selected risks:

- Insufficient knowledge and control of the subsoil. Design and construction methods are not aligned with the geotechnical and geo-hydrological situation of the subsoil (10 M€);
- Damage to the existing lock complex (40 M€);
- Delay on schedule (30 M€);
- Time delay and the experience of hinder for navigation (25 M€);
- Quality of the works, integrated design in combination with internal processes by the Contractor that are not mastered (25 M€);
- Imperfect connection in the existing lock complex; not or insufficient functioning of the industrial automated control of the New Lock (25 M€);
- Increased Life Cycle Cost (40 M€).

To mitigate these top 7 risks, a RMP had to be written of maximum 10 pages per risk. A score was given to every JV for each of his 7 risks (4 = excellent extra value, 3 = significant extra value, 2 = obvious extra value, 1 = extra value, 0 = no or little extra value), which then were converted to a (virtual) amount in Million euros. The maximal achievable (virtual) amount per risk is given in the list above between brackets, with a total of 195 M€.

The second EMVI-criterion was the possibility to bring a maximum of 2.9 million m³ sand (d_{50} > 150µm) as foreshore nourishment to Knokke-Heist (BE), for which a (virtual) amount of 3€/m³ was given to the JV who engaged to fulfil this nourishment. A total of 8.7 M€ could be earned by this second criterion.

The different biddings by the 3 JV's were compared to each other after subtracting the virtual earned amount of M€ from the offered price. In this manner, a JV with a higher price but a better EMVI-score could still win the tender. For example: a JV with a price of 600M€ and an EMVI-score of 100M€ (virtual total price for comparison 500M€), has a lower price but still loses the tender from a JV with a price of 620M€ and an EMVI-score of 150M€ (virtual total price for comparison 470M€).

The offered price had to be below 700M€ excl VAT. Together with the price, also the planning, a 4D model (BIM) and a landscape quality plan had to be submitted.

The winning JV will carry out the work for his offered price, not for the virtual price that was only for selecting the winning JV in the EMVI tender procedure.

2.5 Client

VNSC (Vlaams-Nederlandse Scheldecommissie, Dutch for Flemish-Dutch Commission for the river Scheldt) is a partnership between the Flemish (BE) and Dutch (NL) government to have a sustainable and balanced policy to manage the common Scheldt estuary. Topics like flooding, accessibility of the harbors and a healthy ecological system are dealt with by VNSC. And so is the New Lock in Terneuzen, that was agreed to be built by both governments in 2012.

VNSC set up a project board with Maritime Access Division of the Flemish Government and Rijkswaterstaat of the Dutch Government as members. Besides the project board, who are running the daily operations, there is also a steering committee with members of the project board and stakeholders like the Port of Ghent, the city Terneuzen, the province, …

The project is physically located in The Netherlands, and is thereby following Dutch Tender and Project procedures. The Netherlands are investing over 190M€ into this project, 48M€ is funded by the European CEF funds and the rest is paid by the Flemish government.

2.6 Contractor

The project was awarded to Joint Venture Sassevaart. This Flemish (BE) – Dutch (NL) combination exists of the following companies:

- DIMCO B.V. (DEME Infra Marine Contractor)
- Dredging International N.V.
- BAM Infra B.V.
- BAM Contractors N.V.
- Algemene Aannemingen Van Laere N.V.

Part of the DEME group

Part of BAM

Sassevaart has cooperation agreements with Engie (electrical and industrial automation) and Fugro (soil investigation). The design of the New Lock is done by the engineering departments of the 5 Sassevaart companies in corporation with Arcadis and IV-Infra.

Sassevaart will carry out the project for 626,6M€ (excl. VAT).

3. THE PROJECT

This section discusses some of the key elements that have contributed to JV Sassevaart winning the tender. But for a good understanding of the project, a first subsection briefly explains different phases of the project.

3.1 Project phasing

The project can be generalized in 6 major phases. Explanation is given below each figure. The navigation through the middle lock is always indicated by dotted lines, the water discharging (too high water level on the Canal is lowered by discharging water over the lock complex during low tide at the Westerschelde) by a twitched line with arrows and the Flood Defense Line (protection of the hinterland against storms) in red.

Figure 4. Phase 1: preparation phase

In Phase 1, the preparations of the project are carried out. Existing cables and wires are dug out and disconnected or relocated, houses, buildings, trees and other obstacles in the project area are removed. On the southern peninsula (indicated in blue in Figure 4) a logistic center is organized with a local concrete factory.

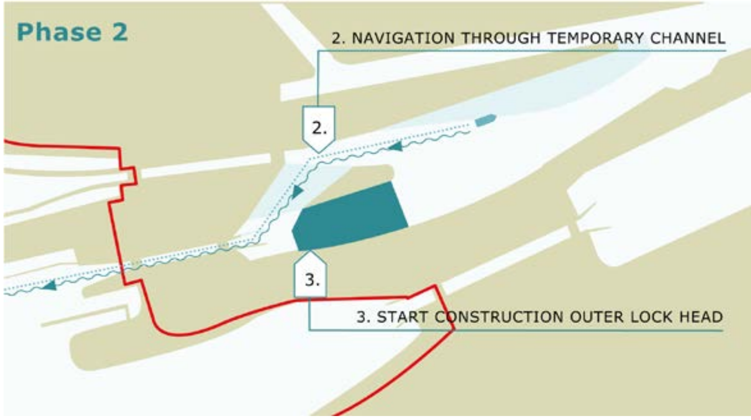

Figure 5. Phase 2: start land reclamation

Figure 5 shows Phase 2, where a temporary channel (see section 3.2) is dug and the land reclamation for the construction site is started. Traffic to/from the Middle Lock can still continue, but has to navigate around the construction area. To make this possible, also a part of the eastern terrain “Schependijk” is removed. The removed terrains are indicated in light blue and the new navigation way is shown by the dotted line.

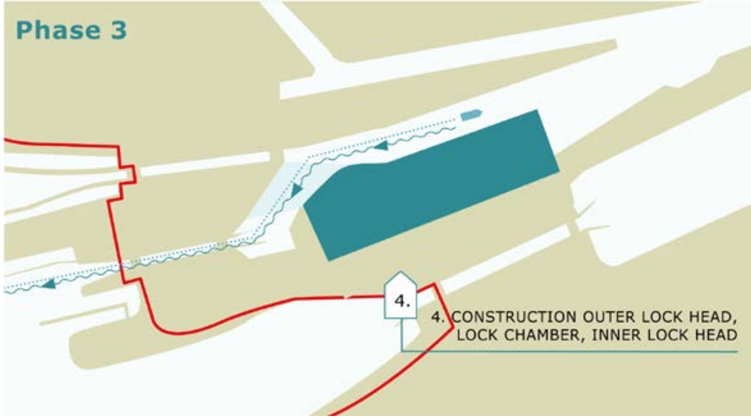

Figure 6. Phase 3: construction New Lock

In Phase 3 the land reclamation is completed and the construction of the New Lock is started. This phase is the longest phase of the project (duration over two years). The rest of outer lock head, the lock chamber and inner lock head are constructed in this phase. As shown on Figure 6, navigation goes similar to navigation in Phase 2.

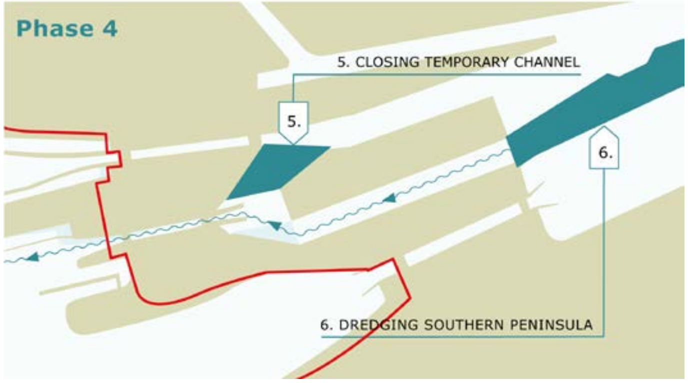

Figure 7. Phase 4: closing temporary cannel and Dredging the southern peninsula.

In Phase 4, the project is already reaching its last year. The civil works of the lock are being finalized and the logistic center can be removed. The southern peninsula, on the right in Figure 7, can thus be dredged and the lock doors, which will be constructed in China, can be installed. After the lock chamber is open, the temporary channel is closed for traffic (no more dotted line in Figure 7). The new lock is not yet open for navigation, the doors are in a testing phase but operate safely behind the original Flood Defense Line which is still in place (red line in Figure 7, equal to previous phases). During this testing phase of the doors, discharging water in times of high water on the Canal can be done through the lock chamber of the new lock that connects via open water to the filling and emptying system of the existing Middle Lock. This is indicated by the twitched line in Figure 7.

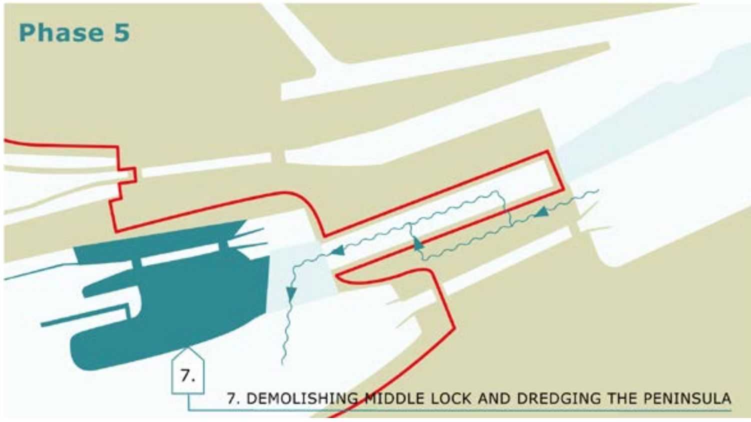

Figure 8. Phase 5: demolishing the middle lock and Dredging the northern peninsula

Phase 5 is for demolishing the existing Middle Lock and its surrounding northern peninsula as indicated in Figure 8. This phase can only start when the new Flood Defence Line, modified in Figure 8 compared to the previous phase, is constructed and offers safety against a storm with return period 4000 years. In this phase, discharging water in times of high water on the Canal is done by the filling and emptying system of the New Lock and by creating a discharging channel in this northern peninsula. This is again indicated by the twisted line in Figure 8.

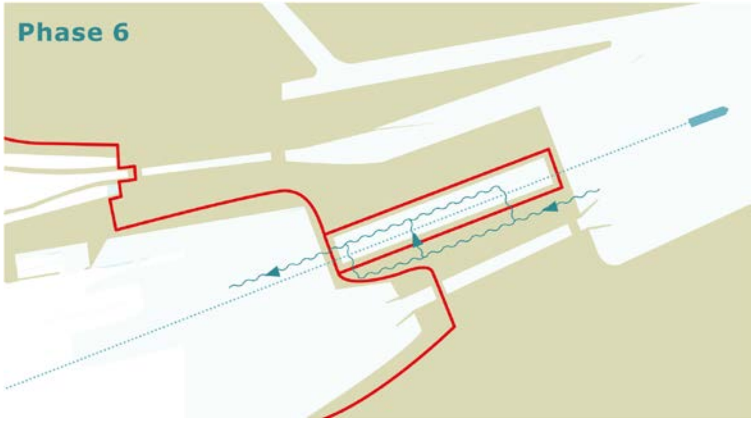

Figure 9. Phase 6: end of construction period, start of maintenance period

The project is finished in Phase 6, where the two year maintenance period starts. As mentioned earlier, the maintenance is not applicable for dredging works and maintenance of nautical depths.

For most of the construction period three locks are available for navigation. In Phase 1, 2 and 3 the three existing locks can be used. Then a short transition period of eleven (11) months in total with only two locks: Phases 4 and 5, where water levelling already uses the New Lock but no navigation is allowed yet. In Phase 6, the New Lock is fully operational offering a renewed lock complex with again three locks.

3.2 Temporary Channel

One of the Client's and stakeholders' main desires was to have a smooth construction period which will maximally avoid obstruction, time delays and other hinder for navigation. Industry along the Ghent-Terneuzen Canal and not in the least the Port of Ghent would benefit from a solid and sound solution that guarantees their daily operation and minimal delay for deliveries. Also shippers from inland navigation clearly stated their wishes to have a project solution that would minimize delay. For seaworthy vessels, VNSC already created a solution where a time-window is created for the seavessels to arrive in Terneuzen's lock complex and immediately be transferred through the Western, Middle or future New Lock. Since inland navigation has lower priority, they could become the victim of only two available locks during the five year lock construction period and increasing waiting times.

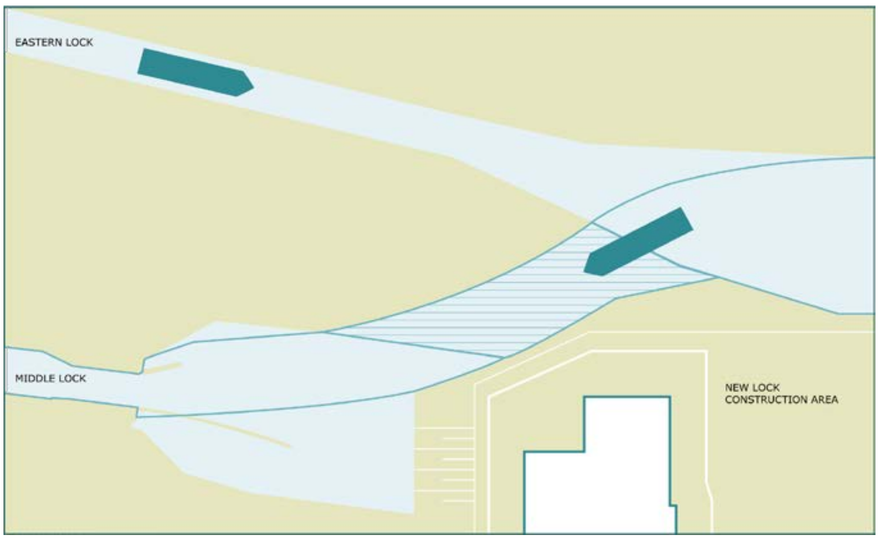

Figure 10. Navigation cannel created to/from the Middle Lock, going around the construction pit.

Sassevaart chose to maximally fulfill this desire of the inland vessel shippers and the Port of Ghent and organized an internal brainstorm session with consultants, shippers and design engineers to investigate different possibilities. The outcome was as sketched in Figure 10: digging a temporary navigation channel to create space for construction but at the same time keep the Middle Lock operational during most of the construction period. According to the Contract, the Middle Lock could be taken out of service upon start of the construction period thereby only having two operational locks. Due to this temporary navigation channel around the construction zone and by a smart planning, Sassevaart will have three locks operational for most of the time (two locks for a period of only eleven months of the five year construction period).

This solution was positively received by VNSC's project team, and two independent studies were carried out to study the feasibility and restrictions to navigation. The outcome was a navigation channel accessible for navigation up to class CEMT IVa or seaworthy ships of the same size (105m x 9.5m x max draught 3m). The temporary channel brings all traffic to/from the Middle Lock in the channel for the Eastern Lock, thereby influencing each other and not being able to transfer ships to the same side at the same time. These measures were taken into account, and the studies then showed a reduction in lost navigation hours by 50.000 to 75.000 and a 25% reduction of the passing time for inland navigation (compared to closing the Middle Lock). This measure has an economical value of 22 to 34 M€.

3.3 Reducing hinder for navigation

Besides the temporary channel, Sassevaart will provide other measures to reduce the hinder for shippers and navigation. Most of this is done by smart dredging and transport of dredged soil.

In the project there is a net volume of about 9 million m³ soil to be removed from the project. With siltation of the harbor during the 5 years construction period, creating working platforms for building the New Lock with soil from the project area and afterwards excavating the lock chambers and lock heads to their final depth, the brut volume soil to be handled is about 13 million m³. A large portion of this (about 40%) is located on the Canal side of the lock complex. A part of it is transported to the Canal side, but most of this soil will be deposited in the direction of the Westerschelde and Knokke-Heist and thus has to pass the lock complex. However, only 11% of the volume is transported by using the lock complex. The other and most significant portion is transported by means of floating pipes and land lines over the construction site (Figure 11) towards the outer harbor basin (Figure 12), where barges are filled to transport the dredged soil towards Westerschelde or Knokke-Heist. For the 11% soil that is transported via the Middle or Western Lock, extra barges are foreseen so the transport can happen mainly during the lee hours and avoid the busy hours of the lock complex. By foreseeing extra barges, full production dredging/excavating can be maintained to guarantee the planning. Finally, Sassevaart is not transporting soil through the lock complex during the eleven months that only two locks are available.

Figure 11. Floating pipe line and bridge construction of land lines over a road.

Figure 12. Cutter dredger (indicated location in orange) transporting its dredged soil via the green floating lines/land lines/bridges (Figure 11) to the barge (indicated location in purple) waiting in the outer harbor. The purple barge will sail direction of the Westerschelde/Knokke-Heist for disposal of dredged material.

Besides smart dredging and soil transport, a few other measures will be carried out by Sassevaart:

- More waiting places for ships during the phase that only two locks are available;
- A nautical advisor is fulltime available on the project;
- Periodic information sessions for shippers, stakeholders and people working on the lock complex;
- Deliveries to/from the logistic center happen in the lee hours of the lock complex.

The measures described in 3.2 and 3.3 lead to a maximum score on the EMVI-risk 4 “Time delay and the experience of hinder for navigation”. They give excellent extra value to the Contract’s requirements.

3.4 Construction technique

A lock can be built in different possible ways. The choice of construction method is always a very project specific choice. No two locks are the same, no two project conditions are the same.

A first possibility is a large open construction pit, like the latest and largest lock that was constructed in the Port of Antwerp (Belgium): Kieldrechtsluis (Figure 13). By creating a water retention wall around the construction site into the water-resisting clay layers, lowering the ground water level and excavating the soil inside the construction site, the lock can be built in dry conditions. This method often has more certainty, easy logistics, a good visual quality control, but uses more concrete (thick walls) and a lot of space. Since the New Lock partly has to come in the middle of an operational lock complex and partly on current waterways, an open construction pit wasn’t the most economic and smart space using solution.

Figure 13. Construction of Kieldrechtsluis in Antwerp by means of a dry construction method.

The opposite possibility is by building all civil constructions from the water with heavy cranes on floating pontoons, as shown in Figure 14. The use of space is smaller, the use of materials is much less, but it's an expensive and time consuming method with lower workability, more difficult to guarantee quality and it might create hinder for navigation. Mainly this last risk was the reason for Sassevaart not to continue with this construction technique.

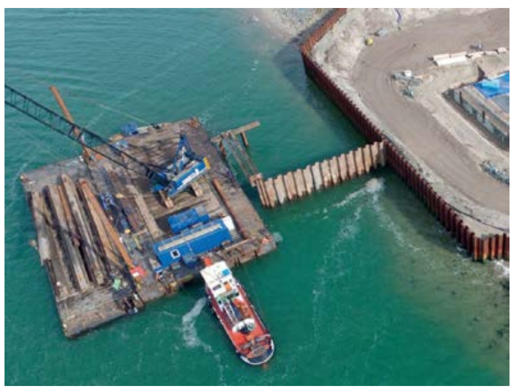

Figure 14. Example of wet construction method.

Besides these two extremes, many "hybrid" solutions are possible with partly wet, partly dry construction techniques. One example is IJmuiden (The Netherlands), where the largest lock in the world is currently being constructed also, like Terneuzen, in the middle of an operational lock complex. The construction zone in IJmuiden is built partly from land and partly from the water. First, combined walls are built along the contours of the new lock from the water side against the landside. When the construction zone was closed, land reclamation took place after which the lock chamber was built with deep diaphragm walls from the land (Figure 15). Simultaneously and also in a dry method, both lock heads are built and sunk to their final level by means of pressurized caissons. The lock chamber zone will then be dredged by a cutter suction dredger.

Figure 15. Construction of new lock in IJmuiden, Combined wet-dry construction method.

Different of the above mentioned and other possibilities have been investigated by Sassevaart for Terneuzen and a TOM (Trade Off Matrix) was set up to find the ideal solution with respect to cost, Contract, EMVI, safety, timing, environment, … The outcome was a combined wet and dry construction technique. The choice was also partly imposed by the geo-hydrologic from the underground, which will be explained in section 3.5. The construction technique by Sassevaart is presented below.

After the navigation channel is diverted as explained in Section 3.2, sheetpile walls are constructed from the water in the North, East and South end of the construction site and a combined wall is built from water on the western side. The eastern sheetpile quaywall is a permanent wall, which forms the eastern boundary of the construction zone during the works. The Eastern lock chamber wall, a combined wall, forms the western boundary of the land reclamation. The permanent walls are indicated in red in Figure 16. The other walls are temporary, for land reclamation purposes and are indicated in green in Figure 16. In between all four constructed walls, land reclamation takes place. These works are planned for end 2018-begin 2019.

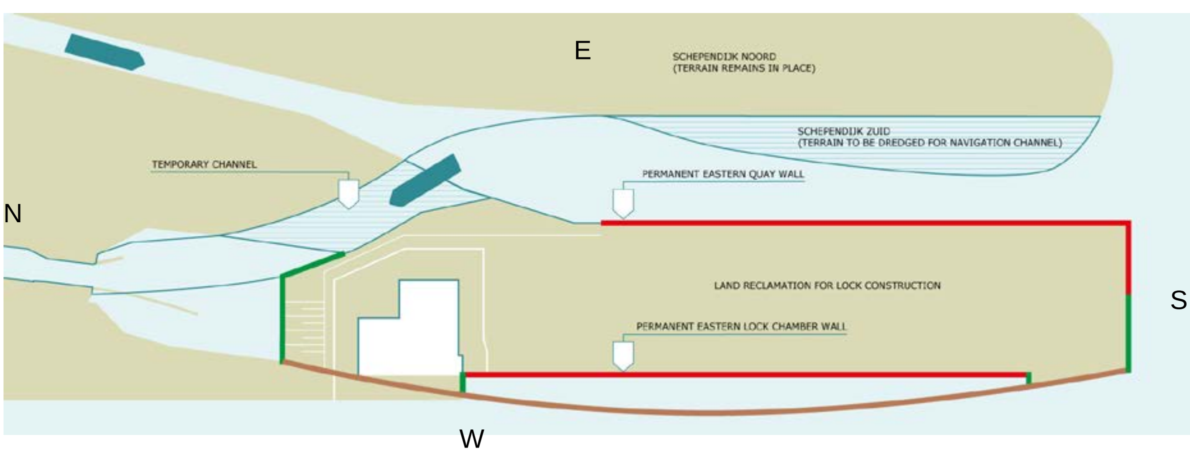

Figure 16. Land reclamation between 2 permanent walls (red) and 2 temporary walls (green)

On the dry (reclaimed) land in between the four boundaries of Figure 16, deep diaphragm walls are installed to create the lock heads, indicated in blue in Figure 17. Also the Western lock chamber wall is built from the (original) land with diaphragm walls (blue in Figure 16). This is the most elaborate construction phase (phase 3 of the project, section 3.1) which lasts until mid- 2021.

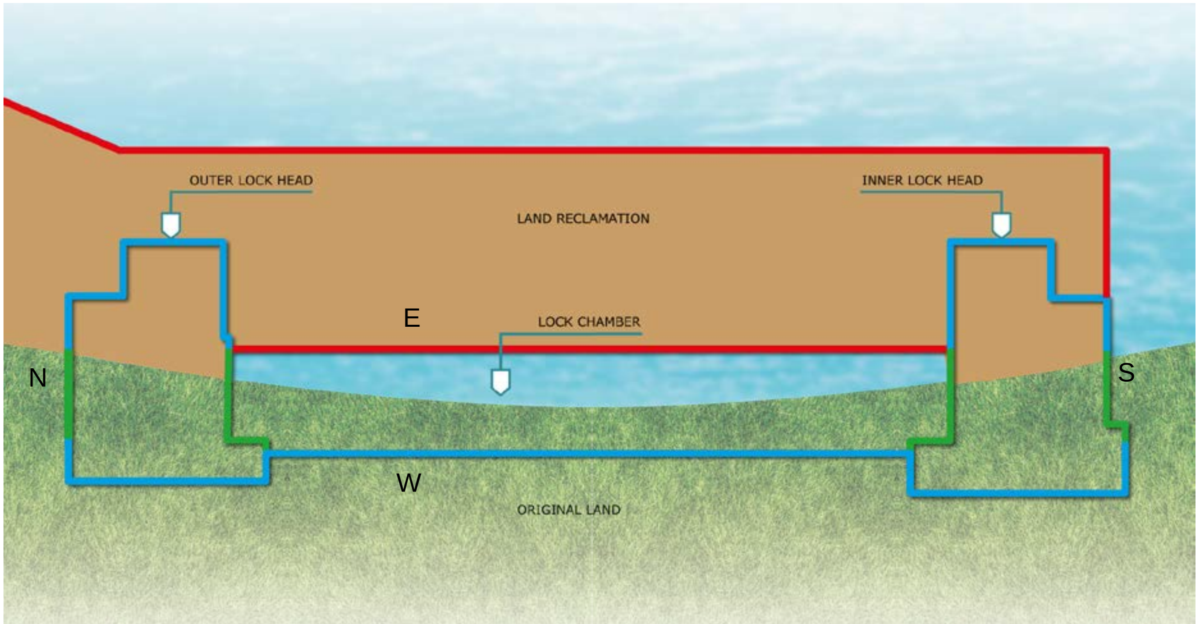

Figure 17. On the reclaimed land, deep diaphragm walls (blue) are built to form the lock heads and western lock chamber Wall.

The lock chamber, with its eastern wall a combined wall installed from water and its western wall a diaphragm wall installed from land, does principally not differ much in construction technique from IJmuiden: two walls are built, then excavated in between the two walls, finally under water concrete is installed as lock chamber floor. Unlike for Kieldrechtsluis (Figure 13), the lock chamber of New Lock Terneuzen is not designed to ever set dry.

The lock heads are built dry in a closed construction pit. To achieve this construction pit, diaphragm walls are built as contours. These diaphragm walls go to well below the water resisting clay layer ("Boomse Clay") and even have combined walls as reinforcement, see section 3.5. In between the diaphragm walls, partly dry excavation (up to NAP – 10m) is carried out, and for stability reasons the deeper excavations (up to NAP – 22m) have to be done with an excavator on a pontoon after the construction pit is filled with water up to NAP level again. After the excavation of the lock heads, a thick underwater concrete floor is installed which acts as strut, required for stability reasons. After this underwater floor is hardened, the water in the construction pit can be pumped out to continue the dry construction of the lock chamber.

3.5 Geo-hydrologic situation

The reason for the deep diaphragm walls of the lock heads, the reason for not going for a large open construction pit and the reason for building the lock chamber walls less deep and where possible from the water, can all be found in the subsoil in Terneuzen and its geo-hydrologic situation.

In that part of the low lands Belgium and The Netherlands, a clay liner is present, called Boomse Clay, at a varying depth. In Terneuzen this clay is present from about NAP – 20m to NAP – 35m. Boomse Clay has perfect water resisting capacity and is for example one of the main reasons why all locks in the port of Antwerp are built in an open construction pit with dewatering and open excavation: a water resisting wall into the Boomse Clay is built around the construction site, and outside this wall no influence of the lowered ground water table can be noticed. However in Terneuzen, thorough soil investigation has shown that this clay liner is not overall present. It's present at both ends, the lock heads, but absent in the middle where the lock chamber has to come. This is visualized in Figure 18.

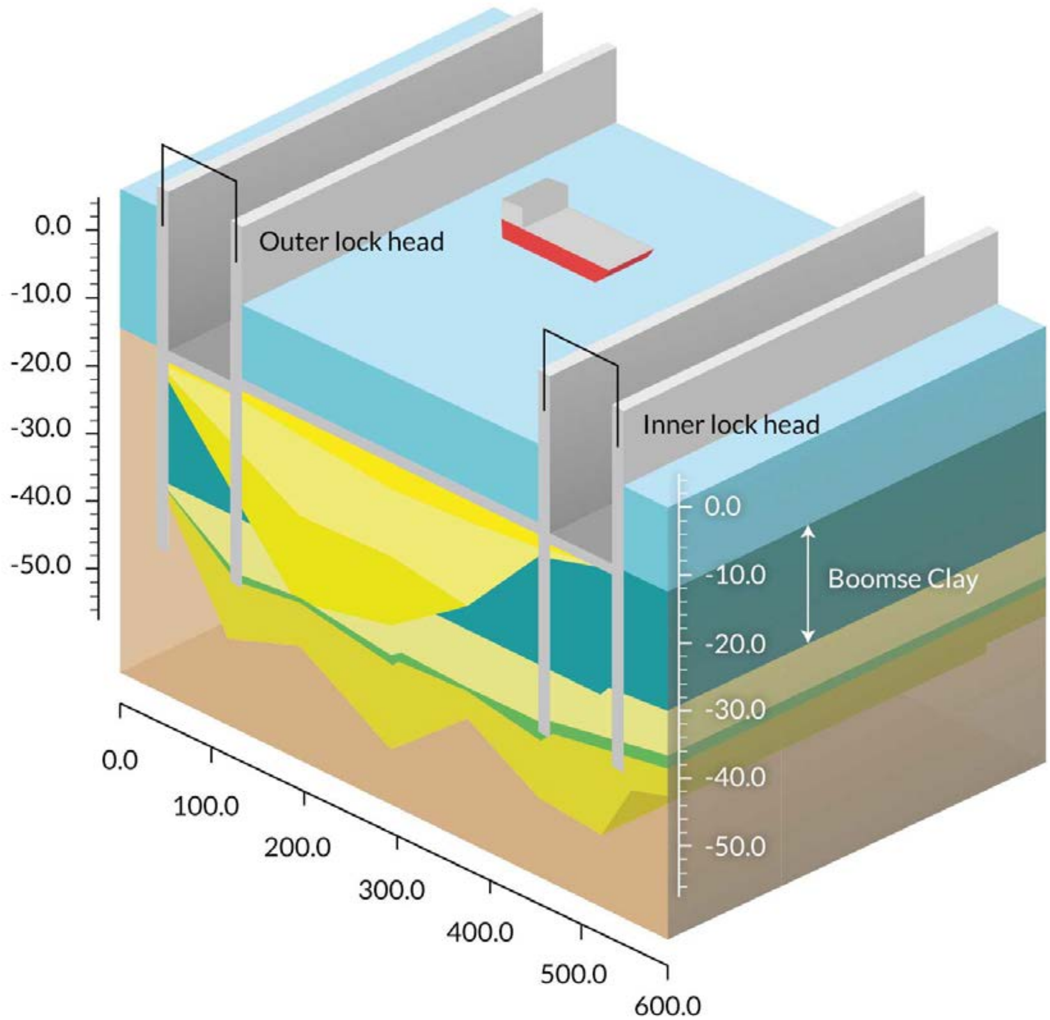

Figure 18. Geological Profile over the length axis of the lock, with indication of the Boomse clay.

Geological and historical investigations showed an ancient gully which has worn out the clay at this location. Through this gully, which got filled with fairly permeable sands, there is an open connection between the project area and the surroundings, such as Terneuzen city center. This has major consequences for the choice of construction technique. In the 1960's, when the Eastern and Western Locks were built, the Client and Contractors were less aware of this phenomenon and constructed the locks in open excavation with lowered water table. Due to this large extraction of ground water in the project area, also the ground water level in Terneuzen city lowered which lead to subsidence and damage to many houses. The church in Terneuzen even had to be broken down.

However, not dewatering at all would lead to high upward water pressures on the clay layer when the lock heads are fully excavated, and even risk uplift or bursting of the clay. Two possible solutions exist: installing pulling anchors or constructing (very) deep diaphragm walls.

- Drilling anchors through the concrete floor and anchoring them into the underground, would avoid the use of dewatering. Calculations showed a very high density of expensive anchors, making this an uneconomic and practically infeasible solution.
- Constructing (very) deep diaphragm walls as contours of the dewatering zone. Since the underground has much higher horizontal than vertical permeability it's important to block the horizontal water transport. Geohydrological calculations and a pumping test, to verify assumptions of soil layers' permeability, have shown that deep diaphragm walls until about NAP – 45m (10m below the Boomse Clay) are sufficient to allow a mild surface tension dewatering with returning

the water into the same soil layer. This has zero effect on the water table in Terneuzen city, which will intensively be monitored.

Creating a large open construction pit would require these very deep water resisting walls over large distances to contour the whole construction zone (which is already larger for an open excavation). This option was uneconomic and thereby not maintained by Sassevaart.

Constructing the lock chamber in the same way as the lock heads are foreseen, would also increase the length of (expensive) deep diaphragm walls. Therefore, only the lock heads will be carried out with deep diaphragm walls until about NAP – 45m. The lock chamber will be carried out as explained, by less deep combined (east) and diaphragm (west) walls with underwater concrete floor installation without ever setting the lock chamber dry.

3.6 More than just a lock

Apart from the New Lock all maritime mooring and berthing facilities are to be renewed by Sassevaart. This means deconstructing or adapting the present facilities and constructing new ones that are designed for the increased size of navigation that will pass through the New Lock. These new mooring and berthing structures are located at various locations within the Project area, shown in Figure 19.

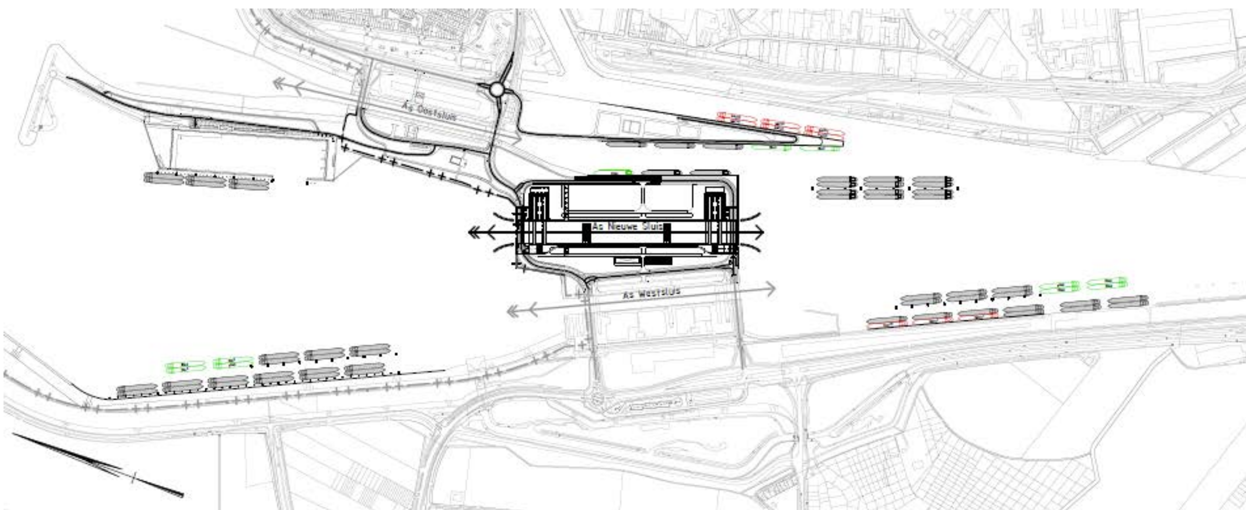

Figure 19. New Lock with new mooring and berthing facilities.

Since most of these facilities are located in and near the embankments of the inner and outer harbour, and also since these inner and outer harbours are to be deepened, the embankments itself are also to be adapted within this Project. The outer harbour embankments are part of the Flood Defence Line, so they have to be designed to withstand a storm with return period 4000 year.

The present Tugboat harbour, currently located on the northern peninsula, is also disappearing. Within the project, a new tug harbour (including various land- and offshore facilities) is to be constructed by Sassevaart.

Finally, also new buildings on the lock complex and new roadway infrastructure has to be designed, built and maintained for two years.

4. ACKNOWLEDGEMENTS

This paper is, like the project, a joint effort of many Belgian and Dutch colleagues, by the Contractor Sassevaart (represented by two authors) and the Client VNSC (represented by two authors). Besides the four authors, this paper and the whole project is a team performance by all people of Sassevaart and VNSC. A special word of thanks goes to the environment manager Nancy Vincke, the communication manager Lisette Booij and technical drawer Ankie Gijsel (Graphic Avenue) for their input and graphics.