THE SEINE-SCHELDT PROJECT: NAUTICAL ACCESSIBILITY OF A NEW LOCK IN HARELBEKE

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SUMMARY

The paper presents the design of a new lock and weir in the city of Harelbeke as based on waterway guidelines and as submitted by three candidates subscribing to a design and build tender published by the waterway manager Waterwegen en Zeekanaal NV. The design vessel of the lock was an ECMT class Vb inland vessel which concerns a combination of a push boat and two barges with total dimensions 185 m x 11.4 m x 3.5 m. The design vessel was not equipped with a bow thruster. The nautical quality of the designs submitted was assessed by performing real-time simulations on the simulator Lara at FHR in case of a rather high water discharge over the weir. In the framework of this assessment it was noticed that the cross current in the fairway had an important impact on the nautical quality of the design. The cross current in the fairway corresponding to the final design submitted by the three candidates was thoroughly studied.

NOMENCLATURE

D&B	Design and Build
ECDIS	Electronic Chart display and Information System
ECMT	European Conference of Ministers of Transport
FHR	Flanders Hydraulics Research
HP	Horse Power
LCD	Liquid Crystal Display

1. INTRODUCTION

The Seine-Scheldt project aims to connect the Seine basin in the Paris region with the Scheldt basin in the region of Antwerp-Rotterdam, for vessels up to ECMT class Vb (4500 tonnes). In order to achieve this by 2016, the Belgian region of Flanders is preparing navigability enhancements of the river Lys, which currently allows vessels up to 2000 tonnes (ECMT class Va).
One of the main challenges for this calibration lies in the construction of a new lock in Harelbeke, to replace the insufficient existing one. Therefore, the reconstruction of the lock and its interconnected weir, and simultaneously the reassessment of the urban site with its waterfront and its two bridges, becomes an important goal for the Seine-Scheldt project.

2. DESIGN AND BUILD OF A NEW LOCK IN HARELBEKE

In order to allow one way traffic of ECMT class Vb vessels with maximum dimensions 185 m x 11.4 m x 3.5 m in Harelbeke, the waterway manager of the river Lys (Waterwegen en Zeekanaal NV) started a Design & Build-procedure (D&B) for a new lock and weir in Harelbeke in 2010. The project area contained the urban site between the bridges ‘Hoge Brug’ and ‘Kuurnebrug’ separated approximately 1 km, and the first bend in the river Lys downstream the bridge ‘Hoge Brug’ (see Figure 1). The project calls for the following actions [1]:

- the deepening of the Lys to a water depth of 4.5 m;
- the construction of a new lock, adapted to vessels of ECMT class Vb;
- the repair of fish migration possibilities around the new lock and (new or existing) weir;
- the rebuilding of the bridge ‘Hoge Brug’, just downstream the lock;
- the lifting of the bridge ‘Kuurnebrug’, just upstream the lock;
- the reconstruction of the necessary mooring structures on both sides of the lock;
- the straightening of the bend of Geldof, downstream the bridge ‘Hoge Brug’;
- the construction of mooring places that are environmentally appealing.

During the construction of the new lock the continuity of the navigation is to be guaranteed for inland vessels up to ECMT class Va. Furthermore the historical buildings ‘Banmolens’ and ‘Bloemmolens’ should be preserved and the design has to take into account constraints regarding urban planning, landscaping and architecture.
Initially seven candidates subscribed to the D&B-tender of which three were selected to work out their proposal into more detail.

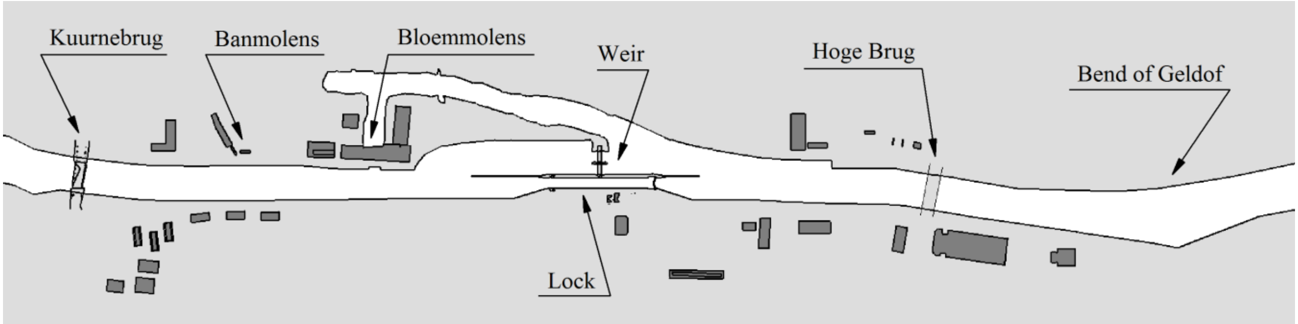

Figure 1: Bird's-eye view of the D&B project zone in Harelbeke (existing situation). Left: upstream, right: downstream.

3. DESIGN BASED ON RVW2011 [2]

3.1 WATERWAY GUIDELINES 2011

For the concept design of inland navigation channels empirical methods exist for estimating the required channel dimensions, taking account of the design ship's dimensions and characteristics. In order to compare the dimensions of the three designs submitted for the lock and weir in Harelbeke to general fairway dimensions, the advised design dimensions of the lock and its approach canal were derived from [2].

3.2 ADVISED DESIGN DIMENSIONS

The D&B tender stipulates that the practical length of the lock (in between the stop marks) should be 230 m, the width of the lock should be at least 12.5 m and the depth should be no less than 4.7 m.
Following the guidelines in [2] the maximum dimensions of an ECMT class Vb inland lock and its upstream and downstream holding basins were calculated. The total length of the lock (practical length increased with the door chambers) was assumed 260 m and the holding basins had to facilitate a funnel (126 m) corresponding to a safety strip of 7 m between the design vessel moored to the line-up zone and the extended lock wall, a line-up zone (276 m) and a run-out zone (184 m). The total length of the lock environment as prescribed by [2] is 1431 m. Taking into account the limited distance between the bridges 'Kuurnebrug' and 'Hoge Brug' measuring 980 m and the specific requirements regarding the tender, a dedicated design of the lock and weir was required.

4. ASSESSMENT OF PROPOSALS

In order to improve the quality of the three selected proposals for the D&B tender several assessments were performed by an evaluation group consisting of experts in the fields of town planning (city of Harelbeke), technical design (Flemish government, department Mobility and Public Works, division Expertise Concrete and Steal and division Maritime Accessibility), nautical design (Flanders Hydraulics Research) and hydraulics (Flanders Hydraulics Research). In this paper only the nautical evaluation of the proposals will be discussed.
The three candidates submitted a proposal in three consecutive selection rounds:

- first round: October 2011;
- second round: June 2012;
- third round: October 2012.

After the first and second round the nautical quality of the proposals was evaluated by means of real-time simulations performed on the inland manoeuvring simulator Lara at Flanders Hydraulics Research (FHR) while the third round consisted of expert judgement.

4.1 INLAND SIMULATOR LARA

On December 3rd 2010 the inland simulator Lara (Figure 2) at FHR was inaugurated by the Minister of Mobility and Public Works H. Crevits. The aim of this simulator is to provide the Flemish Government with a tool for research and development on inland navigation.

Figure 2: Inland navigation simulator LARA

Lara is based on the hardware and software simulator technology of FHR with following features:

- Full mission bridge with 210° aerial view displayed on seven 52" LCD monitors (Visualisation software Vegaprime Presagis)
- Equipped with ECDIS and radar (Tresco, Alphatron, Sindel)
- Controllable camera views
- Controllable bridge height as on many inland vessels

4.2 DESIGN VESSEL

The new lock in Harelbeke will be accessible for ECMT class Vb vessels with maximum dimensions 185 m x 11.4 m x 3.5 m. This vessel concerns a combination of a push boat with two barges connected in longitudinal direction. In the simulator a somewhat longer push boat was applied so that the total length of the combination was 191 m. The push boat was equipped with two propellers and two coupled rudders. Mathematical manoeuvring models were available for both the maximum draught (3.5 m) and a more moderate draught (2.4 m). In simulations at maximum draught the barges were transporting bulk cargo (coal). In this situation no bow thruster was available in any of the two barges. In simulations at moderate draught (2.4 m) container cargo was presumed with containers piled up three high in the barges. This resulted in an air draught equal to 6 m. In reality barges carrying containers are equipped with a bow thruster. In the simulations a bow thruster (350 HP) was available in the front barge when simulating with container cargo.
The simulations revealed that all designs were acceptable if the vessel was equipped with a bow thruster. In this paper only the accessibility for ECMT class Vb vessels without bow thruster will be discussed.

4.3 LOCK AND WEIR

At present the lock at Harelbeke is located at the right bank of the river Lys and the weir is positioned to the left of the lock (see Figure 1). In every design submitted, the lock and weir were positioned in a similar way resulting in a weir positioned between the lock and the left bank. In case of an important discharge of water over the weir the current in the waterway influences the manoeuvring on the river. Furthermore the respective position of the lock and weir implicates a cross current in the region where the water is dissipated between the fairway and the weir canal.
All simulations were performed with a discharge of 100 m³/s over the weir. The current profiles resulting from this flow rate were supplied by the candidates for every design submitted and were implemented in the inland simulator Lara.

5. UPSTREAM

In the following the designs submitted in the first round and the final designs together with their nautical evaluation based on real-time simulation will be presented. The candidates were not allowed to significantly adapt the position of the lock with respect to the first design submitted.

5.1 CANDIDATE ONE

The first candidate positioned the lock at a similar position as the existing lock and with the same orientation. The distance between the lock and the bridge ‘Kuurnebrug’ was 450 m and the longitudinal distance between the lock and the corner of the building ‘Bloemmolen’ on the left bank was 63 m. The lateral distance between the extended left lock wall and this corner was in the first design 3.8 m and was increased to 6.1 m in the final design.
In the first round the left lock wall was provided with a 48 m long guiding wall aligned with the lock wall. In the final design the length of the guiding wall was decreased to 31 m and the orientation of the guiding wall with respect to the orientation of the lock was chosen at 12.5°.
A line-up zone was created at the right bank resulting in a safety distance of 5.7 m between a moored vessel and the extended right lock wall (see Figure 3).
Real-time simulations revealed that the design submitted in the first round was not acceptable for the design vessel (without bow thruster) leaving the lock. As the ship leaves the lock the lateral current, resulting from the flow of the weir, moves the bow towards the left bank.

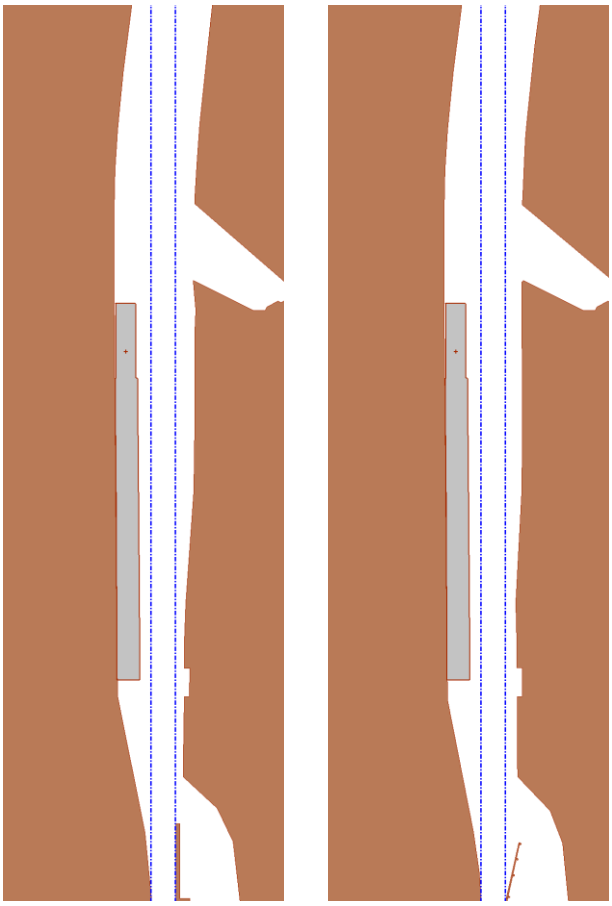

Figure 3: Upstream designs of the project environment submitted by candidate 1. First round (left) and final design (right). Blue parallel lines indicate the extended lock walls.

The lateral distance between the lock and the left bank was only 3.8 m and there was no space available for the push boat to move sideways to starboard (towards the left bank). The combination of current and small distances towards the left bank associated with the first design led to unacceptable small distances between the vessel and the left bank. In the final design the problem of leaving the lock was moderated by shifting the 'Bloemmolen' corner towards the left bank and by rotating the guiding wall near the left lock wall. Nevertheless the distance towards the left bank for the design vessel leaving the lock remains a disadvantage in the final design.
In both the first and final design the discharge of water to the weir was performed at relatively short distance of the lock entrance, implicating an important distortion of the motion of the bow when approaching the lock.

5.2 CANDIDATE TWO

The second candidate positioned the lock at a more downstream position than candidate one, leading to a longer distance between the corner of the 'Bloemmolens' building and the lock entrance (see Figure 4). The lateral distance between the extended left lock wall and the left bank is at least 6.3 m. Furthermore the orientation of the lock differed 1.5° from the orientation of the existing lock.
In the first round the left lock wall was followed by a soft fendering in order to minimize the pressure on the ship hull. The fendering existed of two fender walls making an angle towards the left bank and was not connected to the lock corner. The design and rigidity of the fendering proposed in the first round were evaluated negatively for guiding barges towards the lock. In the final design candidate two adapted the fendering at the left lock wall to a continuous wooden guiding construction connected to the left corner of the lock which is indeed a favourable guiding construction for barges.
The line-up zone was chosen at the right bank at a relatively long distance (240 m) from the lock entrance. The lateral distance between the design vessel moored to the line-up zone and the extended right lock wall was 5.6 m. The position of the line-up zone with respect to the lock implicates a longer time required to bring a ship from the line-up zone to the lock for the design of candidate two.
The water flow between the fairway and the weir is led over a relatively long distance along the fairway leading to moderate cross currents in the fairway.
During the leaving of the lock the bow of the vessel is gradually moved towards the left bank. When the vessel has completely left the lock the push boat had (especially in the final design) enough space to move sideways in order to compensate the lateral motion as a result of cross currents. Granted that the leaving of the lock is performed with sufficient speed – in order to decrease the effect of the cross current – this manoeuvre could be performed acceptably for the final design.

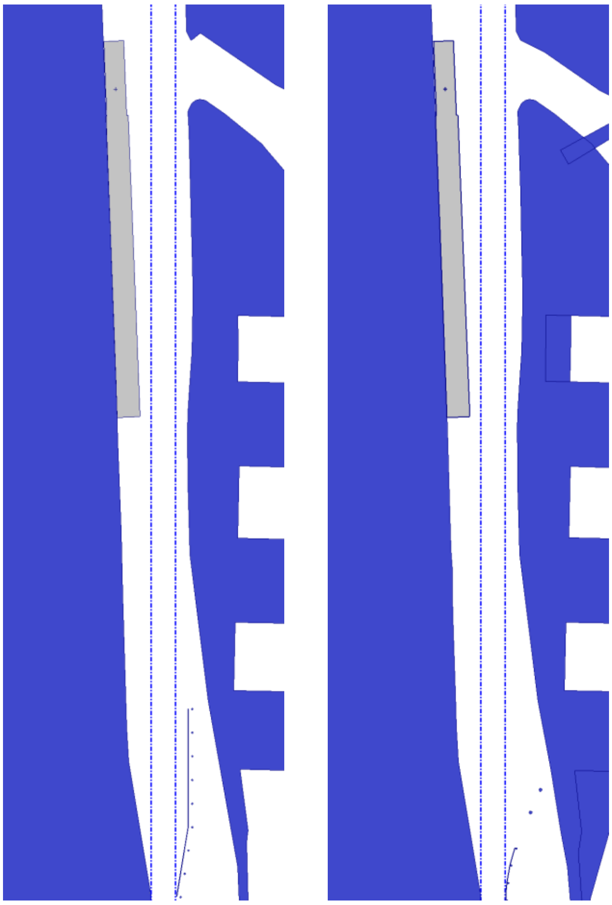

Figure 4: Upstream designs of the project environment submitted by candidate 2. First round (left) and final design (right). Blue parallel lines indicate the extended lock walls.

The skippers performing entering manoeuvres noticed only a small distortion of the vessel as a result of the cross current, thus leading to a controlled lock approach and moderate contacts between ship and (guiding) constructions.

5.3 CANDIDATE THREE

In the design submitted by candidate three the new lock is accomplished by extending the existing lock in Harelbeke in upstream and downstream directions. This implicates that the width, orientation and position of the new lock equals those of the existing lock. Furthermore the lock is characterised by 180 m long guiding walls extending the left lock wall (see Figure 5). The first 130 m of the upstream guiding wall concerned a closed construction while the last 50 m concerned a half open construction, leading the current from the fairway to the weir.
The line-up zone is chosen at the right bank directly after the lock funnel. The safety distance between a ship moored at the line-up zone and the extended right lock wall was 5.6 m. The position of the line-up zone implicates a short time to bring a vessel moored at the line-up zone to the lock. This manoeuvre is facilitated by

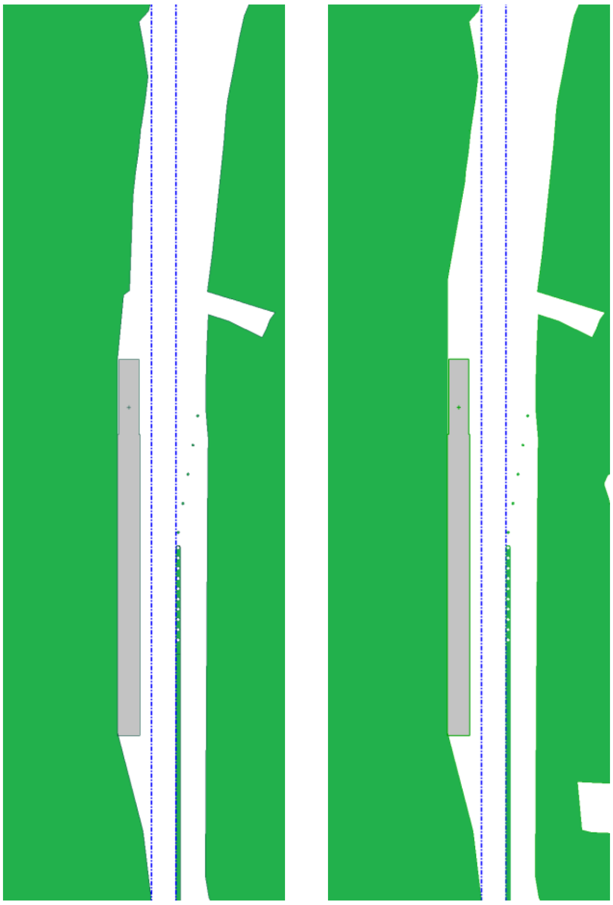

Figure 5: Upstream designs of the project environment submitted by candidate 3. First round (left) and final design (right). Blue parallel lines indicate the extended lock walls.

the currents resulting from important flow rates.

During the leaving of the lock the vessel can slide along the guiding wall in order to keep an acceptable distance to the vessel moored at the line-up zone. The cross current from the fairway to the weir presses the vessel against the guiding wall while this structure prevents the ship from drifting towards the left bank. As a result the ship is positioned along the guiding wall and once the vessel passed it partly the bend to starboard was initiated by moving the push boat sideways towards to moored vessel. Because the lateral motion due to cross currents is prevented by the guiding wall there is no need to increase speed to compensate current as was the case for the upstream designs of the other candidates.

For the lock approach remarks were made regarding the available space at the right bank corresponding to the design submitted in the first round. In order to bring the ship in a favourable position to enter the lock the ship should apply a drift angle corresponding to a position of the bow towards the guiding wall. Therefore in the first design the available space at the right bank directly after the bridge 'Kuurnebrug' was evaluated insufficiently. In the final design the right bank was adapted so the lock approach could be performed successfully.

As the first 130 m of the guiding wall concerns a closed construction no current was present at the lock entrance, leading to a smooth lock entering with the bow along or very close to the guiding wall.

6. DOWNSTREAM

After presenting the upstream holding basin as submitted by the three candidates, the downstream holding basin will be discussed in a similar way. For all candidates the design of the downstream holding basin is more or less symmetric to the upstream design. However, in the downstream holding basin the water flow from the weir on the left bank results in a completely different situation for navigation.

6.1 CANDIDATE ONE

As was the case in the upstream holding basin candidate one applied straight guiding walls aligned with the left lock wall in their first design. The line-up zone was chosen at the right bank directly after the funnel. As can be noticed from Figure 6, the orientation of the lock does not correspond to the orientation of the fairway.

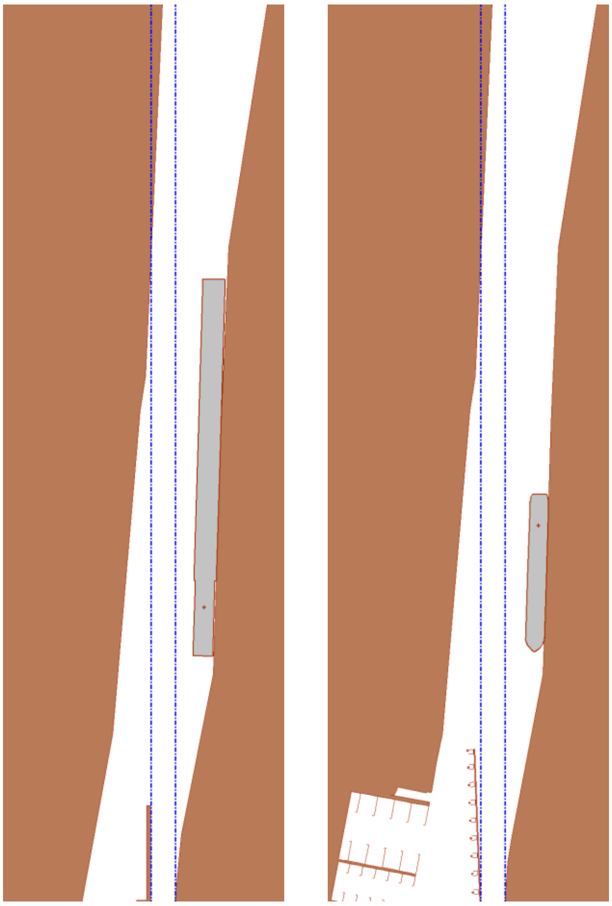

Figure 6: Downstream designs of the project environment submitted by candidate 1. First round (left) and final design (right). Blue parallel lines indicate the extended lock walls.

As a result the left bank intersects the extended left lock wall at 320 m from the lock entrance and the lateral distance between the extended right lock wall and the design vessel moored to the line-up zone was relatively large (8 m). Nevertheless simulating the leaving of the lock revealed the unfavourable position of the line-up zone for vessels with a beam of 11.4 m. The discharge of water from the weir to the fairway is associated with relatively large cross currents at short distance from the lock entrance. This induces a lateral speed of the bow towards the right bank leading to relatively small passing distances to the moored vessel. As candidate one also implemented a second line-up zone downstream the lock (and downstream the bridge 'Hoge Brug') it was concluded that, in those cases where the design vessel (without bow thruster) has to leave the lock, an upstream sailing vessel with a beam larger than 9 m should line-up at the second line-up zone. For the final design simulations were performed with an ECMT class IV inland vessel moored to the line-up zone directly after the funnel and an ECMT class Vb inland vessel moored to the line-up zone downstream the bridge 'Hoge Brug'. Simulations revealed that in this condition the design vessel could leave the lock without any problems.

Although the lock is not aligned with the fairway downstream the lock, the lock approach could be performed satisfactory as the lock was approached with a drift angle with the bow towards the guiding wall. Nevertheless in case of important water flow over the weir, relatively large cross currents at short distance of the lock entrance occur. These currents disturbed the position of the bow shortly before lock entering and led in several simulations to severe collisions between ship and construction.

Although the nautical evaluation of the first downstream design of the holding basin did not suggest the adaptation of the guiding wall, in the final design the guiding wall was extended and given a small angle (2.2°) with the left lock wall. This angle was unfavourable for guiding barges to the lock.

6.2 CANDIDATE TWO

For the design of the guiding or fendering constructions proposed in the first design, the same remarks were made at the upstream and downstream side of the lock. In the final design the left lock wall was supplied with a streamlined wooden guiding construction favourable for guiding barges.

In the downstream holding basin candidate two proposed the line-up zone at the left bank. The position of this line-up zone has the following advantages compared to a line-up zone at the right bank: the water flow from the weir to the fairway induces a lateral speed from the left bank to the right bank from which a vessel moored to the left bank benefits when making way to the lock; for an upstream sailing vessel the left bank corresponds to the starboard side of the fairway.

From Figure 7 it can be noticed that as a result of the adapted orientation of the lock, the lateral distance between the extended right lock wall and the right bank for the first design was very small (5 m) over a long distance (160 m). Also alongside the vessel moored at the line-up zone the available fairway is very narrow. Simulations performed for the first design led to very small passing distances with respect to the right bank for a vessel leaving the lock. The cross current resulting from the water flow moves the vessel towards the right bank. The space available between the extended right lock wall and the right bank is insufficient to compensate the position of the vessel by moving the push boat sideways towards the right bank. As a result the vessel passed the right bank at very small distances. Furthermore the insufficient space to move the push boat towards starboard, prevents the skipper to initiate the bend of Geldof when sailing downstream (bend to port, See Figure 1). In the final design candidate two partly overcame the problems regarding the passing distances with respect to the right bank for the design vessel leaving the lock by increasing the lateral distance between the right bank and the extended right lock wall to 7.2 m directly after the funnel and 8.1 m at a position 235 m from the lock entrance. After this point the fairway widens in order to initiate the bend of Geldof.

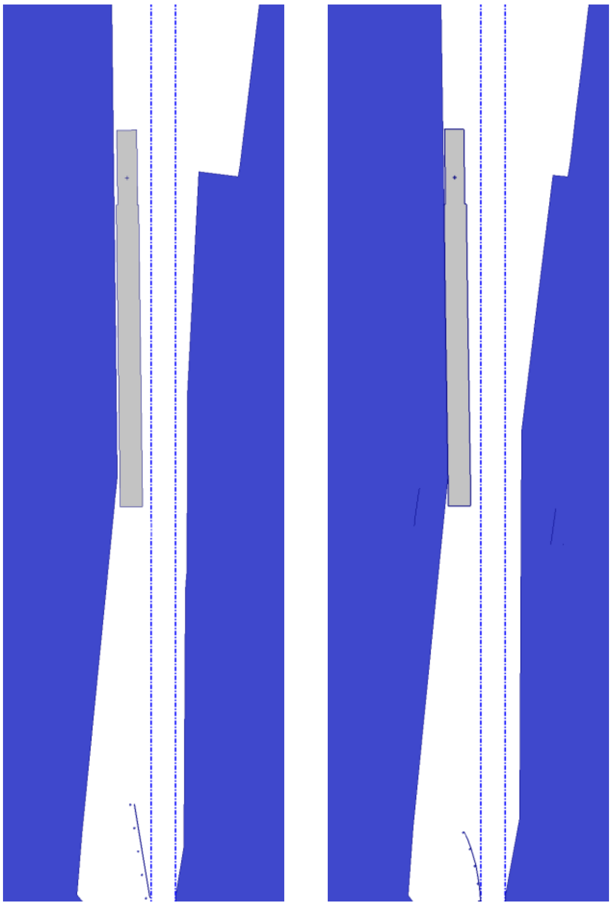

Figure 7: Downstream designs of the project environment submitted by candidate 2. First round (left) and final design (right). Blue parallel lines indicate the extended lock walls.

After simulating the final design it was concluded that the adaptations made to the right bank made it possible to sail through the bend of Geldof. On the other hand the passing distances with respect to the angle in the right bank (235 m from the lock entrance) remained very small in case of important water flow over the weir. It was concluded that potential sliding of the barges along the angle in the right bank does not correspond to a unfavourable situation granted that the right bank is equipped with wooden fendering. The final design was adapted in such a way.
The orientation of the lock designed by candidate two implicates that the lock is aligned with the fairway and that a vessel can approach the lock in a comfortable way. The small distance with respect to the right bank did not lead to unfavourable lock entering. The skippers performing the simulations noticed only a small distortion of the bow due to cross currents in the fairway.

6.3 CANDIDATE THREE

The design of the downstream holding basin of the third candidate is very similar to the design of the upstream holding basin. In the upstream holding basin the water flow held the vessel against the guiding wall. In the downstream situation however the water flow moves the vessel towards the vessel moored at the line up-zone at the right bank (see Figure 8). The lateral distance between the extended right lock wall and the vessel moored to the line-up zone (5.7 m) was insufficient to avoid contact between the design vessel leaving the lock and a 11.4 m wide vessel moored to the line-up zone. In the second round candidate three applied a guiding wall which was a completely closed construction in order to postpone the lateral motion of the bow for a vessel leaving the lock. Real-time simulations revealed that this adaptation did not lead to acceptable manoeuvres. Furthermore the application of a fully closed guiding wall proved to have disadvantages for the hydraulic design of the environment. As a result in the final design the guiding wall was again a partly open construction. In order to allow safe leaving of the lock when another vessel is lined-up in the holding basin, a second line-up zone was added to the environment. This line-up zone is located at the left bank downstream the bridge 'Hoge Brug' and did allow successful passing of the design vessel.
When approaching the lock important cross currents were observed, leading to a distortion of the approach as the cross currents pushed the bow away from the guiding wall. Nevertheless the design of the guiding walls was evaluated positively as it allows to slide in a controlled manner into the lock.

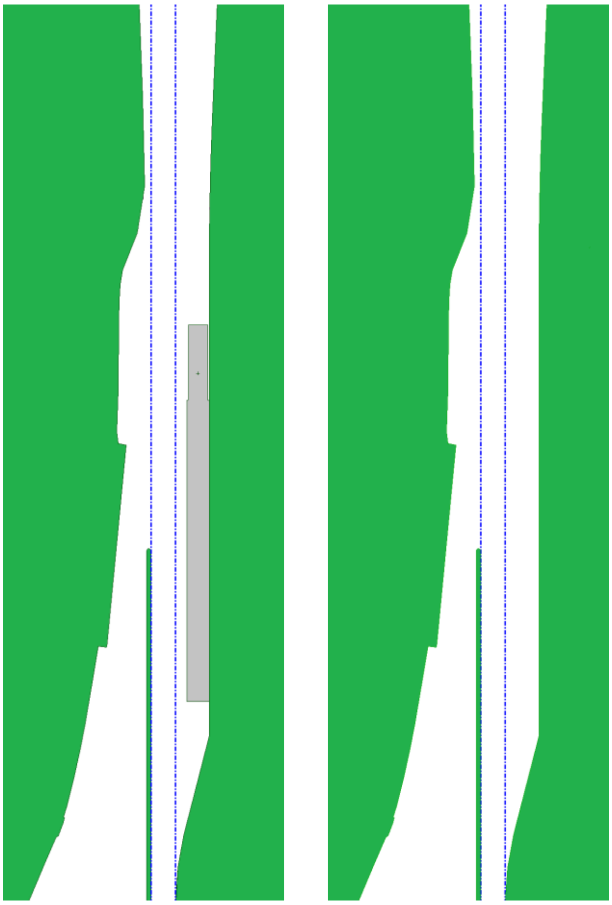

Figure 8: Downstream designs of the project environment submitted by candidate 3. First round (left) and final design (right). Blue parallel lines indicate the extended lock walls.

7. CURRENT PROFILE

More than once the skippers performing the simulations for the different project alternatives, stated the current in the fairway has an important impact on the feasibility of the manoeuvre. Especially the cross current perpendicular to the axis of the lock influenced the approach and leaving manoeuvres unfavourably. In order to compare the cross currents in the fairway for the designs of the three candidates Figure 9 and Figure 10 were generated for upstream and downstream holding basin respectively.
From Figure 9 it can be noticed that for the upstream design of candidate one important cross currents occur near the lock entrance leading to a disturbed lock approach as noticed by the skipper performing the simulations. The upstream cross currents involved with the design of candidate two are smaller and occur at a larger distance from the lock entrance leading to a more controlled lock approach. The design of the third candidate involved a guiding wall which concerned a closed construction for the first 130 m and a half open construction for the final 50 m. The effect of this construction on the cross current in the extension of the left lock wall is clearly illustrated in Figure 9. As the

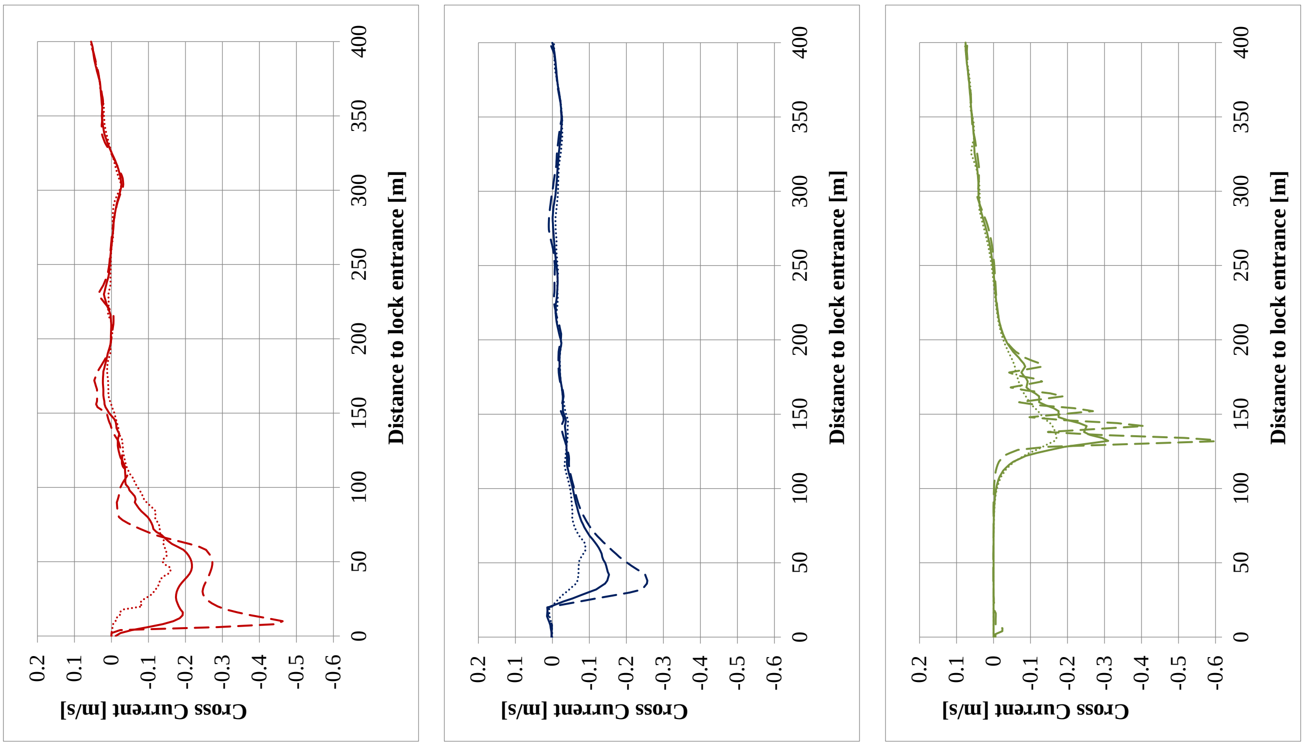

Figure 9: Cross current in the fairway upstream the lock in the extended left lock wall (dashed line) in the axis of the lock (full line) and in the extended right lock wall (dotted line) for the final designs of candidate one (left), two (middle) and three (right)

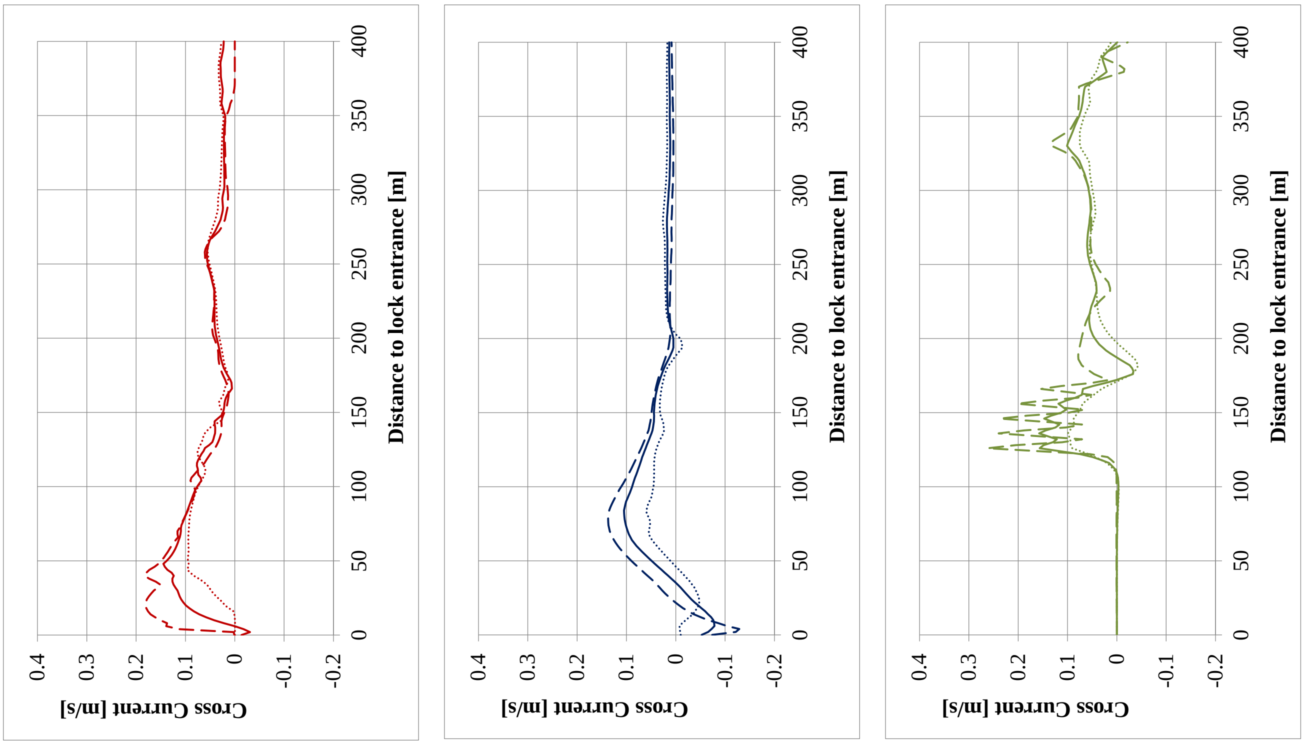

Figure 10: Cross current in the fairway downstream the lock in the extended left lock wall (dashed line) in the axis of the lock (full line) and in the extended right lock wall (dotted line) for the final designs of candidate one (left), two (middle) and three (right)

cross current moves the vessels towards the guiding wall, which is the favourable motion for both leaving and approaching the lock, the cross currents in the upstream design of candidate three are not unfavourable.
From Figure 10 similar conclusions can be drawn. The cross currents are smallest for the design of candidate two, vary gradually and occur at relatively large distance from the lock entrance. For candidate three however, the orientation of the cross currents corresponding to the design of the downstream holding basin are unfavourable for both the approach (with a drift angle towards the guiding wall) and the leaving of the lock.
In general the cross currents in the downstream holding basin are smaller than in the upstream holding basin as the currents in the upstream holding basin are strongly concentrated near the most downstream obstruction between fairway and weir channel.

7. CONCLUSIONS

The paper presents the design of a new lock and weir in the city of Harelbeke as based on waterway guidelines and as submitted by three candidates subscribing to a design and build tender published by the waterway manager Waterwegen en Zeekanaal NV. The design vessel of the lock was an ECMT class Vb inland vessel which concerns a combination of a push boat and two barges with total dimensions 185 m x 11.4 m x 3.5 m. The design vessel was not equipped with a bow thruster.
The nautical quality of the designs submitted was assessed by performing real-time simulations on the simulator LARA at FHR in case of a rather high water discharge over the weir. In the framework of this assessment it was noticed that the cross current in the fairway has an important impact on the nautical quality of the design. The cross current in the fairway corresponding to the final design submitted by the three candidates was studied more in detail and revealed the major differences in cross currents in proximity of the lock entrance which validated the remarks made by skippers during the real-time simulations.
The final designs submitted by candidate two and candidate three were evaluated more positively. The strengths of the design of candidate two are the moderate cross currents in the fairway and the streamlined guiding constructions combined with a lock wall aligned with the fairway upstream and downstream the lock. Furthermore the favourable position of the line-up zones increase the quality of the design. A disadvantage of the design, especially at important water discharge over the weir, concerns the small safety distance with respect to the right bank downstream the lock.
In the final design submitted by candidate three important cross currents in the fairway were noticed. As candidate three applied long guiding constructions which partly evacuated the cross currents at the end and avoided currents close to the lock entrance, the unfavourable effect of these currents on manoeuvring was overcome. The design of the holding basin was evaluated positively for the accessibility of the design vessel to the lock. Two line-up zones were defined in the downstream holding basin in order to allow safe leaving of the lock with a design vessel lined up.
From a nautical point of view the design of candidate three was evaluated best. Taking into account all aspects regarding the D&B tender the evaluation group selected the design of candidate two for implementation.

7. ACKNOWLEDGEMENTS

The Design & Build procedure for Harelbeke was only possible due to the efforts of all 7 candidates submitting a conceptual design. A special "thank you" goes out to the three candidates that submitted a detailed design in the second and third phase of the procedure. Their efforts to attain a multifunctional design for the entire project are highly appreciated by all members of the screening commission.
The authors like to express their appreciation to the inland skippers participating in the simulation study for their valuable contribution to the assessment.

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