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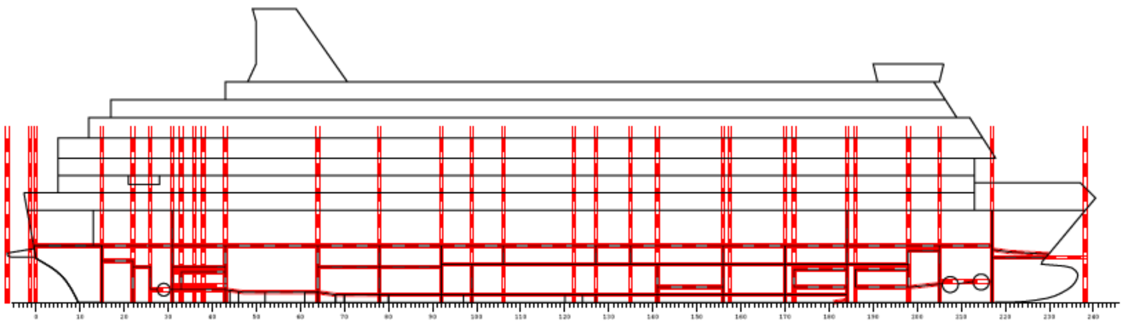

Impact of the ”Stockholm Agreement” on new probabilistic damage stability rules

Master of Science Thesis in the International Master Degree Programme in Naval Architecture

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Summary

The purpose of this thesis is to study the impact of the “Stockholm Agreement” on the new probabilistic damage stability rules used in the revised SOLAS Ch. II-1. This is done by studying attained indices and damage cases for 8 different ro-ro passenger ships.

Some of the ships were calculated for the design before and after the ships were rebuilt to fulfil the Stockholm agreement. The changes in attained indices were studied as well as specific damage cases that contributed to the change of the attained index. Some models were not appropriate to calculate before the vessels were rebuilt. In this case only the designs used today, when the ships fulfil the Stockholm Agreement, were calculated and their attained indices were analysed.

The probabilistic damage stability according to the revised SOLAS Ch. II-1 was calculated using the computer software NAPA Release 2005.2-6 and actual stability data, such as loading conditions, were taken from the Swedish Maritime Administrations archive.

The result shows that the attained indices, calculated in this work, increases significant when the ships are rebuilt to comply with the Stockholm agreement. Another notable result is that low attained indices are obtained for larger ro-ro passenger vessels.

One of the main conclusions is that the “Stockholm Agreement” might not longer be needed when a ro-ro passenger ships are calculated and approved according to the revised SOLAS Ch. II-1. The author’s opinion is that the Stockholm Agreement not longer is needed when ships are designed according to the revised SOLAS.

Preface

This Master Thesis report is written as a part of the Master's degree of the Naval Architectural education at Chalmers University of Technology, and has been carried out during the autumn of 2005 on commission of the Swedish Maritime Administration.

I want to thank Mikael Huss and Bruno von Sicard at the Swedish Maritime Administrations for giving an interesting thesis subject and for all valuable help and advices during the project.

I would also like to thank Martin Schreuder and the examiner Professor Olle Rutgersson at the department of Shipping and Marine Technology at Chalmers University of Technology for their encouragement and helpful assistance. Especially I want to thank Professor Anders Ulfvarson at the department of Shipping and Marine Technology for all help in the initial stage of the Thesis work.

Gothenburg in December 2005

Andreas Hildingsson

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1 Introduction

1.1 Background

This report is written as a master thesis work in the Naval Architecture education at Chalmers University of Technology, Gothenburg, in cooperation with and for the Swedish Maritime Administration. The background to the study is the revised text of SOLAS Chapter II-1, using the probabilistic damage stability approach, as adopted at MSC 80 and the impact of the Stockholm Agreement when calculating the attained index according to the new probabilistic approach.

1.2 Purpose

The purpose of the thesis work is to investigate how some of the existing ro-ro passenger vessels under Swedish flag, rebuilt to fulfil the Stockholm agreement, comply with the new revised text of SOLAS Chapter II-1, handling probabilistic damage calculation. The report also discusses possible impacts of the Stockholm agreement when calculating the damage stability according to the new probabilistic approach. The main purpose is to investigate if the increased safety with the Stockholm Agreement affects the results using the revised SOLAS Ch. II-1 and if water on an open ro-ro deck is taken into account in the new probabilistic rules.

1.3 Methods

To investigate the ro-ro passenger ships damage stability and the impact of the Stockholm Agreement when using the new probabilistic damage stability rules, the ships are calculated according to the revised text of SOLAS Chapter II-1, before and after they were rebuilt to comply with the rules of the Stockholm Agreement. Some calculations are only made of the existing vessel arrangement because the ships fulfil the Stockholm Agreement without rebuilding. Some ships have, at the same time as when rebuilt to fulfil the SA, changed their arrangement for other purposes. No comparison of the Stockholm Agreement impact can be made on these models, but they are interesting when studying the overall effect of the revised SOLAS for ro-pax vessels. The calculations are done by the computer software NAPA Release 2005.1, which has implemented the revised SOLAS Ch. II-1 into the software release. Archive material from the Swedish Maritime Administration has been used to get stability documentation and to find information about how the ships are rebuilt to fulfil SA. An attained index is calculated before and after the Stockholm Agreement. The results are investigated to get some knowledge how the Stockholm Agreement improves the safety of the ship, calculated according to the revised SOLAS Ch. II-1.

1.4 Limitations

The report does not discuss the adaptiveness of the existing regulations, but the effect of the regulations are discussed and taken into consideration. The investigated ro-ro passenger vessels are limited to eight vessels, which all of them flies' Swedish flag and are in some extent rebuilt to comply with the Stockholm Agreement. All calculations have been carried out according to the revised SOLAS, but no consideration has been taken to immersion of vertical escape hatch in the bulkhead deck. This assumption might decrease the attained indices, but not significantly.

2 Relevant regulations

This chapter gives a brief introduction to the legislation and regulations used in this report. The two main set of rules used are SjöFS 1997:2 and the revised text of SOLAS Chapter II-1, adopted during MCS80. SjöFS 1997:2 is the Swedish regulation usually referred to as "the Stockholm Agreement". For the revised text of SOLAS IMO document MSC 80/24/Add.1, Annex I "Resolution MSC.194(80) – Adoption of Amendments to the International Convention for the Safety of Life at Sea, 1974, as amended" is used.

2.1 The Stockholm Agreement

To increase the safety of passenger vessels eight European states agreed, 1996, to set higher stability requirements than stated in the SOLAS convention. This added requirement takes into account an amount of water accumulated on e.g. a ro-ro deck in case of an accident. The states agreed were Sweden, Denmark, Finland, Germany, Ireland, United Kingdom, the Netherlands and Norway. For more information of this agreement see Resolution 14 of the 1995 SOLAS Conference.

The ships subjected to this agreement are ro-ro passenger ships operating from and to designated ports on scheduled international voyages carrying passenger in North-Western Europe and in the Baltic Sea. To establish specified height of accumulated water on deck a significant wave height is considered. The significant wave height is set by the operational waters. These regulations apply to all ro-ro passenger ships irrespective of flag. The Stockholm Agreement is in this report also known as SA.

2.1.1 Directive from European Parliament and Council

In a directive from the European Parliament and Council the Stockholm Agreement stability requirements has been extended to include all ro-ro passenger vessels, independent of flag state, in traffic operating to and from designated ports on international voyages in the European Union. With this directive the Stockholm Agreement is applied through Europe to ensure a common minimum level of safety for ro-ro passenger vessels in the European Union. New ro-ro passenger vessels are today required to fulfil the rules. Existing ro-ro passenger vessels must fulfil the rules during a period of transition.

2.1.2 Rebuilding to fulfil the Stockholm Agreement

There are two different ways to fulfil the Stockholm Agreement. One is to show that the ship fulfils the requirements using model testing. The model should be a copy of the actual ship for both internal arrangement and outer configuration and fulfil some requirements given in the regulations.

The second way is to comply with the regulations by calculating the stability related to the SA and the height of accumulated water on the ro-ro deck.

To comply with the SA most of the existing ships have to be rebuilt in some way. One way is to reduce the amount of accumulated water on the ro-ro deck by installing one or several movable transverse bulkheads somewhere on the ro-ro deck or in another way reduce the possible deck area flooded with water. Another way to rebuild an existing vessel to fulfil the requirements is to add sponsons to the hull, to be able to keep a sufficient stability with the specified height accumulated water on the ro-ro deck. Some vessels have also made rooms adjacent to car deck watertight by changing door constructions. Some specific vessels have also been approved by having a possibility to counter fill one or several tanks in special damage cases.

2.2 The revised text of SOLAS Ch. II-1 adopted at MSC80

The revised text of SOLAS Chapter II-1 uses the probabilistic approach of calculating the damage stability and this is a large change in the way to calculate damage stability. Previous probabilistic damage stability was applicable for cargo ships and some probabilistic calculations were also possible to apply on passenger vessels, but not in the same extent as for the cargo vessels. With the revised SOLAS Ch. II-1 probabilistic damage stability is supposed to be calculated using the probabilistic approach for all cargo ships of 80 m in length and upwards and all passenger vessels regardless of length. Ships already approved according to existing probabilistic rules are excluded.

To understand this Master Thesis Work and the analysis in the report some basic knowledge of the new damage stability rules are needed. This chapter gives a brief introduction to the variables and constants needed to analyse how the ways to rebuild ships, to fulfil the SA, are changing the results in the probabilistic damage calculations. For a deeper study of the new legislation and the design of the rules see IMO document MSC 80/24/Add.1, Annex I.

2.2.1 The Required index

The new rule is based on a Required Index, R, which is a ship specific constant depending only on the Subdivision Length, L_s, number of persons for whom lifeboats are provided (N_1), and the number of persons the ship is permitted to carry in excess of N_1, (N_2). For passenger ships the required index is defined as follows:

$$R = 1 - \frac{5000}{L_S + 2.5N + 15225} \qquad N = N_1 + 2N_2$$

2.2.2 The Attained index

An Attained Index, A, is calculated for the ship and this index must exceed or be equal to the required index. The Attained Index is obtained by the summation of the partial indices A_s, A_p and A_l. The attained index, A, is defined in the following way:

$$A = 0.4A_s + 0.4A_p + 0.2A_l$$

A_s, A_p and A_l are the indices calculated for deepest subdivision draught (d_s), partial subdivision draught (d_p) and light service draught (d_l). These draughts are further described in the regulations. Briefly the three initial conditions are defined by draught, metacentric height and trim. Basically you continue the calculation of the attained index, under consideration of specific damages, until the attained index reaches the required index.

Each partial index is a summation from all damage cases taken in consideration, using following formula:

$A = \Sigma(p_i \cdot s_i)$, where

i = compartment or group of compartments under consideration

p_i = the probability that only the compartment or group of compartments under consideration may be flooded.

s_i = the probability of survival after flooding the compartment or group of compartments under consideration

2.2.3 The factor p

The vessel is subdivided into different zones (see Appendix B for subdivisions for ships used in this report) and from the subdivision p-factors for different damage cases are generated. The vessel is subdivided into longitudinal, horizontal and vertical zones limited by watertight bulkheads and decks.

2.2.4 The factor s

As previously described the factor s_i, referred to as the survivability index, is the probability to survive the specific damage, p_i. This factor is obtained by the following formula:

$s_i = \text{minimum } \{s_{intermediate,i} \text{ or } s_{final,i} \cdot s_{mom,i}\}$

"$s_{intermediate,i}$" is the probability to survive all intermediate flooding stages until final equilibrium and is defined as:

$$s_{intermediate,i} = \left[\frac{GZ_{\max}}{0.05} \cdot \frac{Range}{7}\right]^{\frac{1}{4}}$$

GZmax and Range are not to be taken as more than 0.05 m respective 7°

"$s_{final,i}$" is the probability to survive the final stage of flooding and this factor is defined as:

$$s_{final,i} = K \cdot \left[\frac{GZ_{\max}}{0.12} \cdot \frac{Range}{16}\right]^{\frac{1}{4}}$$

GZ_{max} and Range are not to be taken as more than 0.12 m respective 16°

"$s_{mom,i}$" is the probability to survive external heeling moments and this is obtained as follows:

$$s_{mom,i} = \frac{(GZ_{\max} - 0.04) \cdot Displacement}{M_{heel}}$$

s_{mom} and $s_{intermediate}$ is only applicable to passenger ships and this makes in the case of a cargo ship the factor s_i equals $s_{final,i}$. This report analyse ro-ro passenger vessels and the factors s_{mom} and $s_{intermediate}$ will in this case be taken into account.

2.2.5 External moments

The maximum assumed heeling moment, M_{heel}, used in the factor $s_{mom,i}$ is defined in the following way:

M_{heel} = maximum $\{M_{passenger}; M_{wind}; M_{SurvivalCraft}\}$

$M_{passenger}$ is the maximum assumed heeling moment resulting from movement of passengers and M_{wind} is the maximum assumed wind force acting in a damaged situation. $M_{SurvivalCraft}$ is the maximum assumed heeling moment due to the launching of all fully loaded davit-launched survival craft on one side of the ship. Usually the largest moment is the passenger moment or the wind moment.

2.2.6 The factor v_m

A reduction factor v_m is used when horizontal watertight boundaries are fitted above the waterline under consideration. The s value calculated for the lower compartment or group of compartments shall be obtained by multiplying the determined factor s (see Ch 2.2.4 above) with the reduction factor v_m. Detailed definitions can be found in MSC 80/24/Add.1, Annex I, revised SOLAS Ch. II-1 Reg. 7-1.

2.2.7 The "Index contribution"

The analyses of the results presented in this report use the expression "index contribution". The index contribution is in this report defined as the contribution a damage case with a specified initial condition and certain damage gives to the attained index, A. E.g. a damage case with a group of consideration, j, and the deepest subdivision as the initial condition gives the index contribution: $0.4 \cdot p_j \cdot v_j \cdot s_j$

3 Calculated index for existing ro-ro passenger vessels

Calculations have been made on existing ro-ro passenger vessels which fulfils the Stockholm Agreement. Some of the vessels have also been calculated with the arrangement before the ship was rebuilt to fulfil the Stockholm agreement. These ships are analysed more in detail in Chapter 4. Calculated indices are shown in table 3.1 below.

Ro-ro passenger ship	R	A After rebuilt	A Before rebuilt	Approx. Ship Length [m]
A	0,69	0,83	0,79	160
B	0,81	0,74	0,62	180
C	0,74	0,85	0,70	100
D (one-comp.)	0,69	0,65	N/A	140
D (two-comp.)	0,73	0,86	N/A	140
E	0,69	0,68	N/A	150
F	0,74	0,70	N/A	190
G	0,79	0,58	N/A	170
H	0,82	0,69	N/A	190

Table 3.1: Indices calculated according to the revised SOLAS Ch. II-1

The results show that redesigns to fulfil the Stockholm Agreement also affect the attained index calculated according to the revised SOLAS Ch II-1. This is shown in the calculations carried out for vessel A-C. The effects of the rebuilding are described in Chapter 4.

Another interesting result is that six of nine studied vessels do not reach their required index as they are designed today. These ships are not considered unsafe in any way, but this result is interesting when studying the behaviour of the new probabilistic stability rules in the revised SOLAS.

The probabilistic damage stability calculations have been carried out in accordance with the document "Development of Explanatory Notes for Harmonized SOLAS Chapter II-1", IMO document number SLF 47/4. At the time of this master thesis work and writing of the report the Explanatory Notes are still under development and in some cases assumptions has been made during the calculation process. The applied assumptions are presented for the specific ships in Chapter 4. These do not, however, influence the comparison between the different arrangements to any large extent.

Because of the accuracy of the subdivisions and the use of quite many zones, the attained indices are calculated for up to 7-zone damages and this gives tolerances for the attained index of about 0.005. All attained indices presented in the calculations are calculated for the port side of the ship and might differ due to asymmetry when calculating the starboard side of the ship. The revised SOLAS defines the attained index as the mean value obtained from calculations involving both sides. Alternatively, it should be taken as that corresponding to the side which gives the least favourable result. The studied ships have no significant unsymmetrical arrangements, but the attained indices can still differ when calculating it for both sides.

As described before no consideration has been taken to immersion of vertical escape hatches and its result to decrease the attained indices. The studied damage cases in this report show that very few damage cases, with immersed bulkhead deck, at equilibrium, contribute to the attained index. On this basis the influence of immersed escape hatches is assumed to be insignificant.

As initial loading conditions drafts according to definitions in revised SOLAS are used. Due to small trim variation ($t = \pm 0.5$ % of L_{pp}) the trim for deepest subdivision draft and partial draft is set to construction trim and for lightest service draft the actual trim is used, all in compliance with the explanatory notes. To get a more exact comparison of the indices using the probabilistic approach and the damage stability calculations used today, the GM- or KG- limit curves for today's deterministic damage stability has been used to set the GM values for the initial cases. Note that it is possible to increase the index by increasing the GM values for the three initial conditions but this will result in increasing values of the GM-limit curve calculated using the probabilistic approach.

Please note that all ships calculated in this report are approved according to existing regulations and are thus, as said before, not considered unsafe in any way. The purpose of the work is to evaluate the effect of the new probabilistic damage stability rules and not the safety of existing ships. The attained indices may not be exact. The probabilistic stability opens up for free choice of subdivision detail as long as the ship complies with the required index. The definitions of subdivisions in this report are however, quite refined and the intention of the calculations was to reach as high attained index as possible under the given circumstances.

Ro-ro passenger vessel G fulfils the Stockholm Agreement by the possibility of counter filling some tanks for specific damages. This is not taken into consideration when calculating the attained index using the revised SOLAS.

An interesting result, not specifically in the scope of this report, is the calculations carried out for vessel D (see table 3.1). The results show attained indices calculated for the same vessel acting and approved as a one – and two-compartment ship. This example shows that the attained index is in a high degree affected by the initial conditions, mainly the deepest subdivision draught, as well as the certified amount of passenger. The passengers are in this case affecting the maximum heeling moment and the required subdivision index, R. But the change in attained index, between one- and two- compartment condition, is mainly due to the increased freeboard in the one-compartment condition. The increased freeboard increases the attained index and the increased amount of passengers decreases the index. In this case the increase of passengers is negligible and, as said before, the increased freeboard is in this case the contributing factor to the increased index.

The results in table 3.1 are discussed further on in Chapter 5: Conclusion and recommendations.

4 Study of existing rebuilt ro-ro passenger ships

This chapter investigates the effects of ways to rebuild the ships to fulfil the Stockholm agreement and the effect of the rebuilding when calculating damage stability in the probabilistic way according to the revised SOLAS Chapter II-1.

The different ships are calculated in the way they are arranged today, with the additional measures applied to fulfil the SA, and calculated again with the design used before they where rebuilt to comply with the Stockholm Agreement. Some of the vessels are also calculated when only some parts of the rebuilding are done. This is carried out to get an experience of how different ways to rebuild the vessels changes the attained indices using the revised SOLAS.

The analysis of different damage cases and in what way they changes the attained index are mainly made on 2- or 3-zone damages. The reason for this choice is that the change of the attained index when rebuilding a ship, to fulfil the SA, is mainly noticed among the 2- and 3-zone damages. This is described further on in this chapter.

Probabilistic indices used in tables are described in Chapter 2. The value ResMrg is the resulting distance from the waterline to the margin line used in today's deterministic calculations. The margin line is not used in the probabilistic calculations, but are still presented in this thesis report to get some feeling about the freeboard and to show that damage cases with immersed margin line contributes to the attained index, when using the revised SOLAS.

Main particulars and initial conditions used for the different ships and calculations can be found in Appendix A, as well as the calculation results.

4.1 Ro-ro passenger ship B

This is a vessel operating in the Baltic Sea. The vessel fulfils the Stockholm agreement by model tests with the significant wave height of 3.8 m. The damage stability is in accordance with a two-compartment ship.

4.1.1 Main particulars for calculations

L_{pp}	184.158 m
B_M	29 m
Depth to car deck	9.10m
Draught mld max two comp.	6.74 m
Passengers acc. to cert.	2560
Lifeboat places	920

This vessel was rebuilt to fulfil the Stockholm Agreement by adding two transverse car deck bulkheads to limit the space for possible accumulated water on deck in case of a damaged ro-ro deck. One bulkhead is located at #81 and another at #151. This construction split the previous open car deck into four parts with the centre casing in the middle. In addition to this modification, stores and spaces along the car deck were made watertight by changing doors and gaskets. These rooms are located in the aft and forward part of the ship. Changes in the watertight subdivision were only made on deck 3 which corresponds to the ro-ro space and no modifications of the hull were needed to comply with the Stockholm agreement. The change in arrangement can be seen figure 4.1 or in the definition of subdivisions, before and after rebuilt, in Appendix B: Ro-ro passenger vessel B.

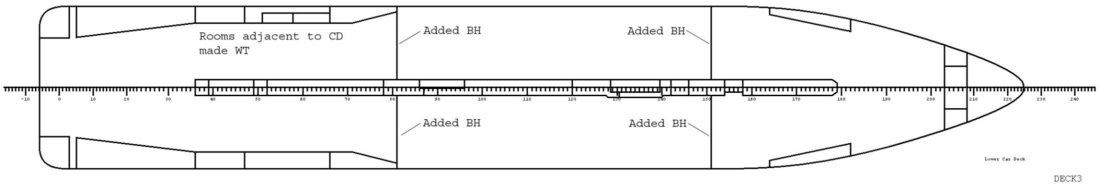

Figure 4.1: Changes in the arrangement, ship B, Deck 3

4.1.2 Results

Probabilistic calculations were carried out before and after the new bulkheads were added and doors to rooms, adjacent to the car deck, were made watertight. The different results were analysed and are presented below.

The way to rebuild this vessel increased the attained index by a value of 0.119 and this correspond to an increase of the attained index by 19.0 %

In these calculations, as well as among the other ships calculated in this report, the largest increase of the attained index can be noticed among the 2- and 3-zone damages which together contributes with over 80 % of the increase of the attained index, A. In this case the deepest subdivision draught, as the initial condition, stands for the largest index increase among the three initial conditions. From this point of view especially 2-zone damages with deepest subdivision draught are studied more thorough in order to see the effect of the way to rebuild the ship and how it affects the attained index contributions for different damage cases.

A study of all the damage cases with deepest subdivision as the initial condition and with 2-zone damages, after the ship was rebuilt, results in 115 cases with damaged ro-ro deck contribute to the attained index. Of these damages 90 cases have increasing their index contribution when the vessel was rebuilt and 29 cases are new damages which are contributing to index. These new damage cases gave zero contribution to the attained index before the ship was rebuilt.

4.1.3 Analysis

To get some understanding of how the way to rebuild this ship affects the features of the new probabilistic rules in the revised SOLAS some special damage cases and their contribution to the attained index were studied. The results shows, as expected, that the main reason of the increased index is due to the added bulkheads, but also making rooms adjacent to car deck watertight did increase the attained index, but not as much as the added bulkheads.

4.1.3.1 Damage case with influence of the new bulkheads

A damage in the forward part of the ship which increased the index contribution after rebuilt is damage case DL/SDSP19-20.0.3. This case consists of damages in zones 19 to 20. For detailed description of damage, floating positions and stability curves see Appendix C, damage case DL/SDSP19-20.0.3. The ro-ro deck is damaged and the vessel has a floating position seen in table 4.1. The ship is trimmed by the bow, without heel and has a freeboard in final equilibrium of 0.54 m. Also in this case one can see the effect of dividing the open ro-ro deck with transverse bulkheads when using the probabilistic approach. Indices and data, taken form the GZ curves, are presented in table 4.2 below. GZ-curves before and after rebuilt are presented in figure 4.2 respective 4.3. The opening named A151P in figure 4.3 corresponds to the upper part of the added transverse car deck bulkheads at frame 151. Other openings are ventilation openings.

DL/SDSP19-20.0.3	T_M [m]	t [m]	heel [°]	ResMrg
Before rebuilt	7,346	2,502	0	0,54
After rebuilt	7,346	2,502	0	0,54

Table 4.1: DL/SDSP19-20.0.3, floating position in damaged case

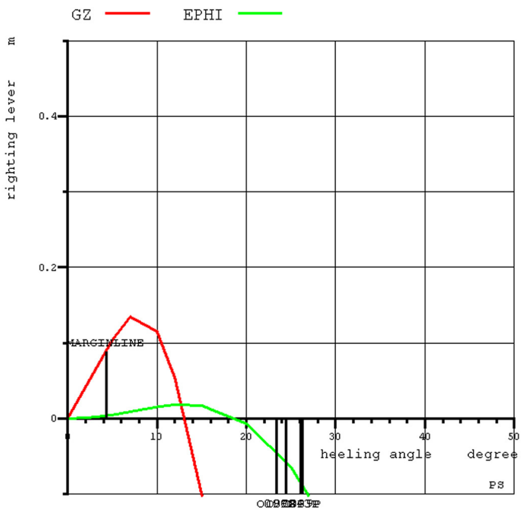

Figure 4.2: DL/SDSP19-20.0.3, GZ-curve before rebuilt

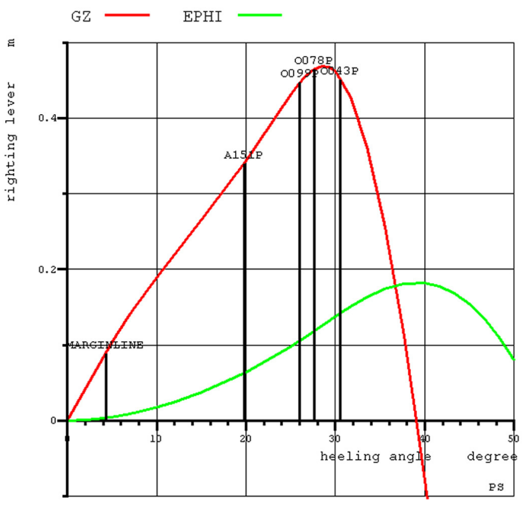

Figure 4.3: DL/SDSp19-20.0.3, GZ-curve after rebuilt

DL/SDSP19-20.0.3	s	p	v	GZ_{max}	RangeF	K_{fac}	s_{final}	s_{mom}	index contr.
Before rebuilt	0,95	0,02	0,56	0,13	13,0	1,00	0,95	1,00	0,00441
After rebuilt	1,00	0,02	0,56	0,47	19,8	1,00	1,00	1,00	0,00464

Table 4.2: DL/SDSP19-20.0.3, calculation data

The calculations show an increase of the attained index contribution, for this specific damage case, from 0.00441 to 0.00464. This increase might not be a large part of the over all increase of the attained index. But many damage cases increases their index contribution in this way, when adding the transverse car deck bulkheads.

The result when studying the GZ curves is a significant increase of both GZ_{max} and the stability range. This damage case has a satisfactory GZ_{max} even before rebuilt because GZ_{max} is not to be taken as more than 0.12 when calculating the survivability factor. It is the increase of the stability range from 13.0 to 19.8 makes the increase of the attained index contribution. When this vessel is rebuilt both GZ_{max} and stability range are higher than the maximum value to be used in the probabilistic calculations. This results in the survivability factor 1 after rebuilt. The external moment will have no influence in this damage case because of the relative high GZ_{max} in both cases and there are no influences of the intermediate stages or large heeling angles. The reason for the increased index in this case is mainly due to the added bulkheads on car deck. This will reduce the amount of accumulated and flooded water, on the open ro-ro deck.

4.1.3.2 Damage case with influence of making doors watertight

A typical case when the attained index contribution is changed by making rooms adjacent to car deck watertight is damage case DL/SDSP3-4.1.4. In this damage case the damage is including zone 3-4 and the transverse extension is limited by the longitudinal bulkhead between the room adjacent car deck and the car deck (for damage definition see appendix C). Before the ship was rebuilt this particular damage constituted a possible risk of flooding the car deck through the unprotected door connecting the room to the car deck. When making this door watertight you prevent the case of accumulated water on car deck. In the probabilistic damage calculations this will of course influence the GZ curve in damaged condition.

This damage generates a floating position in equilibrium presented in the table below. The floating positions are identical before and after the vessel was rebuilt and doors made watertight. As shown in table 4.3 the ship is trimmed by the stern and with a list of 6.0° to port side. The distance to the previous used margin line is about 0.26 m.

By making the door watertight and prevent the possibility of accumulated water on the car deck the GZ curve changes significant. GZ-cuves , before and after rebuilt can be seen below. Current indices and data taken from the GZ-curve are presented in table 4.4 below. Openings presented in the GZ-curves corresponds to ventilation openings.

DL/SDSP3-4.1.4	T_M [m]	t [m]	heel [°]	ResMrg
Before rebuilt	6,805	-0,800	6,0	0,26
After rebuilt	6,805	-0,800	6,0	0,26

Table 4.3: DL/SDSP3-4.1.4, floating position in damaged case

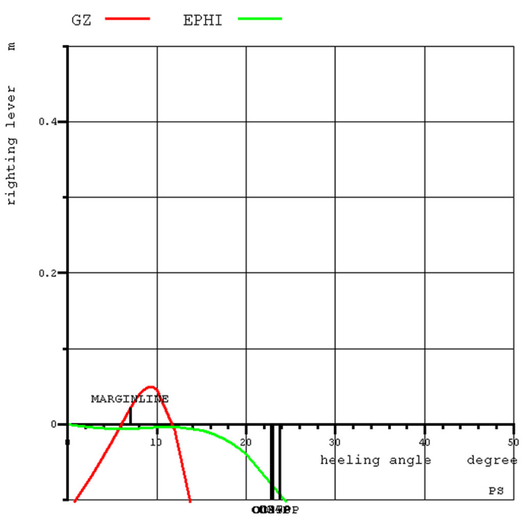

Figure 4.4: DL/SDSP3-4.1.4, GZ-curve before rebuilt

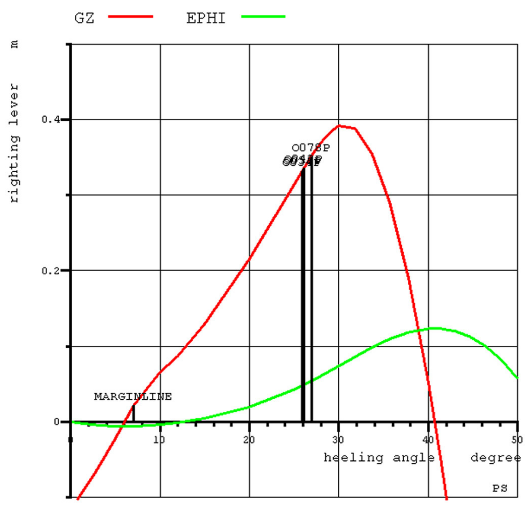

Figure 4.5: DL/SDSP3-4.1.4, GZ-curve after rebuilt

DL/SDSP3-4.1.4	s	p	v	GZ_{max}	RangeF	K_{fac}	s_{final}	s_{mom}	index contr.
Before rebuilt	0,08	0,00046	0,56	0,05	5,6	1,00	0,62	0,14	0,00001
After rebuilt	1,00	0,00046	0,56	0,39	19,8	1,00	1,00	1,00	0,00010

Table 4.4: DL/SDSP3-4.1.4, calculation data

The result shows a large increase of both the stability range and the maximum GZ value. The maximum GZ value before rebuilt is actually so low that also the external moment will affect the survivability factor by reducing the factor s_{mom} (see Chapter 2 in this report for definition). This reduction of the survivability factor is not present after rebuilding the ship, due to the increased GZ $_{max}$. There are no effects of intermediate stages in this damage case. This damage case is an example of a very large increase of the survivability factor when rebuilding the vessel, but the probability of this damage, with a small transverse extension, to occur is very low. Because of the low factor, p, for this type of damage cases the contribution to the attained index is less significant. But still you have a contribution of those damages and the change of the attained index, by this type of damage cases, expressed as a percentage is quite large.

4.1.3.3 New damage case contributing to the index

The last example for this vessel of how the Stockholm Agreement comes to effect in the revised SOLAS is damage case DL/ SDSP13-14.2.3-1. In this case as in all other cases studies for this vessel, the deepest subdivision draught is the used as the initial condition. The damage includes zones 13 and 14 and the ro-ro deck is damaged. Because of no changes of the arrangement under car deck and no changes of the hull were made when rebuilding the ship, the floating position for this damage is identical before and after the ship was rebuilt. The floating positions can be seen in table 4.5.

Before the ship was rebuilt, this damage case involved the whole car deck. By adding the two transverse bulkheads on the car deck the damaged car deck open for possible flooding is limited to an area between the two new bulkheads and the centre casing. This construction will affect the stability GZ curve in the damaged floating position and make this damage case contributing to the attained index after rebuilt. Some results can be seen in table 4.6. GZ-curves before and after rebuilt are presented in figure 4.6 and 4.7. Opening A151P in figure 4.7 corresponds to the upper part of the added car deck bulkhead at frame 151.

DL/SDSP13-14.2.3-1	T_M [m]	t [m]	heel [°]	ResMrg [m]
Before rebuilt	7,424	1,255	3,7	0,39
After rebuilt	7,424	1,255	3,7	0,39

Table 4.5: DL/SDSP13-14.2.3-1, floating position in damaged case

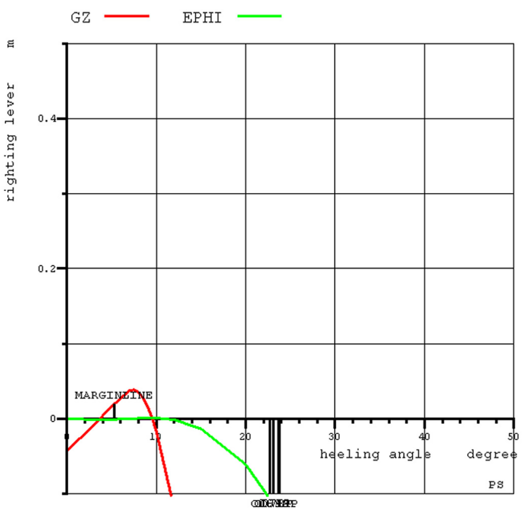

Figure 4.6: DL/SDSP13-14.2.3-1, GZ-curve before rebuilt

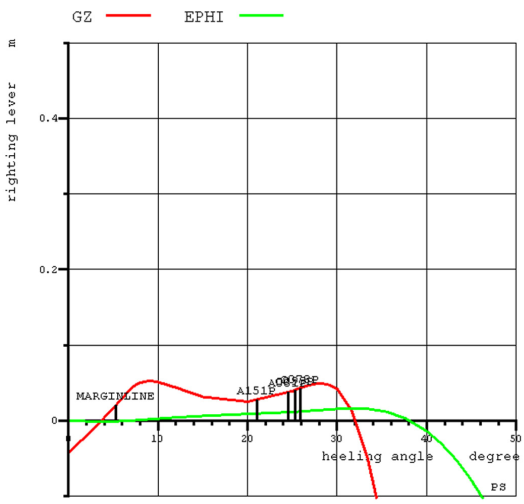

Figure 4.7: DL/SDSP13-14.2.3-1, GZ-curve after rebuilt

DL/SDSP13-14.2.3-1	s	p	v	GZ_{max}	RangeF	K_{fac}	s_{final}	s_{mom}	index contr.
Before rebuilt	0,00	0,01	0,56	0,04	5,8	1,00	0,59	0,00	0,00000
After rebuilt	0,14	0,01	0,56	0,05	17,4	1,00	0,80	0,14	0,00025

Table 4.6: DL/SDSP13-14.2.3-1, calculation data

The large open ro-ro space in the case before rebuilt gives a GZ_{max} of 0.04. In the probabilistic rules a GZ_{max} of 0.04 or less sets the factor s_{mom} to zero and the survivability factor in this case becomes zero. When adding the two transverse bulkheads the stability range and the GZ_{max} increases. The change of GZ_{max} increases s_{mom} and s_{final} and the extended stability range contributes to an increased s_{final}. All together the added bulkheads give a new damage case contributing to the attained index, thus $s = s_{final} \cdot s_{mom}$. Even in this case the intermediate stages are not affecting the survivability factor, s.

4.1.4 Conclusion

Calculations for this vessel show a significant increase of the attained index by adding transverse bulkheads on the car deck. It is mainly those bulkheads which are related to the increase of the attained index, but the stores which were made watertight also affect the index, but not to the same extent as the transverse bulkheads. The bulkheads will have an effect in almost all damage cases involving a damaged ro-ro deck, independent of vertical damage extension. The effect of making unprotected doors watertight influences almost only damages with a limited vertical extension, only damaging the rooms adjacent to the car deck and this type of damage cases have a very low factor, p. By making the rooms adjacent to the car deck, watertight, you also prevent accumulated water flooded form car deck and to the adjacent rooms. In this point of view you decrease the surface area of potential water at the car deck level, but this feature has an insignificant affect of the attained index compared to the added transverse car deck bulkheads.

4.2 Ro-ro passenger ship A

During the calculations this vessel was operating in the Baltic Sea and was approved as a one compartment ship. The vessel complies with the Stockholm Agreement with a significant wave height of 1.9 m and the ship is approved according to calculations and not by model testing.

4.2.1 Main particulars for calculations

L_{pp}	148.4 m
BM	21.6 m
Depth to upper car deck	13.5 m
Depth mld to train deck	7.7 m
Draught mld max one comp.	5.72 m
Passengers acc. to cert.	400
Lifeboatplaces	376

To fulfil the Stockholm Agreement the ship was rebuilt by adding a stern sponson and four rooms adjacent to the car deck were made watertight. Two of these rooms are located in the aft part of the car deck and two located in the forward part. Because of lack of old stability data from before rebuilt the same initial conditions are used before and after rebuilt. The added sponsons are located above the waterline for deepest subdivision in static equilibrium and there are assumed to be no changes of the displacement in the initial conditions before and after rebuilt. Note the fact that the centre of gravity has been changed in reality. This assumption might not influence the results and comparisons in any large extent, but this is not however accounted for. The change in arrangement can be seen in figure 4.8 below or in the definition of subdivisions, before and after rebuilt, in Appendix B: Ro-ro passenger vessel A.

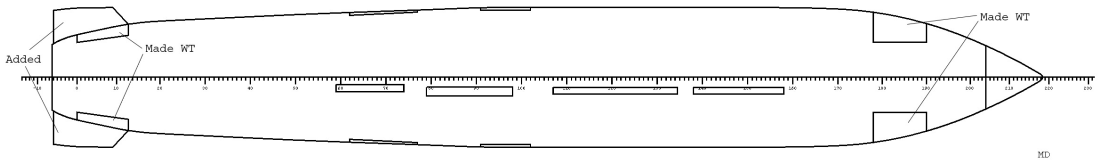

Figure 4.8: Changes in the arrangement, ship A, Deck 3

4.2.2 Results

Calculations before and after vessel A was rebuilt were made and the effect of rebuilding the ship was analysed. Following results was achieved:

This way to rebuild the ship with sponsons and watertight doors results in an increase of the attained index by 6.81 %.

To get an understanding how the rebuilding of the doors adjacent to car deck from unprotected to watertight changes the attained index calculations were done in the case of only rebuilt the ship by watertight doors and no added sponsons. The result shows an increase of the attained index by 1.47 %.

Just like all previous calculations the largest increases of the index is achieved among the 2-zone damages and the deepest subdivision as the initial condition. From this observation damage cases with deepest subdivision and 2-zone damages are studied in detail.

A study of these cases after the ship is was rebuilt results in 25 damage cases with damages including the open ro-ro deck. 10 of these cases have an increased index contribution and 7 of the damage cases consist of completely new cases, not contributing to the index before the vessel was rebuilt.

4.2.3 Analysis

It's obvious that the rebuilding made to comply with the Stockholm Agreement changes the attained index for this specific ship. The results show that the increase of index is mainly due to the added sponsons and the watertight rooms adjacent to the ro-ro deck do not changes the index significantly. The aft sponsons affect the GZ-curve and change the stability range for many cases, but the main part of the change consist of new more favourable floating position in equilibrium after the damage. The sponsons reduce the trim for damage cases trimmed by the stern and for cases with large heeling angles the heel is reduced by adding sponsons. An interesting feature is that some of the damage cases, were the car deck is undamaged, increases their index because of the reduced heel in damaged condition by the added sponsons. This can be noticed when comparing the same damage cases before and after rebuilding the ship to fulfil the Stockholm Agreement. To describe the features further, some special damage cases are studied more in detail. As shown in the results, the added watertight doors do not change the index significantly. The increase of the attained index is for this vessel is only 6.81% and one reason for this small increase is that the attained index is rather high even before rebuilt, due to survivability factors, s_i, around one for many of the damage cases involving an open ro-ro space.

4.2.3.1 A new damage case contributing to the attained index

One of the new damage cases contributing to the index is case DL/SDSP13-14.0.0. The index contribution for this damage was, before rebuilt, zero and after rebuilding the vessel the case gives a contribution of 0.00405. This is a quite significant change of the index contribution and the reason for this large change is as usual mainly related to the change in GZ curve and the change of the floating position in damaged condition. As described before this vessel is approved as a one-compartment ship and this specific damage case corresponds to a two-compartment damage. This explains the immersed margin line in the damage case before rebuilt (table 4.7). Factors and indices for this damage case are presented in table 4.8. For detailed descriptions of this damage case, floating positions and GZ curve see appendix D, damage case DL/SDSP13-14.0.0.

DL/SDSP13-14.0.0	T_M [m]	t [m]	heel [°]	ResMrg [m]
Before rebuilt	6,499	-0,263	6,2	-0,11
After rebuilt	6,505	-0,182	5,4	0,06

Table 4.7: DL/SDSP13-14.0.0, floating position in damaged case

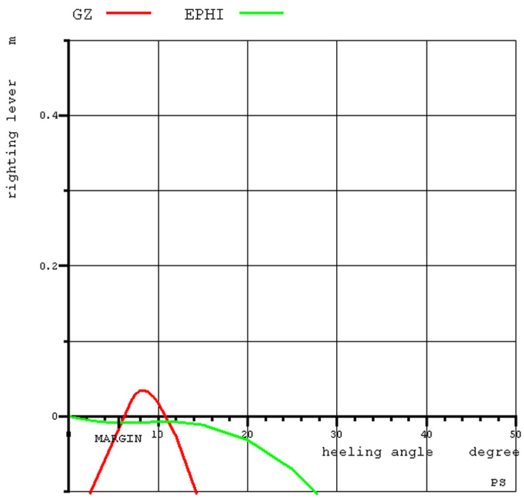

Figure 4.9: DL/SDSP13-14.0.0, GZ-curve before rebuilt

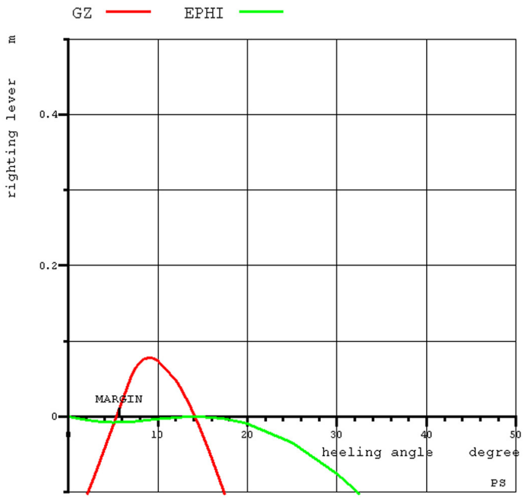

Figure 4.10: DL/SDSP13-14.0.0, GZ-curve after rebuilt

DL/SDSP13-14.0.0	s	p	v	GZ_{max}	RangeF	K_{fac}	s_{final}	s_{mom}	index contr.
Before rebuilt	0,00	0,02	0,80	0,04	4,3	1	0,55	0	0,00000
After rebuilt	0,75	0,02	0,80	0,08	8,8	1	0,75	1	0,00405

Table 4.8: DL/SDSP13-14.0.0, calculation data

As seen in tables above the sponsons reduce the heel and this affects the GZ curve used in definition of s_{final}. The more favourable floating position in damaged condition in combination of the sealed doors also increases the stability range and the maximum GZ. The increased stability range and GZ_{max} increase the factor s_{final}, but most important is the increased GZ_{max} effect on the factor s_{mom}. A GZ_{max} over 0.04 gives a factor $s_{mom} > 0$ and because of a quite high probability for this damage to occur (factor p) this damage case gives a quite high index contribution. (for definition of factors used in the analysis see Ch. 2 in this report)

4.2.4 Damage case with intact ro-ro deck changing the index contribution

There are also some damage cases with intact ro-ro deck with changed attained index contribution when rebuilding the vessel to comply with the Stockholm Agreement. One example is damage case DL/SDSP12-13.0.1 with floating position and result seen in table 4.9 and 4.10 respectively. For detailed descriptions of this damage case, floating positions and GZ curve see appendix D, damage case DL/SDSP12-13.0.1.

DL/SDSP12-13.0.1	T_M [m]	t [m]	heel [°]	ResMrg [m]
Before rebuilt	6,434	-1,359	7,3	-0,55
After rebuilt	6,447	-1,212	5,9	-0,27

Table 4.9: DL/SDSP12-13.0.1, floating position in damaged case

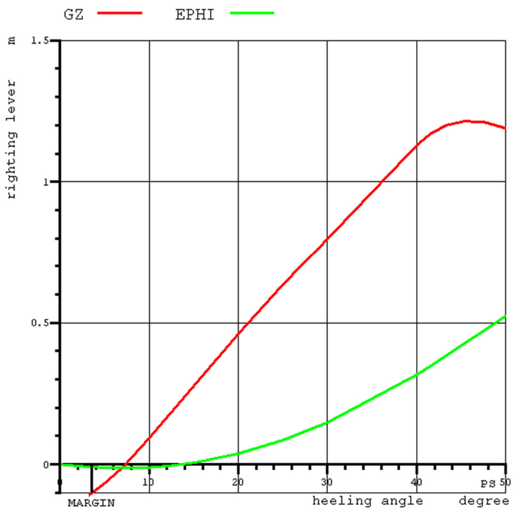

Figure 4.11: DL/SDSP12-13.0.1, GZ-curve before rebuilt

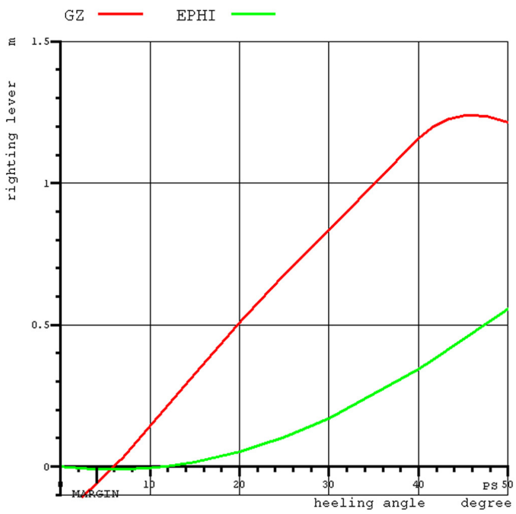

Figure 4.12: DL/SDSP12-13.0.1, GZ-curve after rebuilt

DL/SDSP12-13.0.1	s	p	v	GZ_{max}	RangeF	K_{fac}	s_{final}	s_{mom}	index contr.
Before rebuilt	0,98	0,02	0,20	1,21	42,7	0,98	1	1	0,00148
After rebuilt	1,00	0,02	0,20	1,24	44,1	1	1	1	0,00151

Table 4.10: DL/SDSP12-13.0.1, calculation data

Floating positions in damaged condition with heeling angles exceeding 7° for passenger ships will, according to the revised text of SOLAS CH II-1, affect the factor K and in this case result in a decreasing survivability factor. Both GZ_{max} and the stability range are in this case large enough to set the survivability factor to 1. The reason for the change of index contribution in this case is only related to the heeling angle for the floating position in damaged case. The result is an effect of changing the heeling angle from 7.3° to 5.9° by adding the sponsons. This type of damages contributes with a very small increase of the index when rebuilding the ship and this effect is almost negligible. But this example shows that ways to rebuild the ship to fulfil the Stockholm Agreement does not only affect damage cases, with a damaged ro-ro deck, but also cases with intact ro-ro deck.

Another interesting effect in this damage case is the immersion of the margin line used in today's deterministic calculations. The reason for presenting the resulting margin line in this report is to get some knowledge about the freeboard in damage floating position and to show that damage cases with immersed margin line actually contributes to the attained index in the revised, probabilistic, SOLAS Ch. II-1.

4.2.5 Conclusion

The result shows that the attained index is affected by redesigns made to comply with the Stockholm agreement. The calculations for this vessel also show the effect of making rooms adjacent to the ro-ro deck watertight. This way to rebuild the ship does not improve the index significant, but there is still a contribution. The probability of damages in a zone, only containing a room adjacent to the car deck and with a transverse extent not penetrating the bulkhead to the ro-ro deck is almost zero. In this point of view the doors which were made watertight do not change the index. The index increase by making the doors watertight depends on the volume of possible flooding when calculating the GZ curves for damage cases involving a damaged ro-ro deck, but not the watertight rooms.

4.3 Ro-ro passenger ship C

Vessel C is a vessel operating in the Baltic Sea, mainly for regular voyages between Stockholm and Åland. The ship is approved to comply with the Stockholm Agreement due to calculations with the significant wave height of 1.9 m and is approved as a two-compartment ship.

4.3.1 Main particulars for calculations

L_{pp}	94 m
B_M	18.6 m
Depth to car deck	6.30 m
Draught mld, two comp.	4.71 m
Passengers acc. to cert.	963
Lifeboat places	362

To comply with the Stockholm Agreement vessel C was rebuilt by making four rooms, in the aft part oft the ship adjacent to car deck, watertight and by adding sponsons on the aft part of the hull. The change in arrangement can be seen in figure 4.13 or in the definition of subdivisions, before and after rebuilt, in Appendix B: Ro-ro passenger vessel C.

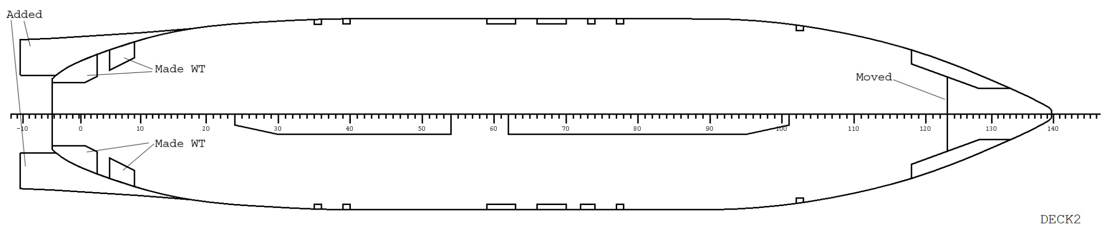

Figure 4.1: Changes in the arrangement, ship C, Deck 2

Some assumptions in the calculations have been made in order to recognize those damage cases with a large change in the index contribution. By adding sponsons the length of zone number one changes as well as the subdivision length. This will result in a change of all contributing damage cases due to the adjusted p-factor for all cases. To be able to compare and analyse the result the length of zone number one is set equal in the cases before and after rebuilt (see definition of subdivision in appendix). Due to lack of loading cases before the ship was rebuilt the same KG values are used as initial data before and after rebuild and the limited KG values taken from the stability documentation after rebuilt are also used in calculations before rebuilt. The GM values are inputs to the initial conditions and because of the changed displacement, when adding the sponsons, the GM values must be recalculated in the case before rebuilt using constant KG in both cases. Assuming equal loading conditions and limiting KG in the cases before and after rebuilt might affect the result and this is something to keep in mind reading this report. But this was the only way to in an effective way sort out and analyse specific damage cases where the contribution to the attained index changes.

4.3.2 Results

When calculating probabilistic damage stability on ro-ro passenger vessel C, before and after rebuilt, to comply with the Stockholm Agreement, an increase of 21.5 % of the attained index can be found.

This ship has also been calculated with the assumption of only making the rooms adjacent to the car deck watertight when rebuilding the vessel. If the ship is rebuilt by only making the rooms adjacent to the car deck watertight, the attained index increases with only 1.0 %.

4.3.3 Analysis

It's difficult to analyse and compare the attained indices for this vessel due to the change of the initial displacement when adding the sponsons to the hull and the assumption of constant KG before and after rebuilt. The initial displacement is changed due to the sponsons, partly located under the still water line. But it's obvious that the redesign of this vessel increases the attained index. To get an understanding of the reasons for the increased index, a comparison between damage cases affecting the index before and after rebuilt, is made. An interesting feature is that the main reason for the increased index is completely new damage cases contributing to the index, not contributing in the case before the vessel was rebuilt. The main parts of these damage cases are located around L/2 and the damages here have a relatively high probability factor, p. Almost all new damage cases involve a damaged ro-ro deck.

4.3.3.1 Damage not contributing to the index before rebuilt

One example of a new damage case, increasing the index when rebuilding the ship, is damage case DL/SDSP9-10.0.0. This is a very large damage, including zone 9 and 10. The added sponsons will results in a different floating position after the ship is rebuilt. Floating positions can be seen in table 4.11 and probabilistic indices are shown in table 4.12. For detailed descriptions of this damage case, floating positions and GZ-curves see appendix E, damage case DL/SDSP9-10.0.0.

In the floating position, before rebuilt, the margin line is immersed. The specific damage case corresponds to a two-compartment damage and the ship is approved as a two compartment ship. The explanation for this behaviour might be a conservative approach in the probabilistic rules. The initial conditions, in this case the deepest subdivision draught (defined in Ch. 3), are defined as draught, trim and metacentric height. All tanks are assumed to be unfilled and have the possibility of be flooded with a defined permeability. In the deterministic calculations some tanks are filled in the initial condition and this corresponding two-compartment damage might not immerse the margin line in that case.

DL/SDSP9-10.0.0	T_M [m]	t [m]	heel [°]	ResMrg [m]
Before rebuilt	5,798	-0,211	2,9	-0,09
After rebuilt	5,739	0,262	2,0	0,13

Table 4.11: DL/SDSP9-10.0.0, floating position in damaged case

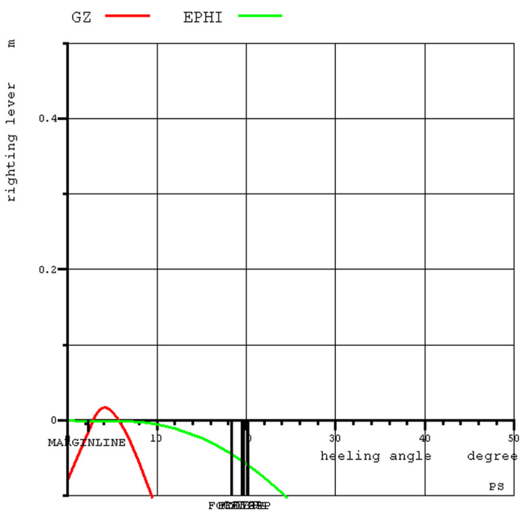

Figure 4.9: DL/SDSP9-10.0.0, GZ-curve before rebuilt

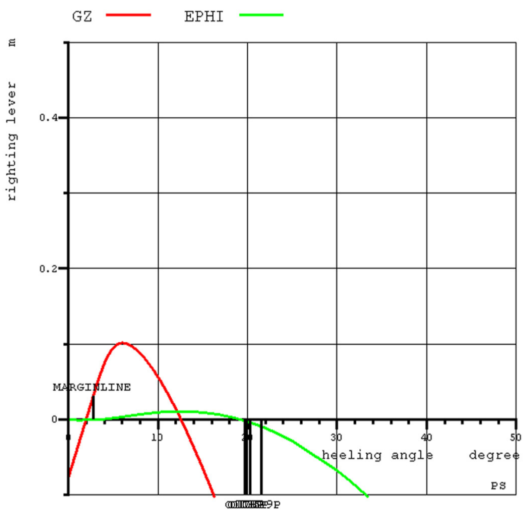

Figure 4.10: DL/SDSP9-10.0.0, GZ-curve after rebuilt

DL/SDSP9-10.0.0	s	p	v	GZ_{max}	RangeF	K_{fac}	s_{final}	s_{mom}	index contr.
Before rebuilt	0,00	0,03	0,84	0,02	3,0	1	0,42	0	0,00000
After rebuilt	0,70	0,03	0,84	0,10	10,6	1	0,86	0,78	0,00766

Table 4.12: DL/SDSP9-10.0.0, calculation data

When studying the floating positions a change of trim can be noticed. From a position trimmed by the stern the trim is changed and after rebuilt, the ship is trimmed by the bow. The added sponsons change the trim, mean draft and heel and this will off course also have effects later in the GZ curve.

A study of the GZ curves for this damage case shows a significant change in both maximum GZ and the stability range when adding sponsons. An notable fact is that the survivability factor is about 0.42 if we not consider the factor S_{mom} and consider the vessel as a cargo ship. The change of the contributing index in this damage case is quite high and represents a typical example for the overall increase of the attained index.

4.3.4 Conclusion

The way to rebuild this ship is affecting the attained index to a high degree and this is mainly due to the added sponsons. With the assumptions described in the beginning of this chapter the attained index is increased by 21.5 % and this is one of the highest increases among the studied vessels. Please note the assumption of unchanged initial draughts and centre of gravity and its way to affect the results. When studying the new damage cases contributing to the index it can be recognized that almost all involve a damaged ro-ro deck.

5 Conclusions and Recommendations

It's obvious that the ordinary way to rebuild ro-ro passenger ships to comply with the Stockholm Agreement increases the attained index, calculated in accordance with the revised SOLAS Ch. II-1. The vessels calculated and studied in this report shows increased attained indices between 6 and 22 %.

Too few ships have been calculated before and after rebuilt to draw any conclusions about how to rebuild a vessel which gives the largest index increase. But as seen in the case of ro-ro vessel B the attained index has increased by 19 % just by adding transverse car deck bulkheads and makes some rooms adjacent to the car deck watertight. This seems to be a good way to increase the attained index for larger ro-ro passenger vessels. The results of ro-ro vessel C also shows a large increase of the attained index, but the added sponsons are quite large and please note the assumptions used in the calculations for this vessel (see Chapter 4.3). Ro-ro vessel A does not show a large increase of the index when the ship was rebuilt, but the added sponsons are relatively small and few rooms, adjacent to car deck, were made watertight. One reason to the small increase of the attained index is the relative high index before the vessel was rebuilt. Many cases have already the survivability factor s = 1 and the changes have no effect on those damage cases.

As seen among the attained indices calculated in this report, the way to only make rooms adjacent to the car deck watertight does not affect the attained index significantly. The survivability factor, for a damage including rooms adjacent to the car deck, but were the watertight doors prevent water to be accumulated on the car deck, is rather high compare to the case with no watertight doors. But the probability factor for such damage, p, is in most cases rather small and this will result in a small increase of the overall index contribution for these cases.

Please note that no analysis of ro-ro passenger ship H has been carried out. This is a ship with large side casings and at the ro-ro deck the casings have the approx. width of B/5. In this case the effect of making rooms adjacent to the car deck watertight might increase the attained index more than in the cases studied in this report. This vessel complies however with the Stockholm Agreement and has a relatively low attained index compared to its required index. As said before, this seems to be common for larger ro-ro passenger vessels.

To draw some parallels from the probabilistic damage stability results to the Stockholm Agreement, I consider that the Stockholm Agreement is taken into consideration in the revised SOLAS Ch II-1. The results show that designs to prevent and resist accumulated water on open ro-ro decks actually increases the attained index.

By adding sponsons you change the floating position to a more favourable one when considering the same damage case before and after rebuilt. The sponsons will affect the stability curves and increase the survivability factor. If you consider the possibility of accumulated water, the sponsons increases the freeboard for the floating position in damaged case, which decreases the risk of accumulated water by waves. The increased freeboard will also affect the GZ curve by increasing the stability range and

GZ_{max}. The sponsons will also increase the possibility to survive damages with some accumulated water on the ro-ro deck.

Adding one or more transverse bulkheads on the car deck will also change the GZ curve and result in an increased maximum GZ and stability range. The change of the GZ curve will off course increase the survivability factor, s, if it is less than one. The added bulkheads will in reality limit the deck area of possible accumulated water. Some spontaneously thoughts about the position of the car deck bulkheads is to place the bulkhead at a frame number in a zone with low possibility of damage to occur to prevent a damage actually penetrate the added bulkhead and open up the ro-ro deck for accumulated water. This way to position the bulkheads might increase the attained index more, but no calculations of this has been carried out. Of course you have to consider the amount of accumulated water and thus place the bulkheads to minimize the accumulated water. But it might be possible to find optima for the placement of the bulkheads, by using this theory.

The attained indices calculated for different vessels are presented in Chapter 3 in this report. Results show that larger vessels, approved according to today's deterministic calculations, in general have difficulties to reach the required index stated in the new probabilistic approach used in the revised SOLAS. When constructing this type of vessels in the future using the revised SOLAS Ch. II-1 it might be necessary to use the designs used to fulfil the Stockholm Agreement to reach the required index in the revised SOLAS. It is possible to reach the required index in different ways using arrangements with side casings etc. It might also be necessary to design vessels with longitudinal subdivisions and bulkheads below the bulkhead deck to comply with the required index. When longitudinal WT-bulkheads are added below the bulkhead deck some cross-flooding arrangements might be needed to prevent large heeling angles.

The conclusion of these calculations is that large ro-ro passenger vessels approved according to the revised SOLAS Ch. II-1, will have a overall high safety compared to today's ships. To fulfil the required index you might use designs used today in the Stockholm Agreement or in some other way construct the ro-ro passenger vessels to improve their safety. It is of course possible to increase the limiting GM values etc. but this is probably not the best option for the ship owner. But by increase the metacentric height one will also get an increased possibility to survive with some accumulated water on a ro-ro deck. The final conclusion in this Master Thesis report is that the use of the Stockholm Agreement is not needed any more when the revised SOLAS is used and taken into consideration when constructing new ro-ro passenger ships.

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Appendix A: Calculation summaries, vessel A to H

This Appendix contains summaries of the probabilistic damage stability calculations done according to the revised SOLAS Ch. II-1. All calculations have been carried out using the computer software NAPA Release 2005.1-6. Some vessels are calculated with the arrangement used before and some with the arrangement used after the ship was rebuilt to comply with the Stockholm Agreement.

If only one calculation is done for a specific vessel, the results correspond to today's arrangement and the vessel fulfils the Stockholm Agreement with this arrangement.

A special case is vessel D which today is approved both as a two-compartment ship and as a one-compartment ship, depending on the amount of passengers and the actual load case. Calculations for this ship have been carried when sailing both as a one-compartment ship and as a two-compartment ship.

For additional information according to the calculation setup, see Chapter 3.

RO-RO PASSENGER VESSEL A AFTER REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	157.784	m
Breadth at the load line	21.600	m
Breadth at the bulkhead deck	21.600	m
Number of persons N1	376	
Number of persons N2	7	

Required subdivision index R = 0.69434

Attained subdivision index A = 0.83250

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	5.720	1.300	1.12	0.77900	0.31160	0.400
LL	4.845	1.300	1.27	0.88315	0.17663	0.200
PL	5.370	1.300	1.24	0.86068	0.34427	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.27208
2-ZONE DAMAGES	0.26308
3-ZONE DAMAGES	0.14887
4-ZONE DAMAGES	0.07510
5-ZONE DAMAGES	0.04286
6-ZONE DAMAGES	0.02136
7-ZONE DAMAGES	0.00914
A-INDEX TOTAL	0.83250

RO-RO PASSENGER VESSEL A BEFORE REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	157.784	m
Breadth at the load line	21.600	m
Breadth at the bulkhead deck	21.600	m
Number of persons N1	376	
Number of persons N2	7	

Required subdivision index R = 0.69434

Attained subdivision index A = 0.77945

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	5.720	1.300	1.02	0.70543	0.28217	0.400
LL	4.845	1.300	1.24	0.85789	0.17158	0.200
PL	5.370	1.300	1.17	0.81425	0.32570	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.27173
2-ZONE DAMAGES	0.22562
3-ZONE DAMAGES	0.14069
4-ZONE DAMAGES	0.07161
5-ZONE DAMAGES	0.04160
6-ZONE DAMAGES	0.02008
7-ZONE DAMAGES	0.00812
A-INDEX TOTAL	0.77945

RO-RO PASSENGER VESSEL B AFTER REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	184.158	m
Breadth at the load line	29.000	m
Breadth at the bulkhead deck	29.000	m
Number of persons N1	920	
Number of persons N2	1640	

Required subdivision index R = 0.80702

Attained subdivision index A = 0.74288

INIT	T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	6.740	1.480	0.91	0.73519	0.29408	0.400
LL	6.394	1.395	0.94	0.75924	0.15185	0.200
PL	6.602	1.425	0.92	0.74239	0.29696	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.30670
2-ZONE DAMAGES	0.26510
3-ZONE DAMAGES	0.12133
4-ZONE DAMAGES	0.03180
5-ZONE DAMAGES	0.01424
6-ZONE DAMAGES	0.00372
A-INDEX TOTAL	0.74288

RO-RO PASSENGER VESSEL B BEFORE REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	184.158	m
Breadth at the load line	29.000	m
Breadth at the bulkhead deck	29.000	m
Number of persons N1	920	
Number of persons N2	1640	

Required subdivision index R = 0.80702

Attained subdivision index A = 0.62422

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	6.740	1.480	0.76	0.61228	0.24491	0.400
LL	6.394	1.395	0.80	0.64576	0.12915	0.200
PL	6.602	1.425	0.77	0.62539	0.25016	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.29783
2-ZONE DAMAGES	0.19920
3-ZONE DAMAGES	0.08827
4-ZONE DAMAGES	0.02399
5-ZONE DAMAGES	0.01131
6-ZONE DAMAGES	0.00362
A-INDEX TOTAL	0.62422

RO-RO PASSENGER VESSEL C AFTER REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	104.134	m
Breadth at the load line	18.600	m
Breadth at the bulkhead deck	18.600	m
Number of persons N1	316	
Number of persons N2	647	

Required subdivision index R = 0.74166

Attained subdivision index A = 0.85008

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	4.710	2.520	1.14	0.84780	0.33912	0.400
LL	4.362	2.245	1.15	0.85012	0.17002	0.200
PL	4.571	2.395	1.15	0.85234	0.34094	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.34330
2-ZONE DAMAGES	0.30824
3-ZONE DAMAGES	0.11250
4-ZONE DAMAGES	0.05309
5-ZONE DAMAGES	0.02083
6-ZONE DAMAGES	0.00843
7-ZONE DAMAGES	0.00369
A-INDEX TOTAL	0.85008

RO-RO PASSENGER VESSEL C BEFORE REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	104.134	m
Breadth at the load line	18.600	m
Breadth at the bulkhead deck	18.600	m
Number of persons N1	316	
Number of persons N2	647	

Required subdivision index R = 0.74166

Attained subdivision index A = 0.69956

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	4.710	1.636	0.95	0.70509	0.28204	0.400
LL	4.362	1.201	0.92	0.68145	0.13629	0.200
PL	4.571	1.436	0.95	0.70309	0.28124	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.33169
2-ZONE DAMAGES	0.20708
3-ZONE DAMAGES	0.08122
4-ZONE DAMAGES	0.05148
5-ZONE DAMAGES	0.01774
6-ZONE DAMAGES	0.00710
7-ZONE DAMAGES	0.00326
A-INDEX TOTAL	0.69956

RO-RO PASSENGER VESSEL D, ACTING AS 1-COMP. VESSEL

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	134.510	m
Breadth at the load line	24.000	m
Breadth at the bulkhead deck	24.000	m
Number of persons N1	220	
Number of persons N2	13	

Required subdivision index R = 0.68700

Attained subdivision index A = 0.64941

INIT	T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	5.840	0.783	0.57	0.39487	0.15795	0.400
LL	4.751	1.175	1.30	0.89684	0.17937	0.200
PL	5.404	1.057	1.13	0.78024	0.31210	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.23850
2-ZONE DAMAGES	0.16320
3-ZONE DAMAGES	0.14980
4-ZONE DAMAGES	0.04737
5-ZONE DAMAGES	0.02618
6-ZONE DAMAGES	0.02053
7-ZONE DAMAGES	0.00383
A-INDEX TOTAL	0.64941

RO-RO PASSENGER VESSEL D, ACTING AS 2-COPM. VESSEL

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	134.510	m
Breadth at the load line	24.000	m
Breadth at the bulkhead deck	24.000	m
Number of persons N1	220	
Number of persons N2	513	

Required subdivision index R = 0.72936

Attained subdivision index A = 0.86393

INIT	T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	5.660	1.703	1.15	0.84234	0.33693	0.400
LL	4.751	1.589	1.24	0.90540	0.18108	0.200
PL	5.296	1.534	1.18	0.86479	0.34592	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.27185
2-ZONE DAMAGES	0.23790
3-ZONE DAMAGES	0.22545
4-ZONE DAMAGES	0.07882
5-ZONE DAMAGES	0.03654
6-ZONE DAMAGES	0.01020
7-ZONE DAMAGES	0.00318
A-INDEX TOTAL	0.86393

RO-RO PASSENGER VESSEL E AFTER REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	153.822	m
Breadth at the load line	21.000	m
Breadth at the bulkhead deck	21.000	m
Number of persons N1	220	
Number of persons N2	44	

Required subdivision index R = 0.69038

Attained subdivision index A = 0.68215

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	5.200	1.940	0.95	0.65342	0.26137	0.400
LL	4.248	1.400	1.04	0.71767	0.14353	0.200
PL	4.591	1.450	1.00	0.69313	0.27725	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.34042
2-ZONE DAMAGES	0.20395
3-ZONE DAMAGES	0.05244
4-ZONE DAMAGES	0.03935
5-ZONE DAMAGES	0.02663
6-ZONE DAMAGES	0.01039
7-ZONE DAMAGES	0.00896
A-INDEX TOTAL	0.68215

RO-RO PASSENGER VESSEL F AFTER REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	188.450	m
Breadth at the load line	23.100	m
Breadth at the bulkhead deck	23.100	m
Number of persons N1	300	
Number of persons N2	70	

Required subdivision index R = 0.69722

Attained subdivision index A = 0.73686

INIT	T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	5.900	1.148	0.94	0.65743	0.26297	0.400
LL	4.800	1.265	1.20	0.83703	0.16741	0.200
PL	5.460	1.150	1.10	0.76620	0.30648	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.29793
2-ZONE DAMAGES	0.27315
3-ZONE DAMAGES	0.08143
4-ZONE DAMAGES	0.04550
5-ZONE DAMAGES	0.02645
6-ZONE DAMAGES	0.01041
7-ZONE DAMAGES	0.00198
A-INDEX TOTAL	0.73686

RO-RO PASSENGER VESSEL G AFTER REBUILT

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	168.808	m
Breadth at the load line	27.600	m
Breadth at the bulkhead deck	27.600	m
Number of persons N1	626	
Number of persons N2	1397	

Required subdivision index R = 0.79118

Attained subdivision index A = 0.57819

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	6.600	1.670	0.72	0.57353	0.22941	0.400
LL	6.056	1.390	0.78	0.61527	0.12305	0.200
PL	6.382	1.430	0.71	0.56432	0.22573	0.400

INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.25538
2-ZONE DAMAGES	0.15830
3-ZONE DAMAGES	0.11207
4-ZONE DAMAGES	0.03218
5-ZONE DAMAGES	0.01407
6-ZONE DAMAGES	0.00620
A-INDEX TOTAL	0.57819

RO-RO PASSENGER VESSEL H

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	194.262	m
Breadth at the load line	31.500	m
Breadth at the bulkhead deck	31.500	m
Number of persons N1	920	
Number of persons N2	1932	

Required subdivision index R = 0.81738

Attained subdivision index A = 0.68522

INIT	T	GM	A/R	A	A*WCOEF	WCOEF
	m	m				
DL	7.100	1.760	0.85	0.69305	0.27722	0.400
LL	6.682	1.660	0.83	0.67755	0.13551	0.200
PL	6.933	1.650	0.83	0.68123	0.27249	0.400

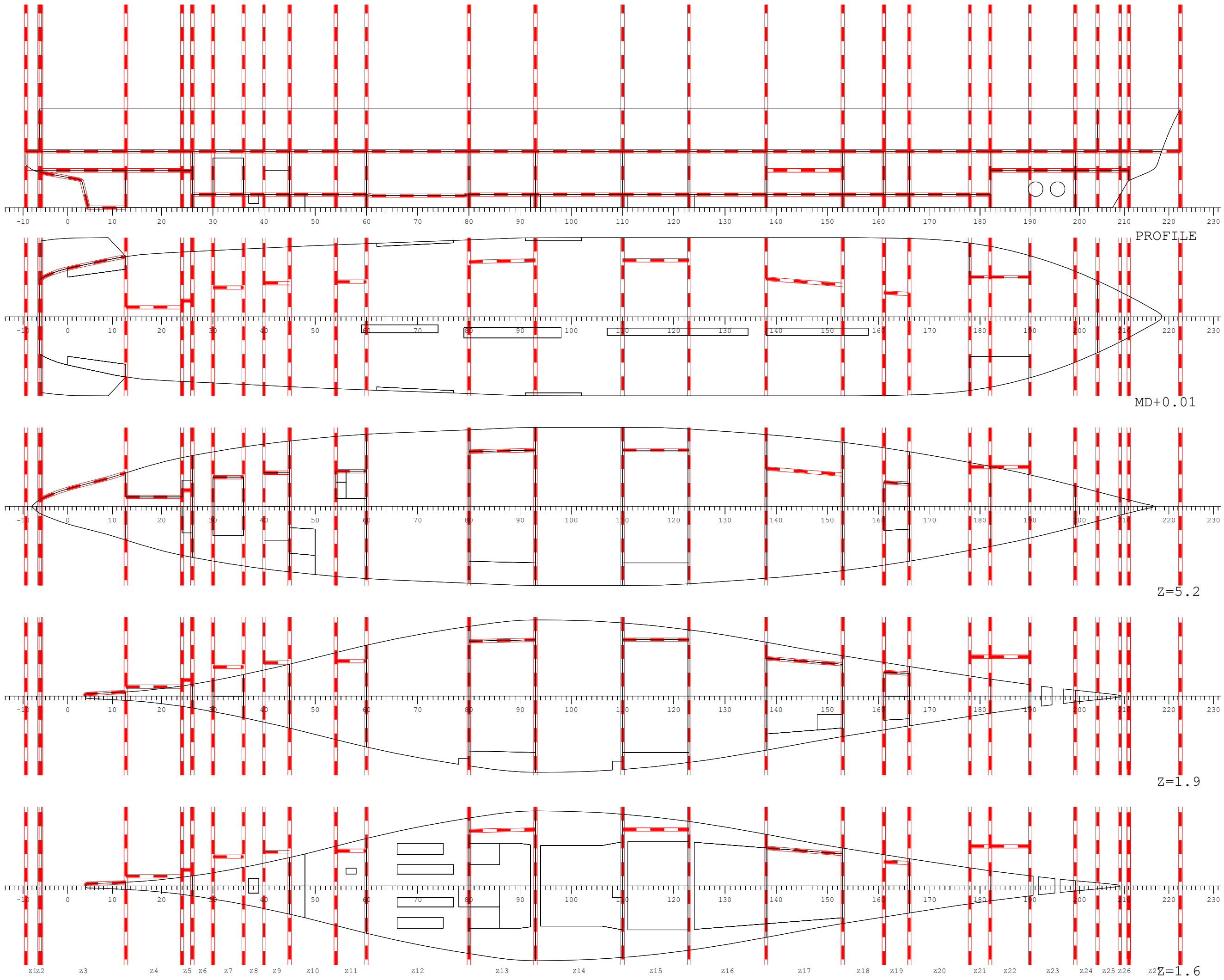
INDEX ACCORDING TO NUMBER OF ZONES

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.26574
2-ZONE DAMAGES	0.23149
3-ZONE DAMAGES	0.10069
4-ZONE DAMAGES	0.05650
5-ZONE DAMAGES	0.03080
A-INDEX TOTAL	0.68522

Appendix B: Definition of Subdivisions, Vessel A-H

This Appendix contains plots of different subdivisions used in the probabilistic damage stability calculations. The subdivisions refer to the vessels presented in Chapter 3 and Appendix A.

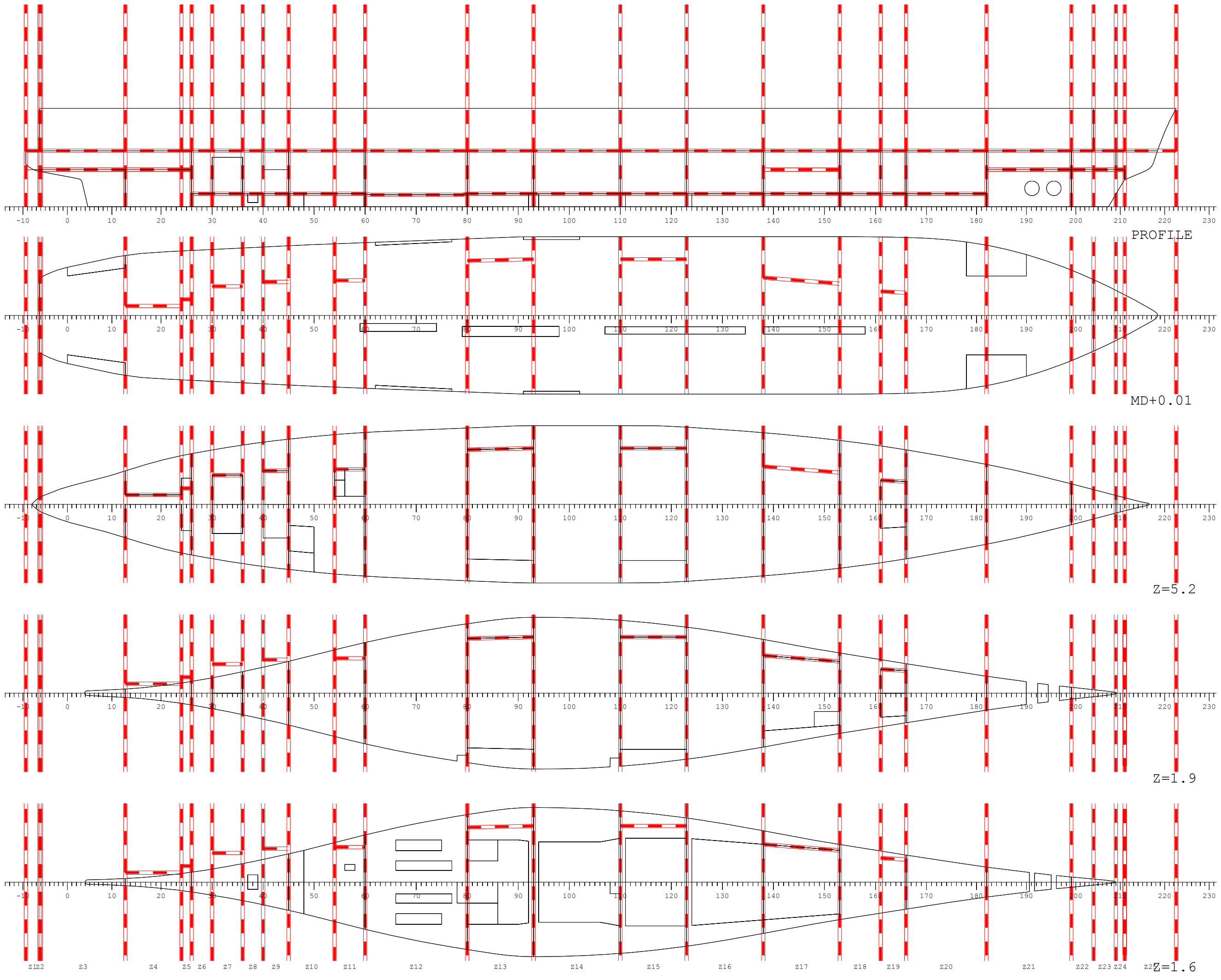
NAPA	Definition of Subdivision Vessel A, After Rebuilt	Proj P118/A Date 2005-12-30 Time 14:07 Sign AH



NAPA

Definition of Subdivision
Vessel A, Before Rebuilt

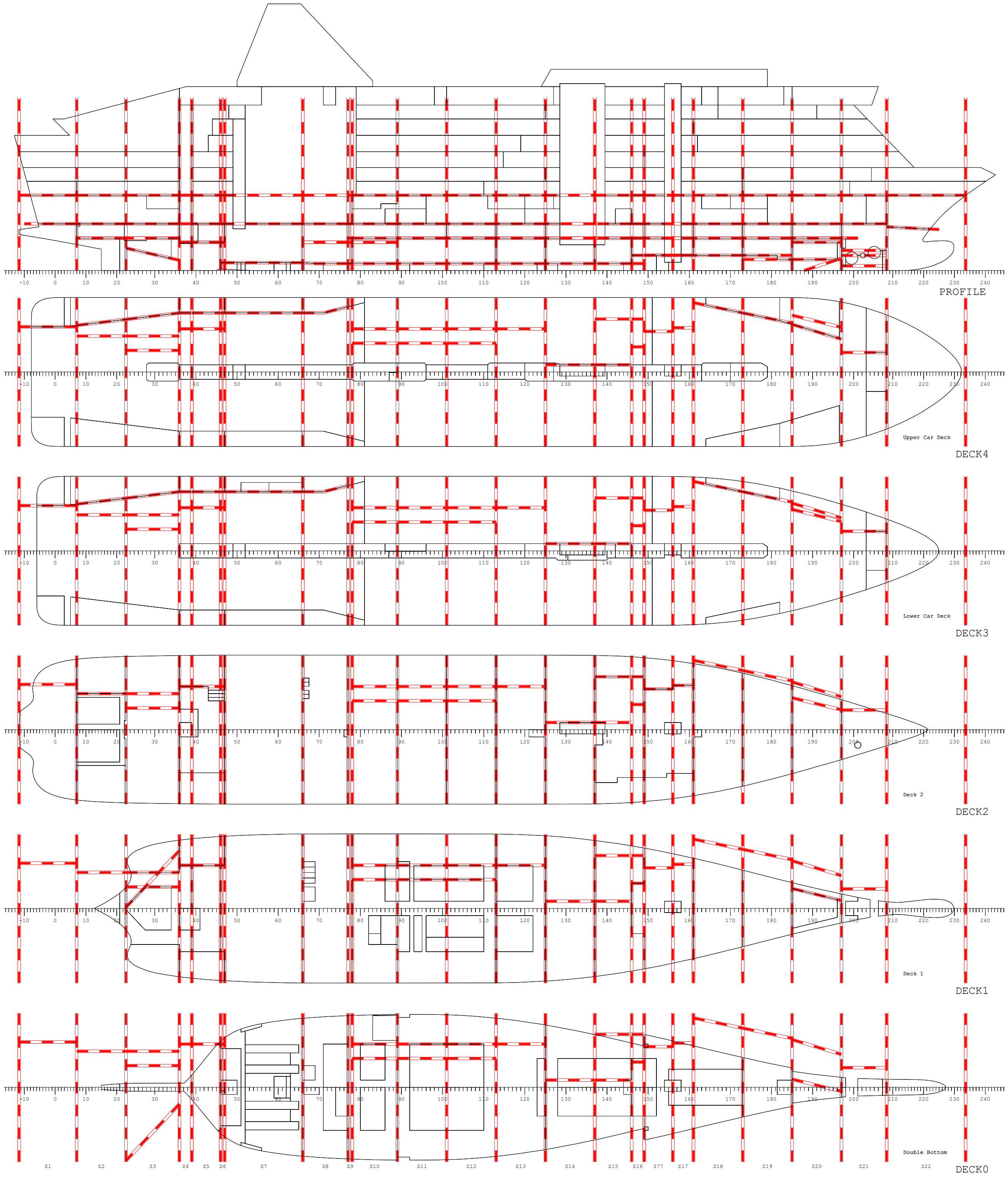
Proj	P118B/A
Date	2005-12-30
Time	14:13
Sign	AH



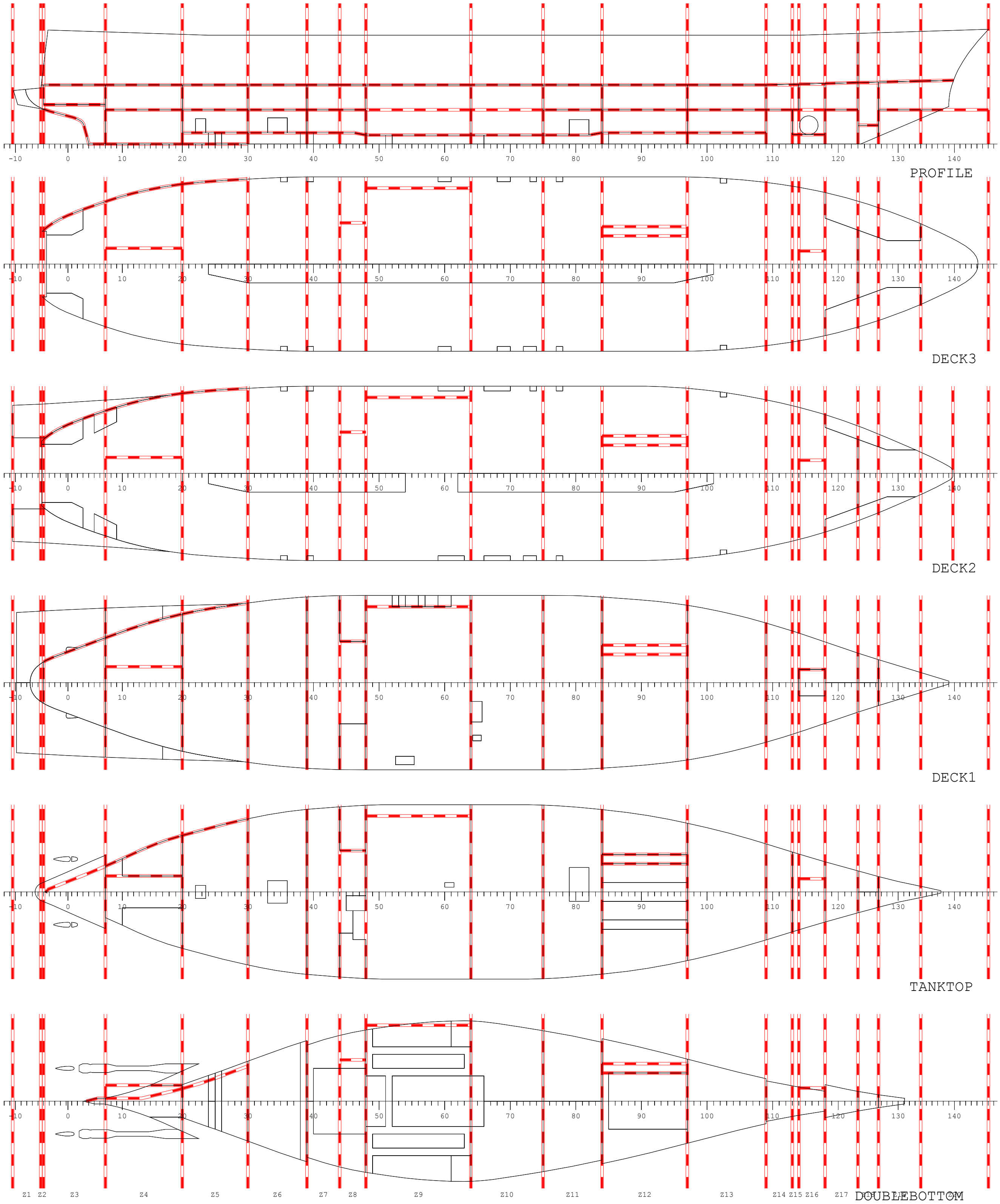
NAPA

Definition of Subdivision
Vessel B

Proj	
Date	2005-12-12
Time	20:33
Sign	AH



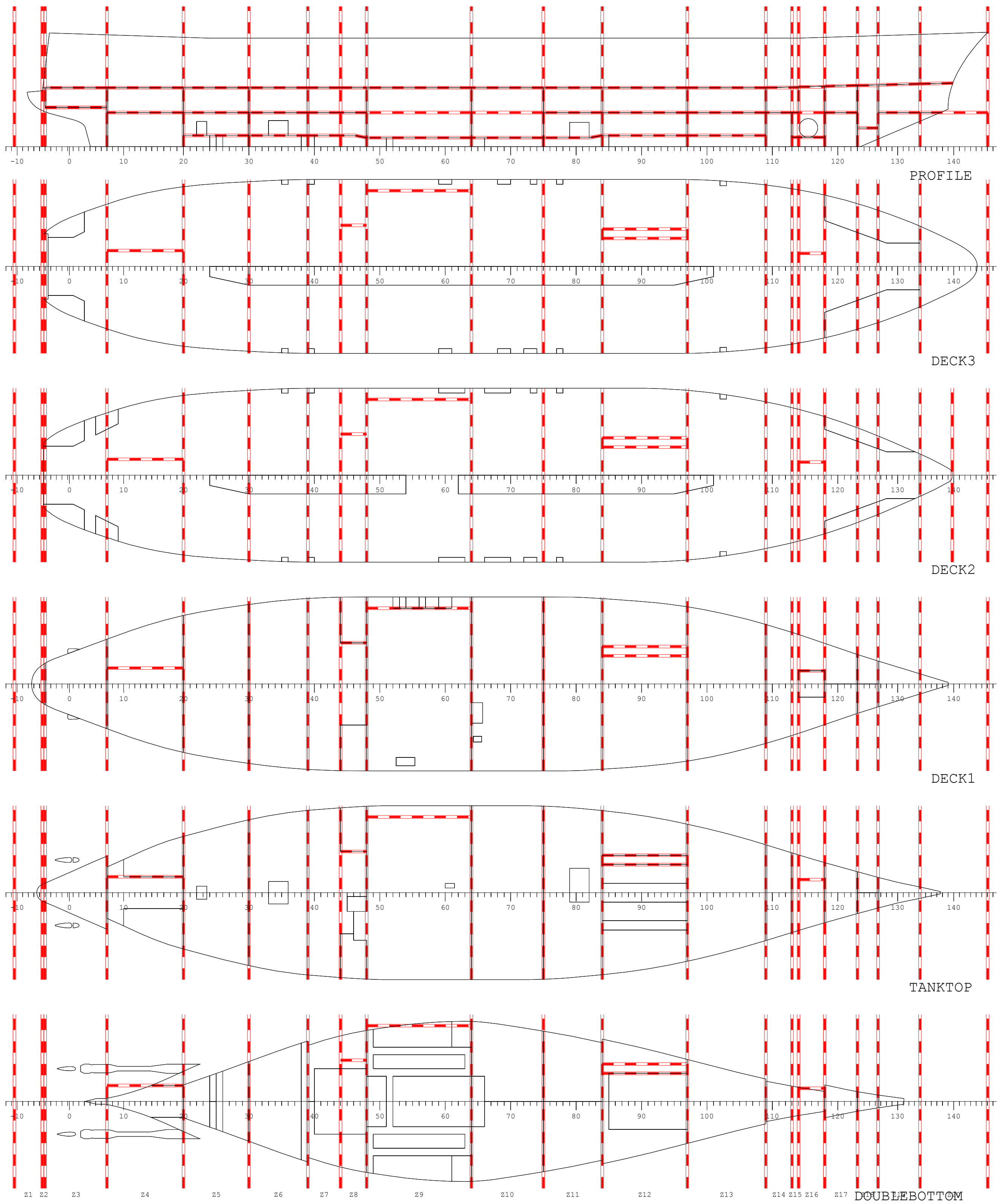
NAPA	Definition of Subdivision Vessel C, After Rebuilt	Proj Date 2005-12-30 Time 14:27 Sign AH



NAPA

Definition of Subdivision Vessel C, Before Rebuilt

Proj	
Date	2005-12-30
Time	14:31
Sign	AH



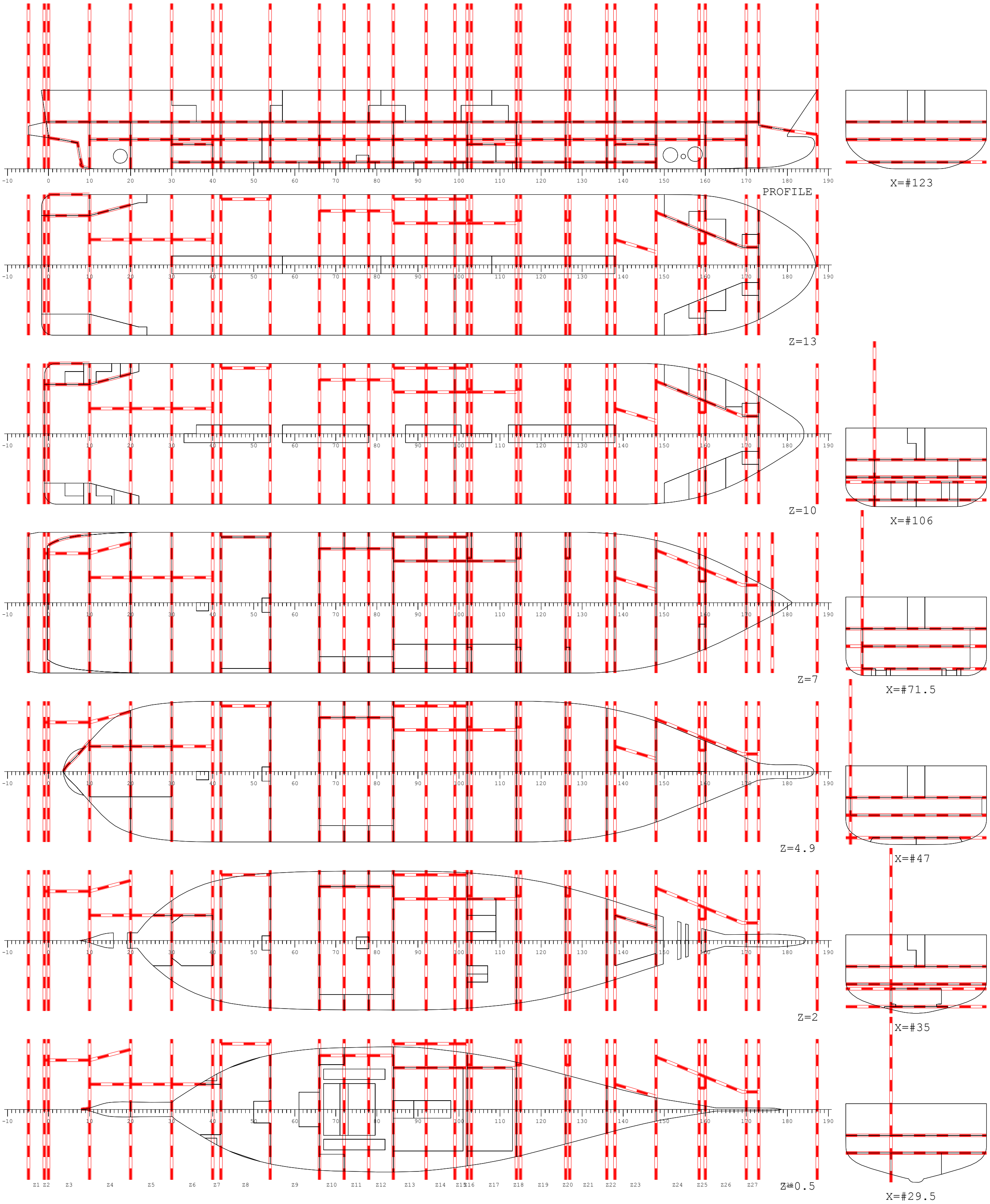
For description of Z1 definition see Chapter 4

NAPA

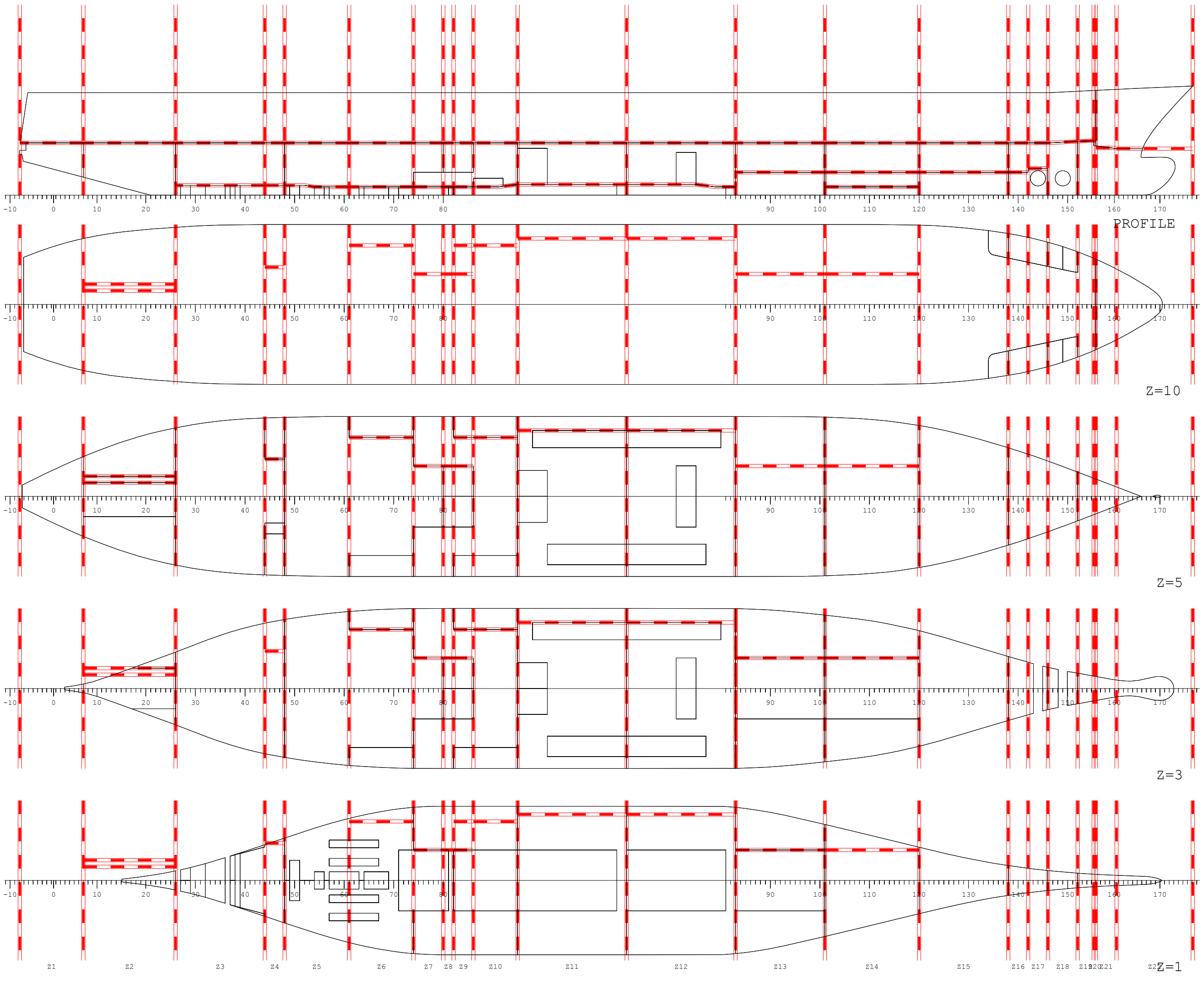
Definition of Subdivision

Vessel D

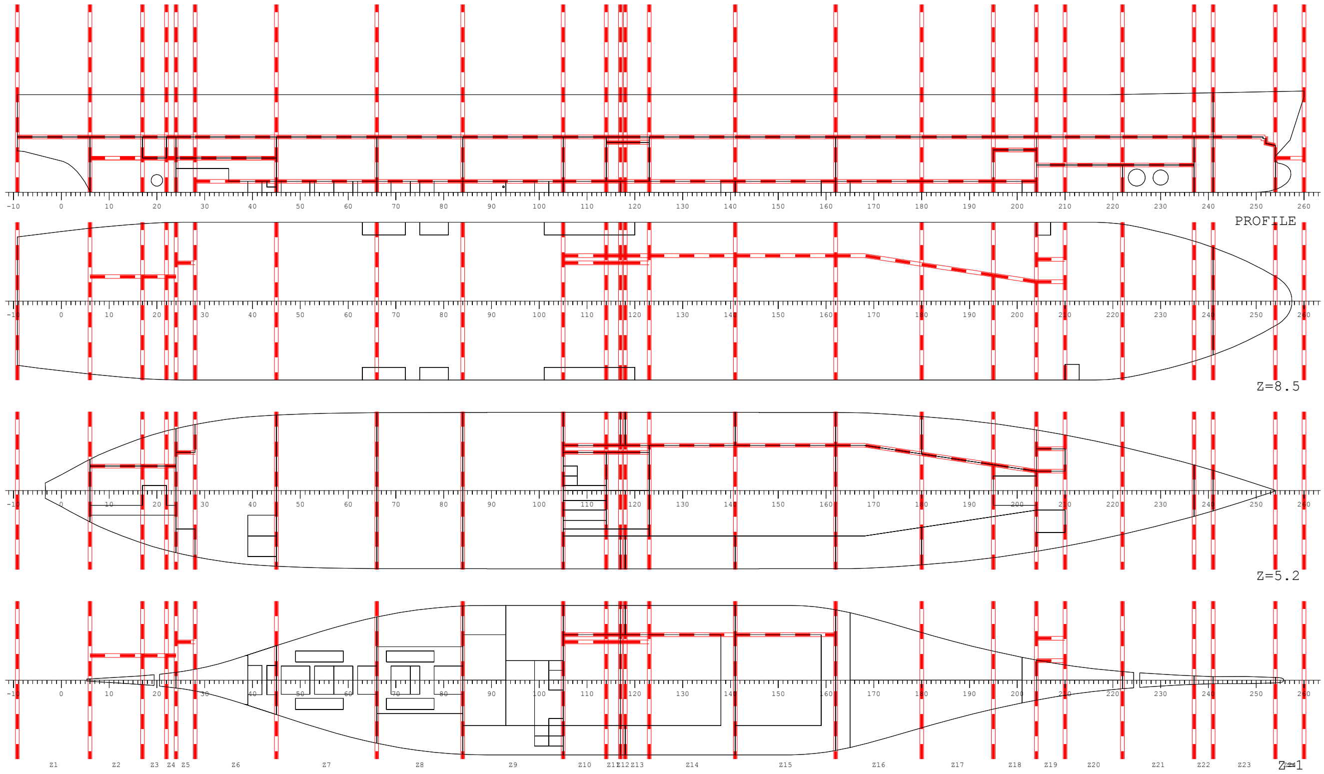
Proj	
Date	2005-12-30
Time	13:33
Sign	AH



NAPA	Definition of Subdivision Vessel E	Proj P38/A Date 2005-12-30 Time 14:20 Sign AH



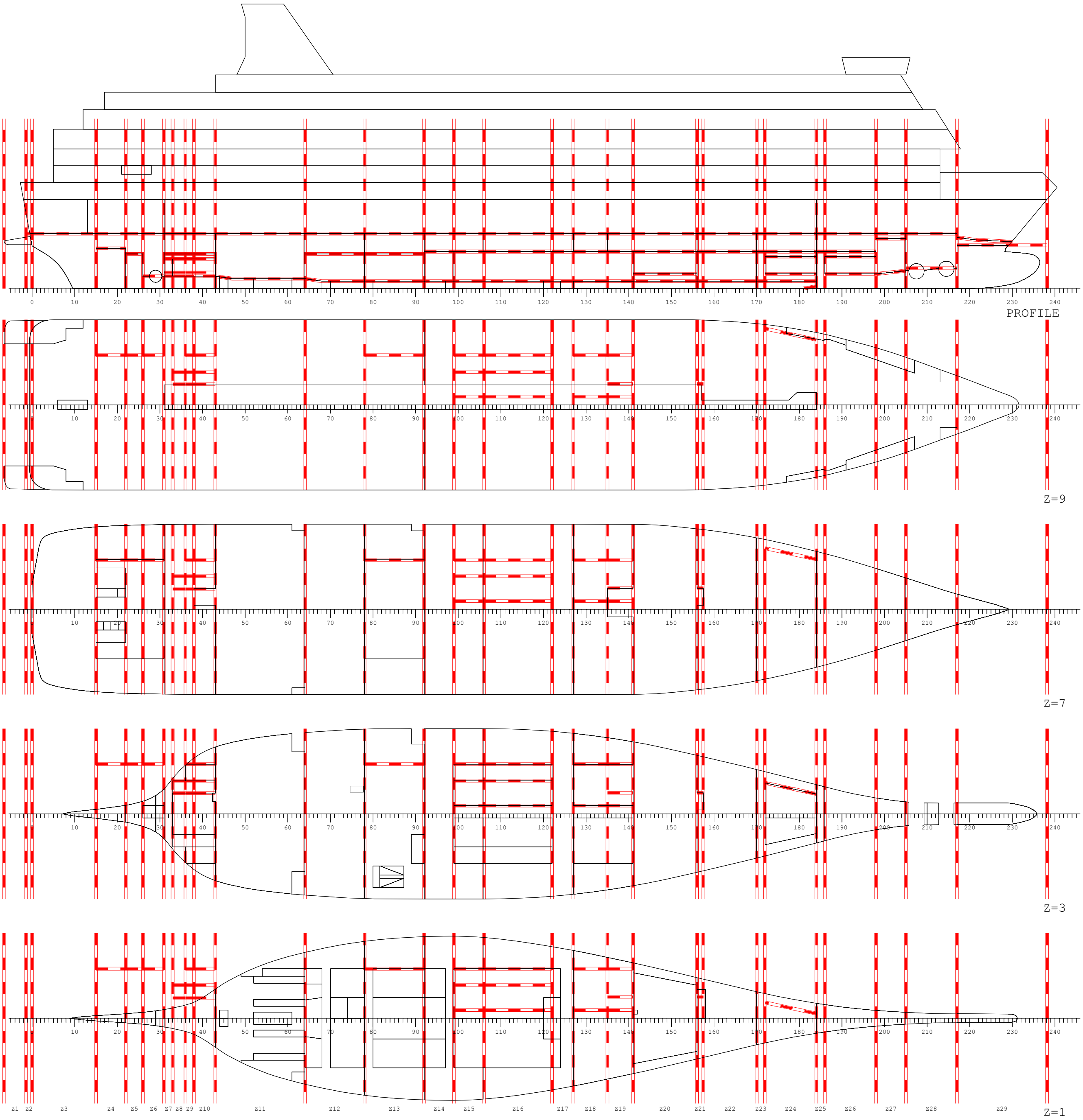
NAPA	Definition of Subdivision Vessel F	Proj Date 2005-12-30 Time 14:20 Sign AH



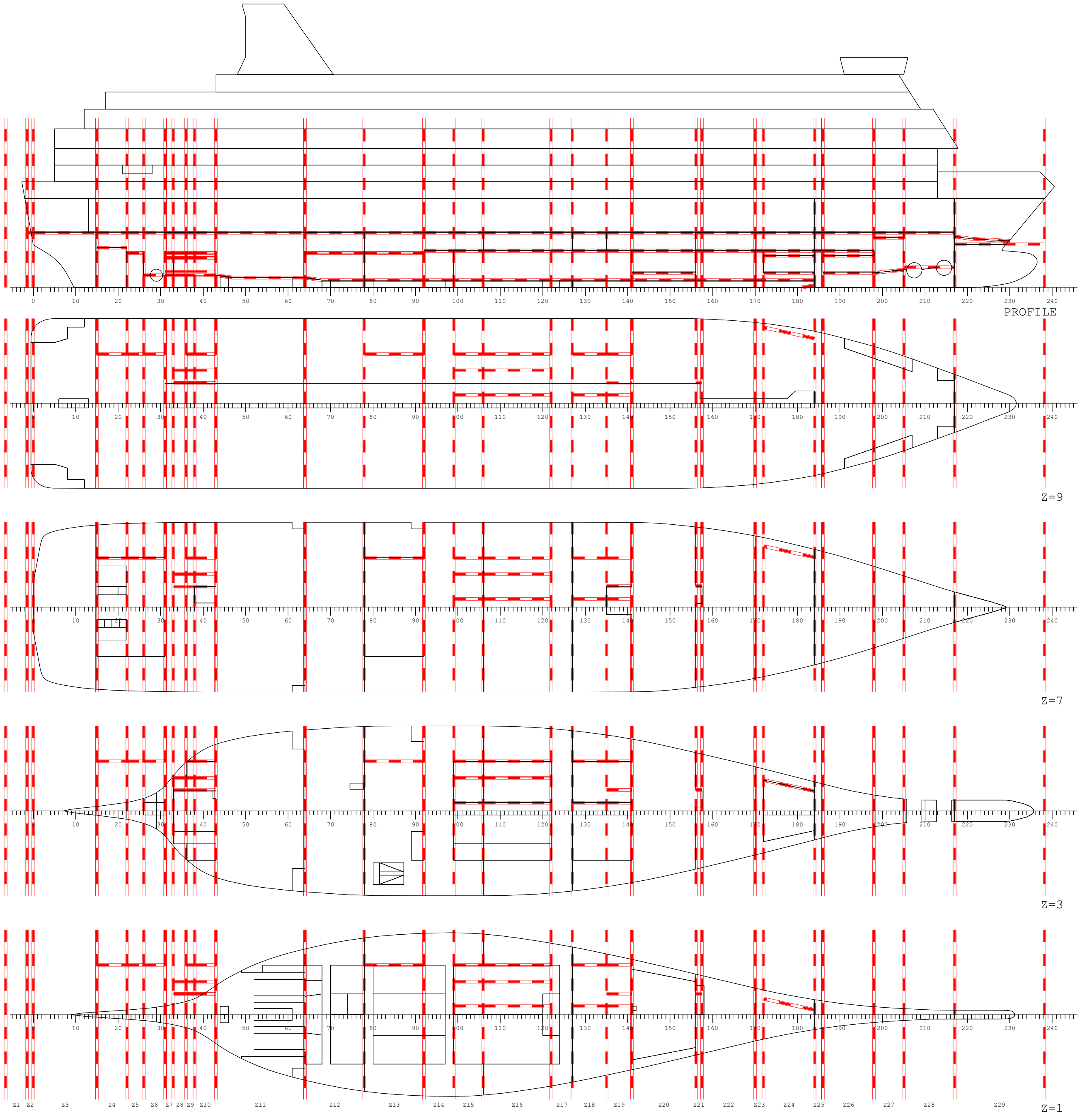
NAPA

Definition of Subdivision
Vessel G, After Rebuilt

Proj	P9/EFF
Date	2005-12-30
Time	13:51
Sign	AH



NAPA	Definition of Subdivision Vessel G, Before Rebuilt	Proj P9B/EFF Date 2005-12-30 Time 13:54 Sign AH



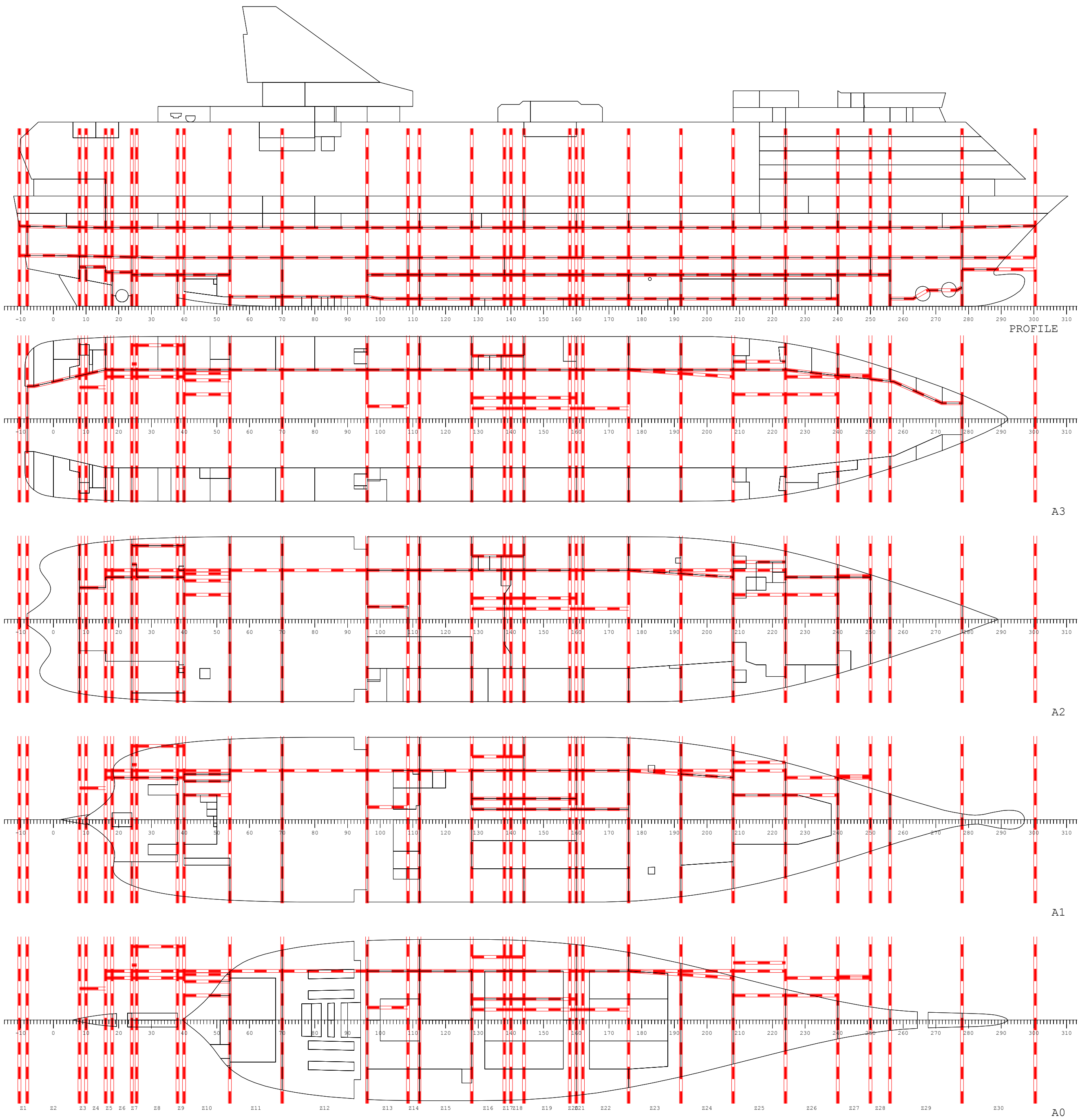
For description of Z1 definition see Chapter 4

NAPA

Definition of Subdivision

Vessel H

Proj	L1301/A
Date	2005-12-12
Time	21:01
Sign	AH



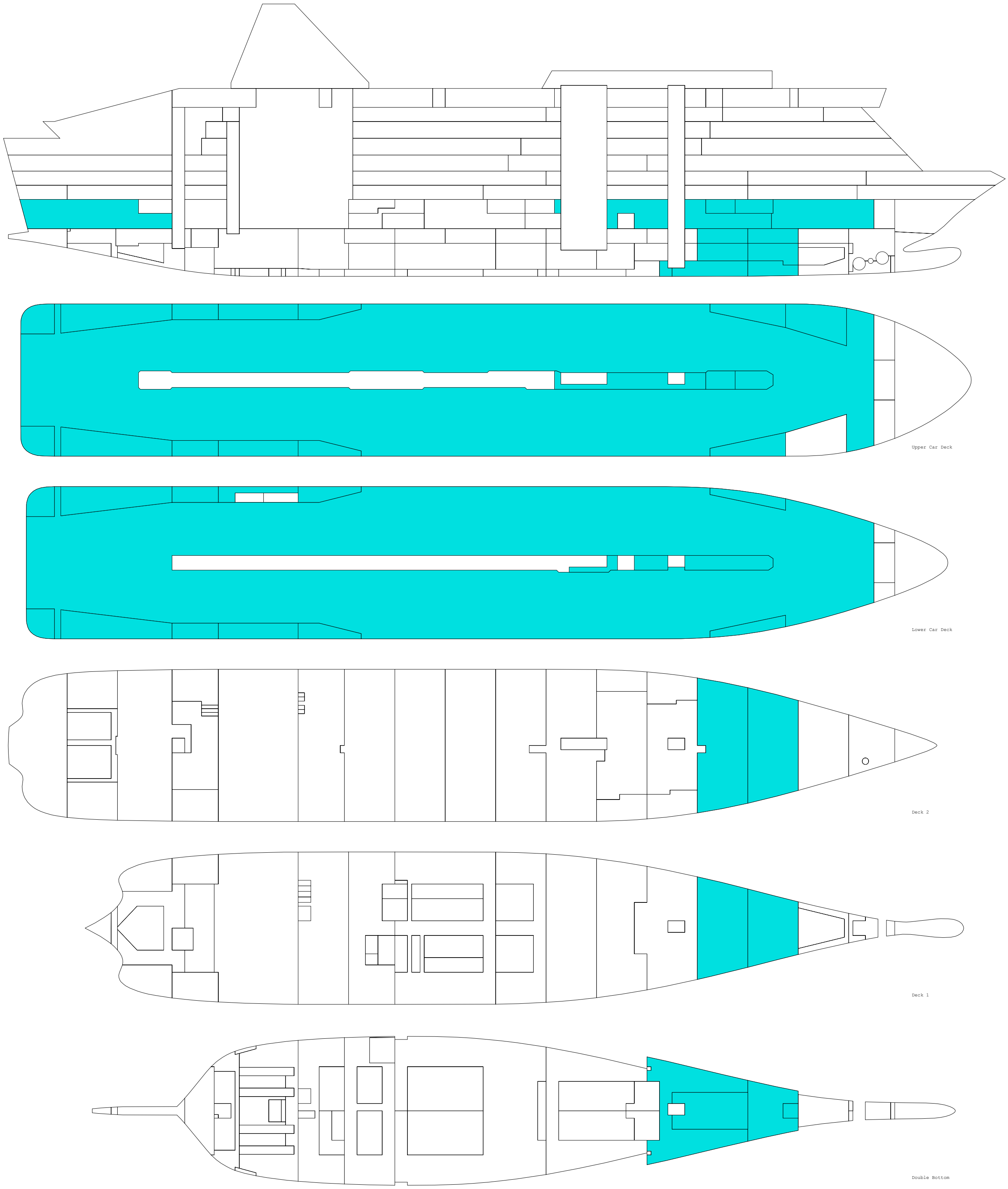
Appendix C: Ro-ro passenger vessel B – Stability data for studied damage cases

This Appendix includes damage definitions, floating positions and stability curves of some damage cases studied in Chapter 4.

Calculated data for ro-ro passenger vessel B, damage case DL/SDSP19-20.0.3: Before the vessel was rebuilt

NAPA	Damage Definition SDSP19-20.0.3	Proj Date 2005-12-13 Time 11:12 Sign AH

Zones Z18-Z19 Port, h3



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP19-20.	INTACT	EQ	-	6.740	0.000	0.0	7.06	O034P	2.29
DL/SDSP19-20.	1	1	-	6.985	0.956	0.0	6.87	O099P	1.61
DL/SDSP19-20.	1	EQ	-	7.346	2.502	0.0	6.60	O099P	0.54

STATE OF COMPARTMENTS

CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP19-20.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3011	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3012	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3022	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3042	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3051	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3052	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3061	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3062	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3142	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	T1301	0.000	0.0	0.0	0.0	252.2	253.5
DL/SDSP19-20.	1	1	T1400	0.000	0.0	0.0	0.0	294.5	296.0
DL/SDSP19-20.	1	1	T1410	0.000	0.0	0.0	0.0	32.8	33.0
DL/SDSP19-20.	1	1	T1420	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R4140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R4150	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	T1500	0.000	0.0	0.0	0.0	162.5	163.3
DL/SDSP19-20.	1	1	T1510	0.000	0.0	0.0	0.0	29.8	29.9
DL/SDSP19-20.	1	1	T1520	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R4161	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3011	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3012	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3022	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3042	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3051	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3052	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3061	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3062	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3142	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	T1301	0.000	0.0	0.0	0.0	252.2	253.5
DL/SDSP19-20.	1	EQ	T1400	0.000	0.0	0.0	0.0	294.5	296.0
DL/SDSP19-20.	1	EQ	T1410	0.000	0.0	0.0	0.0	342.7	344.5
DL/SDSP19-20.	1	EQ	T1420	0.000	0.0	0.0	0.0	357.9	359.7
DL/SDSP19-20.	1	EQ	R4140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R4150	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	T1500	0.000	0.0	0.0	0.0	162.5	163.3
DL/SDSP19-20.	1	EQ	T1510	0.000	0.0	0.0	0.0	255.1	256.3
DL/SDSP19-20.	1	EQ	T1520	0.000	0.0	0.0	0.0	319.6	321.2
DL/SDSP19-20.	1	EQ	R4161	0.000	0.0	0.0	0.0	0.0	0.0

NAPA

Floating position

Case: DL/SDSP19-20.0.3

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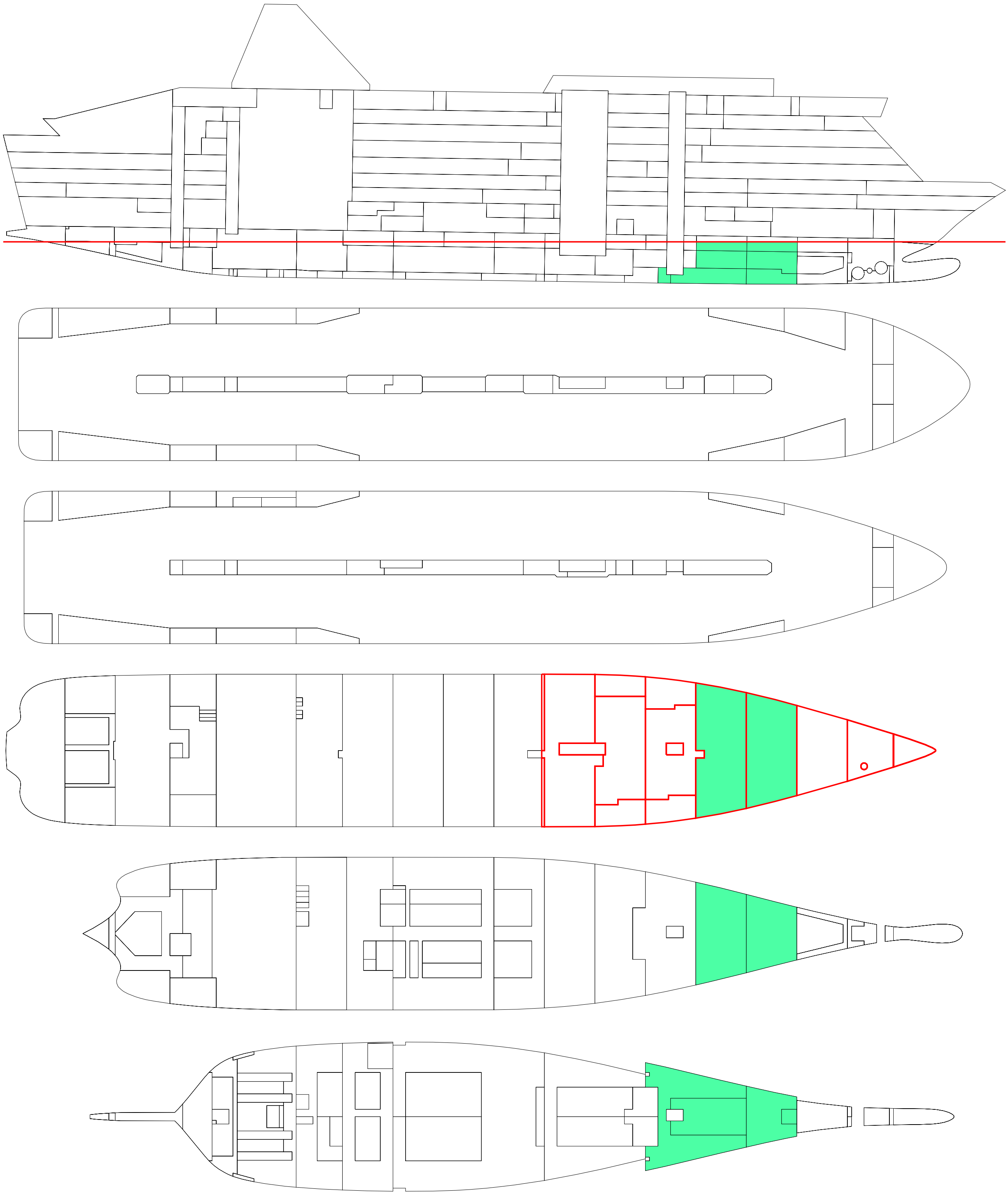
Time	10:11
Sign	AH



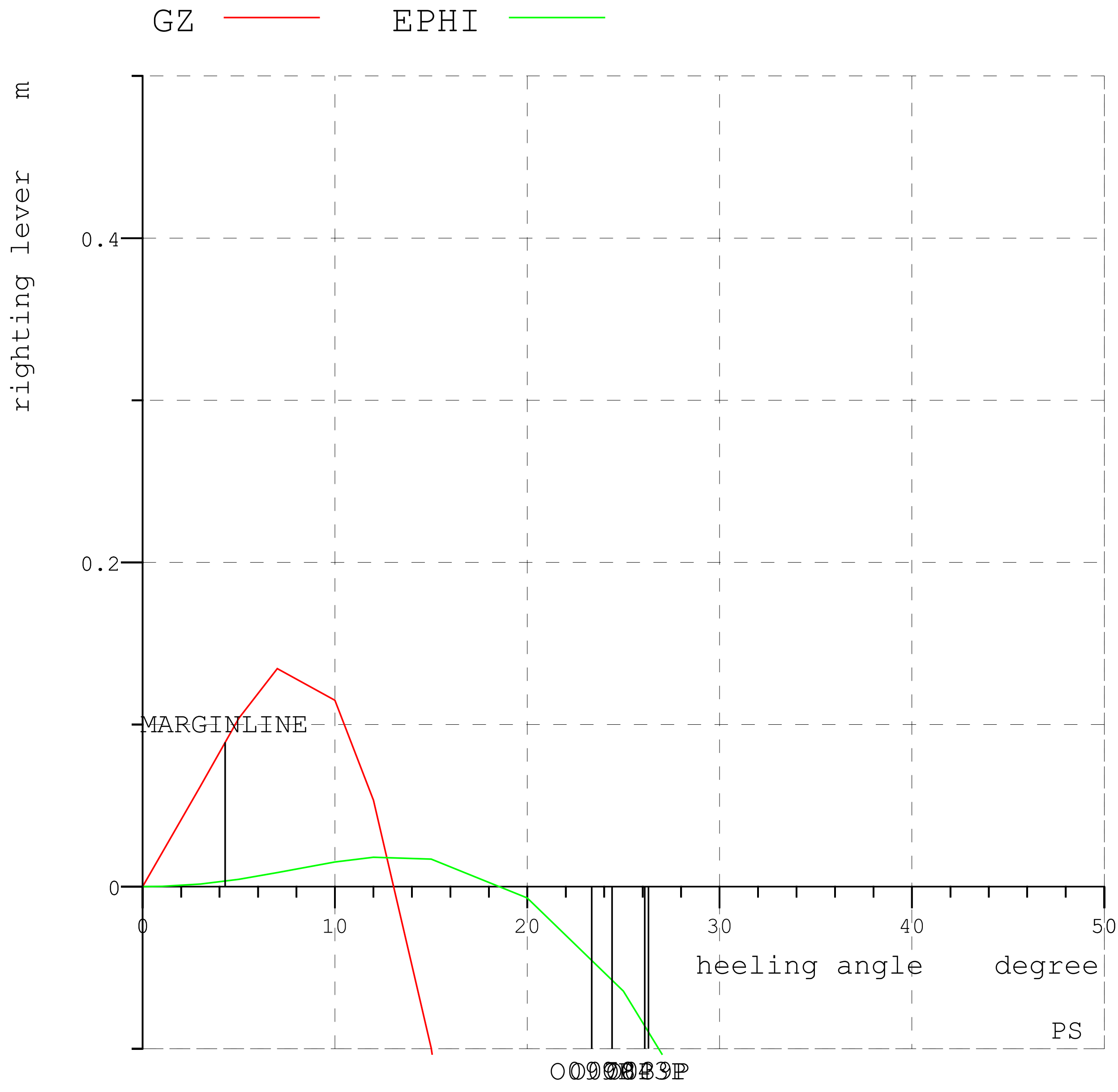
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP19-20.0.3

Proj	
Date	2005-12-01
Time	10:12
Sign	AH



Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel B, damage case DL/SDSP19-20.0.3: After the vessel was rebuilt

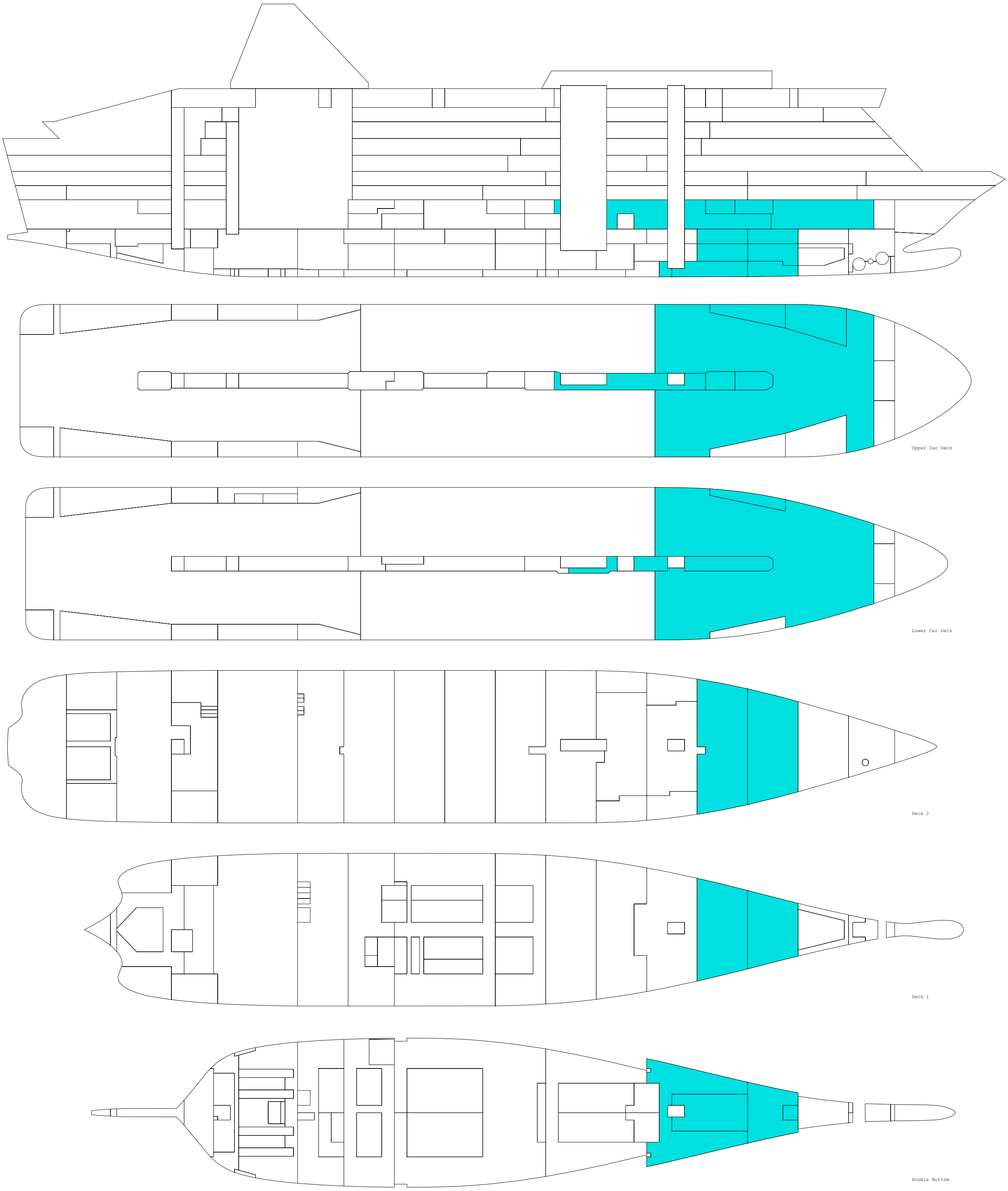
NAPA

Damage Definition

SDSP19-20.0.3

Proj	
Date	2005-12-13
Time	11:15
Sign	AH

Zones Z18-Z19 Port, h3



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP19-20.	INTACT	EQ	-	6.740	0.000	0.0	7.06	O034P	2.29
DL/SDSP19-20.	1	1	-	6.985	0.956	0.0	5.94	A151P	1.61
DL/SDSP19-20.	1	EQ	-	7.346	2.502	0.0	5.28	A151P	0.54

STATE OF COMPARTMENTS

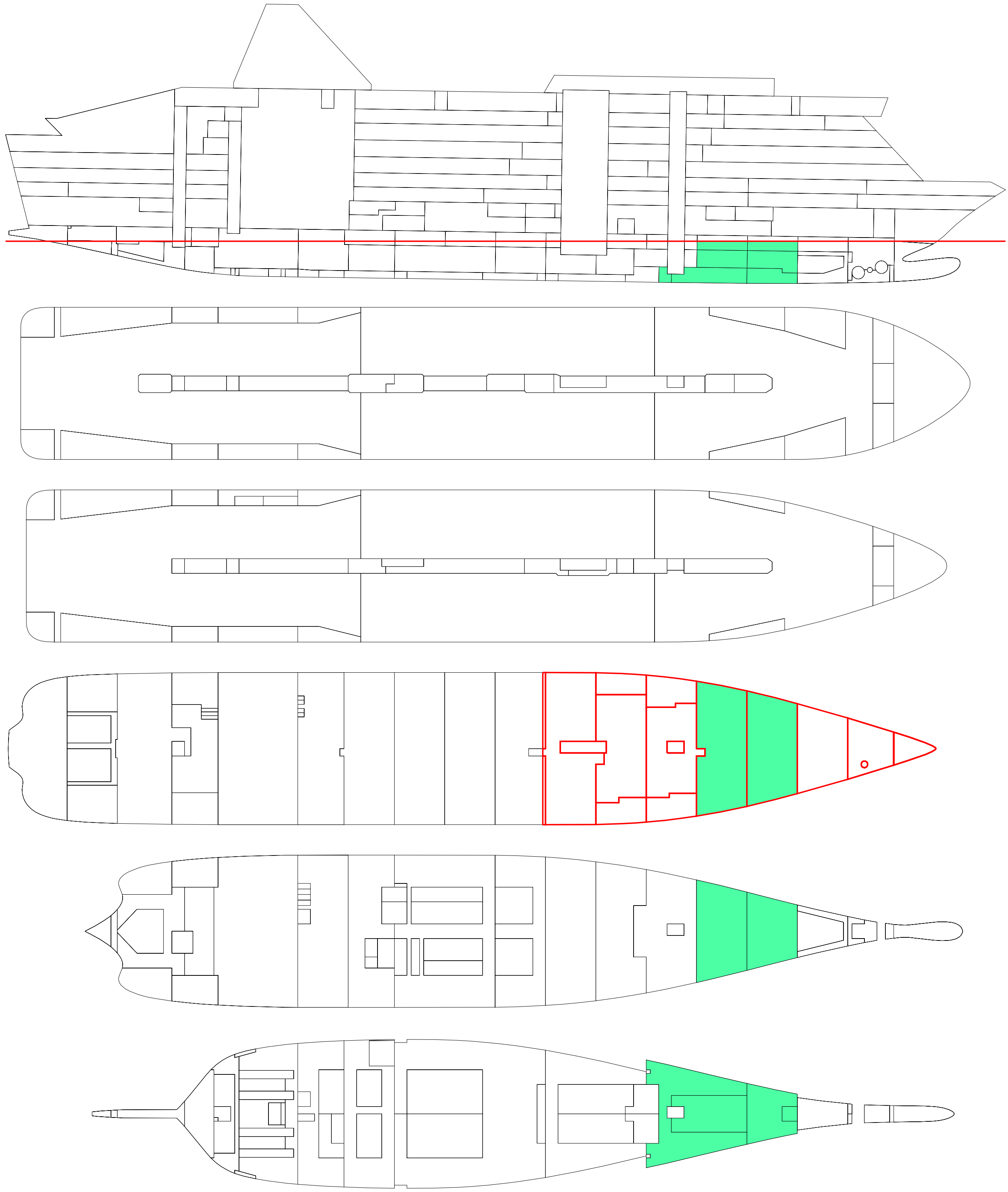
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP19-20.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	T1301	0.000	0.0	0.0	0.0	252.2	253.5
DL/SDSP19-20.	1	1	T1400	0.000	0.0	0.0	0.0	294.5	296.0
DL/SDSP19-20.	1	1	R3150	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	T1410	0.000	0.0	0.0	0.0	32.8	33.0
DL/SDSP19-20.	1	1	T1420	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R4140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R4150	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	T1500	0.000	0.0	0.0	0.0	162.5	163.3
DL/SDSP19-20.	1	1	T1510	0.000	0.0	0.0	0.0	29.8	29.9
DL/SDSP19-20.	1	1	T1520	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	1	R4161	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	T1301	0.000	0.0	0.0	0.0	252.2	253.5
DL/SDSP19-20.	1	EQ	T1400	0.000	0.0	0.0	0.0	294.5	296.0
DL/SDSP19-20.	1	EQ	R3150	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	T1410	0.000	0.0	0.0	0.0	342.7	344.5
DL/SDSP19-20.	1	EQ	T1420	0.000	0.0	0.0	0.0	357.9	359.7
DL/SDSP19-20.	1	EQ	R4140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	R4150	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP19-20.	1	EQ	T1500	0.000	0.0	0.0	0.0	162.5	163.3
DL/SDSP19-20.	1	EQ	T1510	0.000	0.0	0.0	0.0	255.1	256.3
DL/SDSP19-20.	1	EQ	T1520	0.000	0.0	0.0	0.0	319.6	321.2
DL/SDSP19-20.	1	EQ	R4161	0.000	0.0	0.0	0.0	0.0	0.0

NAPA

Floating position

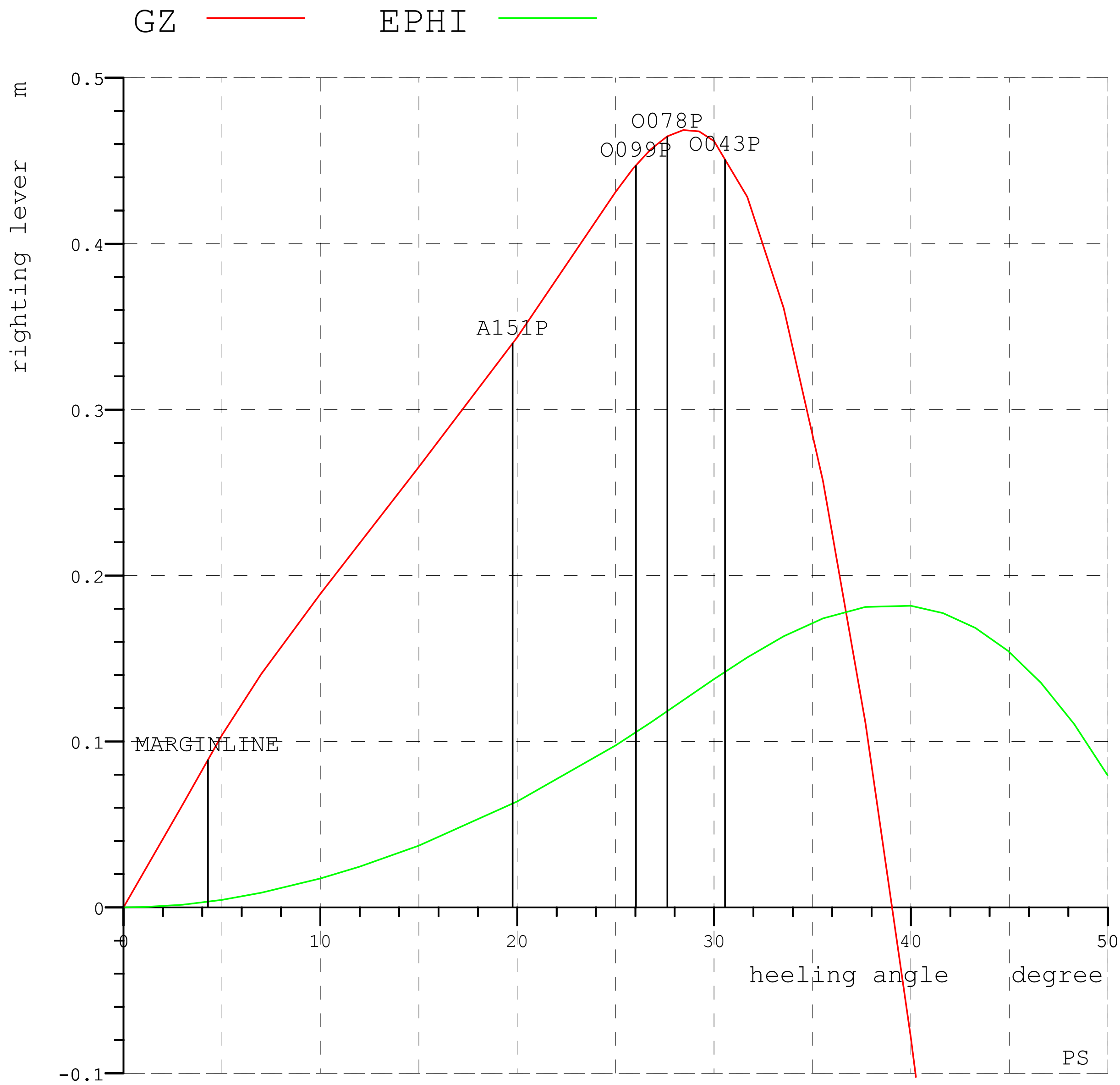
Case: DL/SDSP19-20.0.3

Proj	
Date	2005-12-01
Time	09:56
Sign	AH



Stage: 1 Phase: EQ

NAPA	GZ curve Case: DL/SDSP19-20.0.3	Proj Date 2005-12-01 Time 09:57 Sign AH

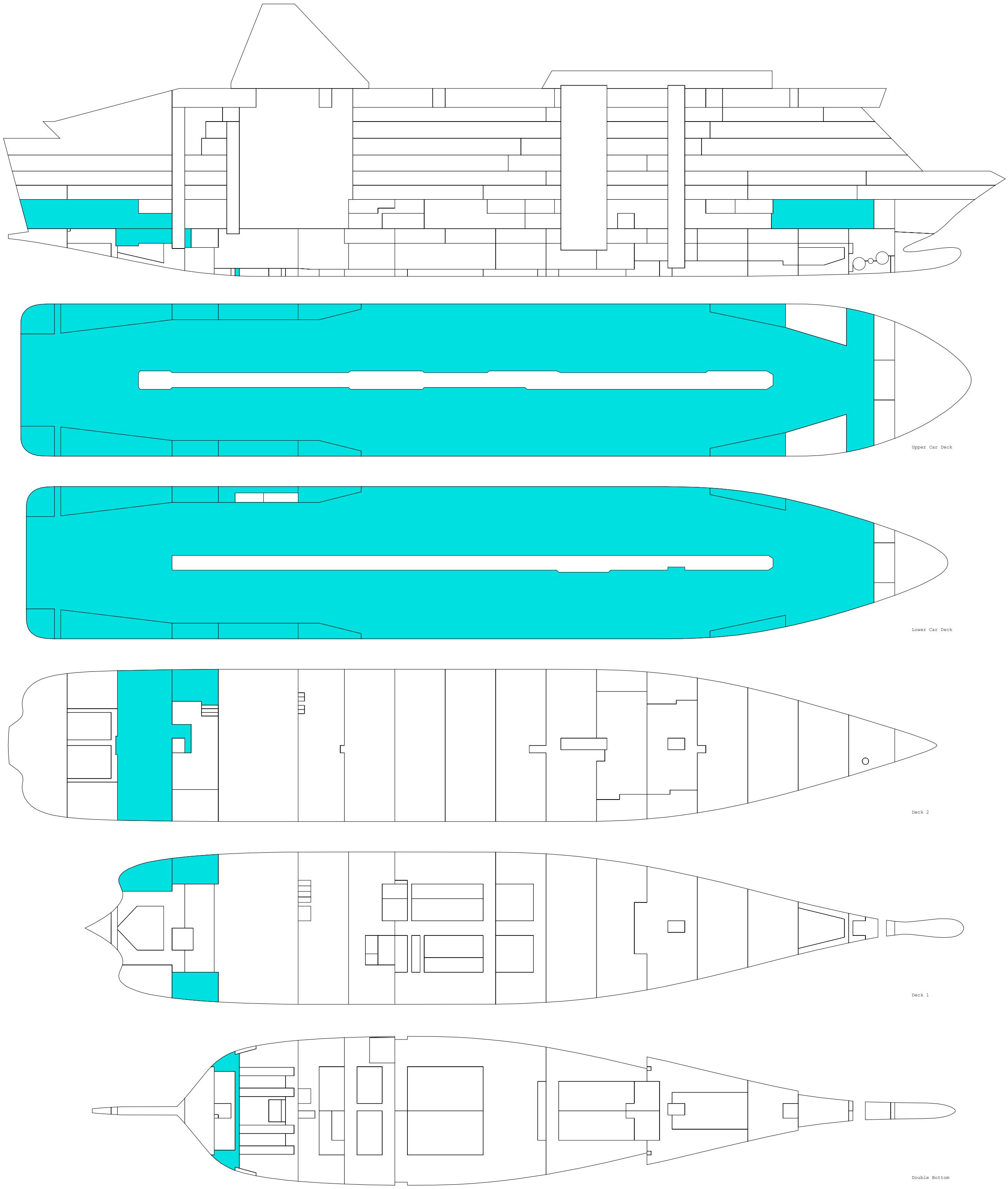


Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel B, damage case DL/SDSP3-4.1.4: Before the vessel was rebuilt

NAPA	Damage Definition SDSP3-4.1.4	Proj Date 2005-12-13 Time 11:08 Sign AH

Zones Z3-Z4 Port, b1, h4



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP3-4.1.	INTACT	EQ	-	6.740	0.000	0.0	7.06	O034P	2.29
DL/SDSP3-4.1.	1	1	PS	6.766	-0.144	0.1	6.94	O034P	2.16
DL/SDSP3-4.1.	1	EQ	PS	6.805	-0.800	6.0	5.12	O034P	0.26

STATE OF COMPARTMENTS

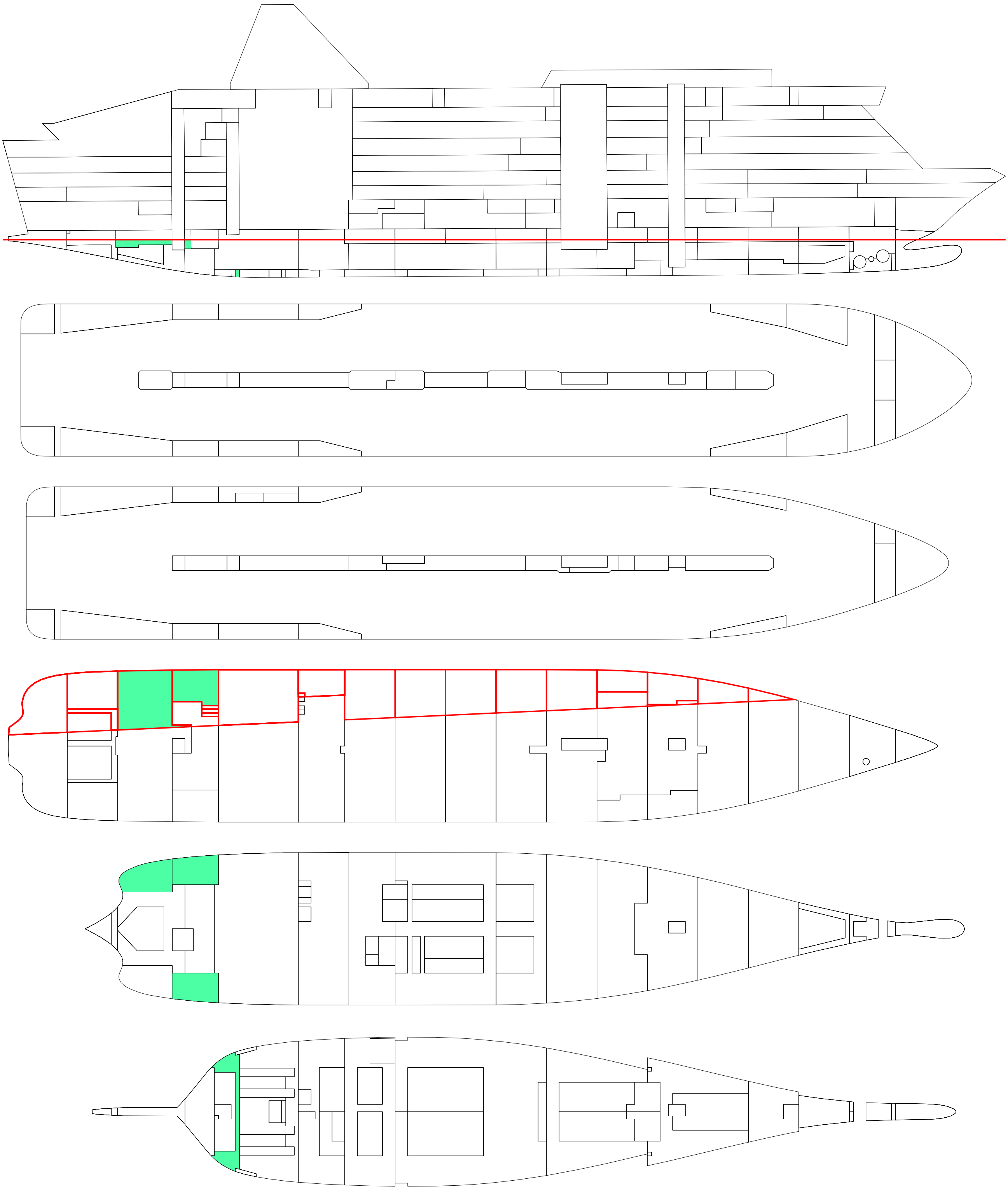
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP3-4.1.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3011	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3012	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3022	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3042	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3051	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3052	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3061	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3062	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3142	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	T320	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	T311	0.000	0.0	0.0	0.0	7.1	7.1
DL/SDSP3-4.1.	1	1	T400	0.000	0.0	0.0	0.0	139.2	139.9
DL/SDSP3-4.1.	1	1	T427	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3011	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3012	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3022	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3042	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3051	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3052	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3061	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3062	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3142	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	T320	0.000	0.0	0.0	0.0	184.6	185.5
DL/SDSP3-4.1.	1	EQ	T311	0.000	0.0	0.0	0.0	158.1	158.8
DL/SDSP3-4.1.	1	EQ	T400	0.000	0.0	0.0	0.0	326.5	328.1
DL/SDSP3-4.1.	1	EQ	T427	0.000	0.0	0.0	0.0	131.2	131.9

NAPA

Floating position

Case: DL/SDSP3-4.1.4

Proj	
Date	2005-12-13
Time	11:09
Sign	AH



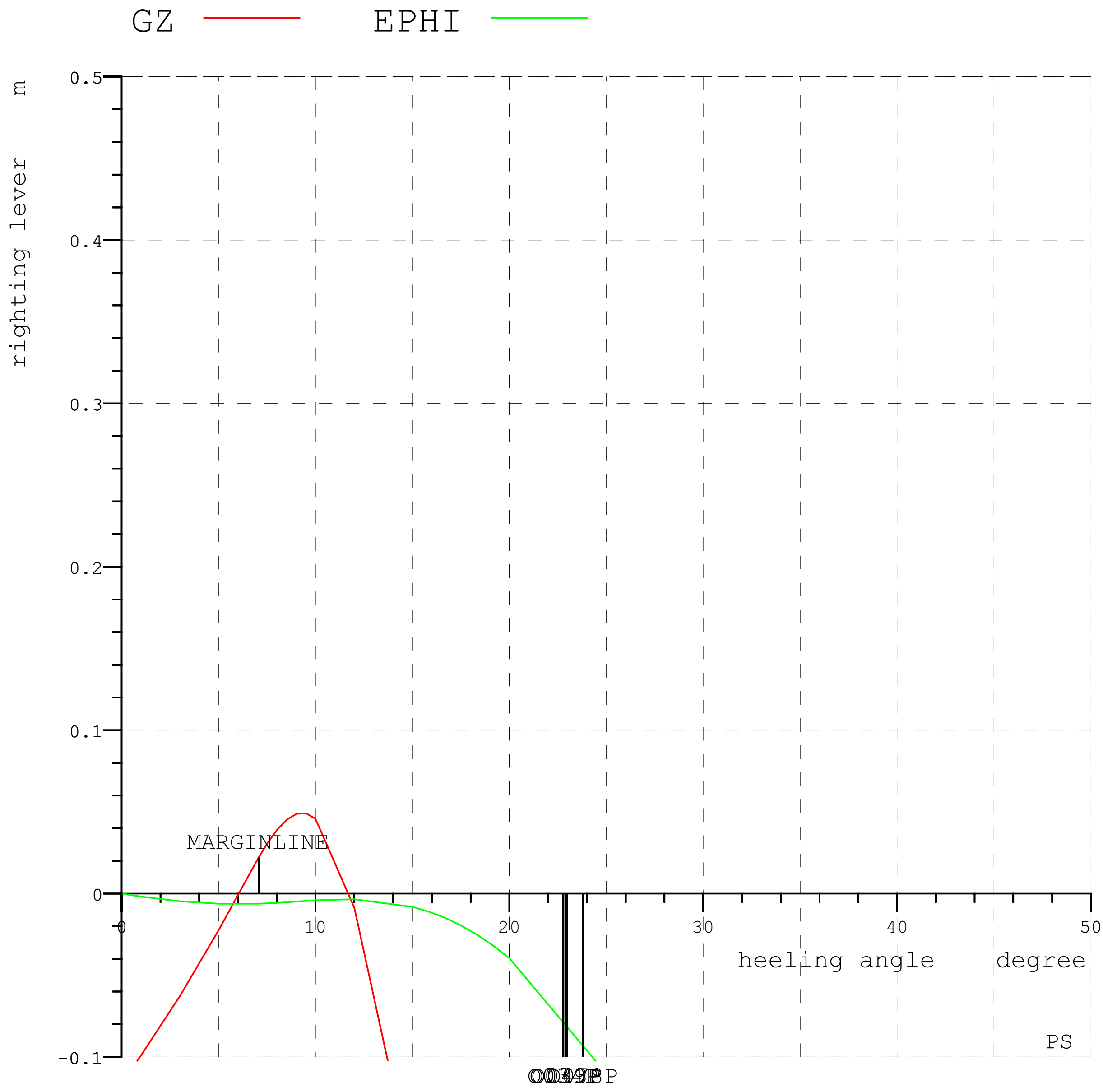
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP3-4.1.4

Proj	
Date	2005-12-13
Time	11:10
Sign	AH

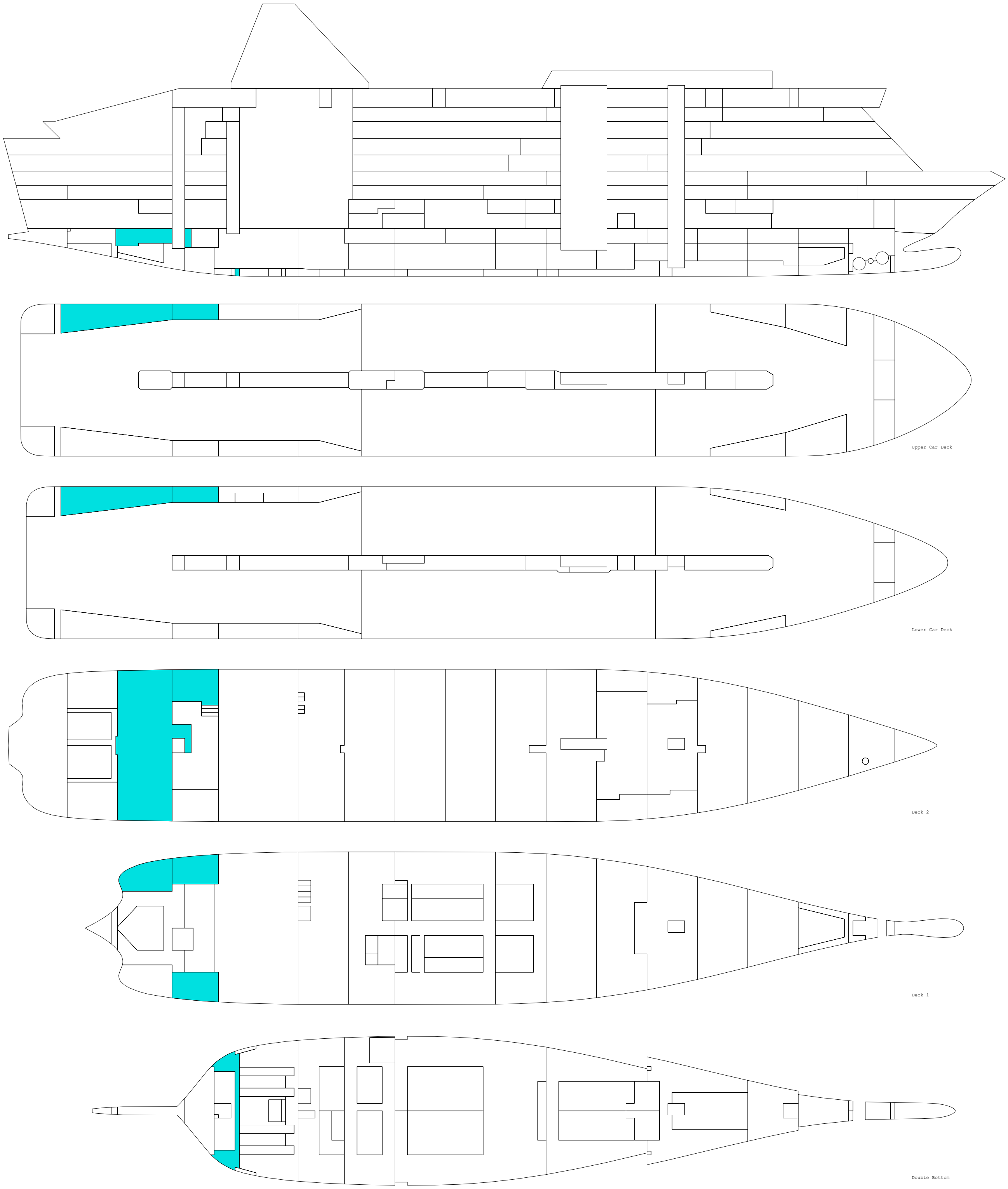


Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel B, damage case DL/SDSP3-4.1.4: After the vessel was rebuilt

NAPA	Damage Definition SDSP3-4.1.4	Proj
		Date 2005-12-13
		Time 11:04
		Sign AH

Zones Z3-Z4 Port, b1, h4



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP3-4.1.	INTACT	EQ	-	6.740	0.000	0.0	7.06	O034P	2.29
DL/SDSP3-4.1.	1	1	PS	6.766	-0.144	0.1	6.94	O034P	2.16
DL/SDSP3-4.1.	1	EQ	PS	6.805	-0.800	6.0	5.12	O034P	0.26

STATE OF COMPARTMENTS

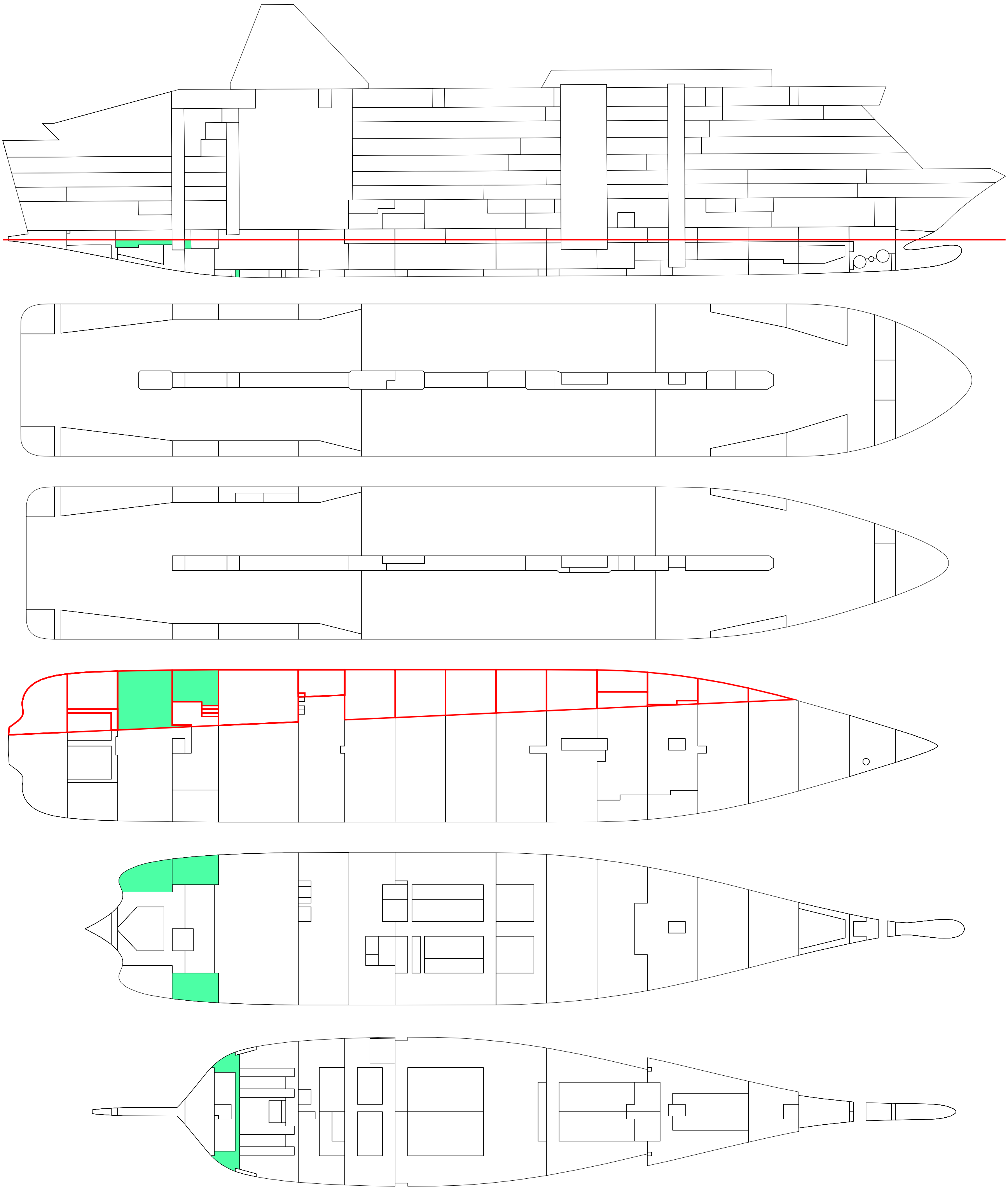
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP3-4.1.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	T320	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	T311	0.000	0.0	0.0	0.0	7.1	7.1
DL/SDSP3-4.1.	1	1	T400	0.000	0.0	0.0	0.0	139.2	139.9
DL/SDSP3-4.1.	1	1	T427	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	1	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP3-4.1.	1	EQ	T320	0.000	0.0	0.0	0.0	184.6	185.5
DL/SDSP3-4.1.	1	EQ	T311	0.000	0.0	0.0	0.0	158.1	158.8
DL/SDSP3-4.1.	1	EQ	T400	0.000	0.0	0.0	0.0	326.5	328.1
DL/SDSP3-4.1.	1	EQ	T427	0.000	0.0	0.0	0.0	131.2	131.9
DL/SDSP3-4.1.	1	EQ	R3041	0.000	0.0	0.0	0.0	0.0	0.0

NAPA

Floating position

Case: DL/SDSP3-4.1.4

Proj	
Date	2005-12-13
Time	11:05
Sign	AH



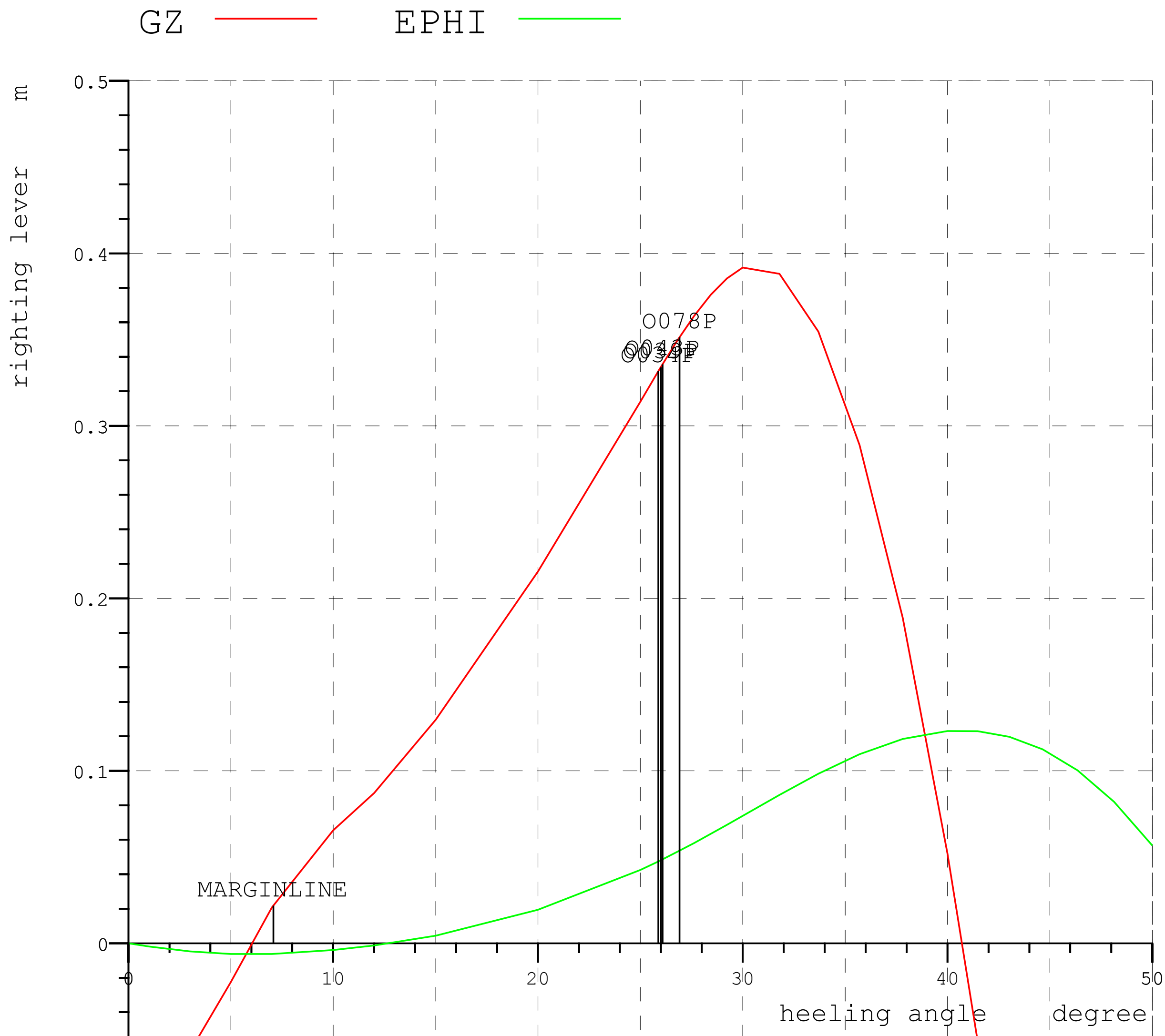
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP3-4.1.4

Proj	
Date	2005-12-13
Time	11:06
Sign	AH



Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel B, damage case DL/SDSP13-14.2.3-1: Before the vessel was rebuilt

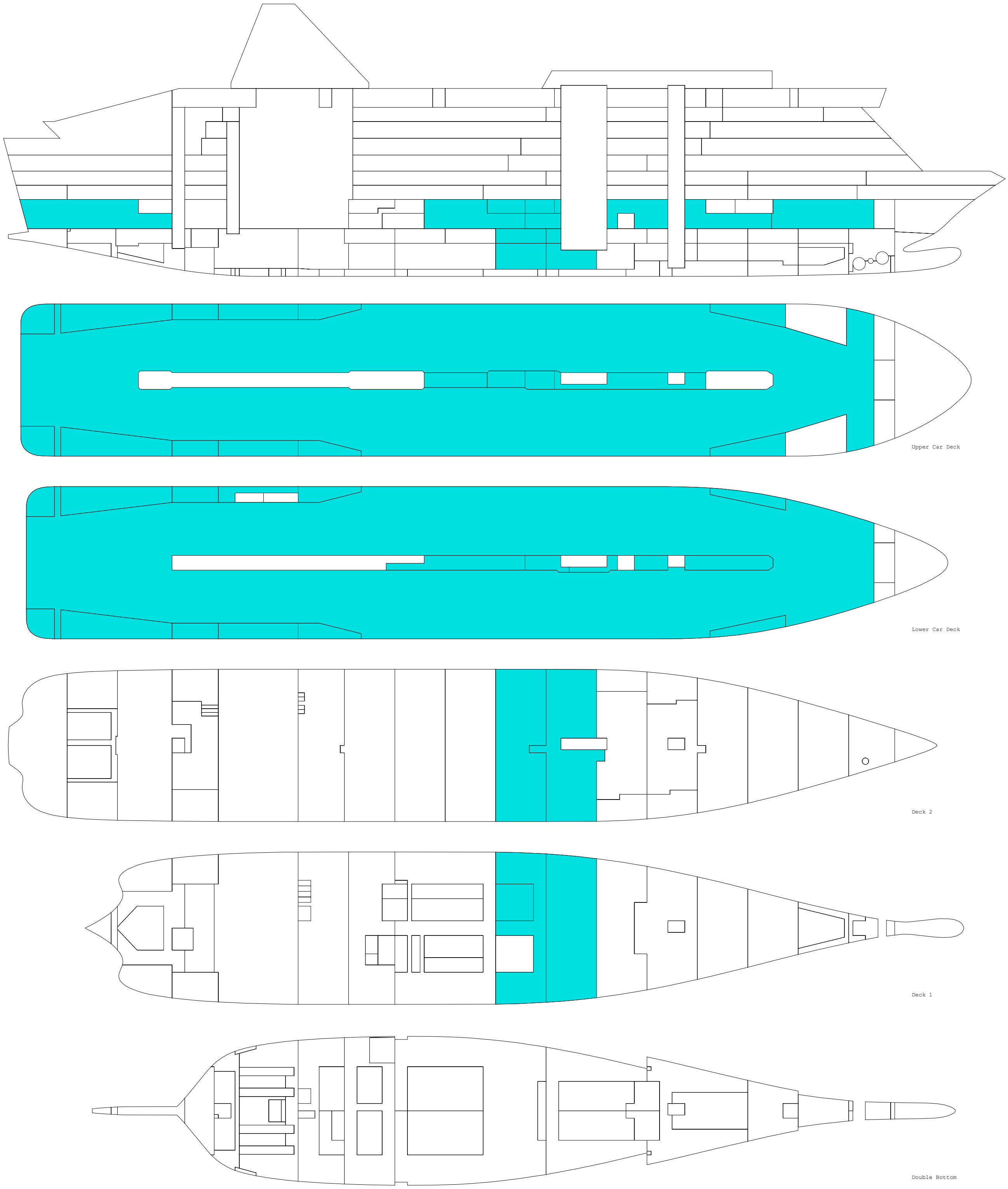
NAPA

Damage Definition

SDSP13-14.2.3-1

Proj	
Date	2005-12-13
Time	11:31
Sign	AH

Zones Z13-Z14 Port, b2, h3, l.ext1



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP13-14.	INTACT	EQ	-	6.740	0.000	0.0	7.06	O034P	2.29
DL/SDSP13-14.	1	1	PS	7.015	0.532	2.6	6.15	O099P	1.25
DL/SDSP13-14.	1	EQ	PS	7.424	1.255	3.7	5.50	O099P	0.39

STATE OF COMPARTMENTS

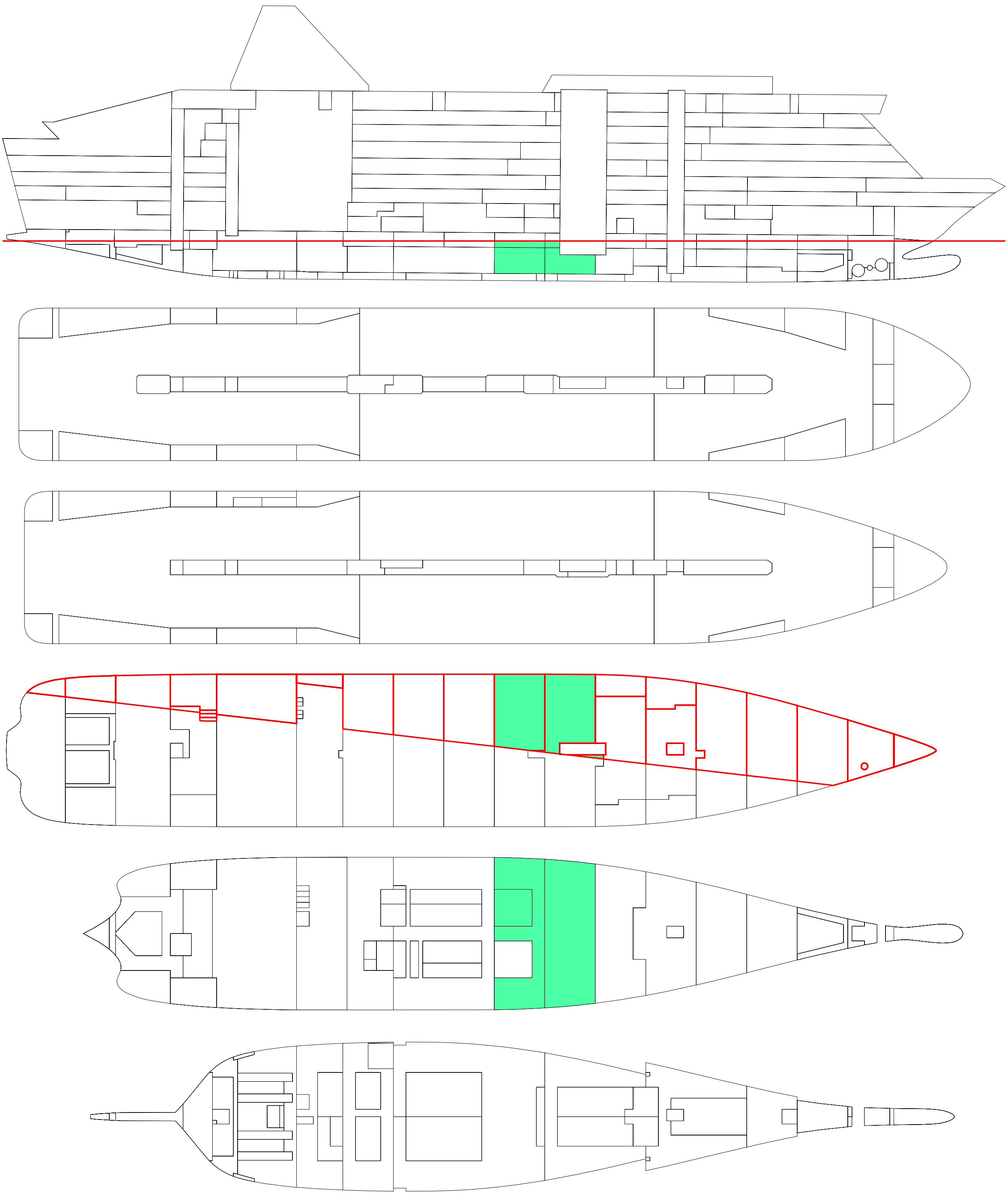
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP13-14.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3011	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3012	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3022	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3042	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3051	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3052	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3061	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3062	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3142	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3090	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R4100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T1010	0.000	0.0	0.0	0.0	368.2	370.0
DL/SDSP13-14.	1	1	T1011	0.000	0.0	0.0	0.0	137.2	137.9
DL/SDSP13-14.	1	1	T1020	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R4110	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T1120	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T1110	0.000	0.0	0.0	0.0	547.2	549.9
DL/SDSP13-14.	1	1	R3140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3011	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3012	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3021	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3022	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3041	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3042	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3051	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3052	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3061	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3062	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3141	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3142	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3090	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R4100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T1010	0.000	0.0	0.0	0.0	780.9	784.8
DL/SDSP13-14.	1	EQ	T1011	0.000	0.0	0.0	0.0	198.7	199.7
DL/SDSP13-14.	1	EQ	T1020	0.000	0.0	0.0	0.0	308.3	309.9
DL/SDSP13-14.	1	EQ	R3100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R4110	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T1120	0.000	0.0	0.0	0.0	322.0	323.6
DL/SDSP13-14.	1	EQ	T1110	0.000	0.0	0.0	0.0	1049.8	1055.0
DL/SDSP13-14.	1	EQ	R3140	0.000	0.0	0.0	0.0	0.0	0.0

NAPA

Floating position

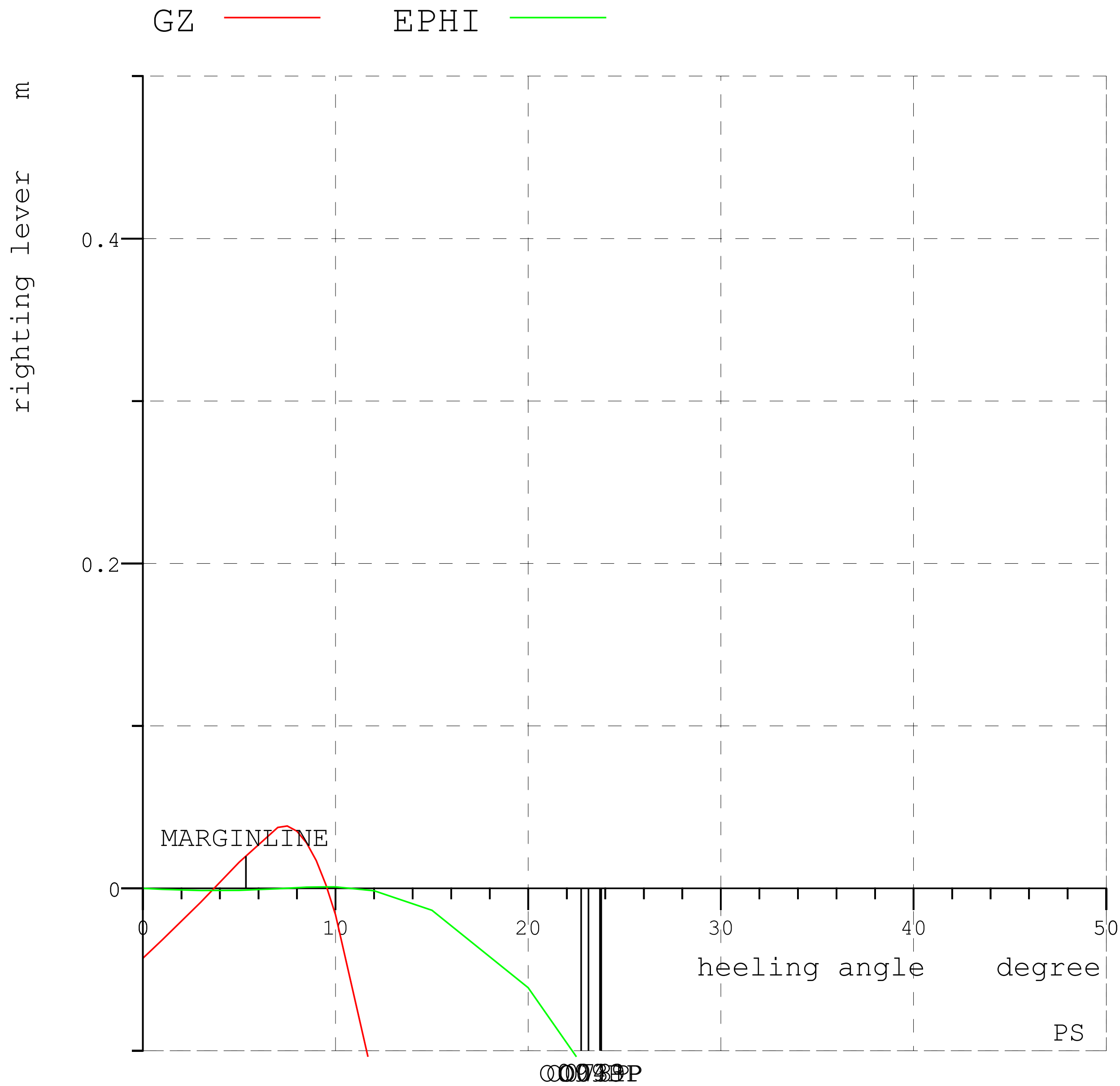
Case: DL/SDSP13-14.2.3-1

Proj	
Date	2005-12-30
Time	11:35
Sign	AH



Stage: 1 Phase: EQ

NAPA	GZ curve Case: DL/SDSP13-14.2.3-1	Proj Date 2005-12-13 Time 11:32 Sign AH



Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel B, damage case DL/SDSP13-14.2.3-1: After the vessel was rebuilt

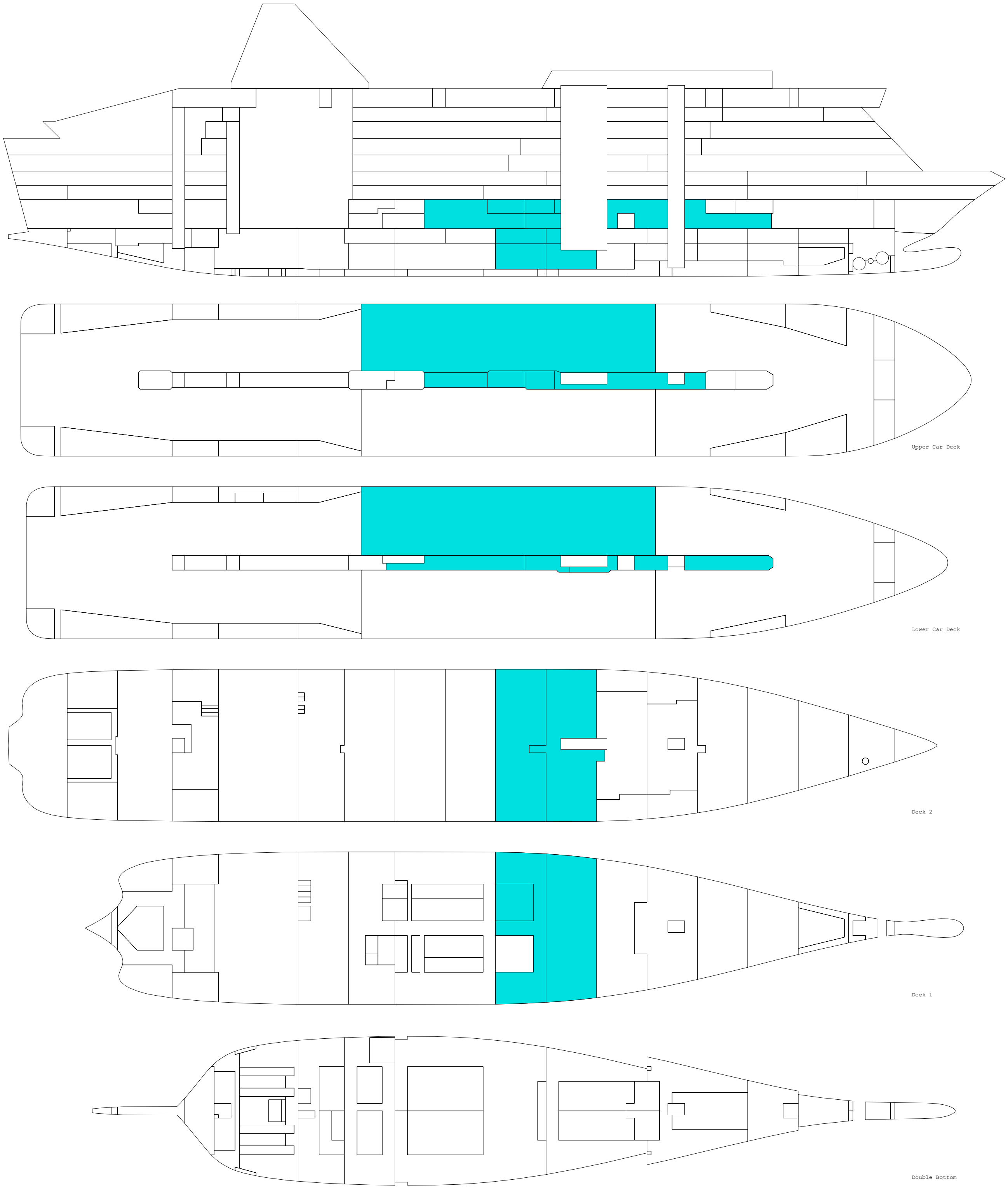
NAPA

Damage Definition

SDSP13-14.2.3-1

Proj	
Date	2005-12-13
Time	11:30
Sign	AH

Zones Z13-Z14 Port, b2, h3, l.ext1



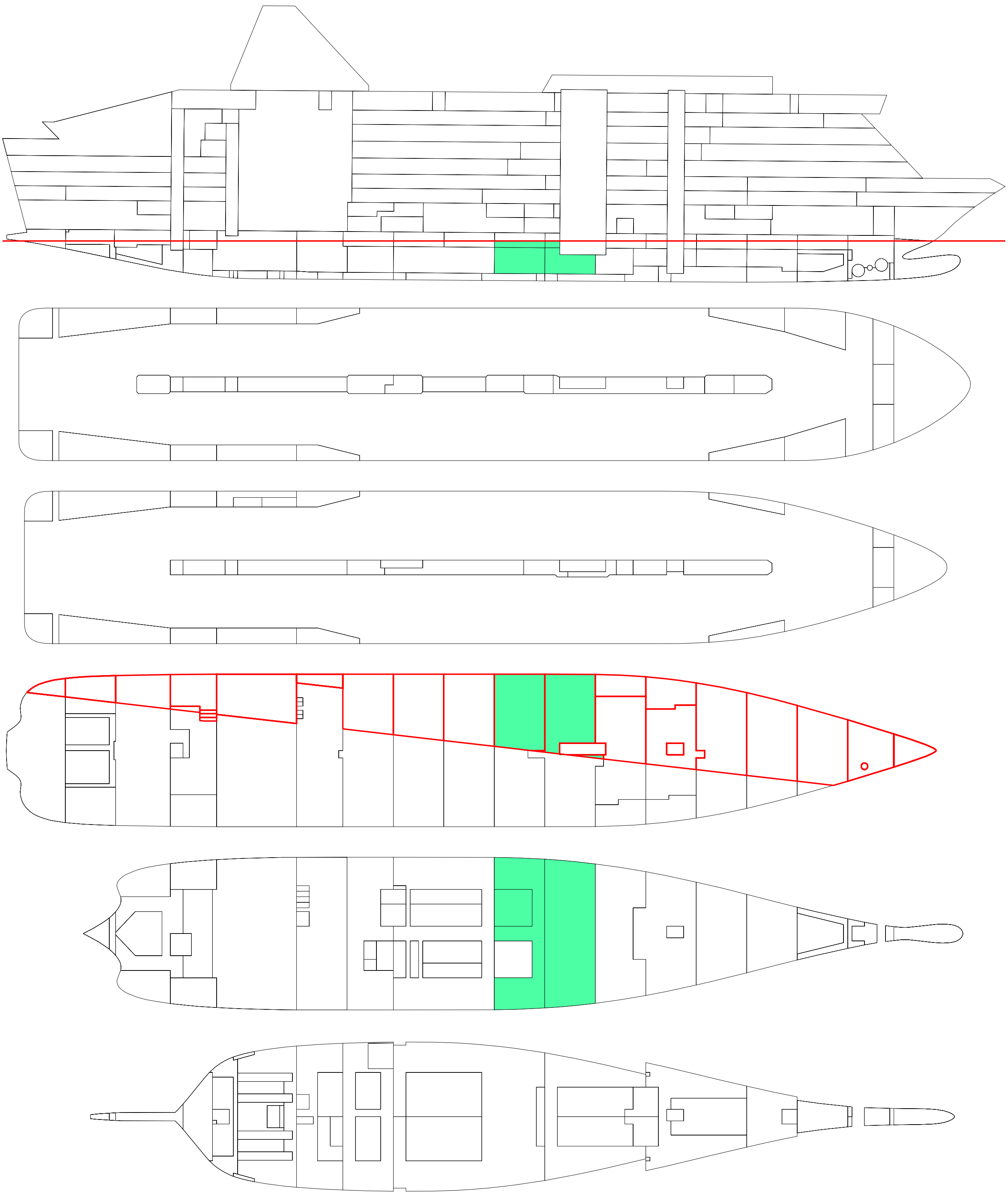
FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP13-14.	INTACT	EQ	-	6.740	0.000	0.0	7.06	O034P	2.29
DL/SDSP13-14.	1	1	PS	7.015	0.532	2.6	5.31	A151P	1.25
DL/SDSP13-14.	1	EQ	PS	7.424	1.255	3.7	4.48	A151P	0.39

STATE OF COMPARTMENTS

CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP13-14.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3101	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3090	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R4100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T1010	0.000	0.0	0.0	0.0	368.2	370.0
DL/SDSP13-14.	1	1	T1011	0.000	0.0	0.0	0.0	137.2	137.9
DL/SDSP13-14.	1	1	T1020	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R3100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	R4110	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T1120	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T1110	0.000	0.0	0.0	0.0	547.2	549.9
DL/SDSP13-14.	1	1	R3140	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3101	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R3090	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R4100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T1010	0.000	0.0	0.0	0.0	780.9	784.8
DL/SDSP13-14.	1	EQ	T1011	0.000	0.0	0.0	0.0	198.7	199.7
DL/SDSP13-14.	1	EQ	T1020	0.000	0.0	0.0	0.0	308.3	309.9
DL/SDSP13-14.	1	EQ	R3100	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	R4110	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T1120	0.000	0.0	0.0	0.0	322.0	323.6
DL/SDSP13-14.	1	EQ	T1110	0.000	0.0	0.0	0.0	1049.8	1055.0
DL/SDSP13-14.	1	EQ	R3140	0.000	0.0	0.0	0.0	0.0	0.0

NAPA	Floating position Case: DL/SDSP13-14.2.3-1	Proj Date 2005-12-30 Time 11:45 Sign AH



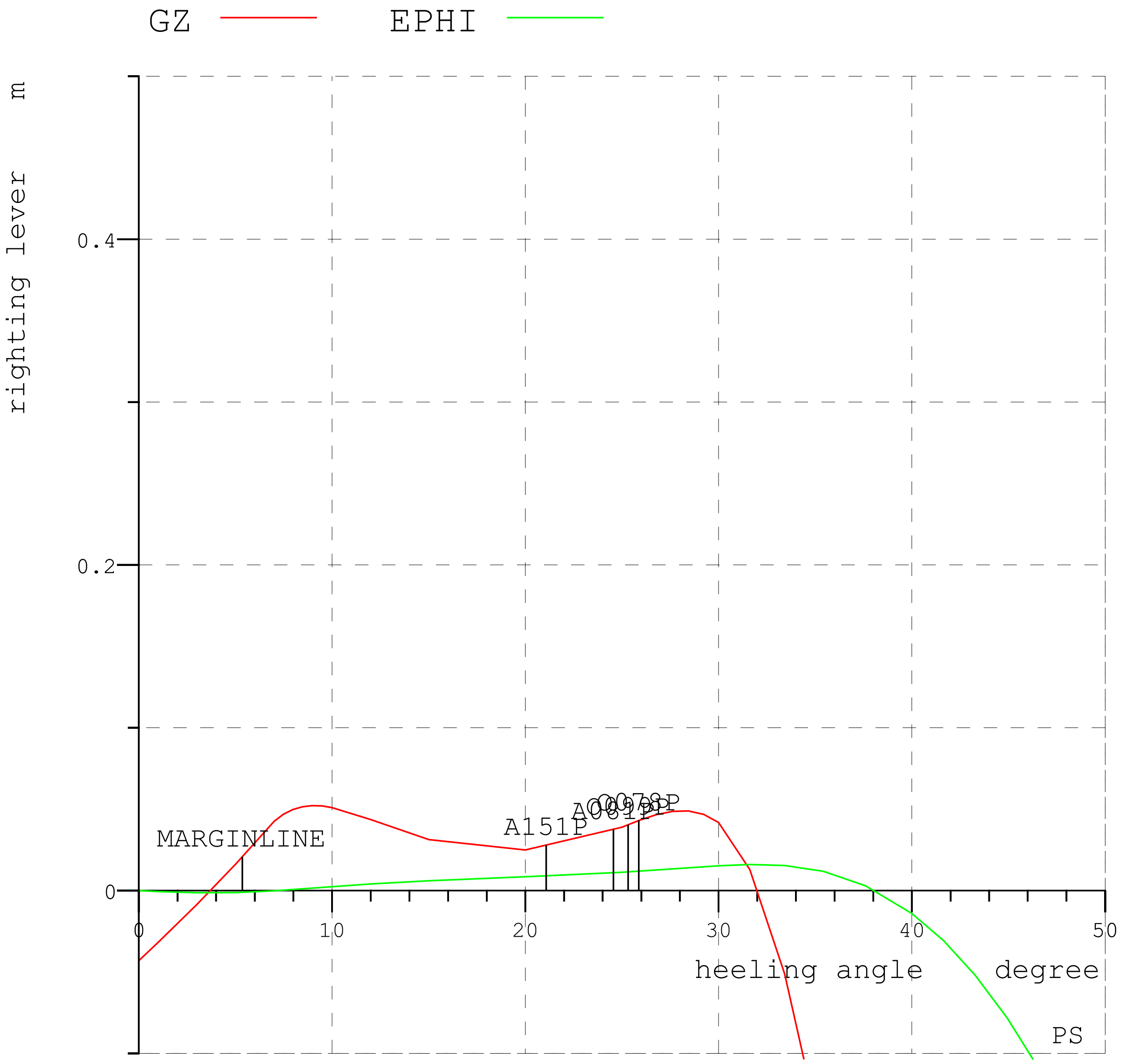
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP13-14.2.3-1

Proj	
Date	2005-12-13
Time	11:29
Sign	AH



Stage: 1 Phase: EQ

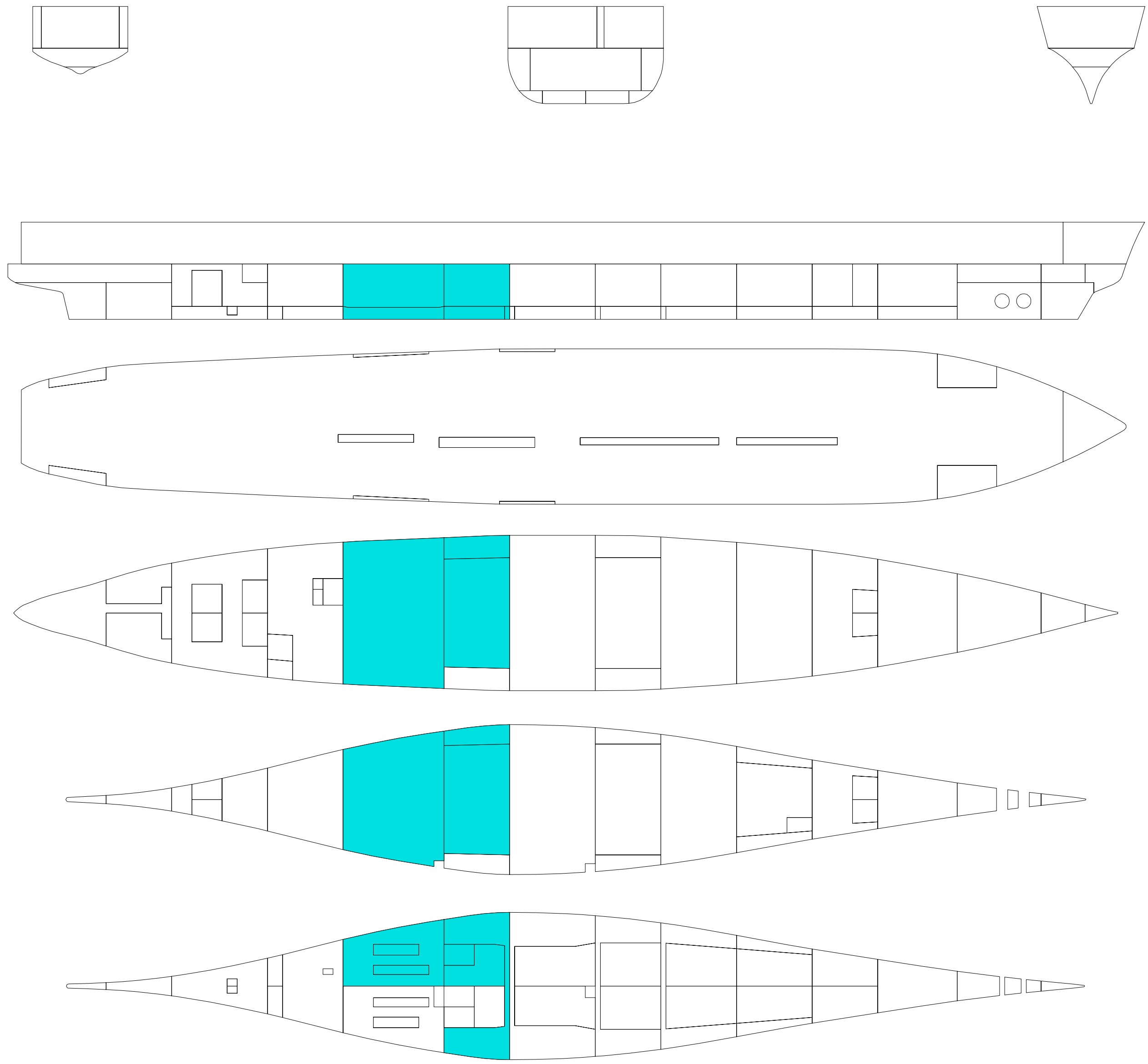
Appendix D: Ro-ro passenger vessel A – Stability data for studied damage cases

This Appendix contains damage definitions, floating positions and stability curves of some damage cases studied in Chapter 4.

Calculated data for ro-ro passenger vessel A, damage case DL/SDSP12-13.0.1: Before the vessel was rebuilt

NAPA	Damage Definition SDSP12-13.0.1	Proj P118B/A Date 2005-12-13 Time 10:32 Sign AH

Zones Z12-Z13 Port, h1



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP12-13.	INTACT	EQ	-	5.720	0.000	0.0	-	-	1.90
DL/SDSP12-13.	1	1	PS	5.936	-0.452	6.0	-	-	0.49
DL/SDSP12-13.	1	EQ	PS	6.434	-1.359	7.3	-	-	-0.55

STATE OF COMPARTMENTS

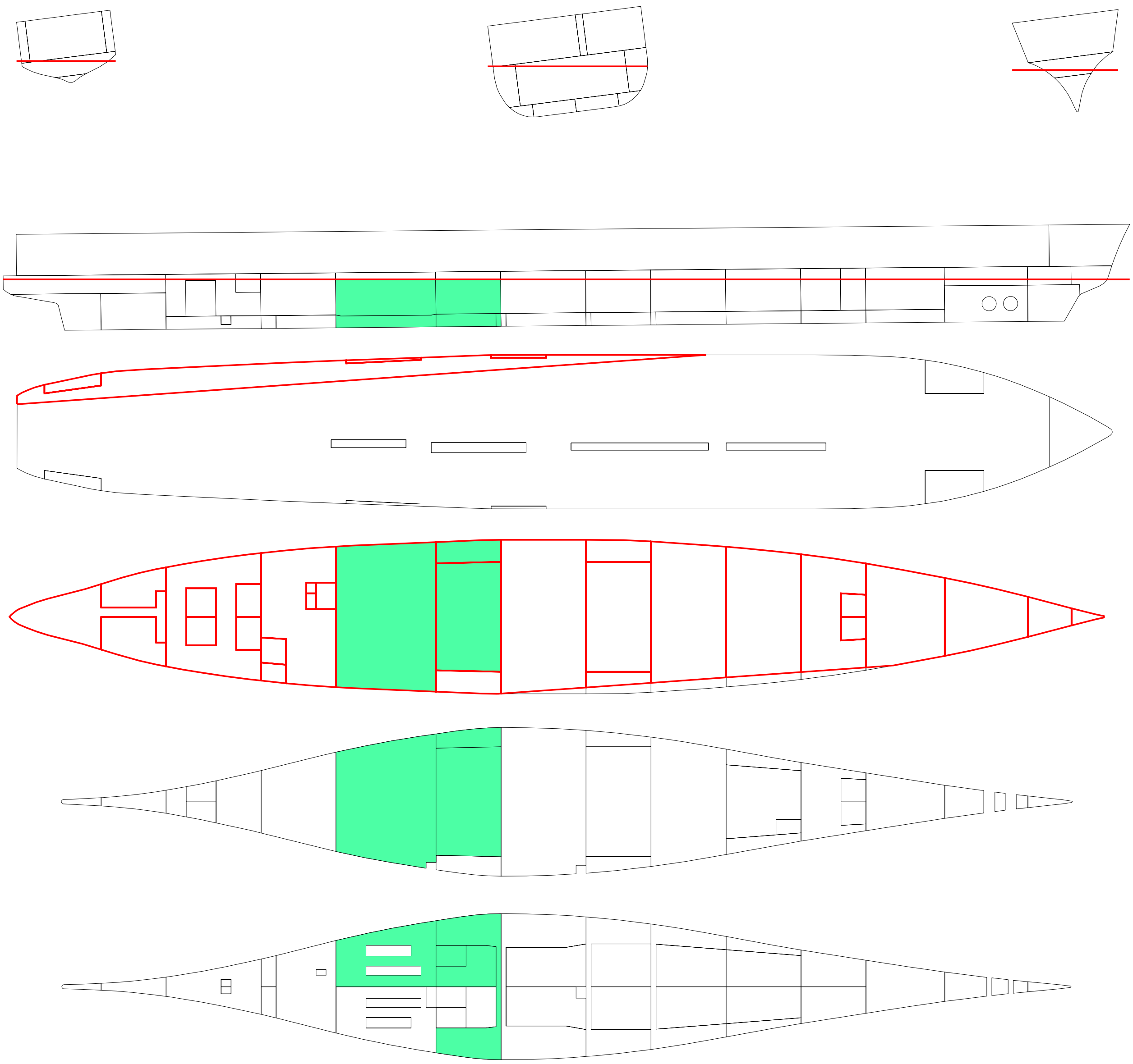
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP12-13.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP12-13.	1	1	T2.4	0.000	0.0	0.0	0.0	15.4	15.8
DL/SDSP12-13.	1	1	T2.6	0.000	0.0	0.0	0.0	12.8	13.2
DL/SDSP12-13.	1	1	T7.12	0.000	0.0	0.0	0.0	116.0	118.9
DL/SDSP12-13.	1	1	R0401	0.000	0.0	0.0	0.0	239.1	245.1
DL/SDSP12-13.	1	1	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP12-13.	1	1	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP12-13.	1	1	T7.11	0.000	0.0	0.0	0.0	113.9	116.8
DL/SDSP12-13.	1	1	T4.12	0.000	0.0	0.0	0.0	46.4	47.5
DL/SDSP12-13.	1	1	R0501	0.000	0.0	0.0	0.0	111.1	113.9
DL/SDSP12-13.	1	EQ	T2.4	0.000	0.0	0.0	0.0	15.4	15.8
DL/SDSP12-13.	1	EQ	T2.6	0.000	0.0	0.0	0.0	12.8	13.2
DL/SDSP12-13.	1	EQ	T7.12	0.000	0.0	0.0	0.0	116.0	118.9
DL/SDSP12-13.	1	EQ	R0401	0.000	0.0	0.0	0.0	1162.8	1191.9
DL/SDSP12-13.	1	EQ	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP12-13.	1	EQ	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP12-13.	1	EQ	T7.11	0.000	0.0	0.0	0.0	114.4	117.2
DL/SDSP12-13.	1	EQ	T4.12	0.000	0.0	0.0	0.0	152.2	156.0
DL/SDSP12-13.	1	EQ	R0501	0.000	0.0	0.0	0.0	567.5	581.7

NAPA

Floating position

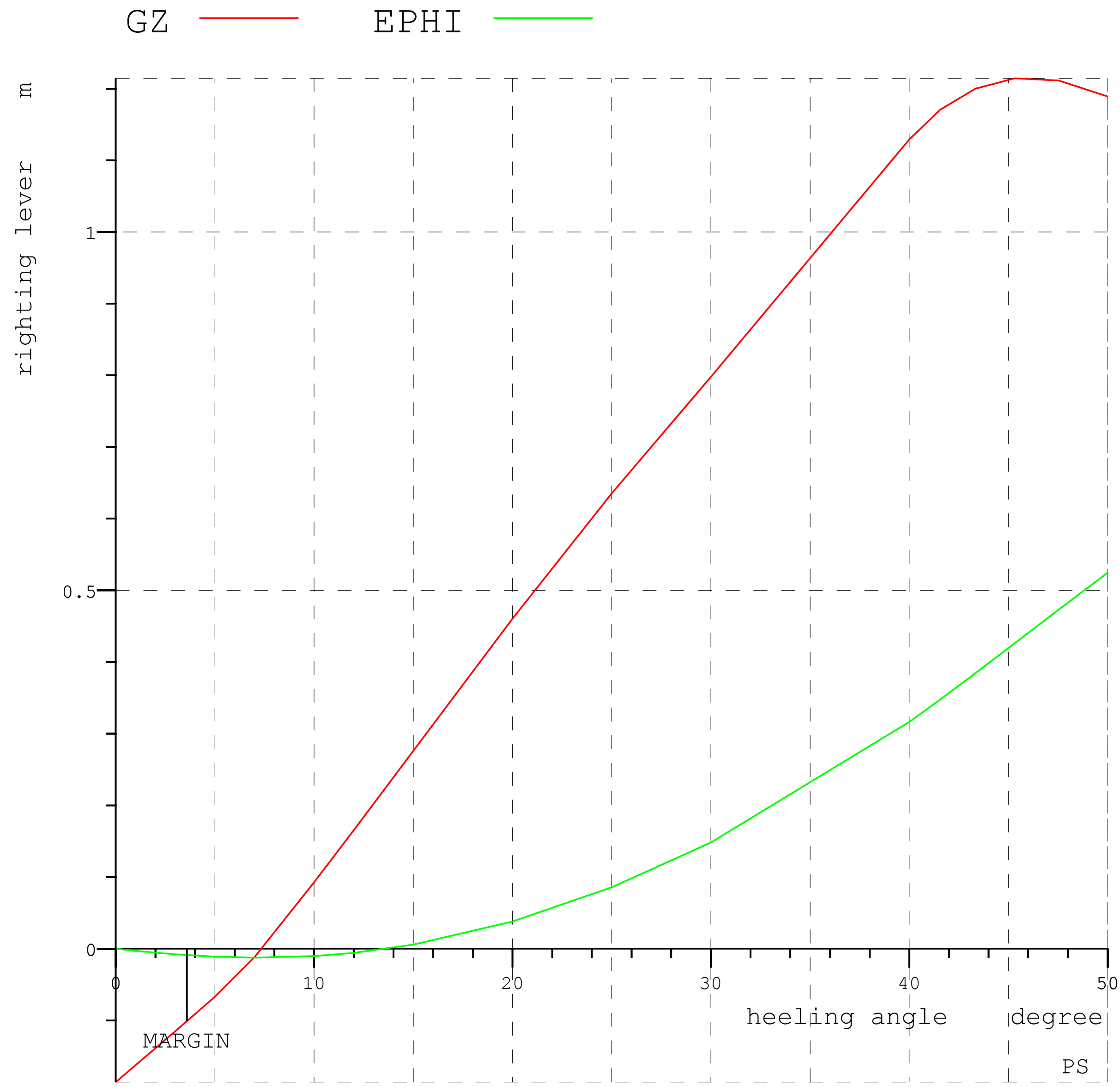
Case: DL/SDSP12-13.0.1

Proj	P118B/A
Date	2005-12-13
Time	10:33
Sign	AH



Stage: 1   Phase: EQ

NAPA	GZ curve Case: DL/SDSP12-13.0.1	Proj P118B/A Date 2005-12-13 Time 10:35 Sign AH

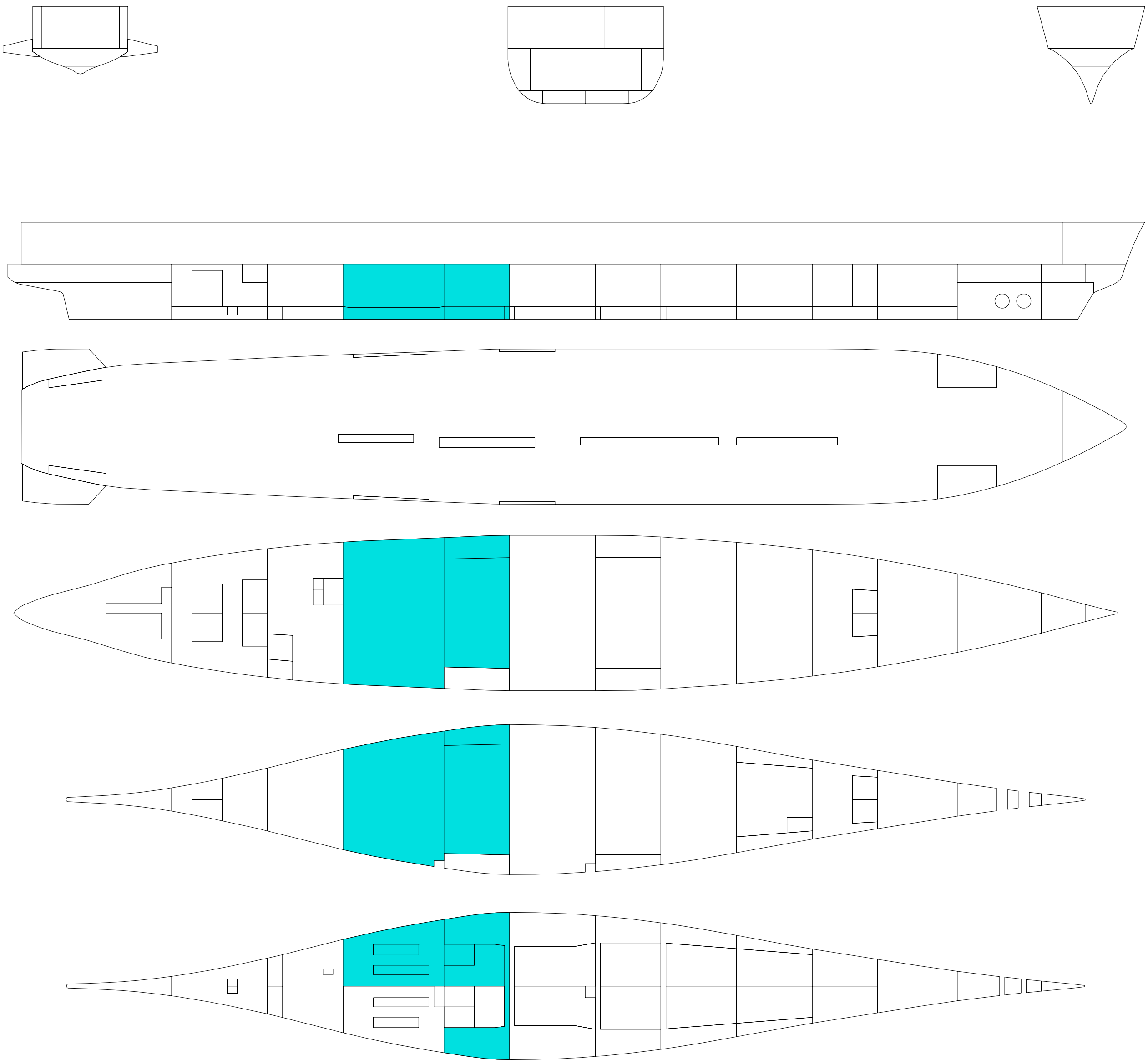


Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel A, damage case DL/SDSP12-13.0.1: After the vessel was rebuilt

NAPA	Damage Definition SDSP12-13.0.1	Proj P118/A Date 2005-12-13 Time 10:26 Sign AH

Zones Z12-Z13 Port, h1



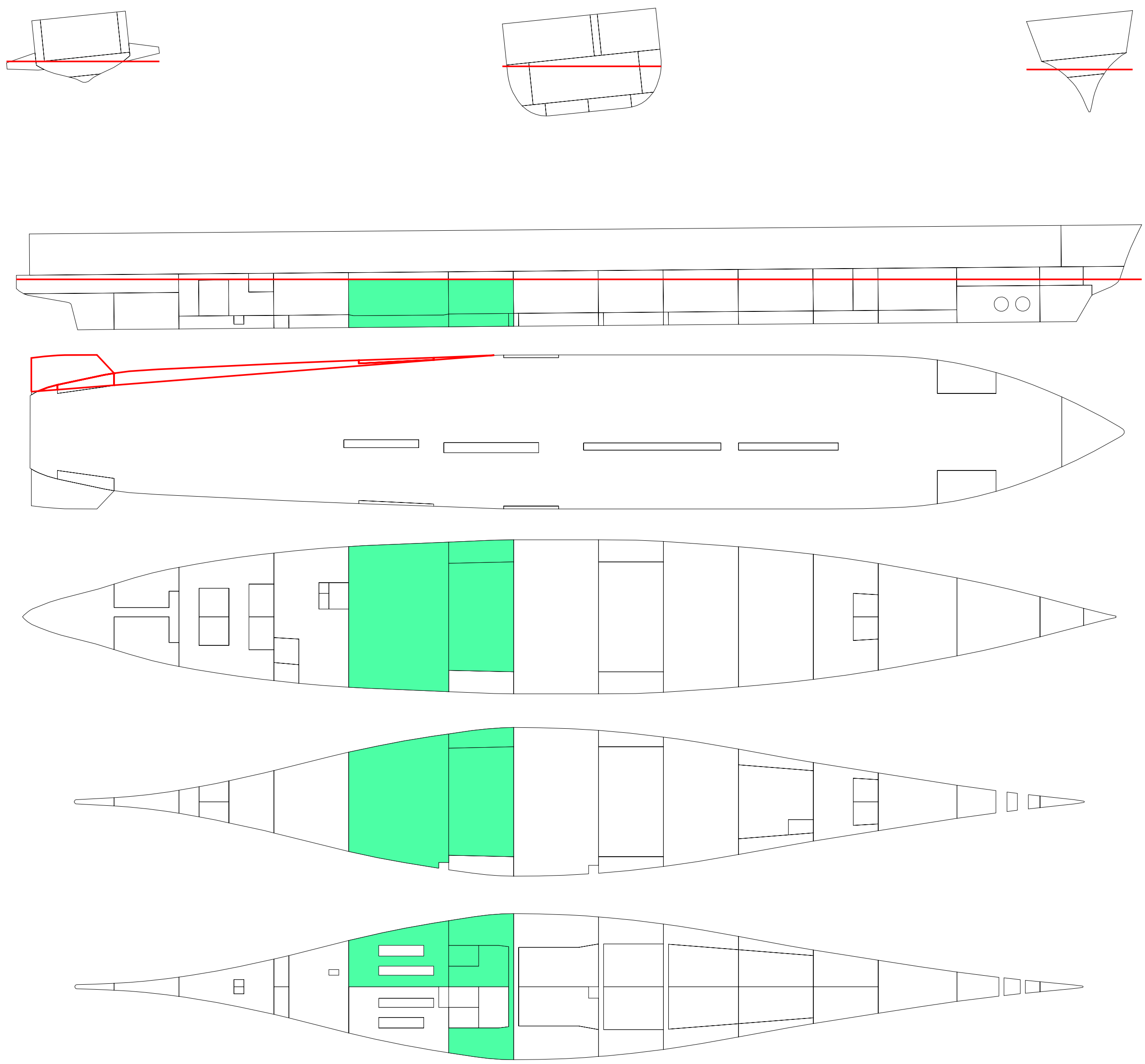
FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T	TR	HEEL	RESFLD	OPEN	RESMRG
				m	m	degree	m		m
DL/SDSP12-13.	INTACT	EQ	-	5.720	0.000	0.0	-	-	1.90
DL/SDSP12-13.	1	1	PS	5.942	-0.427	5.5	-	-	0.57
DL/SDSP12-13.	1	EQ	PS	6.447	-1.212	5.9	-	-	-0.27

STATE OF COMPARTMENTS

CASE	STAGE	PHASE	NAME	DENS	FILL	VOL	W	VFL	WFL
				t/m3	%	m3	t	m3	t
DL/SDSP12-13.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP12-13.	1	1	T2.4	0.000	0.0	0.0	0.0	15.4	15.8
DL/SDSP12-13.	1	1	T2.6	0.000	0.0	0.0	0.0	12.8	13.2
DL/SDSP12-13.	1	1	T7.12	0.000	0.0	0.0	0.0	116.0	118.9
DL/SDSP12-13.	1	1	R0401	0.000	0.0	0.0	0.0	239.2	245.2
DL/SDSP12-13.	1	1	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP12-13.	1	1	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP12-13.	1	1	T7.11	0.000	0.0	0.0	0.0	114.3	117.2
DL/SDSP12-13.	1	1	T4.12	0.000	0.0	0.0	0.0	44.8	45.9
DL/SDSP12-13.	1	1	R0501	0.000	0.0	0.0	0.0	112.0	114.8
DL/SDSP12-13.	1	EQ	T2.4	0.000	0.0	0.0	0.0	15.4	15.8
DL/SDSP12-13.	1	EQ	T2.6	0.000	0.0	0.0	0.0	12.8	13.2
DL/SDSP12-13.	1	EQ	T7.12	0.000	0.0	0.0	0.0	116.0	118.9
DL/SDSP12-13.	1	EQ	R0401	0.000	0.0	0.0	0.0	1160.1	1189.1
DL/SDSP12-13.	1	EQ	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP12-13.	1	EQ	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP12-13.	1	EQ	T7.11	0.000	0.0	0.0	0.0	114.4	117.2
DL/SDSP12-13.	1	EQ	T4.12	0.000	0.0	0.0	0.0	148.7	152.4
DL/SDSP12-13.	1	EQ	R0501	0.000	0.0	0.0	0.0	565.0	579.1

NAPA	Floating position Case: DL/SDSP12-13.0.1	Proj	P118/A
		Date	2005-12-13
		Time	10:27
		Sign	AH



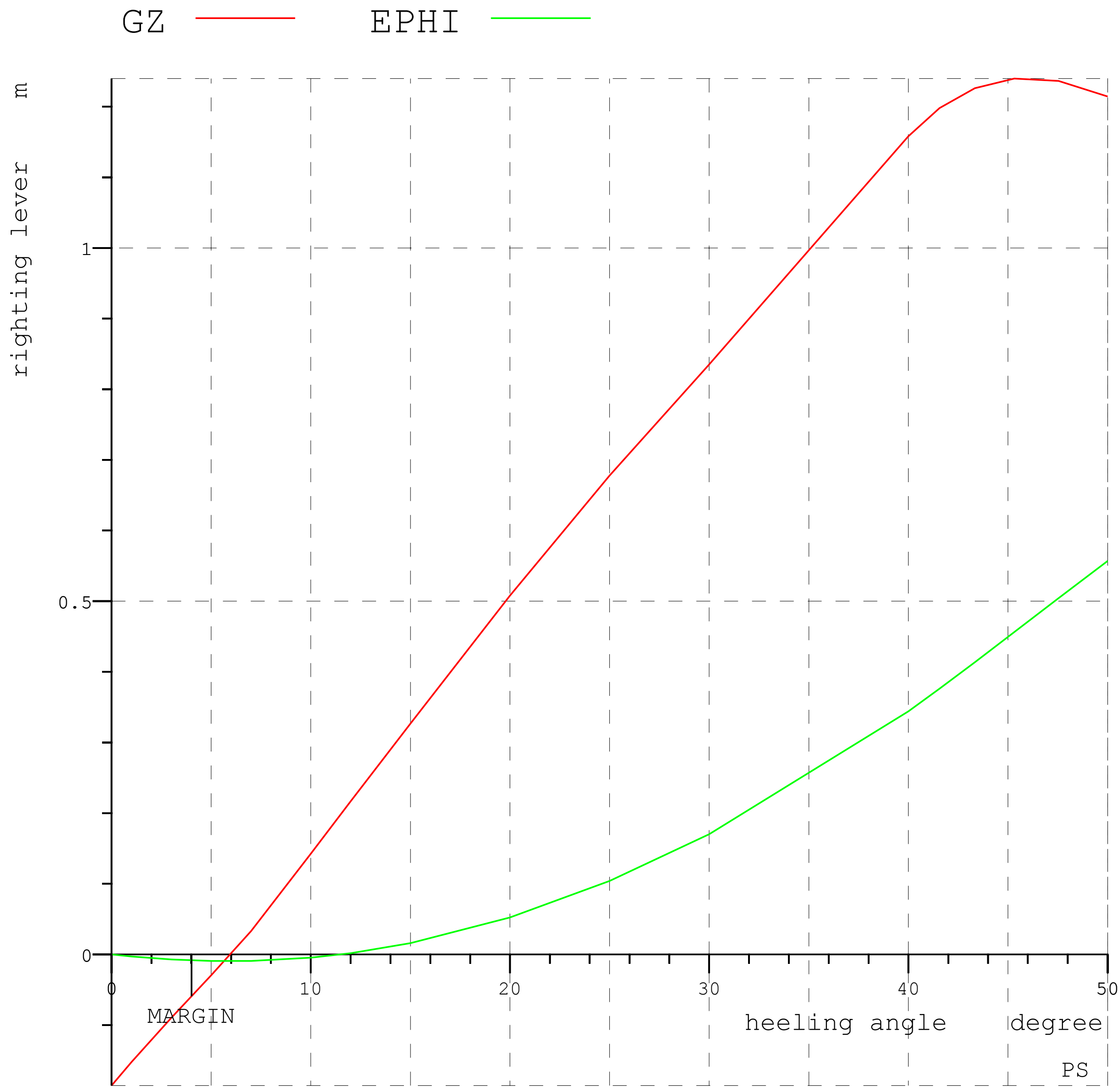
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP12-13.0.1

Proj	P118/A
Date	2005-12-13
Time	10:28
Sign	AH



Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel A, damage case DL/SDSP13-14.0.0: Before the vessel was rebuilt

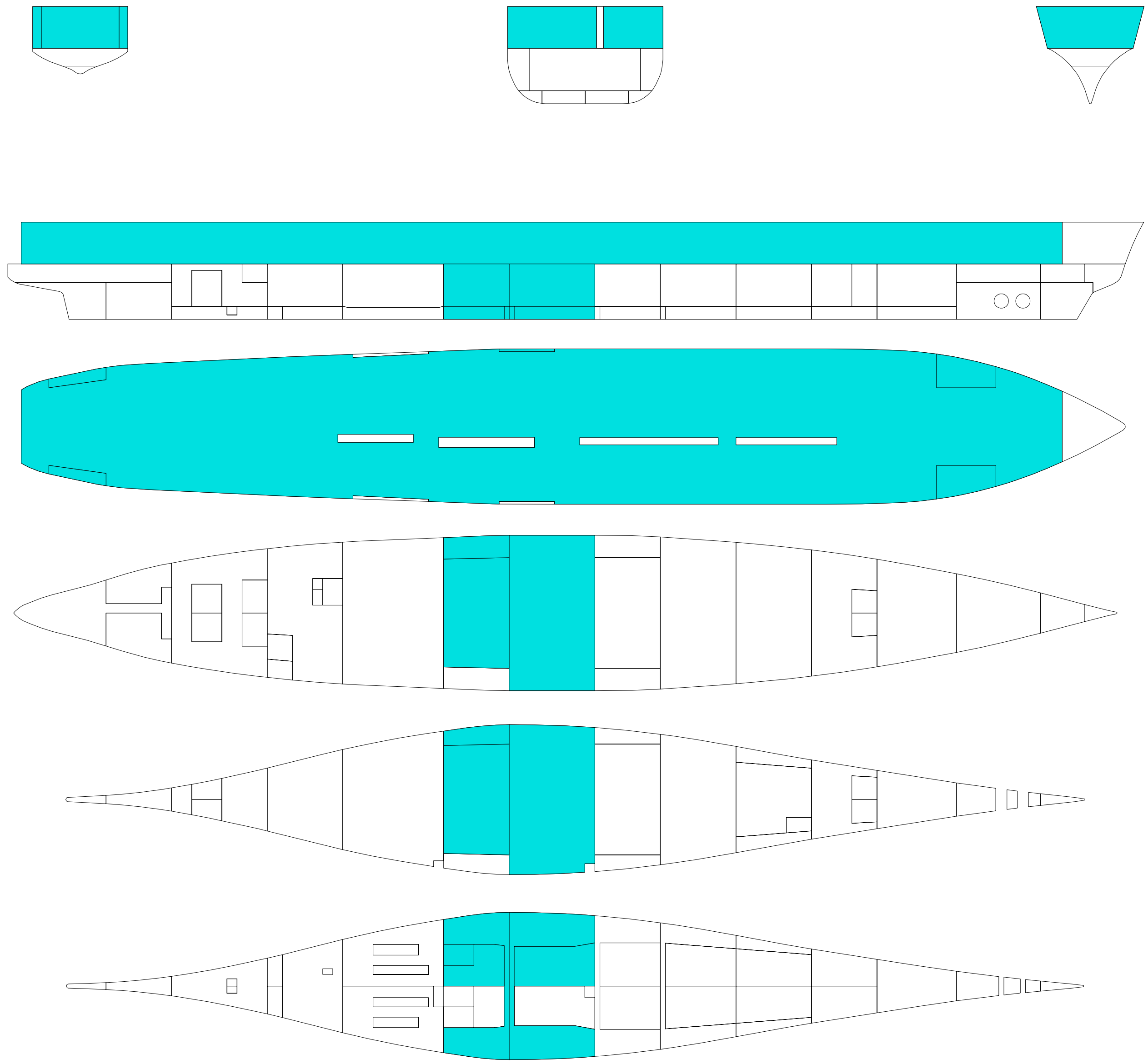
NAPA

Damage Definition

SDSP13-14.0.0

Proj	P118B/A
Date	2005-12-13
Time	10:31
Sign	AH

Zones Z13-Z14 Port



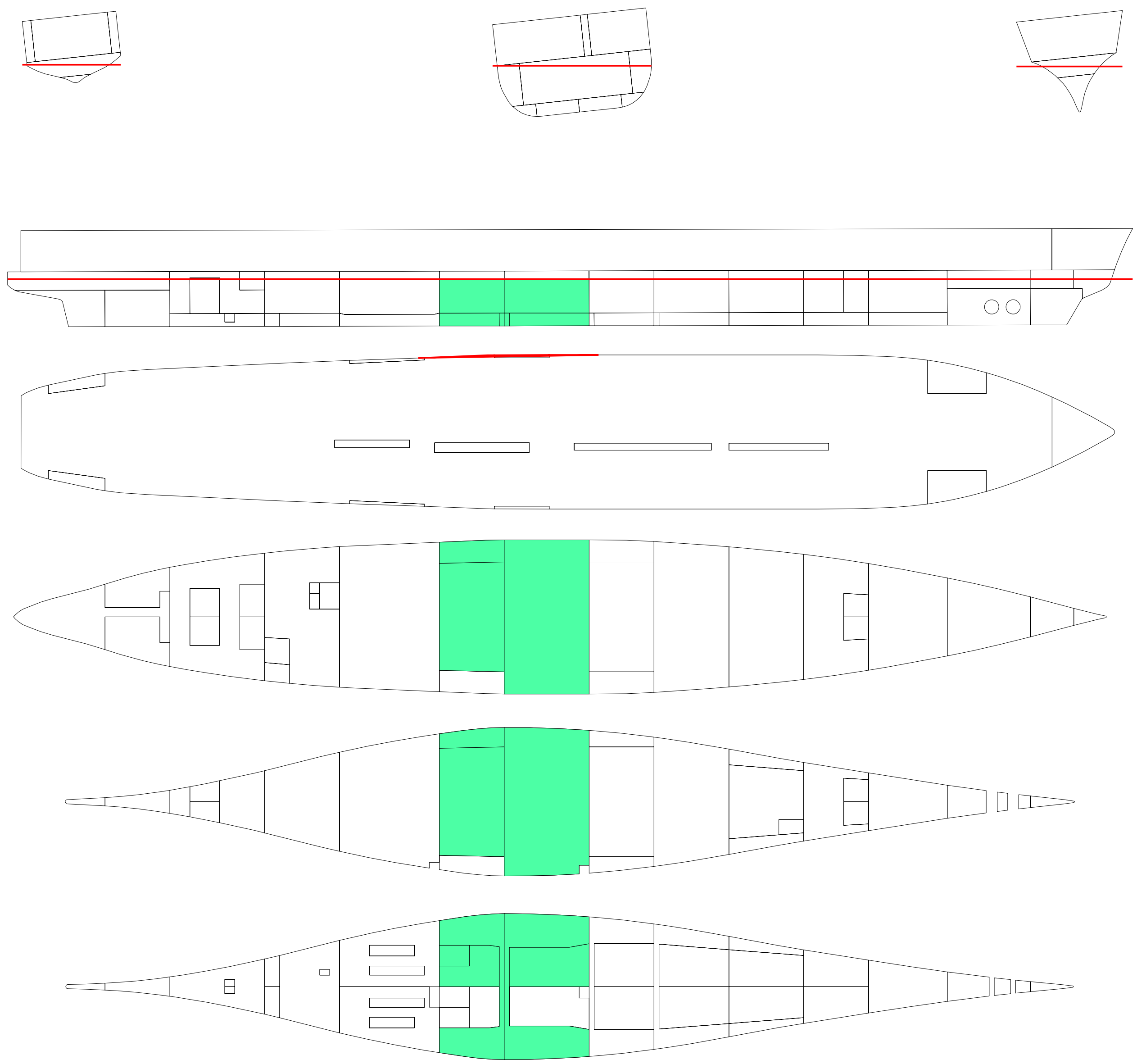
FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP13-14.	INTACT	EQ	-	5.720	0.000	0.0	-	-	1.90
DL/SDSP13-14.	1	1	PS	6.004	-0.106	5.3	-	-	0.59
DL/SDSP13-14.	1	EQ	PS	6.499	-0.263	6.2	-	-	-0.11

STATE OF COMPARTMENTS

CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP13-14.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CASS1	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CASP1	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CAP3S	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CAP3P	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP13-14.	1	1	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP13-14.	1	1	T7.11	0.000	0.0	0.0	0.0	114.4	117.2
DL/SDSP13-14.	1	1	T4.12	0.000	0.0	0.0	0.0	44.7	45.8
DL/SDSP13-14.	1	1	R0501	0.000	0.0	0.0	0.0	116.5	119.4
DL/SDSP13-14.	1	1	CAP2P	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T4.10	0.000	0.0	0.0	0.0	106.7	109.4
DL/SDSP13-14.	1	1	T7.9	0.000	0.0	0.0	0.0	164.5	168.6
DL/SDSP13-14.	1	1	R0601	0.000	0.0	0.0	0.0	210.9	216.2
DL/SDSP13-14.	1	EQ	CA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	CASS1	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	CASP1	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	CAP3S	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	CAP3P	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP13-14.	1	EQ	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP13-14.	1	EQ	T7.11	0.000	0.0	0.0	0.0	114.4	117.2
DL/SDSP13-14.	1	EQ	T4.12	0.000	0.0	0.0	0.0	148.8	152.5
DL/SDSP13-14.	1	EQ	R0501	0.000	0.0	0.0	0.0	560.2	574.2
DL/SDSP13-14.	1	EQ	CAP2P	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T4.10	0.000	0.0	0.0	0.0	106.7	109.4
DL/SDSP13-14.	1	EQ	T7.9	0.000	0.0	0.0	0.0	164.5	168.6
DL/SDSP13-14.	1	EQ	R0601	0.000	0.0	0.0	0.0	1027.9	1053.6

NAPA	Floating position Case: DL/SDSP13-14.0.0	Proj P118B/A Date 2005-12-06 Time 13:14 Sign AH



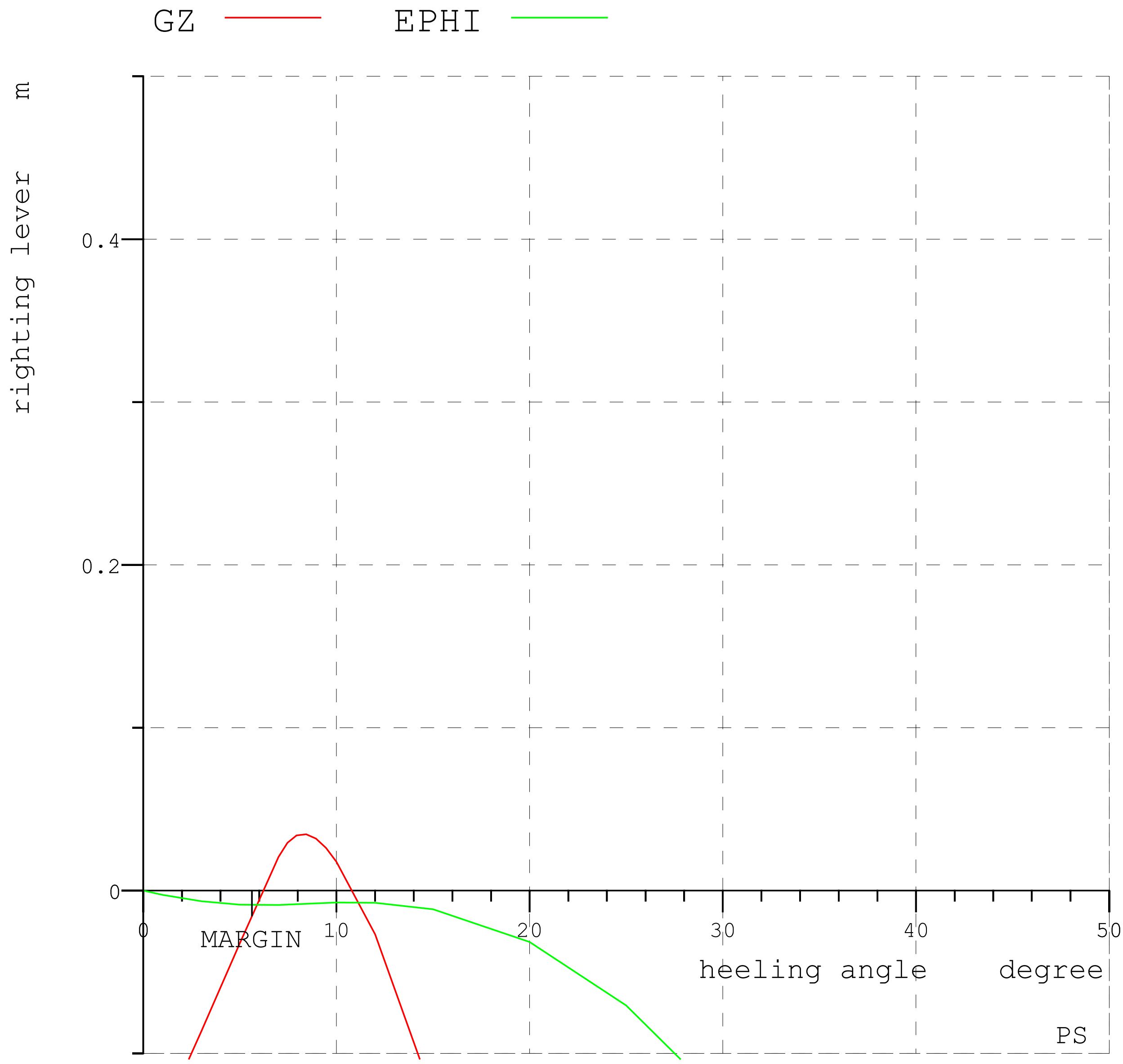
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP13-14.0.0

Proj	P118B/A
Date	2005-12-06
Time	13:16
Sign	AH

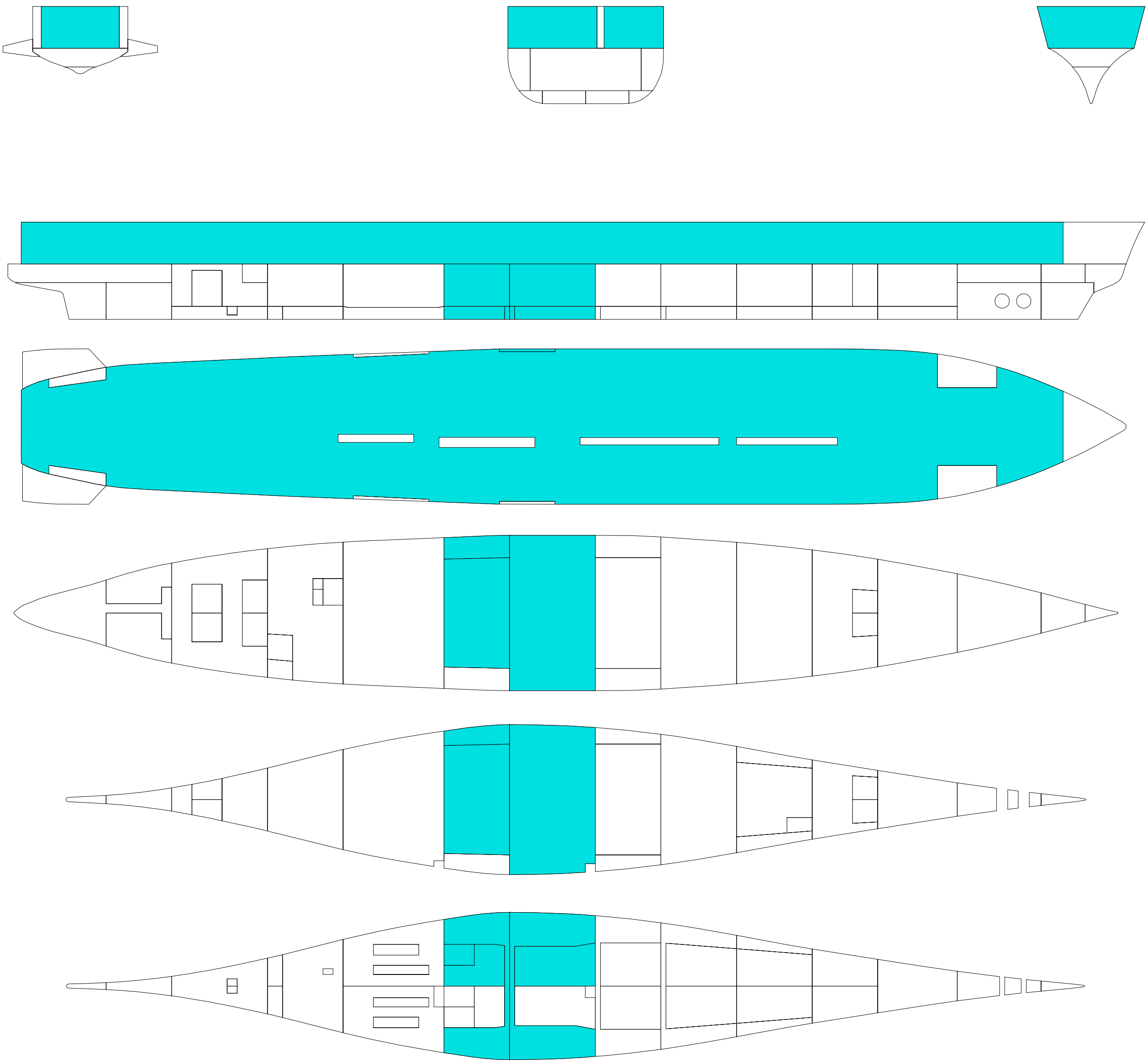


Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel A, damage case DL/SDSP13-14.0.0: After the vessel was rebuilt

NAPA	Damage Definition SDSP13-14.0.0	Proj	P118/A
		Date	2005-12-13
		Time	10:25
		Sign	AH

Zones Z13-Z14 Port



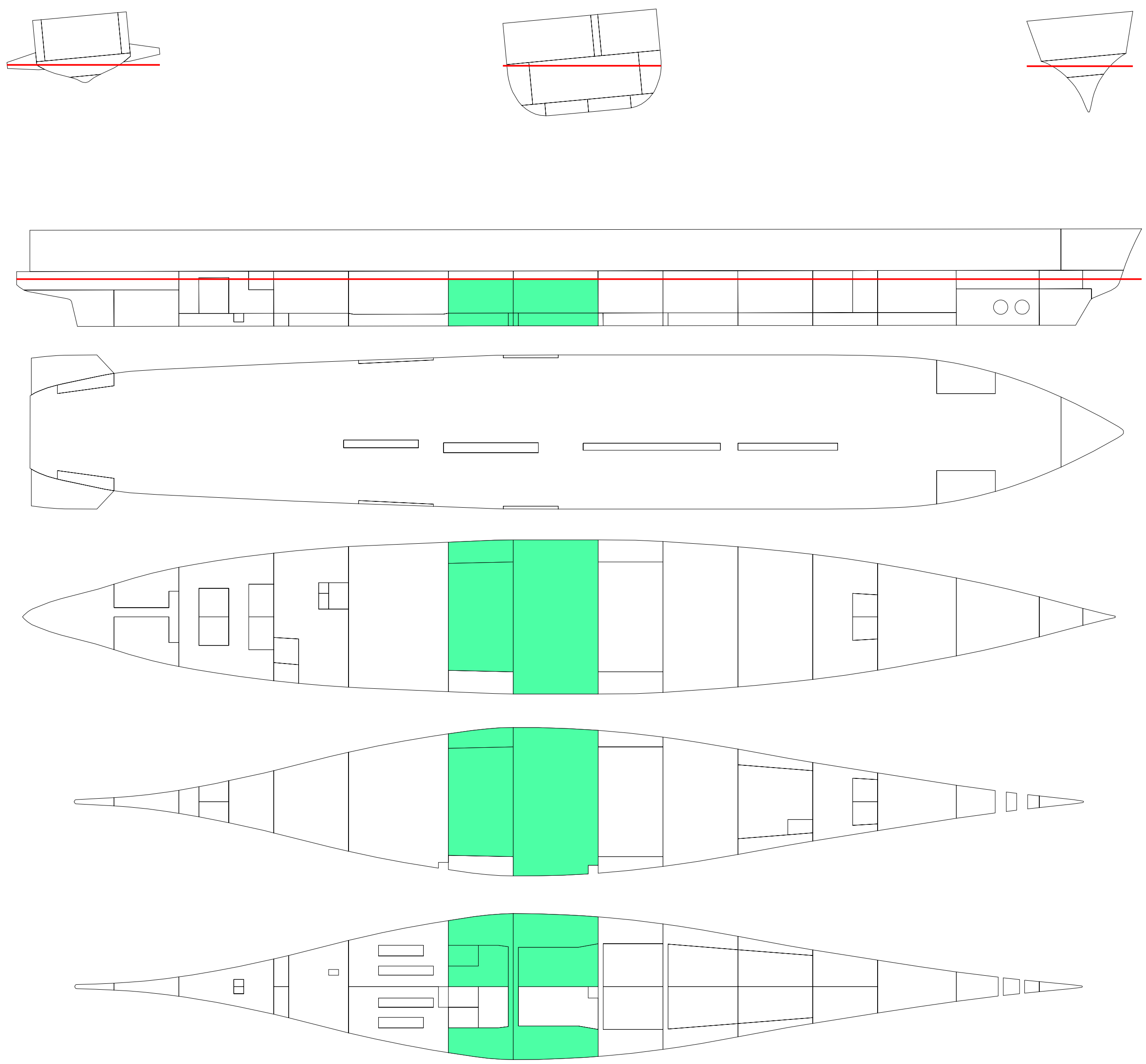
FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP13-14.	INTACT	EQ	-	5.720	0.000	0.0	-	-	1.90
DL/SDSP13-14.	1	1	PS	6.005	-0.099	5.1	-	-	0.61
DL/SDSP13-14.	1	EQ	PS	6.505	-0.182	5.4	-	-	0.06

STATE OF COMPARTMENTS

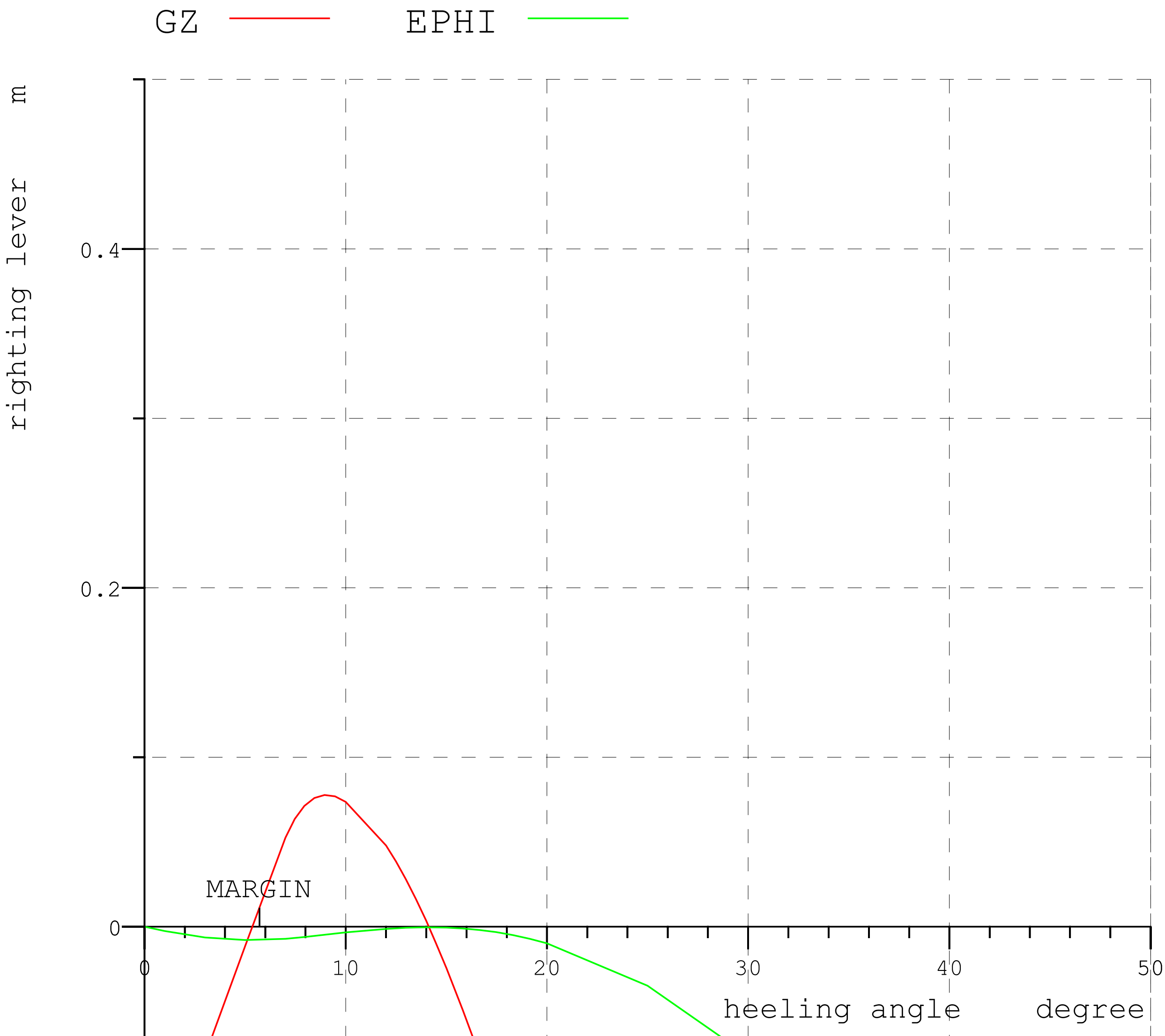
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP13-14.	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	CA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP13-14.	1	1	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP13-14.	1	1	T7.11	0.000	0.0	0.0	0.0	114.4	117.2
DL/SDSP13-14.	1	1	T4.12	0.000	0.0	0.0	0.0	44.2	45.3
DL/SDSP13-14.	1	1	R0501	0.000	0.0	0.0	0.0	116.6	119.5
DL/SDSP13-14.	1	1	CAP2P	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	1	T4.10	0.000	0.0	0.0	0.0	106.7	109.4
DL/SDSP13-14.	1	1	T7.9	0.000	0.0	0.0	0.0	164.5	168.6
DL/SDSP13-14.	1	1	R0601	0.000	0.0	0.0	0.0	211.2	216.4
DL/SDSP13-14.	1	EQ	CA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T7.10	0.000	0.0	0.0	0.0	62.1	63.7
DL/SDSP13-14.	1	EQ	T3.3	0.000	0.0	0.0	0.0	20.8	21.3
DL/SDSP13-14.	1	EQ	T7.11	0.000	0.0	0.0	0.0	114.4	117.2
DL/SDSP13-14.	1	EQ	T4.12	0.000	0.0	0.0	0.0	144.8	148.4
DL/SDSP13-14.	1	EQ	R0501	0.000	0.0	0.0	0.0	558.8	572.7
DL/SDSP13-14.	1	EQ	CAP2P	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP13-14.	1	EQ	T4.10	0.000	0.0	0.0	0.0	106.7	109.4
DL/SDSP13-14.	1	EQ	T7.9	0.000	0.0	0.0	0.0	164.5	168.6
DL/SDSP13-14.	1	EQ	R0601	0.000	0.0	0.0	0.0	1026.5	1052.2

NAPA	Floating position Case: DL/SDSP13-14.0.0	Proj P118/A Date 2005-12-06 Time 13:07 Sign AH



Stage: 1 Phase: EQ

NAPA	GZ curve Case: DL/SDSP13-14.0.0	Proj	P118/A
		Date	2005-12-06
		Time	13:12
		Sign	AH



Stage: 1 Phase: EQ

Appendix E: Ro-ro passenger vessel C – Stability data for studied damage cases

This Appendix contains damage definitions, floating positions and stability curves of some damage cases studied in Chapter 4.

Calculated data for ro-ro passenger vessel C, damage case DL/SDSP9-10.0.0: Before the vessel was rebuilt

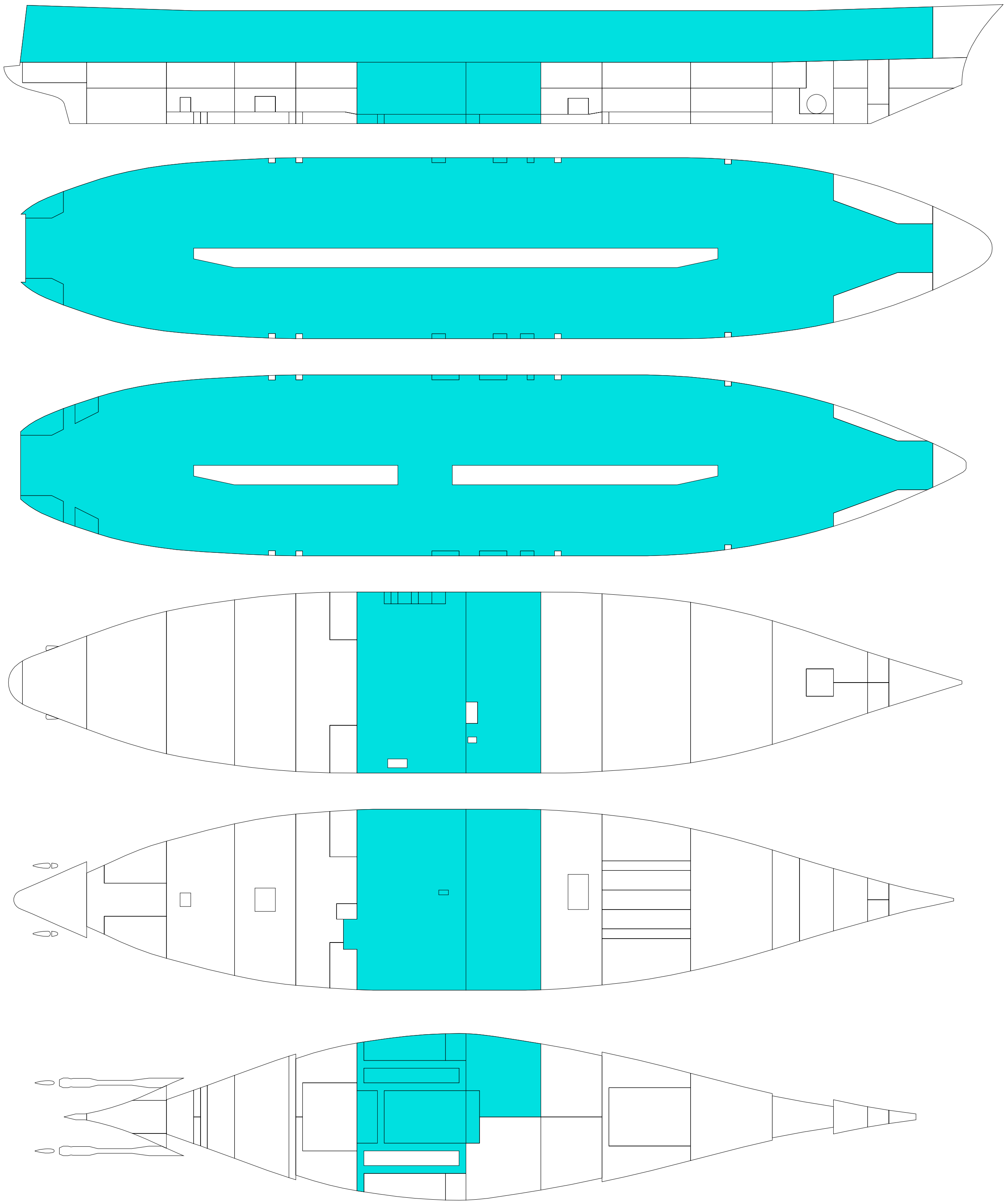
NAPA

Damage Definition

SDSP9-10.0.0

Proj	
Date	2005-12-13
Time	10:18
Sign	AH

Zones Z9-Z10 Port



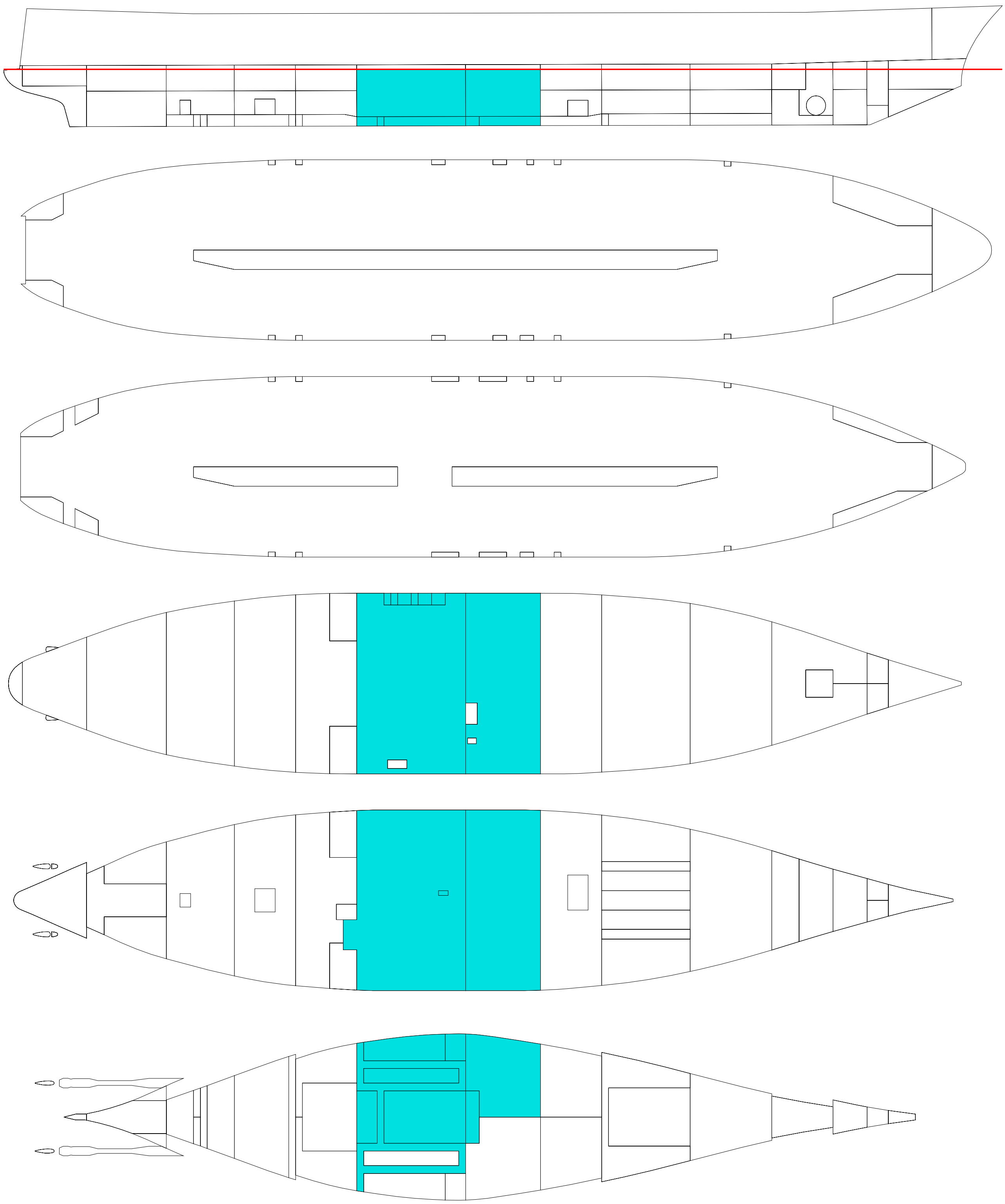
FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T m	TR m	HEEL degree	RESFLD m	OPEN	RESMRG m
DL/SDSP9-10..	INTACT	EQ	-	4.710	0.000	0.0	4.89	FO035P	1.53
DL/SDSP9-10..	1	1	PS	5.077	-0.092	5.1	3.63	FO035P	0.28
DL/SDSP9-10..	1	EQ	PS	5.798	-0.211	2.9	3.27	FO035P	-0.09

STATE OF COMPARTMENTS

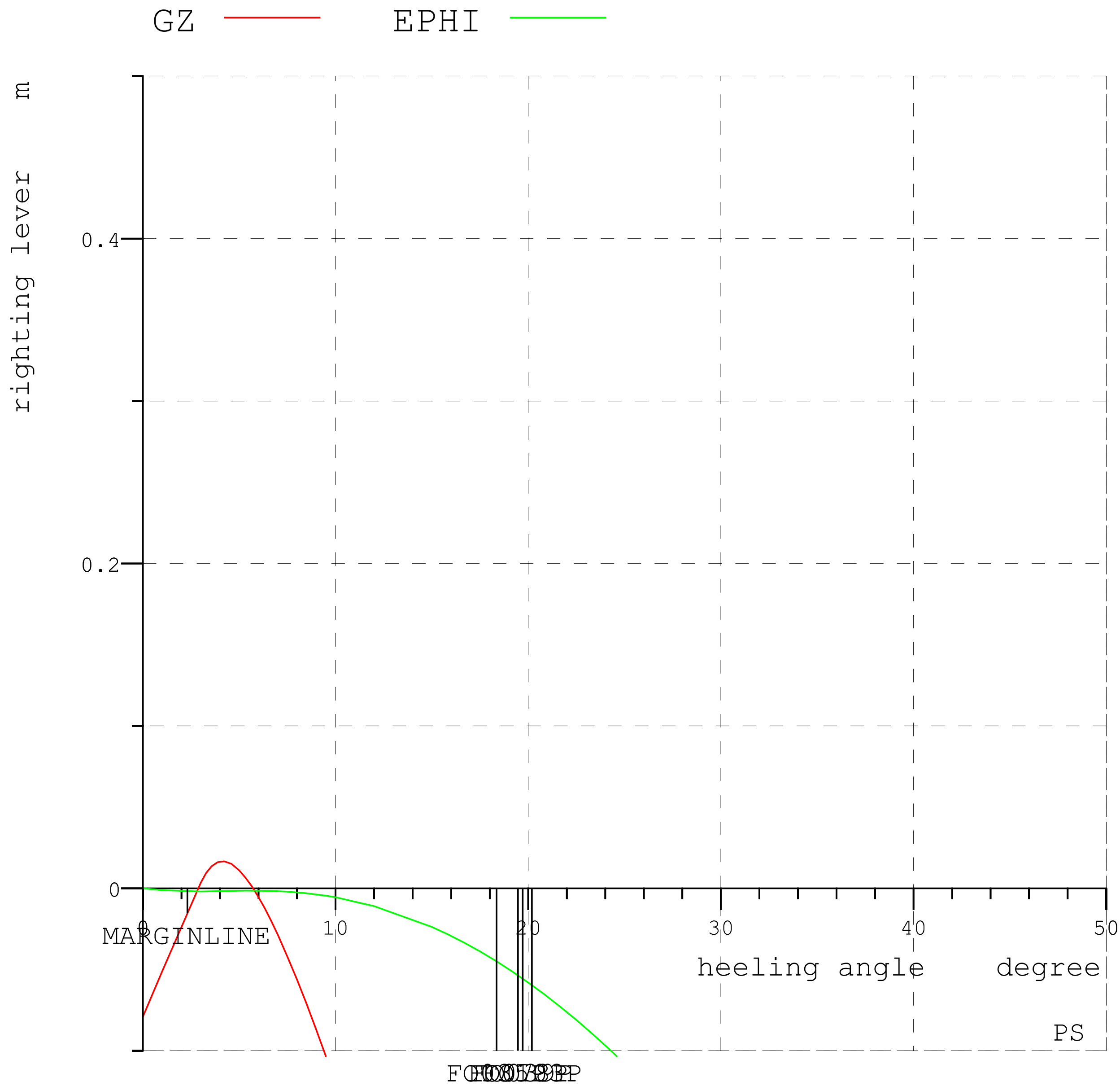
CASE	STAGE	PHASE	NAME	DENS t/m3	FILL %	VOL m3	W t	VFL m3	WFL t
DL/SDSP9-10..	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	CDBSA	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T1131	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T1231	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T1132	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T1232	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T700	0.000	0.0	0.0	0.0	39.6	39.8
DL/SDSP9-10..	1	1	T701	0.000	0.0	0.0	0.0	12.4	12.5
DL/SDSP9-10..	1	1	T703	0.000	0.0	0.0	0.0	3.9	3.9
DL/SDSP9-10..	1	1	T705	0.000	0.0	0.0	0.0	12.9	12.9
DL/SDSP9-10..	1	1	T707	0.000	0.0	0.0	0.0	41.0	41.2
DL/SDSP9-10..	1	1	T708	0.000	0.0	0.0	0.0	10.3	10.3
DL/SDSP9-10..	1	1	T710	0.000	0.0	0.0	0.0	236.8	238.0
DL/SDSP9-10..	1	1	T711	0.000	0.0	0.0	0.0	0.7	0.7
DL/SDSP9-10..	1	1	T721	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T722	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T723	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T724	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T725	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T726	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T601	0.000	0.0	0.0	0.0	46.4	46.6
DL/SDSP9-10..	1	1	T603	0.000	0.0	0.0	0.0	6.8	6.9
DL/SDSP9-10..	1	1	T610	0.000	0.0	0.0	0.0	158.4	159.2
DL/SDSP9-10..	1	EQ	CDBSA	0.000	0.0	0.0	0.0	0.1	0.1
DL/SDSP9-10..	1	EQ	T1131	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	EQ	T1231	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	EQ	T1132	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	EQ	T1232	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	EQ	T700	0.000	0.0	0.0	0.0	39.6	39.8
DL/SDSP9-10..	1	EQ	T701	0.000	0.0	0.0	0.0	12.4	12.5
DL/SDSP9-10..	1	EQ	T703	0.000	0.0	0.0	0.0	3.9	3.9
DL/SDSP9-10..	1	EQ	T705	0.000	0.0	0.0	0.0	12.9	12.9
DL/SDSP9-10..	1	EQ	T707	0.000	0.0	0.0	0.0	41.0	41.2
DL/SDSP9-10..	1	EQ	T708	0.000	0.0	0.0	0.0	10.3	10.3
DL/SDSP9-10..	1	EQ	T710	0.000	0.0	0.0	0.0	835.4	839.6
DL/SDSP9-10..	1	EQ	T711	0.000	0.0	0.0	0.0	0.7	0.7
DL/SDSP9-10..	1	EQ	T721	0.000	0.0	0.0	0.0	4.2	4.2
DL/SDSP9-10..	1	EQ	T722	0.000	0.0	0.0	0.0	4.2	4.2
DL/SDSP9-10..	1	EQ	T723	0.000	0.0	0.0	0.0	2.1	2.1
DL/SDSP9-10..	1	EQ	T724	0.000	0.0	0.0	0.0	4.2	4.2
DL/SDSP9-10..	1	EQ	T725	0.000	0.0	0.0	0.0	2.1	2.1
DL/SDSP9-10..	1	EQ	T726	0.000	0.0	0.0	0.0	2.1	2.1
DL/SDSP9-10..	1	EQ	T601	0.000	0.0	0.0	0.0	46.4	46.6
DL/SDSP9-10..	1	EQ	T603	0.000	0.0	0.0	0.0	6.8	6.9
DL/SDSP9-10..	1	EQ	T610	0.000	0.0	0.0	0.0	571.9	574.7

NAPA	Floating position Case: DL/SDSP9-10.0.0	Proj Date 2005-12-12 Time 17:26 Sign AH



Stage: 1 Phase: EQ

NAPA	GZ curve Case: DL/SDSP9-10.0.0	Proj Date 2005-12-12 Time 17:28 Sign AH

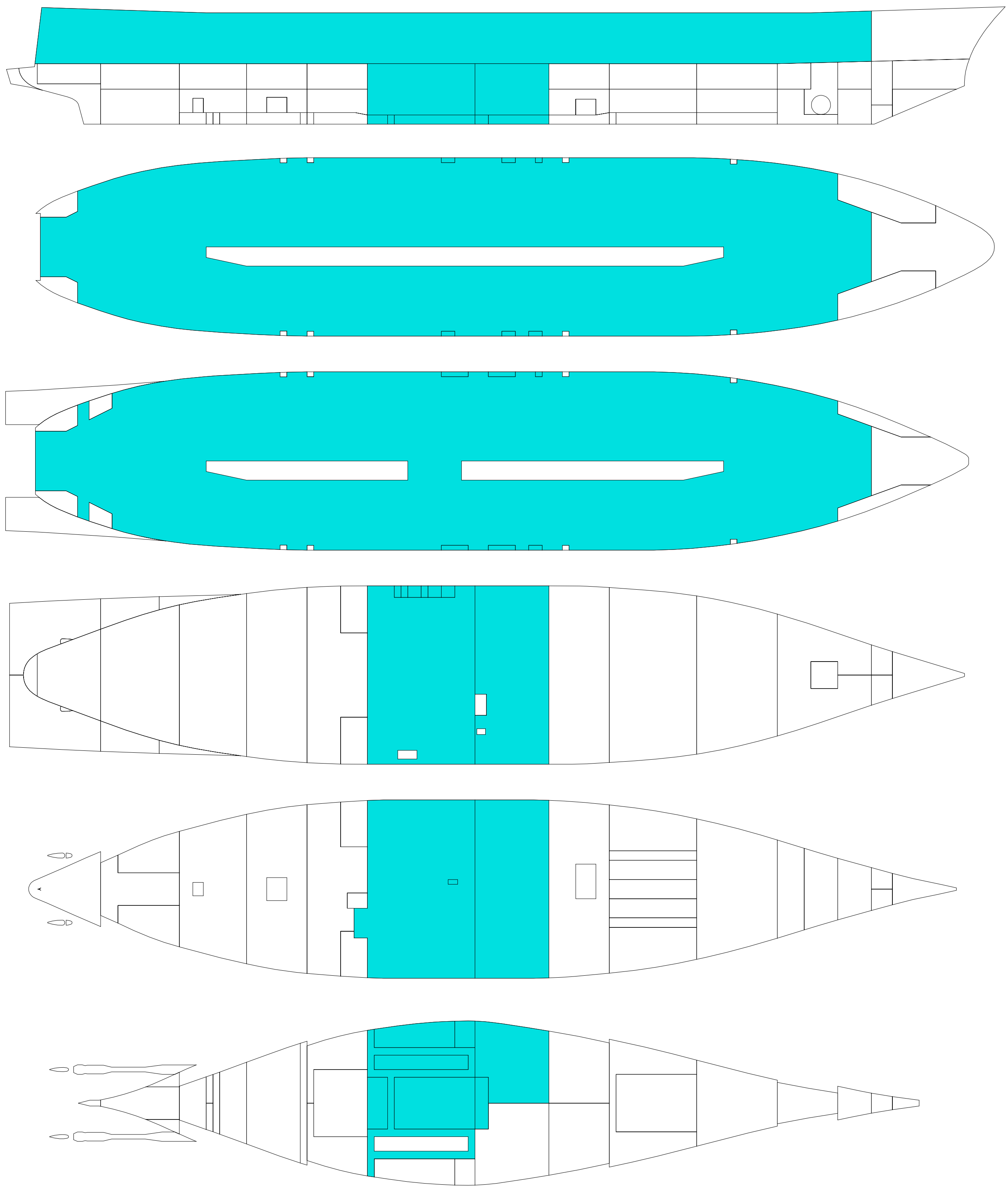


Stage: 1 Phase: EQ

Calculated data for ro-ro passenger vessel C, damage case DL/SDSP9-10.0.0: After the vessel was rebuilt

NAPA	Damage Definition SDSP9-10.0.0	Proj Date 2005-12-12 Time 18:50 Sign AH

Zones Z9-Z10 Port



FLOATING POSITION

CASE	STAGE	PHASE	SIDE	T	TR	HEEL	RESFLD	OPEN	RESMRG
				m	m	degree	m		m
DL/SDSP9-10..	INTACT	EQ	-	4.710	0.000	0.0	4.89	O035P	1.53
DL/SDSP9-10..	1	1	PS	5.085	0.105	2.5	4.07	O103P	0.72
DL/SDSP9-10..	1	EQ	PS	5.739	0.262	2.0	3.47	O103P	0.13

STATE OF COMPARTMENTS

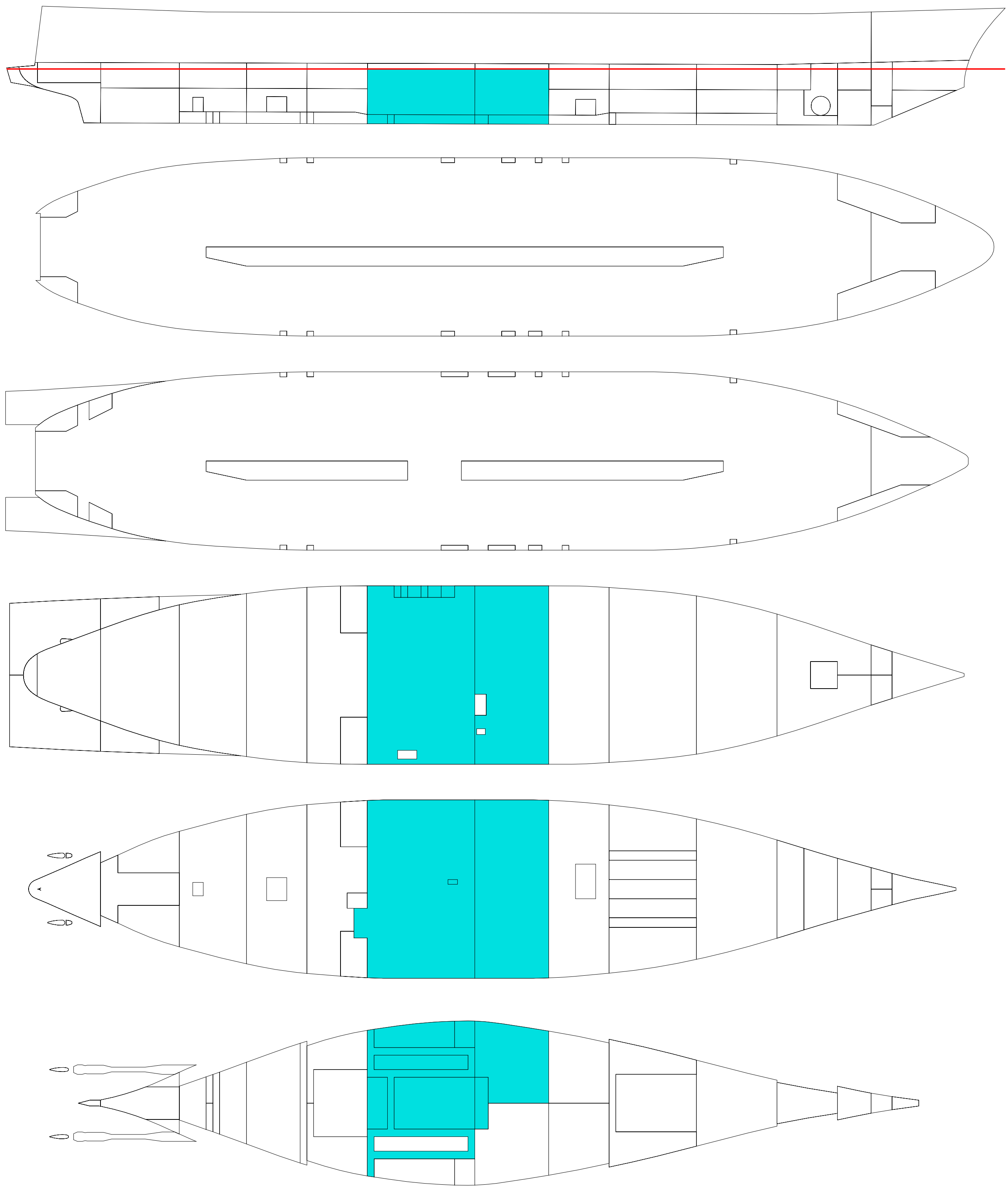
CASE	STAGE	PHASE	NAME	DENS	FILL	VOL	W	VFL	WFL
				t/m3	%	m3	t	m3	t
DL/SDSP9-10..	INTACT	EQ				0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	CD	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T700	0.000	0.0	0.0	0.0	39.6	39.8
DL/SDSP9-10..	1	1	T701	0.000	0.0	0.0	0.0	12.4	12.5
DL/SDSP9-10..	1	1	T703	0.000	0.0	0.0	0.0	3.9	3.9
DL/SDSP9-10..	1	1	T705	0.000	0.0	0.0	0.0	12.9	12.9
DL/SDSP9-10..	1	1	T707	0.000	0.0	0.0	0.0	41.0	41.2
DL/SDSP9-10..	1	1	T708	0.000	0.0	0.0	0.0	10.3	10.3
DL/SDSP9-10..	1	1	T710	0.000	0.0	0.0	0.0	235.7	236.9
DL/SDSP9-10..	1	1	T711	0.000	0.0	0.0	0.0	0.7	0.7
DL/SDSP9-10..	1	1	T721	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T722	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T723	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T724	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T725	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T726	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	1	T601	0.000	0.0	0.0	0.0	46.4	46.6
DL/SDSP9-10..	1	1	T603	0.000	0.0	0.0	0.0	6.8	6.9
DL/SDSP9-10..	1	1	T610	0.000	0.0	0.0	0.0	159.4	160.2
DL/SDSP9-10..	1	EQ	CD	0.000	0.0	0.0	0.0	0.0	0.0
DL/SDSP9-10..	1	EQ	T700	0.000	0.0	0.0	0.0	39.6	39.8
DL/SDSP9-10..	1	EQ	T701	0.000	0.0	0.0	0.0	12.4	12.5
DL/SDSP9-10..	1	EQ	T703	0.000	0.0	0.0	0.0	3.9	3.9
DL/SDSP9-10..	1	EQ	T705	0.000	0.0	0.0	0.0	12.9	12.9
DL/SDSP9-10..	1	EQ	T707	0.000	0.0	0.0	0.0	41.0	41.2
DL/SDSP9-10..	1	EQ	T708	0.000	0.0	0.0	0.0	10.3	10.3
DL/SDSP9-10..	1	EQ	T710	0.000	0.0	0.0	0.0	817.3	821.4
DL/SDSP9-10..	1	EQ	T711	0.000	0.0	0.0	0.0	0.7	0.7
DL/SDSP9-10..	1	EQ	T721	0.000	0.0	0.0	0.0	3.8	3.8
DL/SDSP9-10..	1	EQ	T722	0.000	0.0	0.0	0.0	3.8	3.8
DL/SDSP9-10..	1	EQ	T723	0.000	0.0	0.0	0.0	1.9	1.9
DL/SDSP9-10..	1	EQ	T724	0.000	0.0	0.0	0.0	3.8	3.8
DL/SDSP9-10..	1	EQ	T725	0.000	0.0	0.0	0.0	1.9	1.9
DL/SDSP9-10..	1	EQ	T726	0.000	0.0	0.0	0.0	1.9	1.9
DL/SDSP9-10..	1	EQ	T601	0.000	0.0	0.0	0.0	46.4	46.6
DL/SDSP9-10..	1	EQ	T603	0.000	0.0	0.0	0.0	6.8	6.9
DL/SDSP9-10..	1	EQ	T610	0.000	0.0	0.0	0.0	564.2	567.0

NAPA

Floating position

Case: DL/SDSP9-10.0.0

Proj	
Date	2005-12-12
Time	17:37
Sign	AH



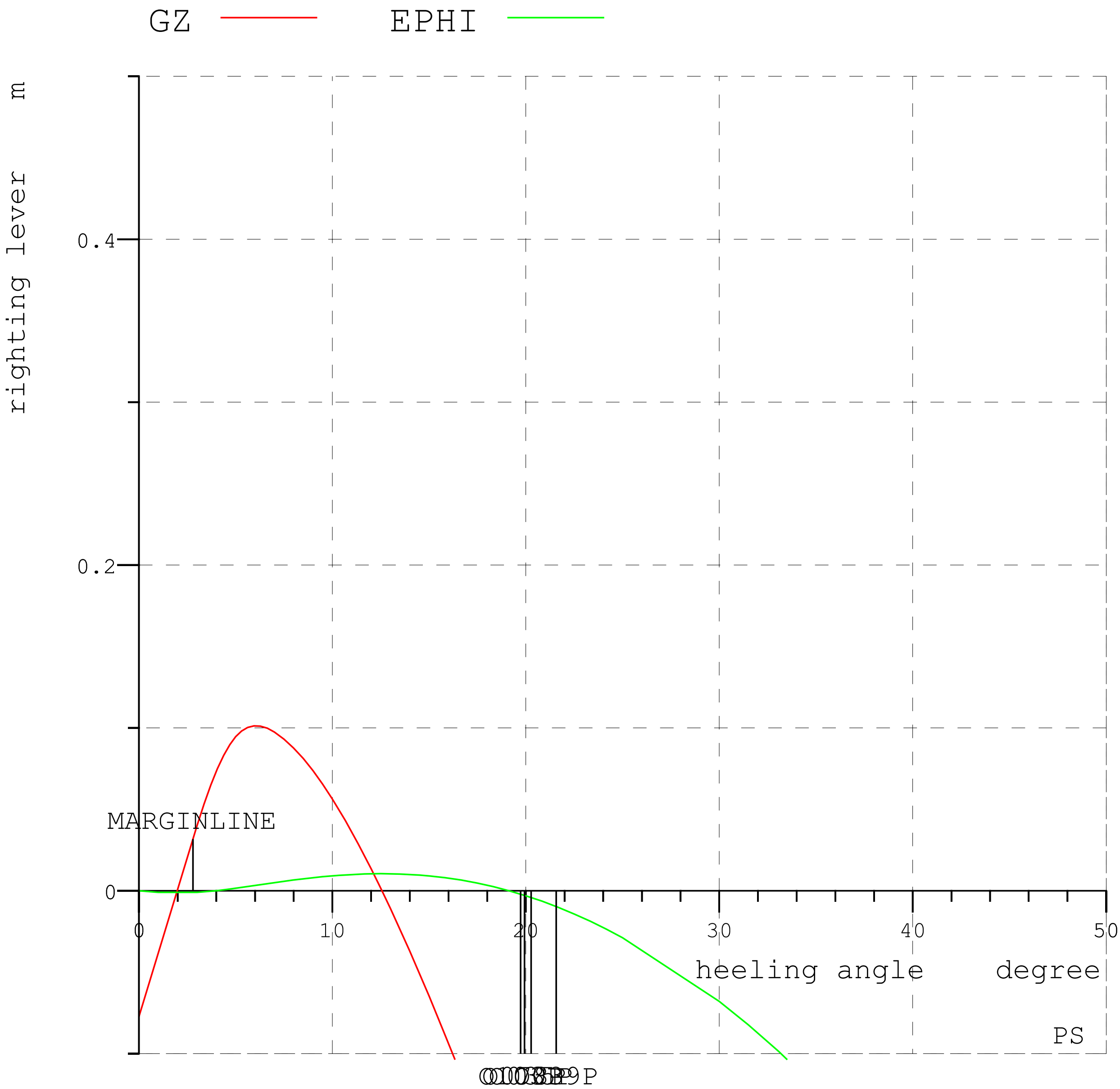
Stage: 1 Phase: EQ

NAPA

GZ curve

Case: DL/SDSP9-10.0.0

Proj	
Date	2005-12-12
Time	17:38
Sign	AH



Stage: 1 Phase: EQ