The Maritime Consultants

BCTQ
Burness Corlett Three Quays

Probabilistic versus Deterministic Damage Stability

Jonathan Strachan
Burness Corlett Three Quays

Introduction

BCTQ
Burness Corlett Three Quays

- Deterministic Requirements
- Probabilistic Requirements
- 120m Yacht Project
  - Passenger Ship
  - Deterministic Two Compartment
  - Probabilistic Analysis
- >160m Yacht Project
  - Passenger Ship
  - Deterministic Two Compartment
  - Probabilistic Analysis
- Conclusion
- Suggested Methodology

Deterministic Damage

- Passenger Yacht Code uses Two Compartment enhanced criteria
- Damage Extent
    - Damage Length 3%L +3m
    - Transverse Extent to B/5
    - Vertical Extent – Upwards without limits
- Lesser Extents
- Criteria
    - Margin Line*
    - Stability Criteria
        - Requirements for Range and Area of GZ curve
        - Heeling moments applied
            - Pax Crowding
            - Lifeboat / Liferaft Launching
            - Wind Pressure

Probabilistic Damage

- **Attained index A >=Required index R**
- **Required index R function of - Length, Number of persons and whether lifeboats are fitted**
- **Attained index A**

$$A=\Sigma Pi\ (Vi.\ Si)$$

Pi probability compartment (s) damaged

Si probability ship survives damage to compartment (s)

- **Pi is a function of the arrangement of transverse bulkheads and longitudinal bulkheads**
- **Vi factor : probability that a watertight deck above the waterline remains intact**

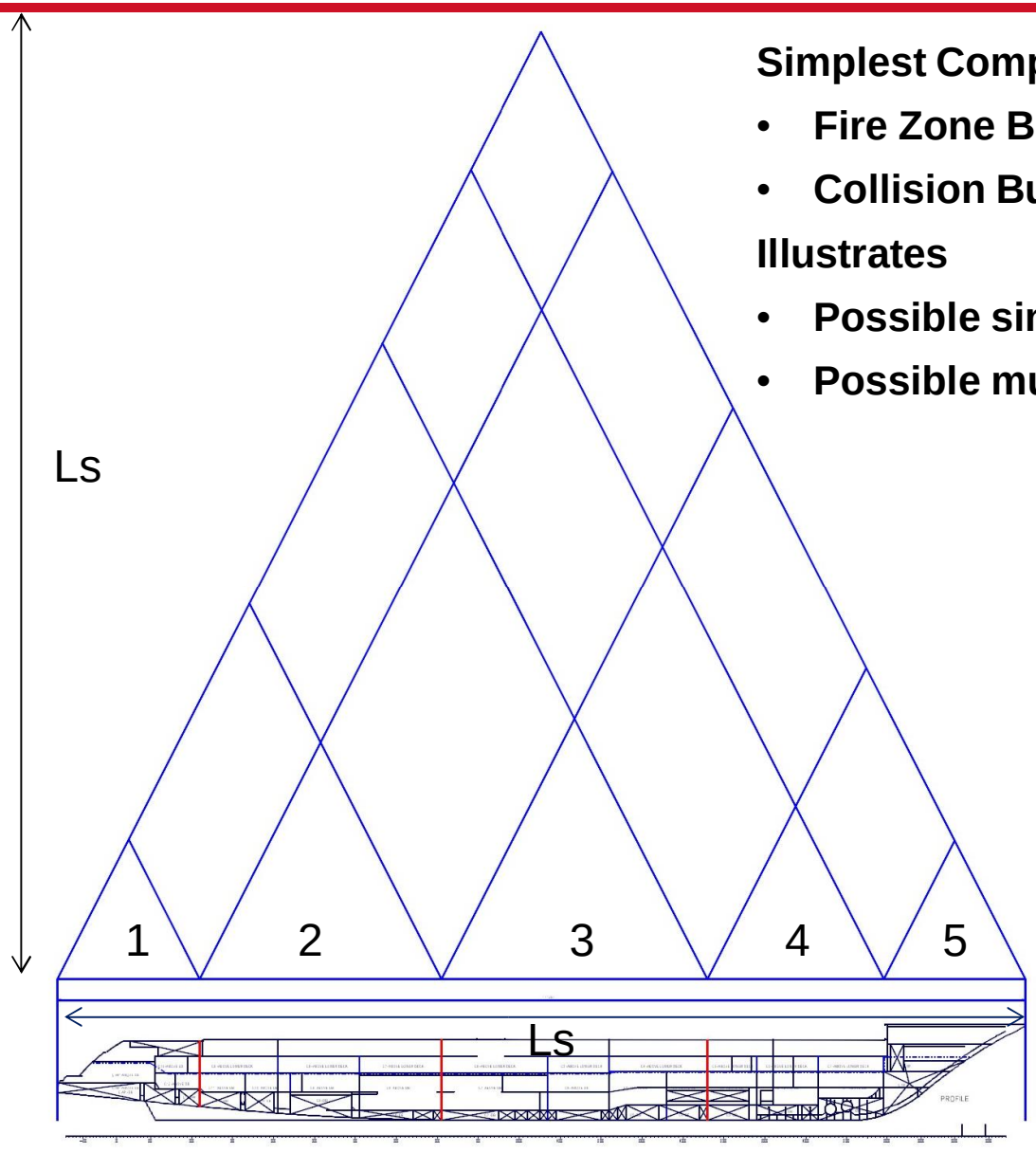
Notes on Probabilistic Damage

BCTQ
Burness Corlett Three Quays

- No longer any reference to One or Two compartment standard
- Transverse extent is to B/2 from shell, therefore damage can extend past the Centreline
- Services are no longer protected by B/5
- No Margin Line requirement
- No rules for subdividing the vessel
- All survived damages (under max damage length) can contribute to the Attained index
- Bearing in mind the above: probabilistic analysis changes the concept of optimum bulkhead arrangements

Compartment Definition

BCTQ
Burness Corlett Three Quays



Simplest Compartment Definition

- **Fire Zone Bulkhead**
- **Collision Bulkhead**

Illustrates

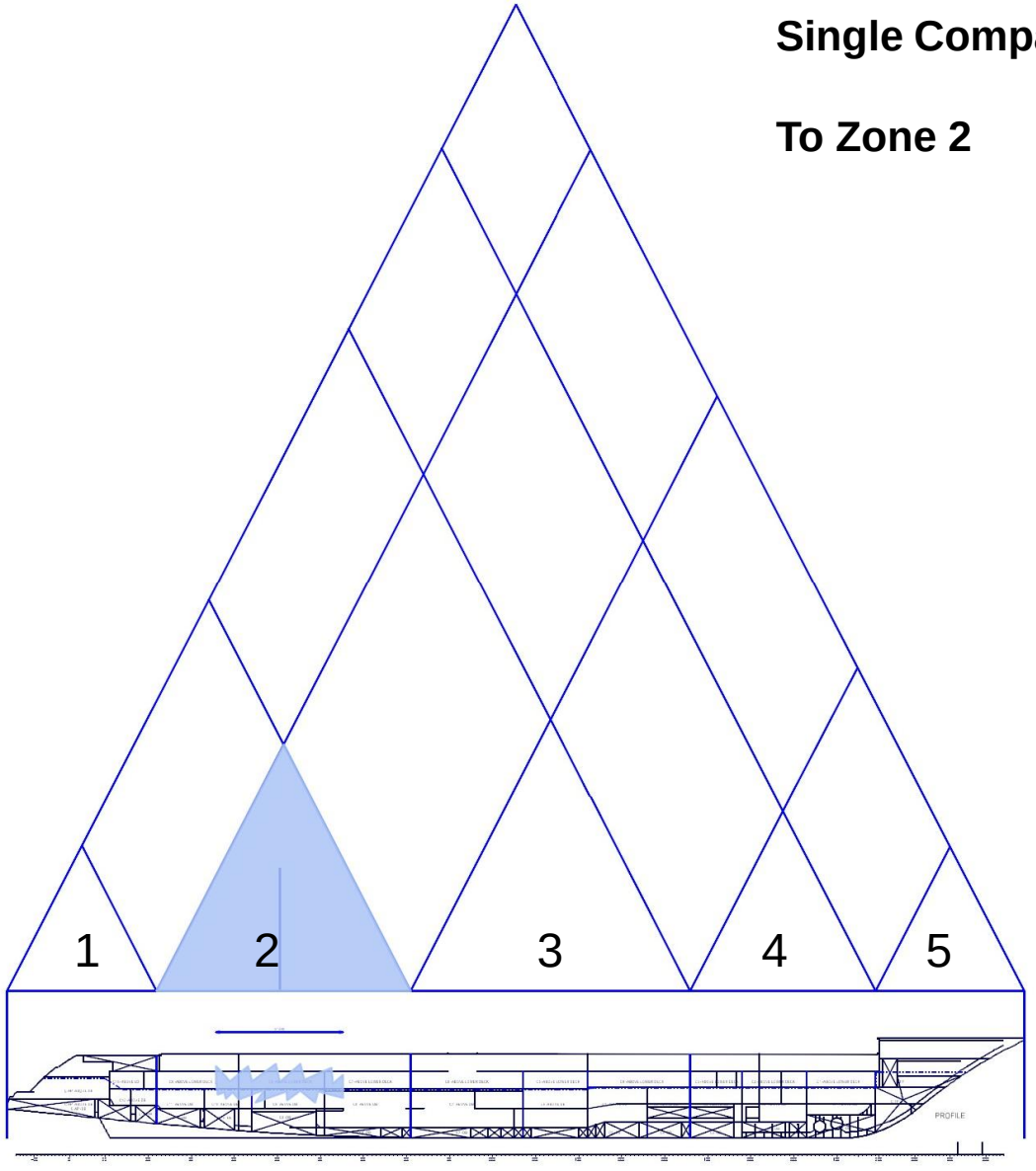
- **Possible single zone damages**
- **Possible multiple zone damages**

Compartment Definition

BCTQ
Burness Corlett Three Quays

Single Compartment Damage

To Zone 2

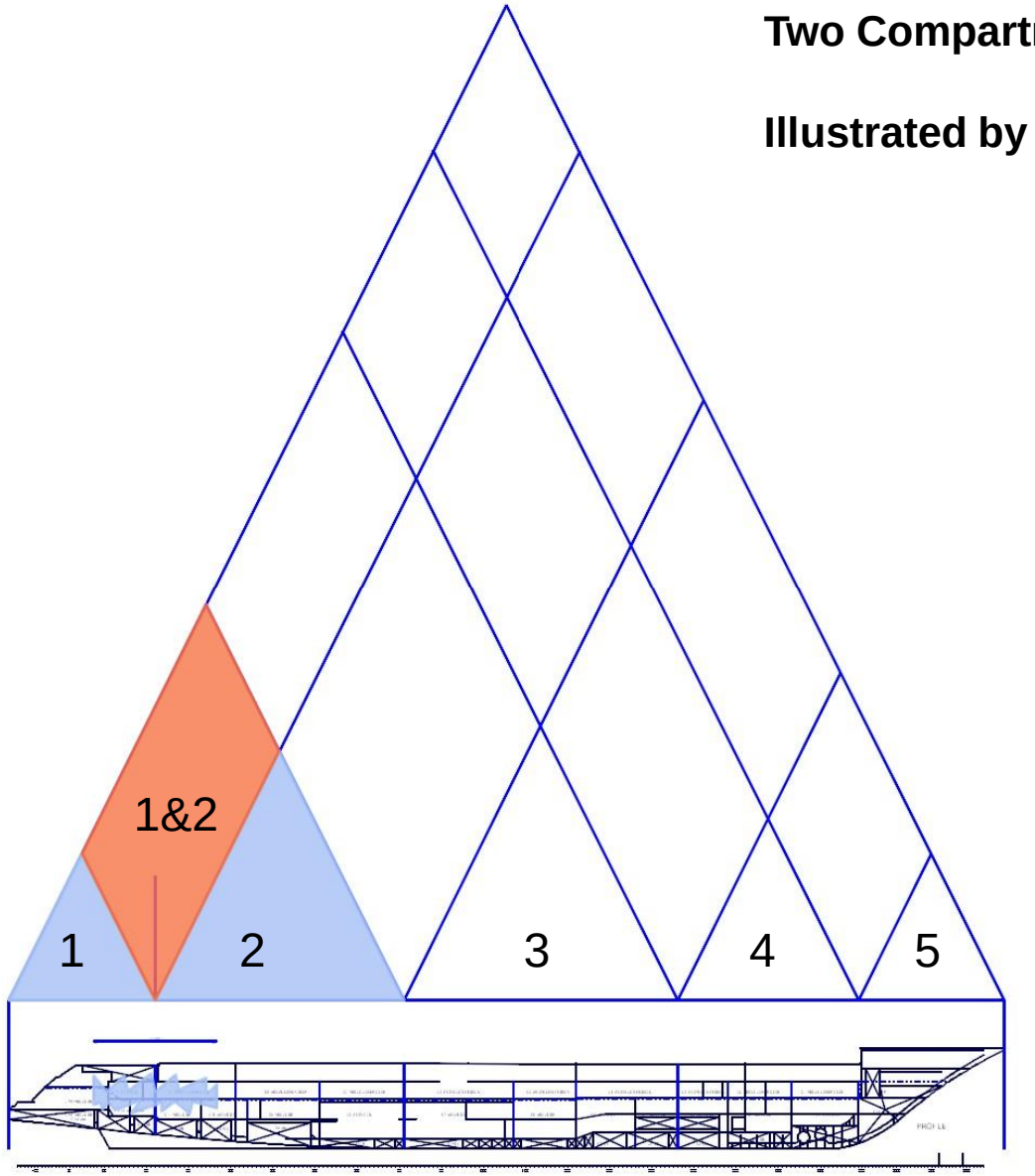


Compartment Definition

BCTQ
Burness Corlett Three Quays

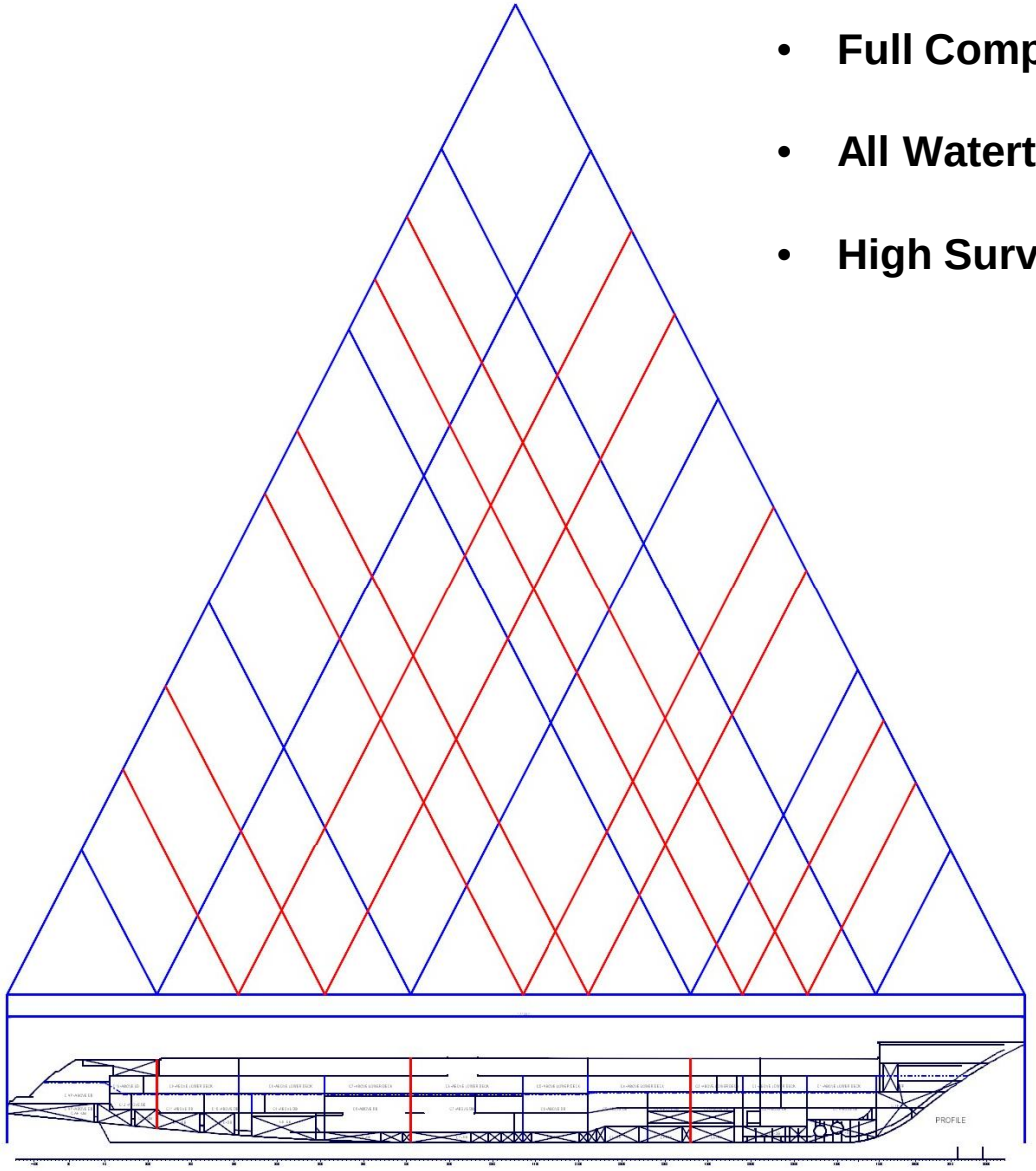
Two Compartment Damage

Illustrated by Red Parallelogram



Compartment Definition

BCTQ
Burness Corlett Three Quays



- **Full Compartment Definition**
- **All Watertight Bulkheads**
- **High Survivability**

Survival Criteria

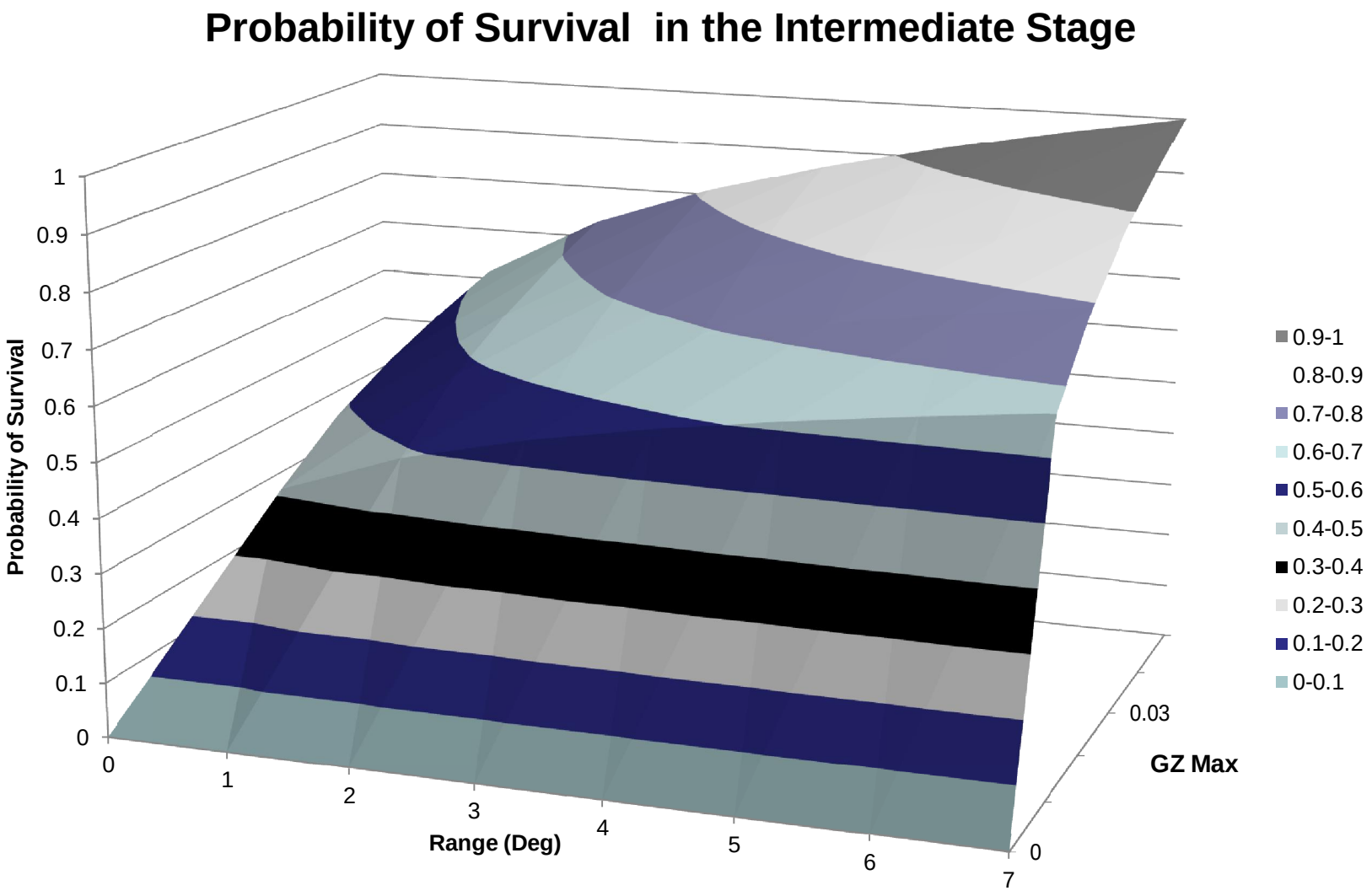
BCTQ
Burness Corlett Three Quays

- **Probability of Survival Si**
- **Calculated for each Damage Case**
- **Si = min(S intermediate, i or S final, i x S mom, i)**
- **Where S intermediate and final are a function of GZ Max and Range**

- **Important**
  - **These criteria represent the probability of survival**

Survival Criteria

BCTQ
Burness Corlett Three Quays



- **Not a step function like Deterministic analysis**

Other Criteria

BCTQ
Burness Corlett Three Quays

Si (Prob of Survival) is taken as zero if the following are immersed in the final stage of damage:

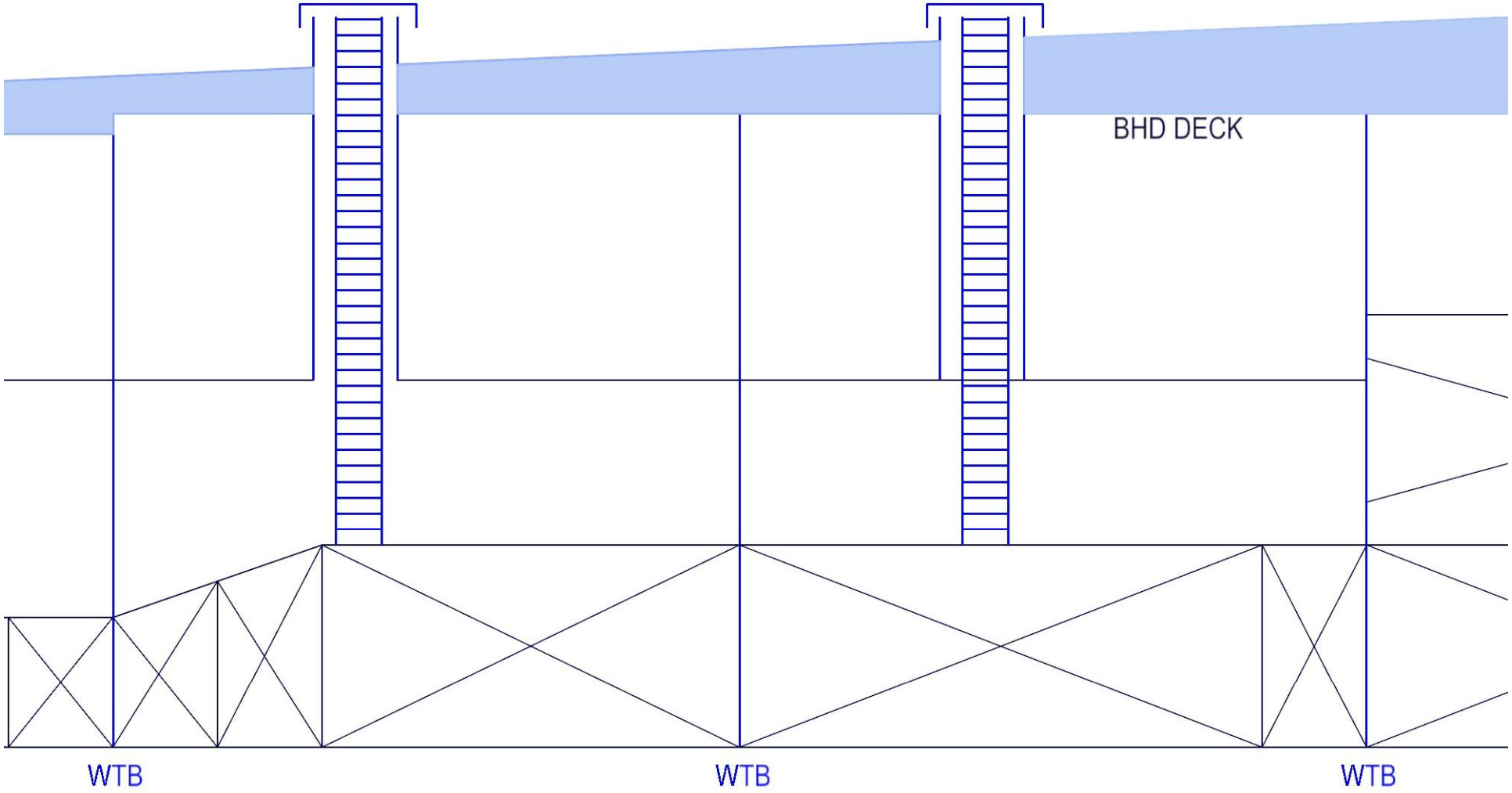
- **Hatches, Doors, Air Pipes ventilation openings**
- **Horizontal escape routes on the Bulkhead deck**

Si (Prob of Survival) is taken as zero if the following are immersed in the intermediate or final stage of damage:

- **Vertical escape hatch**
- **Control station for operation of WT doors**
- **Piping or ventilation that causes progressive flooding**

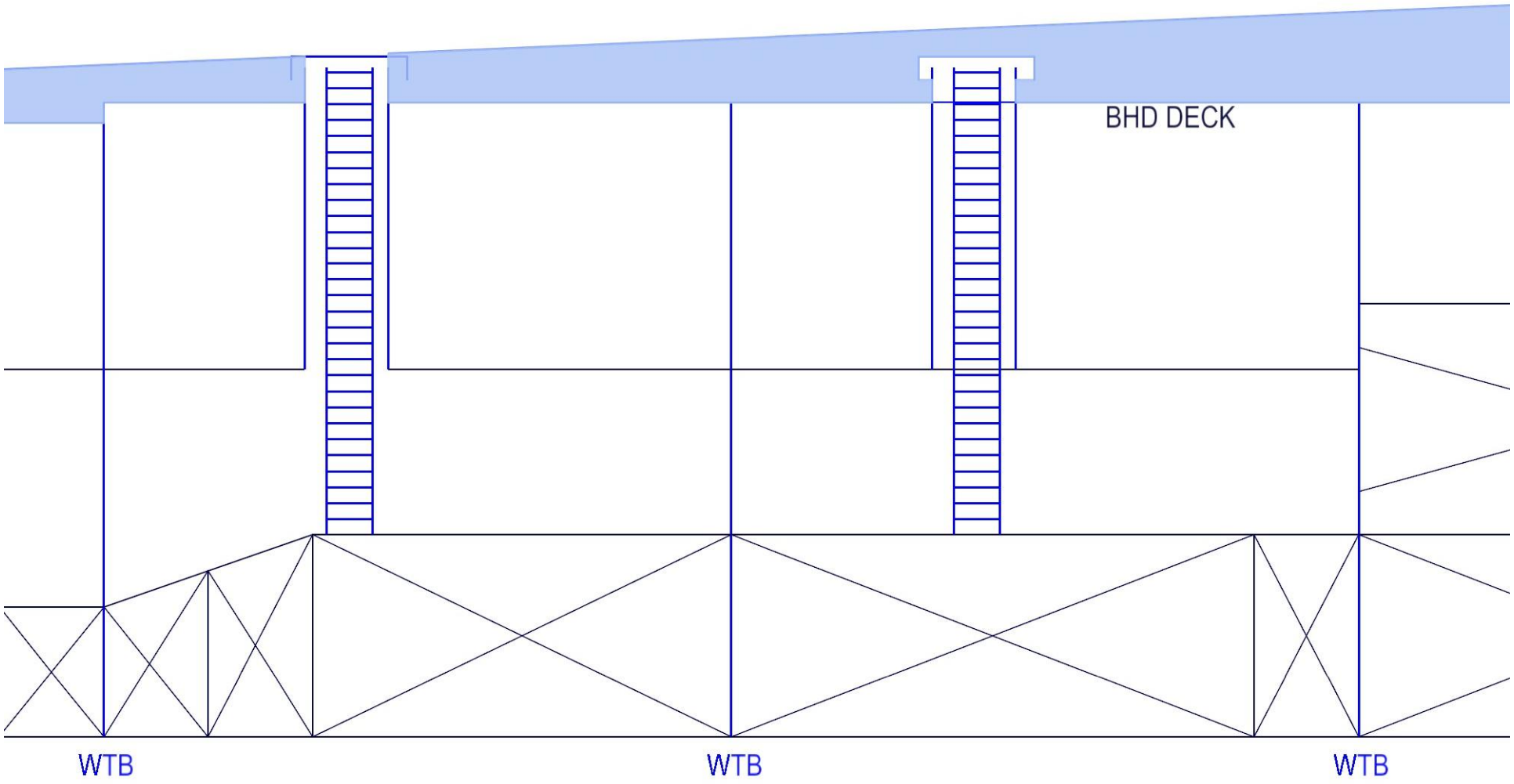
Vertical Escape Hatches

BCTQ
Burness Corlett Three Quays



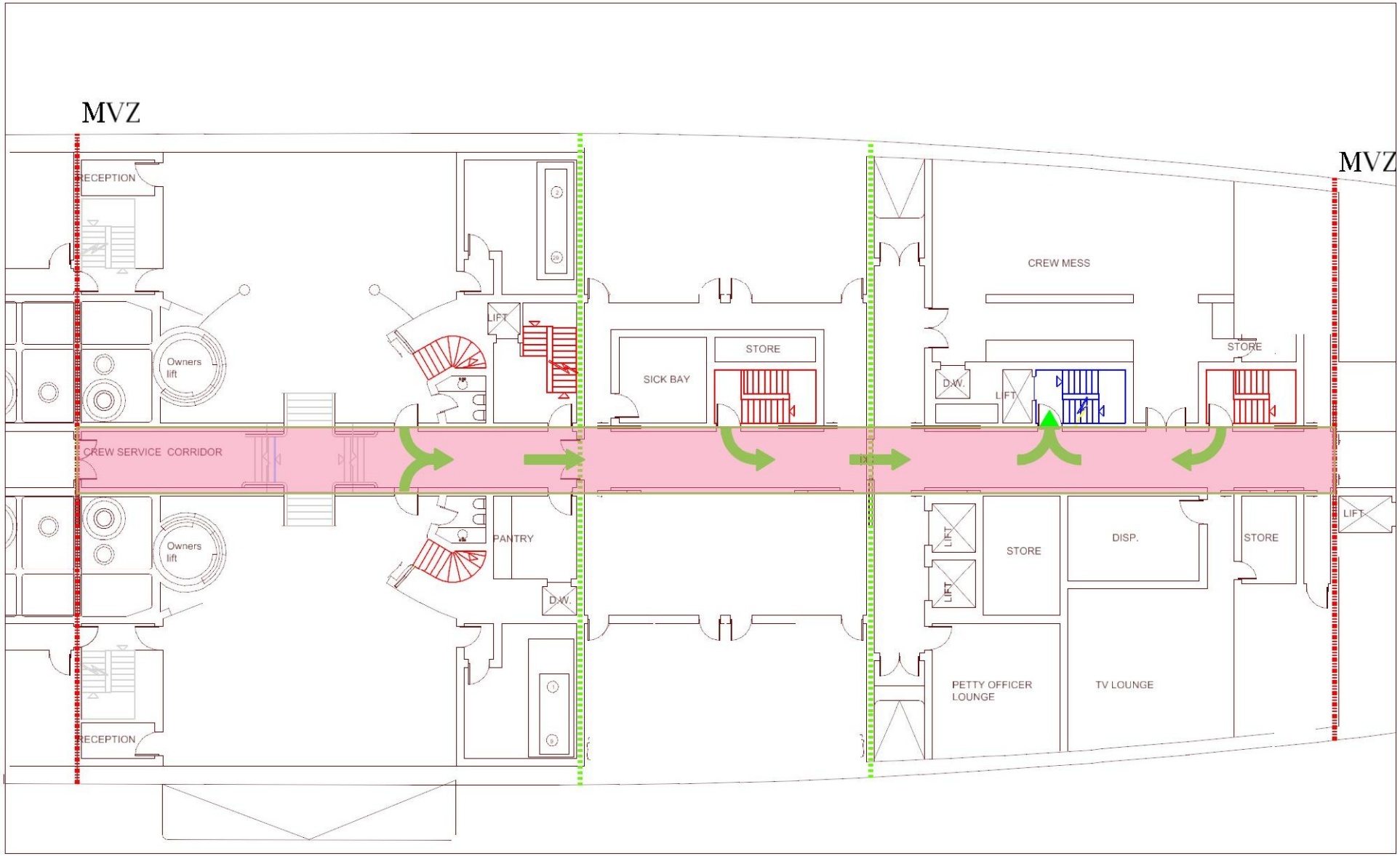
Vertical Escape Hatches (S=0)

BCTQ
Burness Corlett Three Quays



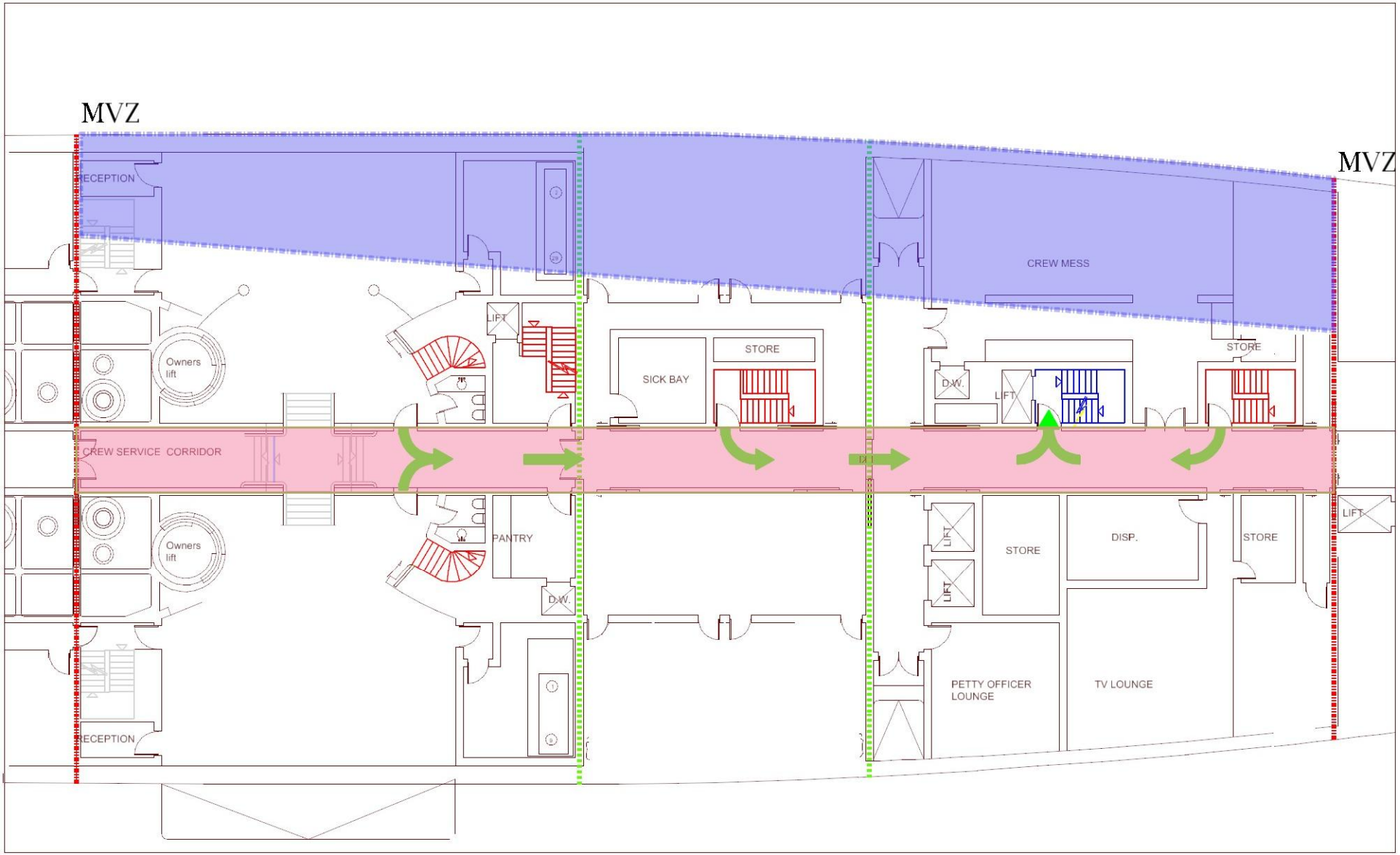
Horizontal Escapes

BCTQ
Burness Corlett Three Quays



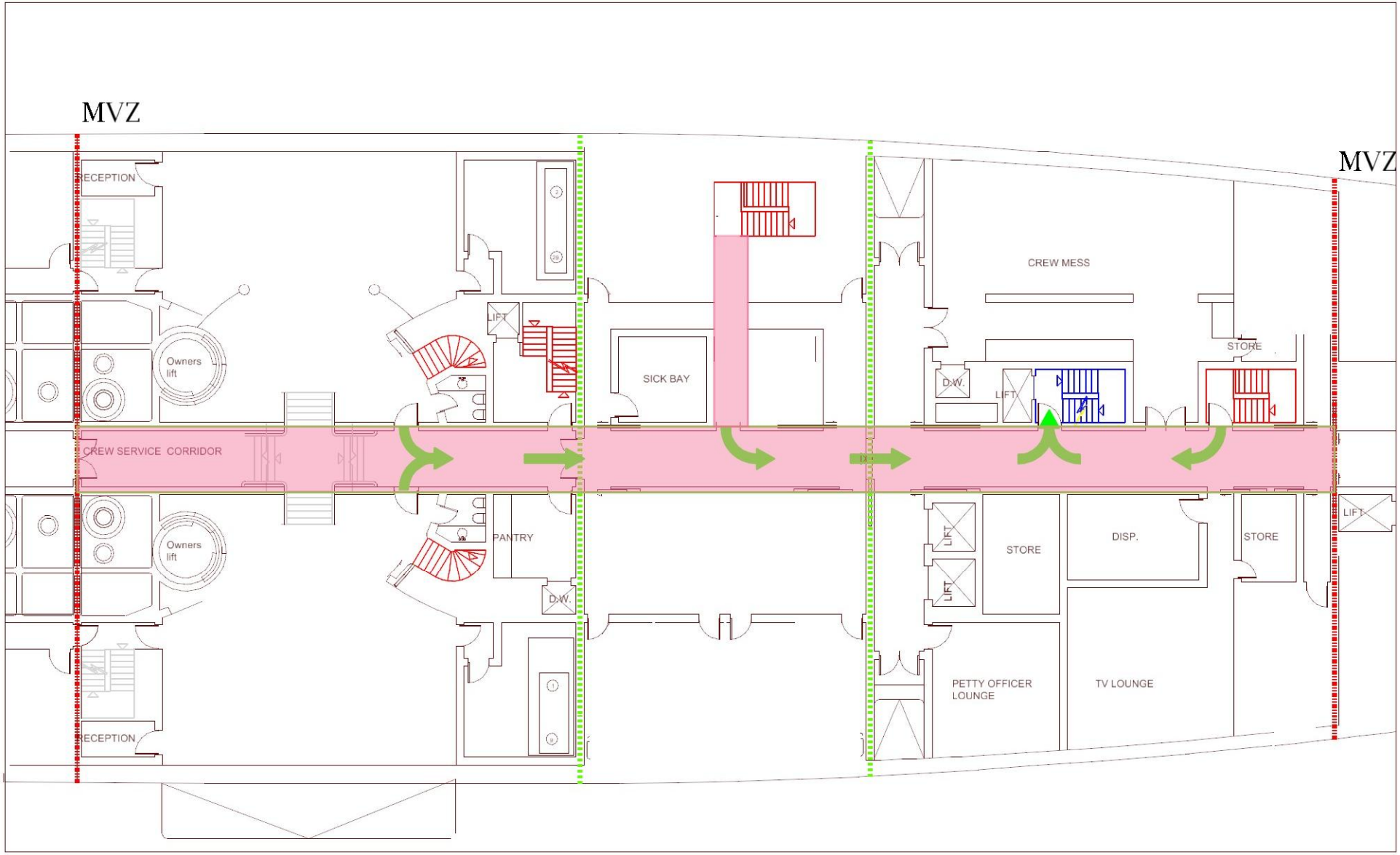
Horizontal Escapes

BCTQ
Burness Corlett Three Quays



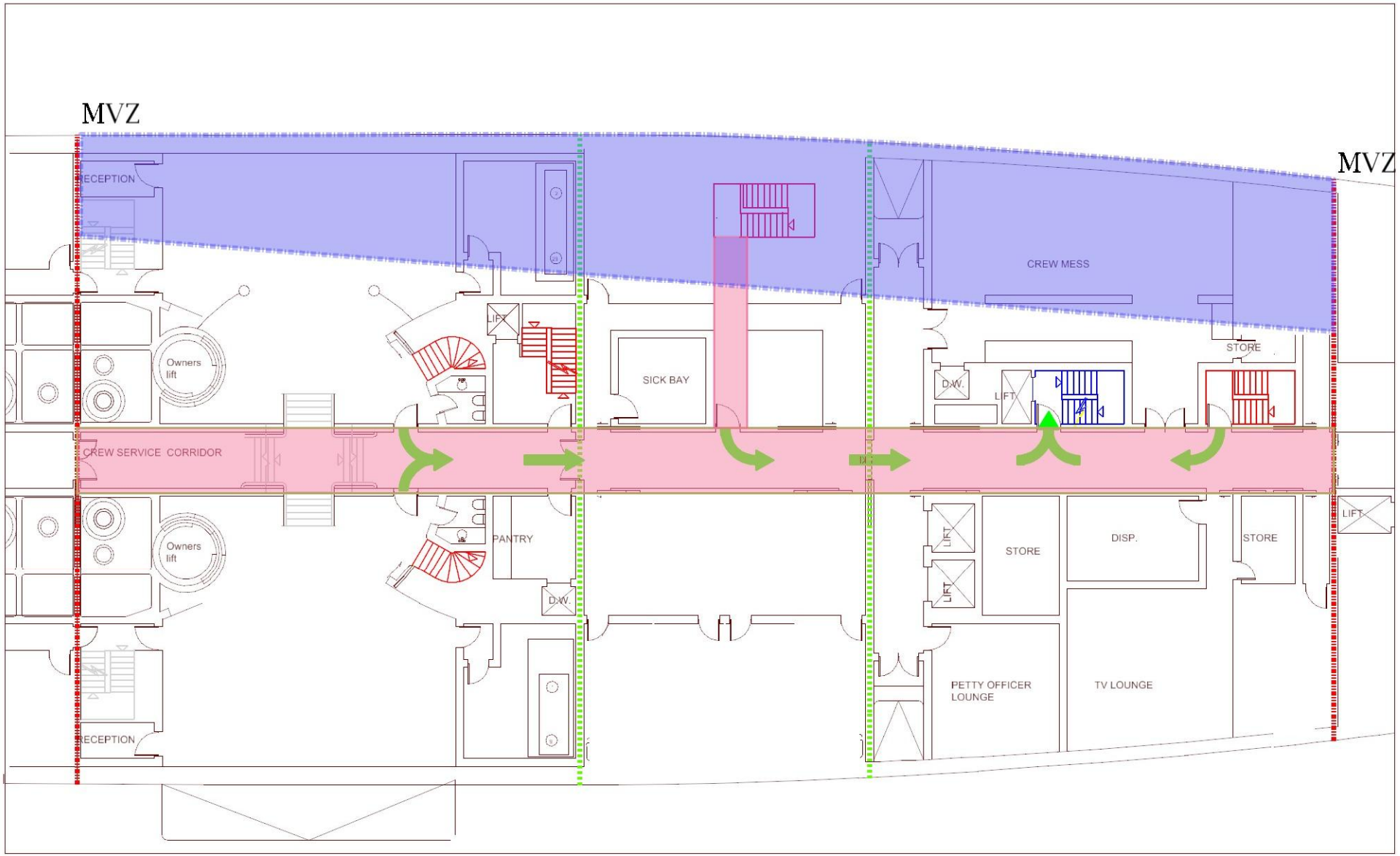
Horizontal Escapes

BCTQ
Burness Corlett Three Quays



Horizontal Escapes (S=0)

BCTQ
Burness Corlett Three Quays



Comparison of Methods

BCTQ
Burness Corlett Three Quays

Based on Two Case Studies:

- **120m Project designed to Two compartment standard**
- **>160m Project designed to Two compartment standard**
- **BCTQ compared Probabilistic Calculation results**

Probabilistic Calculation

BCTQ
Burness Corlett Three Quays

- **BCTQ have developed a Probabilistic Module for in-house Naval Architecture Software HYDAS**
- **Software calculates:**
  - **Probability of damage Pi**
  - **Probability of Survival Si**
  - **A=ΣPi Si is then calculated for each draft condition:**
    Subdivision Draft
    Partial Draft
    Light Draft

Attained index A= 0.4 As+0.4Ap+0.2Al

As, Ap and Al >= 0.9R

Then vary KG and rerun till A >= R

Additional Calculations

BCTQ
Burness Corlett Three Quays

- Minor Damages
  - Deterministic analysis to a One compartment standard
  - Damage length between 1.5%L and 3%L
  - Transverse extent is between B/10 and B/20
  - Si >=0.90 for the 3 draft conditions
- Double bottom
  - Required to extend throughout ship, otherwise additional calculations are required
  - S=1.00

120m Yacht Project

BCTQ
Burness Corlett Three Quays

Beam: 18.2m

Draft: 5.5m

22 Guests

65 Crew

Designed in 2008 with MES instead of Lifeboats

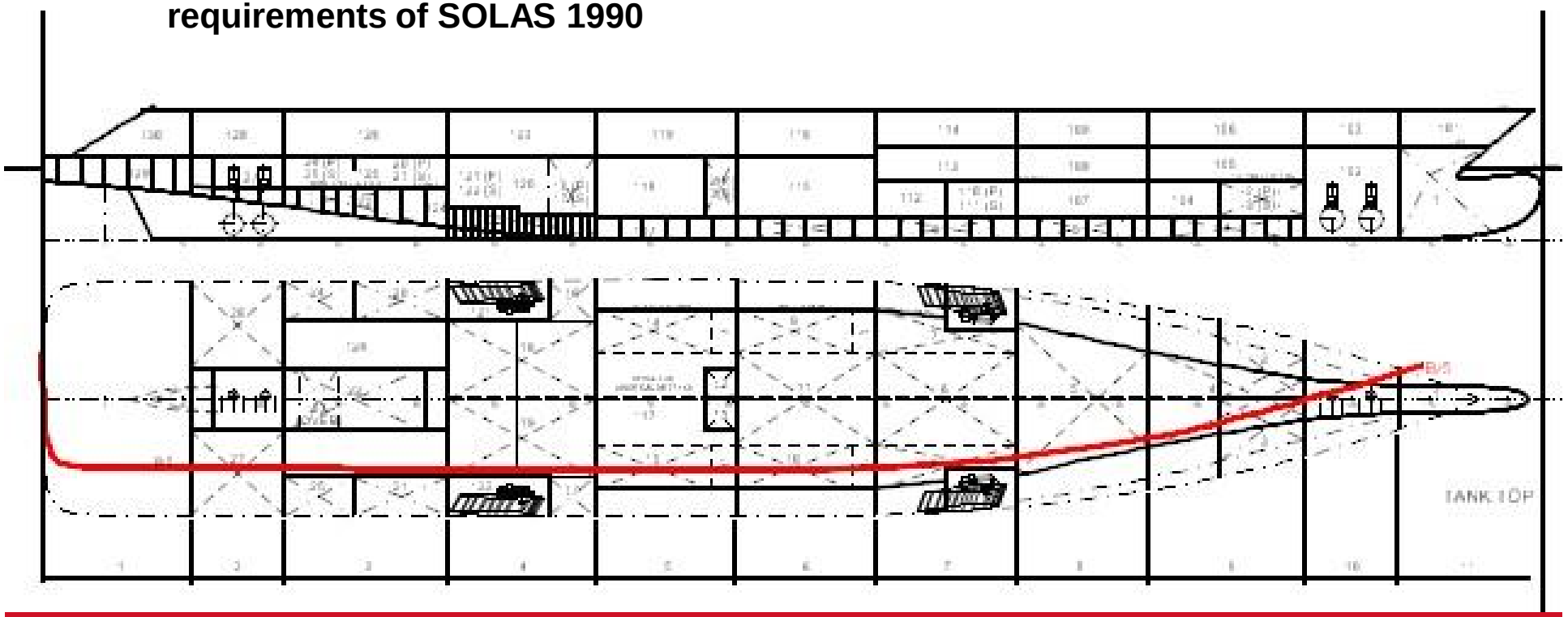
Designed to Passenger Ship requirements of SOLAS 1990

Deterministic Analysis

Two compartment standard

11 watertight compartments

Total 550 Damage Cases



120m Yacht Project - Probabilistic

BCTQ
Burness Corlett Three Quays

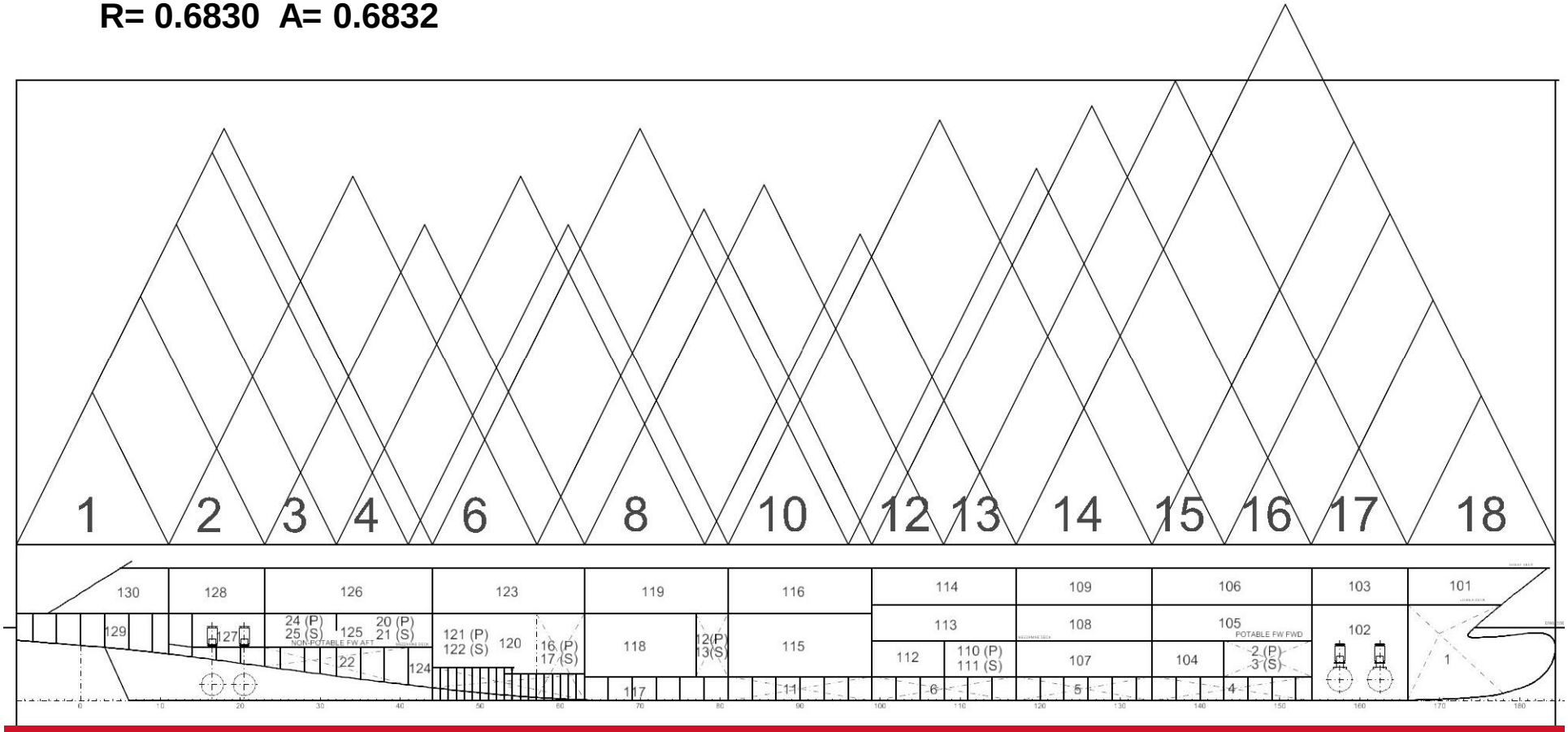
Compartments in DB included in analysis

18 Damage Zones

Calculation undertaken with up to 5 Zones

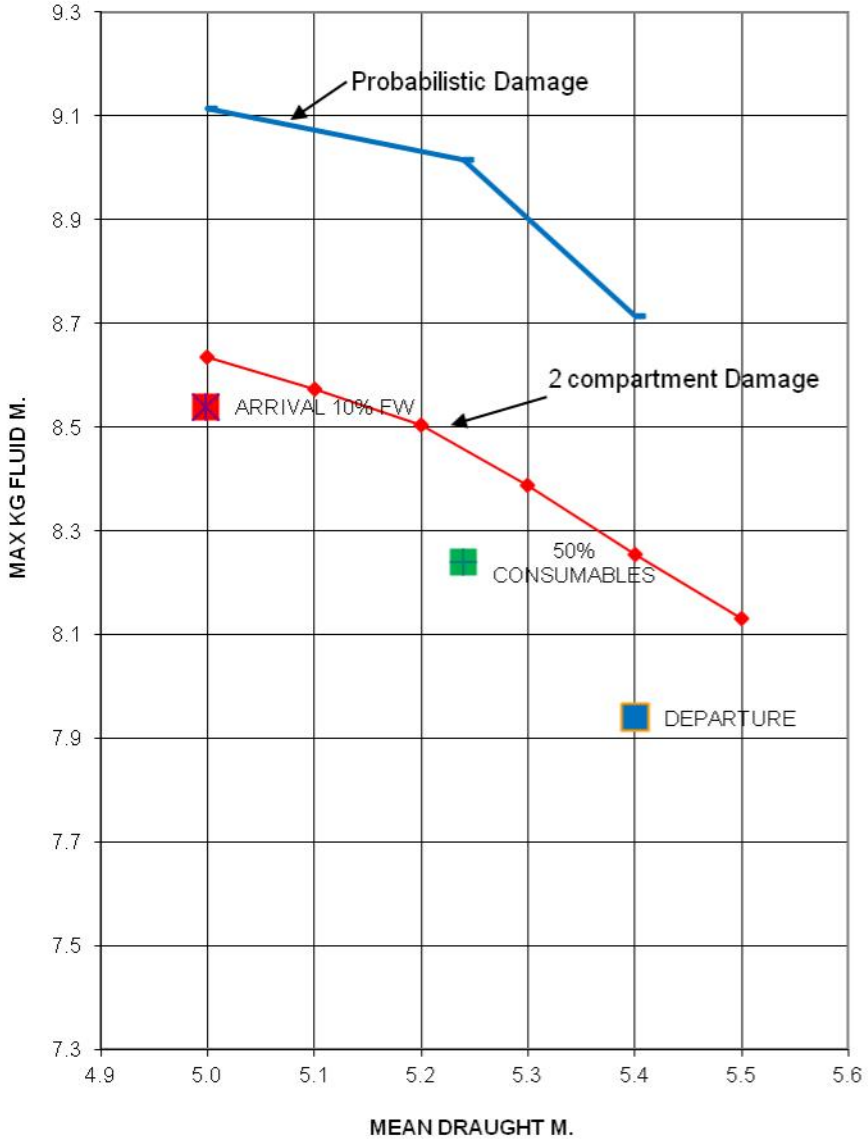
Total 1776 Damage Cases

R= 0.6830 A= 0.6832



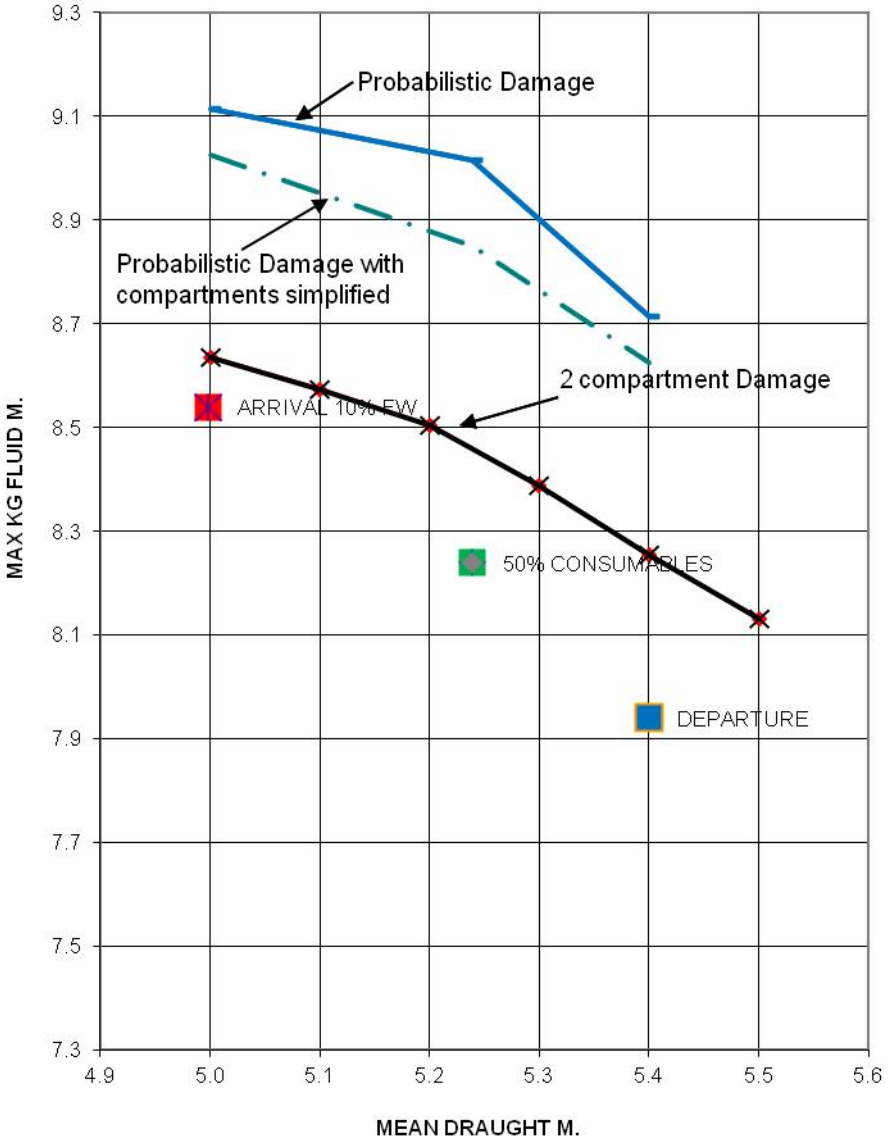
120m Yacht Project Results

BCTQ
Burness Corlett Three Quays



- **Loading conditions comply with both probabilistic and Two Compartment standard**
- **Two compartment standard is more onerous**
- **Probabilistic analysis requires 1776 damage cases**
- **Deterministic analysis requires 550 damage cases**

Simplified Compartment Arrangement



Includes:

- **Watertight Bulkheads**
- **Double Bottom defined**
- **Horizontal escapes defined**
- **Vertical Escapes**
- **No tanks**

- **Yacht divided into 12 zones**
  3 zone damages

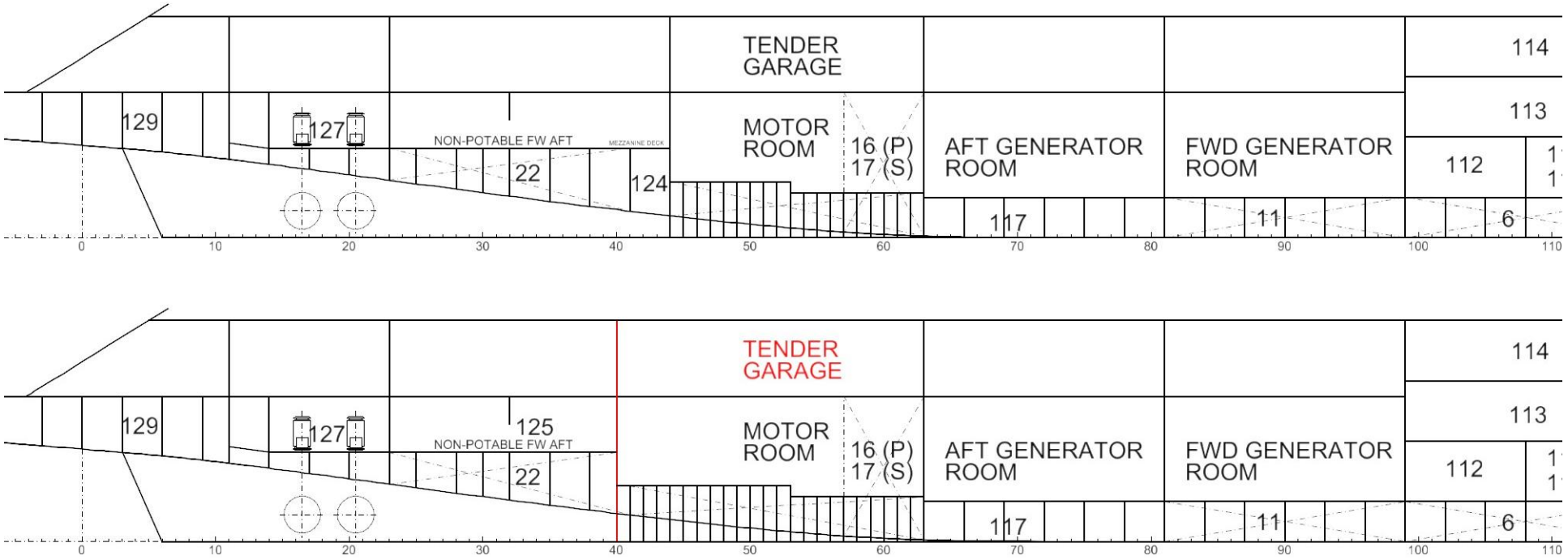
- **Reasonable correlation with full results**

- **430 damage cases**
  Reduced analysis time

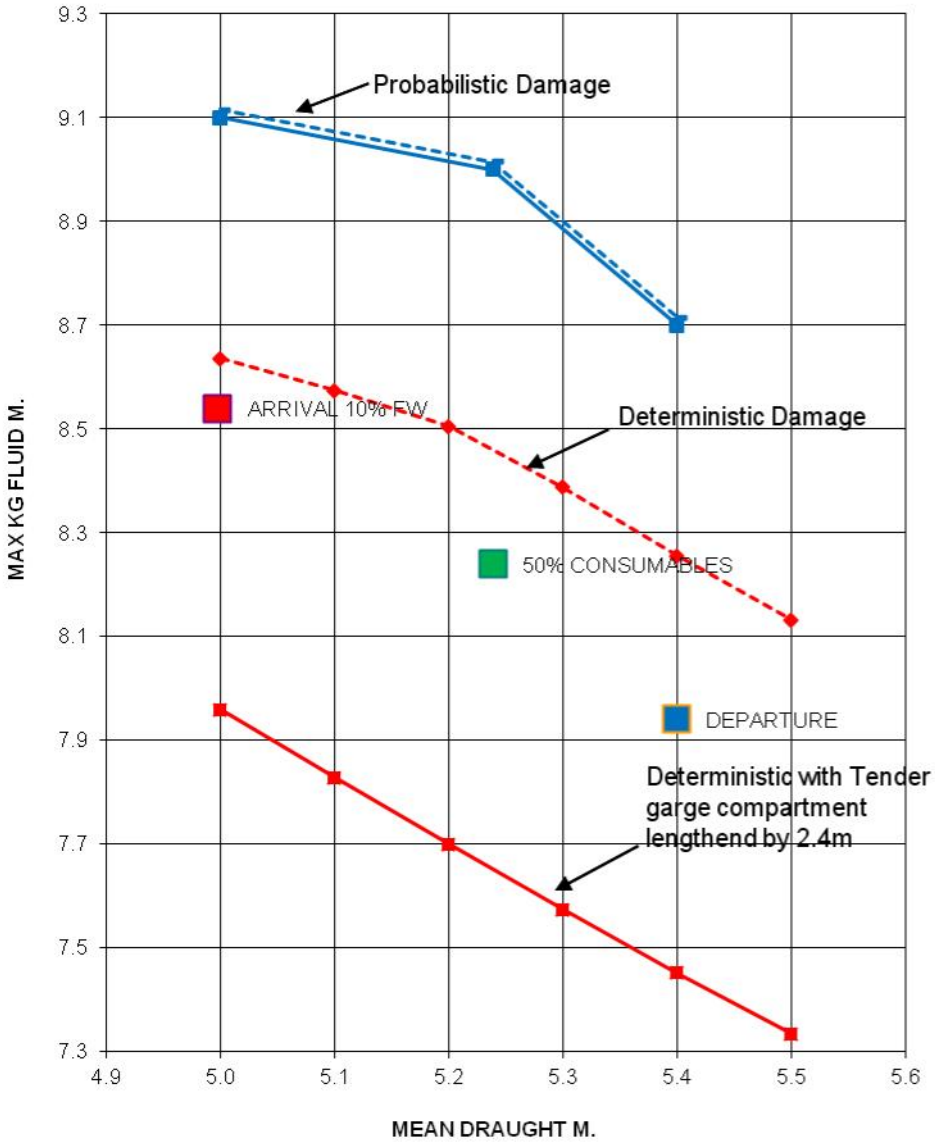
- **Allows optimisation of bulkhead arrangement**

Tender Garage Example

- **Tender garage increased by 2.4m to take a 12m Tender**
- **For this example the motor room increased in size**



Tender Garage Example



Results

- **Probabilistic results unchanged**
- **Two Compartment results severely effected by modification**

Conclude that:-

- **Probabilistic is less rigid in the positioning of bulkheads**

>160m Yacht Project

BCTQ
Burness Corlett Three Quays

Beam: 24m

Draft: 6.3m

50 Guests

126 Crew

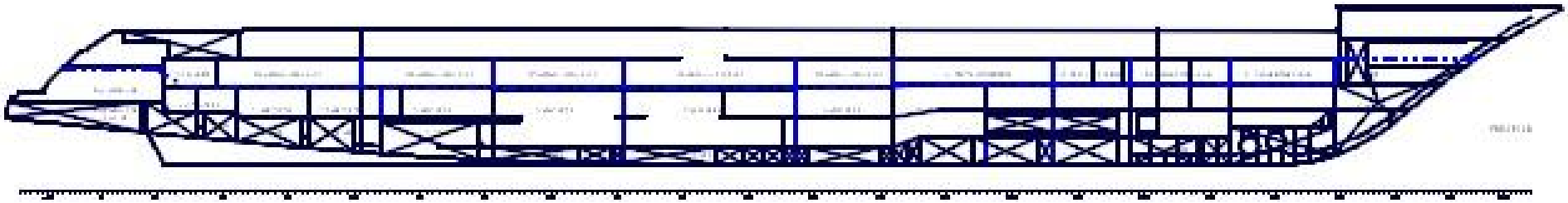
Designed in 2006

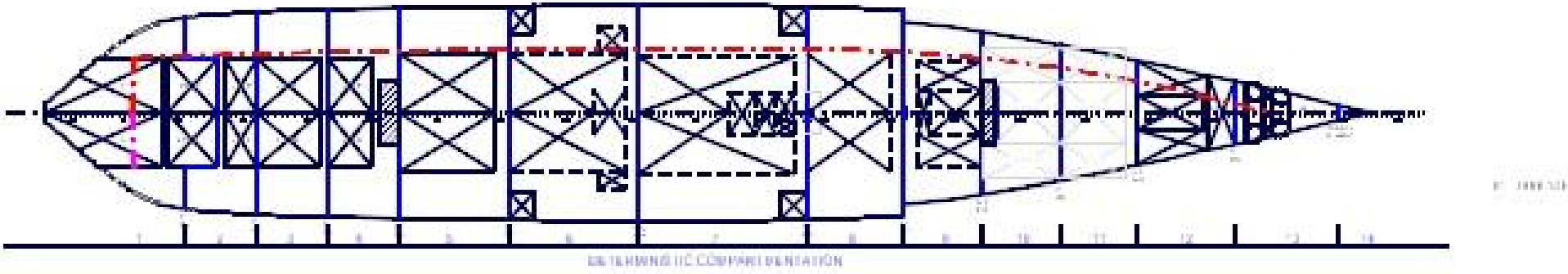
Designed with Lifeboats

Designed to Deterministic Passenger Ship requirements of SOLAS 1990

Two compartment standard

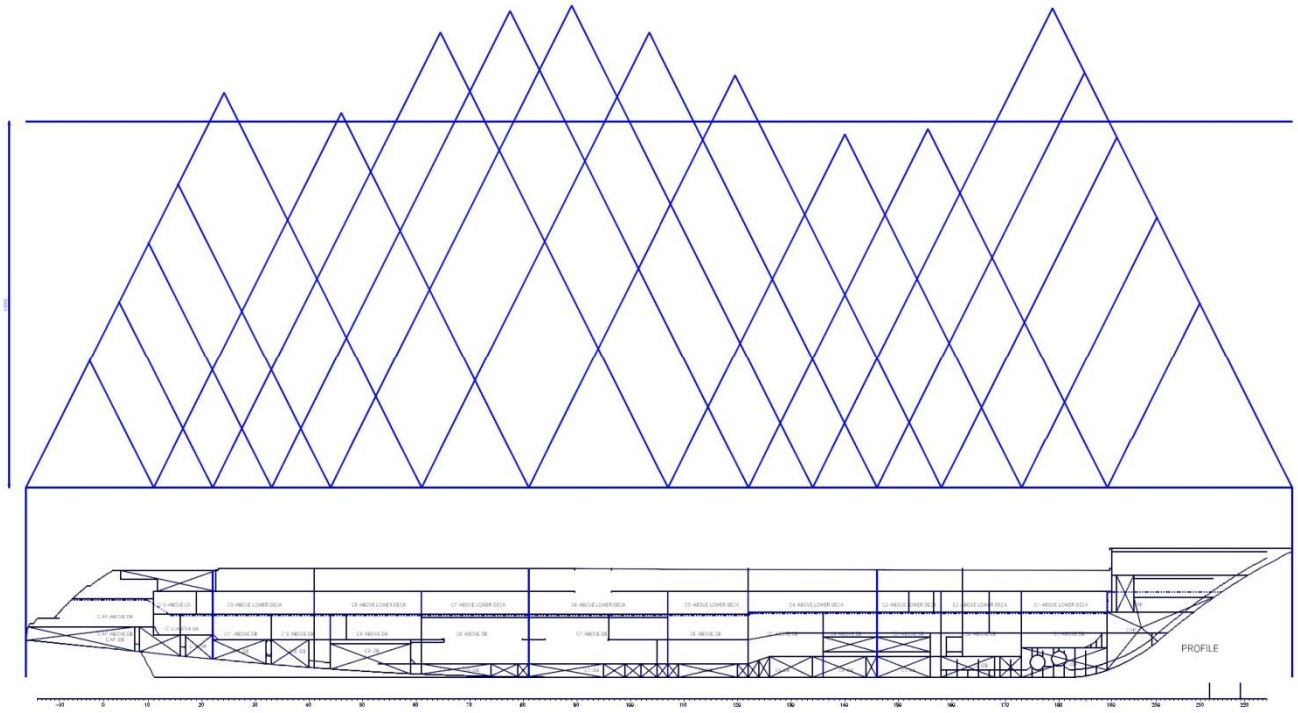
14 watertight compartments





>160m Yacht Project Probabilistic

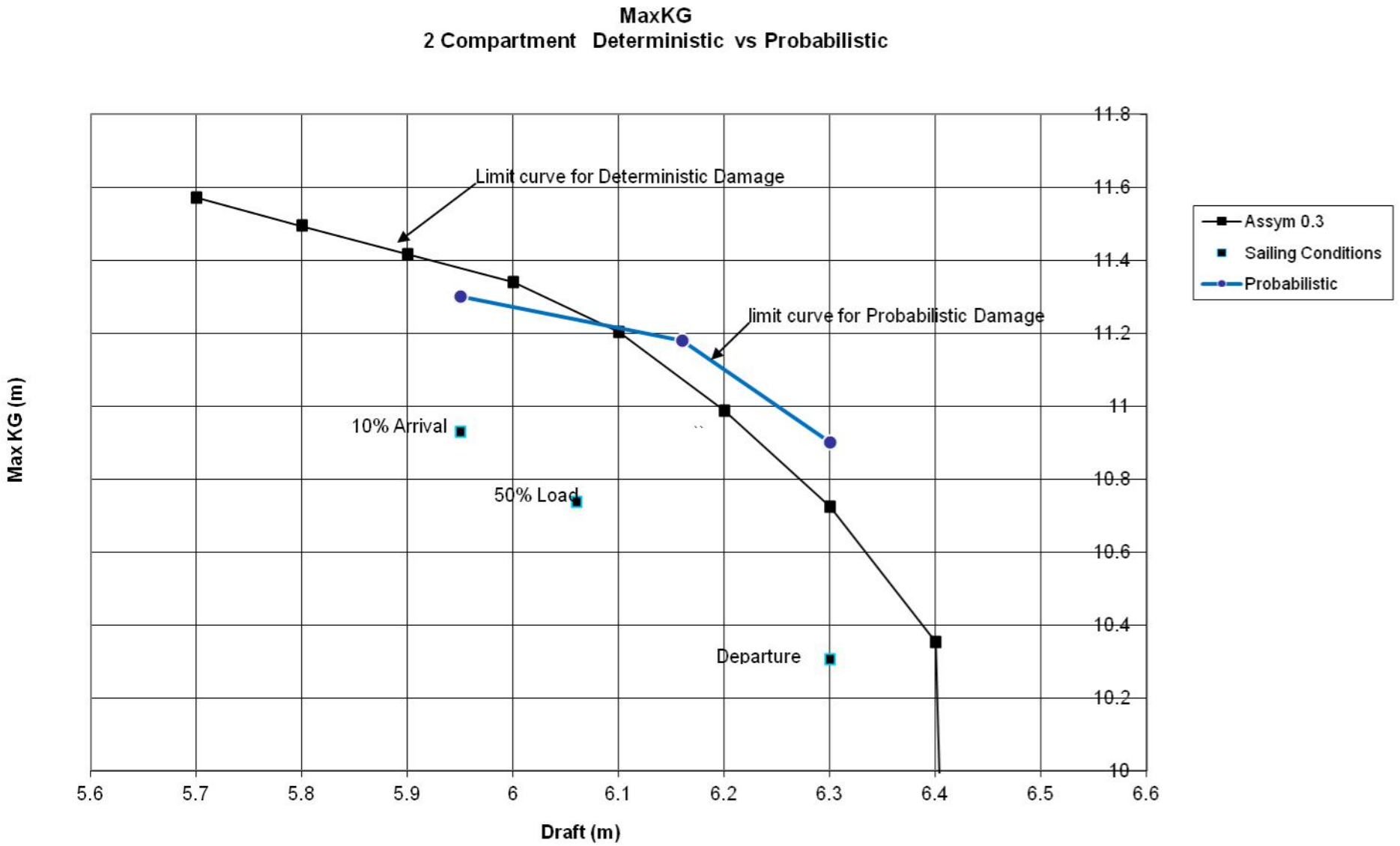
BCTQ
Burness Corlett Three Quays



- **Same Watertight Compartments**
- **DB compartment included**
- **More Zones**
- **Damage to B/2**
- **4677 Damage Cases**

>160m Yacht Analysis Results

BCTQ
Burness Corlett Three Quays



Conclusion

BCTQ
Burness Corlett Three Quays

- Probabilistic analysis
  - More work
  - More flexible bulkhead arrangement
- The 2 Yachts designed as Two compartment standard comply with probabilistic requirements
- Margin line replaced by WT hatches, horizontal escape routes on bulkhead deck
  - There is a benefit of locating these on CL
- Damages assumed to occur up to B/2, therefore more systems will require bulkhead valves
- Simplification of Compartment Arrangement
  - Reasonable step in Initial Analysis

Initial Probabilistic Analysis - Methodology

BCTQ
Burness Corlett Three Quays

Six Steps

1. Undertake Two compartment deterministic analysis if required
2. Define loading conditions Draft, Trim and KG
3. Use a simplified compartment arrangement
    - Locate Collision bulkhead
    - Locate Fire Zone bulkheads
    - Locate Engine Room and other bulkheads
    - Insert Double Bottom
    - Define Horizontal and Vertical escapes routes
4. Optimise and once working arrangement is found
5. Arrange tanks, including cross flooding
6. Analyse to include minor damages and double bottom damages

BCTQ
Burness Corlett Three Quays

Thank You.