Stability and capsizing

- What is stability?
- Basic concepts –righting moment and “GZ curve”
- Large angle stability
- Things that affect stability
- Guidelines for choosing a design
- Guidelines when modifying a boat

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Session Contents

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- Basic concepts –righting moment and “GZ curve”
- Large angle stability
- Things that affect stability
- Guidelines for choosing a design
- Guidelines when modifying a boat

What is stability?

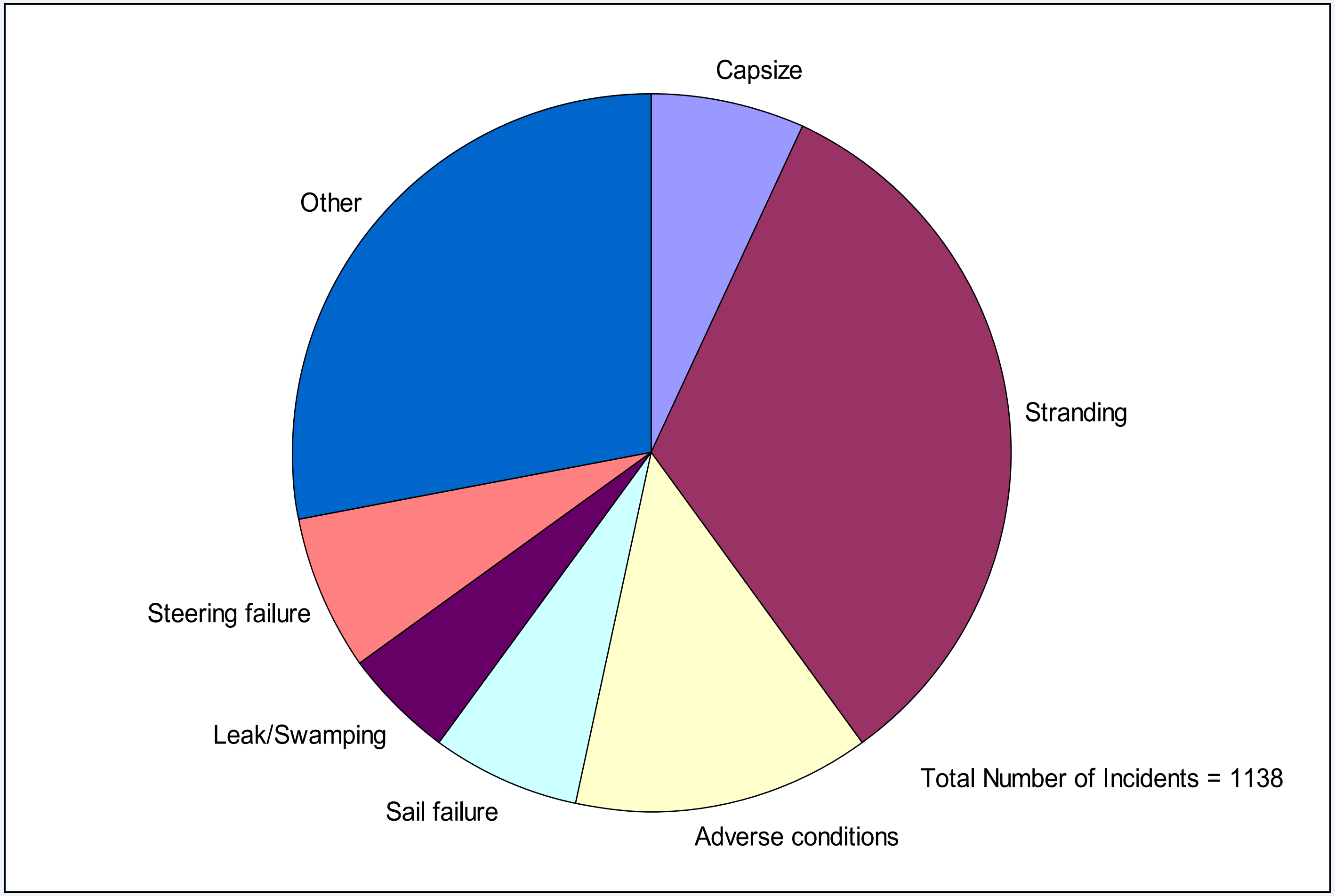
- Normal sailing:

Stability = power to carry sail

- Extreme conditions:

Stability = ability to resist capsize

Monohull - Casualty Statistics



RNLI lifeboat launches (5 year period)

Causes of Capsize

- Overpowered by the wind

Potential hazard for vessel with low range of stability ie. less than 90 degrees.

- Knocked down by a gust or squall

Can happen to any craft, not a hazard if structure remains buoyant and stable at large angles.

- Rolled by a breaking wave

Small craft more likely to encounter waves large enough to capsize them.

How stability is studied

Real world:

- Waves
- Roll motion
- Large heel angles

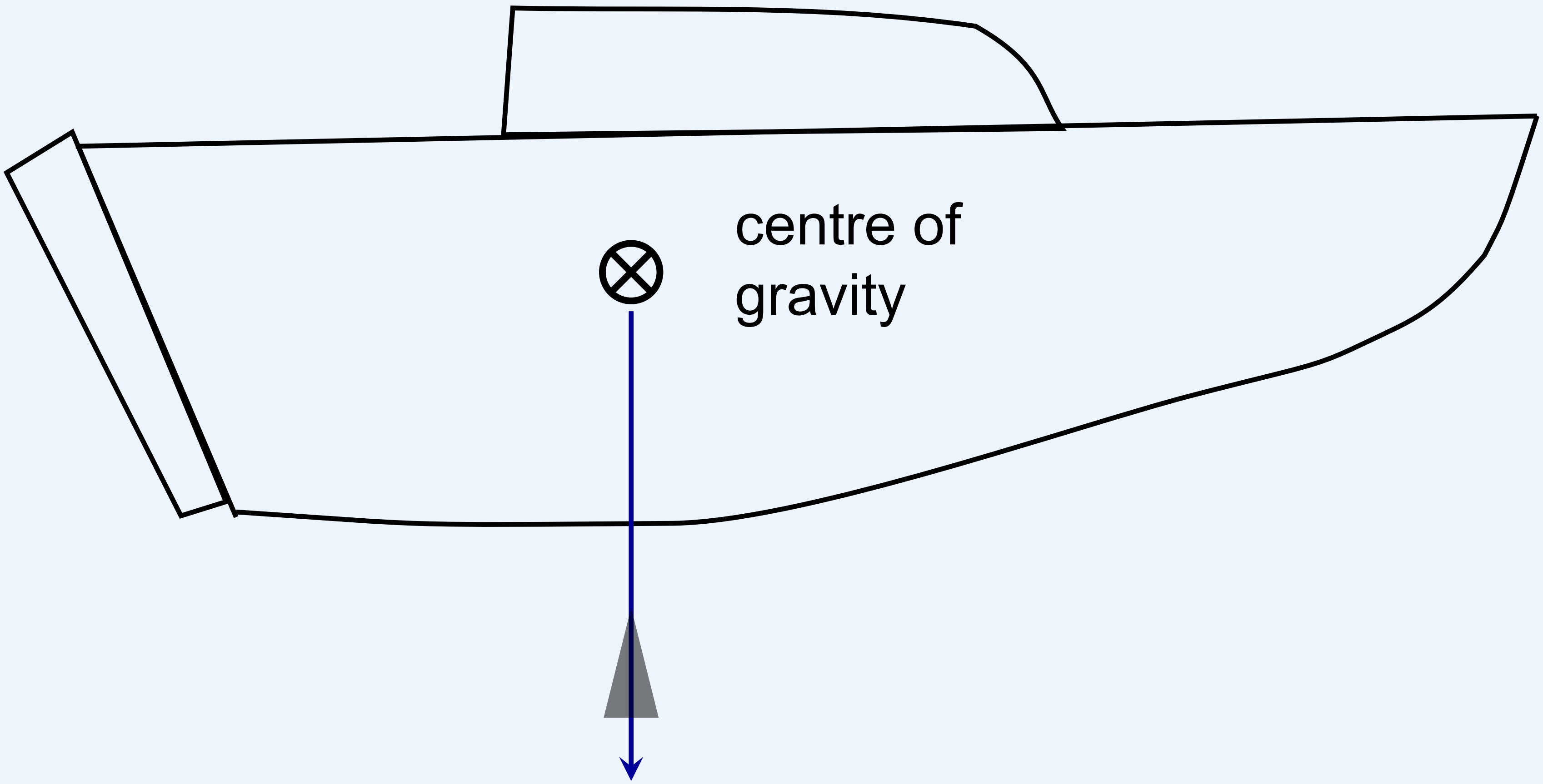
Simplify

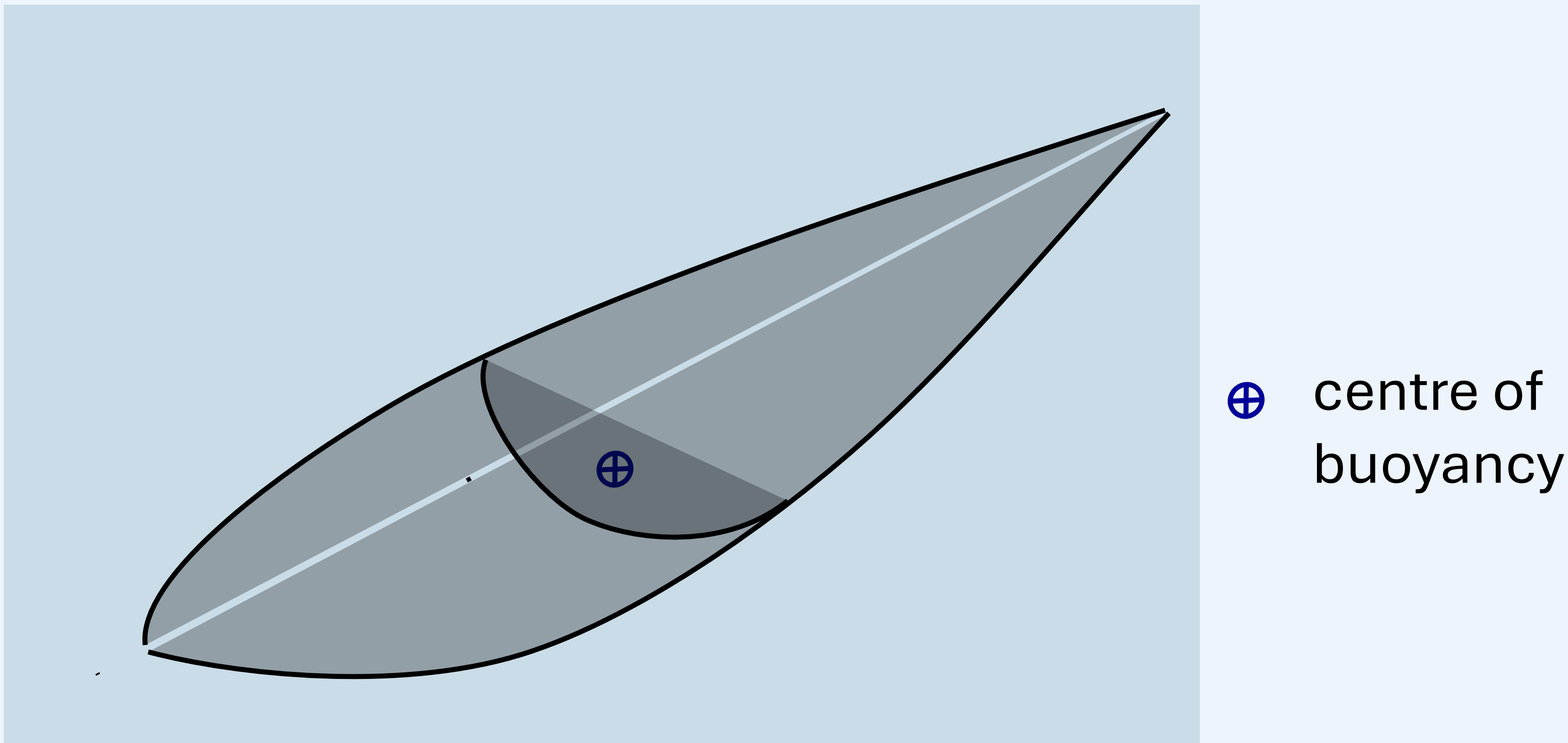
- Calm water
- Small angles
- "quasi-static"

Realistic hull shapes

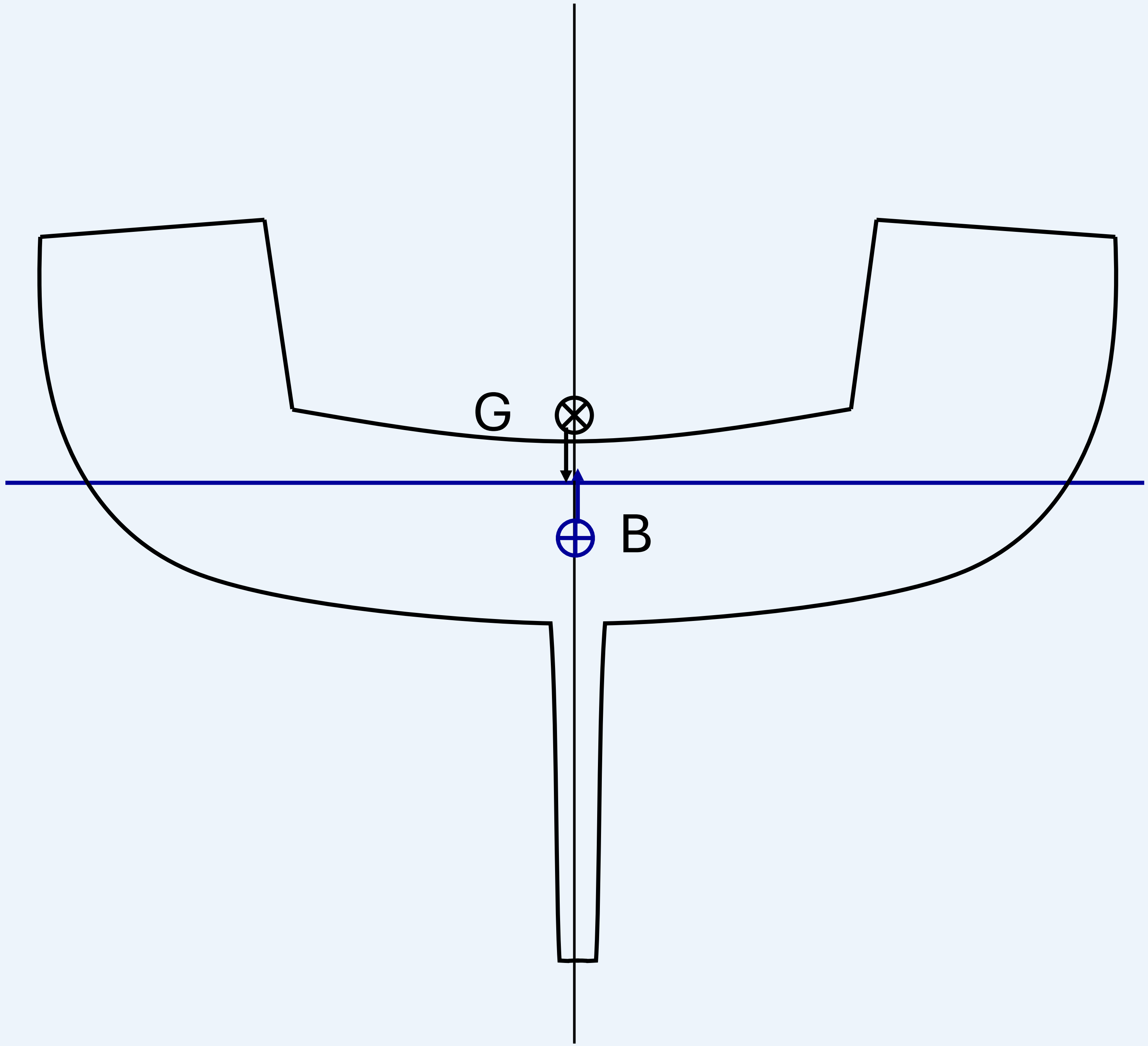
Large heel angles

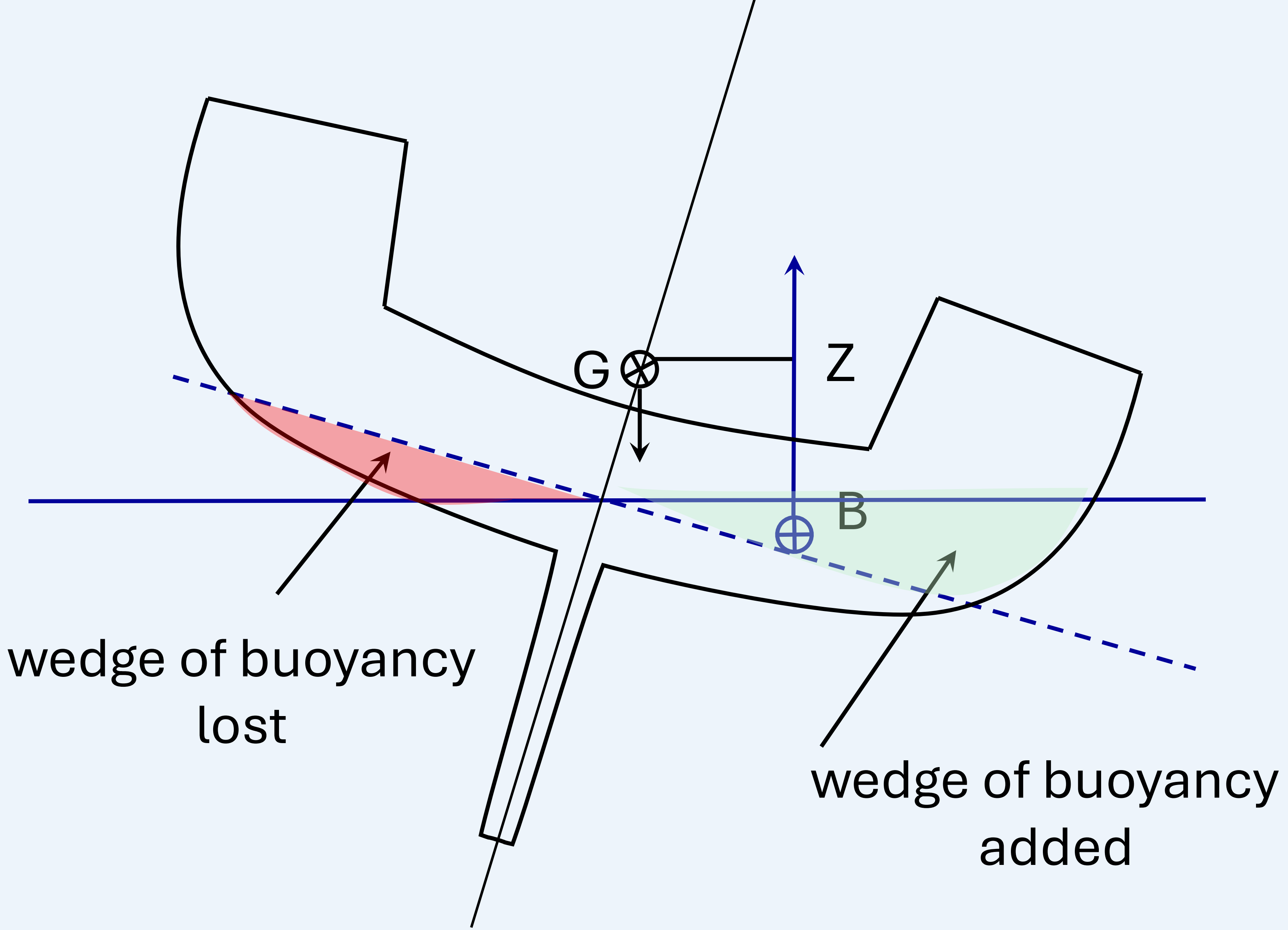
Waves

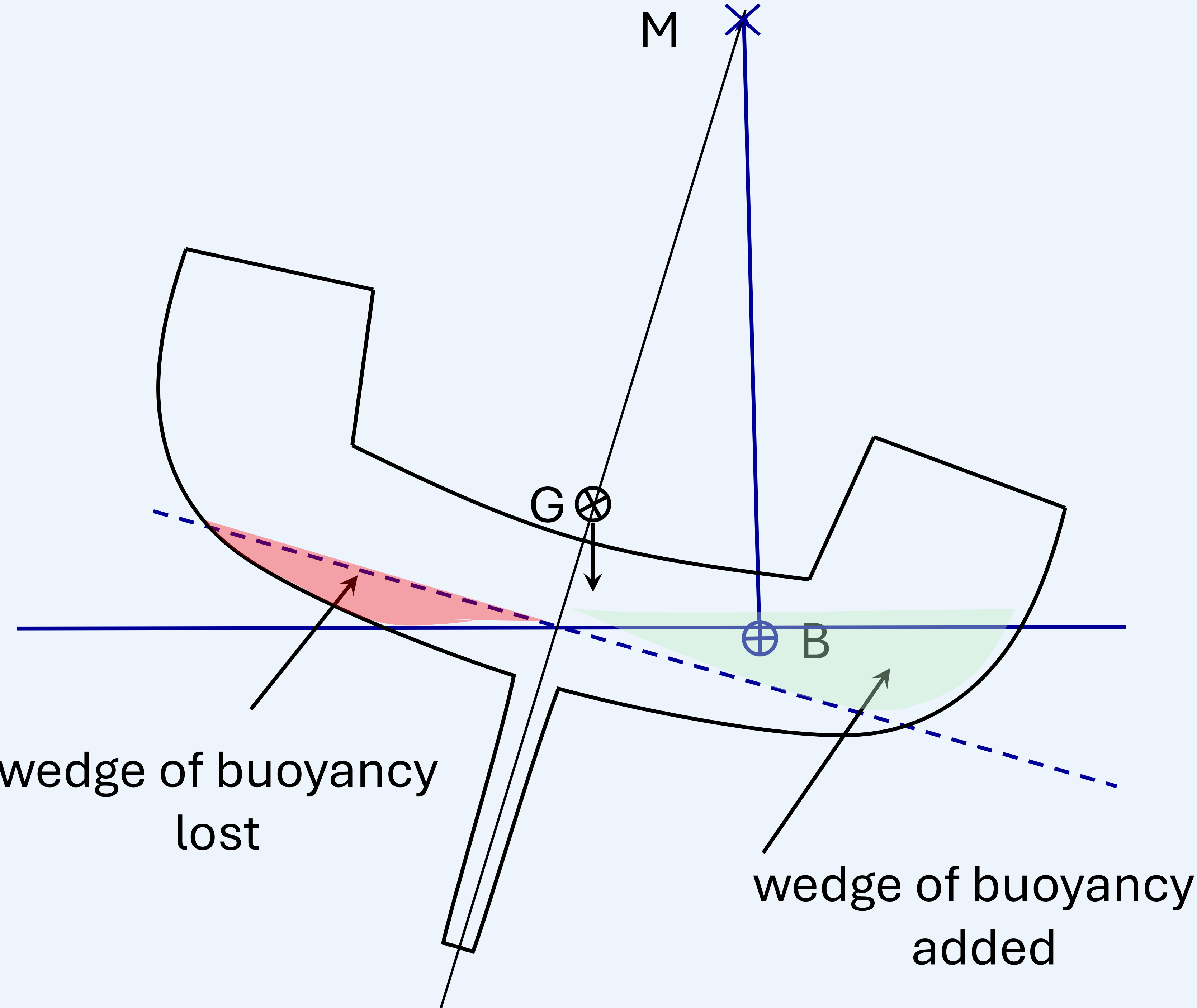

centre of
gravity

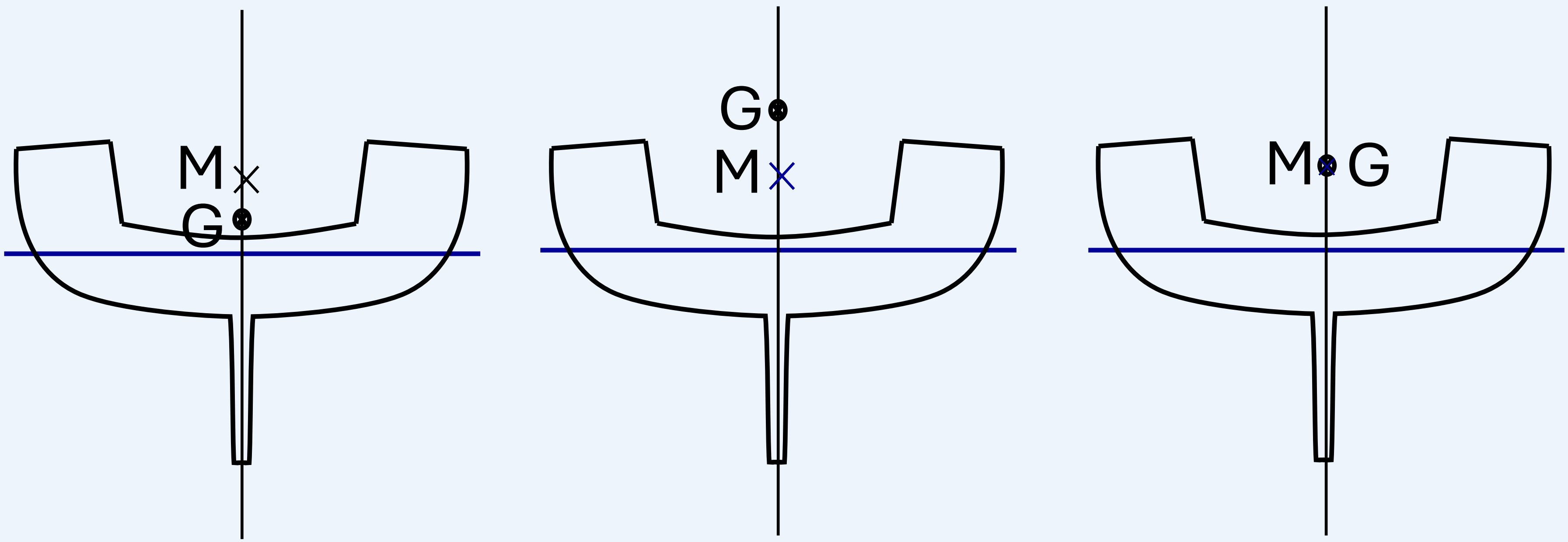


centre of buoyancy


G
B


G
Z
B
wedge of buoyancy lost
wedge of buoyancy added

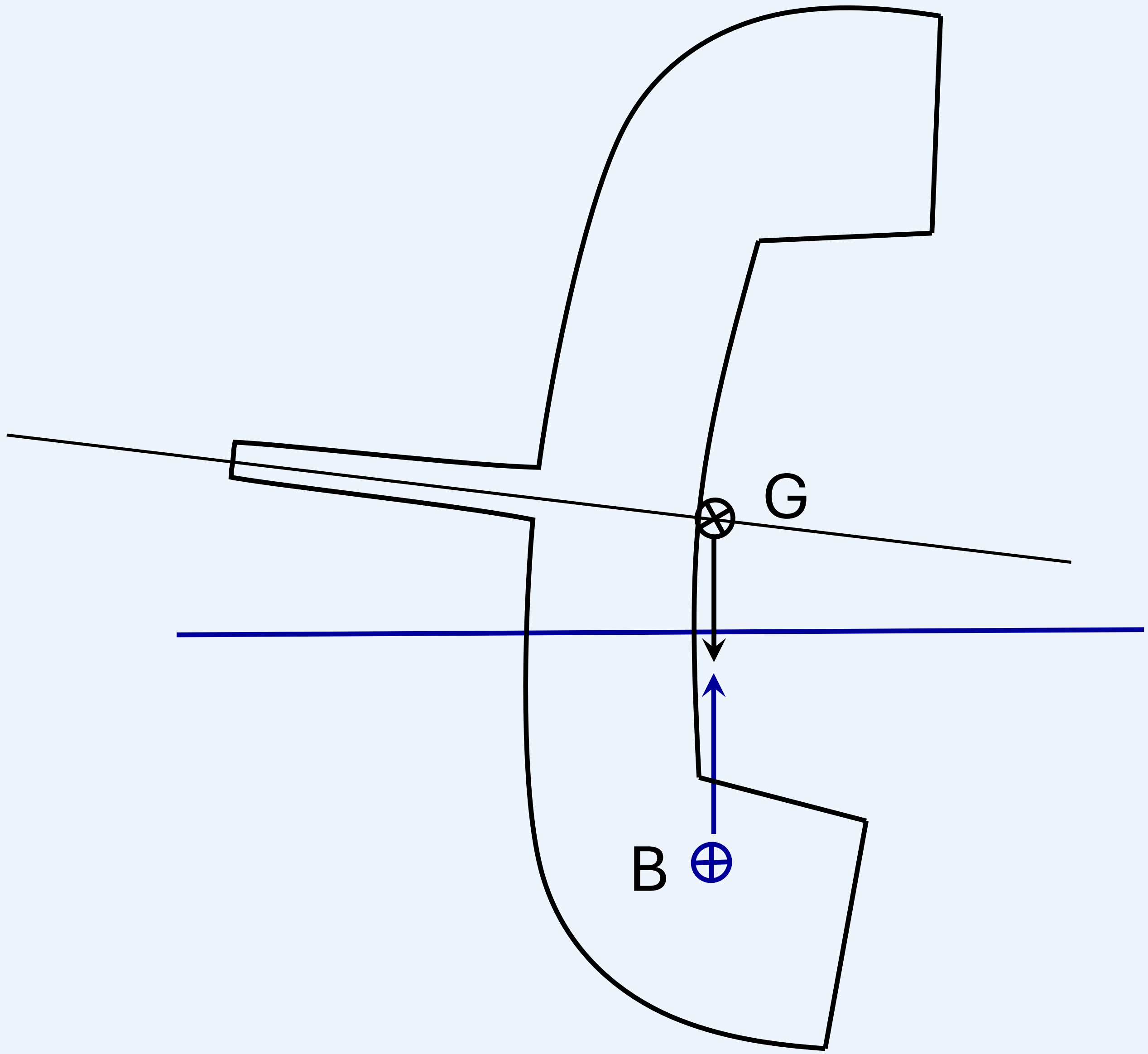

M
G
B
wedge of buoyancy
lost
wedge of buoyancy
added

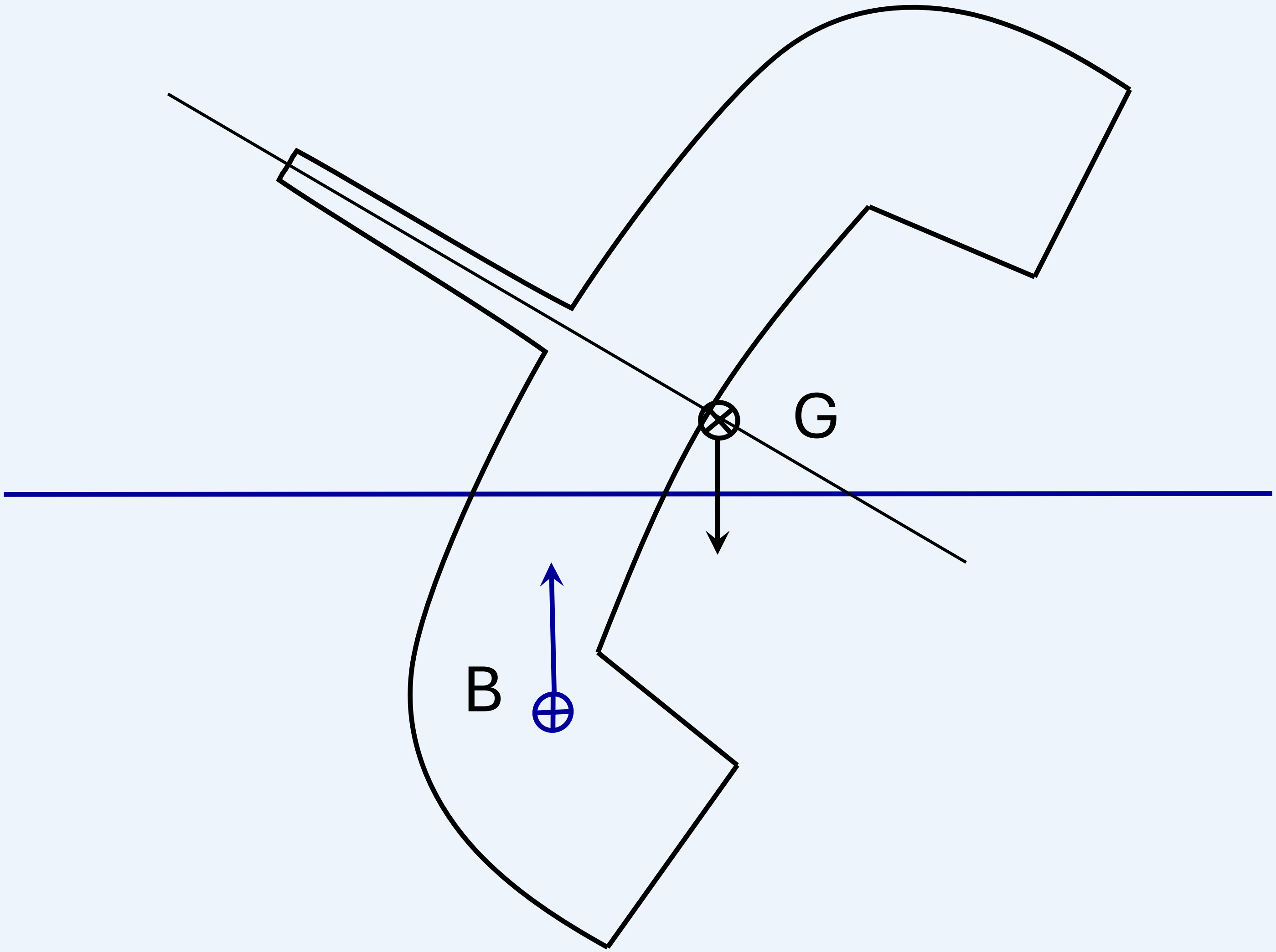


Positive stability

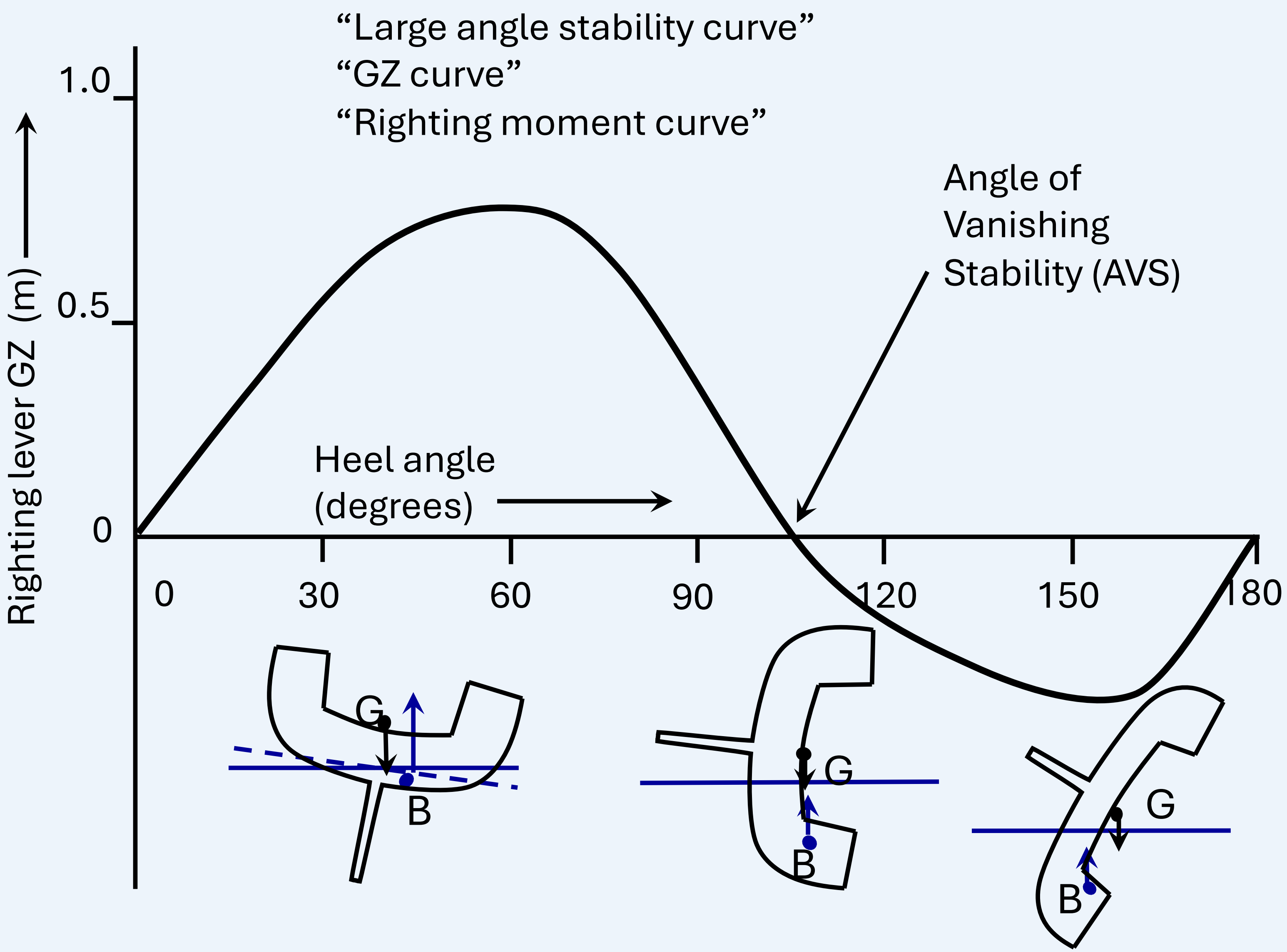
Negative stability

Neutral stability


G
B



G
B

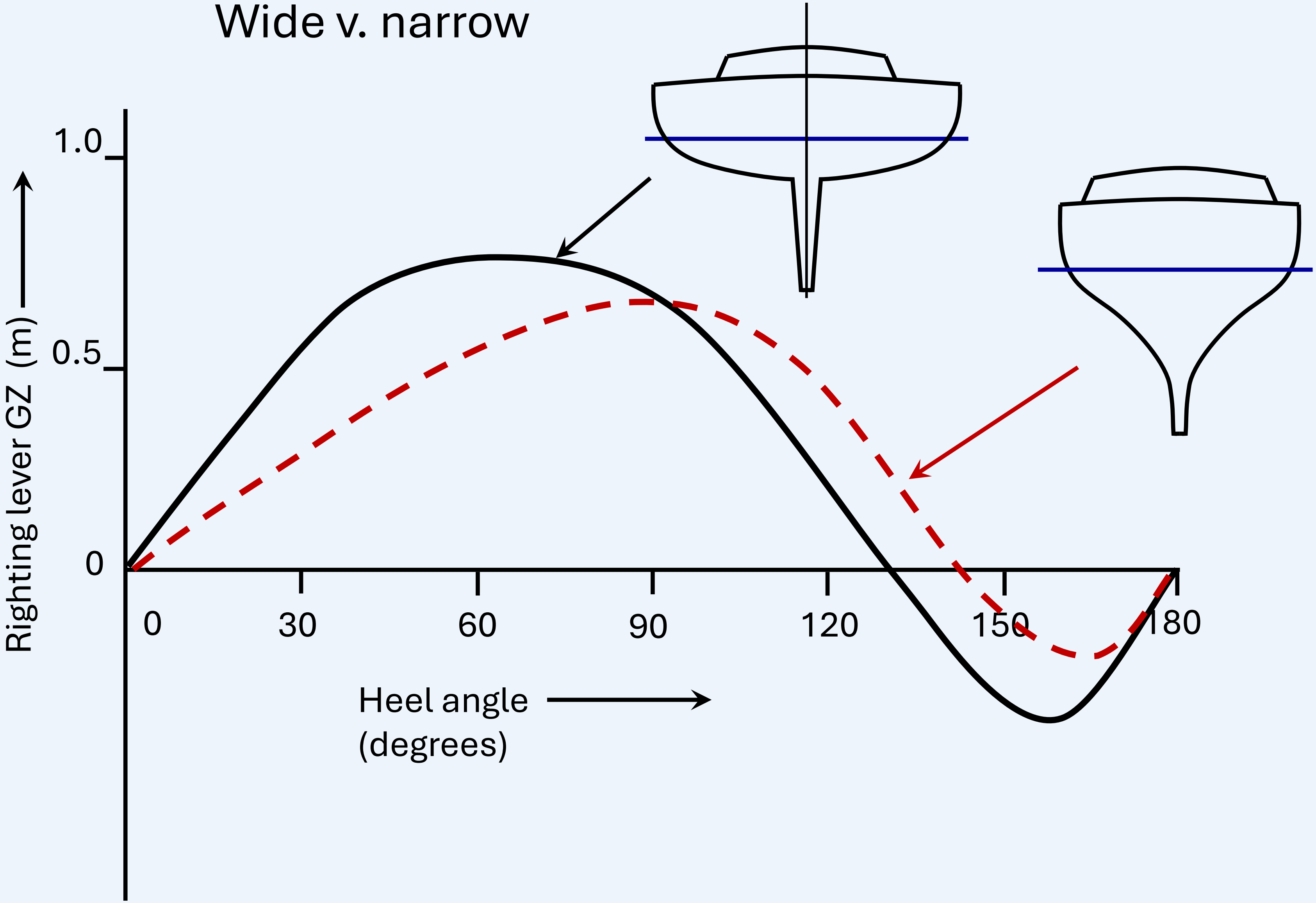


"Large angle stability curve"
"GZ curve"
"Righting moment curve"
Righting lever GZ (m)
1.0
0.5
0
Angle of
Vanishing
Stability (AVS)
Heel angle
(degrees)
0
30
60
90
120
150
180
G
B
G
B
G
B

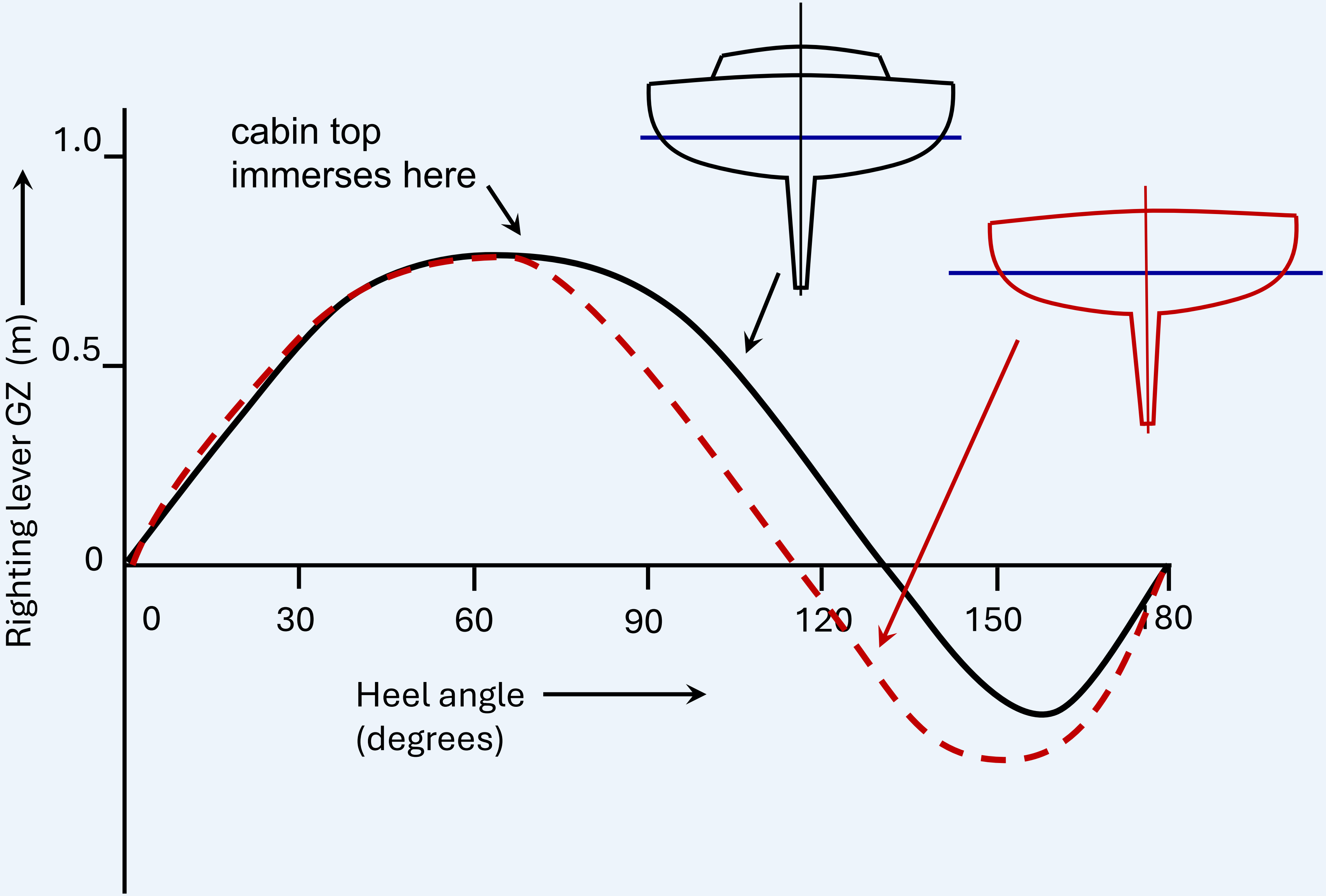
Recap:

- Centre of gravity G: the centre of mass of the entire boat.
- Centre of Buoyancy B: the centre of the ***underwater*** volume of the boat.
- G does not have to be below B for a boat to be stable.
- G has to be below M (the "metacentre)" for boat to be stable.
- The amount of stability is measured by the horizontal distance between G and B, "GZ".

Wide v. narrow



Cabin v. flush deck

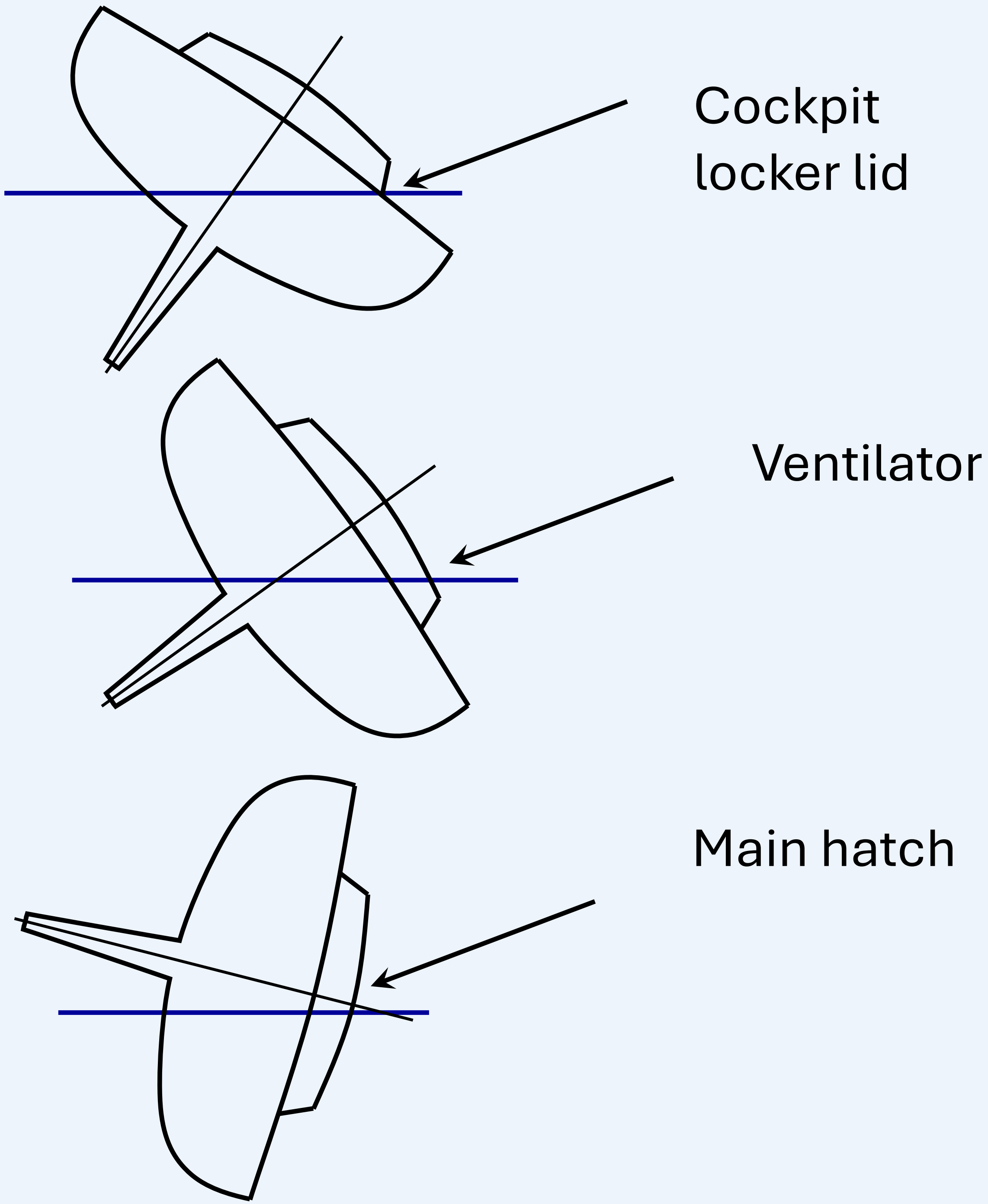


Downflooding angle

Heel angle at which water starts to enter boat:

- Open hatch
- Ventilator
- Tank breather
- Cockpit locker lid

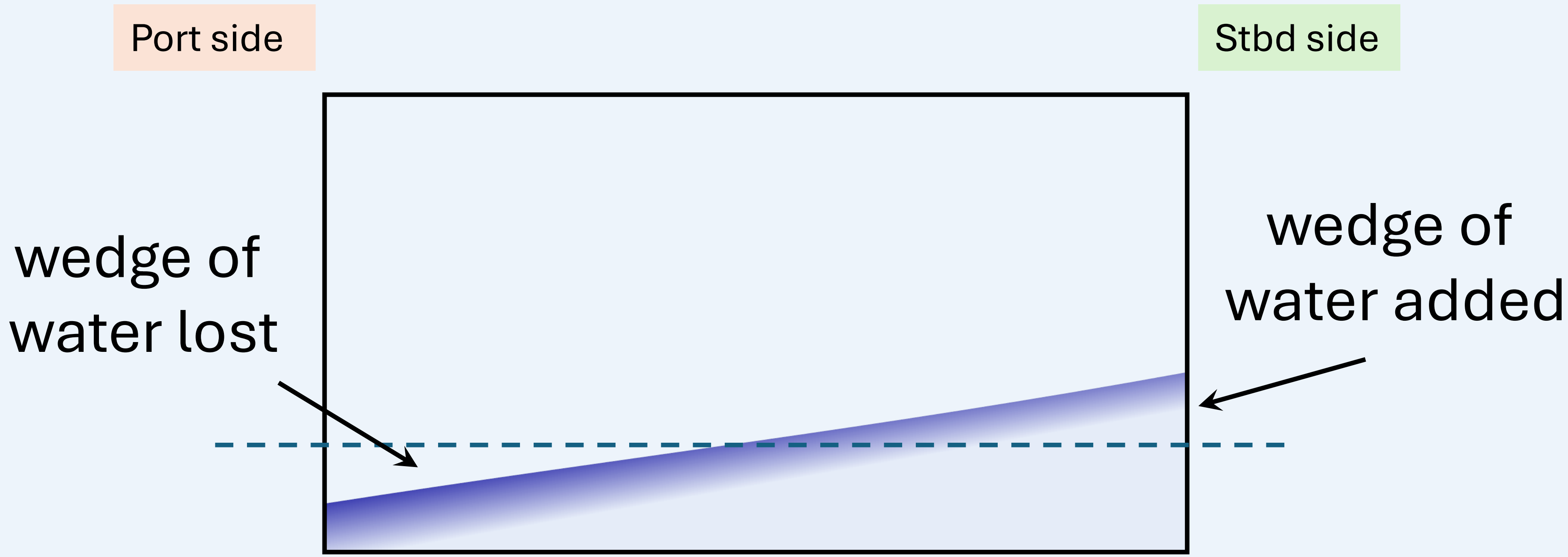
Stability curve after downflooding angle becomes irrelevant!


Cockpit
locker lid
Ventilator
Main hatch

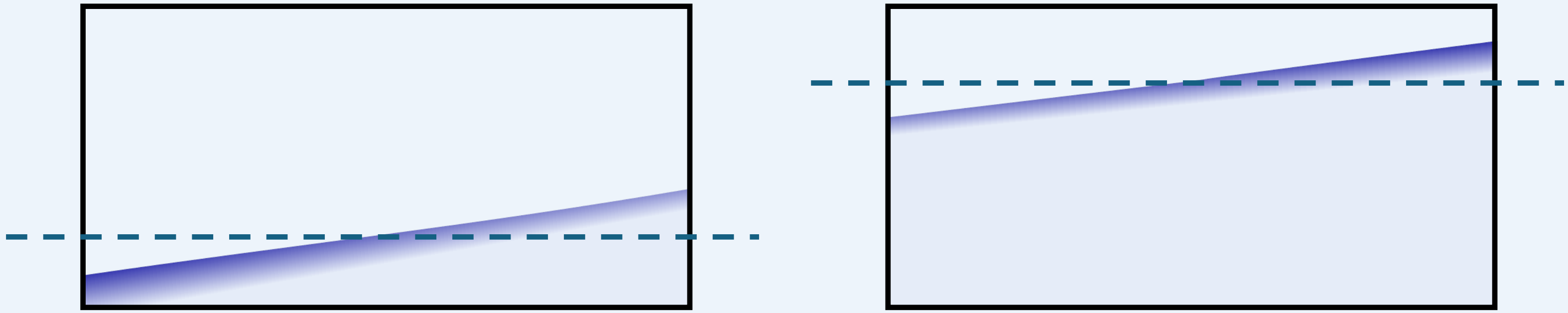
Sloshing liquids – the “free surface” effect

- Occurs whenever a liquid is added to the boat:
  - ❑ Water tank
  - ❑ Fuel tank
  - ❑ Bilge water
  - ❑ Leaky buoyancy tank
- The liquid adds weight, which moves the centre of gravity “G”
- ***ALSO*** reduces stability by the fluid sloshing from side to side

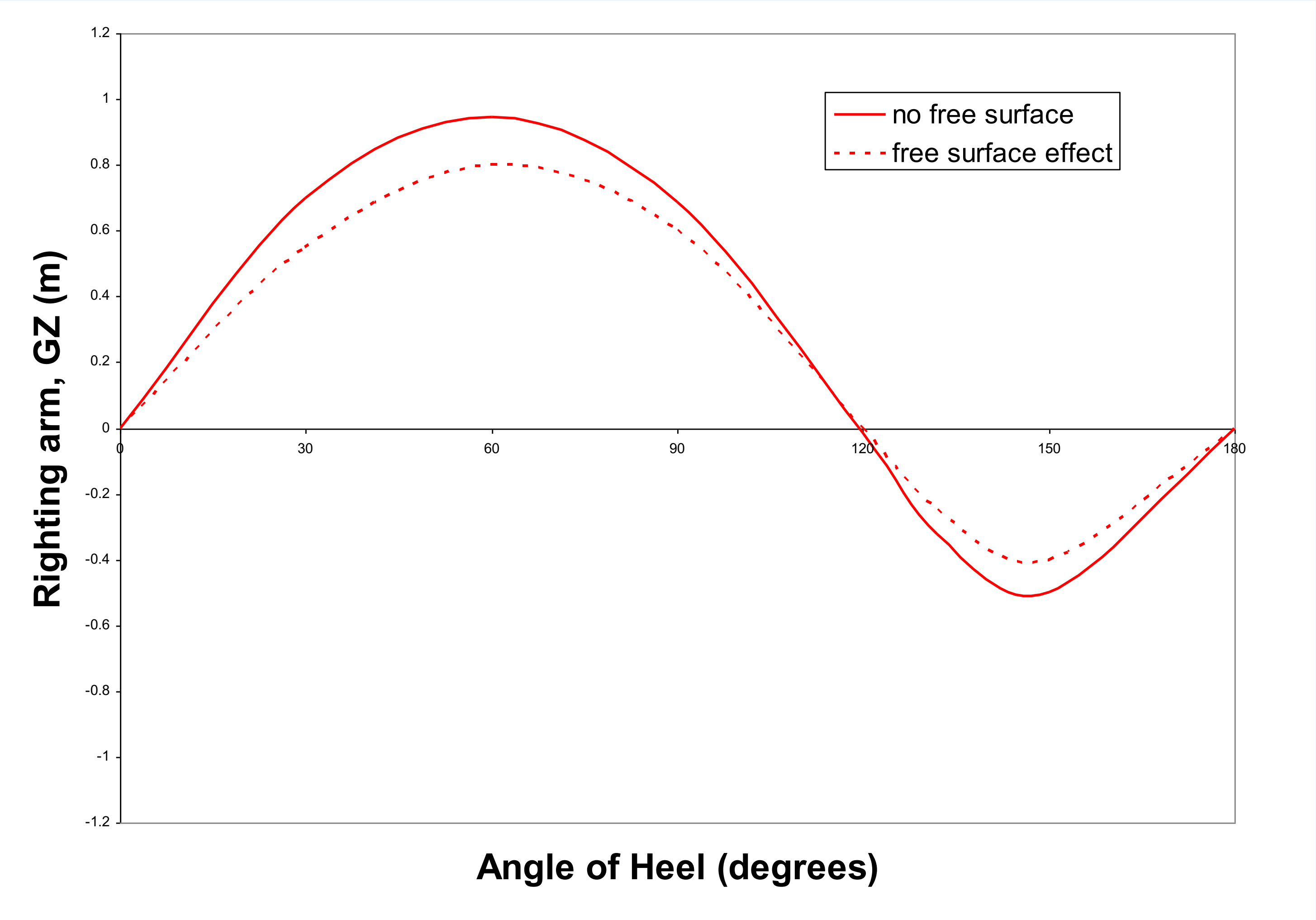
End view of a water tank

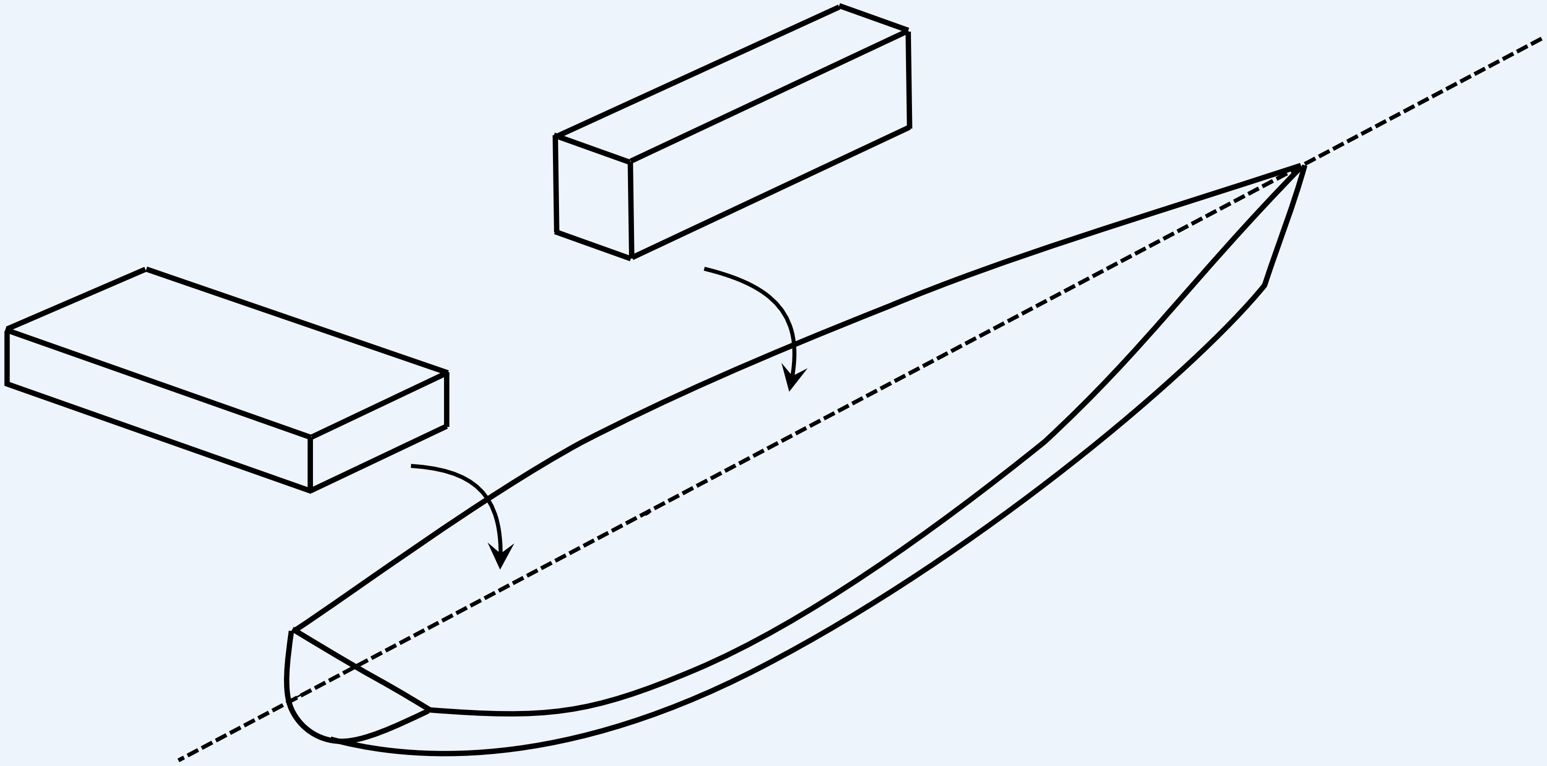


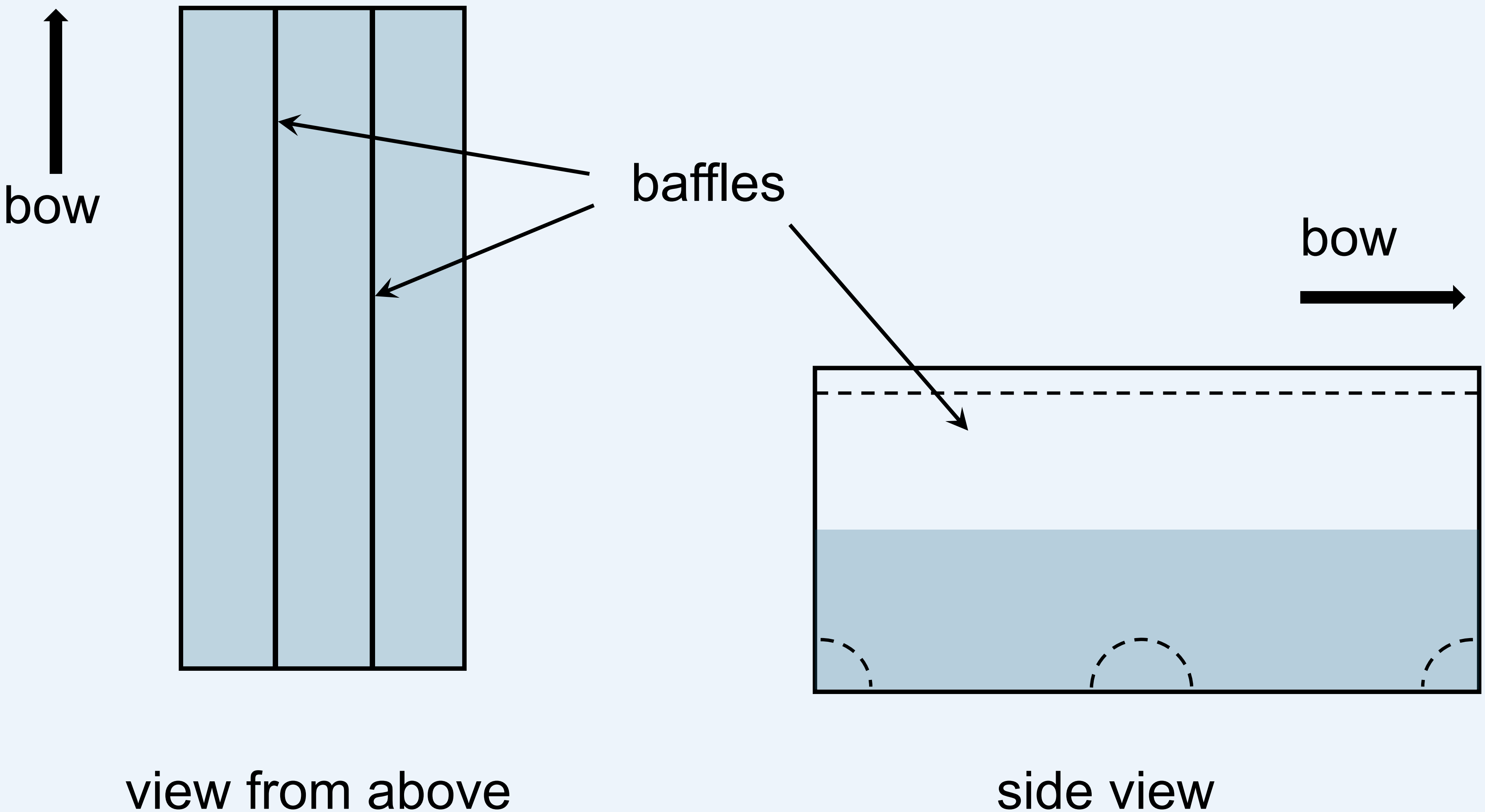
- Amount of fluid is irrelevant
- It is the distance it moves across the boat that matters



Free surface effect – tanks, bilge water etc







bow
baffles
bow
view from above
side view

How to compare boats?

- Compare stability curves (rarely published) ***best***
- Find EC-ISO classification (mainly for modern production boats) ***industry best***
- Compare ”STIX” number (mostly modern boats) ***accurate***
- Compare “SSSN” (mostly modern boats) ***approximate***
- Compare Screening Value “SV” (length and weight) ***very approximate***
- Read my book on sailing yacht design ☺ (just Google “Klaka yacht design”)

Coverage/accuracy comparison

EC-ISO	**STIX**	**SSSN**	**SV**
STIX	Full hull shape	Length	Length
Buoyancy	Centre of gravity	Weight	Weight
Construction strength	Full stability curve	Beam	
	Wind heeling moment	Sail area	
	Downflooding angle	Freeboard?	

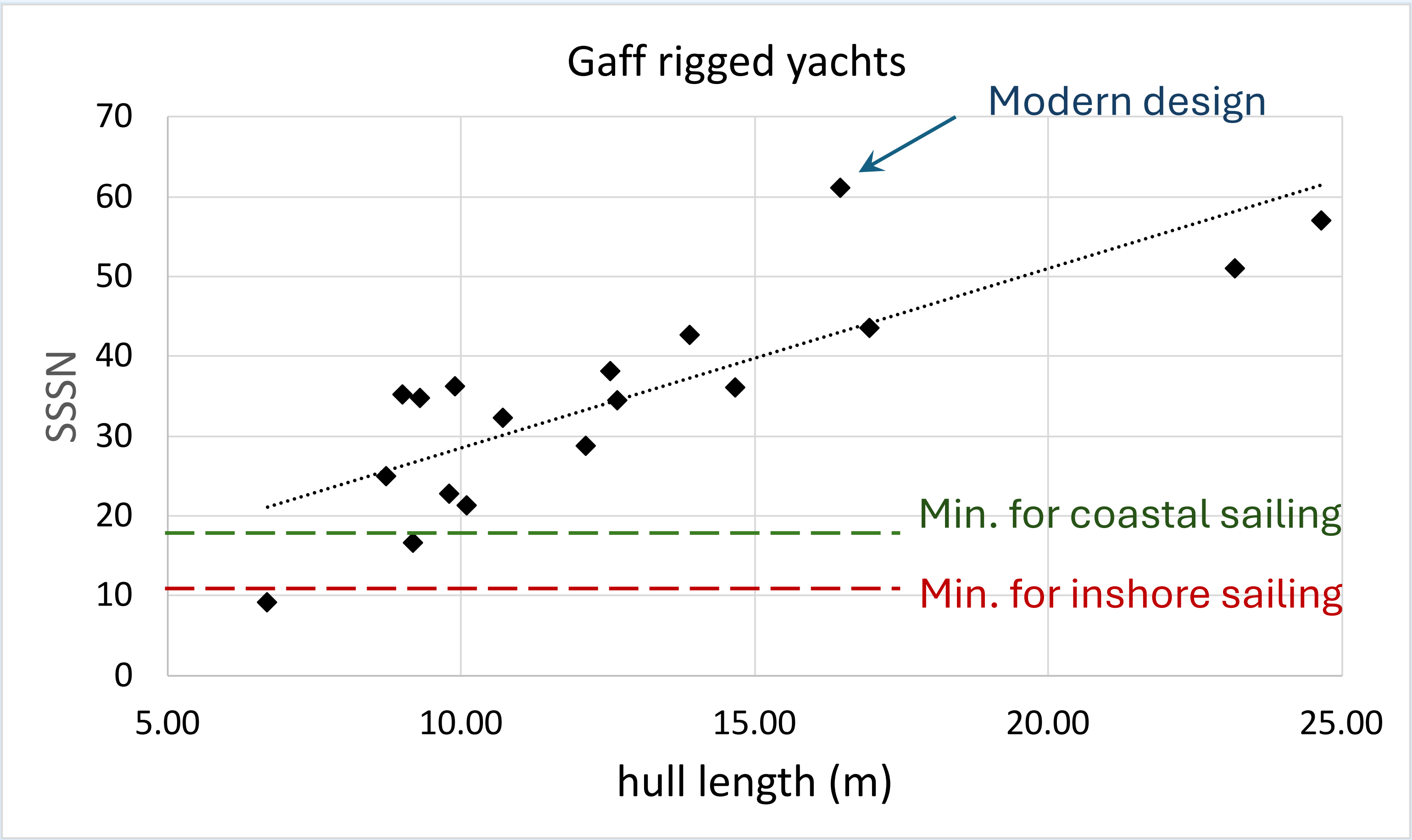
EC-ISO classification:

- Class A: Off-shore i.e. extended sailing on open sea with waves up to 10m and wind up to 55 knots
- Class B: Coastal (within 500 nm from the coast waves up to 4m and wind up to 34 knots
- Class C: Inshore (e.g. Bayraider)
- Class D: Protected waters

STIX number

EU category	Min STIX
A	32
B	23
C	14
D	5

The SSS Number



Screening Value SV

- SV = 2.83 x hull length (m) / weight (tonnes)
- ***very*** approximate
- Low SV is ***high*** stability (unlike STIX and SSSN)
- For coastal sailing SV<10
- For inshore sailing SV<14
- e.g.1: GRP BayRaider 20, no water ballast:

  length = 6m, weight = 0.5 tonnes, so SV = 34

  With 0.3 tonnes water ballast SV = 21
- e.g. 2: Couta boat “Thistle”:

  length = 8.6m, weight = 5.8 tonnes, so SV = 4.2

How stability is studied

Real world:

- Waves
- Roll motion
- Large heel angles

Simplify

- Calm water
- Small angles
- “quasi-static”

Realistic hull shapes

Large heel angles

Waves

Guidelines for selecting a design

“good” features for resisting capsize:

- Long
- Heavy
- Narrow

“good” features for speed, comfort and cost:

- Short (cost)
- Light (speed)
- Wide (space)

Guidelines for selecting a design

- Decide type of sailing (inland, coastal, offshore, ocean)
- Obtain stability curve, ISO classification, STIX or similar design data
- Compare with known designs
- Decide if OK (you choose, or consult a naval architect)

Guidelines when modifying a boat

- Avoid adding weight high up (e.g. in-mast furlers, bigger gaff, thicker deck planking)
- Avoid adding weight to keel without reviewing strength
- Avoid adding weight!
- Do not add tanks without lateral baffles
- Do not add off-centre openings (hatches, breathers, ventilators)

Summary: do not change designer’s specs

End