Explaining the Alphabet Soup of Stability Screening

Richard Hinterhoeller

SAIL·VOILE CANADA

LPS

STIX

ISO

AG_z

ORC Stability Index

SSS

AVS

Explaining the Alphabet Soup of Stability Screening

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Part 1: Introduction to OSR 3.04

- Quickly review the methods
- Show where to find the numbers
- Detailed explanations come in part 2
- Questions

The purpose of OSR 3.04

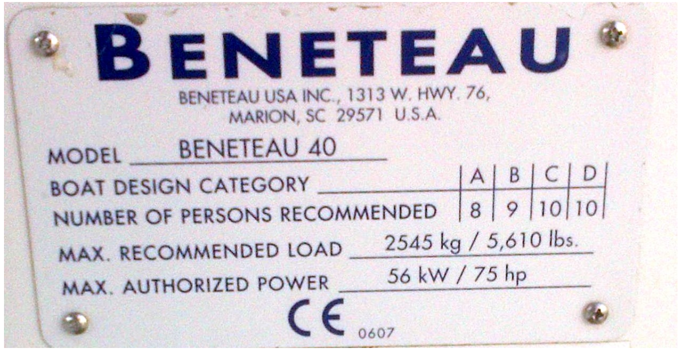
- Capsize avoidance
- Capsize survivability

OSR 3.04.1 (Primary)

"Able to demonstrate compliance with ISO 12217-2* design category B or higher, either by EC Recreational Craft Directive certification having obtained the CE mark or the designer's declaration"

Capacity Plate or Owner's Manual

- CE mark at bottom
- ISO permits certification for more than 1 category. In this case:
  - 8 or fewer crew – ISO Cat A (OSR Cat 0,1,2)
  - 9 or fewer crew – ISO Cat B (OSR Cat 3)
  - OSR has no equivalent for ISO Cat C or D but 10 or fewer crew would make sense for OSR Cat 4 or 5



OSR 3.04.2 a) (alternative 1)

- a *STIX* value not less than 23; and
- *AVS* not less than 130 - 0.005*m, but always >= 95°, (where “m” is the mass of the boat in the minimum operating condition as defined by *ISO* 12217-2); and
- a *minimum righting energy* *m*AGZ*>57000 (where *AGZ* is the positive area under the righting lever curve in the minimum operating condition, expressed in kg metre degrees from upright to *AVS*)
- **Minimum “m” of 1,500 kg** (Sail Canada prescription, precursor to minimum m*AGZ ca 2012)

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Stability Screening

OSR 3.04.2 b) (alternative 2)

- Stability Index in *ORC* Rating System of not less than 103
- **Ideally this comes from an ORCi certificate for the boat**
- **Offshore Racing Rule (ORR) uses the same criteria so a fully measured ORR certificate is equivalent to ORCi**
- **Sistership data has issues:**
  - **Has either boat been modified?**
  - **Is it fair to have one owner pay so that another gets a free certification?**

Stability Screening

OSR 3.04.2 c) (alternative 3)

- IRC SSS Base value of not less than 15
  - Published on an IRC Certificate
  - Sail Canada has a public domain copy of the equations – SC Listing

Introduction Recapitulation

- Primary: ***ISO*** **from the capacity plate or owner's manual**
- Secondary
  - ***STIX*** **etc. from a declaration by the yacht designer**
  - ***ORC stability index*** **from an ORC certificate**
  - ***SSS*** **from IRC certificate or Sail Canada**

Part 2: OSR 3.04 Details

- Why the different systems - history
- Acronyms - technical

It was believed that boats capsize due to wind.

- Dinghies and multihulls could capsize
- Keelboats couldn't

It was believed that boats capsize due to wind.

- Dinghies and multihulls could capsize
- Keelboats couldn’t
- That was disproved in the

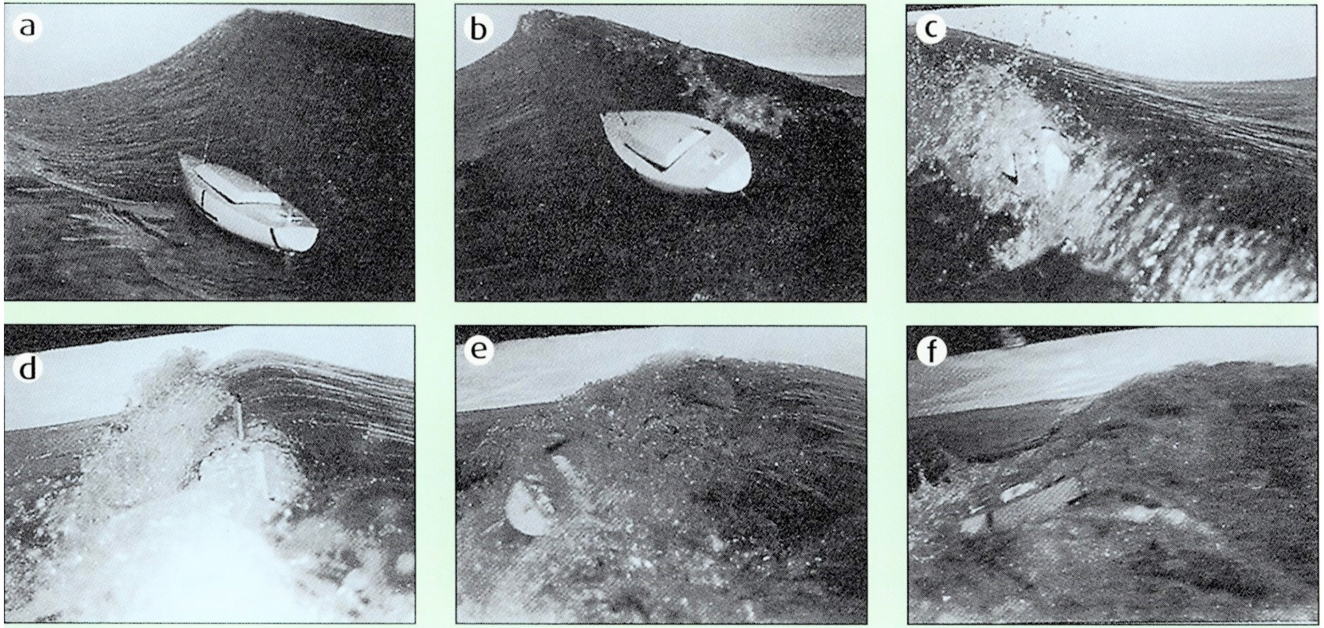
1979 Fastnet Race

- 15 sailors died
- 75 **keelboats** were **capsized** (some remained turtled)
- 5 sank

Stability Screening

Wave Tank Tests

- Series of models
- Image credit next page



A fin keel parent model under test showing beam-on 360°capsize.

a Beam-on to a large wave.
b Crest begins to break.
c 90° heel angle (transom visible).
d Upside down (keel and rudder pointing to the sky).
e Nearly upright again.
f Returned to normal!

Image Credit

- The image on the preceding slide was scanned from:

  Adlard Coles Heavy Weather Sailing, 6^{th} Edition

  Peter Bruce

  McGraw Hill

Tests in wave tanks determined that

- A keelboat caught beam-to a breaking wave can be capsized
- A breaking wave 30% of the hull length will capsize some boats
- No boat will resist capsize if the breaking wave is 60% of the boat's hull length

Category 3

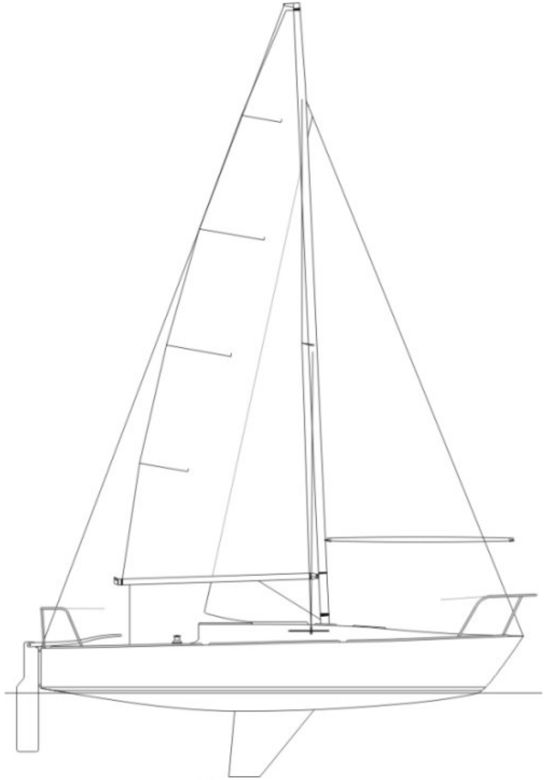
- 4 m significant wave height, 40 knots of wind
- Some keelboats as long as 13 m (43’) can capsize
- No boat shorter than 6.7 m (22 ft) can resist capsize
- Boat length is no longer used for screening – too many other factors

IRC Base SSS Value

- In 1979 IOR was the dominant rating system
- Detailed stability information was not published
- The RYA used what they could lay their hands on, effectively brochure data, combined with the wave tank data
- created the **Stability, Safety and Screening** (SSS) numeral (*IRC SSS Base value in OSR 3.04.2 c)*)
- Based upon Length, multiplied by other factors (excess beam, large sailplan, light displacement)

SSS worked for boats of that vintage

- J/24 (1977)
- Cg of keel is high
- SSS = 9
- Does not meet category 3 using SSS
- No other screening lets it meet Cat 3

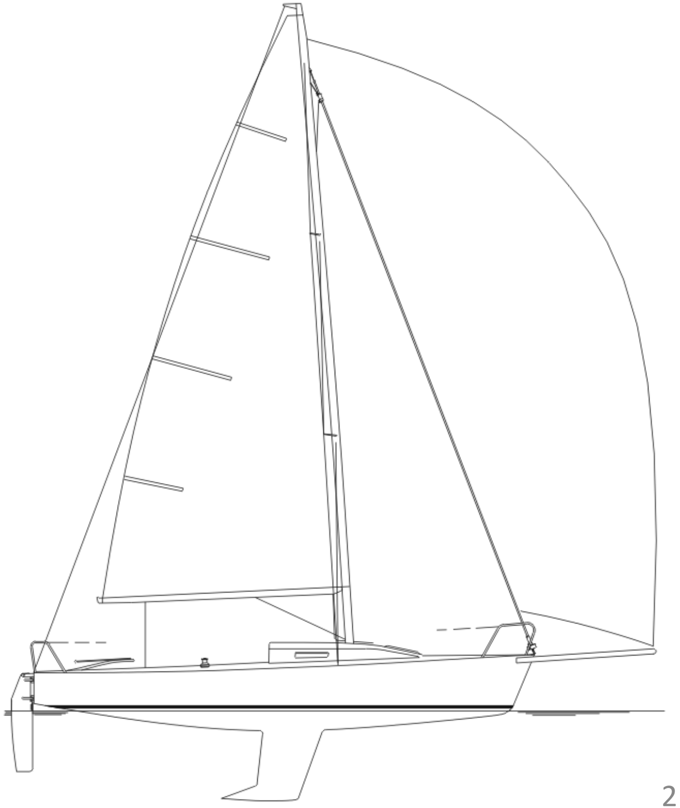


Supported by Empirical Evidence

- J/24
- Rochester, NY
- 2006
- Crew rescued
- Boat sank, later recovered

SSS doesn't handle this well

- J-80 (1992)
- Cg Keel is very low
- SSS = 11 (no input for keel Cg)
- Under SSS it does not meet category 3
- The J-80 does meet category 3 using ISO



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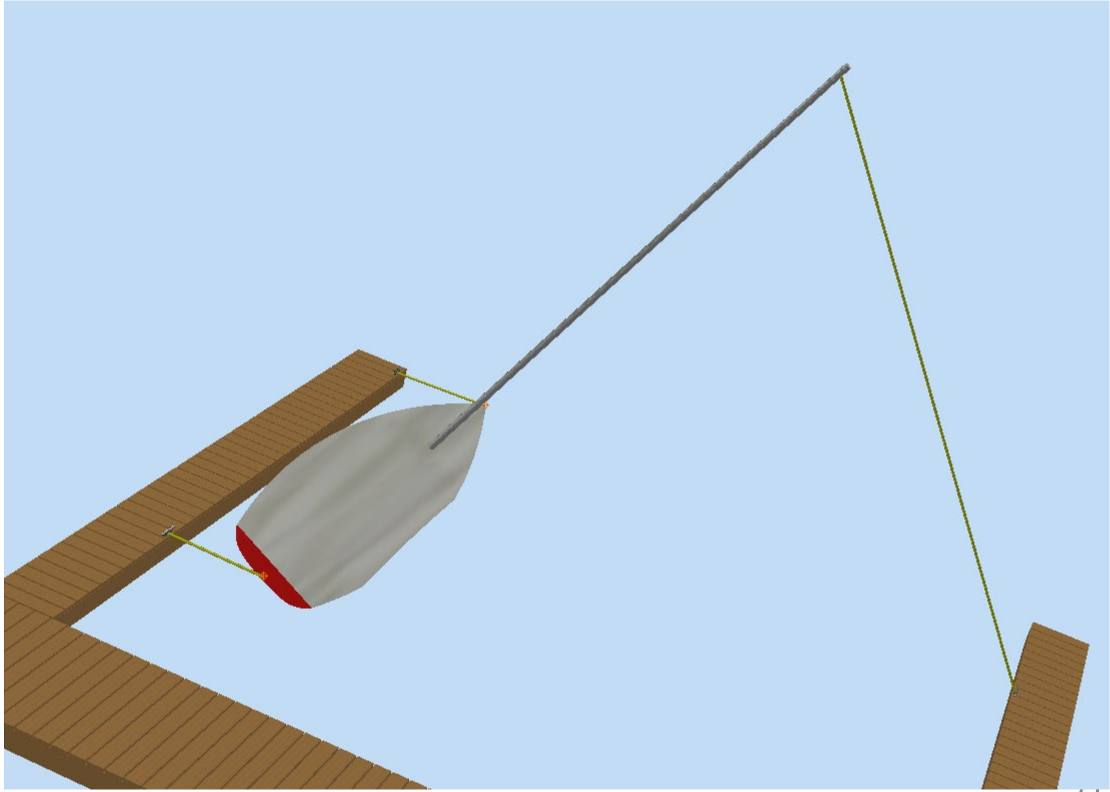
Stability Screening

Stability 101

- Stability is a key metric for ISO and ORC
- Laser or similar dinghy
- Bow and stern lines to 1 dock
- Light cord attached to mast
- Pull on the cord so as to heel the dinghy
- Measure cord tension



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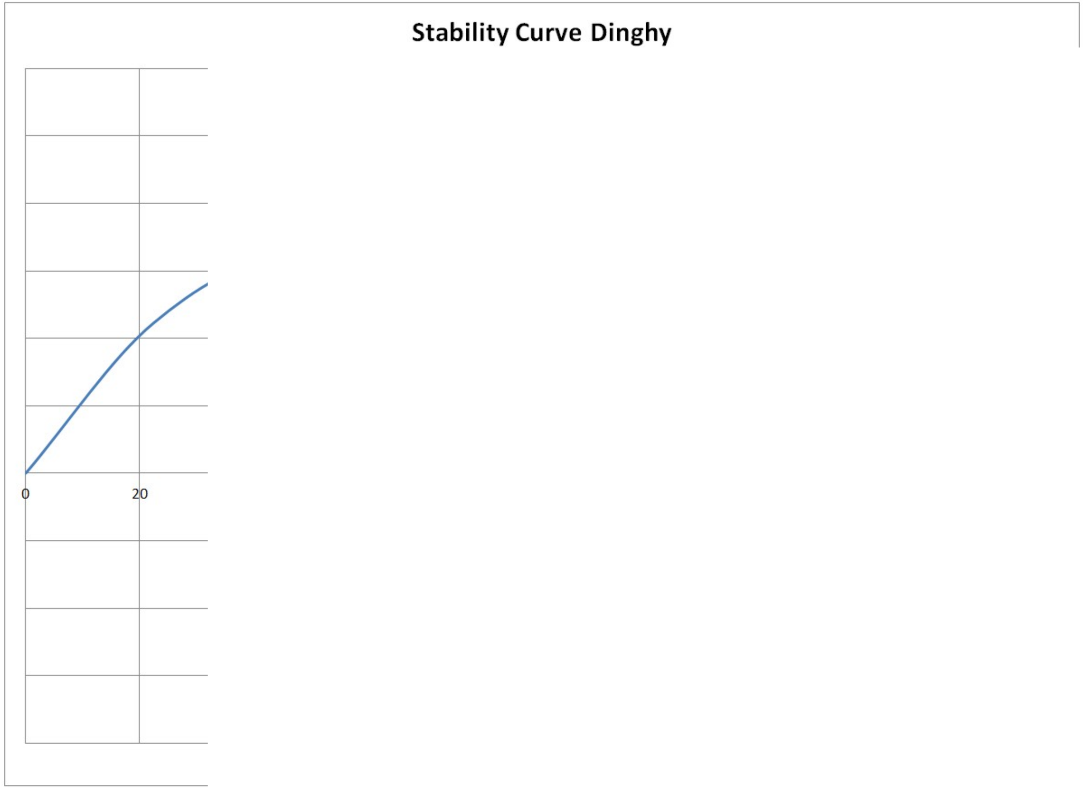
Stability Screening

Stability 101

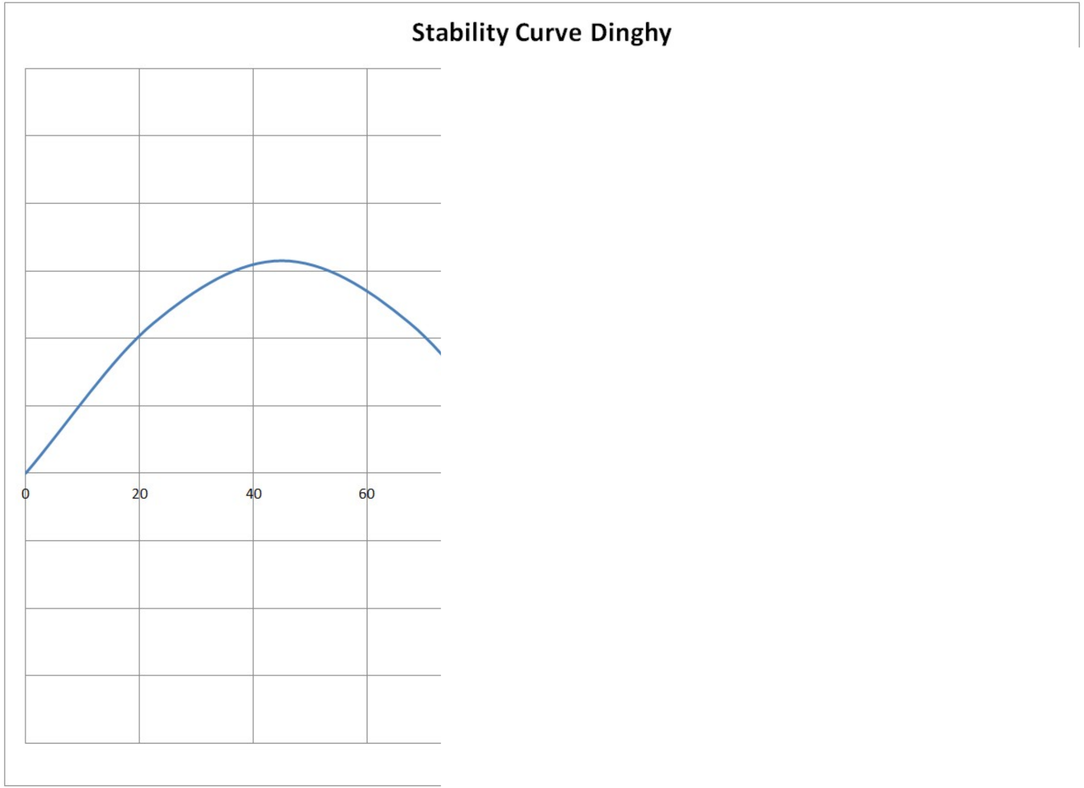
- Plot cord tension against heel angle
- 0° requires 0 tension
- 10° requires some tension
- 20° requires almost twice the 10° tension
- At 30° requires noticeably less than 3 times the 10° tension



Stability Screening

Stability 101

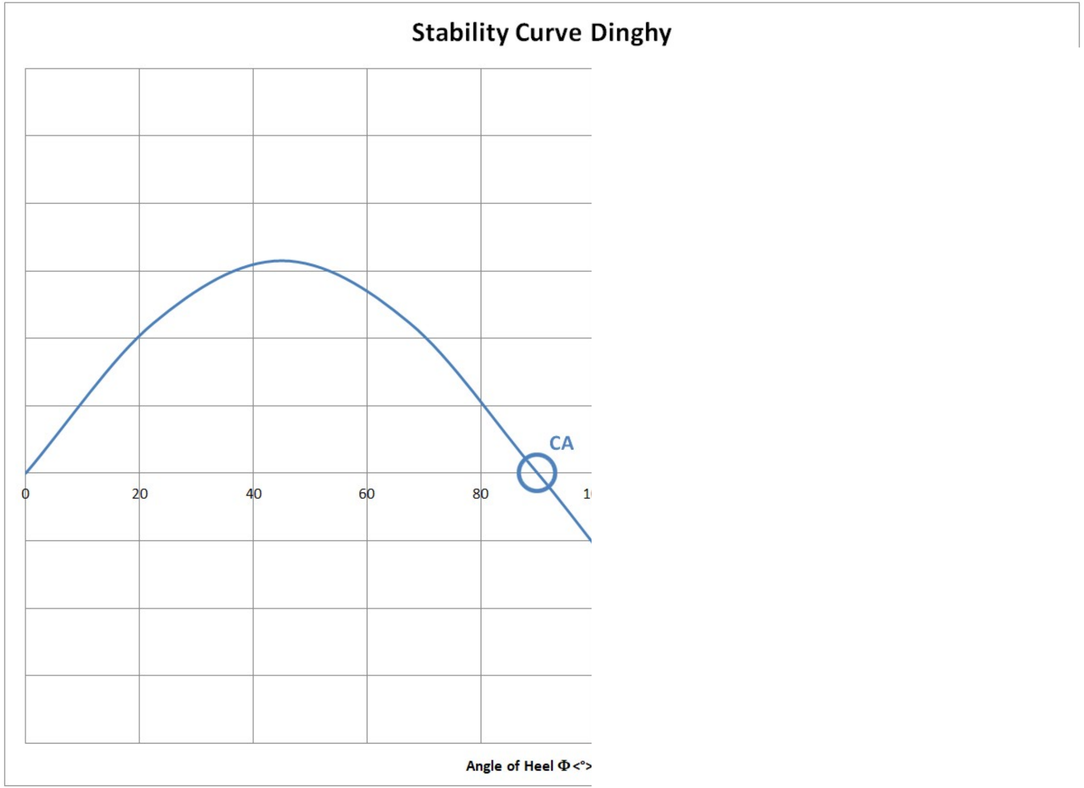
- Beyond 40° - 50° the tension diminishes with heel angle



Stability Screening

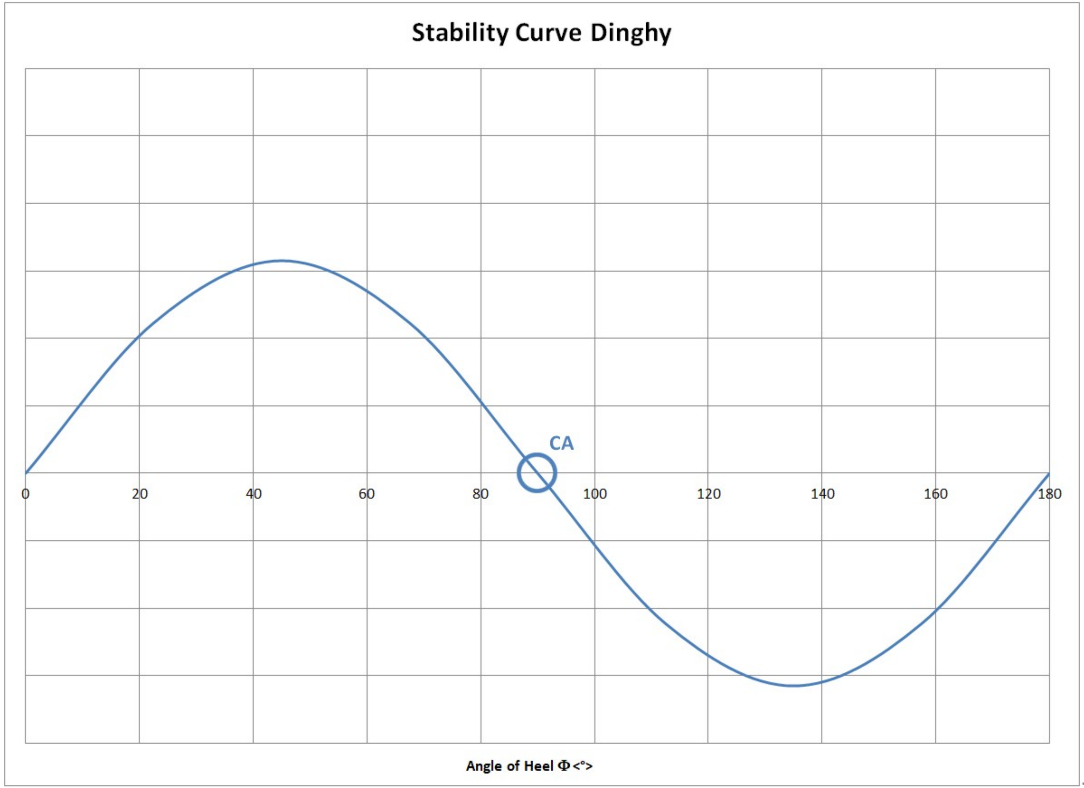
Stability 101

- Near 80° - 90° the tension diminishes to 0
- Lift the mast tip up a bit and the boat will return to upright
- Lower the mast tip and the boat will turn turtle
- Capsize Angle (CA) is the 2nd point where there is no righting moment



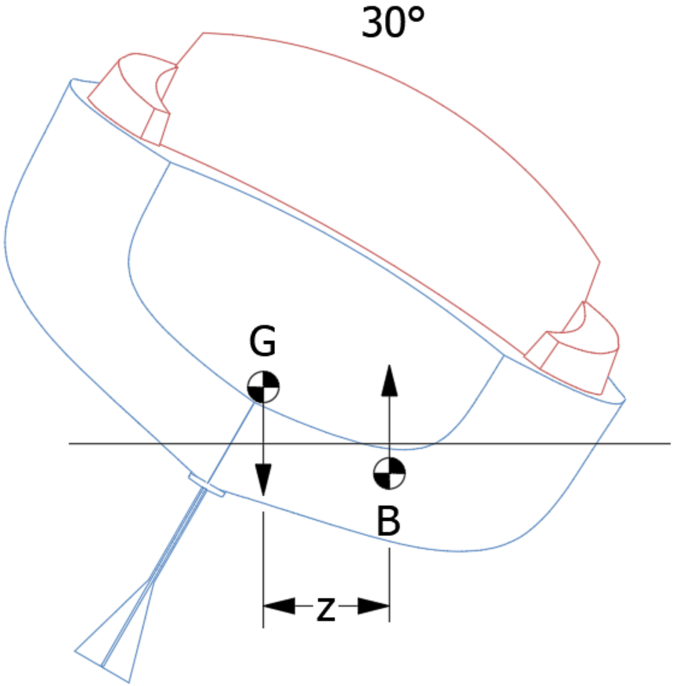
Stability 101

- Turtled (180° heel) is the 3rd angle where there is no heeling moment
- The curve to the right of CA is the cord tension required to bring the boat back to CA
- A curve of this shape applies to most sailboats



Gz Arm

- **G** is the centre of gravity
- **G** does not have to be below the waterline
- **B** is the centre of buoyancy
- Distance between them is **z**
- Referred to as **Gz** arm or the righting arm



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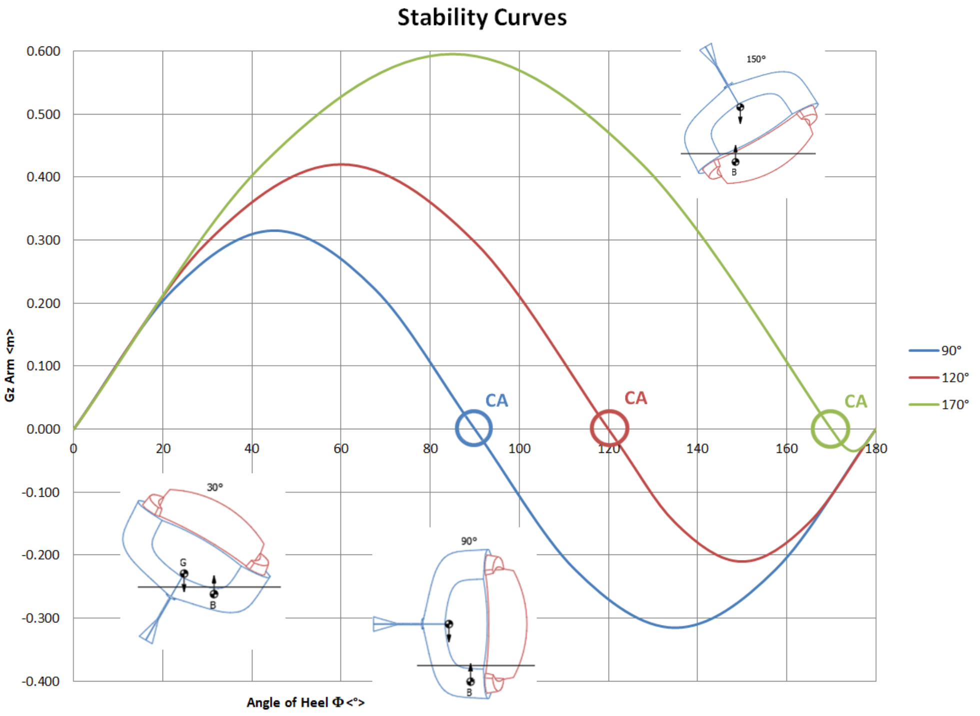
Stability Screening

Stability Curves

- Gz is 0 at 3 heel angles, 0°, 180° and at the Capsize Angle (CA)
- CA ≈ 90° dinghy/multihull
- CA > 170° highly stable
- CA ≈ 120°± most keelboats
- Initial stability (0° to 10°) is the same



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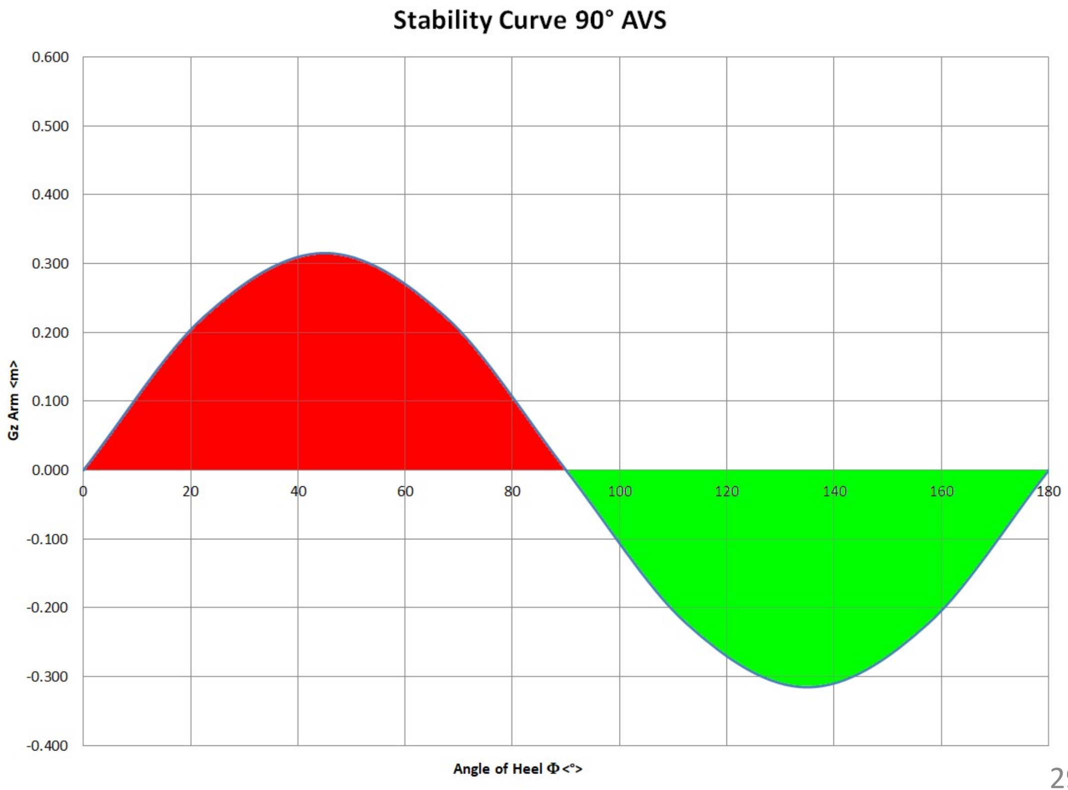
Stability Screening

Righting Energy

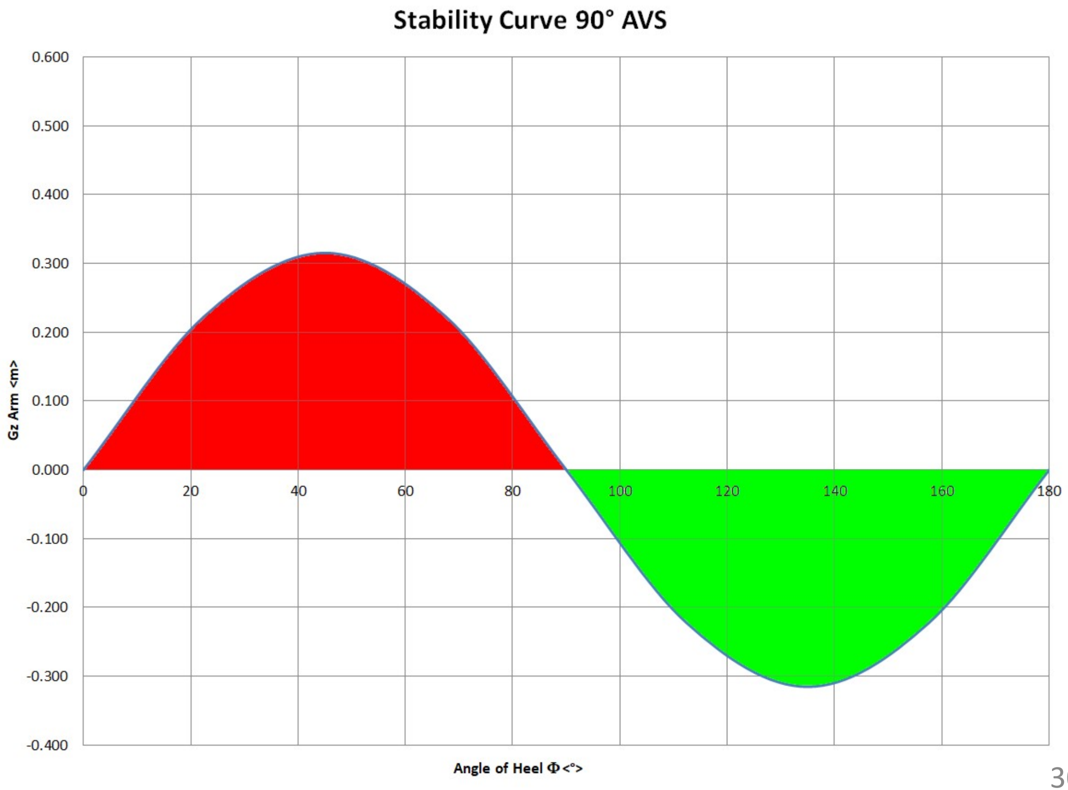
- The red area represents the energy required to capsize the boat
- The green area represents the energy required to re-right the boat
- Since red area = green area, 50% time capsized



Stability Screening

Righting Energy

- The red area is AGZ
- Multiply by m
- *m*AGZ is righting energy in OSR 3.04.2 a) iii (kg m °)*



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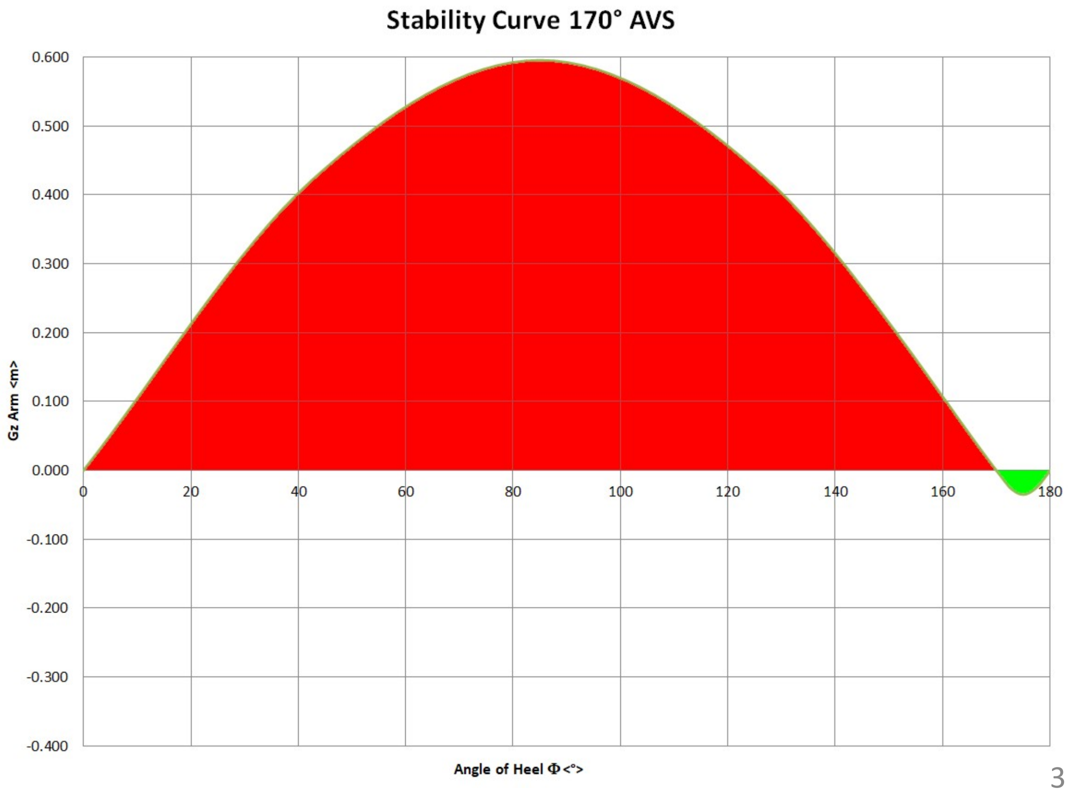
Stability Screening

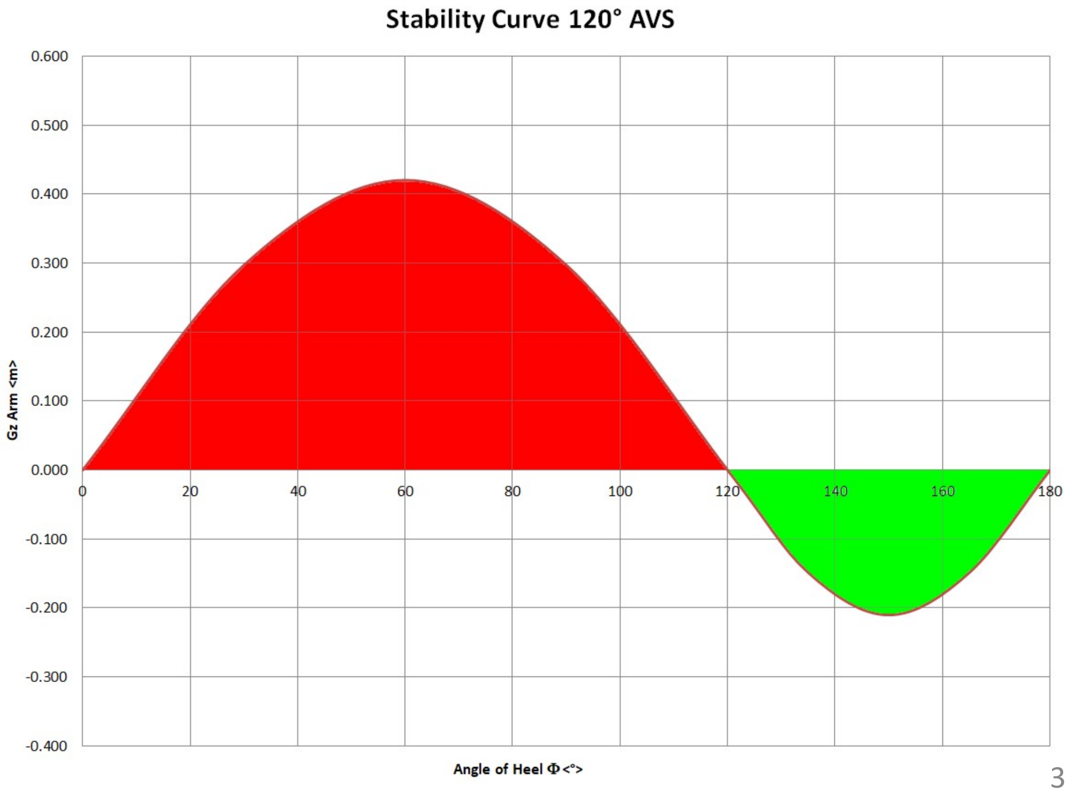
High Stability

- The red area is about 300 times the green area
- The likelihood of the boat staying in the 180°±10° inverted position is miniscule
- This boat is unlikely to stay inverted so, if overturned, it would roll back upright



Normal Stability

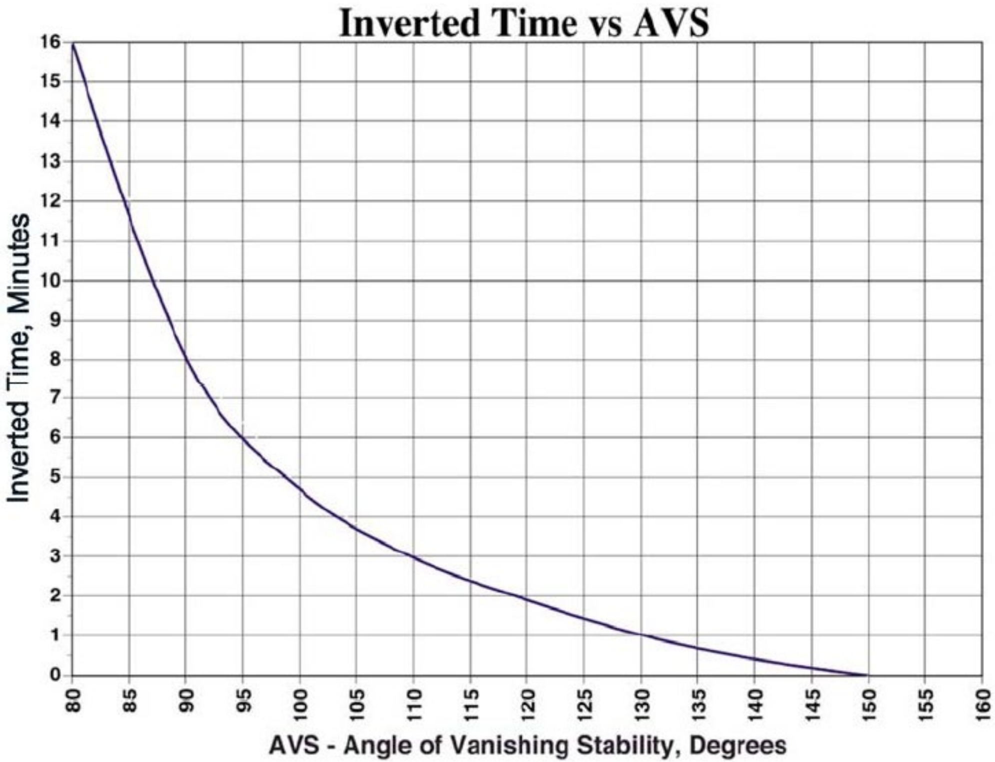
- The red area is about 4 times the green area
- It's likely that the wave following that which capsized the boat will have at least ¼ of the energy
- This boat is likely to continue rolling through 360°
- Capsize Survivability



Stability Screening

Inverted Time

- http://gerrmarine.com/Articles/StabilityPart2.pdf
- At AVS = 120° inverted time = 2 minutes
- Analysis from the 1979 Fastnet race



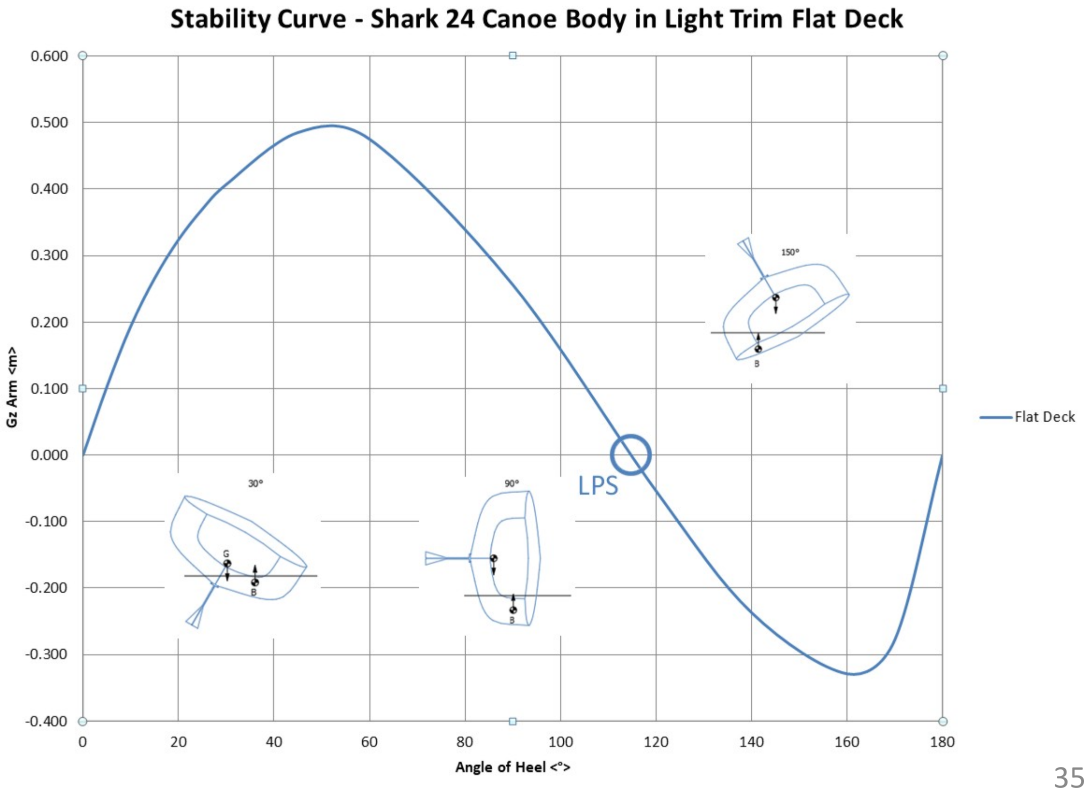
ORC Stability Index

- Over the next few years (mid 1980s)
- International Measurement System (IMS) gradually replaced IOR
- IMS required measurements to determine the displacement and Cg
- IMS briefly fell out of favour, but continues as ORC (ORR in parts of USA)

Stability Screening

ORC LPS

- ORC calculates the stability curve using a flat deck
- It uses the term Limit of Positive Stability (LPS) for the capsize angle



ORC Stability Index = LPS + Capsize Increment + Size increment *(OSR 3.04.2 b))*

- Capsize Increment (accounts for excess topside flare)
- Shark CI = -0.6 (small penalty for being a bit beamy for its weight)
- J/24 CI = -8.2 (large penalty due to excess flare)
- When knocked down by a wave, the narrow boat will slide sideways but the high-flare boat be will be tripped by its gunwale and continue to roll
- Scientific approach is much better than SSS

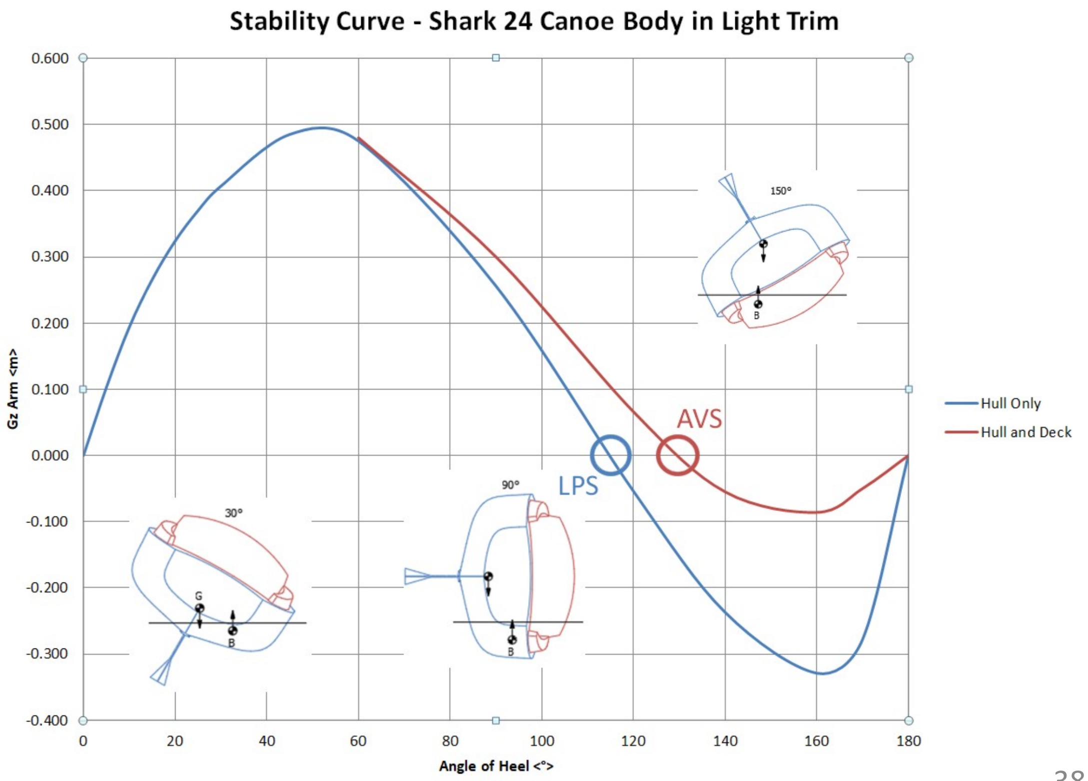
ISO 12217-2

- By approximately 1998
- The European Economic Community (EEC) was eliminating non-tariff barriers
- One barrier was the different stability screening methods between nations
- International Standards Organization (*ISO*)
- Having experience developing the *SSS*, the RYA got involved
- The result is ISO 12217 part 2 (ISO 12217-2) (sailing boats ≥ 6m), which uses:
- Minimum values for STability IndeX (*STIX*), *AVS* and *righting energy* (*OSR 3.04.2 a)*)

Stability Screening

AVS vs LPS

- **Angle of Vanishing Stability** (AVS) includes the cabin and cockpit (red)
- In this load trim AVS is 130 vs LPS of 113
- Since ISO loading is different from ORC, AVS can be smaller than LPS
- The 2 cannot be reliably interchanged



Stability Index (*STIX*) *(OSR 3.04.2 a) i)*

- **(Base Length) x (FDS x FIR x FKR x FDL x FBD x FWM x FDF)$^{1/2}$**
- Dynamic Stability Factor (righting energy, relative to length, to AVS)
- Inversion Recovery Factor (ability to recover after an inversion)
- Knockdown Recovery Factor (ability of a boat to spill water out of sails after a knockdown)
- Displacement to Length Factor (accounts for the favourable effect of heavier displacement)
- Beam Displacement Factor (accounts for increased vulnerability due to excess topside flare)

Stability Screening

STIX continued

- Wind Moment Factor (accounts for risk of downflooding due to a gust)
- Downflooding Factor (represents the risk of downflooding in a knockdown)

Compliance with ISO 12217-2 (OSR 3.04.1)

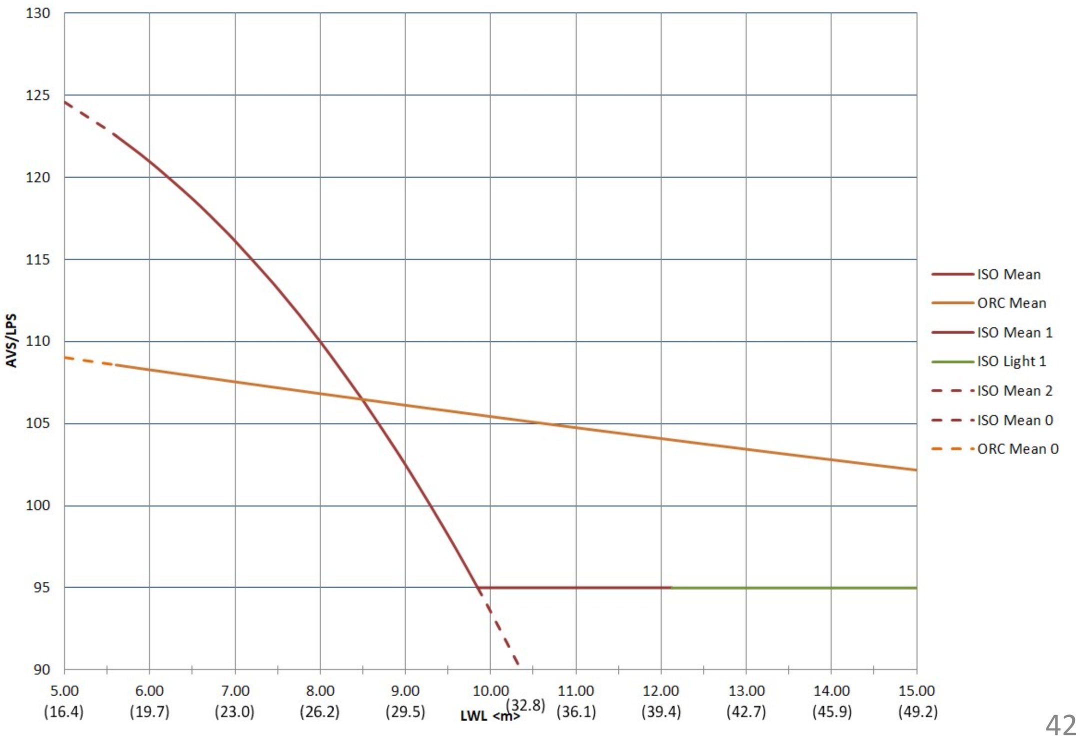
ISO determined that STIX wasn't robust enough

- Added a minimum AVS
- Initially they added a minimum sailing mass "m"
- In 2011 the minimum "m" was replaced by the minimum righting energy (m*AGZ)
- A boat which meets all of the STIX, AVS and m*AGZ in OSR 3.04.2 a) complies with an ISO 12217-2 category
- **Very thorough and well thought-out system**
- **Considered by World Sailing to be the Gold Standard for stability screening**

Methods Compared Average Disp. Boats

- SSS doesn't graph well
- SSS very conservative
- ORC (orange)
- ORC slope is due to Size Increment
- ISO (red) (130-.005m)
- ISO gets very demanding for the smaller boats

ISO Cat B, ORC 103 - Mean Displacment



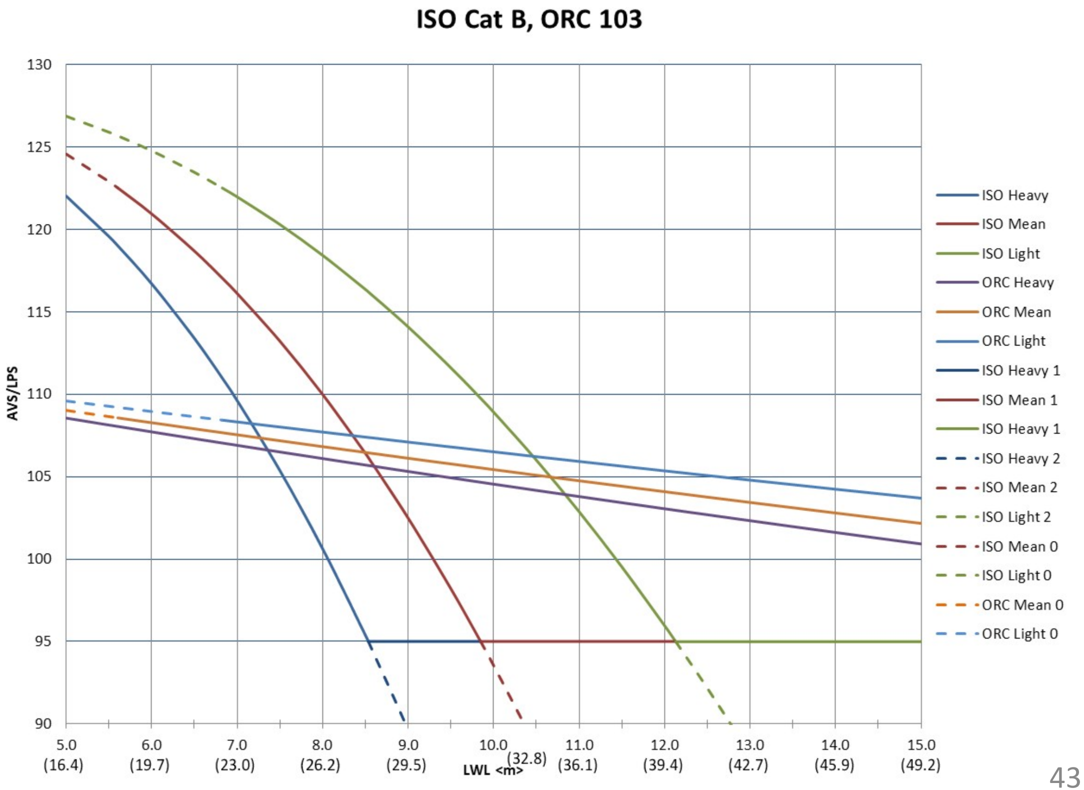
Stability Screening

Heavy Displacement

- ISO – Dark blue (left)
- ORC – Purple (lowest)

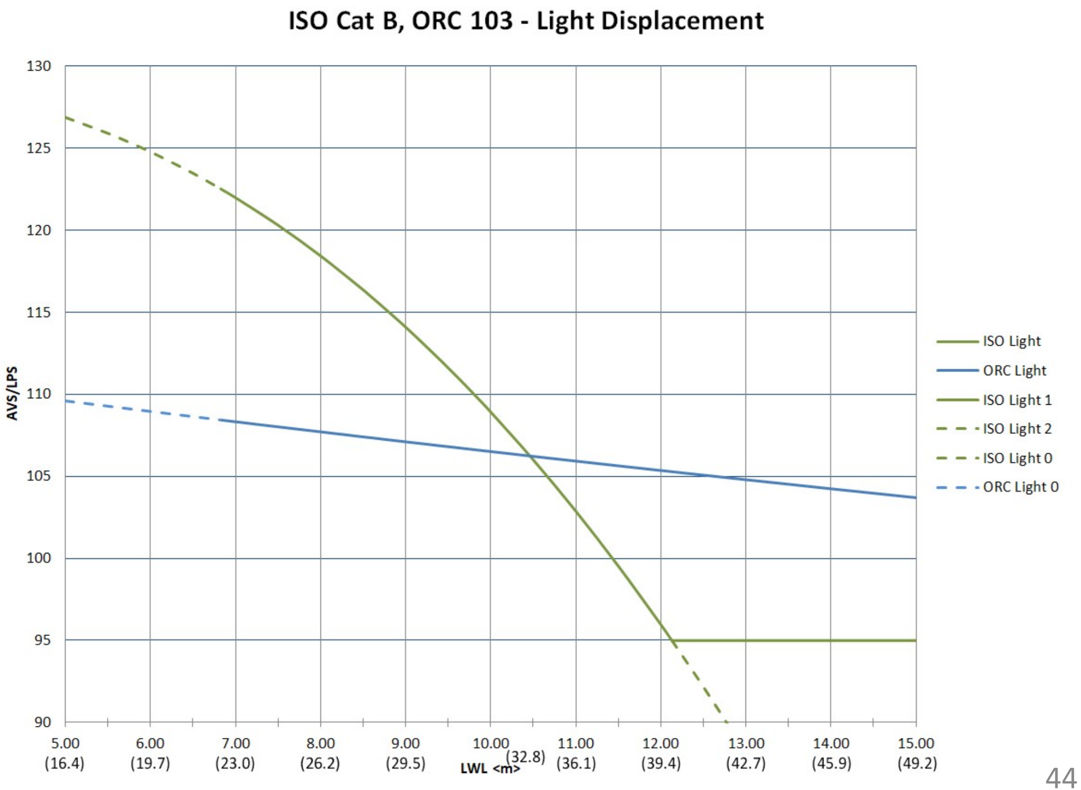
Light Displacement

- ISO – Green (right)
- ORC – Medium blue (highest)



OA Dilemma – the zones between the lines – small light boats

- To the right of the intersection (LWL > 10.5 m) there's rarely an issue
- Boats that size are geared toward OSR Cat 2
- Most of those are above ORC



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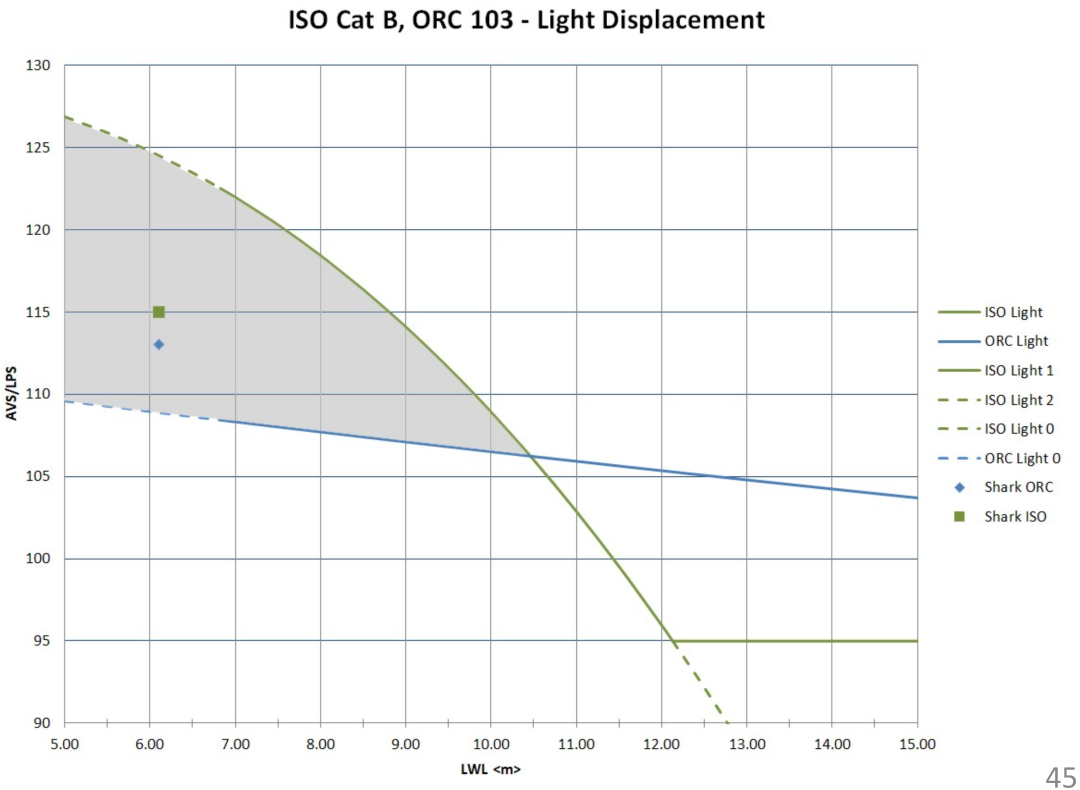
Stability Screening

OA Dilemma

The gray zone

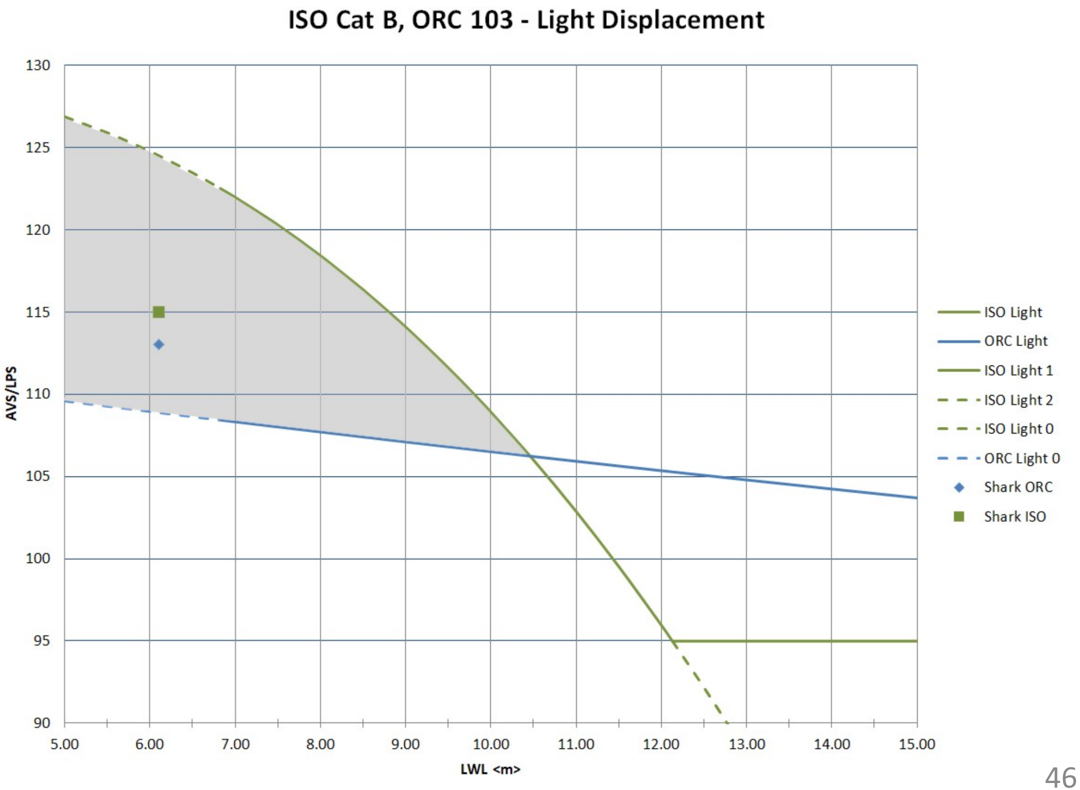
- The blue diamond is the Shark 24 (ORC) LPS = 113
- ORC stability index = 109.1 (exceeds 103)
- Under OSR 3.04.2 b) it meets Cat 3



OA Dilemma

The gray zone

- Whereas STIX = 27.7 meets Cat 3
- The green square is the Shark 24 (ISO) AVS = 115
- m*AGS ~ 40,000 is too small
- AVS is too small
- Under ISO it fails Cat 3



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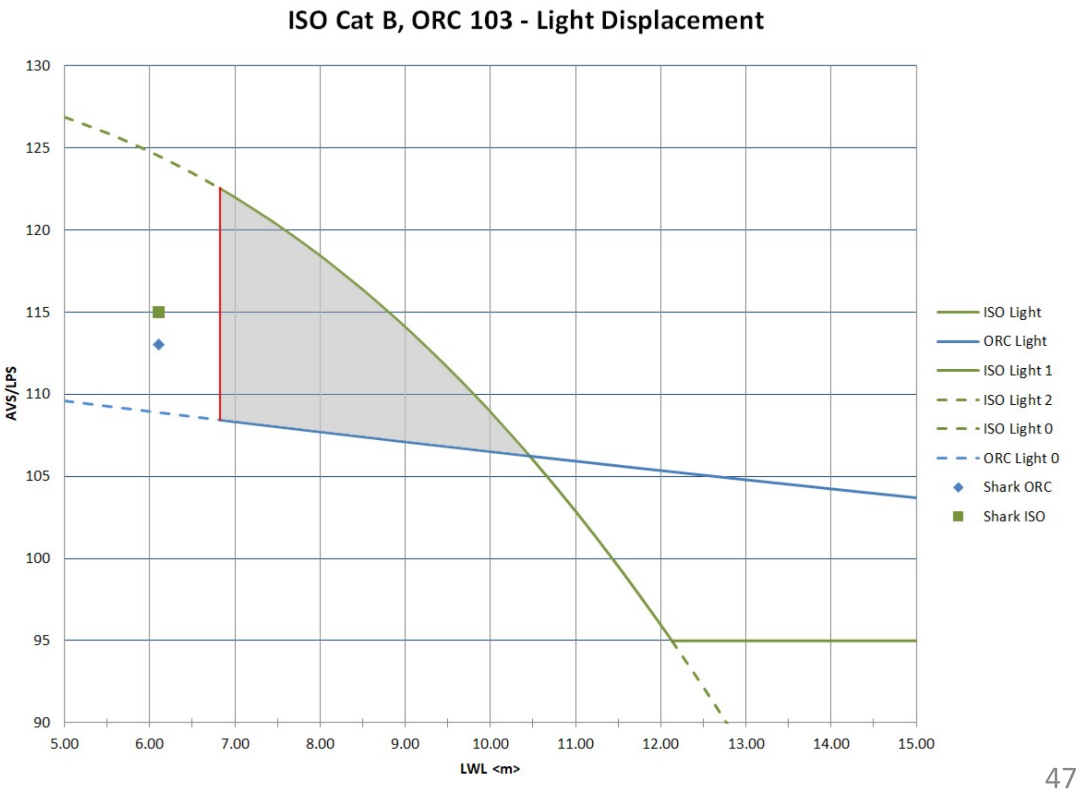
Stability Screening

Minimum “m”

- The red line shows m = 1,500 kg (precursor to m*AGS)
- Apply that to ORC (per the SC prescription)
- Modified ORC now agrees that the Shark is Cat 4
- We can’t eliminate the gray area, just reduce it



4 Methods for Stability Screening

- Primary
  - ISO 12217-2 for boats sold in the EEC since 1998 (capsize avoidance)
- Secondary **Minimum "m" of 1,500 kg**
  - ISO 12217-2 equivalent if declared by the designer (capsize avoidance)
  - ORC/ORR Stability Index (capsize survivability)
  - SSS for the rest (capsize avoidance)

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Stability Screening

Lake Ontario Waves

- https://apps.dtic.mil/dtic/tr/fulltext/u2/020099.pdf
- 13 ft once per year
- Near shore – study for erosion

Southern Straits 2010

- 26' boat with ORC SI=114.1 360° roll

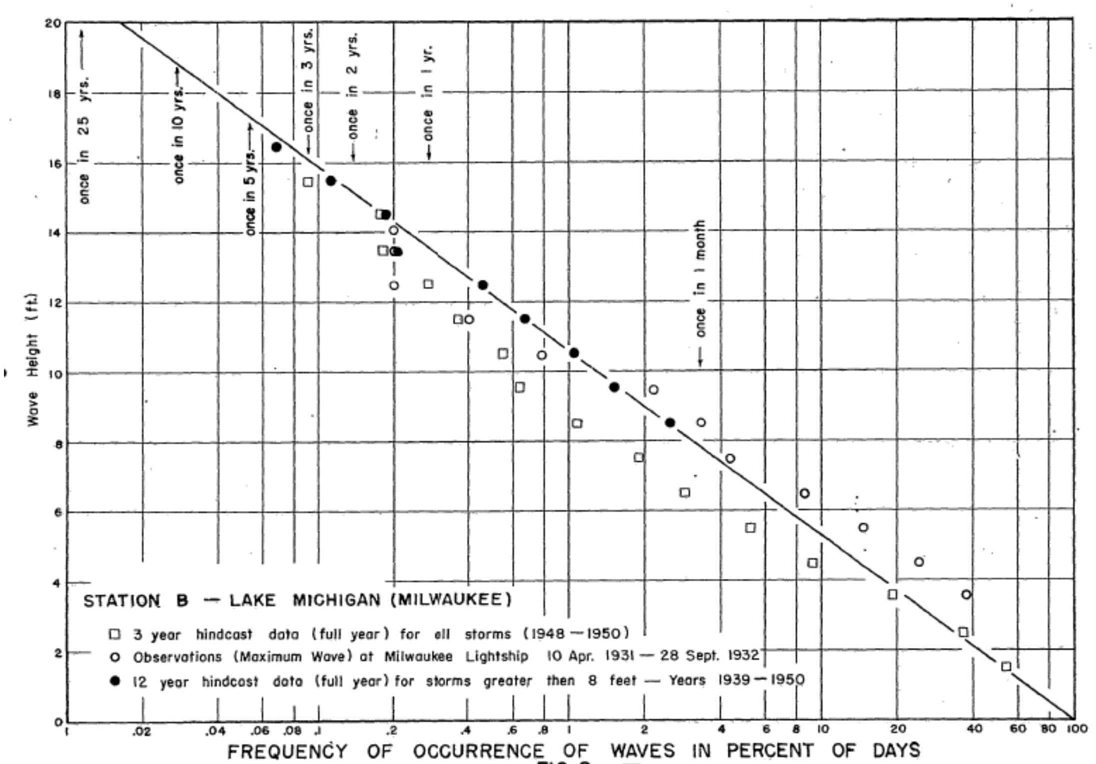

FIG. 2