Marine Navigation II

Marine Navigation II

- Tides
- Obtaining a Fix
- Dead Reckoning
- Piloting Techniques
- Navigation Rules
- Electronic Navigation Systems
- Additional Resources

Recap of Marine Navigation I

- Navigation means:
  - Determining your location
  - Determining a route to a destination
  - Collision avoidance

- Latitude & Longitude
  - Use degrees & minutes format
  - Use consistent horizontal datum
    - (WGS84 and/or NAD83)

Recap of Marine Navigation I

- Nautical Mile:
  - Exactly 1852 meters
  - *Almost* exactly one minute of latitude
  - **NOT** one minute of longitude

- Mercator Projection
  - Scale changes with latitude
  - Direction angles can be measured on maps
  - Rhumb lines are straight lines

Recap of Marine Navigation I

- Nautical Chart Features:
  - Scale, colors, depth soundings, chart symbols

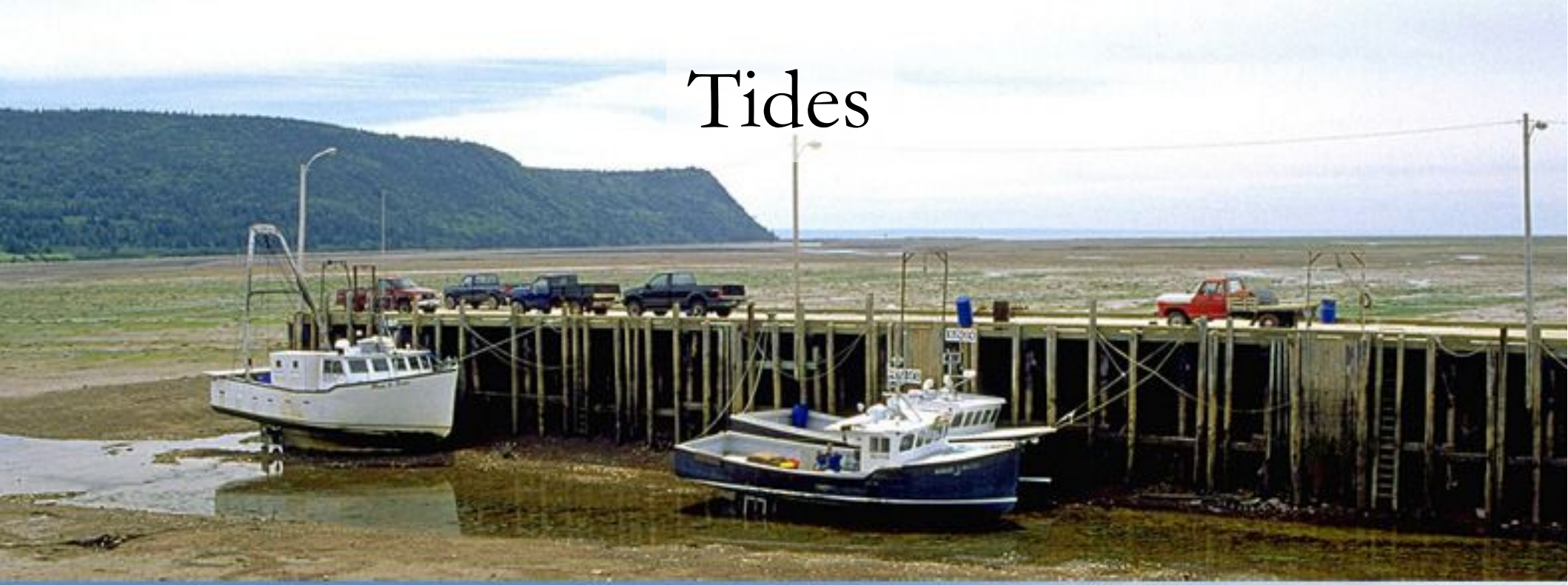
- Aids to Navigation
  - Buoys, lights & daybeacons
  - Colors, shapes, sounds, lights, markings
  - Lateral marks, center-channel, danger, etc.
  - Symbols and labels on charts

Recap of Marine Navigation I

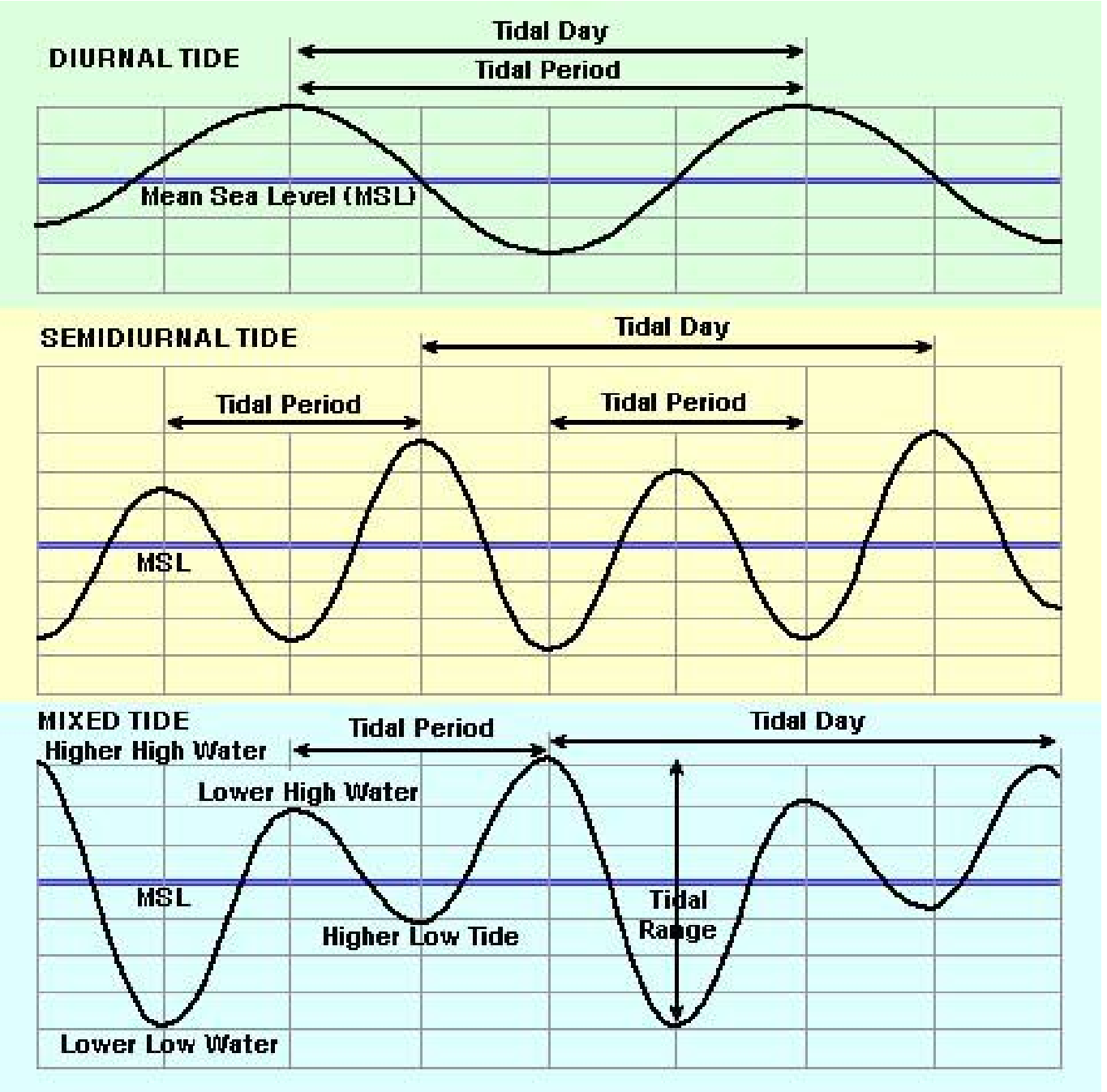
- Magnetic Compass:
  - Variation (magnetic vs. true direction)
  - Deviation (compass error)
  - Var. and Dev. expressed as degrees E. or W.

  - Can Dead Men Vote Twice (add E)
  - TV Makes Dull Children (add W)

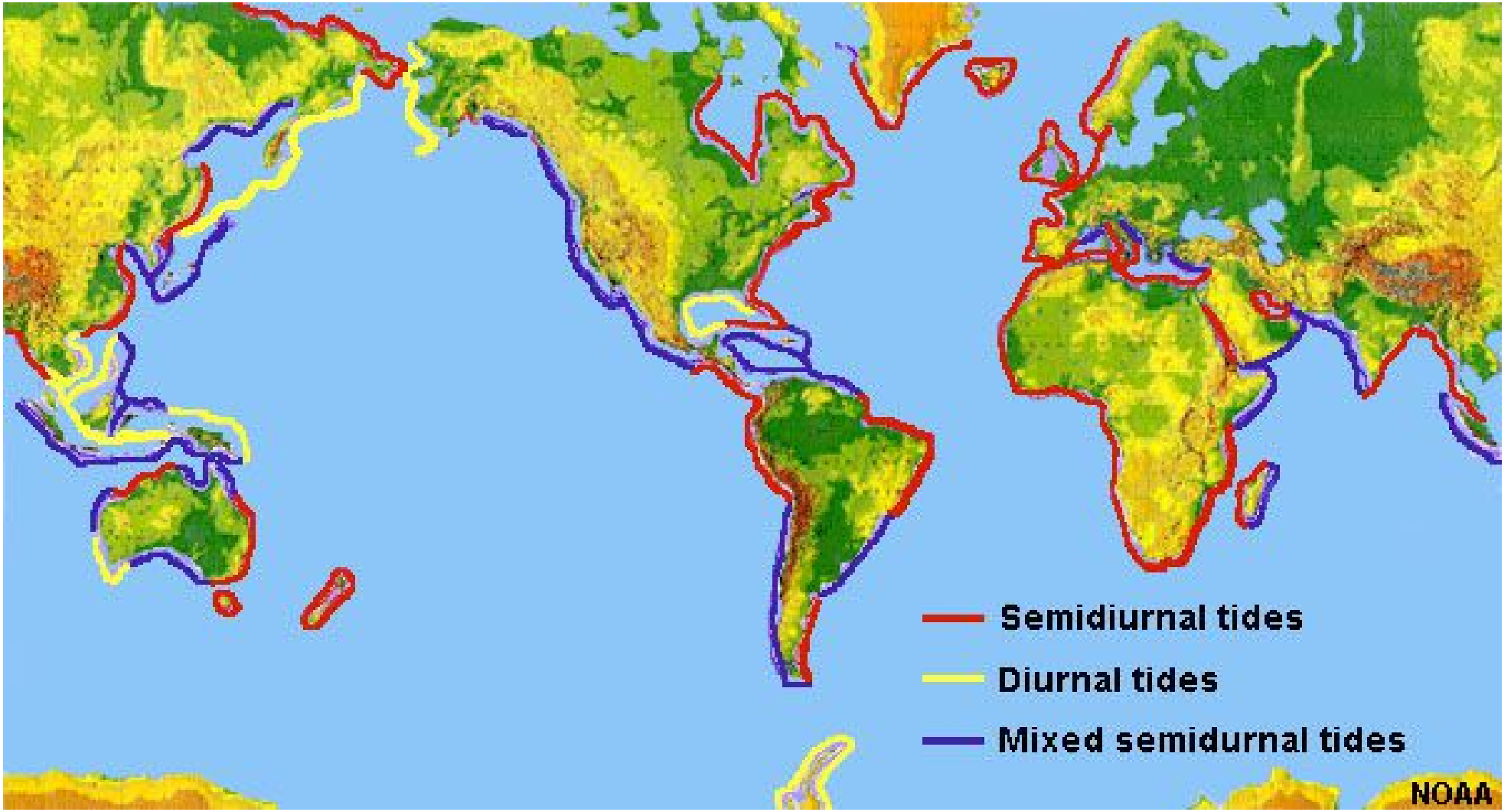
Tides



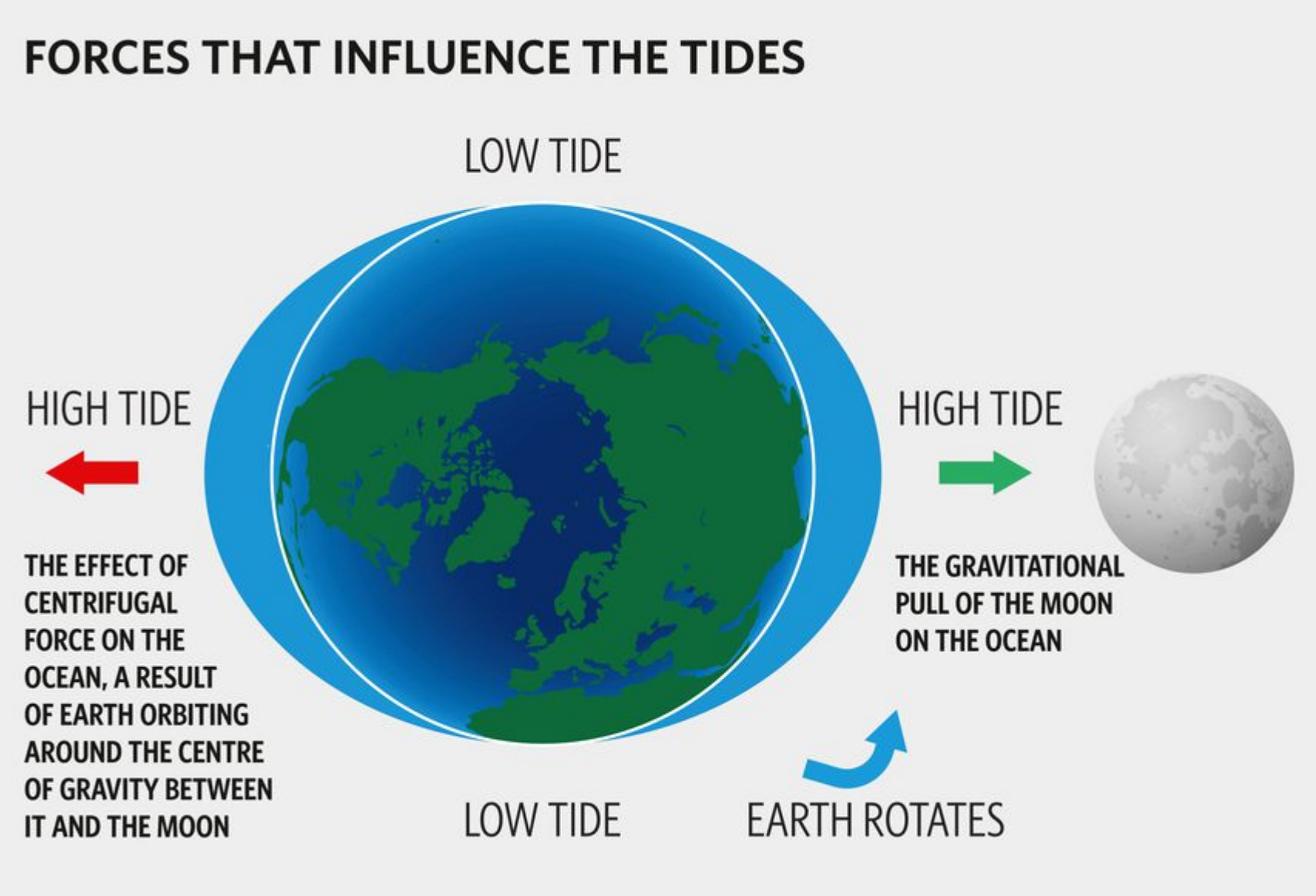
Tides


DIURNAL TIDE
Tidal Day
Tidal Period
Mean Sea Level (MSL)
SEMIDIURNAL TIDE
Tidal Day
Tidal Period
Tidal Period
MSL
MIXED TIDE
Higher High Water
Tidal Period
Tidal Day
Lower High Water
MSL
Higher Low Tide
Tidal Range
Lower Low Water

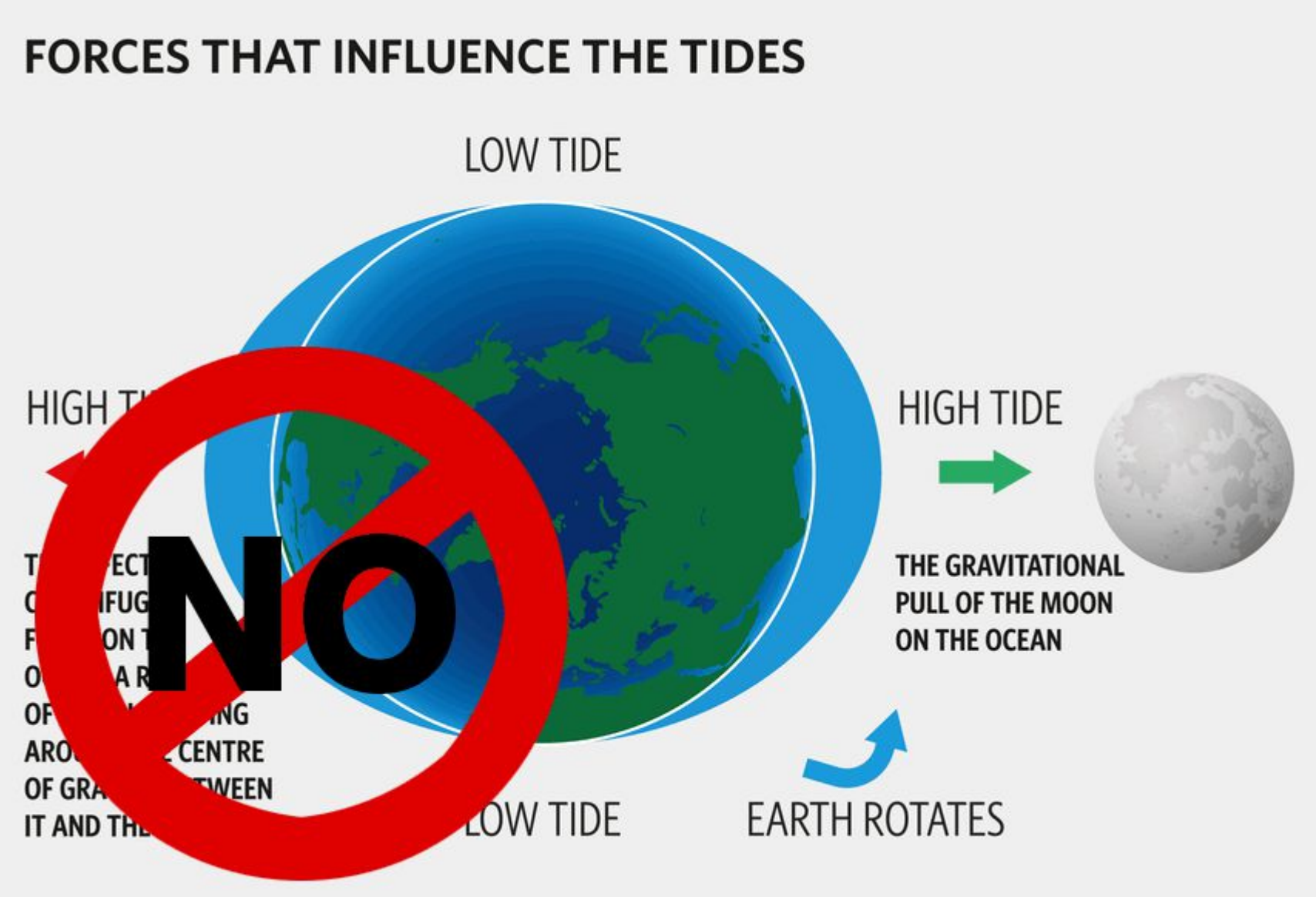
Tides


Semidiurnal tides
Diurnal tides
Mixed semidurnal tides
NOAA

Tides

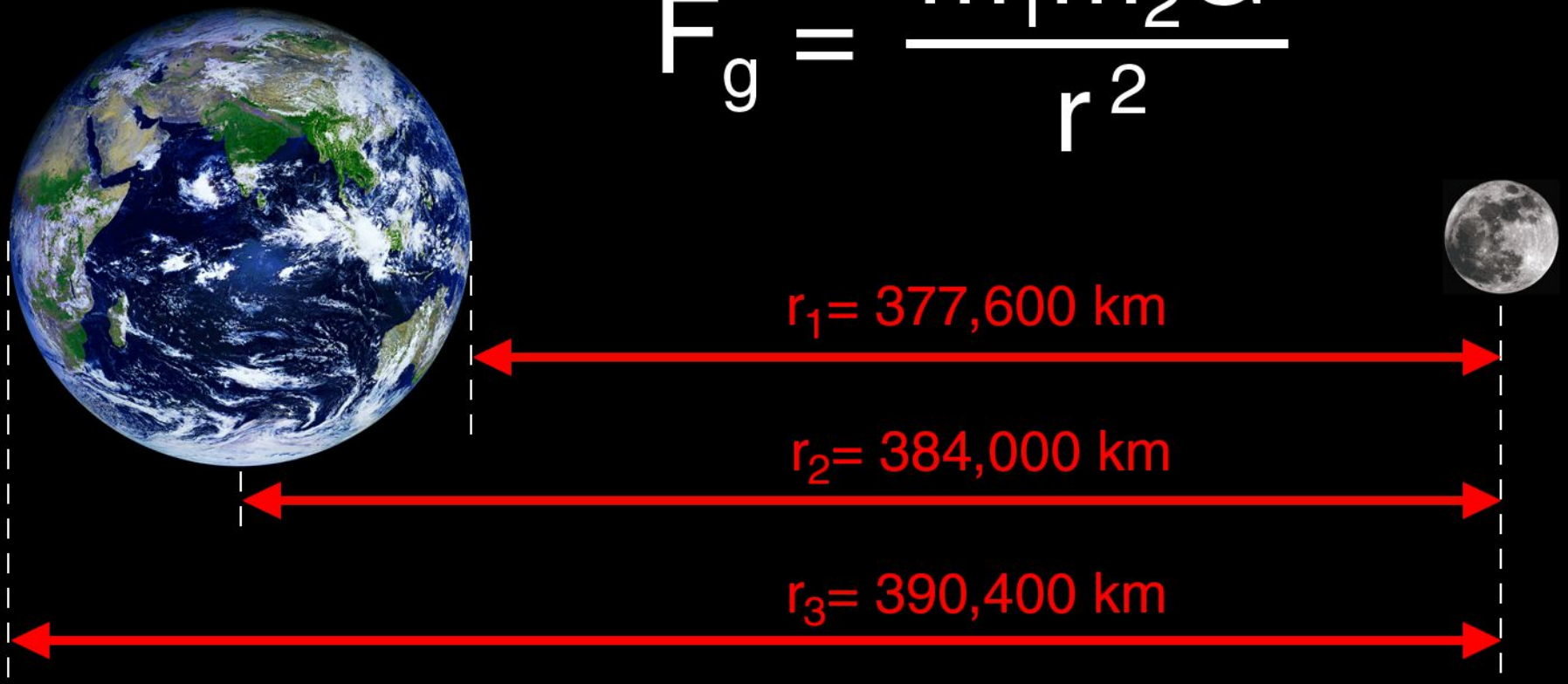

FORCES THAT INFLUENCE THE TIDES
LOW TIDE
HIGH TIDE
HIGH TIDE
THE EFFECT OF CENTRIFUGAL FORCE ON THE OCEAN, A RESULT OF EARTH ORBITING AROUND THE CENTRE OF GRAVITY BETWEEN IT AND THE MOON
THE GRAVITATIONAL PULL OF THE MOON ON THE OCEAN
LOW TIDE
EARTH ROTATES

Tides


FORCES THAT INFLUENCE THE TIDES
LOW TIDE
HIGH TIDE
THE GRAVITATIONAL PULL OF THE MOON ON THE OCEAN
LOW TIDE
EARTH ROTATES
NO

Tidal Forces

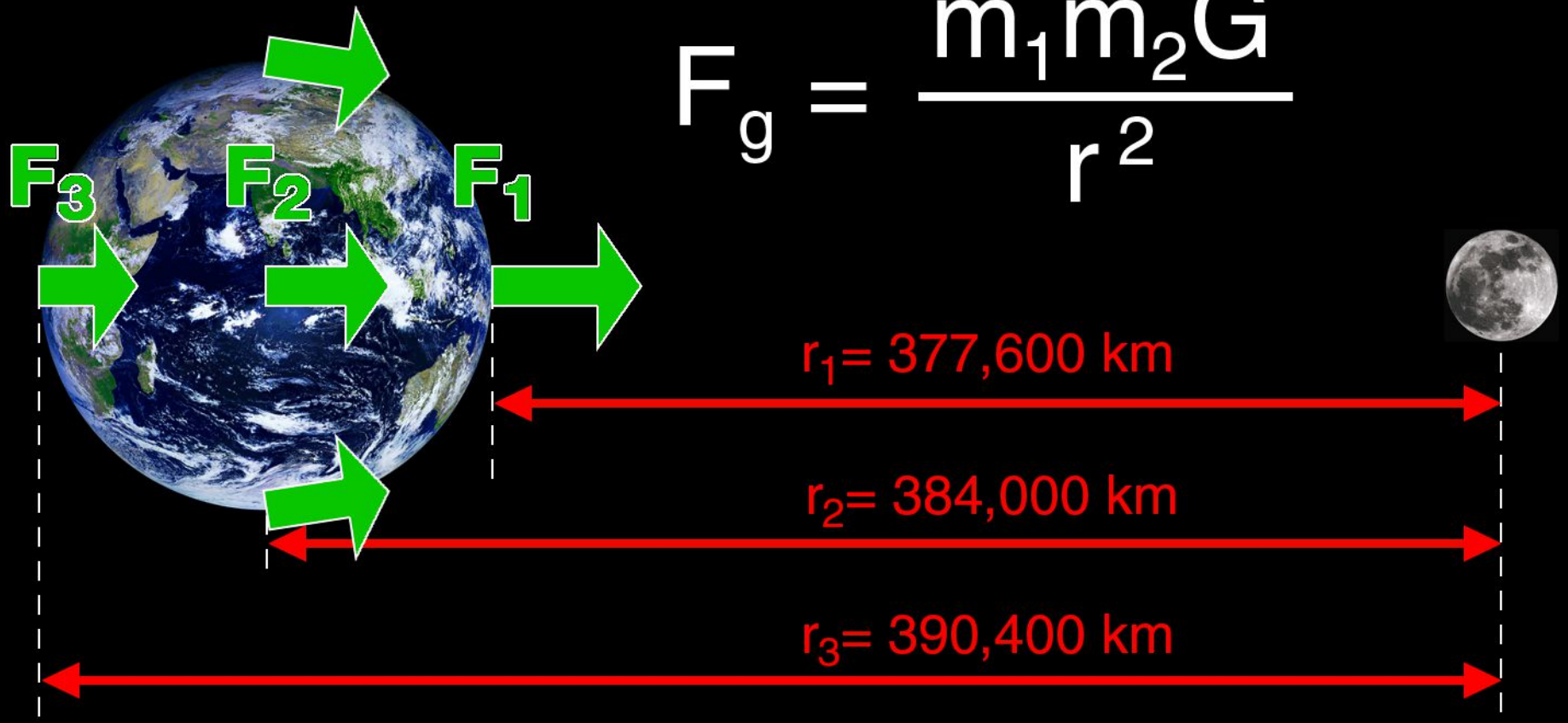
$$F_g = \frac{m_1 m_2 G}{r^2}$$



(Distances not to scale)

Tidal Forces

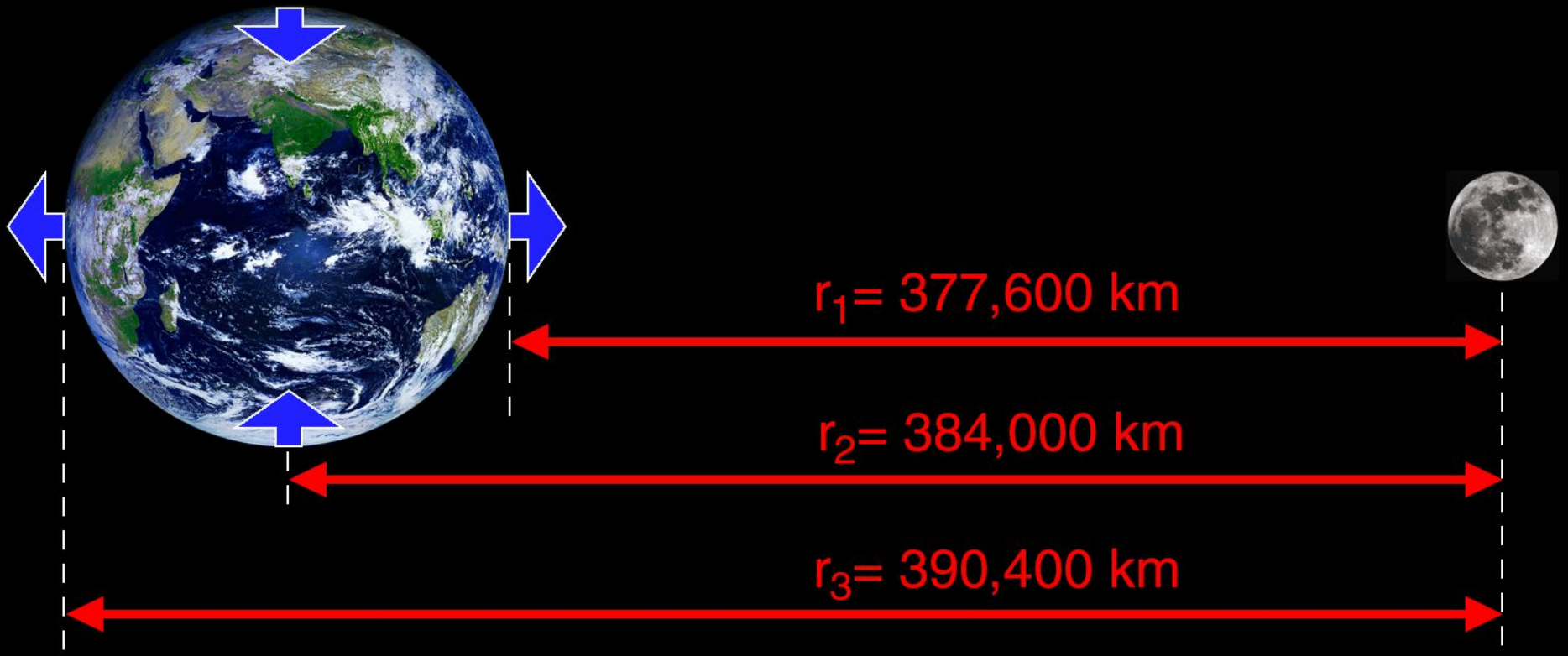
$$F_g = \frac{m_1 m_2 G}{r^2}$$



(Distances not to scale)

Tidal Forces

Tidal forces are the forces acting on an object caused by the difference in gravitational pull of another object relative to the force acting on the center of that object.



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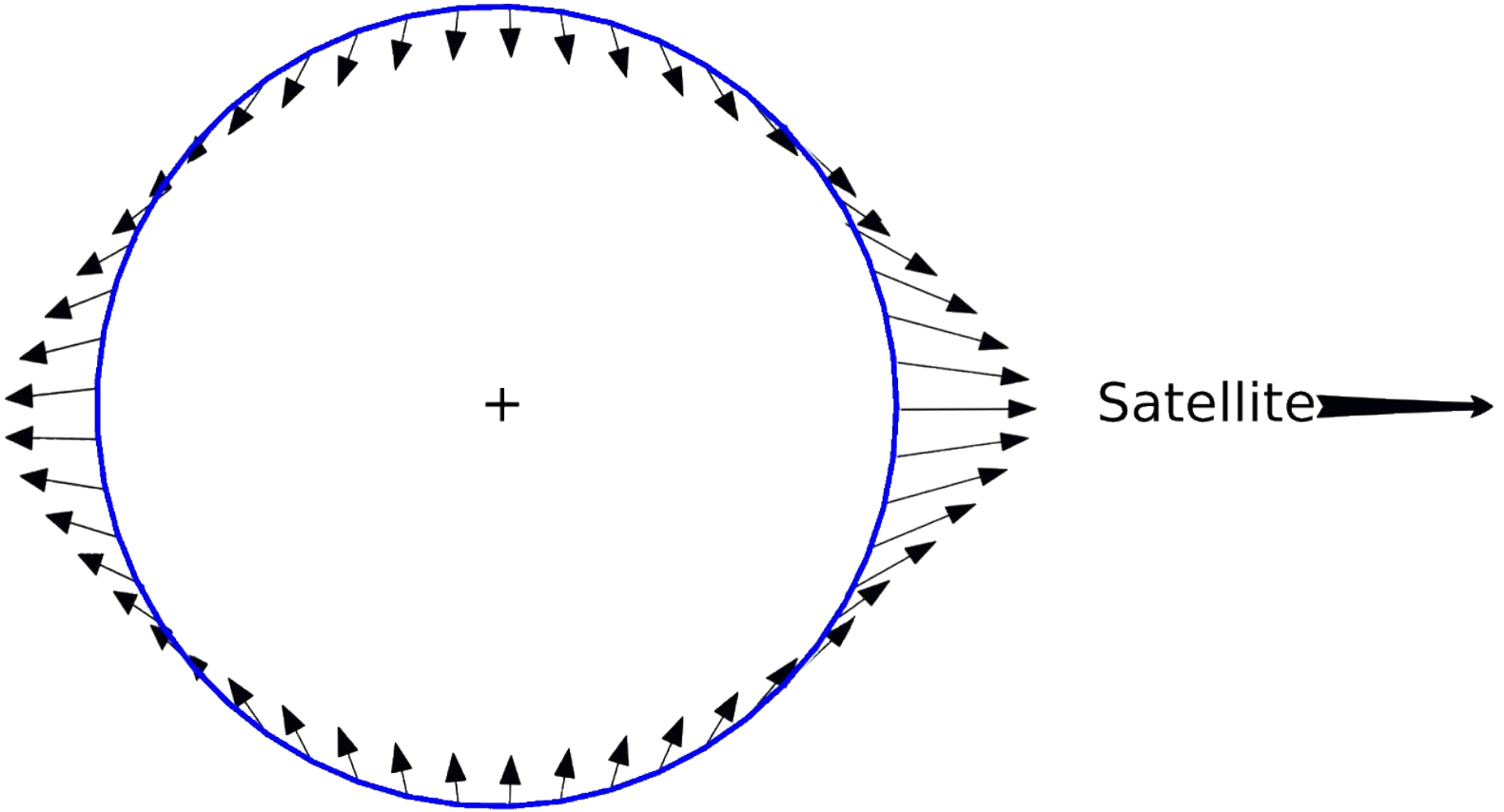

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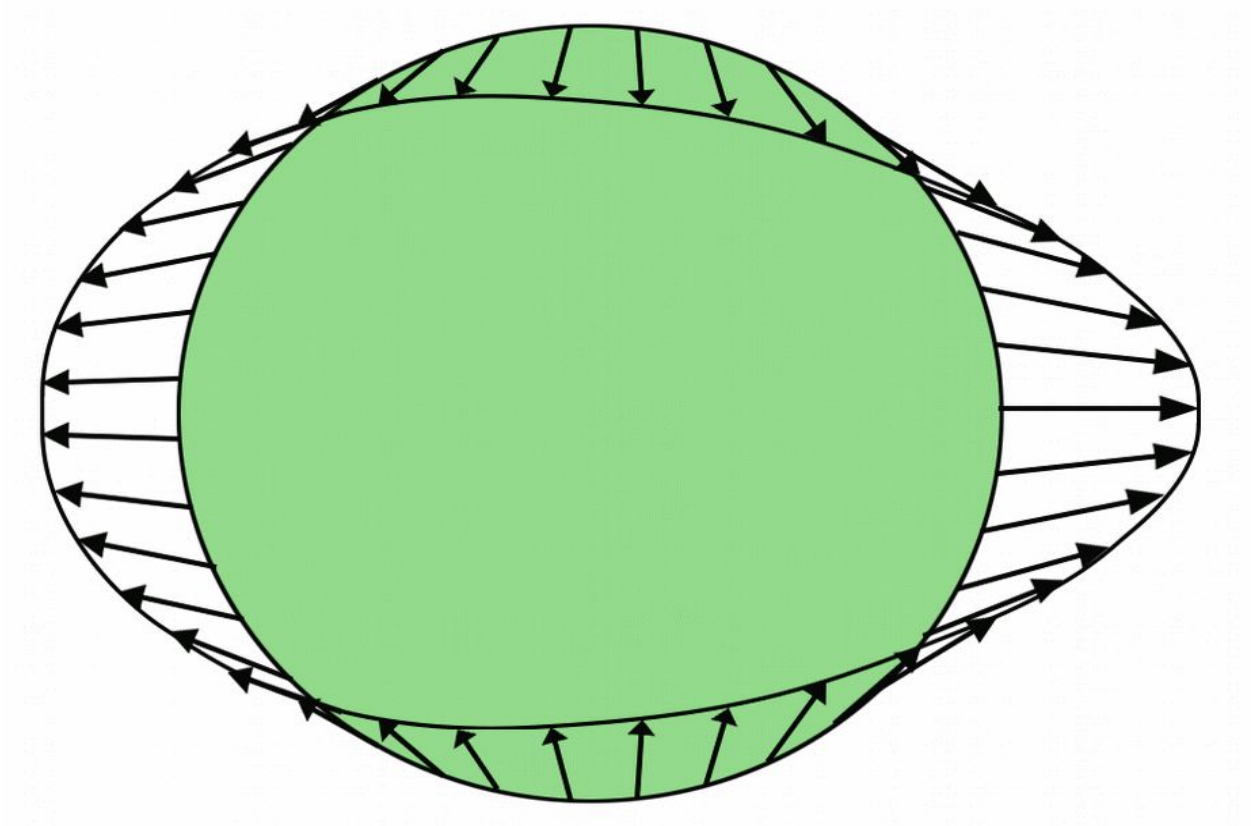
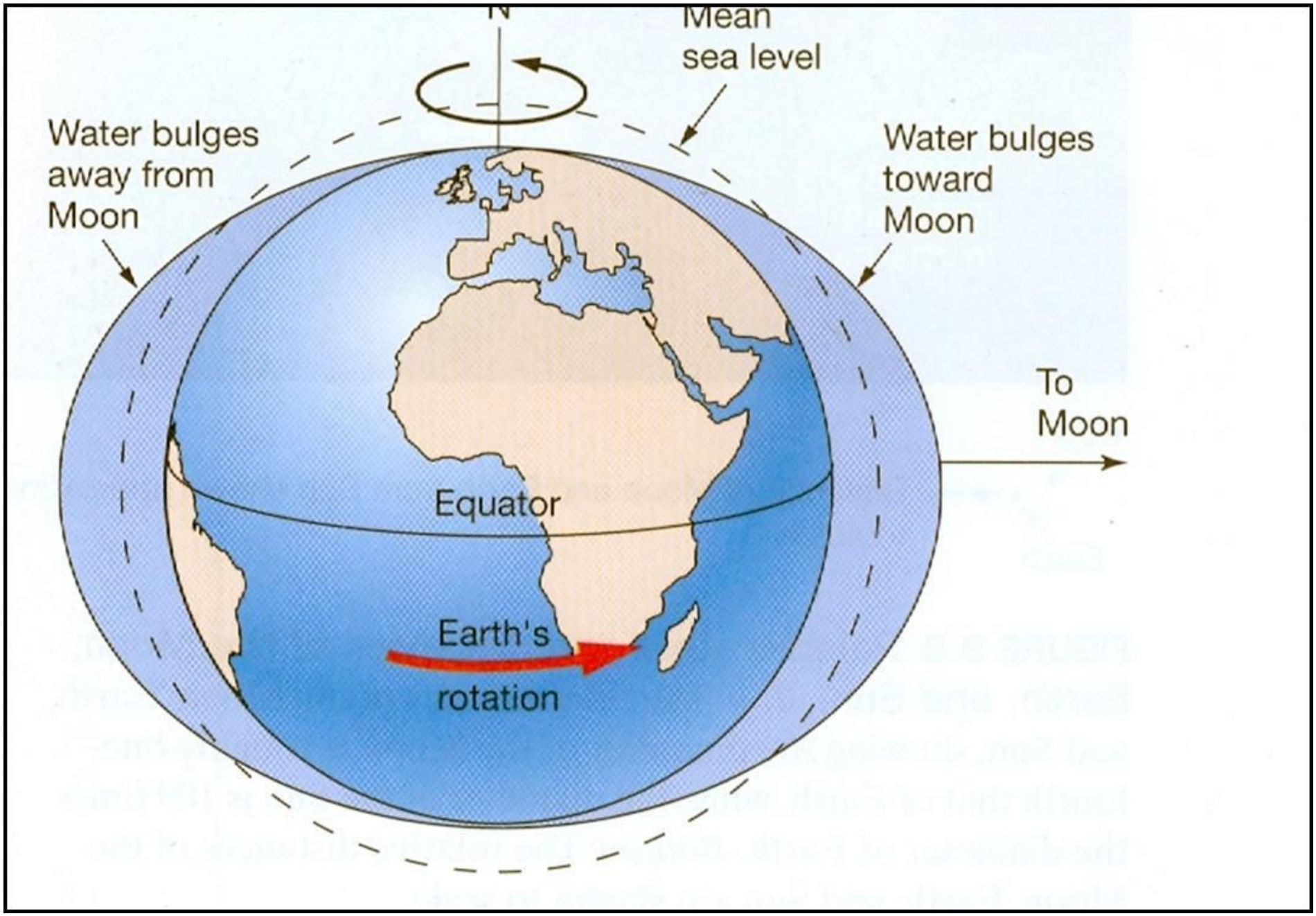
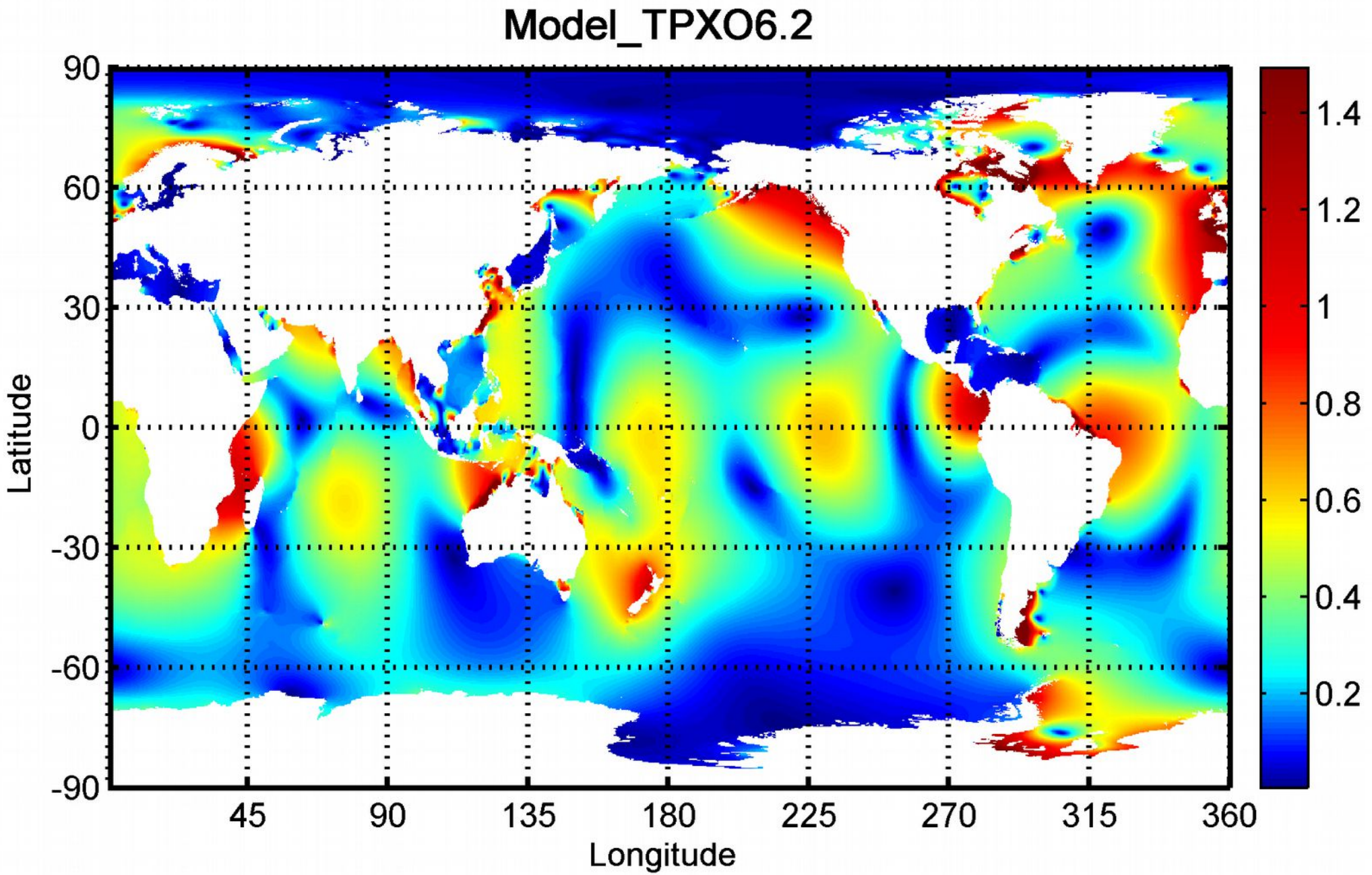


Satellite →

Tides


N
Mean
sea level
Water bulges
away from
Moon
Water bulges
toward
Moon
To
Moon
Equator
Earth's
rotation

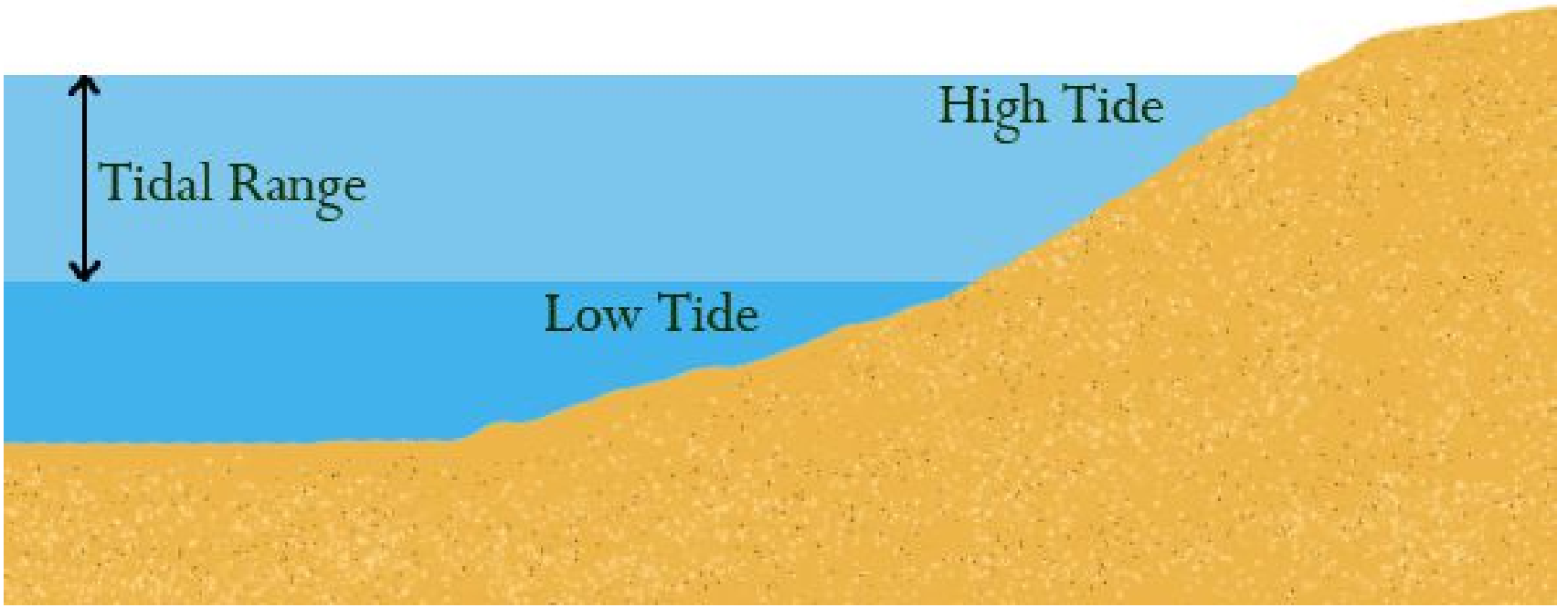
Tidal Amplitudes



Tidal Range

What affects the range of the tides at a location?

- Shape of the sea floor:
  - Bays and inlets act as funnels
  - Rapidly rising sea floor will amplify a wave



Tidal Range

What affects the range of the tides?

- The size of the sea basin
  - Smaller bodies of water have negligible tides
  - Basins the right size create resonance

Tidal Range

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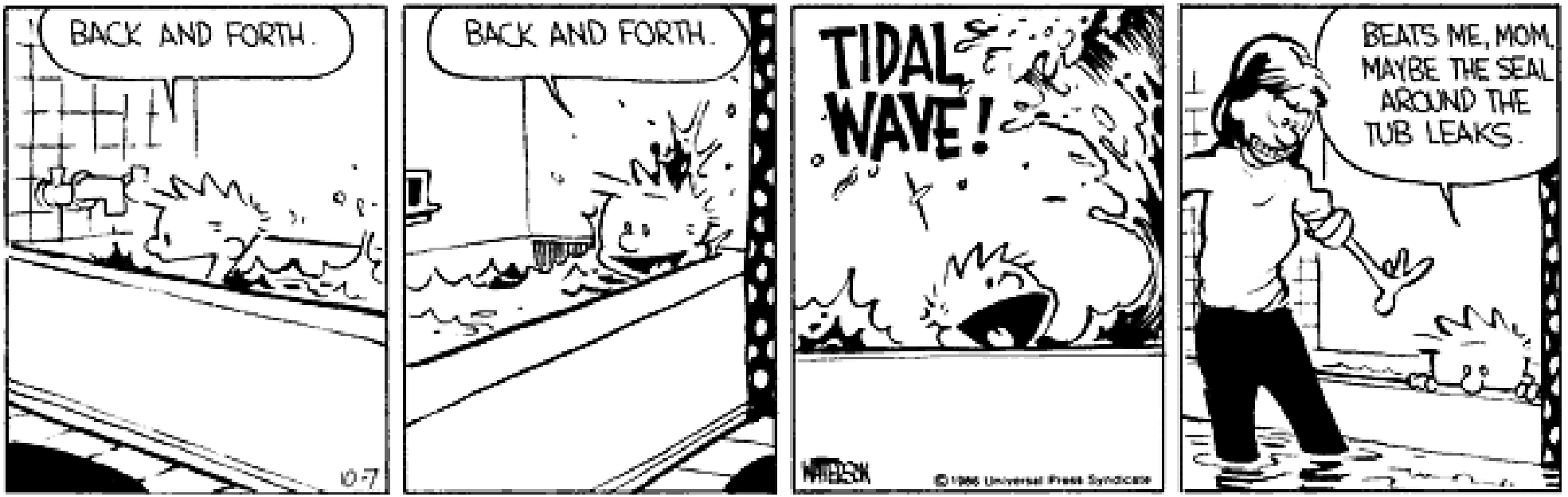
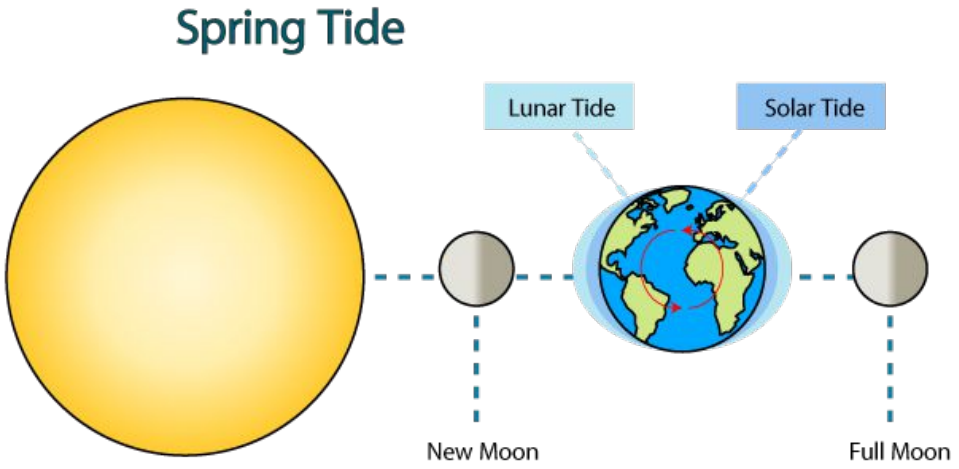
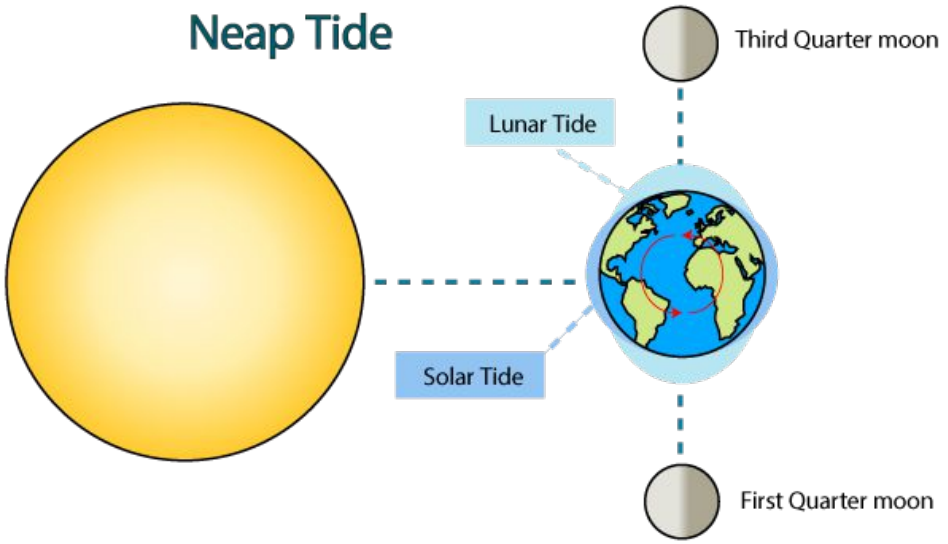
- The size of the sea basin
  - Smaller bodies of water have negligible tides
  - Basins the right size create resonance



Spring Tides & Neap Tides



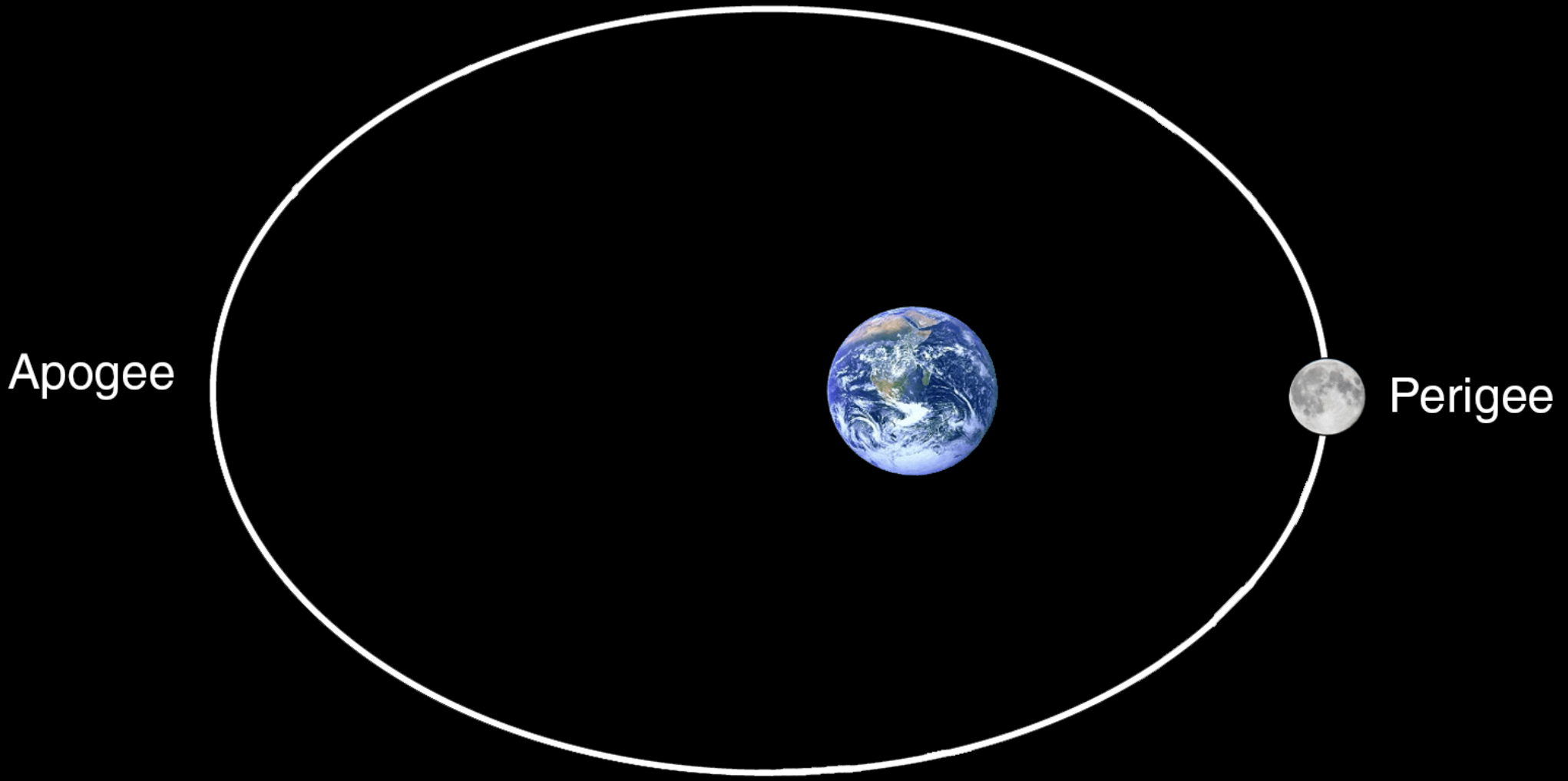


(Drawing not to scale)

Lunar Orbit

Sidereal Period: 27.3 days

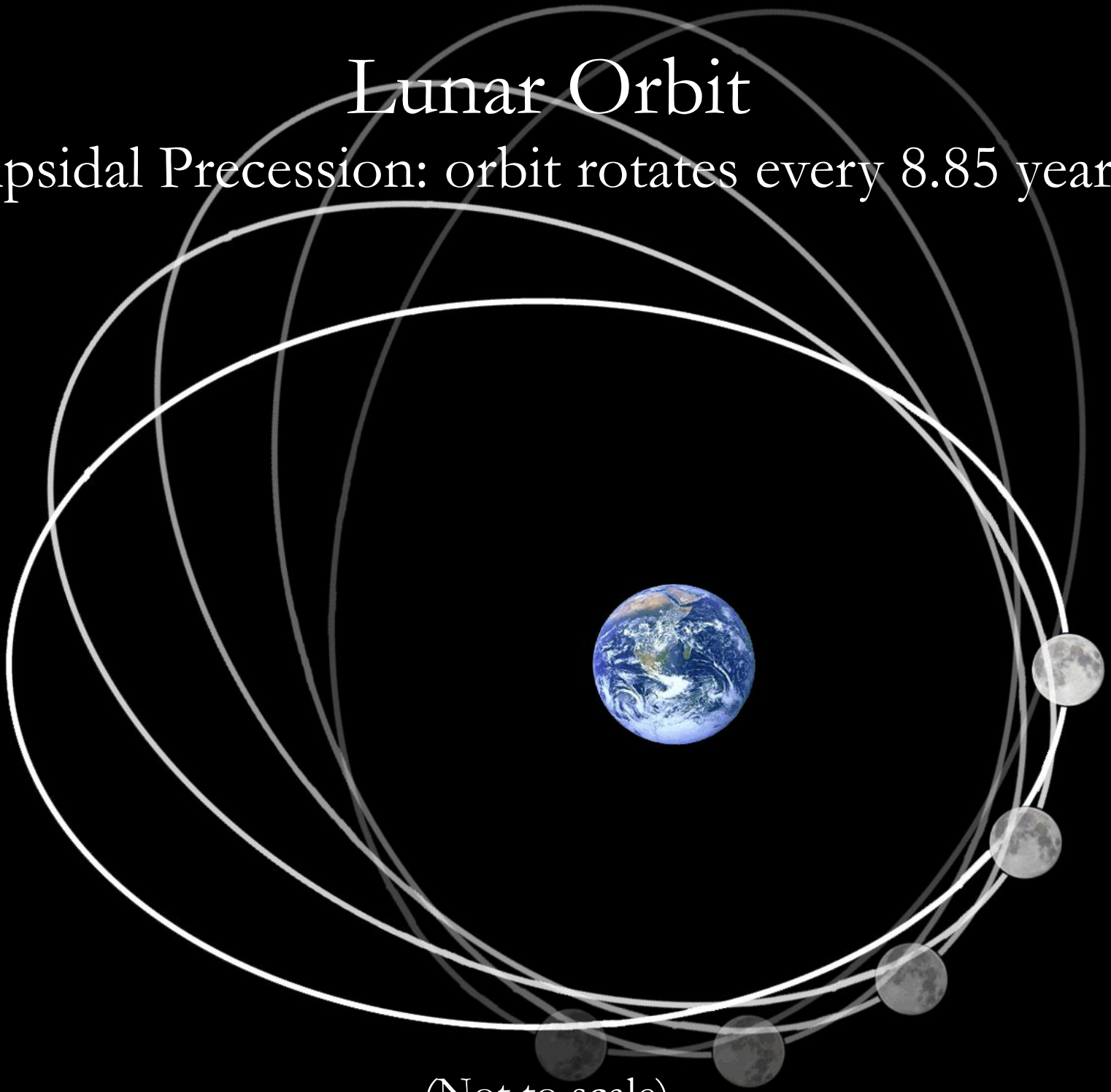
Synodic Period (lunar phases): 29.5 days



(Not to scale)

Lunar Orbit

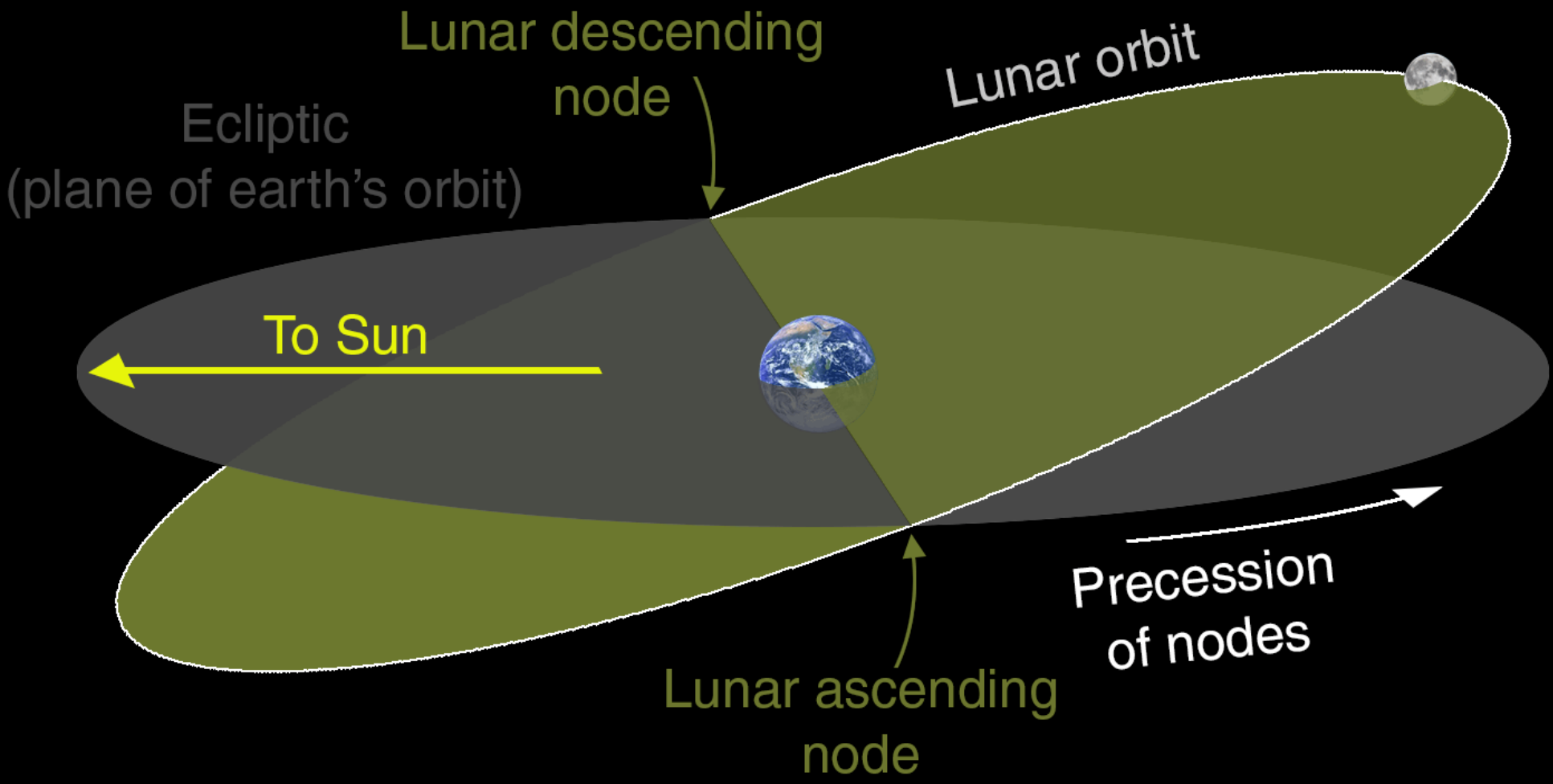
Apsidal Precession: orbit rotates every 8.85 years



(Not to scale)

Lunar Orbit

Nodal Precession: every 18.6 years



(Not to scale)

Tide Predictions

How to predict tides at a specific location:

- Monitor the sea level for 19 years at a tidal station.
- Perform harmonic analysis on the data.
- Determine amplitude and phase for 37 harmonic factors.
- Each harmonic factor has a different period (frequency)
- Sum the 37 sine waves for a given time and date.

Main factors in the tide prediction function:

- Movement of the moon across the sky (12 hours, 24 min.)
- Movement of the sun across the sky (12 hours)
- Position of the moon on its elliptical orbit (12 hours 39.5 min.)

Vertical Datum

National Tidal Datum Epoch: 1983-2001

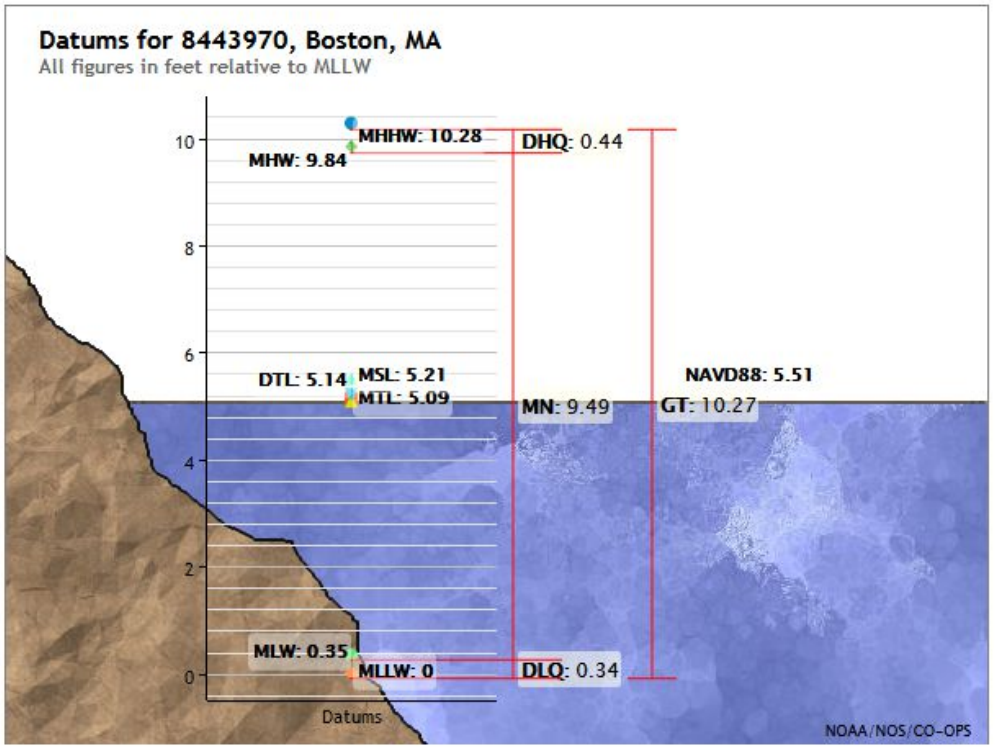
- The various reference levels are derived from this data:
  - Highest Astronomical Tide (HAT)
  - Mean Higher High Water (MHHW)
  - Mean High Water (MHW)
  - Mean Tide Level (MTL)
  - Mean Sea Level (MSL)
  - Mean Low Water (MLW)
  - Mean Lower Low Water (MLLW)
  - Lowest Astronomical Tide (LAT)

Vertical Datum

Elevations on Mean Lower Low Water

Station: 8443970, Boston, MA
Status: Accepted (Apr 17 2003)
Units: Feet
Control Station:
T.M.: 0
Epoch: 1983-2001
Datum: MLLW

Datum	Value	Description
MHHW	10.28	Mean Higher-High Water
MHW	9.84	Mean High Water
MTL	5.09	Mean Tide Level
MSL	5.21	Mean Sea Level
DTL	5.14	Mean Diurnal Tide Level
MLW	0.35	Mean Low Water
MLLW	0.00	Mean Lower-Low Water
NAVD88	5.51	North American Vertical Datum of 1988
STND	-3.52	Station Datum
GT	10.27	Great Diurnal Range
MN	9.49	Mean Range of Tide
DHQ	0.44	Mean Diurnal High Water Inequality
DLQ	0.34	Mean Diurnal Low Water Inequality
HWI	3.74	Greenwich High Water Interval (in hours)
LWI	9.93	Greenwich Low Water Interval (in hours)
Max Tide	15.17	Highest Observed Tide
Max Tide Date & Time	01/04/2018 17:42	Highest Observed Tide Date & Time
Min Tide	-3.72	Lowest Observed Tide
Min Tide Date & Time	03/24/1940 00:00	Lowest Observed Tide Date & Time
HAT	12.43	Highest Astronomical Tide
HAT Date & Time	11/05/1998 16:30	HAT Date and Time
LAT	-2.27	Lowest Astronomical Tide
LAT Date & Time	12/23/1999 22:30	LAT Date and Time



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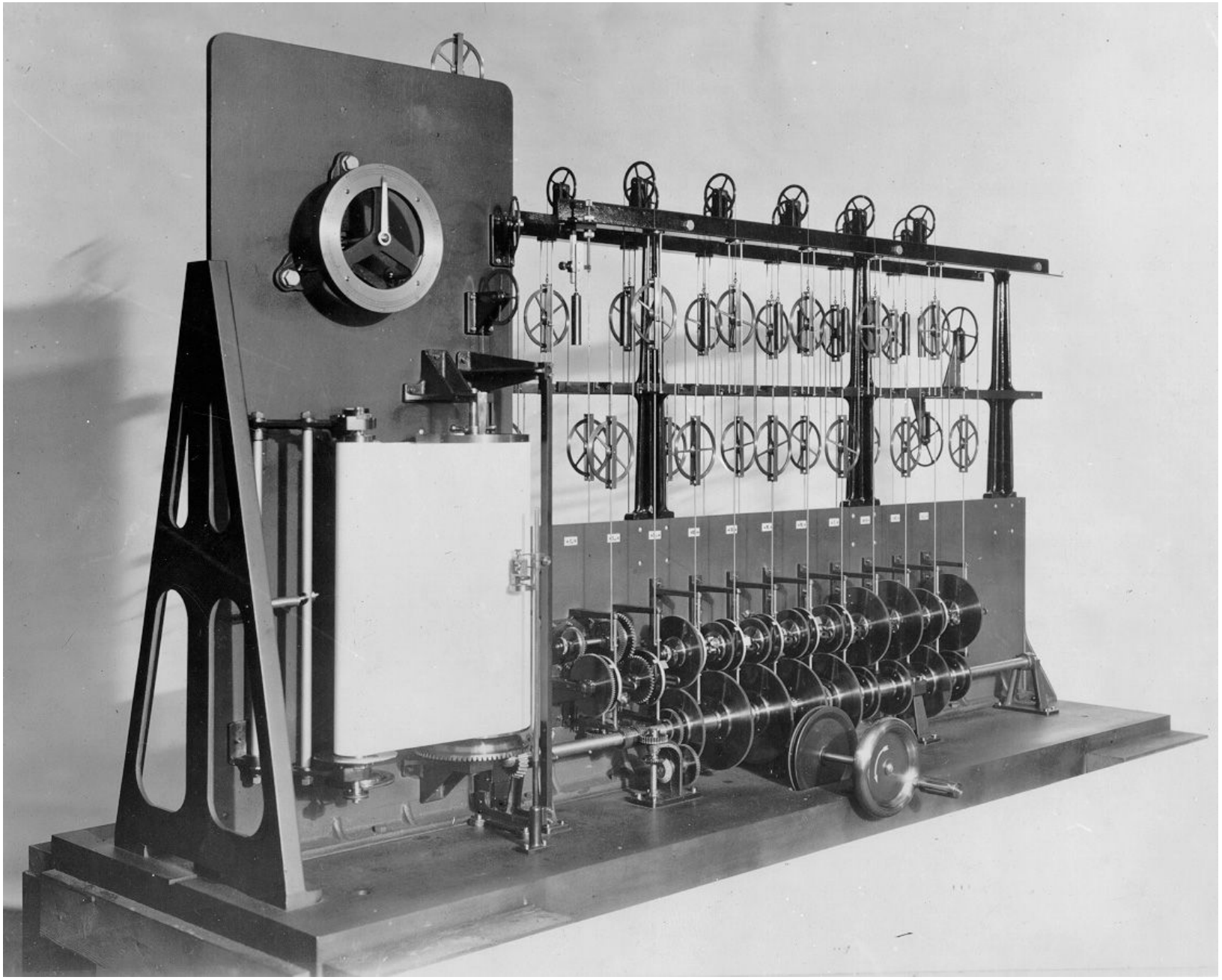

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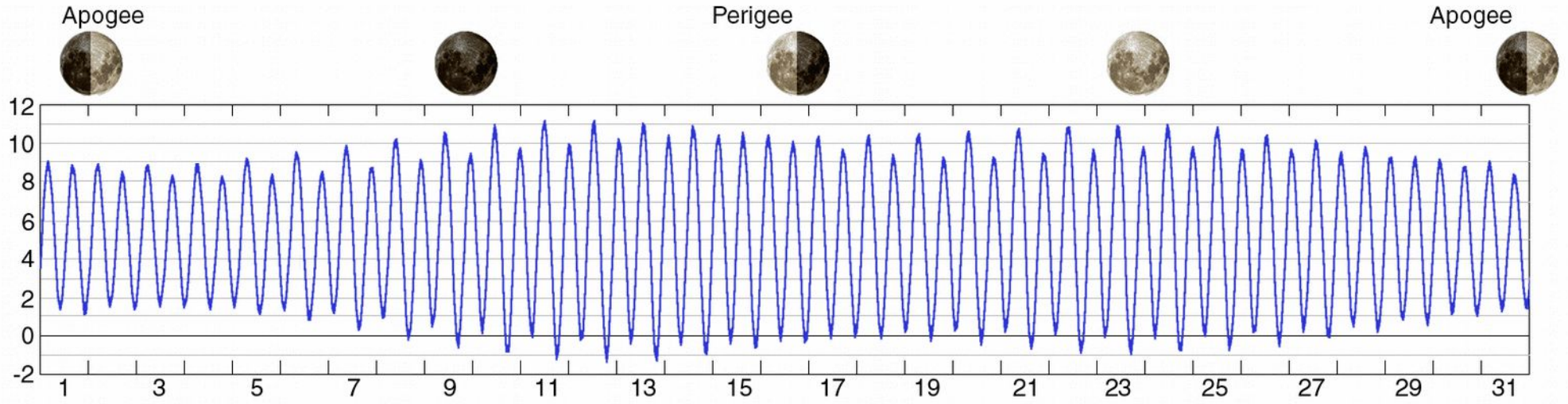
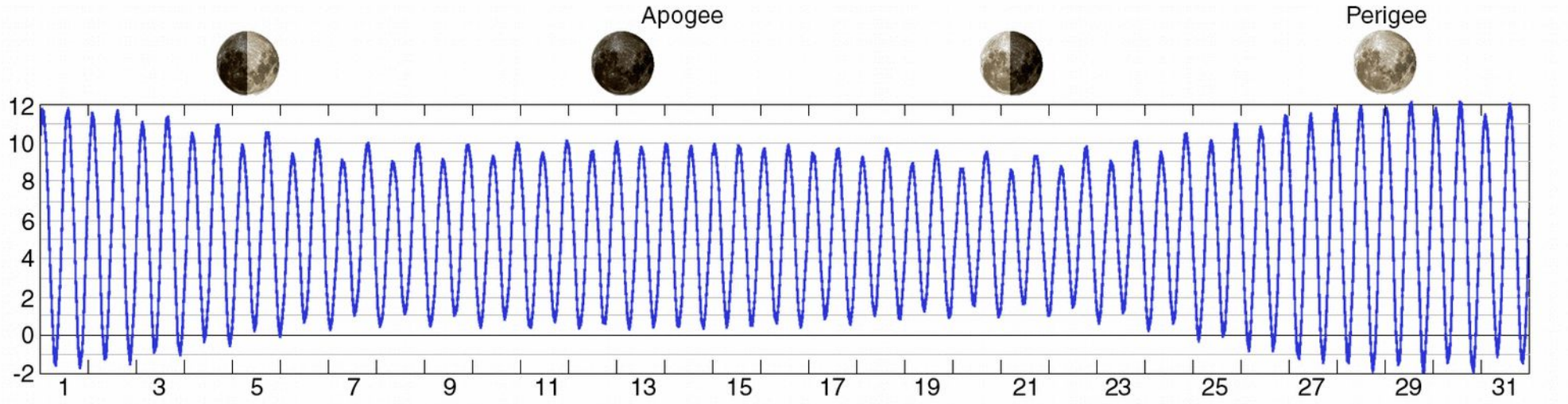


Predicted Tides, Boston Harbor, January 2016



Predicted Tides, Boston Harbor, September 2015

Tide Predictions

Source of tide prediction information:

- NOAA website (http://tidesandcurrents.noaa.gov)
- NOAA weather radio
- Printed in various publications (Eldridge Tide Book)
- GPS chartplotter
- Many software applications

Tide Predictions

January

	Time	Height		Time	Height
	h m	ft		h m	ft
1 F	03:57 AM	9.0	**16** Sa	03:43 AM	10.4
	10:03 AM	1.4		09:57 AM	-0.2
	04:14 PM	8.9		04:07 PM	10.1
	10:27 PM	1.0	◐	10:22 PM	-0.4
2 Sa ◑	04:47 AM	8.9	**17** Su	04:40 AM	10.4
	10:56 AM	1.5		10:58 AM	-0.1
	05:08 PM	8.5		05:09 PM	9.7
	11:17 PM	1.3		11:20 PM	-0.1
3 Su	05:38 AM	8.9	**18** M	05:39 AM	10.4
	11:52 AM	1.5		12:01 PM	-0.1
	06:03 PM	8.3		06:14 PM	9.4
4 M	12:09 AM	1.5	**19** Tu	12:20 AM	0.1
	06:30 AM	9.0		06:41 AM	10.5
	12:47 PM	1.4		01:05 PM	-0.2
	06:59 PM	8.3		07:19 PM	9.3

Tide Predictions

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	10:56 AM	1.5		10:58 AM	-0.1
	05:08 PM	8.5		05:09 PM	9.7
◑	11:17 PM	1.3		11:20 PM	-0.1
3 Su	05:38 AM	8.9	**18** M	05:39 AM	10.4
	11:52 AM	1.5		12:01 PM	-0.1
	06:03 PM	8.3		06:14 PM	9.4
4 M	12:09 AM	1.5	**19** Tu	12:20 AM	0.1
	06:30 AM	9.0		06:41 AM	10.5
	12:47 PM	1.4		01:05 PM	-0.2
	06:59 PM	8.3		07:19 PM	9.3

Tide Predictions

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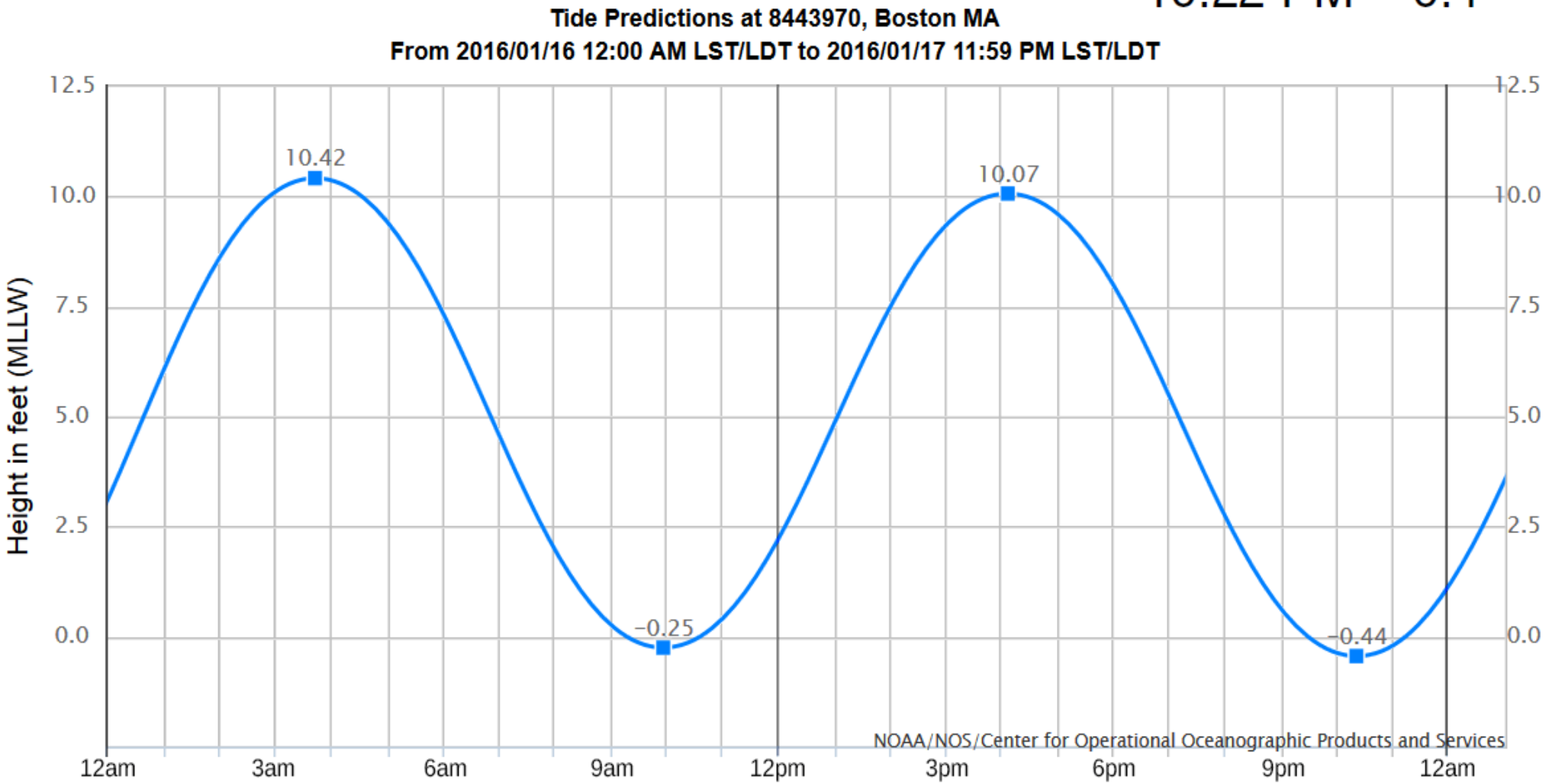
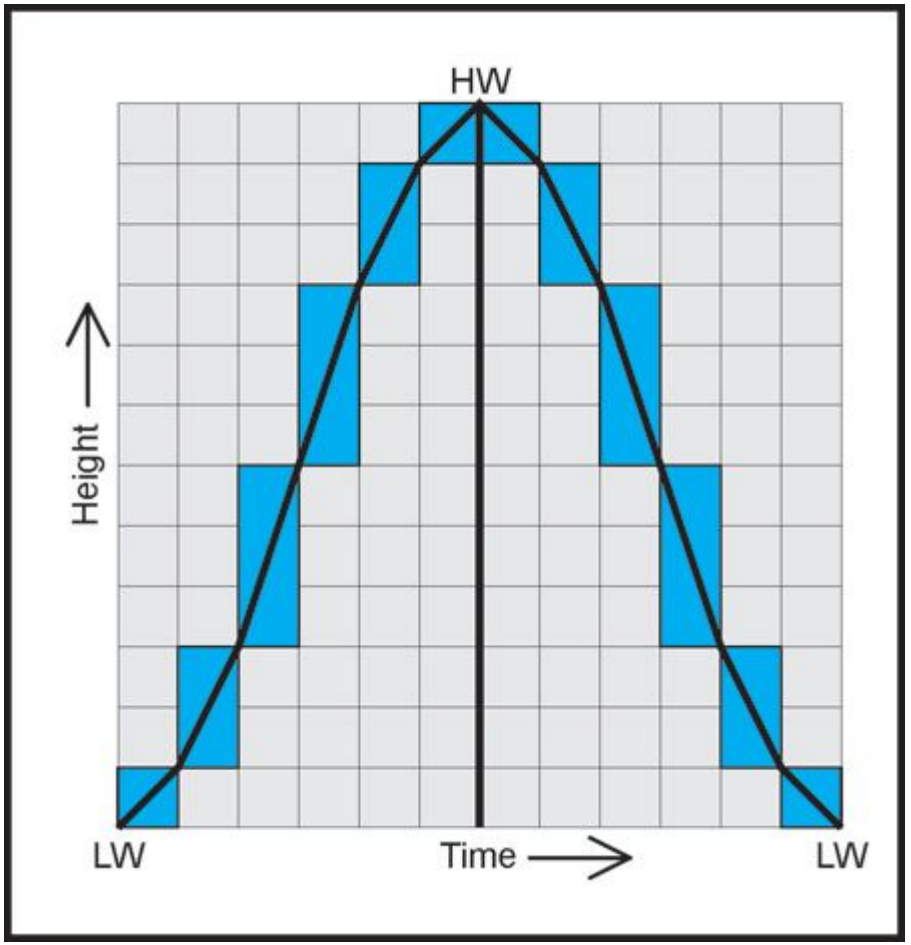


Tide Predictions

Rule of Twelfths



Time	Height	Height	12ths
0/12	0%	0/12	
1/12	7%	1/12	1
2/12	25%	3/12	2
3/12	50%	6/12	3
4/12	75%	9/12	3
5/12	93%	11/12	2
6/12	100%	12/12	1
7/12	93%	11/12	1
8/12	75%	9/12	2
9/12	50%	6/12	3
10/12	25%	3/12	3
11/12	7%	1/12	2
12/12	0%	0/12	1

Tide Predictions

Rule of Twelfths

Remember: “1 2 3 - 3 2 1”

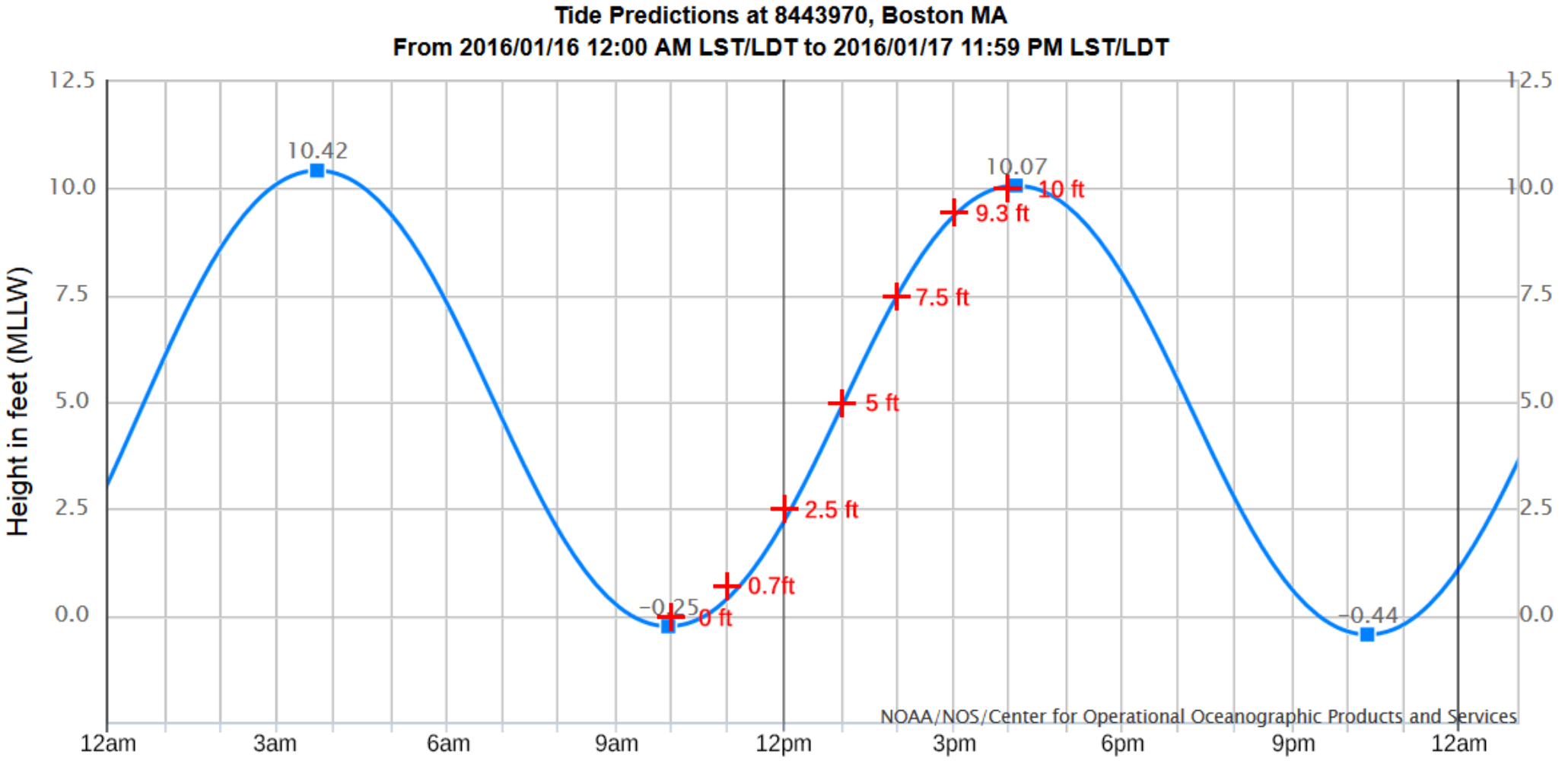
h	m	ft
03:43	AM	10.4
09:57	AM	-0.2
04:07	PM	10.1
10:22	PM	-0.4

10 AM	0	0	~0 feet
11 AM	Add 1/12	1/12	~0.7 feet
12 PM	Add 2/12	3/12	~2.5 feet
1 PM	Add 3/12	6/12	~5 feet
2 PM	Add 3/12	9/12	~7.5 feet
3 PM	Add 2/12	11/12	~9.3 feet
4 PM	Add 1/12	12/12	~ 10 feet

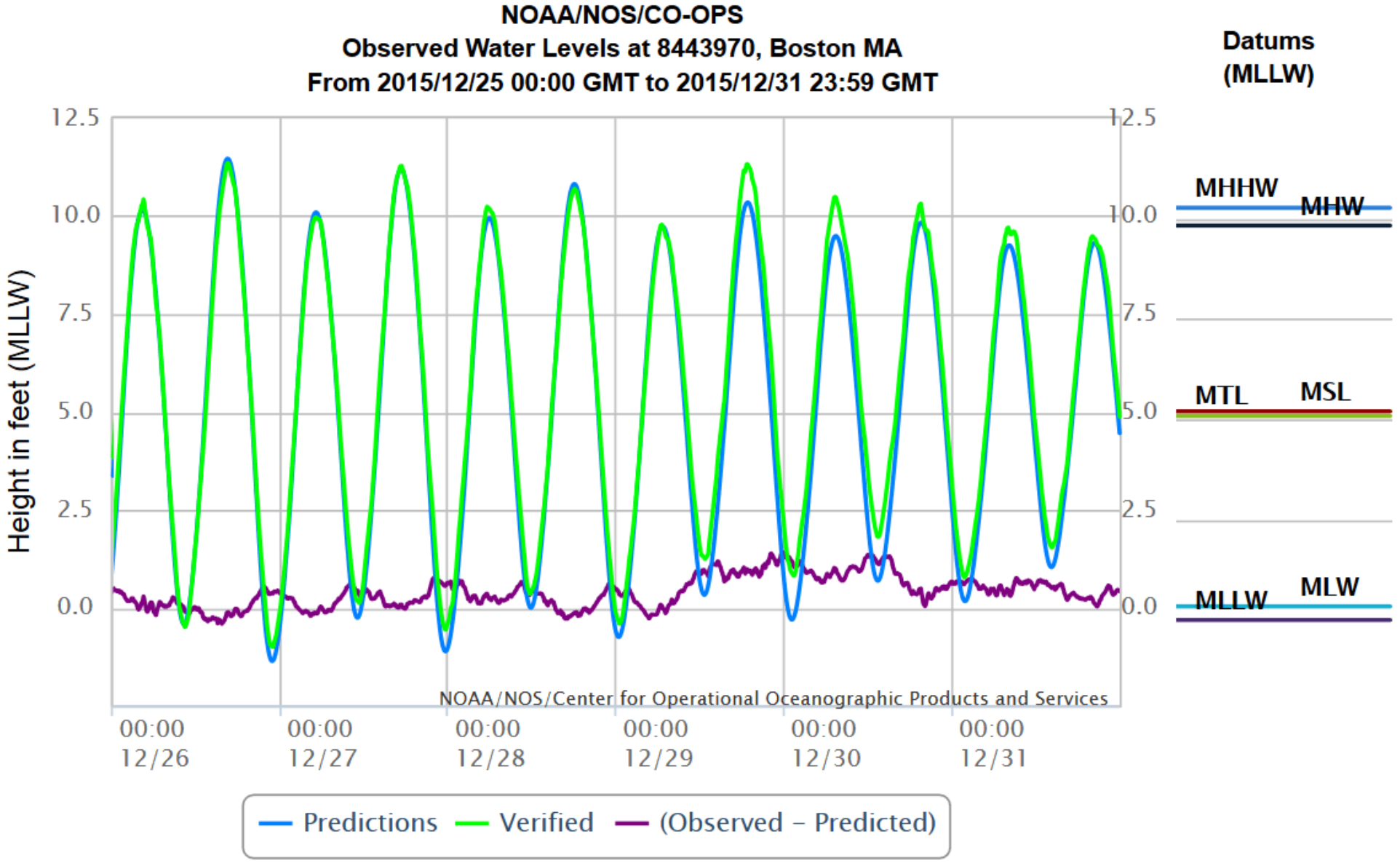
Tide Predictions

Rule of Twelfths

h	m	ft
03:43	AM	10.4
09:57	AM	-0.2
04:07	PM	10.1
10:22	PM	-0.4



Tide Predictions



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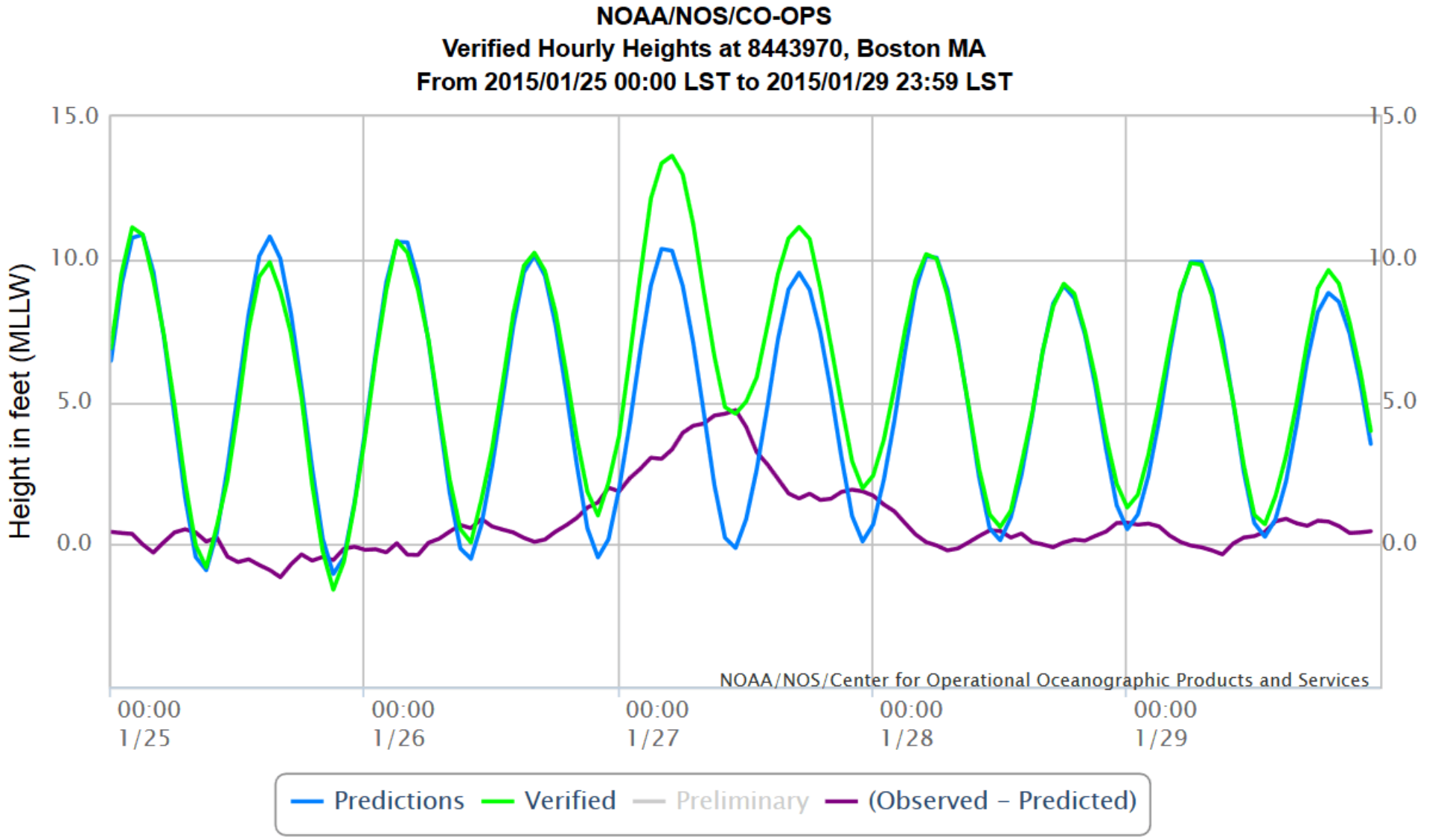
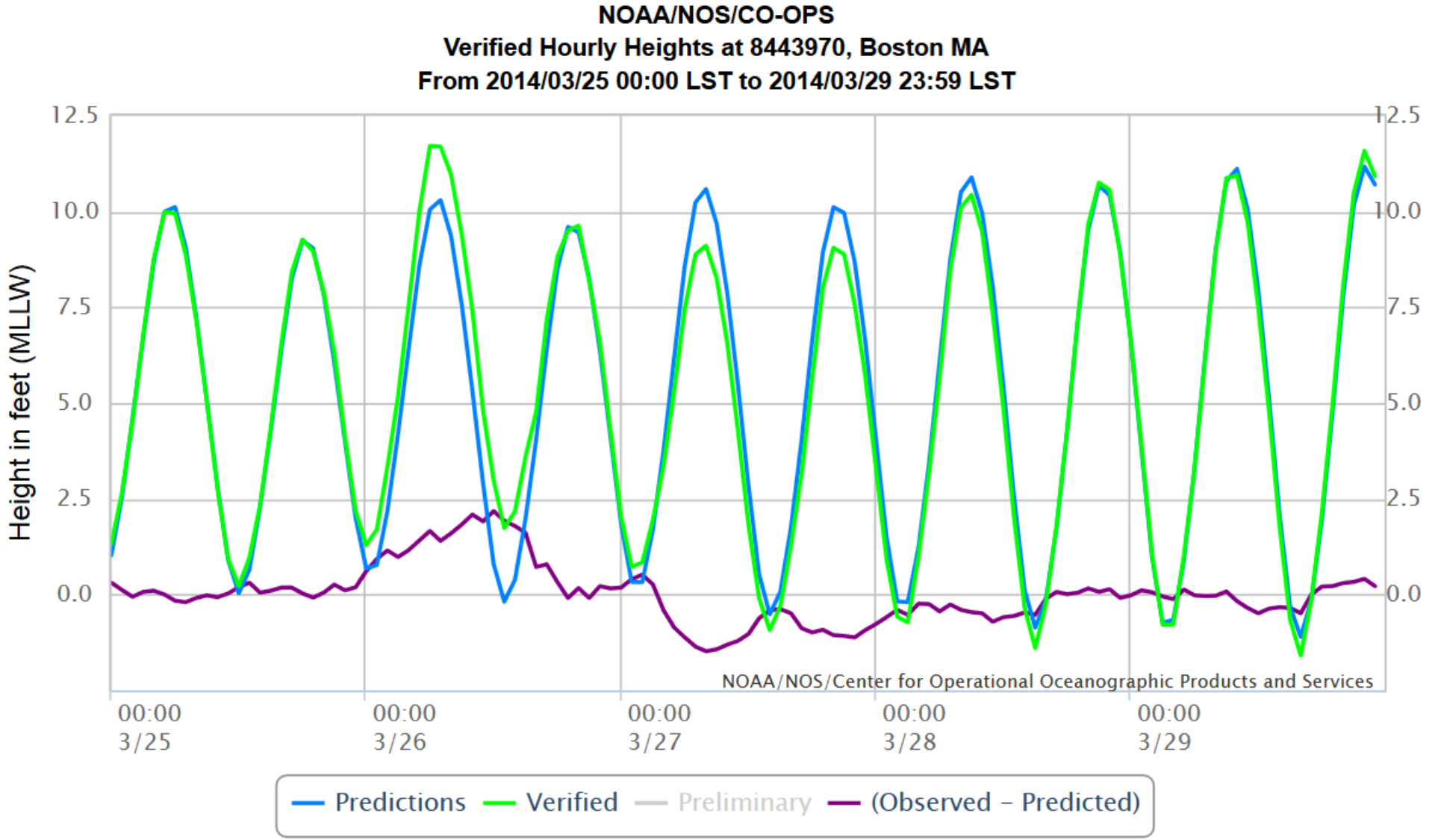


Tide Predictions



Current Predictions

Station ID: BOS1111 Depth: 8 feet
Source: NOAA/NOS/CO-OPS
Station Type: Harmonic
Time Zone: LST/LDT

NOAA Tidal Current Predictions

Boston Harbor (Deer Island Light), 2016

Latitude: 42.3378° N Longitude: 70.9558° W
Mean Flood Dir. 264° (T) Mean Ebb Dir. 112° (T)
Times and speeds of maximum and minimum current, in knots

January

	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1 F		01:12AM	1.1F	16 Sa ◐	03:18AM	07:24AM	-1.3E
	03:48AM	07:54AM	-1.0E		10:06AM	12:12PM	1.5F
	10:30AM	01:36PM	0.9F		03:36PM	07:42PM	-1.2E
	04:06PM	08:06PM	-0.9E		10:30PM		
	10:48PM						
2 Sa ◑		02:06AM	1.0F	17 Su		12:42AM	1.5F
	04:36AM	08:30AM	-1.0E		04:12AM	08:18AM	-1.3E
	11:24AM	02:36PM	0.9F		11:06AM	01:18PM	1.4F
	05:00PM	08:30PM	-0.8E		04:42PM	08:36PM	-1.2E
	11:42PM				11:30PM		
3 Su		03:00AM	0.9F	18 M		01:42AM	1.4F
	05:30AM	09:24AM	-0.9E		05:12AM	09:30AM	-1.3E
	12:18PM	03:30PM	0.9F		12:12PM	02:24PM	1.3F
	05:54PM	09:06PM	-0.8E		05:48PM	09:54PM	-1.1E
4 M	12:30AM	03:54AM	0.9F	19 Tu	12:30AM	02:42AM	1.4F
	06:24AM	10:42AM	-0.9E		06:12AM	10:54AM	-1.3E
	01:12PM	04:30PM	0.9F		01:18PM	03:42PM	1.3F
	06:48PM	10:18PM	-0.8E		06:48PM	11:12PM	-1.2E
5 Tu	01:18AM	04:48AM	0.9F	20 W	01:30AM	03:54AM	1.3F
	07:12AM	11:30AM	-1.0E		07:12AM	11:54AM	-1.5E
	02:00PM	05:18PM	0.9F		02:18PM	05:06PM	1.4F
	07:36PM	11:18PM	-0.9E		07:54PM		

February

	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1 M ◑		01:12AM	0.9F	16 Tu		01:18AM	1.4F
	04:48AM	08:24AM	-0.9E		04:48AM	09:18AM	-1.3E
	11:36AM	02:48PM	0.8F		11:54AM	02:18PM	1.3F
	05:18PM	08:18PM	-0.8E		05:30PM	09:36PM	-1.1E
	11:42PM						
2 Tu		01:54AM	0.9F	17 W	12:06AM	02:24PM	1.3F
	05:42AM	09:06AM	-0.9E		05:54AM	10:36AM	-1.3E
	12:30PM	03:48PM	0.8F		01:00PM	03:36PM	1.3F
	06:12PM	09:12PM	-0.8E		06:36PM	11:00PM	-1.1E
3 W	12:36AM	02:36AM	0.9F	18 Th	01:12AM	03:48AM	1.3F
	06:30AM	10:36AM	-0.9E		06:54AM	11:42AM	-1.4E
	01:24PM	04:48PM	0.9F		02:00PM	04:54PM	1.3F
	07:06PM	10:24PM	-0.9E		07:36PM		
4 Th	01:24AM	03:30AM	0.9F	19 F		12:00AM	-1.2E
	07:18AM	11:30AM	-1.0E		02:06AM	05:06AM	1.3F
	02:12PM	05:30PM	1.0F		07:54AM	12:36PM	-1.5E
	07:54PM	11:30PM	-1.0E		02:54PM	05:48PM	1.4F
					08:36PM		
5 F	02:18AM	04:24AM	1.0F	20 Sa		12:54AM	-1.3E
	08:06AM	12:12PM	-1.1E		03:06AM	06:00AM	1.4F
	03:00PM	06:00PM	1.0F		08:54AM	01:24PM	-1.5E
	08:42PM				03:48PM	06:36PM	1.5F
					09:36PM		

March

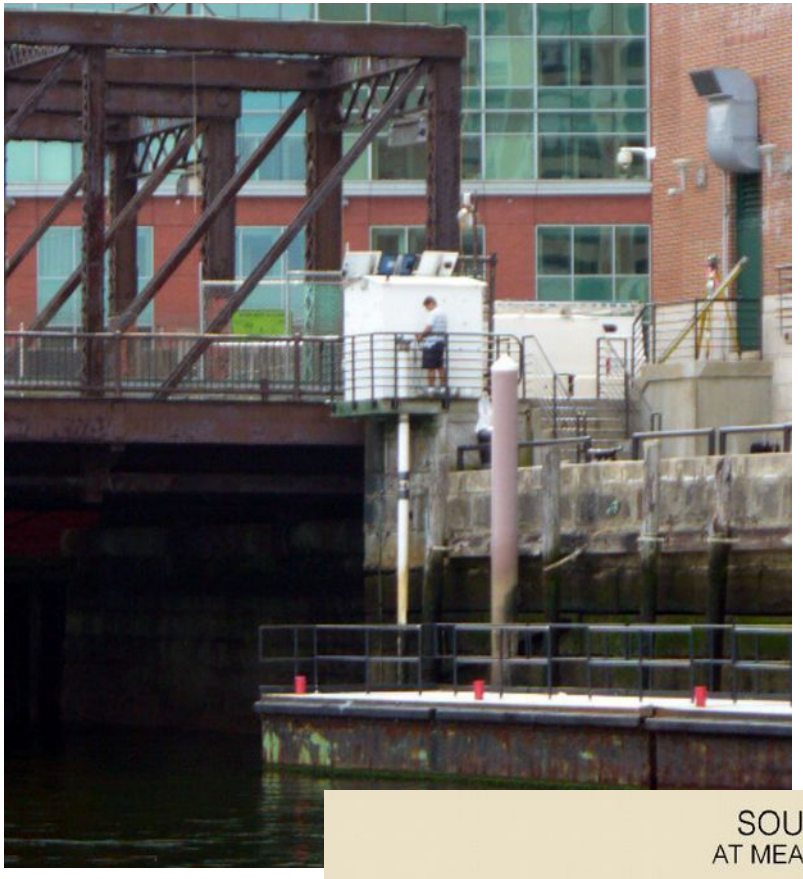
	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1 Tu ◑		12:18AM	1.0F	16 W		02:00AM	1.3F
	04:06AM	07:48AM	-1.0E		05:24AM	10:06AM	-1.3E
	11:00AM	01:06PM	0.8F		12:36PM	03:12PM	1.2F
	04:42PM	07:48PM	-0.9E		06:12PM	10:18PM	-1.0E
	11:00PM						
2 W		01:06AM	0.9F	17 Th	12:48AM	03:12AM	1.2F
	05:00AM	08:36AM	-0.9E		06:30AM	11:18AM	-1.3E
	11:54AM	02:00PM	0.8F		01:36PM	04:24PM	1.2F
	05:36PM	08:42PM	-0.9E		07:18PM	11:42PM	-1.1E
3 Th	12:00AM	02:00AM	0.9F	18 F	01:48AM	04:36AM	1.2F
	05:48AM	09:30AM	-0.9E		07:36AM	12:24PM	-1.4E
	12:48PM	02:48PM	0.9F		02:36PM	05:36PM	1.3F
	06:30PM	09:48PM	-0.9E		08:18PM		
4 F	12:54AM	02:48AM	0.9F	19 Sa		12:42AM	-1.2E
	06:42AM	10:48AM	-1.0E		02:48AM	05:54AM	1.2F
	01:36PM	03:54PM	0.9F		08:36AM	01:12PM	-1.4E
	07:24PM	11:00PM	-0.9E		03:36PM	06:30PM	1.4F
					09:18PM		
5 Sa	01:42AM	03:42AM	1.0F	20 Su		01:36AM	-1.2E
	07:30AM	11:42AM	-1.1E		03:48AM	06:48AM	1.3F
	02:24PM	05:06PM	1.1F		09:30AM	02:06PM	-1.4E
	08:12PM	11:54PM	-1.1E		04:24PM	07:18PM	1.4F
					10:12PM		

Current Predictions

January

	Slack	Maximum			Slack	Maximum	
	h m	h m	knots		h m	h m	knots
1		01:12AM	1.1F	**16**	03:18AM	07:24AM	-1.3E
	03:48AM	07:54AM	-1.0E		10:06AM	12:12PM	1.5F
F	10:30AM	01:36PM	0.9F	Sa	03:36PM	07:42PM	-1.2E
	04:06PM	08:06PM	-0.9E		10:30PM		
	10:48PM			◐			
2		02:06AM	1.0F	**17**		12:42AM	1.5F
	04:36AM	08:30AM	-1.0E		04:12AM	08:18AM	-1.3E
Sa	11:24AM	02:36PM	0.9F	Su	11:06AM	01:18PM	1.4F
	05:00PM	08:30PM	-0.8E		04:42PM	08:36PM	-1.2E
◑	11:42PM				11:30PM		
3		03:00AM	0.9F	**18**		01:42AM	1.4F
	05:30AM	09:24AM	-0.9E		05:12AM	09:30AM	-1.3E
Su	12:18PM	03:30PM	0.9F	M	12:12PM	02:24PM	1.3F
	05:54PM	09:06PM	-0.8E		05:48PM	09:54PM	-1.1E

Tide Stations



SOUNDINGS IN FEET
AT MEAN LOWER LOW WATER

Additional information can be obtained at nauticalcharts.noaa.gov.

TIDAL INFORMATION

PLACE		Height referred to datum of soundings (MLLW)		
NAME	(LAT/LONG)	Mean Higher High Water	Mean High Water	Mean Low Water
		feet	feet	feet
Boston Light	(42°19'N/70°53'W)	9.8	9.4	0.3
Charlestown Bridge	(42°22'N/71°04'W)	10.2	9.8	0.3
Weymouth Fore River Bridge	(42°15'N/70°58'W)	10.2	9.8	0.3
Cohasset Harbor	(42°15'N/70°47'W)	9.5	9.1	0.3

Dashes (- - -) located in datum columns indicate unavailable datum values for a tide station. Real-time water levels, tide predictions, and tidal current predictions are available on the Internet from http://tidesandcurrents.noaa.gov.

(Jan 2011)

Taking a Fix

A “fix” is a determination of a position at a particular time.

How do you take a fix?

Taking a Fix

A “fix” is a determination of a position at a particular time.

How do you take a fix?

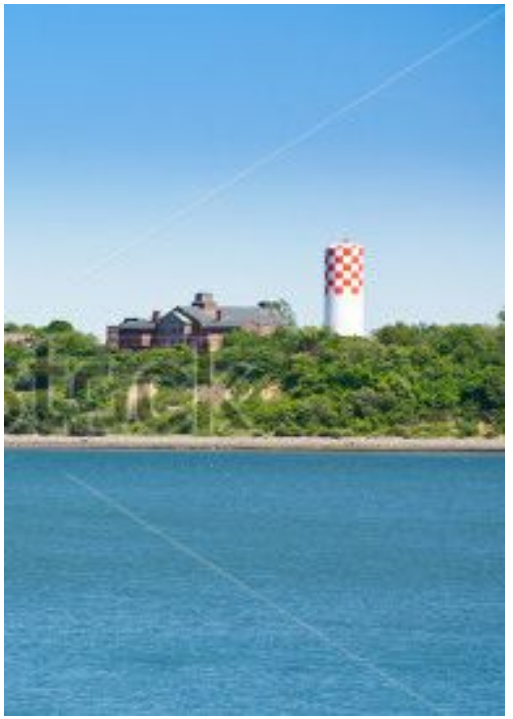
Taking a Fix

- Determining distance at sea is difficult
- Determining angles is easier

Taking a Fix

Using compass bearings to take a fix:

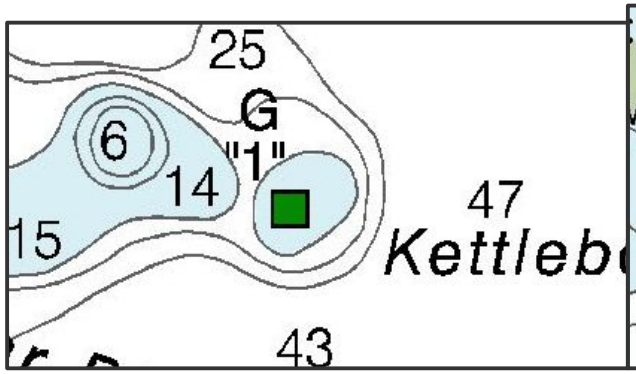
- Find three good targets to take bearings on:
  - Beacons and objects on land are better than buoys
  - Targets that are separated by large angles are better
  - Close targets are better than distant targets

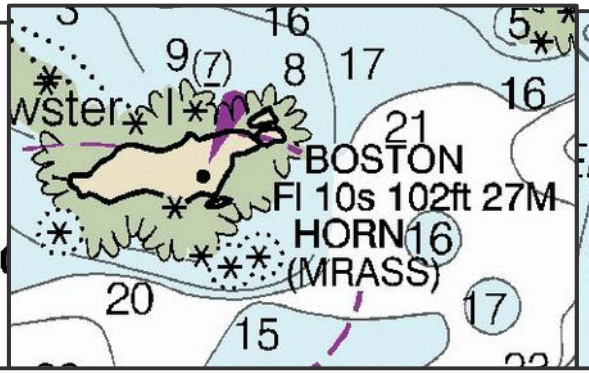


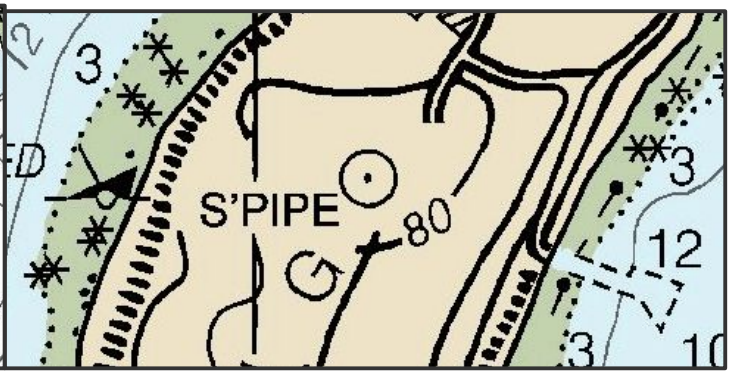
Taking a Fix

Using compass bearings to take a fix:

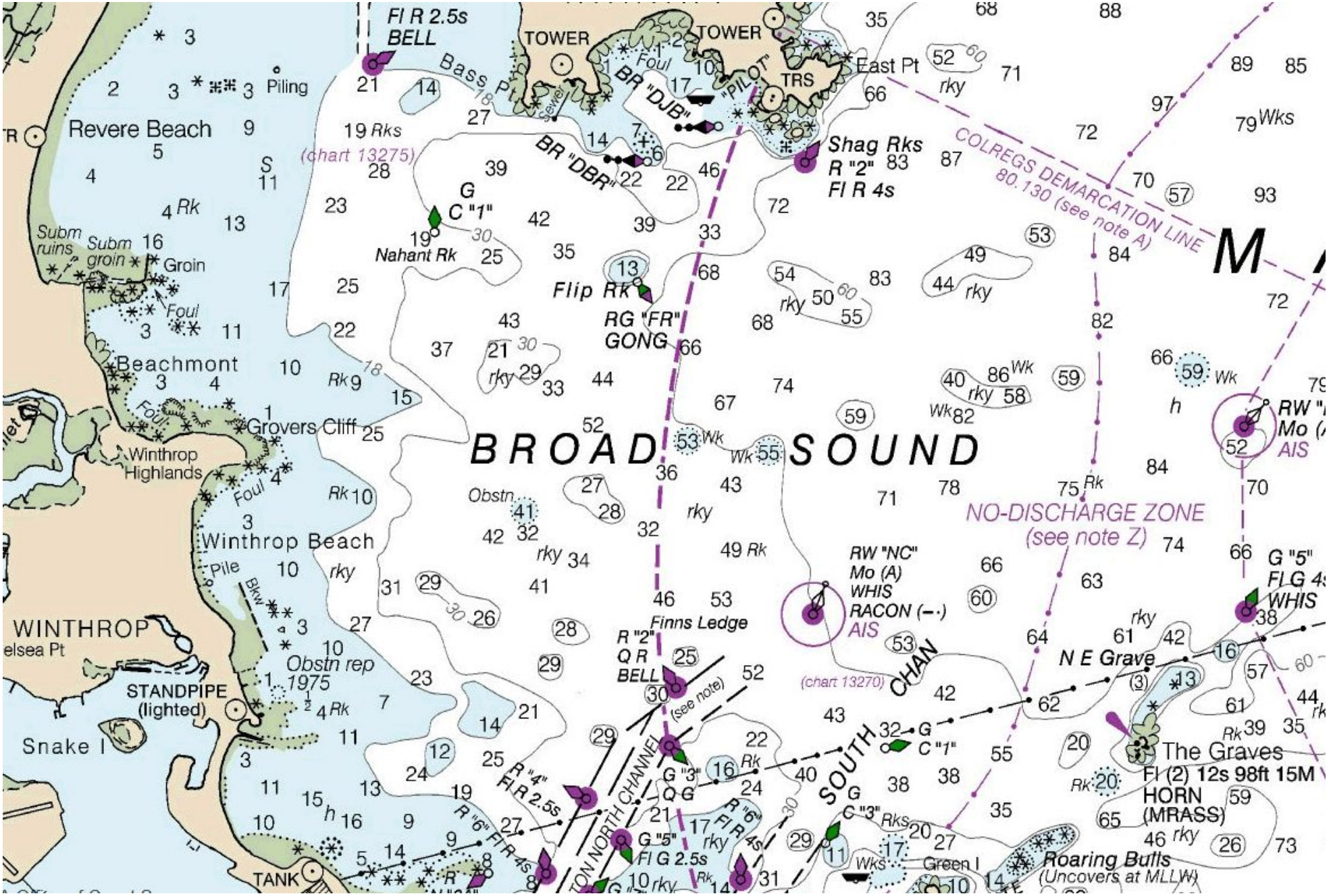
- Locate the targets on your chart.



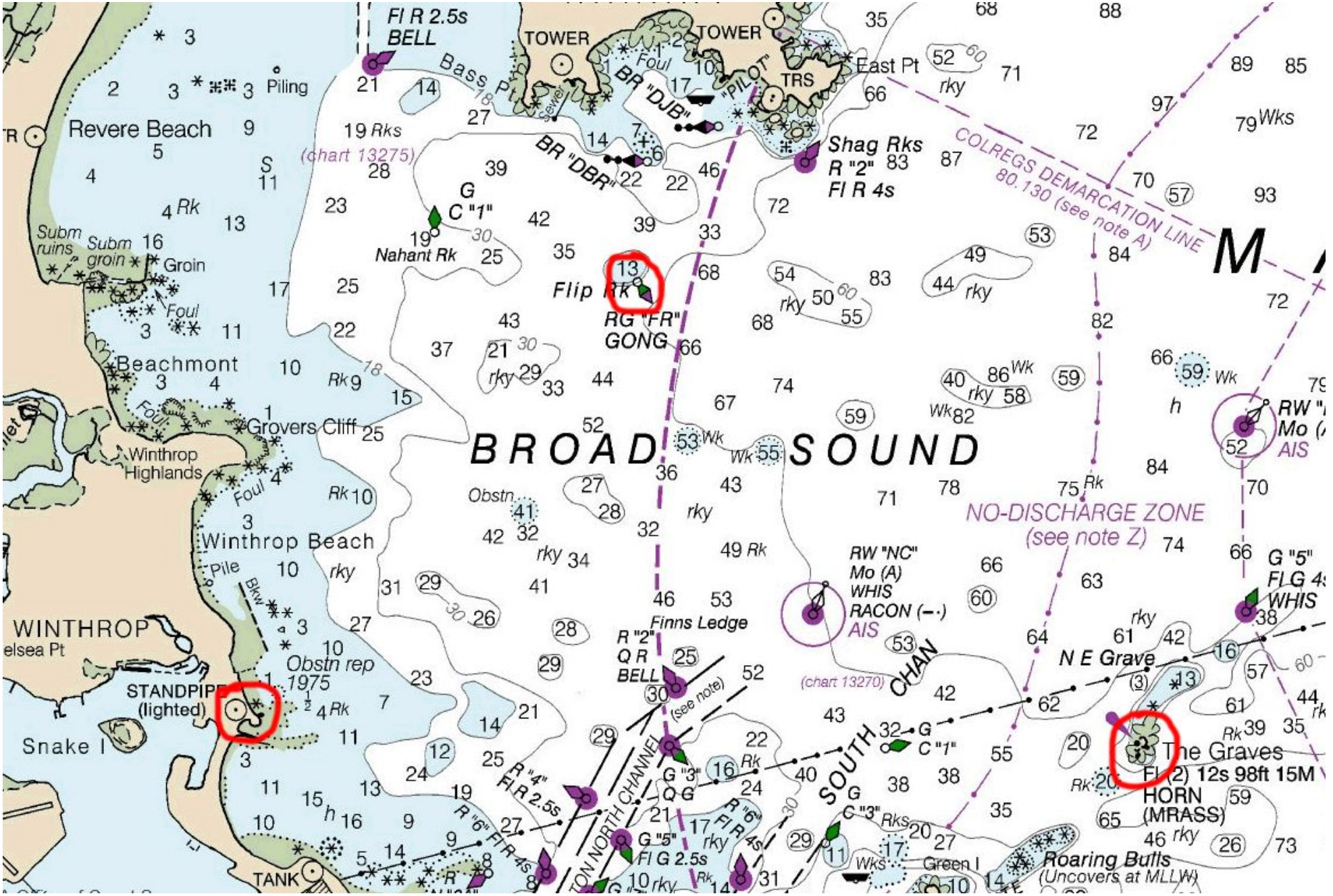




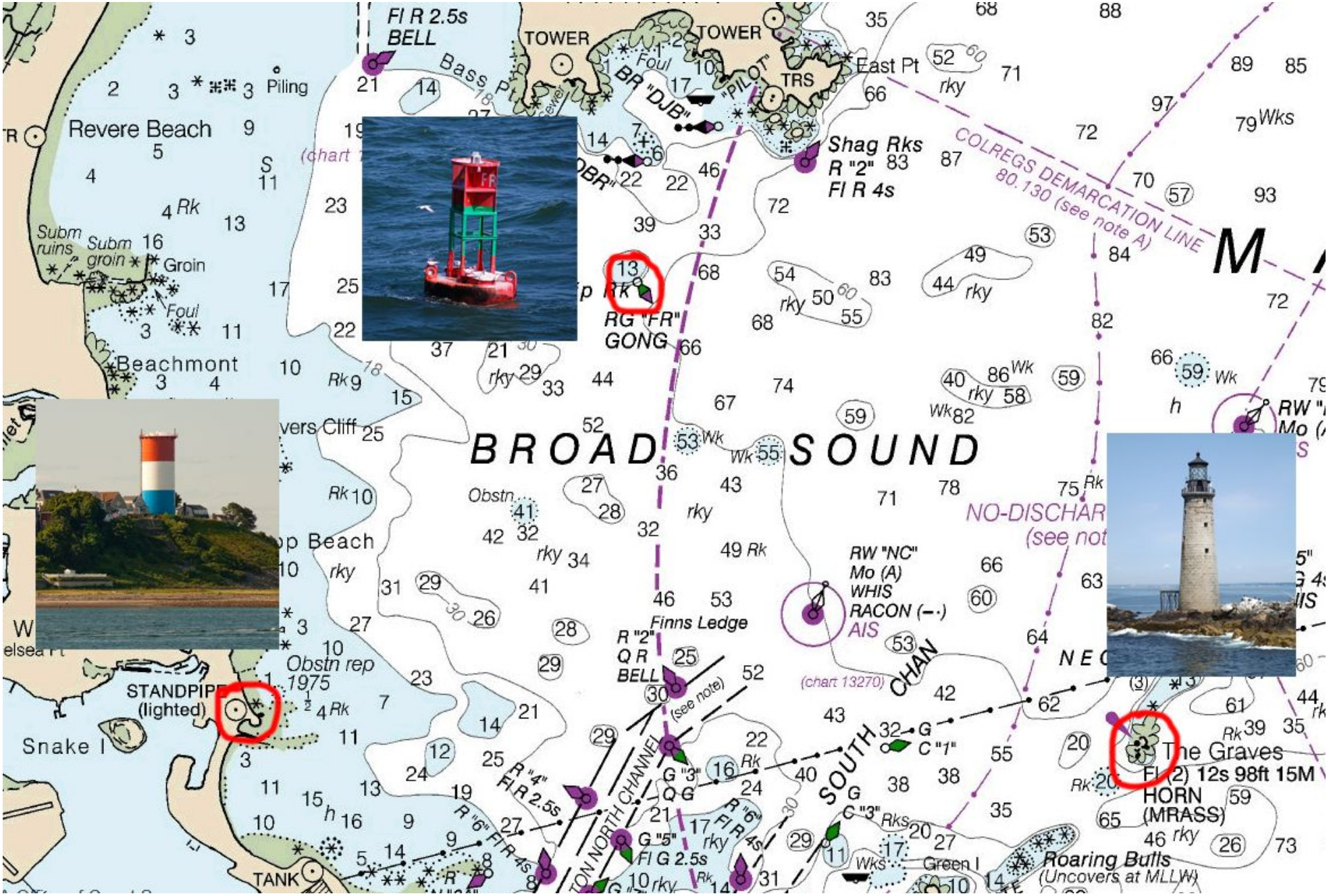
Taking a Fix


Fl R 2.5s
BELL
TOWER
TOWER
Foul
Bass Pt
BR "DJB"
"PILOT"
TRS
East Pt
Piling
Revere Beach
(chart 13275)
BR "DBR"
Shag Rks
R "2"
Fl R 4s
COLREGS DEMARCATION LINE
80.130 (see note A)
G
C "1"
Nahant Rk
Subm ruins
Subm groin
Groin
Foul
Flip Rk
RG "FR"
GONG
Beachmont
Grovers Cliff
Winthrop Highlands
Foul
BROAD SOUND
Obstn
Winthrop Beach
Pile
Bkw
Obstn rep
1975
WINTHROP
elsea Pt
STANDPIPE
(lighted)
Snake I
TANK
NO-DISCHARGE ZONE
(see note Z)
RW "NC"
Mo (A)
WHIS
RACON (–·)
AIS
Finns Ledge
R "2"
Q R
BELL
(see note)
(chart 13270)
CHAN
SOUTH
N E Grave
The Graves
Fl (2) 12s 98ft 15M
HORN
(MRASS)
G "5"
Fl G 4s
WHIS
R "4"
Fl R 2.5s
G "3"
Q G
R "6"
Fl R 4s
G "5"
Fl G 2.5s
TON NORTH CHANNEL
G
C "3"
Green I
Roaring Bulls
(Uncovers at MLLW)

Taking a Fix


Fl R 2.5s
BELL
TOWER
TOWER
Foul
BR "DJB"
"PILOT"
TRS
East Pt
Bass Pt
Piling
Revere Beach
(chart 13275)
BR "DBR"
Shag Rks
R "2"
Fl R 4s
COLREGS DEMARCATION LINE
80.130 (see note A)
G
C "1"
Nahant Rk
Flip Rk
RG "FR"
GONG
Subm ruins
Subm groin
Groin
Foul
Beachmont
Grovers Cliff
Winthrop Highlands
Winthrop Beach
Pile
Obstn rep
1975
STANDPIPE
(lighted)
WINTHROP
elsea Pt
Snake I
TANK
BROAD SOUND
Obstn
Finns Ledge
R "2"
Q R
BELL
(see note)
RW "NC"
Mo (A)
WHIS
RACON (–·)
AIS
NO-DISCHARGE ZONE
(see note Z)
(chart 13270)
SOUTH CHAN
N E Grave
The Graves
Fl (2) 12s 98ft 15M
HORN
(MRASS)
G "5"
Fl G 2.5s
G "3"
Q G
R "4"
Fl R 2.5s
R "6"
Fl R 4s
TON NORTH CHANNEL
C "3"
Green I
Roaring Bulls
(Uncovers at MLLW)
rky
Wk
Rk
Wks

Taking a Fix


Fl R 2.5s
BELL
TOWER
TOWER
Foul
BR "DJB"
"PILOT"
TRS
East Pt
Bass Pt
Piling
Revere Beach
Shag Rks
R "2"
Fl R 4s
COLREGS DEMARCATION LINE
80.130 (see note A)
Subm ruins
Subm groin
Groin
Foul
RG "FR"
GONG
Beachmont
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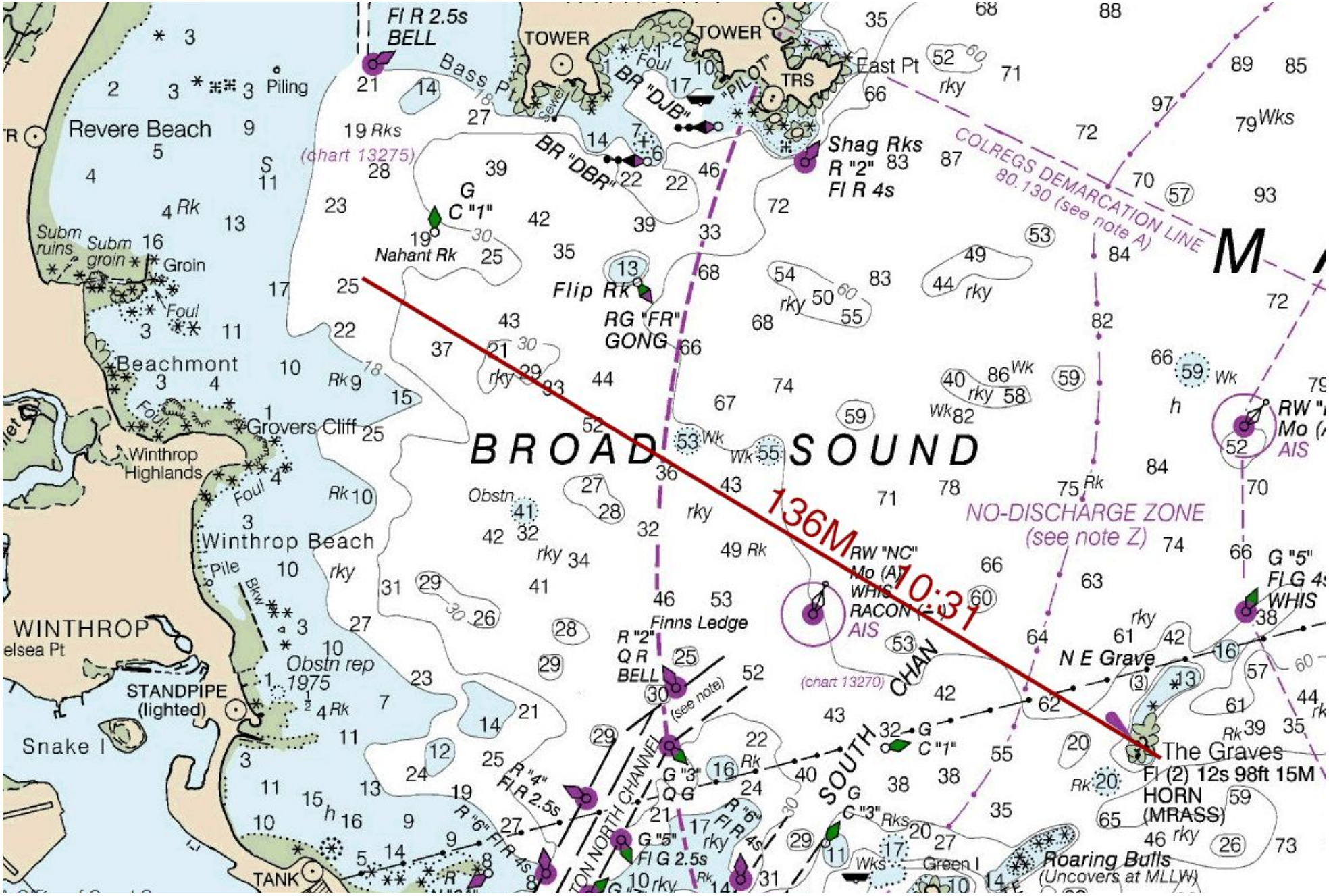
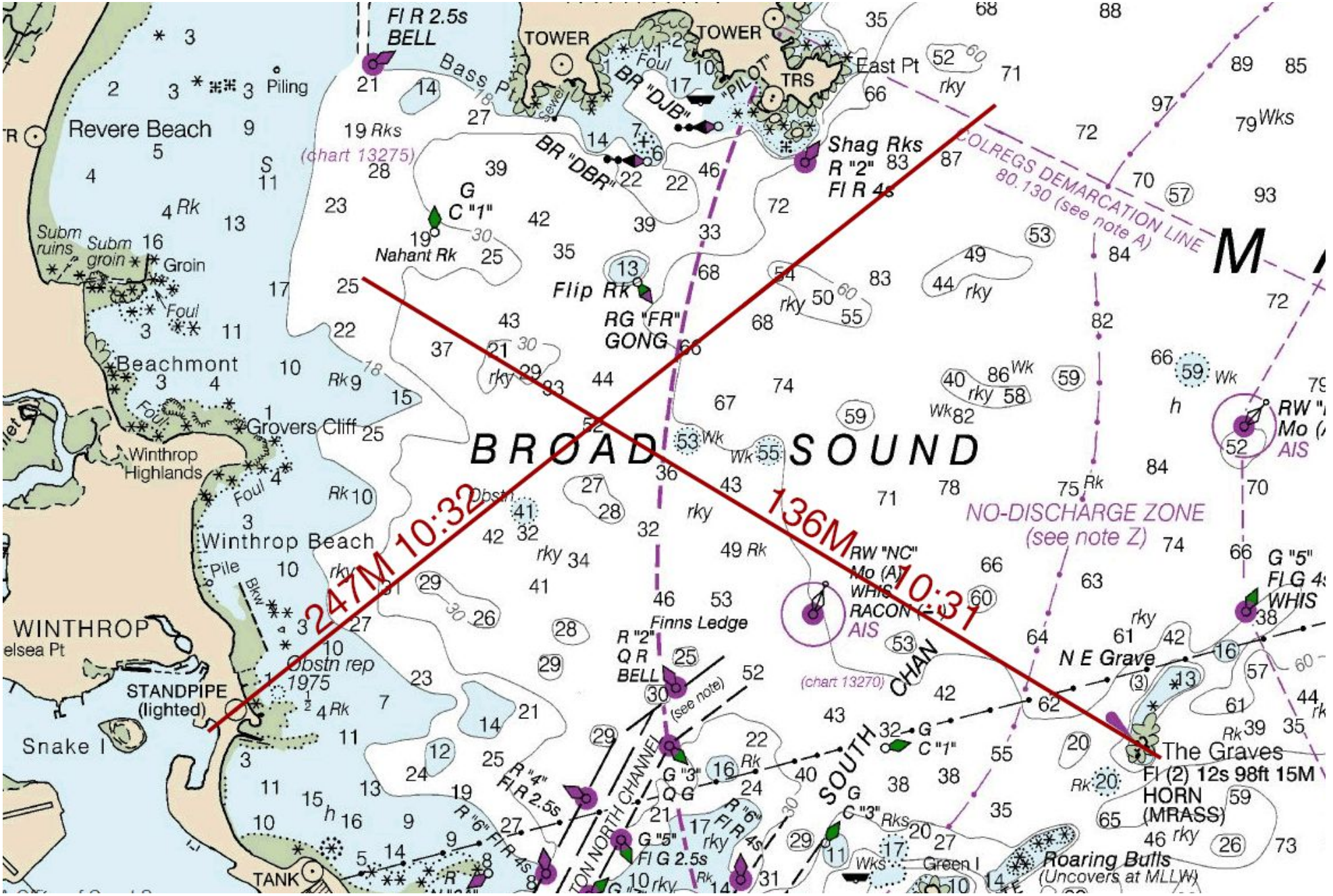
Finns Ledge
R "2"
Q R
BELL
RW "NC"
Mo (A)
WHIS
RACON (–·)
AIS
(chart 13270)
SOUTH CHAN
NO-DISCHAR
(see not
STANDPIPE
(lighted)
Obstn rep
1975
Snake I
TANK
R "4"
Fl R 2.5s
G "3"
Q G
G "5"
Fl G 2.5s
R "6"
Fl R 4s
G "1"
C "3"
Rks
The Graves
Fl (2) 12s 98ft 15M
HORN
(MRASS)
Roaring Bulls
(Uncovers at MLLW)
Green I
Wks
rky

Taking a Fix


BROAD SOUND
136M
10:31
Fl R 2.5s
BELL
TOWER
TOWER
Foul
BR "DJB"
"PILOT"
TRS
East Pt
Bass Pt
Revere Beach
Piling
(chart 13275)
BR "DBR"
Shag Rks
R "2"
Fl R 4s
COLREGS DEMARCATION LINE
80.130 (see note A)
G
C "1"
Nahant Rk
Subm ruins
Subm groin
Groin
Flip Rk
RG "FR"
GONG
Beachmont
Grovers Cliff
Winthrop Highlands
Winthrop Beach
Obstn
NO-DISCHARGE ZONE
(see note Z)
RW "NC"
Mo (A)
WHIS
RACON (
AIS
Finns Ledge
R "2"
Q R
BELL
(see note)
(chart 13270)
CHAN
N E Grave
G "5"
Fl G 4s
WHIS
WINTHROP
elsea Pt
Obstn rep
1975
STANDPIPE
(lighted)
Snake I
TANK
R "4"
Fl R 2.5s
G "3"
Q G
R "6"
Fl R 4s
G "5"
Fl G 2.5s
TON NORTH CHANNEL
SOUTH
G
C "1"
G
C "3"
The Graves
Fl (2) 12s 98ft 15M
HORN
(MRASS)
Roaring Bulls
(Uncovers at MLLW)
Green I

Taking a Fix


BROAD SOUND
247M 10:32
136M 10:31
Fl R 2.5s
BELL
TOWER
TOWER
Foul
BR "DJB"
"PILOT"
TRS
East Pt
Bass Pt
Piling
Revere Beach
(chart 13275)
BR "DBR"
Shag Rks
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COLREGS DEMARCATION LINE
80.130 (see note A)
G
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Beachmont
Grovers Cliff
Winthrop Highlands
Winthrop Beach
Pile
Obstn rep 1975
STANDPIPE
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WINTHROP
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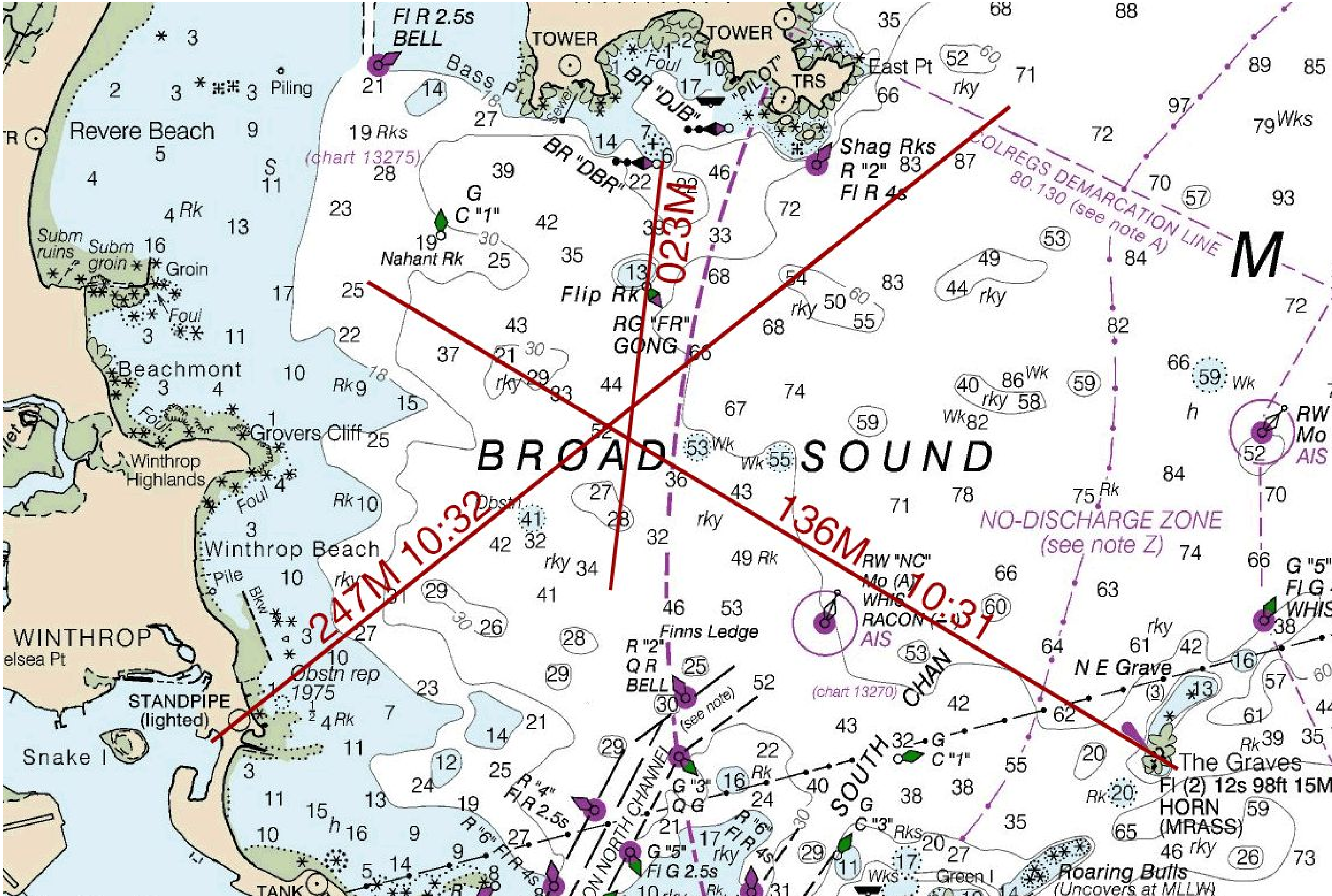
Snake I
TANK
Finns Ledge
R "2"
Q R
BELL
(see note)
RW "NC"
Mo (A)
WHIS
RACON
AIS
(chart 13270)
SOUTH CHAN
NORTH CHANNEL
R "4"
Fl R 2.5s
G "3"
Q G
R "6"
Fl R 4s
G "5"
Fl G 2.5s
G "1"
C "3"
Rks
Green I
Roaring Bulls
(Uncovers at MLLW)
N E Grave
The Graves
Fl (2) 12s 98ft 15M
HORN
(MRASS)
NO-DISCHARGE ZONE
(see note Z)
G "5"
Fl G 4s
WHIS
RW "
Mo (A
AIS

Taking a Fix



023M
247M 10:32
136M 10:31
BROAD SOUND
Fl R 2.5s
BELL
TOWER
TOWER
Bass Pt
BR "DJB"
BR "DBR"
"PILOT"
TRS
East Pt
Shag Rks
R "2"
Fl R 4s
COLREGS DEMARCATION LINE
80.130 (see note A)
Revere Beach
(chart 13275)
G
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WINTHROP
STANDPIPE
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Snake I
Obstn rep
1975
NO-DISCHARGE ZONE
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RW "NC"
Mo (A)
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R "2"
Q R
BELL
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N E Grave
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Fl (2) 12s 98ft 15M
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G "5"
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Roaring Bulls
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Green I
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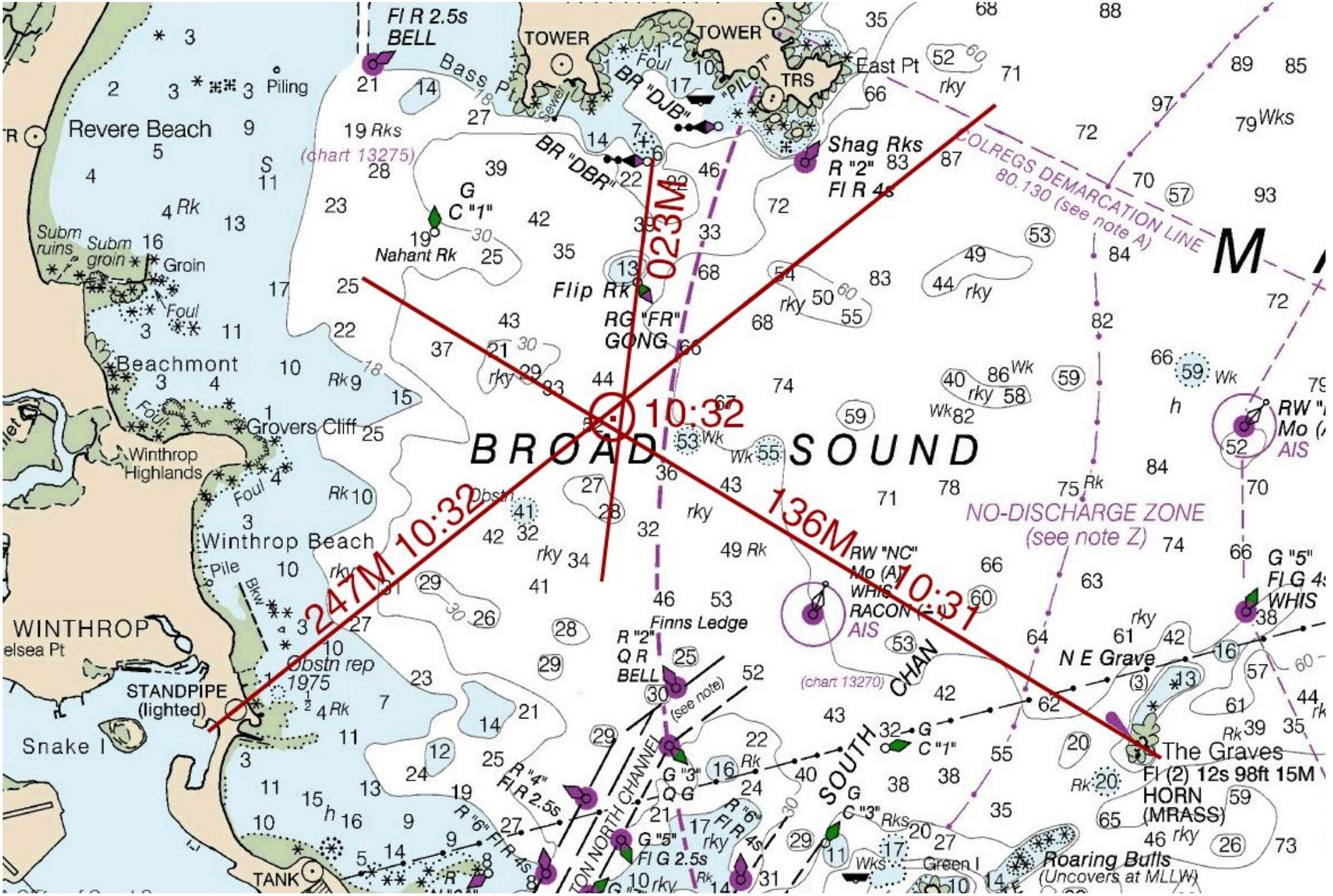
Taking a Fix


Fl R 2.5s
BELL
TOWER
TOWER
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BR "DJB"
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023M
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Winthrop Highlands
10:32
BROAD SOUND
247M 10:32
136M 10:31
NO-DISCHARGE ZONE
(see note Z)
Winthrop Beach
Pile
Obstn
RW "NC"
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WHIS
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G
C "3"
The Graves
Fl (2) 12s 98ft 15M
HORN
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Green I
Roaring Bulls
(Uncovers at MLLW)
TANK

Taking a Fix

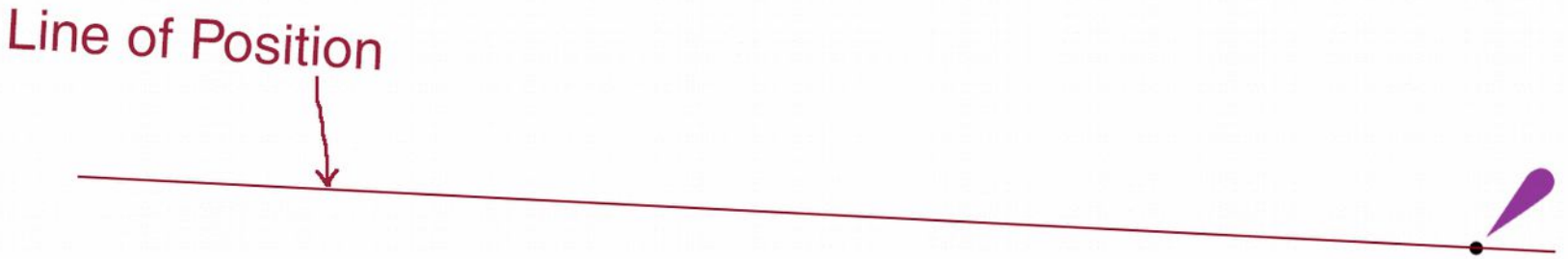
Beacons and objects on land are better than buoys

- Buoys are not in an exact position
- Buoys can be off-station

Taking a Fix

Closer targets are better than farther targets

- Error in position will be proportional to angle measurement error times the distance to the target.



Taking a Fix

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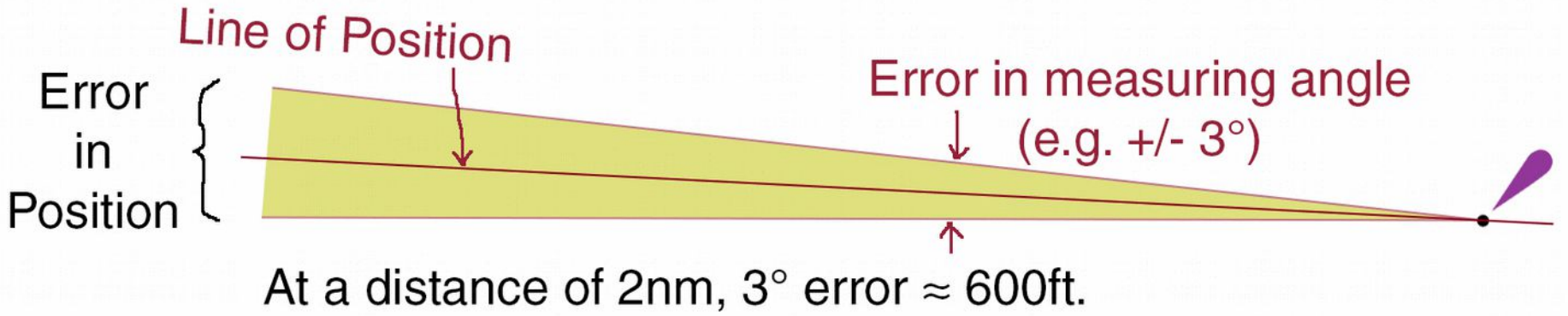

Taking a Fix

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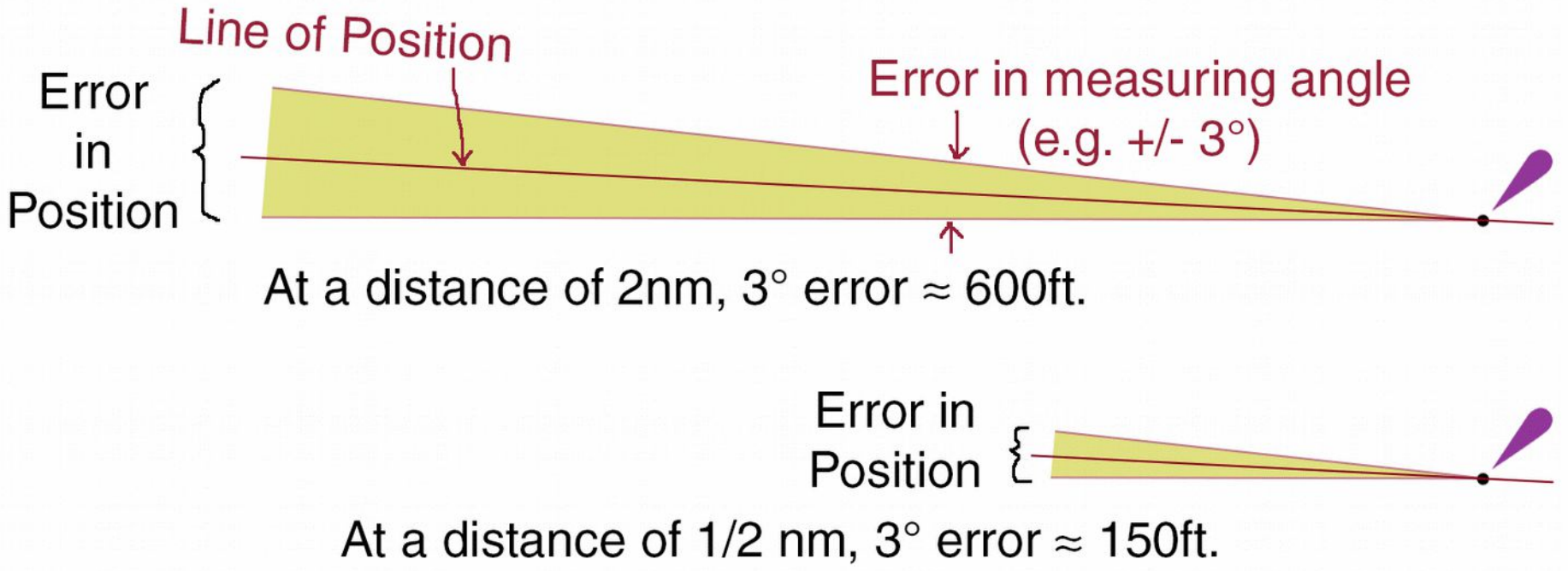
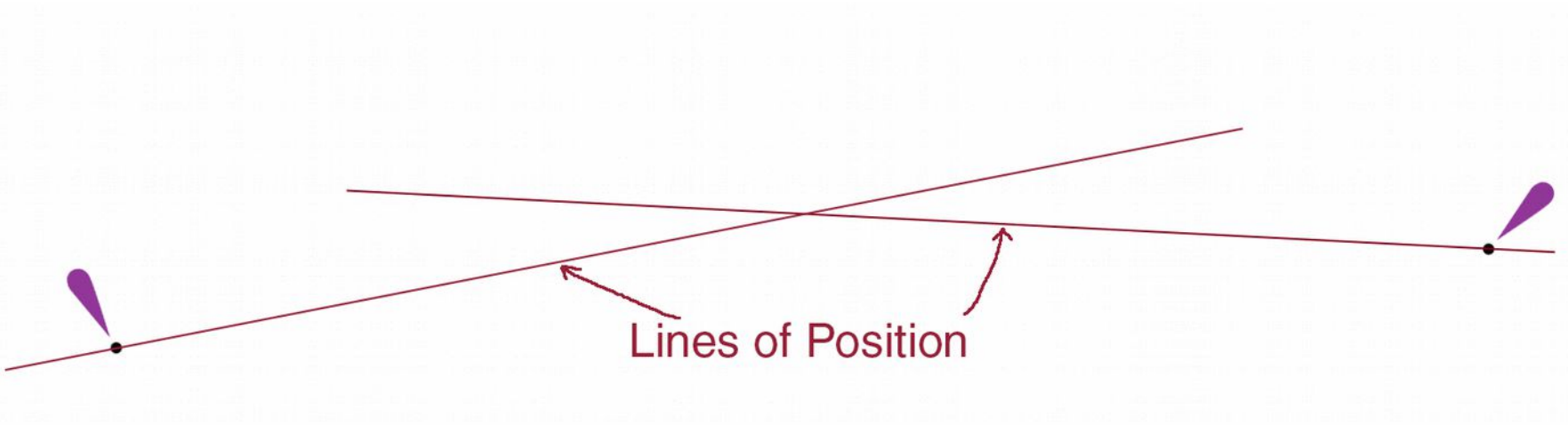


Taking a Fix

Lines of Position should be at wide angles to each other

- LOP's at smaller angles cause greater error
- Optimal angle for two LOP's is 90°
- Optimal angles for three LOP's is 120°



Taking a Fix

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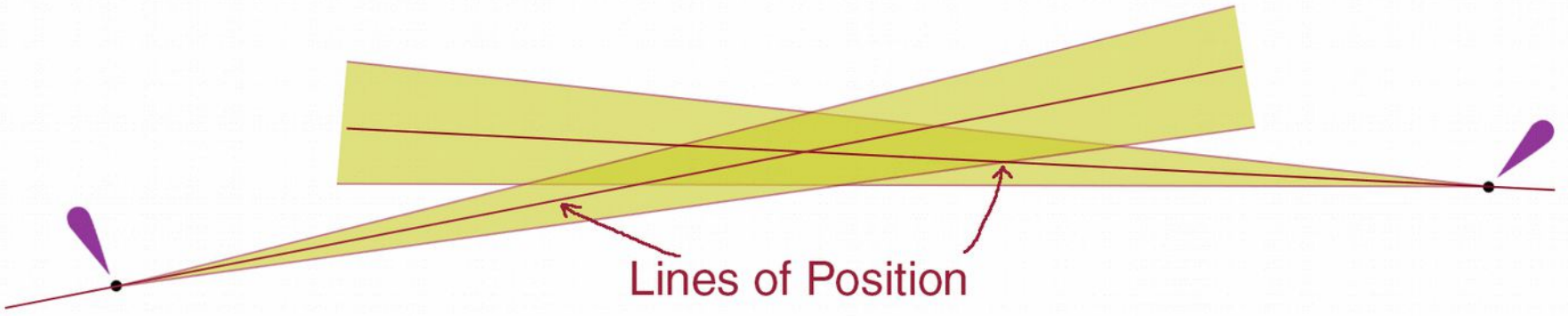

Taking a Fix

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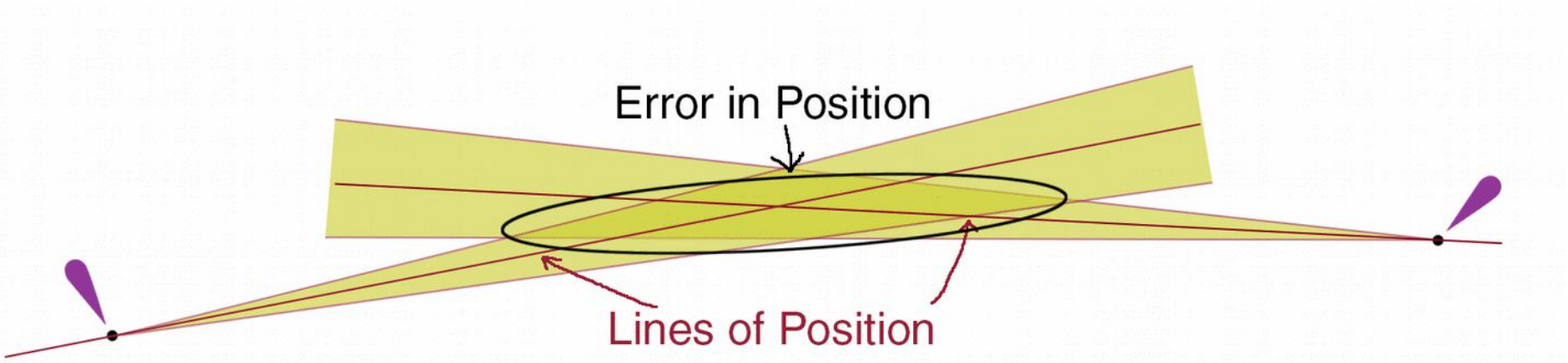
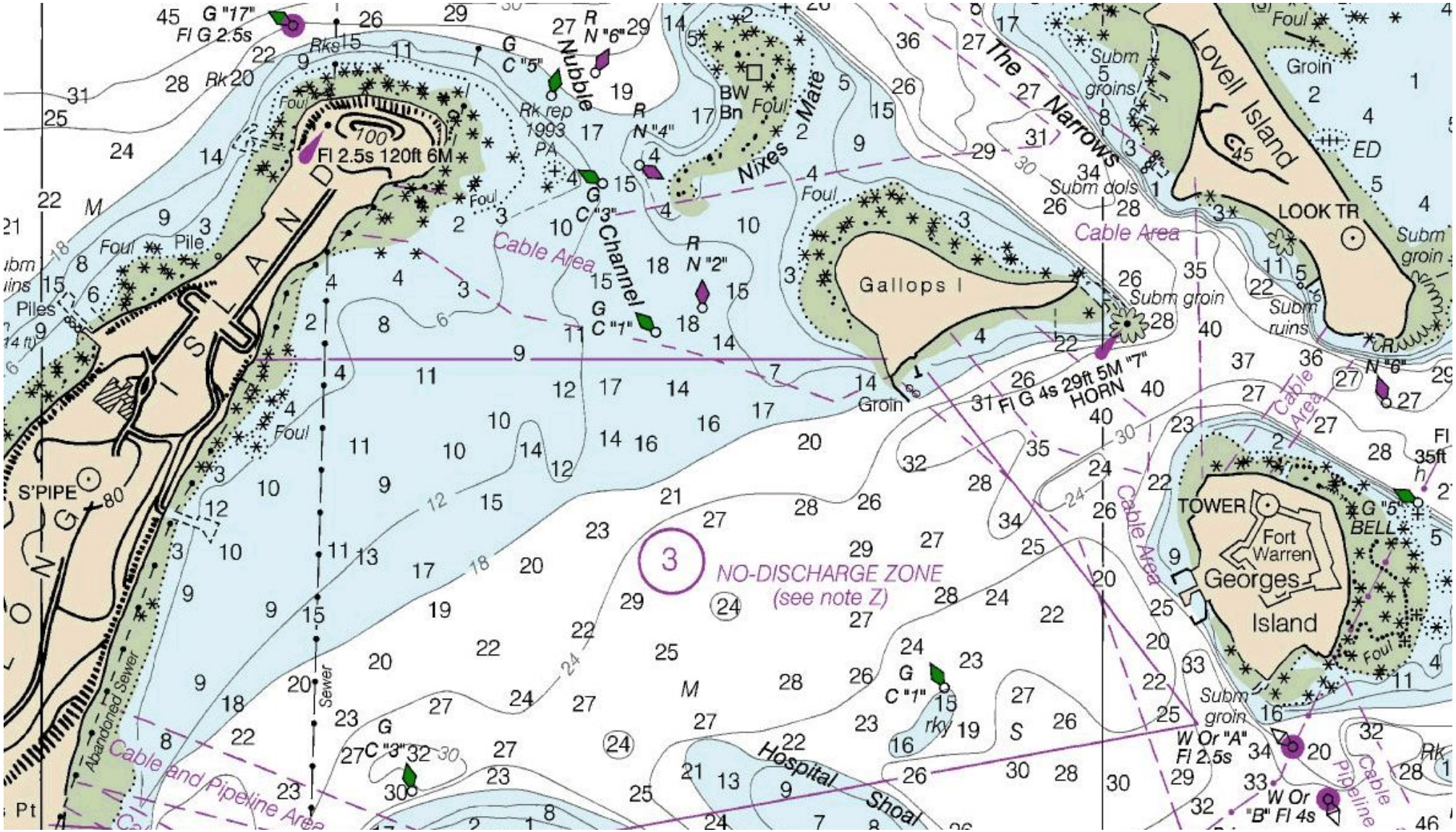


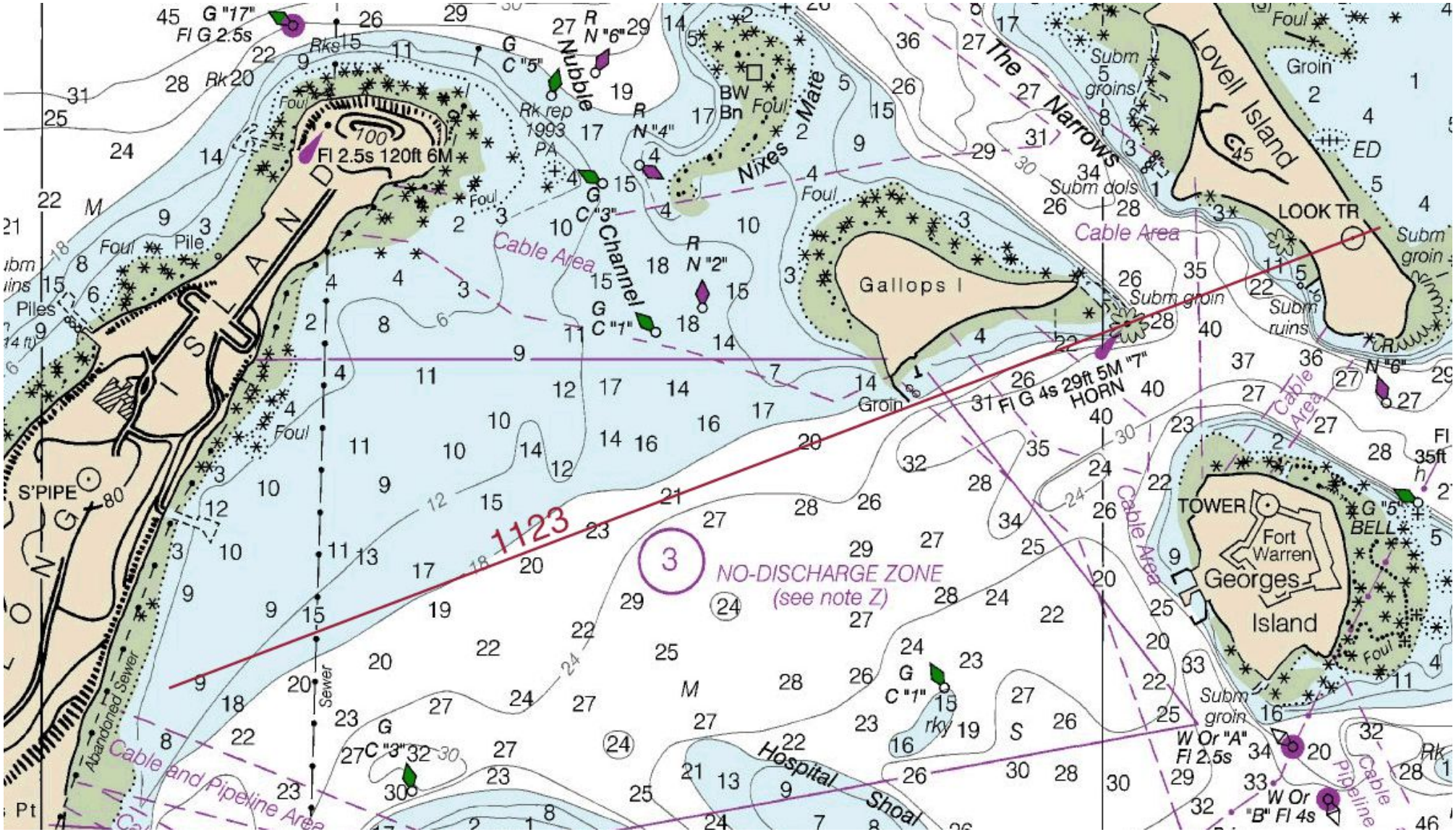
Taking a Fix

Using a Range as a Line of Position



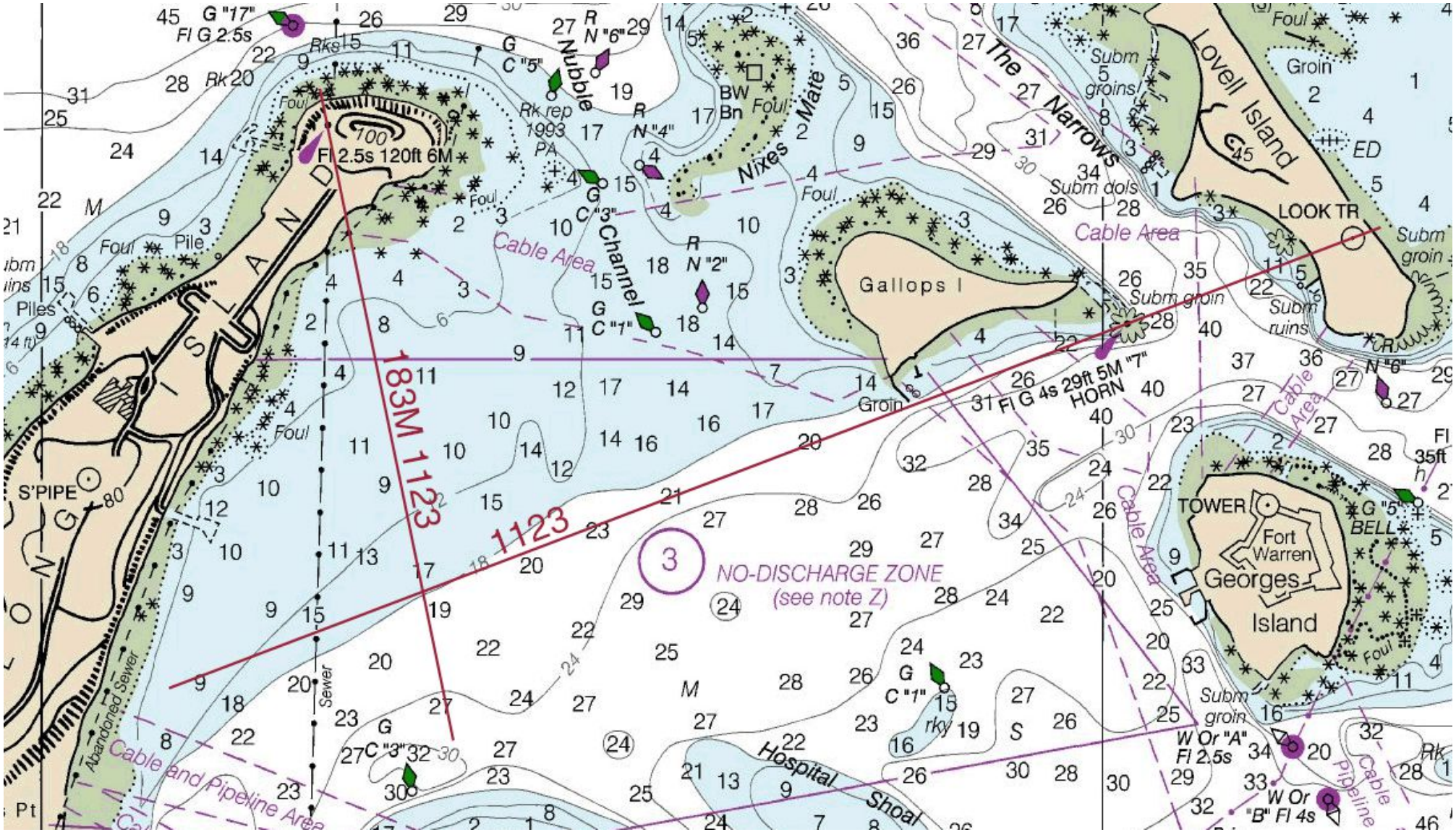
Taking a Fix

Using a Range as a Line of Position



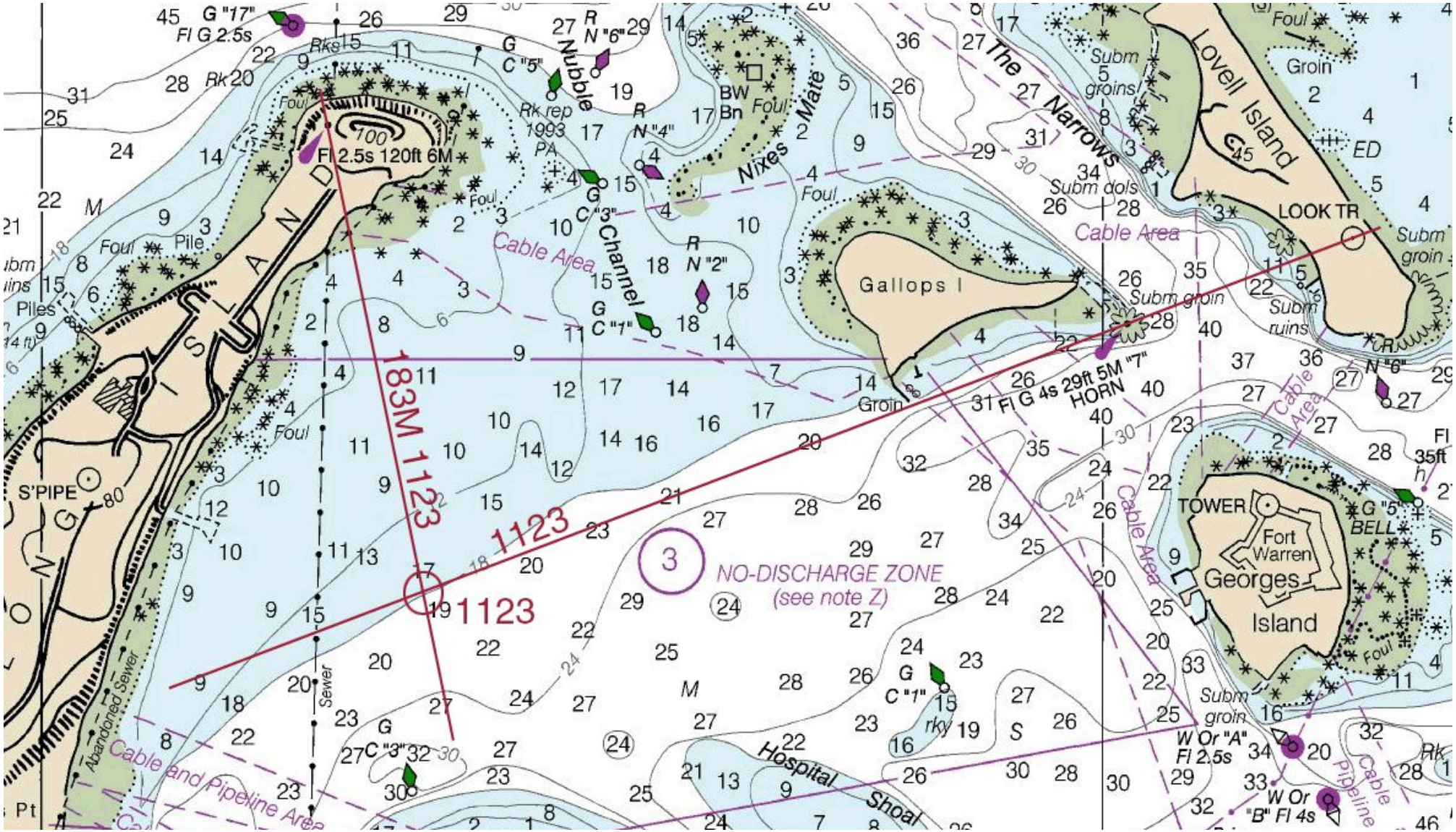
Taking a Fix

Using a Range as a Line of Position



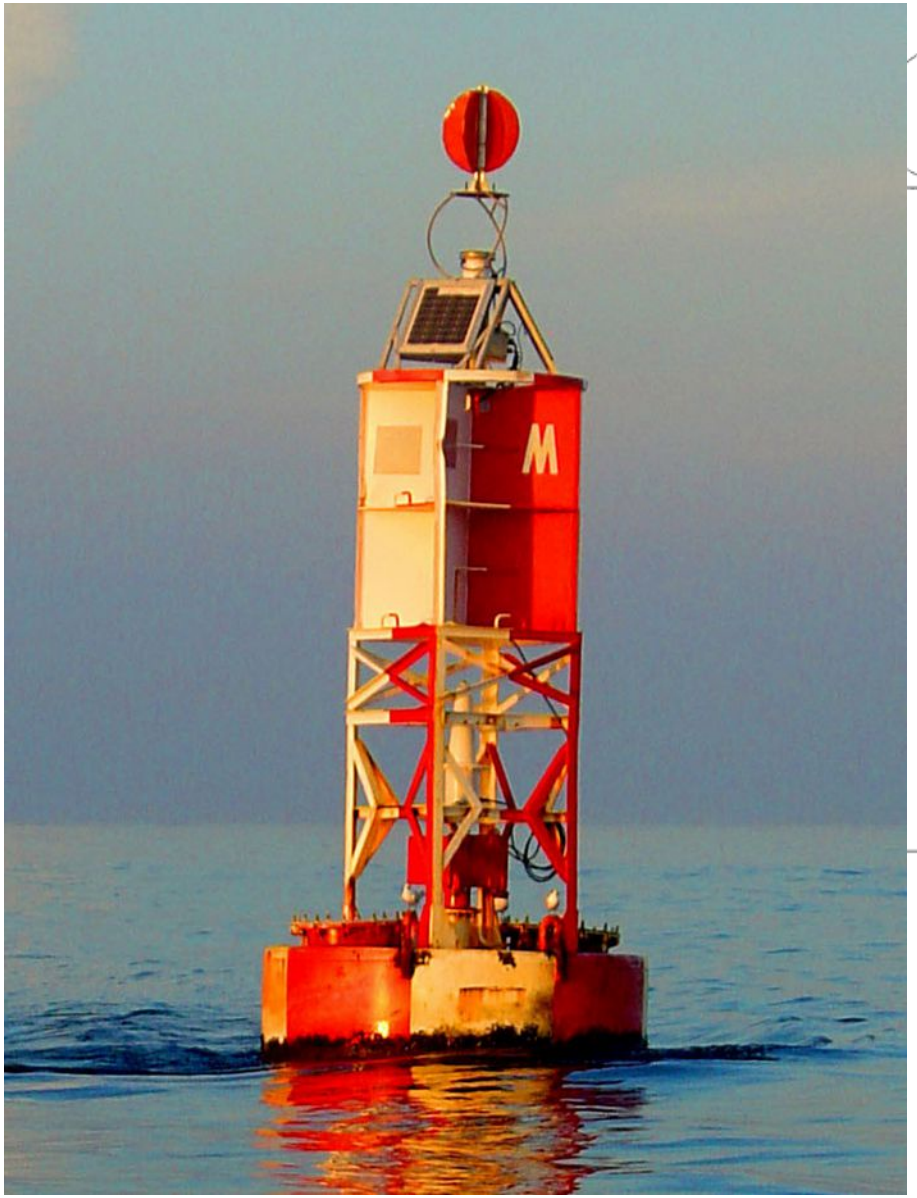
Taking a Fix

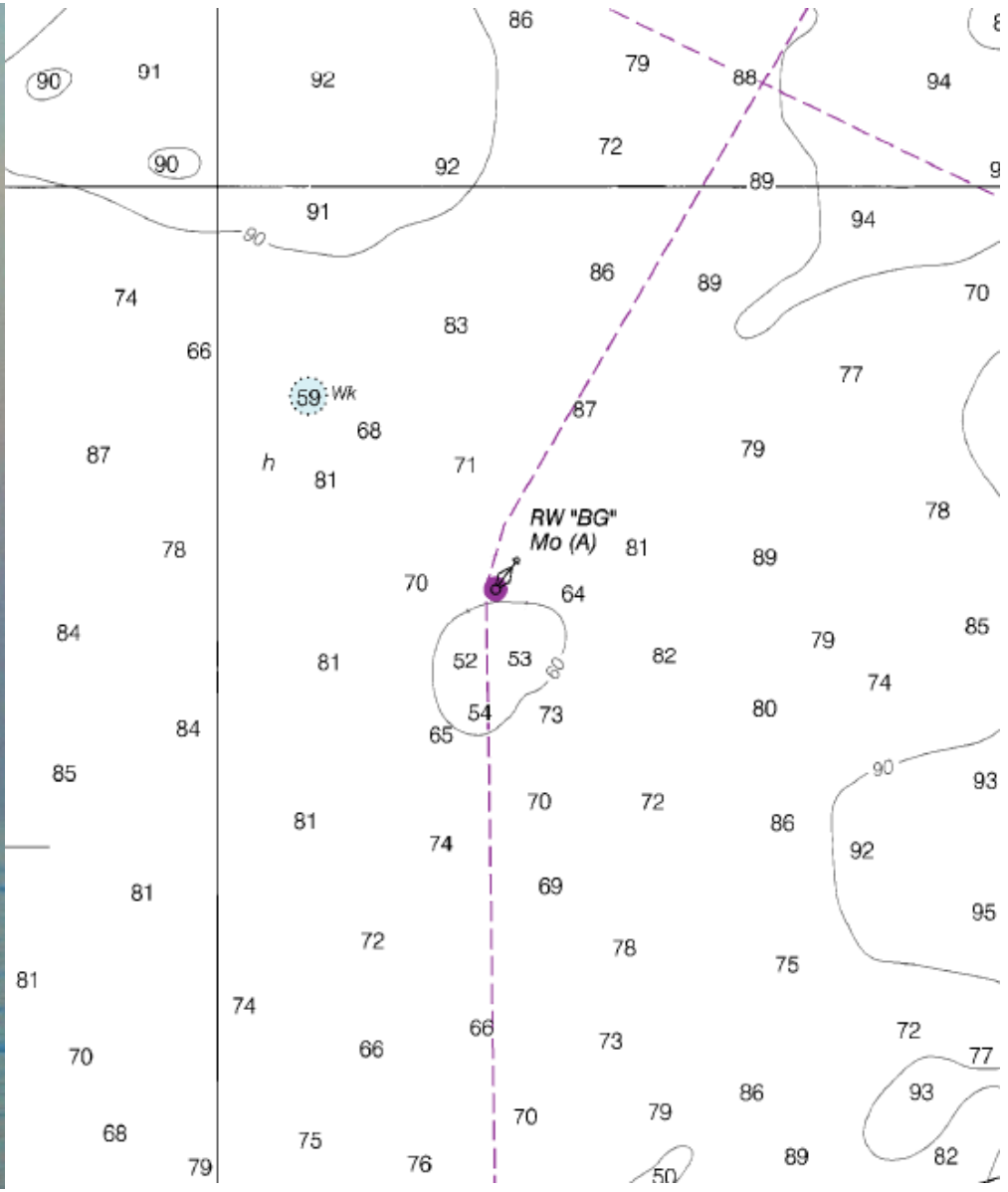
Using a Range as a Line of Position



Taking a Fix

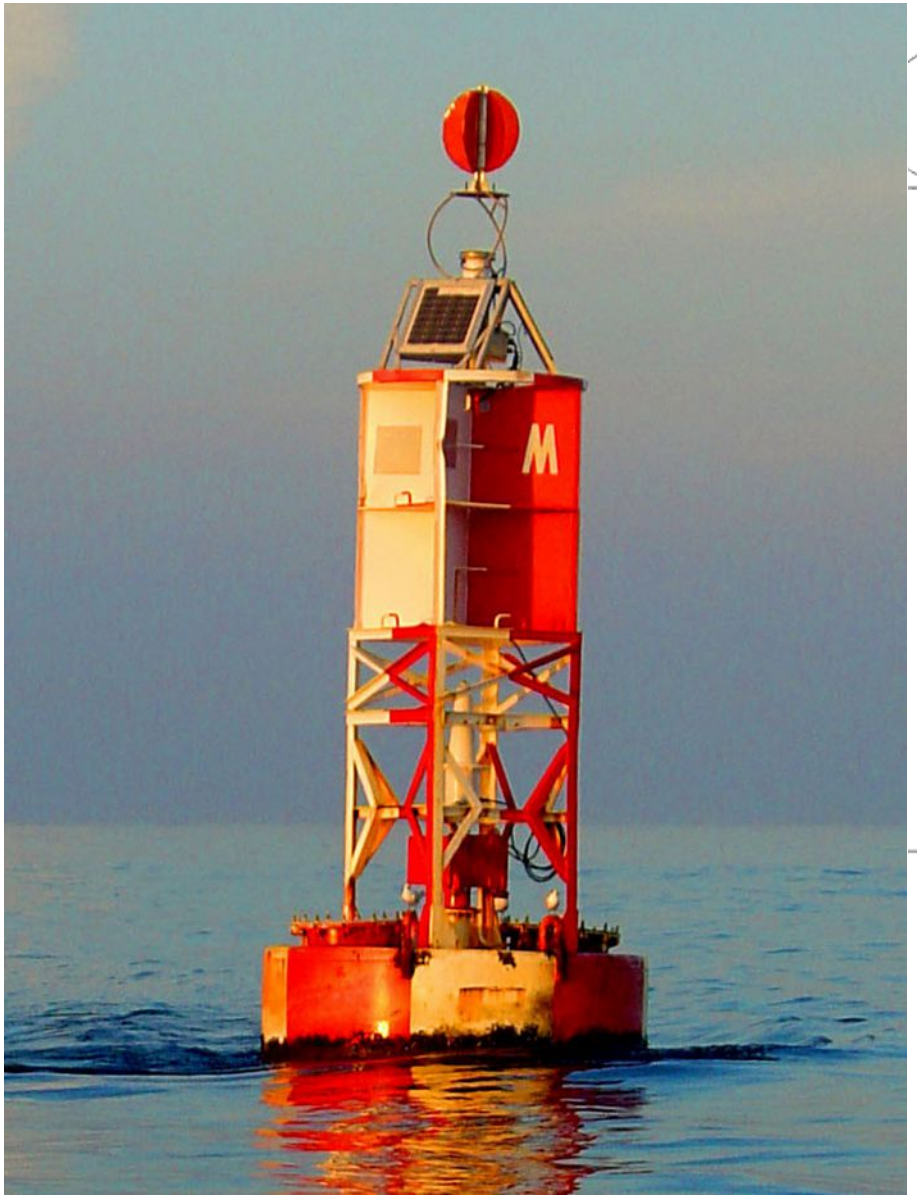
Very close to a navigational aid or landmark.

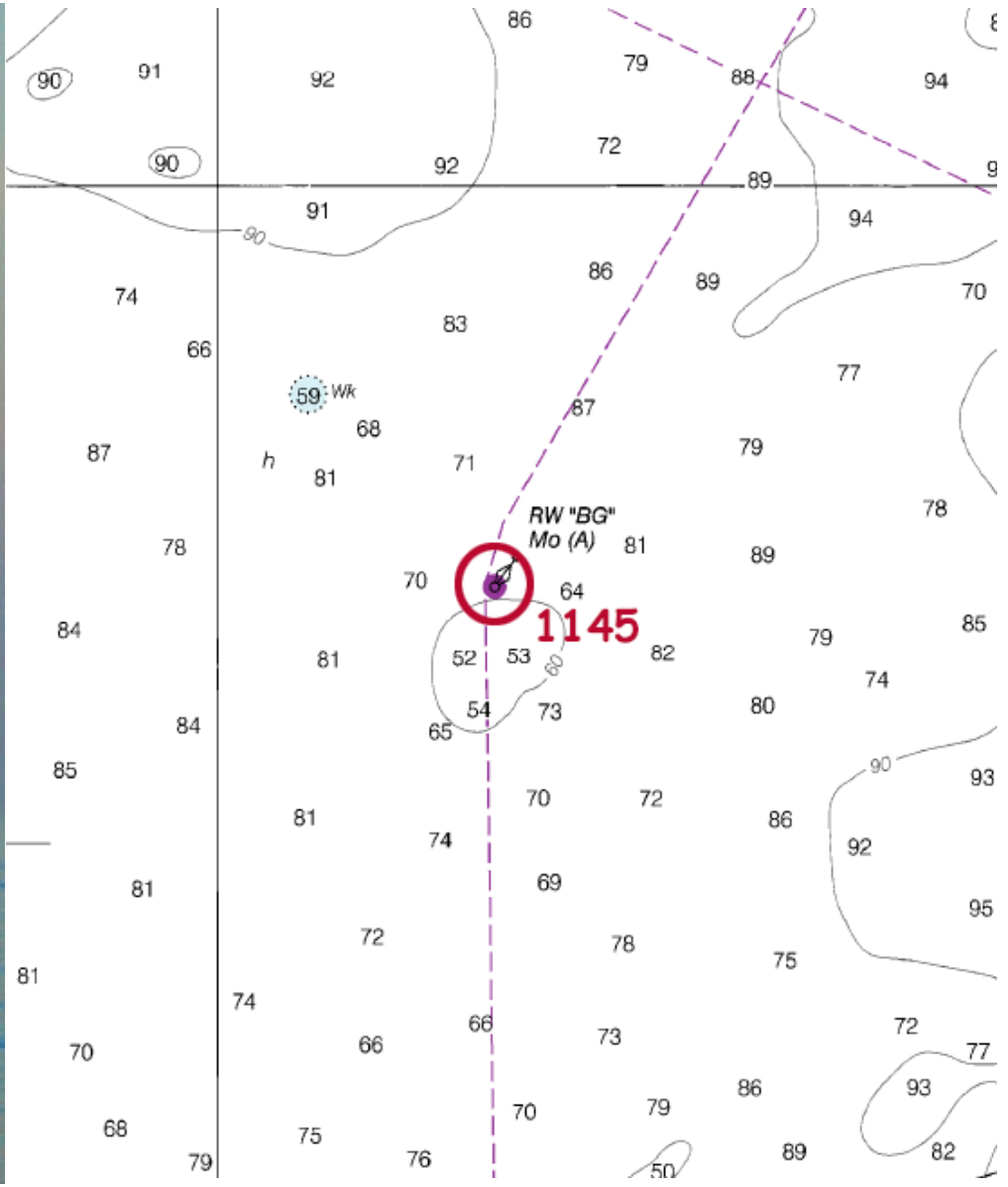




Taking a Fix

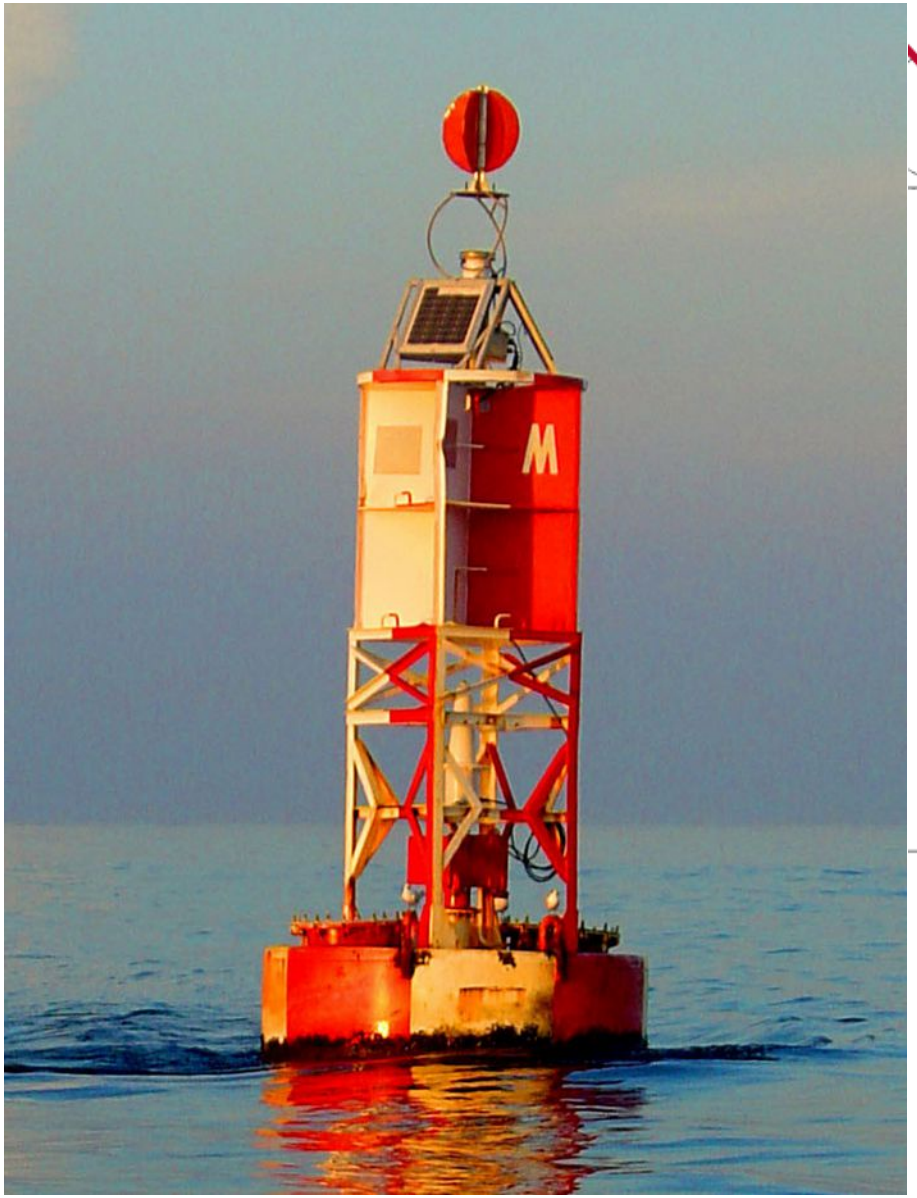
Very close to a navigational aid or landmark.

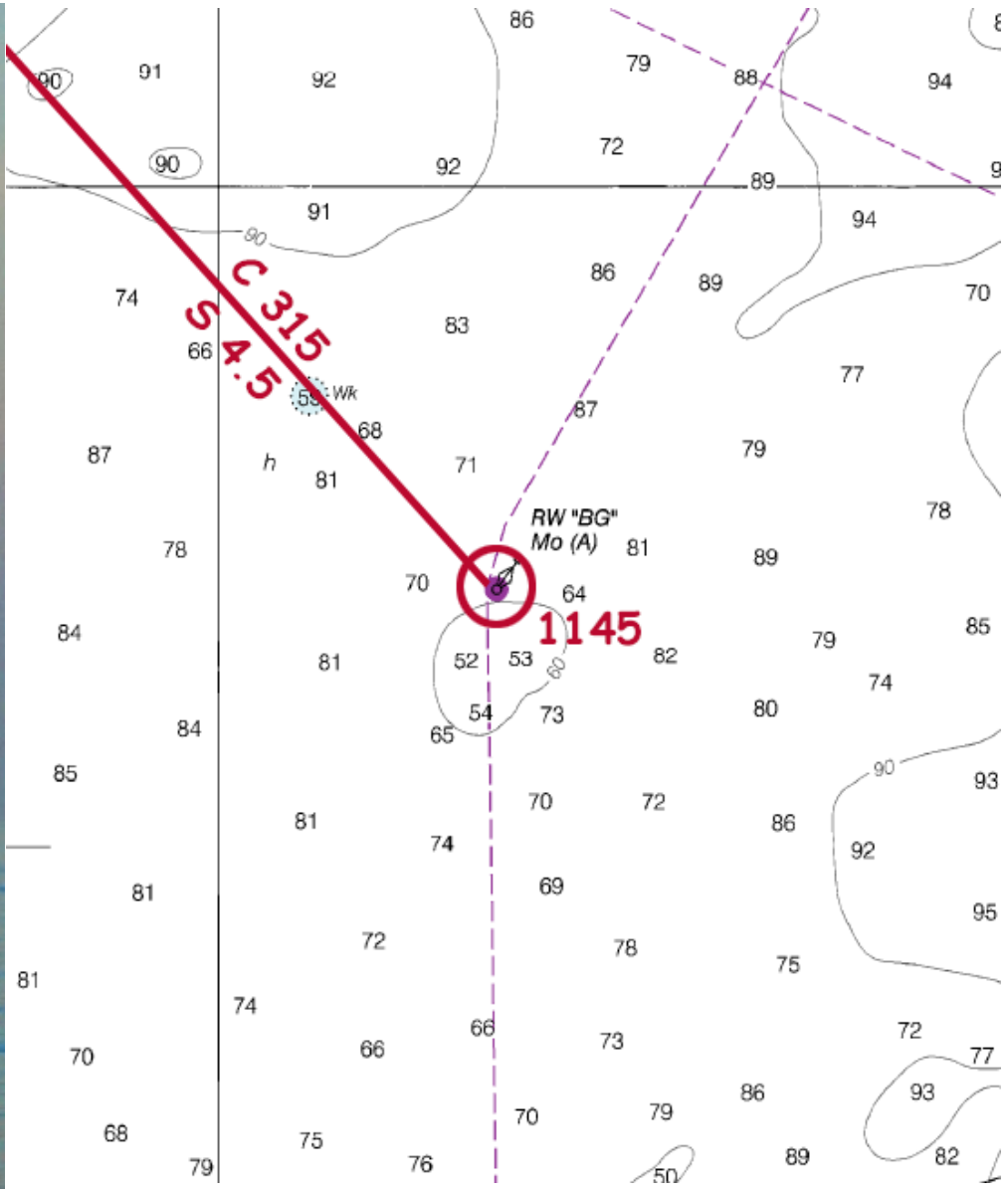




Taking a Fix

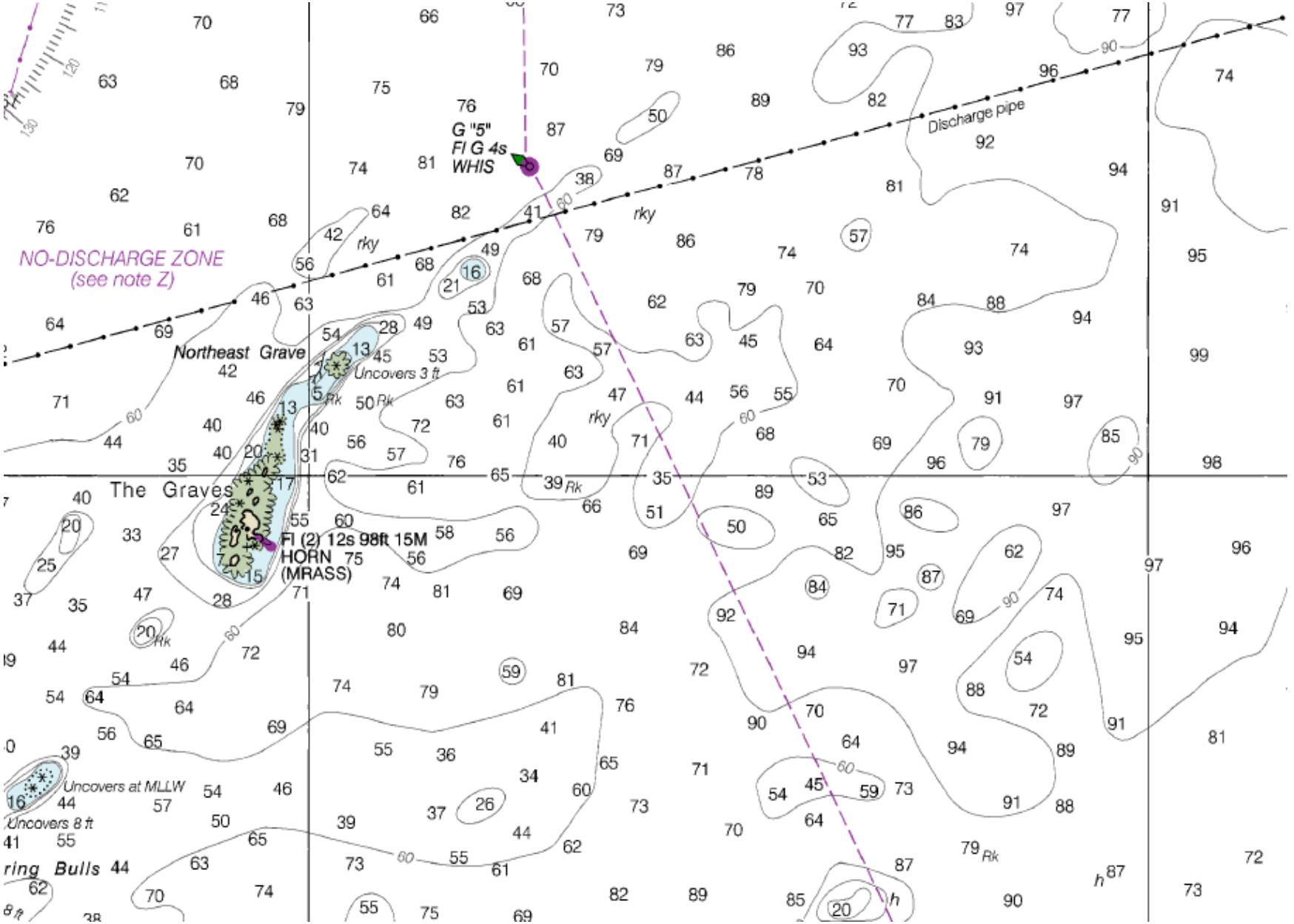
Very close to a navigational aid or landmark.





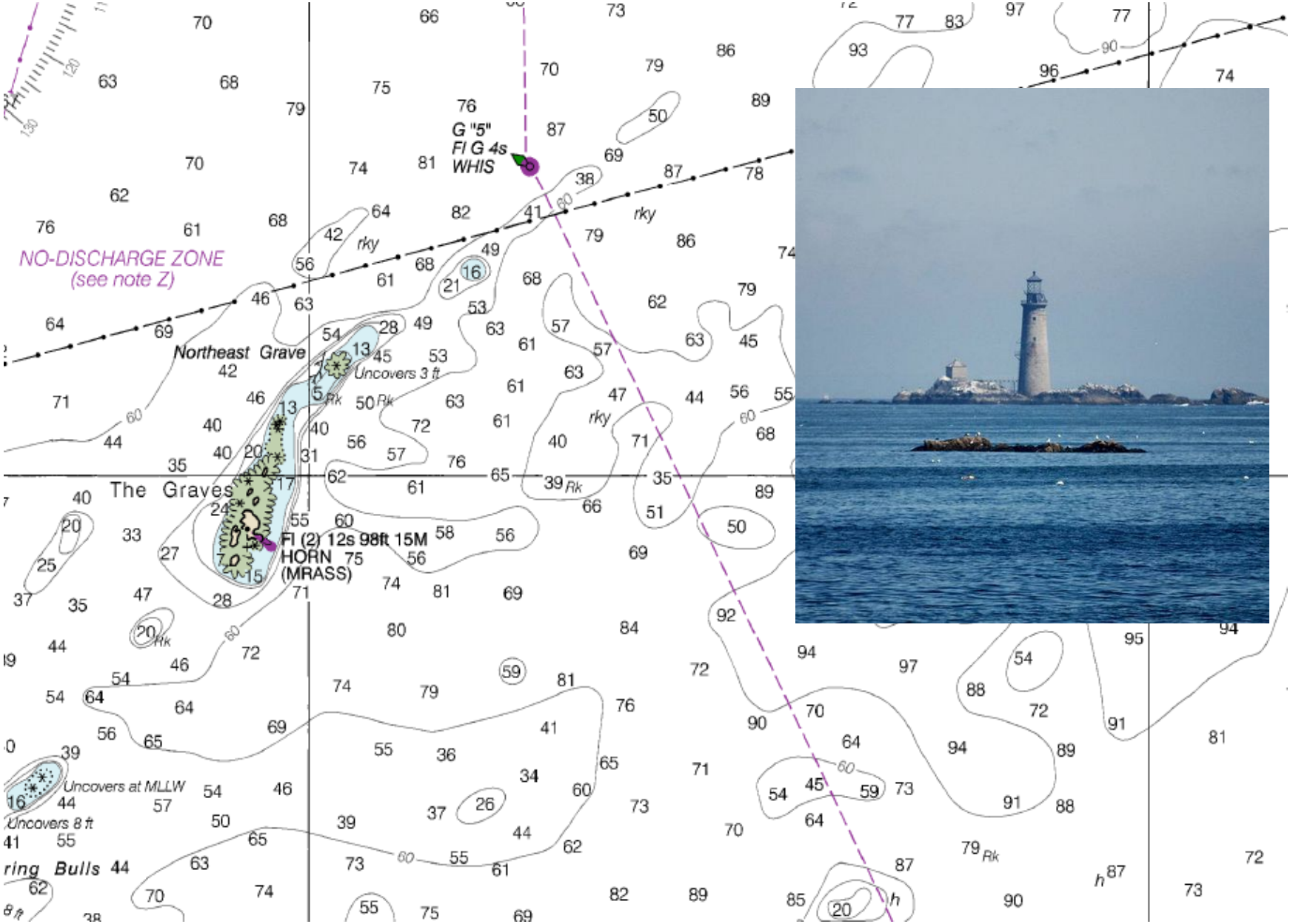
Taking a Fix

Use Distance and Direction



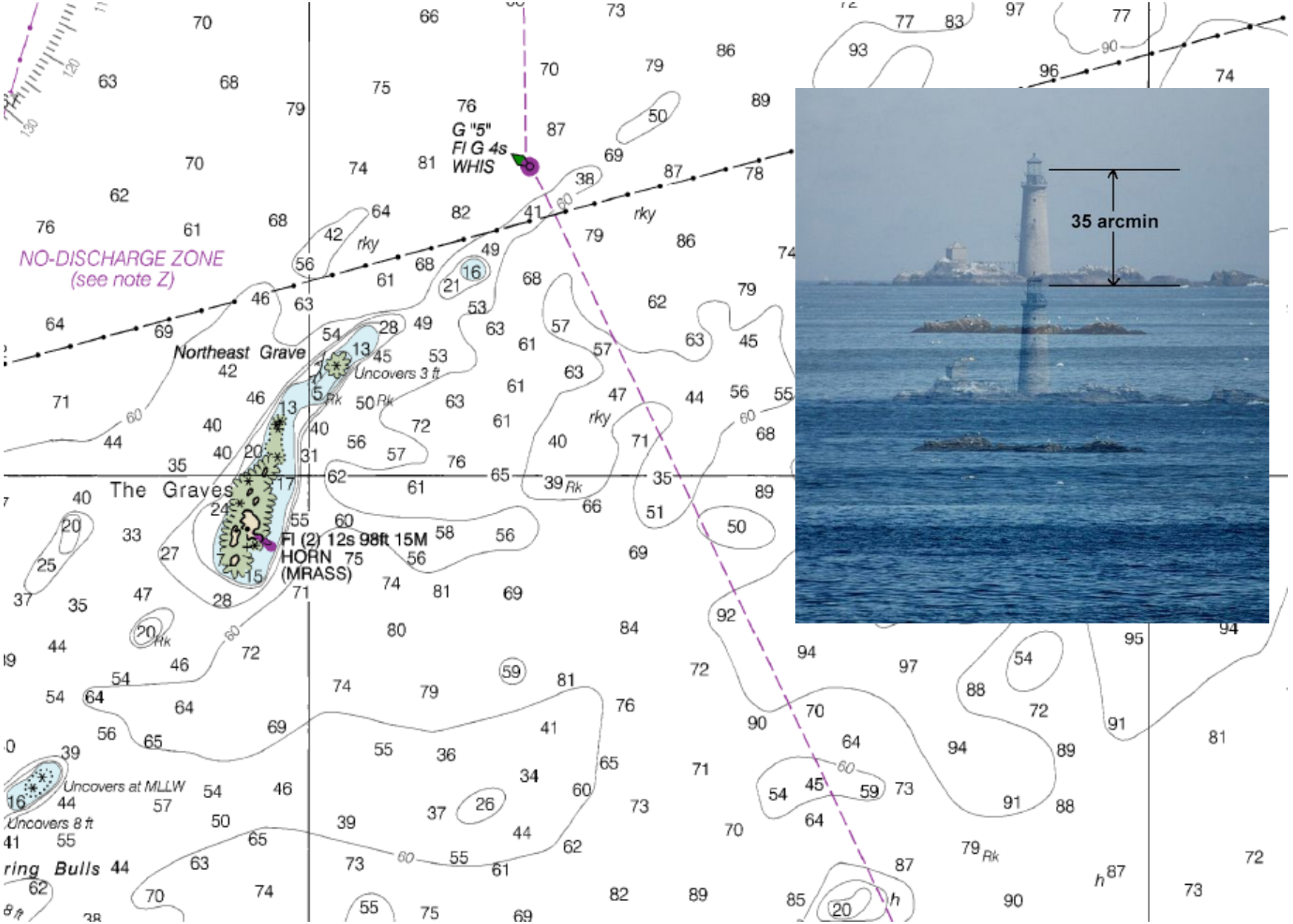
Taking a Fix

Use a sextant to determine distance based on height



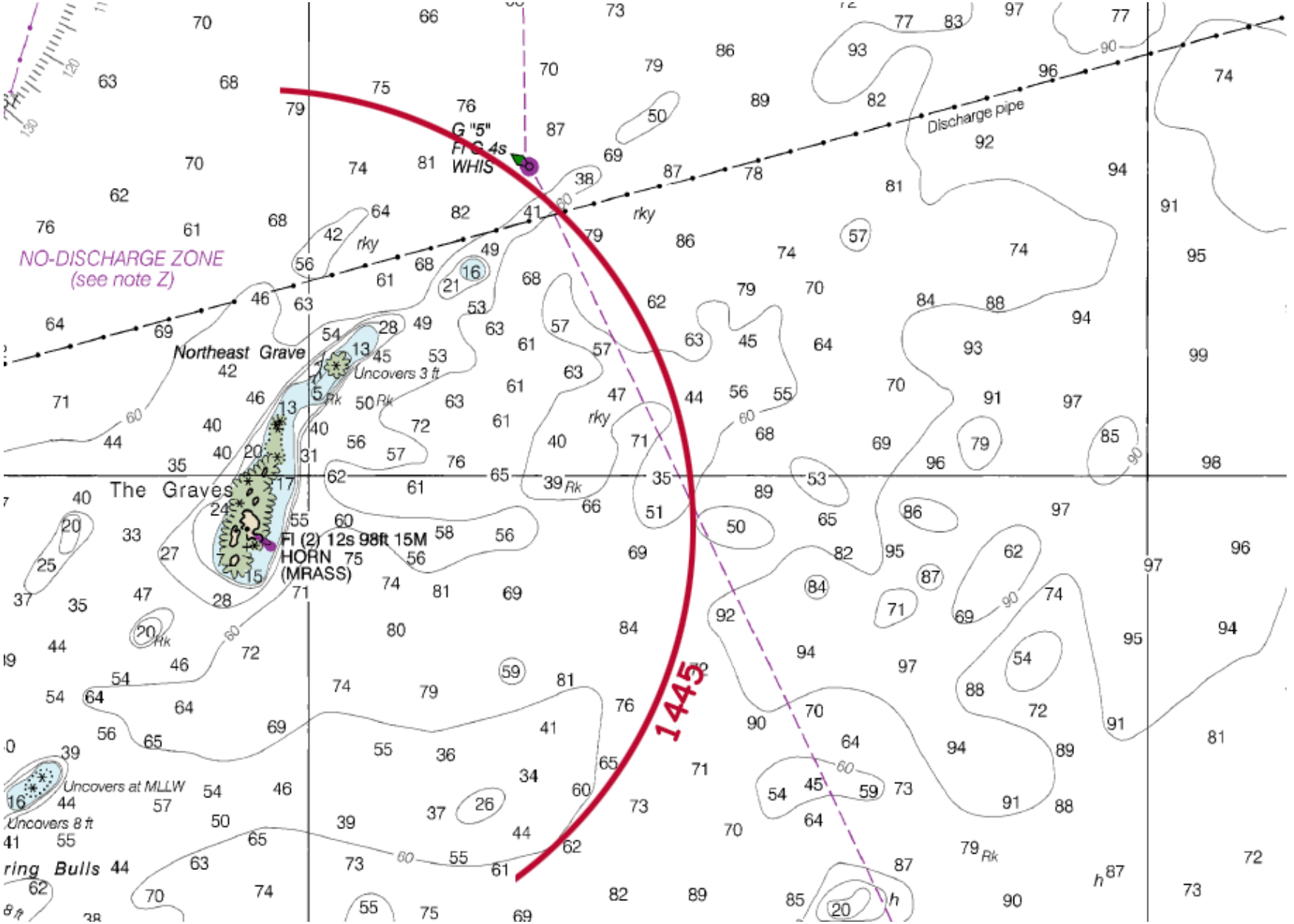
Taking a Fix

Use a sextant to determine distance based on height



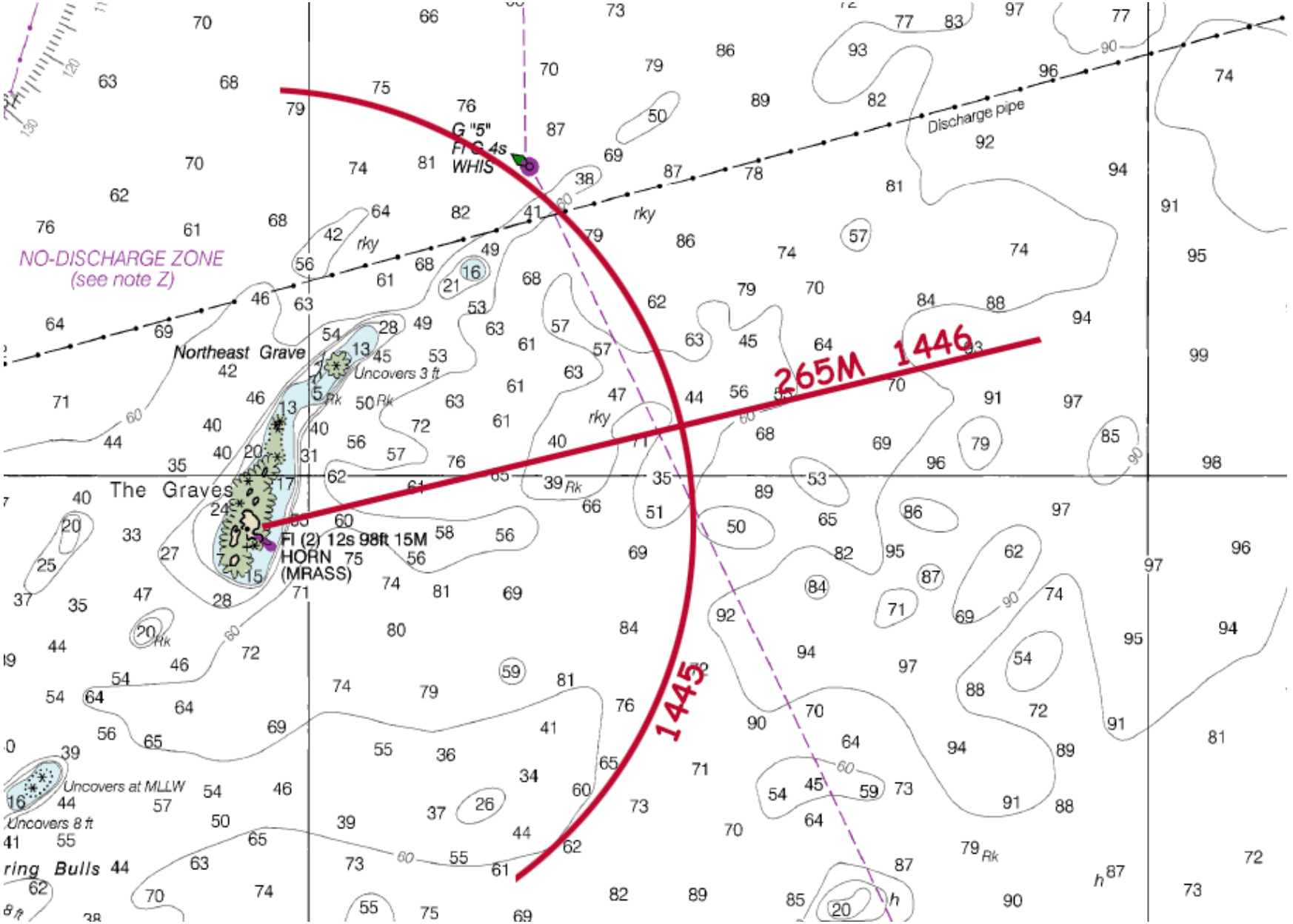
Taking a Fix

Use a compass to draw a COP (Circle of Postion)



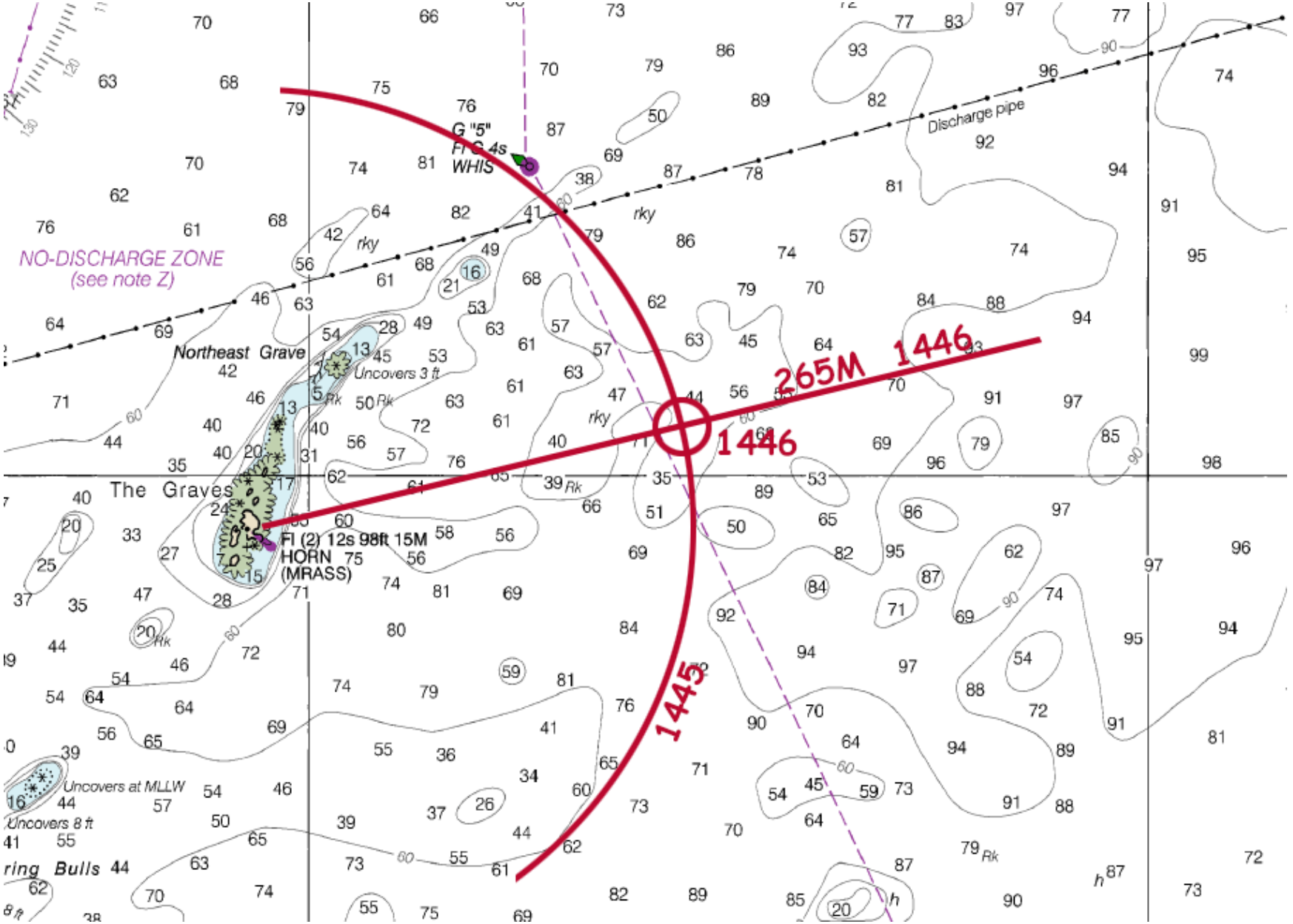
Taking a Fix

Determine a Line of Postion



Taking a Fix

Indicate the fix on the chart



Dead Reckoning

Estimating your position based on:

- Previously known position
- Known course and speed

To do this you need:

- Way to measure course (ship's compass)
- Way to measure speed (knotmeter)
- Way to measure time
- Chart
- Dividers, Ruler, Protractor or Parallels
- Pencil & Eraser

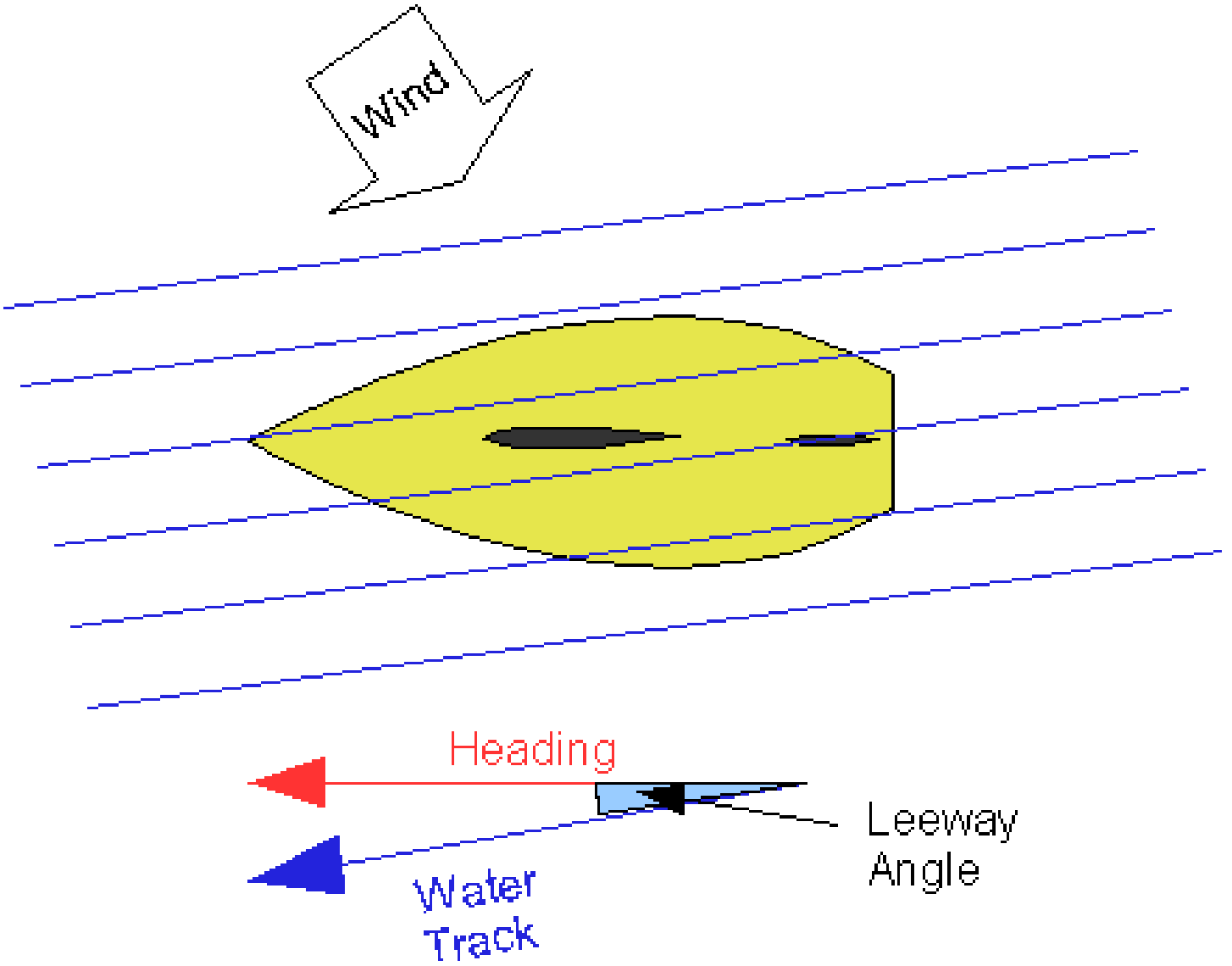
Dead Reckoning

Definitions

- Heading: direction the boat is pointing
- Course: intended direction for the boat to travel
- Track: actual direction the boat is traveling and/or the path the boat has taken (sometimes called Course Made Good (CMG))
- Bearing: direction to another object
- Relative Bearing: direction to another object relative to the heading of the boat

Dead Reckoning

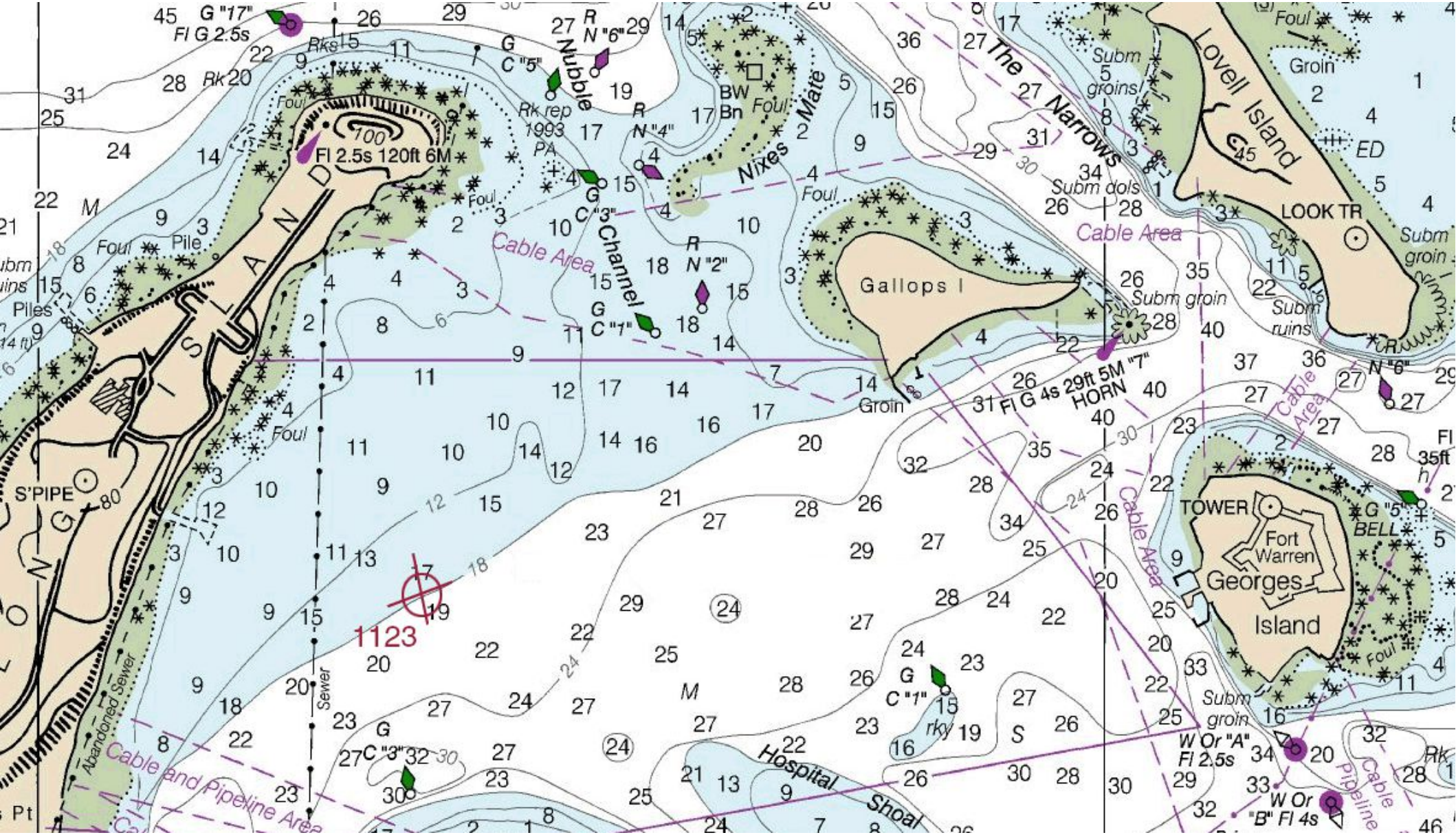
Heading vs. Track (Leeway)



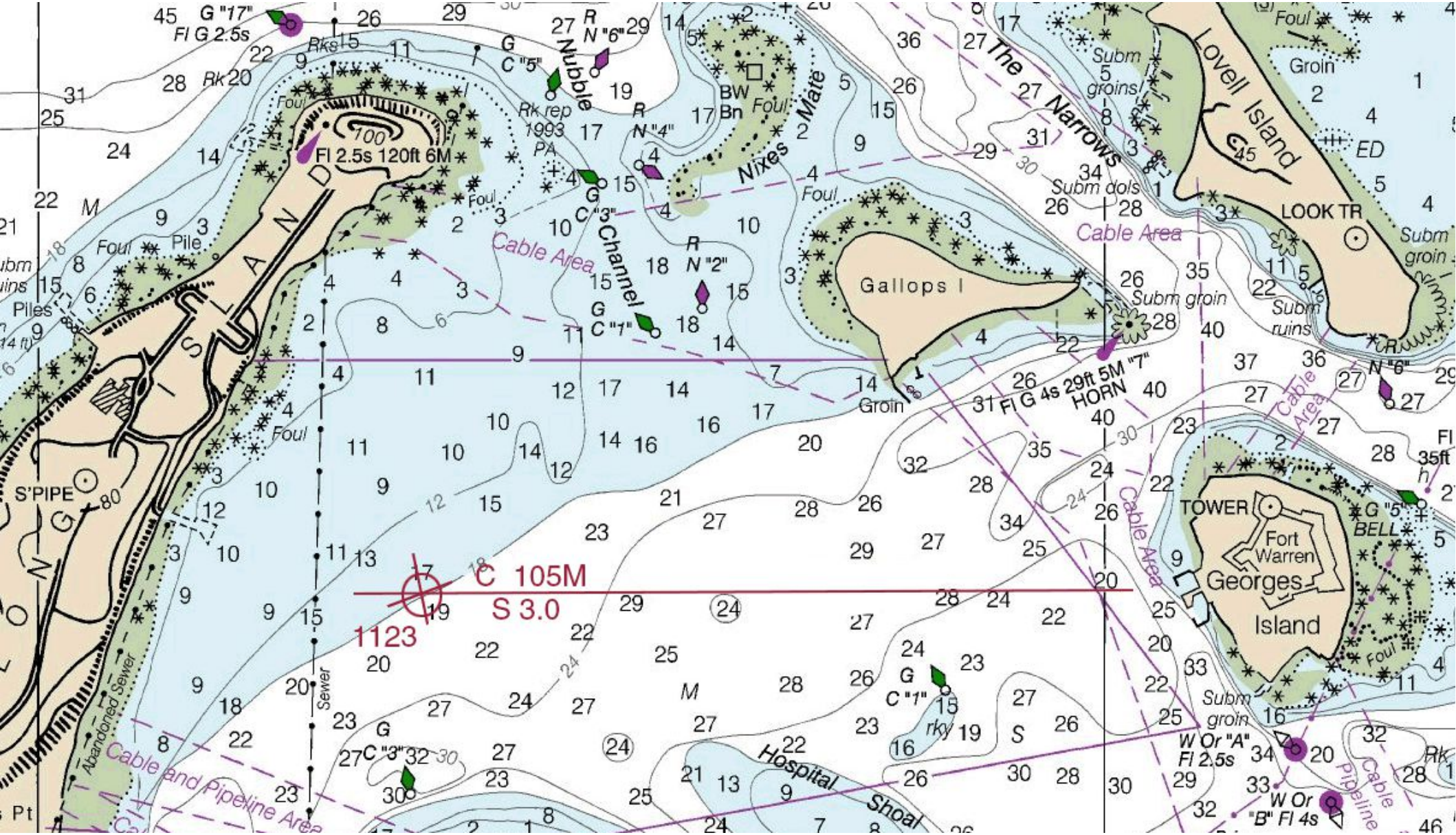
Dead Reckoning

- Start with a fix (a position and a time)
- Steer to a course.
- Maintain constant speed.
- After a period of time, calculate distance traveled and mark it on the chart as a Dead Reckoning position (DR). Be sure to label the time.

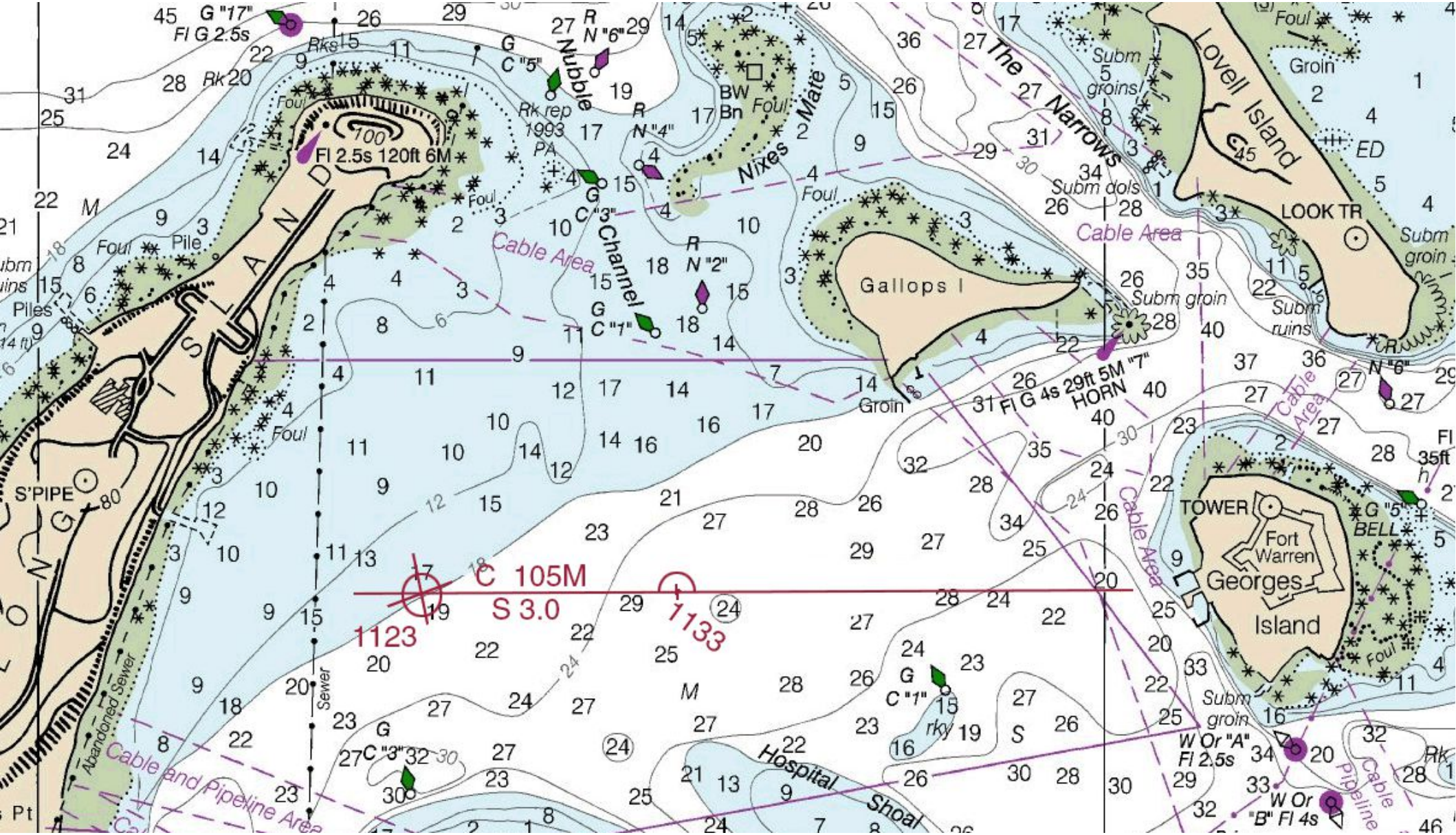
Dead Reckoning



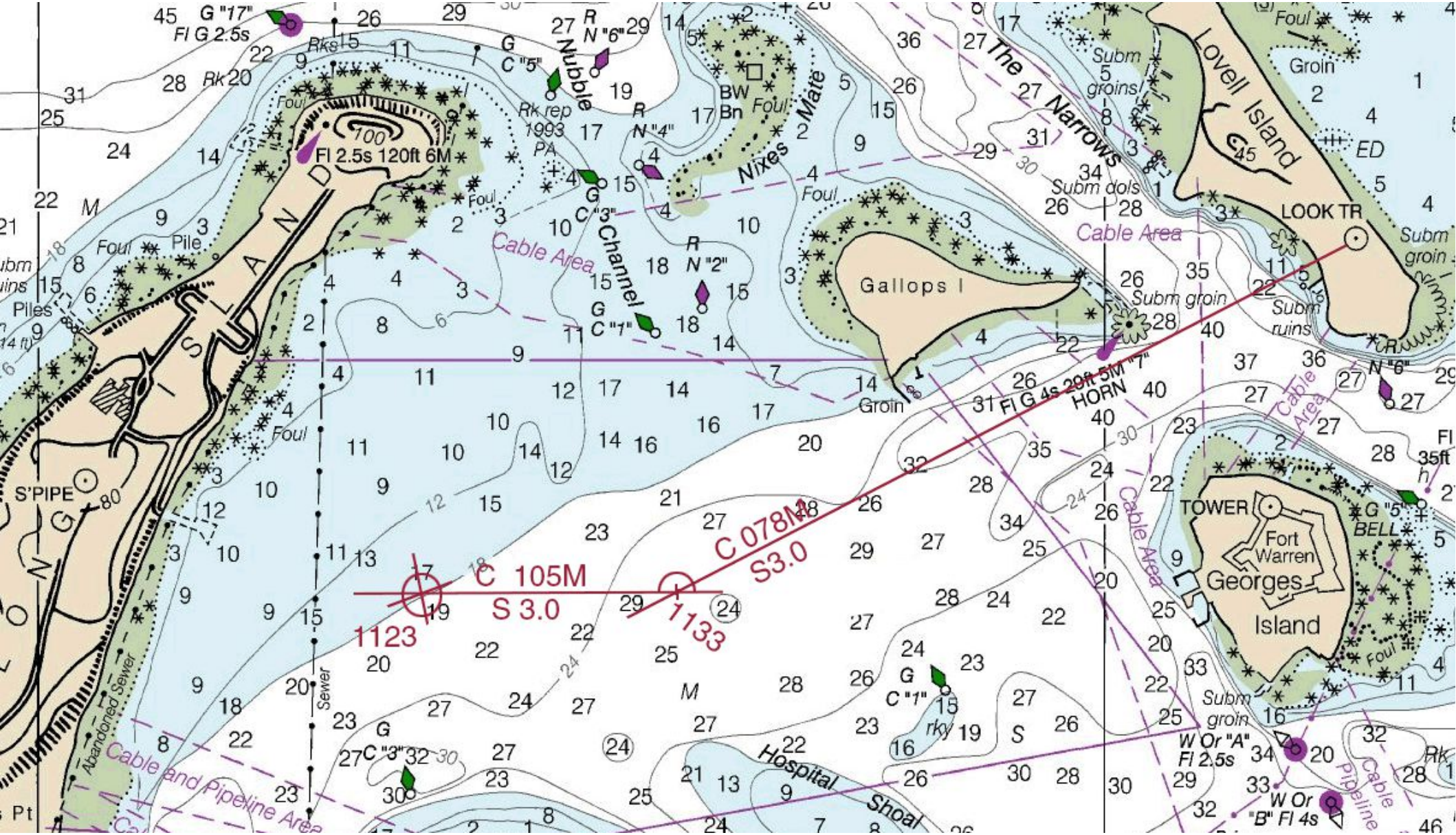
Dead Reckoning



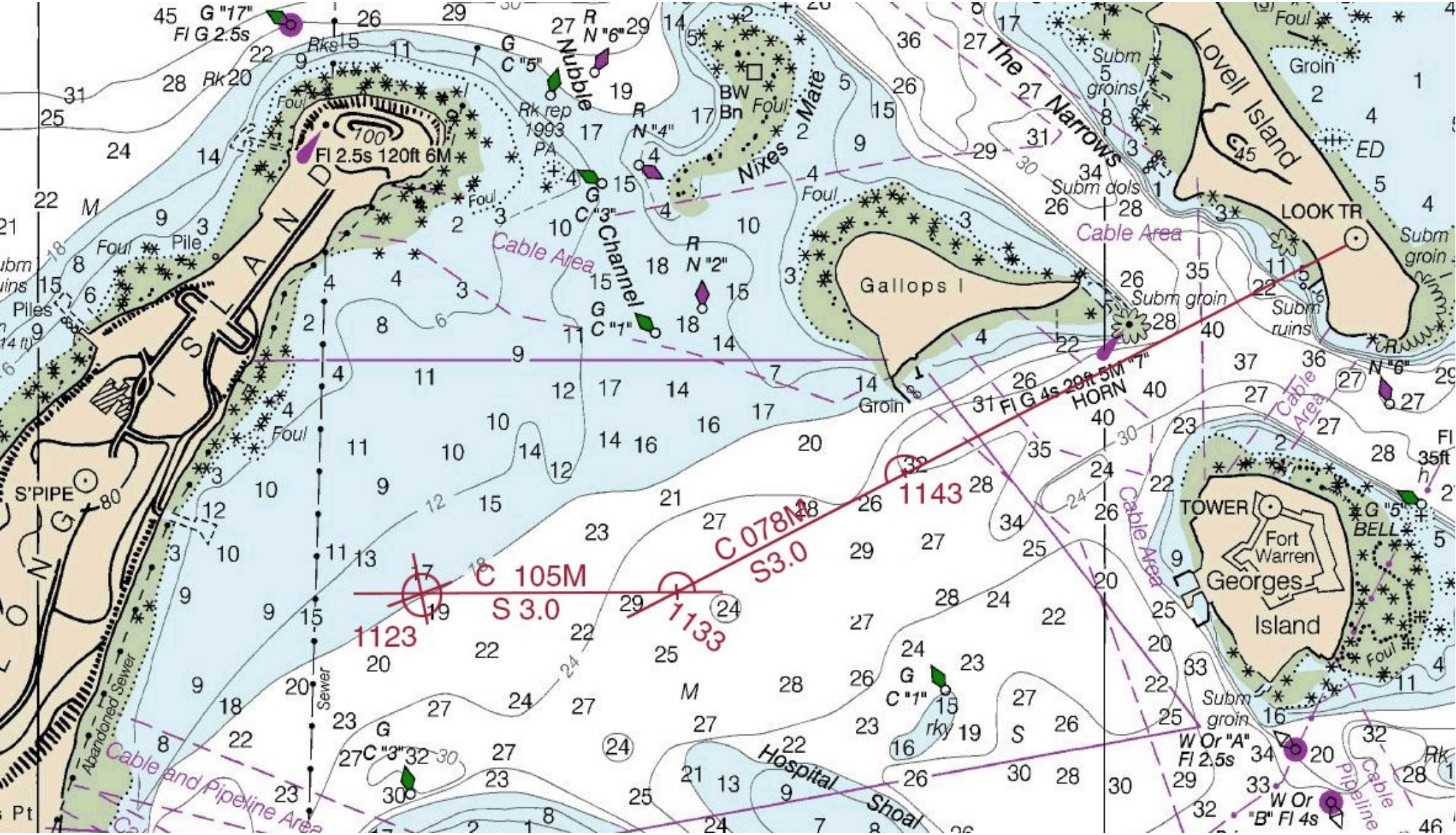
Dead Reckoning



Dead Reckoning



Dead Reckoning



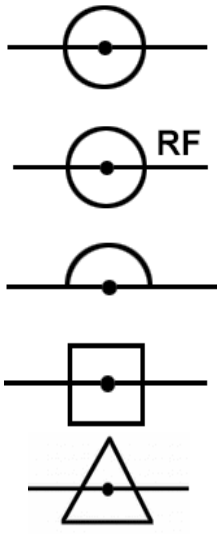
Dead Reckoning

Mark DR positions:

- at regular intervals (at least once per hour)
- any time there is a change in course or speed
- any time a fix is taken

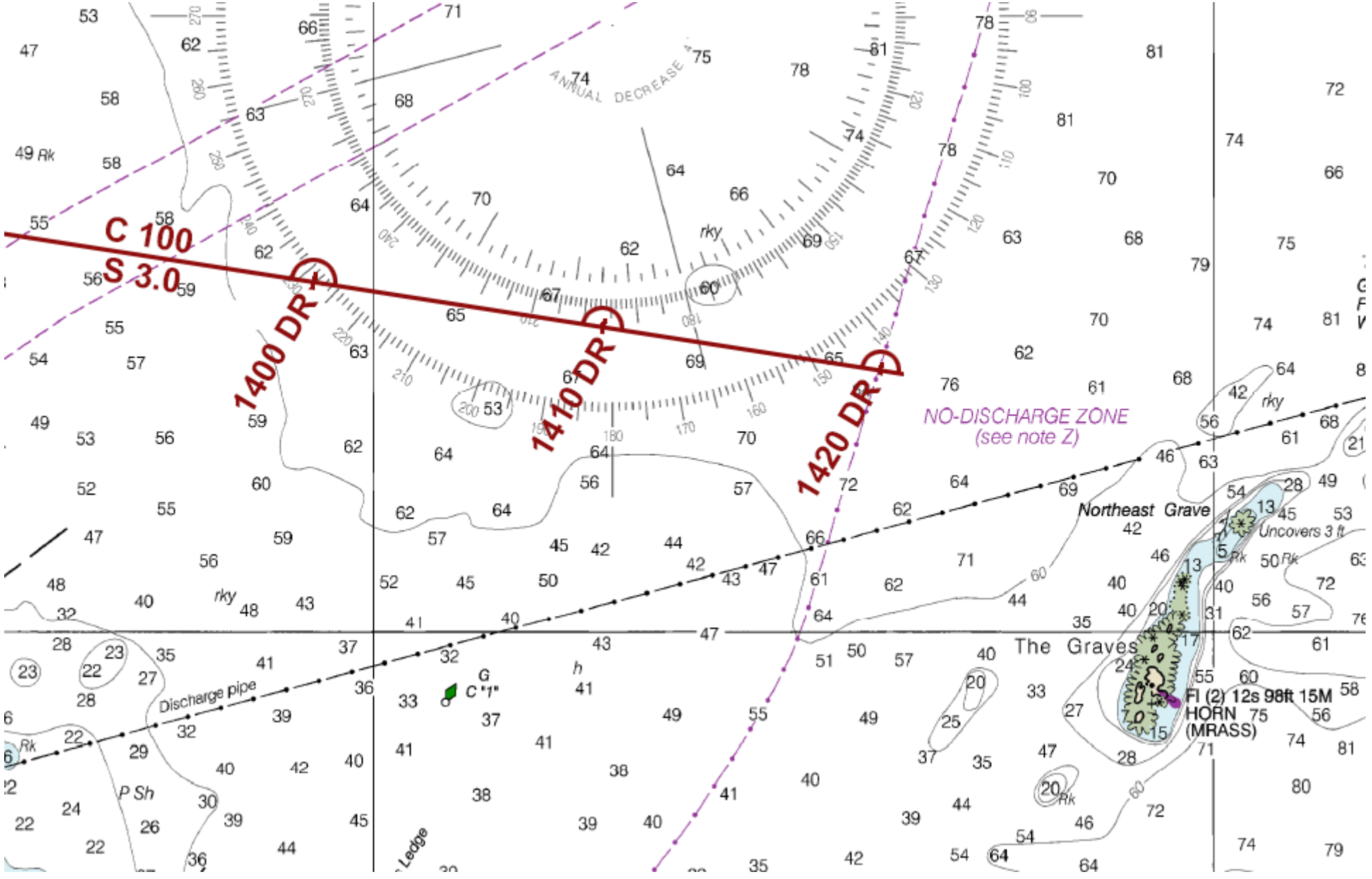
Common symbols:

- Fix
- Running Fix
- Dead Reckoning
- Estimated Postion
- GPS Fix



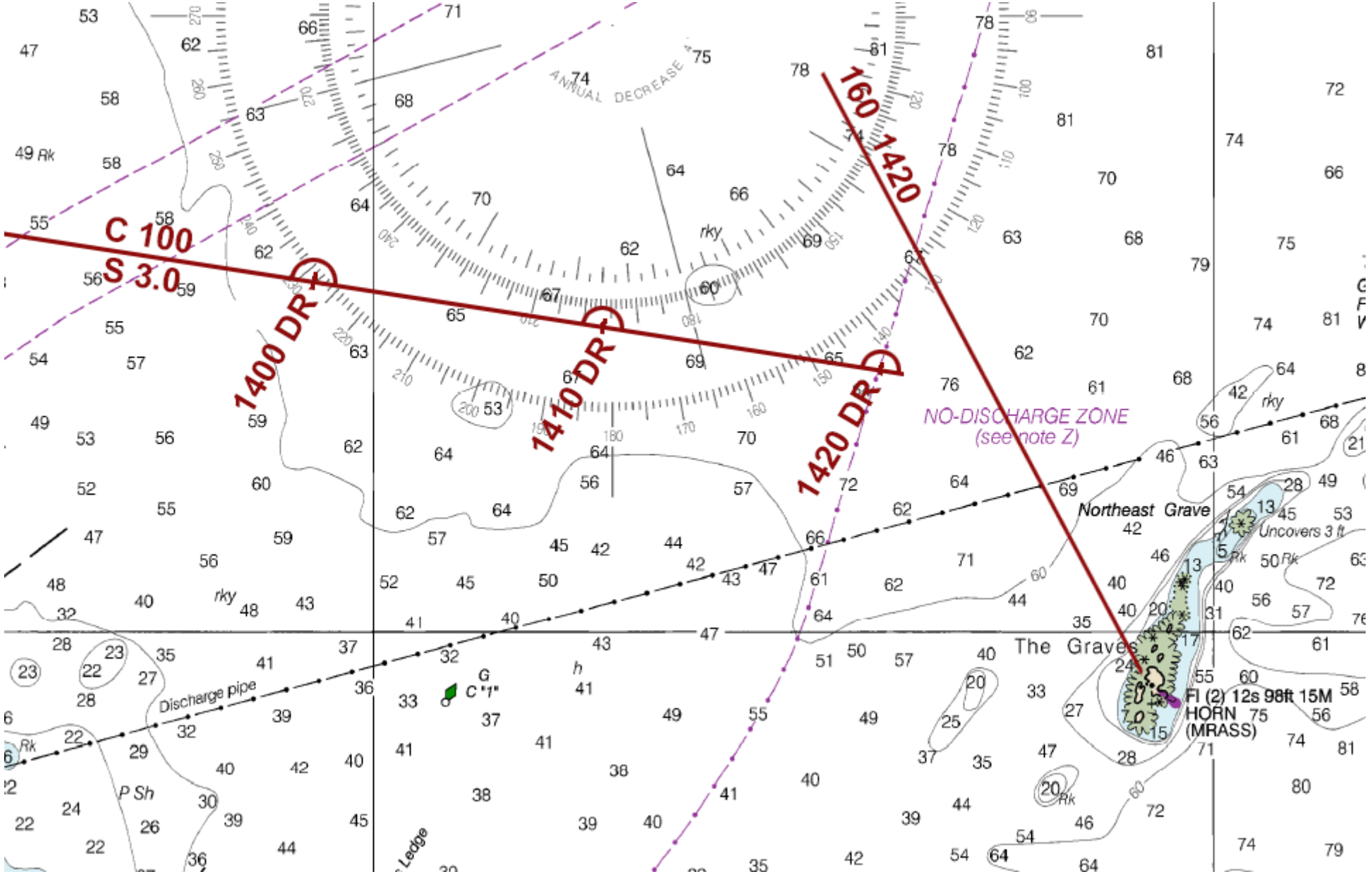
Running Fix

Start with dead reckoning position



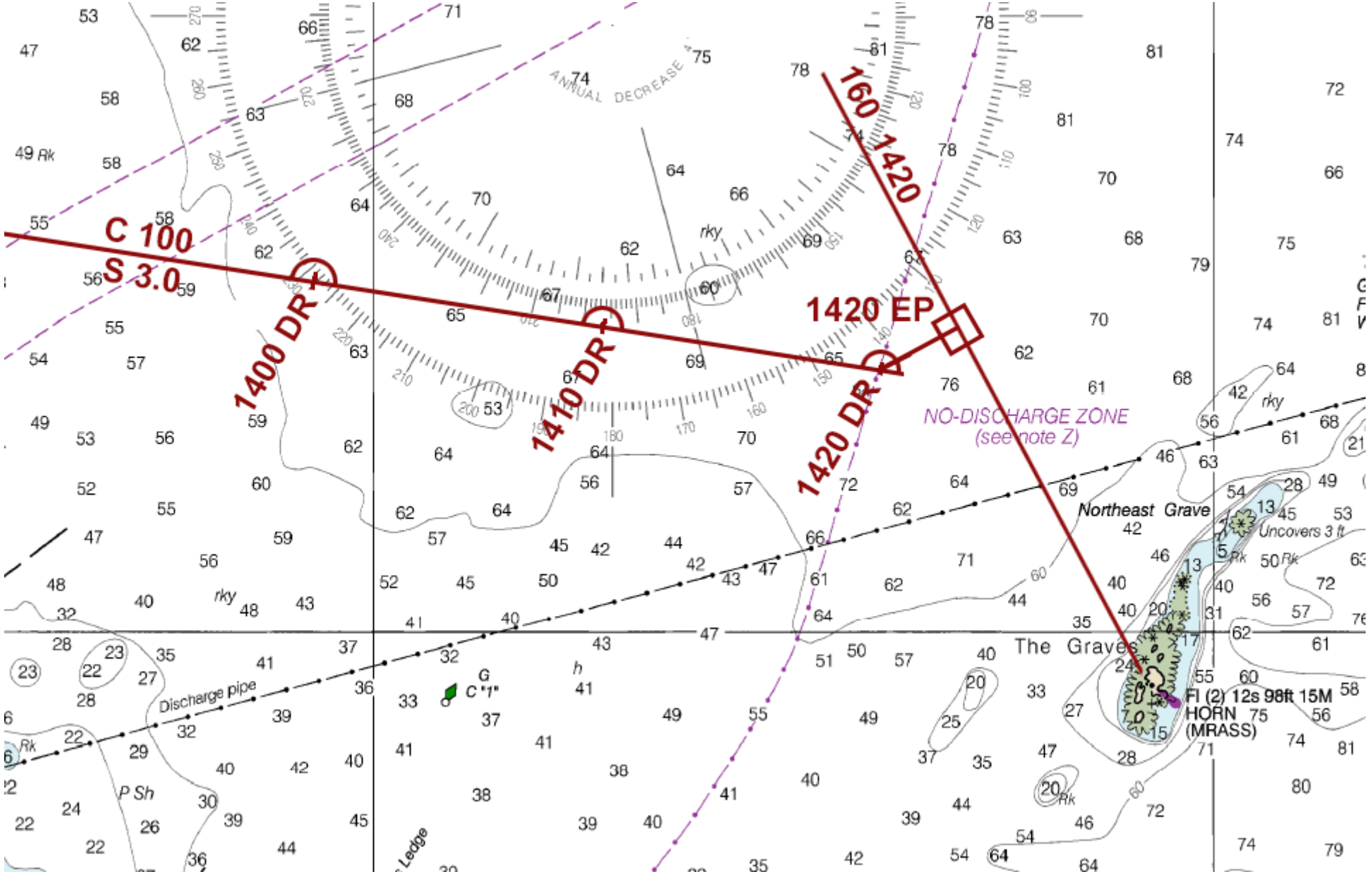
Running Fix

Take a bearing on a mark (get an LOP)



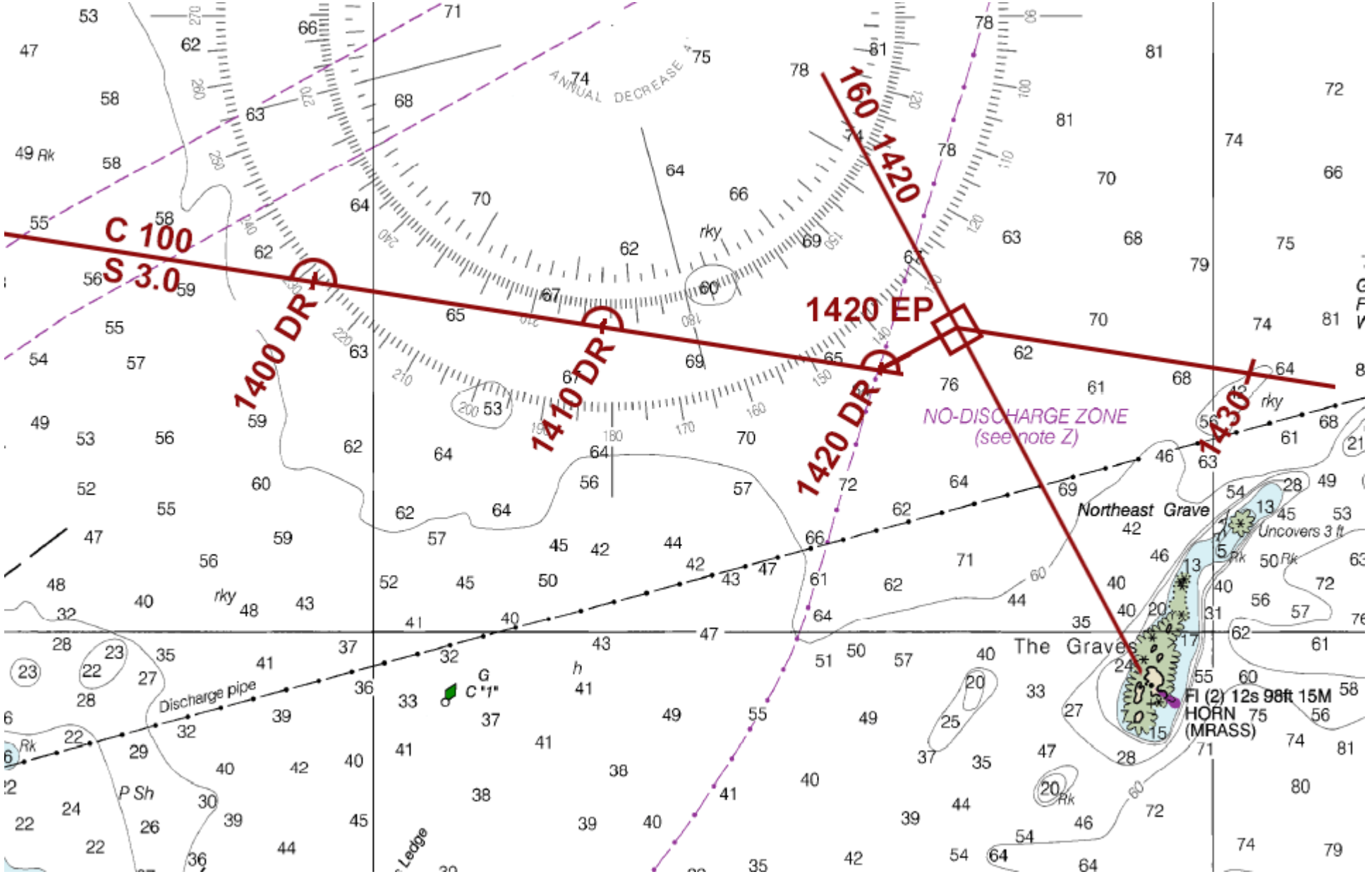
Running Fix

Estimated Position: Nearest point on LOP



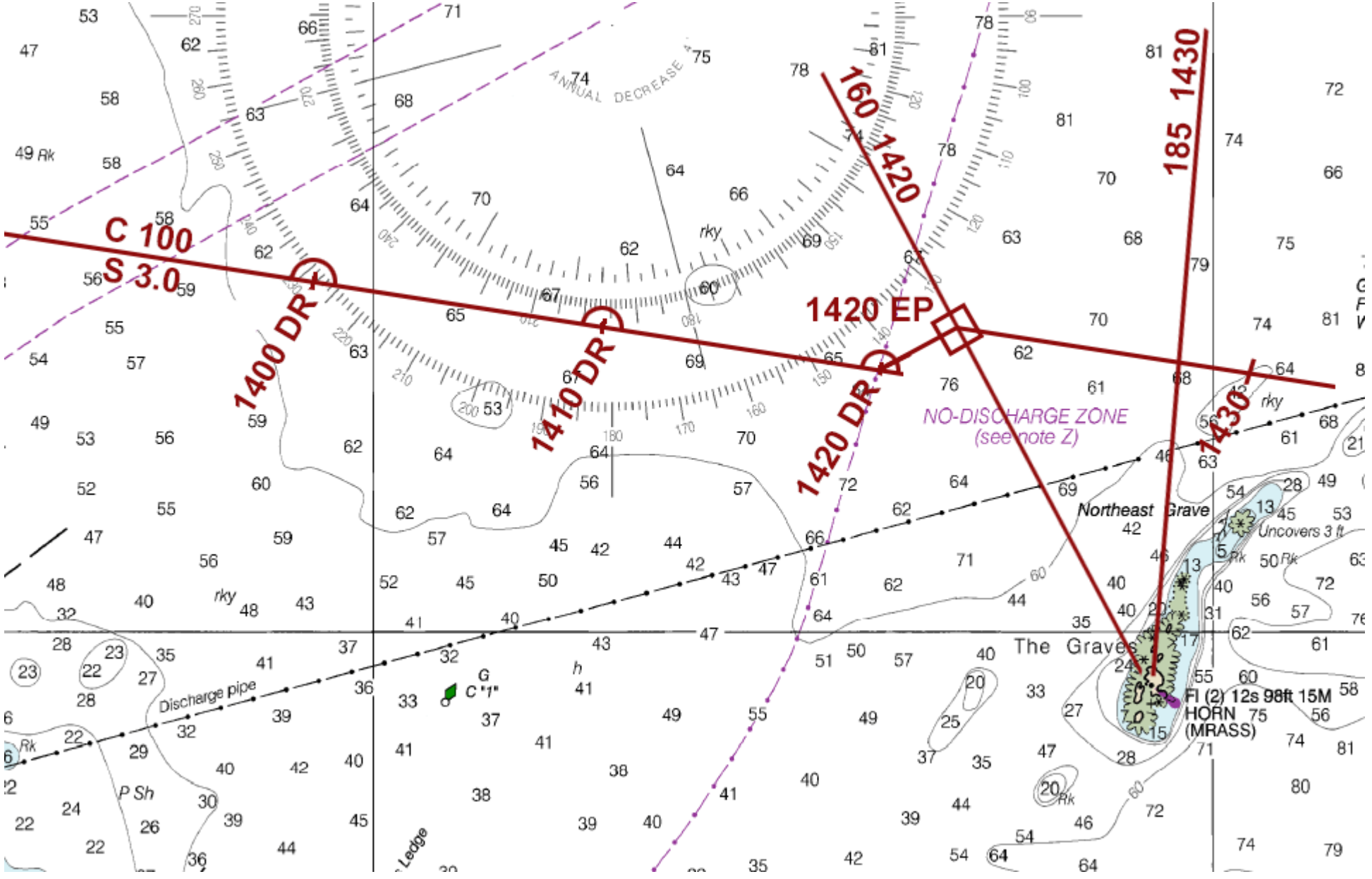
Running Fix

Move your course line to intersect the EP



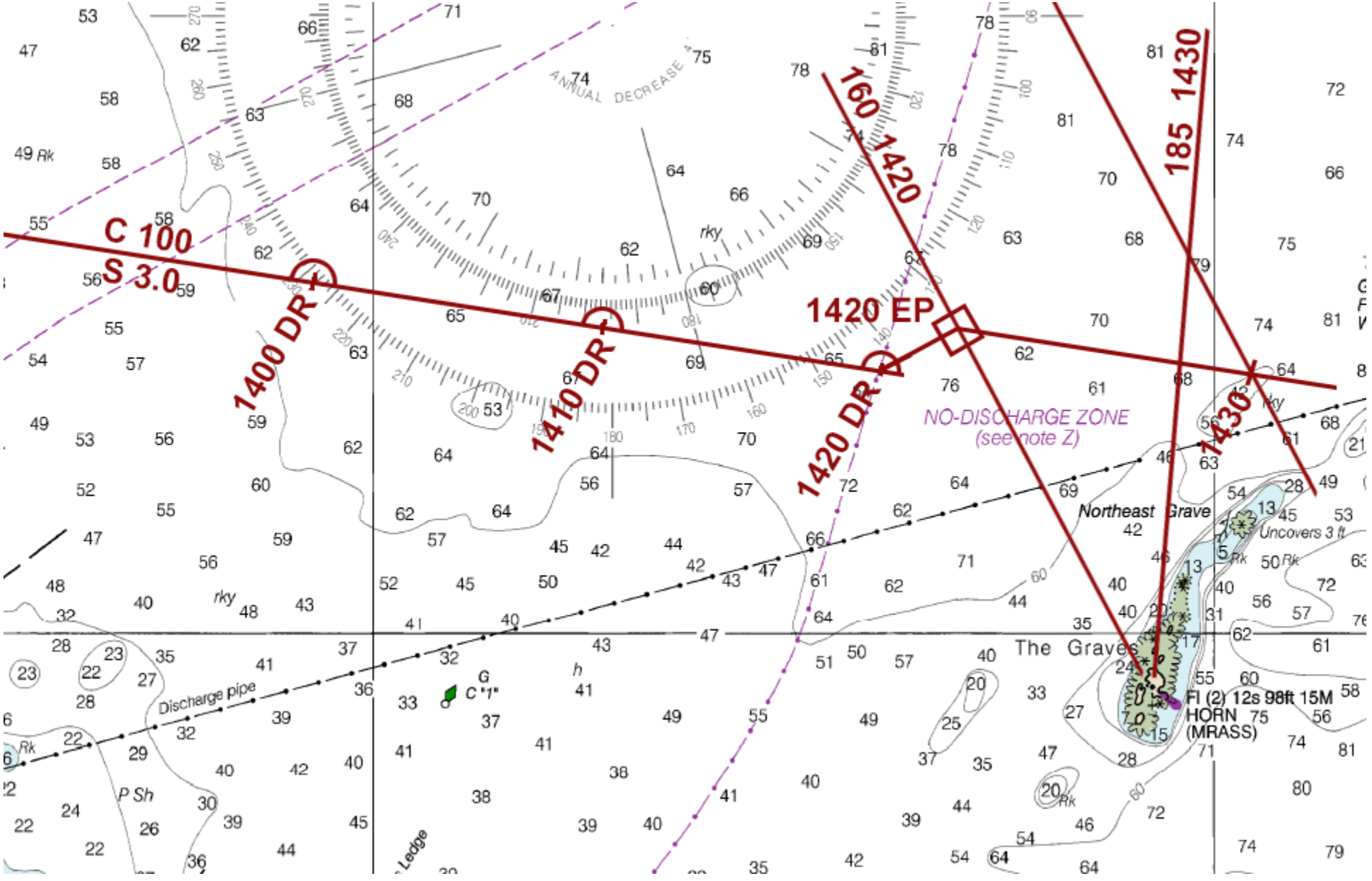
Running Fix

Take a new bearing on the mark (new LOP)



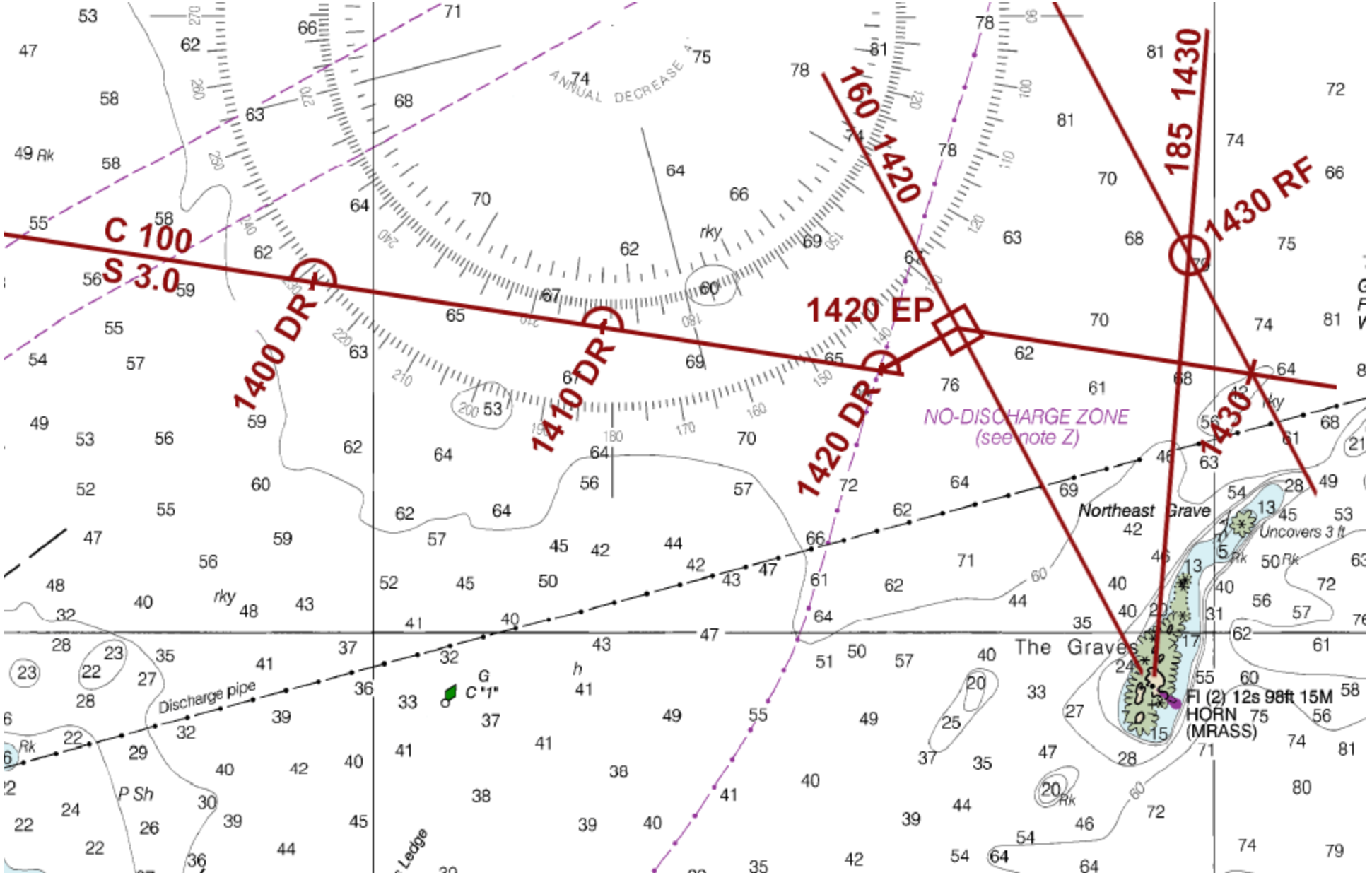
Running Fix

Advance the first LOP over the new point



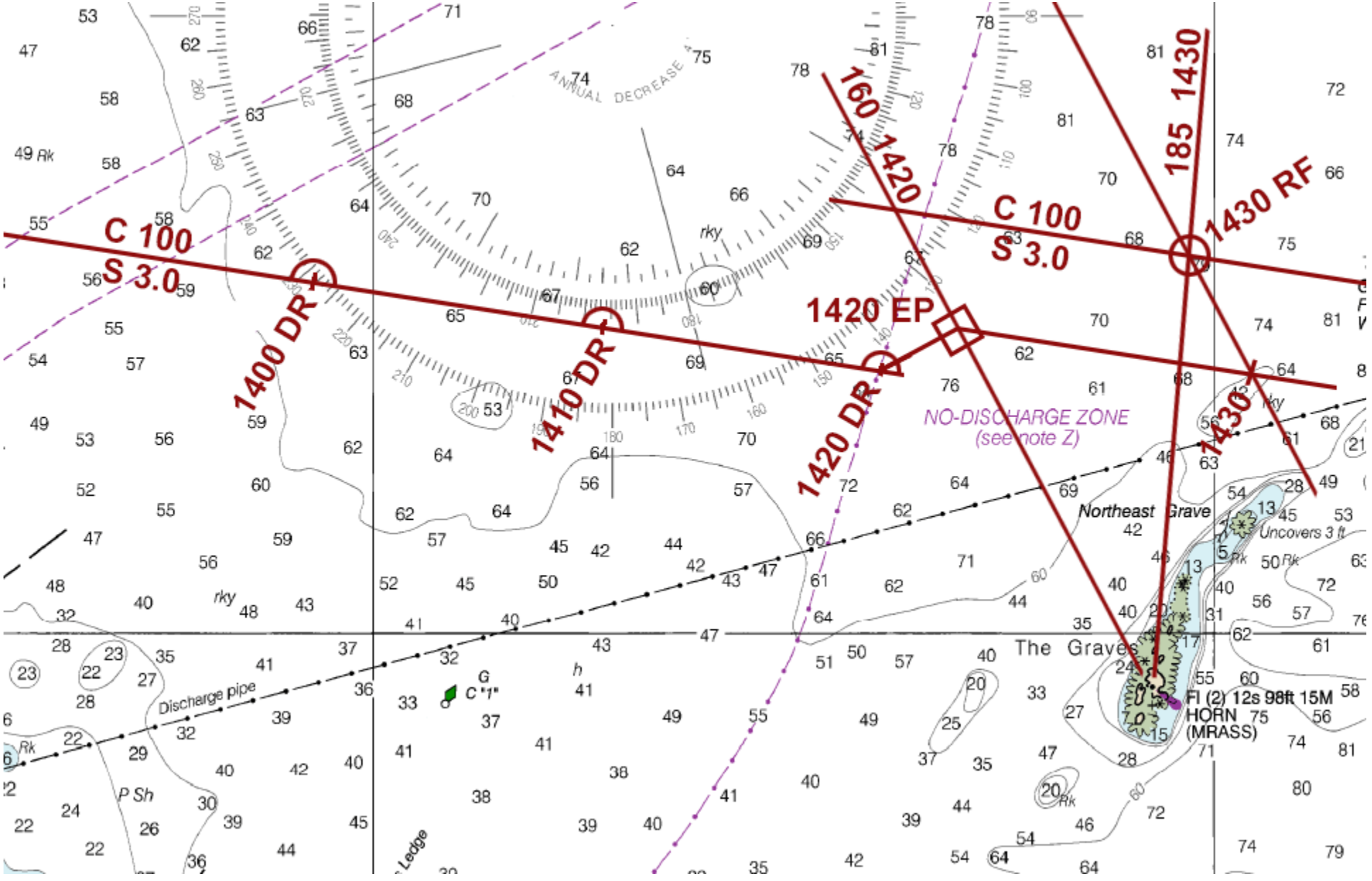
Running Fix

Intersection of the two lines is your Running Fix



Running Fix

Advance your course line over the RF position



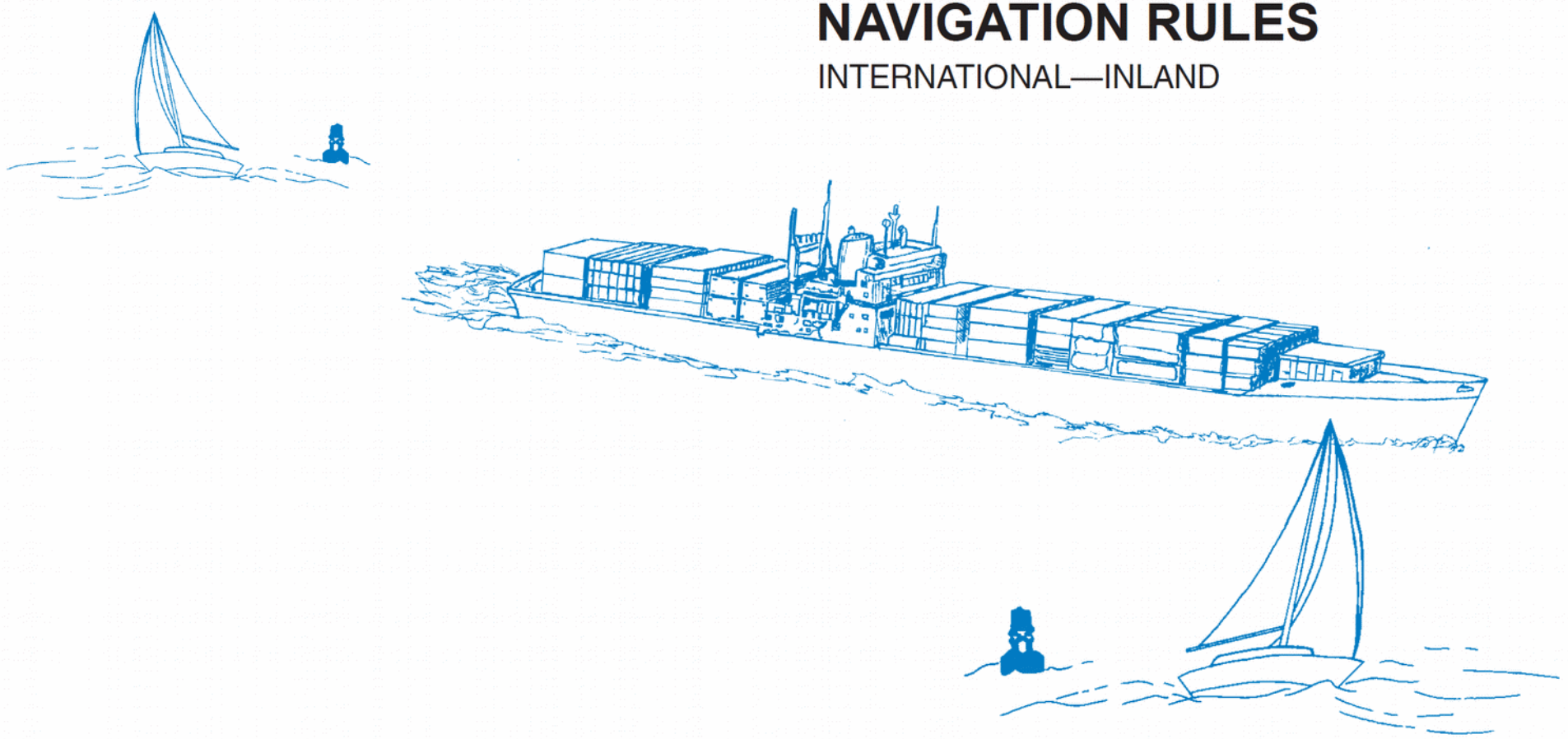
Navigation Rules

U.S. Department
of Transportation

**United States
Coast Guard**

NAVIGATION RULES

INTERNATIONAL—INLAND



Navigation Rules

The Navigation Rules are the national and international laws that govern seagoing vessels on the high seas and all navigable connected waterways.

The Navigation Rules that are applicable to U.S. waters are divided into two sections:

- International Rules
- Inland Rules

Navigation Rules

International Rules

- Based on the 1972 International Treaty for the Prevention of Collisions at Sea
- Known as the 72 COLREGS

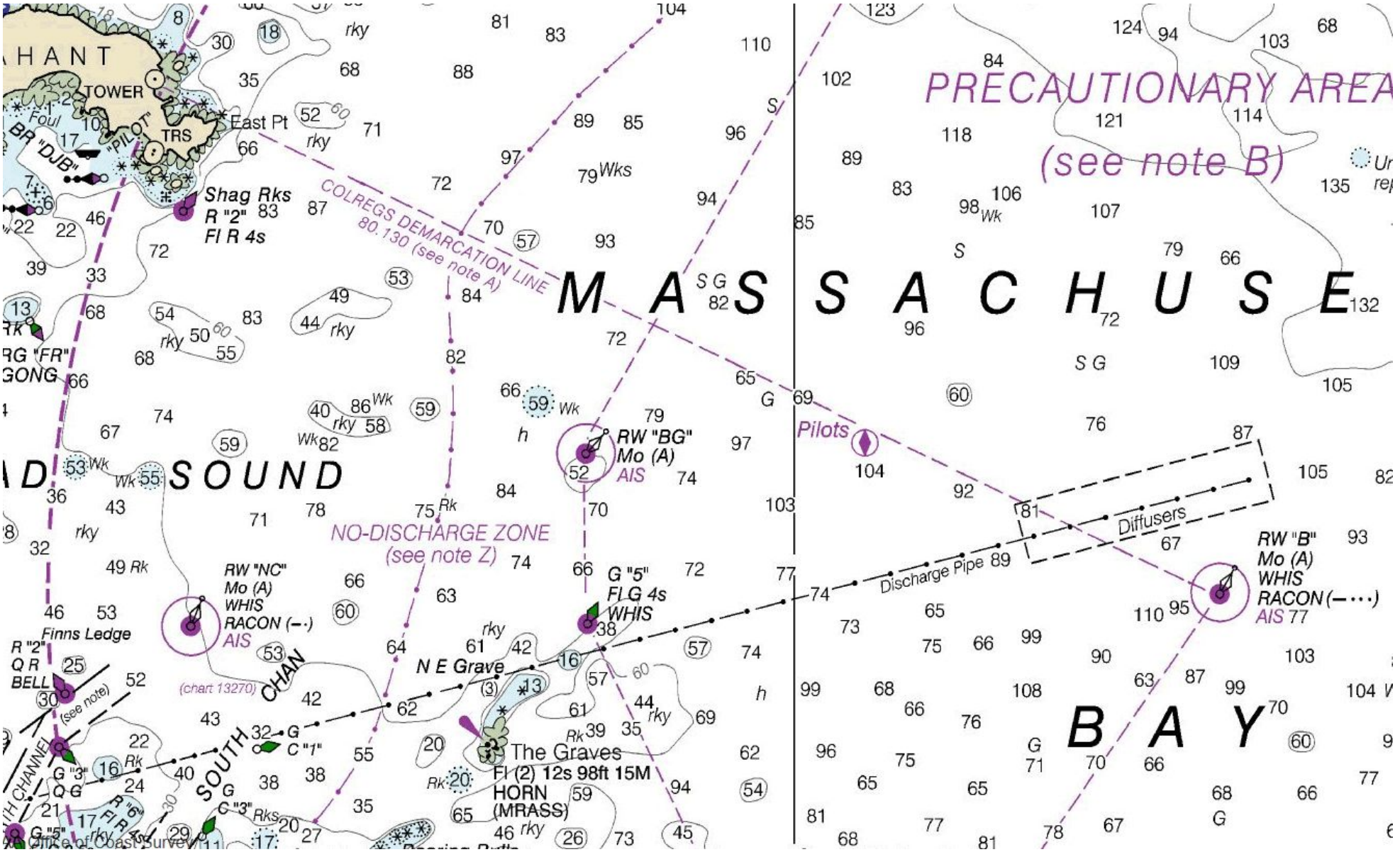
Inland Rules

- Almost identical to the International Rules
- A few minor differences

Demarcation lines exist between areas subject to Inland vs. International rules.

Navigation Rules

COLREGS demarcation lines are marked on charts



Navigation Rules

Rule 2 – Responsibility

"Due regard shall be had to all dangers of navigation and collision and to any special circumstances, … which may make a departure from these Rules necessary to avoid immediate danger."

You are responsible for operating your vessel safely and breaking a rule is ok if necessary to avoid a collision.

Navigation Rules

Rule 3 – Definitions

- Power Driven Vessel
- Sailing Vessel
- Vessel Engaged in Fishing
- Vessel Not Under Command
- Vessel Restricted in Its Ability to Maneuver
- Underway
- Give-Way Vessel
- Stand-On Vessel
- Restricted Visibility
- et al.

Navigation Rules

Rule 5 – Lookout

You are required to have an proper lookout at all times. If you have a collision, your lookout was not adequate.

Rule 6 – Safe Speed

You are required to proceed at safe speed at all times. You must be going slow enough to prevent collisions regardless of the conditions and circumstances.

Navigation Rules

Rule 7 – Risk of Collision

"Every vessel shall use all available means ... to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist."

Also if you have a working radar system, you are required to use it.

Navigation Rules

Rule 8 – Action to Avoid Collision

"Any action taken to avoid collision shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship."

"Any alteration of course and/or speed to avoid collision shall, if the circumstances of the case admit, be large enough to be readily apparent to another vessel...."

Take action early. Make it count. Make it obvious.

Navigation Rules

Rule 9 – Narrow Channels

- Stay to the right if possible.
- Do not impede larger vessels that must stay in the channel.
- Fishing vessels cannot impede traffic in the channel.
- Avoid anchoring in the channel.

Rule 10 – Traffic Separation Schemes

- Smaller boats should avoid the lanes.
- If necessary, cross lanes at right angles.
- Ships using the lanes have right of way over small boats and sailboats.

Navigation Rules

Rule 12 – Sailing Vessels

- Boats on port tack stay clear of boats on starboard tack.
- If on the same tack, windward boats stay clear of leeward boats.

Rule 13 – Overtaking

- Overtaking boats keep clear of the vessel being overtaken.
- A vessel is overtaking if it is approaching at an angle of more than 22° aft of abeam of the other vessel.
- Overtaking vessel must keep clear until “she is finally past and clear”.

Navigation Rules

Rule 14 – Head-On Situation

- Both boats turn to starboard and pass port-to-port.

Rule 15 – Crossing Situation

- Boat on the left gives way to the boat on the right.

Rule 16 – Action by Give-Way Vessel

- Take action early and stay well clear.

Rule 17 – Action by Stand-On Vessel

- Must maintain course and speed.
- Unless it looks like the other boat isn't going to turn.

Navigation Rules

Rule 18 – Responsibilities between Vessels

- The pecking order for stand-on vessels is:
  - Vessels not under command
  - Vessels “restricted in their ability to maneuver”
  - Vessels engaged in fishing
  - Sailing vessels
  - Power driven vessels
  - Seaplanes

Navigation Rules

Rule 19 – Conduct of Vessels in Restricted Visibility

- Proceed at safe speed.
- Be on the lookout.
- Use due regard to the prevailing circumstances when complying with all other rules.
- Be prepared to slow down or stop if another vessel is ahead.

Navigation Rules

Rule 20 – Lights and Shapes - Application

- Rules 21-31 describe lights and shapes.
- Lights must be used at night (sunset to sunrise).
- Shapes must be used during the day.

Navigation Rules

Rule 21 – Lights and Shapes - Definitions

- Masthead light – white facing forward 225° arc
- Sidelights – red and green, each 112.5° arc
- Sternlight – white, 135° arc
- Towing light – yellow stern light, 135° arc
- All-round light – 360°
- Flashing light – 120 flashes per minute or more
- Special flashing light – forward facing yellow light, flashing 50-70 flashes per minute, over an arc of 180-225°

Navigation Rules

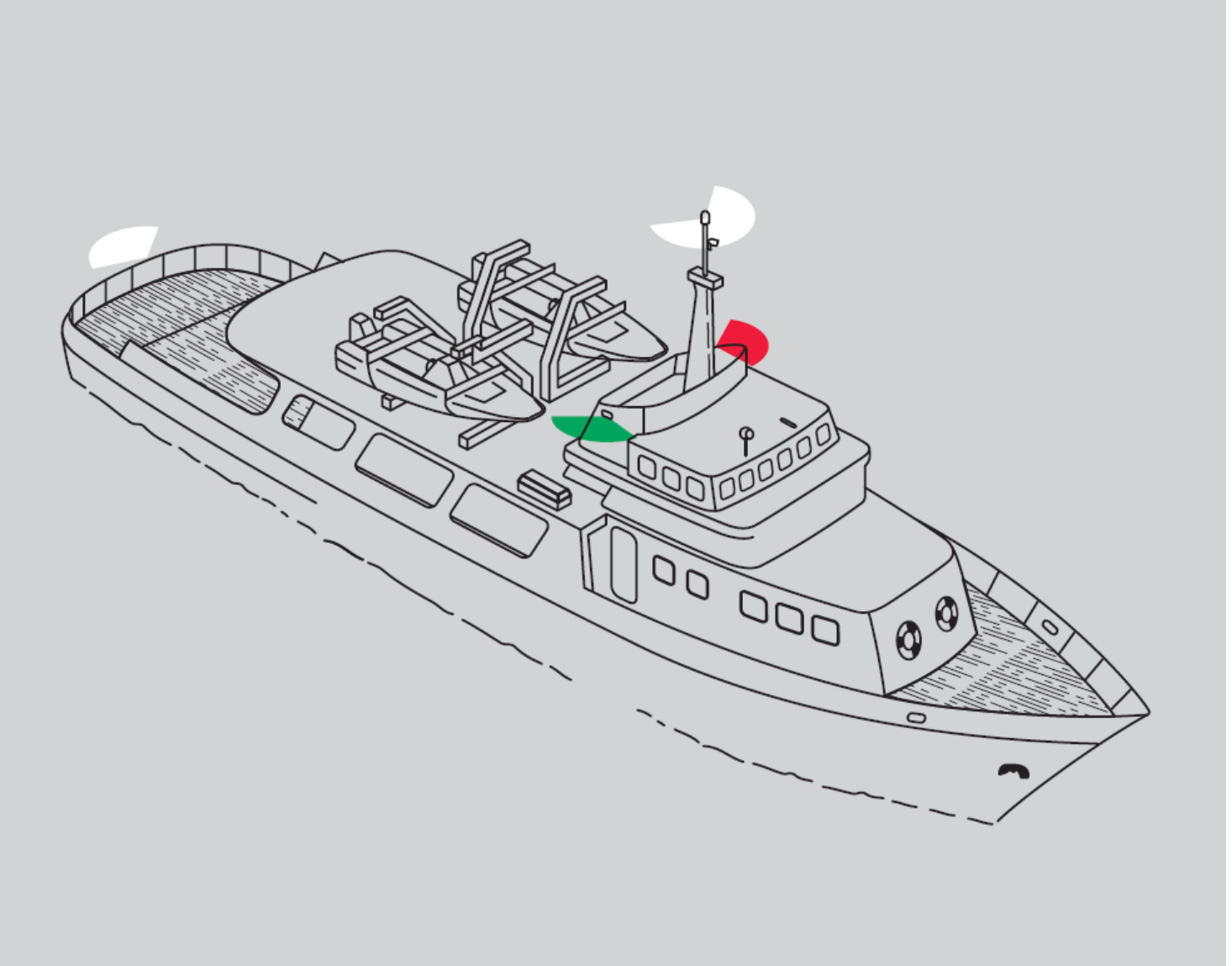
Rule 22 – Visibility of Lights

- The visibility of the various lights (in miles) are specified
- Larger vessels are required to have brighter lights

Rule 23 – Power Driven Vessels Underway

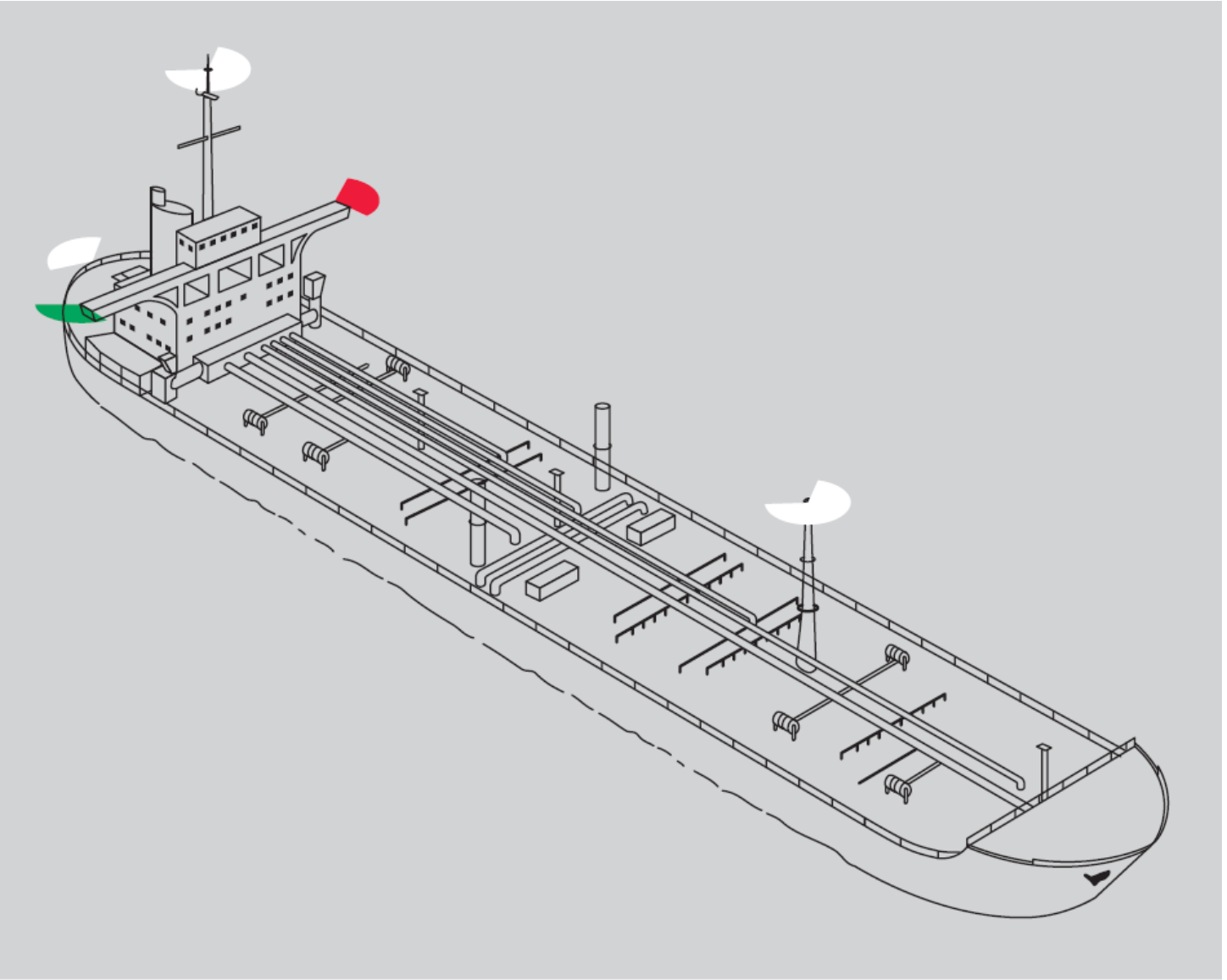
- Masthead light
- A second masthead light for vessels longer than 50m
- Sidelights
- Sternlight
- If less than 12m, can just use and all-round white light and sidelights.
- If less than 7m, can just use an all-round white light.

Navigation Rules



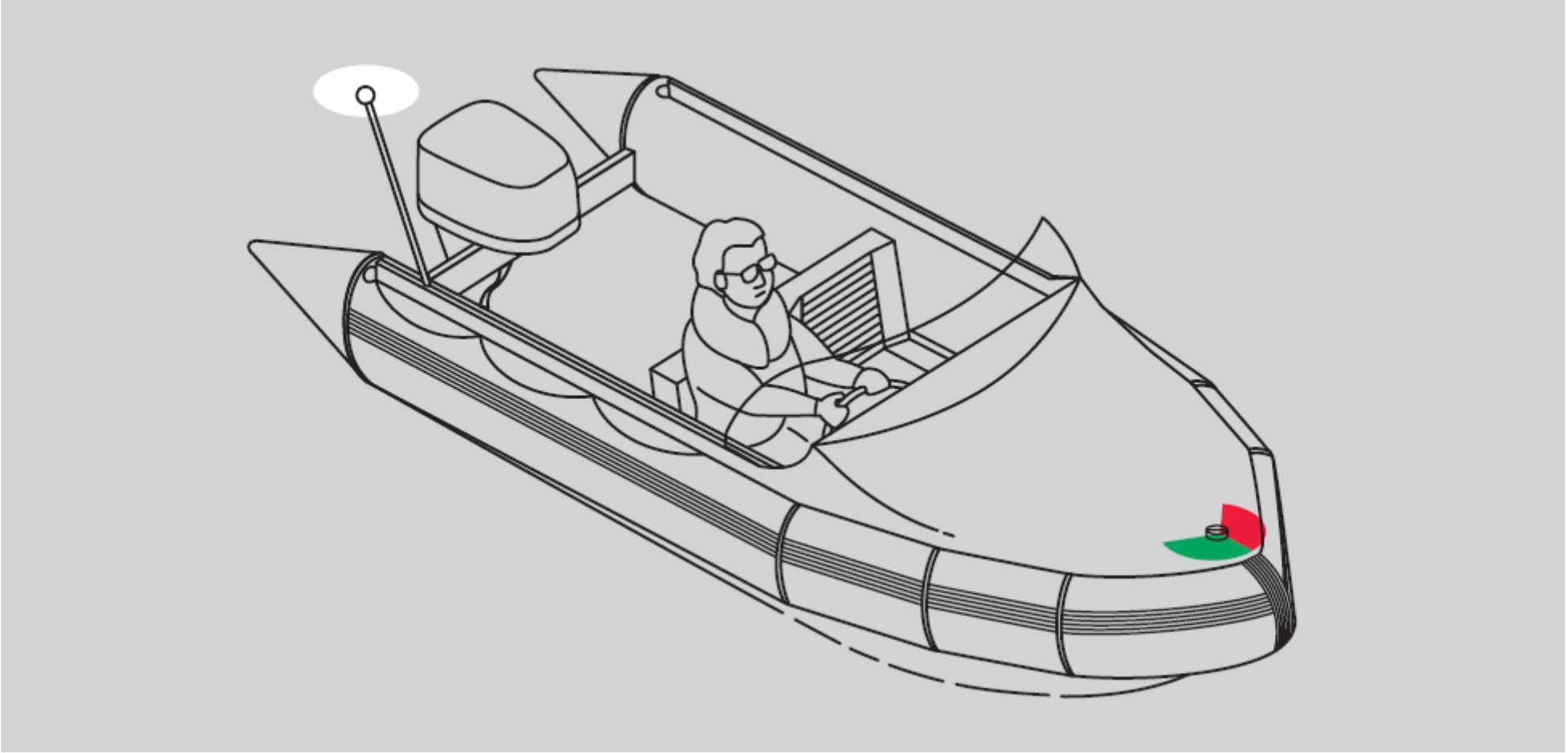
Vessel shorter than 50m: one masthead light, sidelights and a sternlight

Navigation Rules



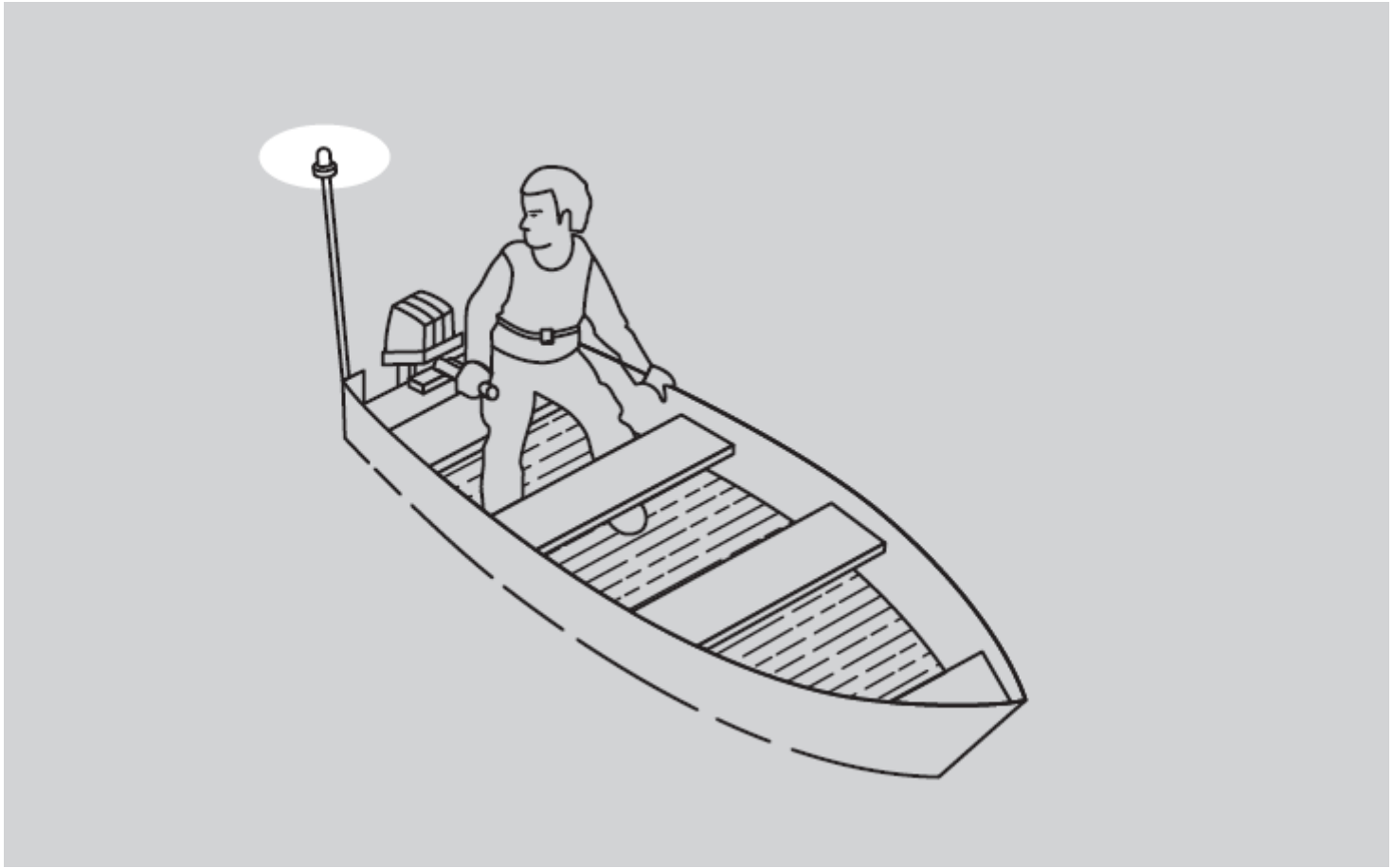
Vessel longer than 50m: two masthead lights, sidelights and a sternlight

Navigation Rules



Vessel shorter than 12m: all-around white light and sidelights

Navigation Rules



Vessel shorter than 7m: all-around white light

Navigation Rules

Rule 24 – Towing and Pushing

- Towing astern:
  - Two masthead lights in a vertical line (3 if over 200m)
  - Sidelights
  - Sternlight
  - Yellow towing light vertically above the sternlight

- Towing aside or pushing, same as above, except:
  - Inland: no sternlight, but two yellow towing lights
  - International: no yellow towing lights

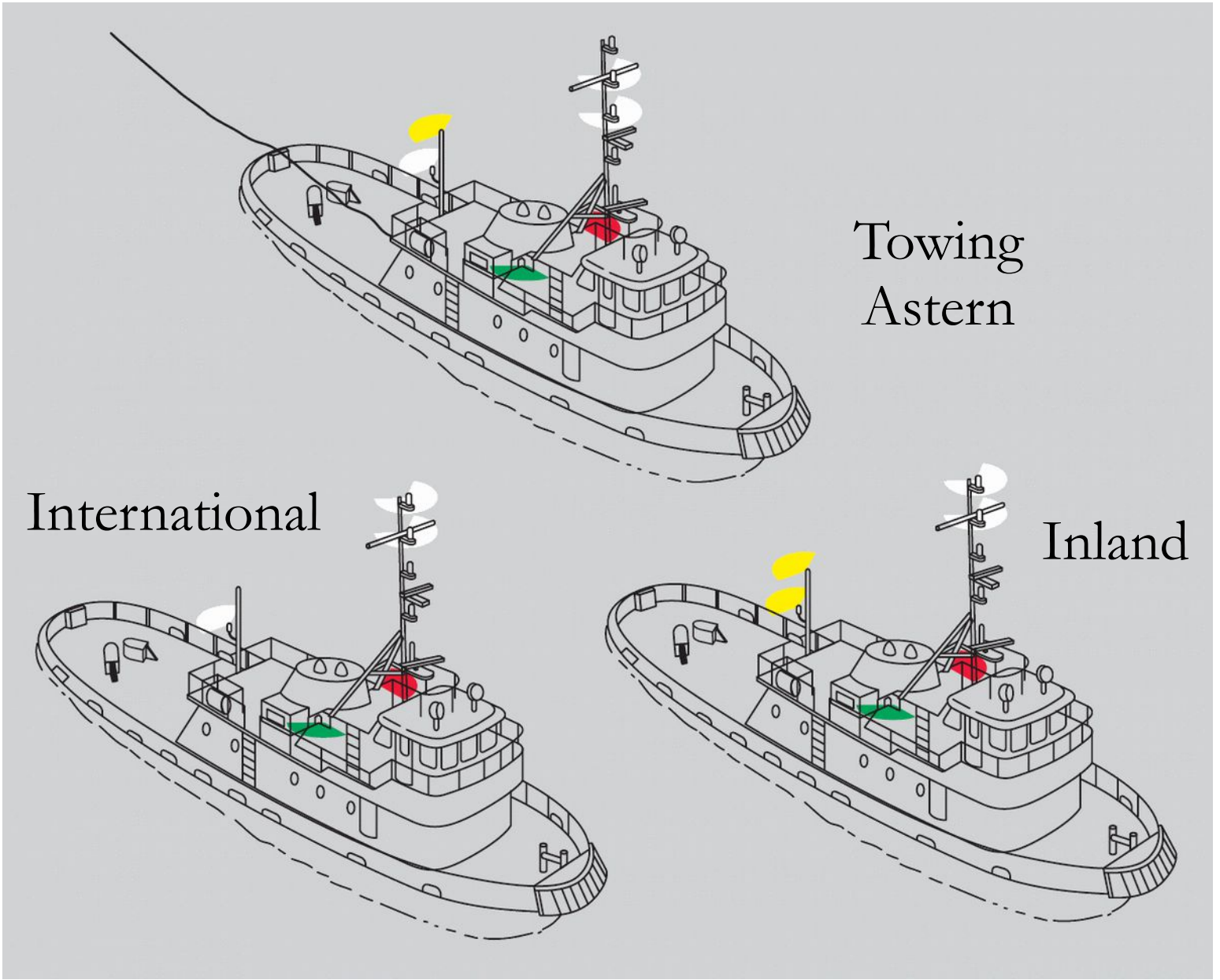
Navigation Rules

Rule 24 – Towing and Pushing

- Vessel being towed from ahead:
  - No masthead light
  - Sidelights
  - Sternlight

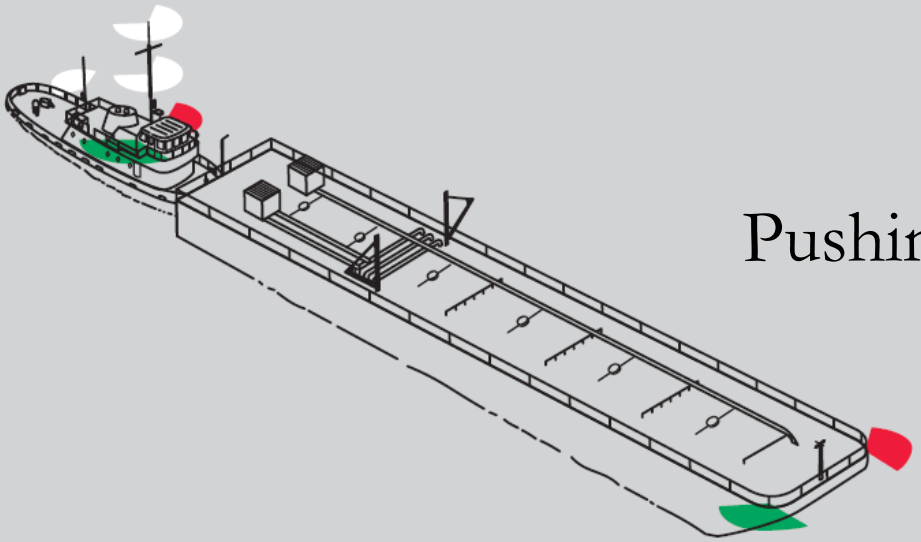
- Vessel being pushed or towed along side:
  - No masthead light
  - Sidelights
  - Sternlight
  - Special flashing yellow light at bow (Inland rules only)

Navigation Rules

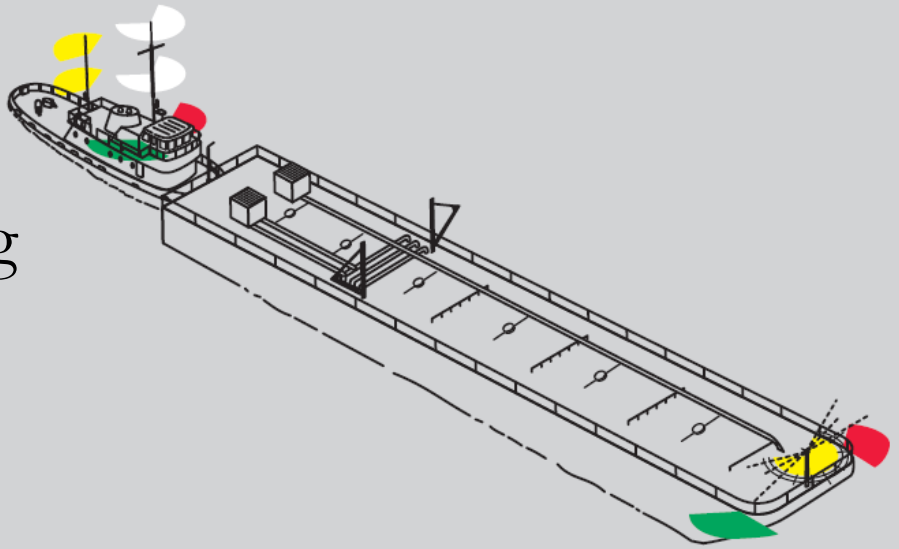


Navigation Rules

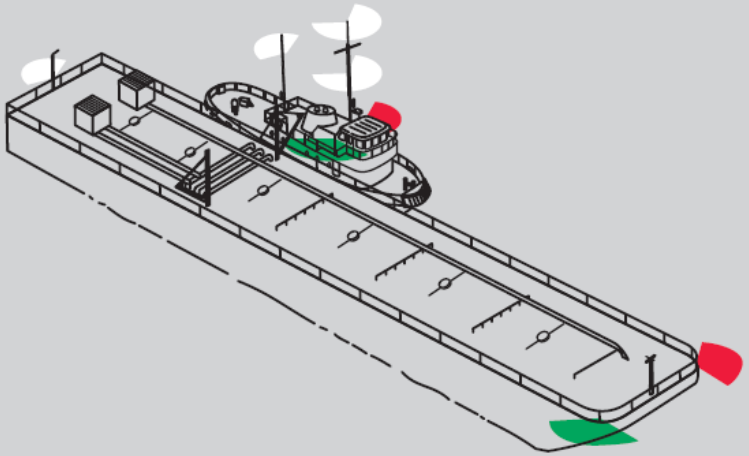
Pushing



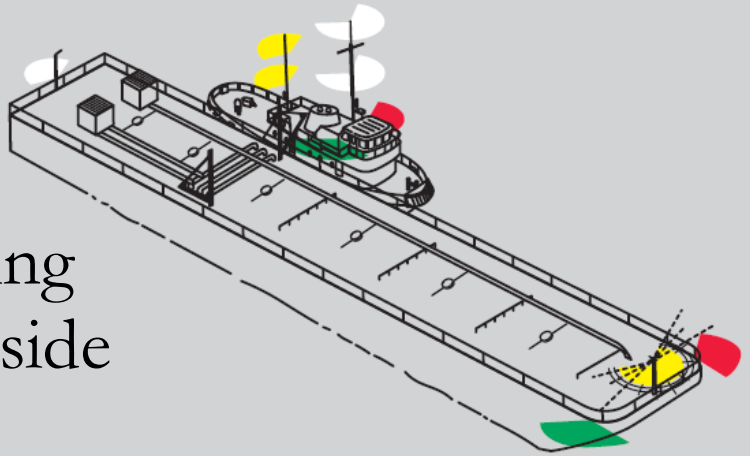
International



Inland



Towing Alongside



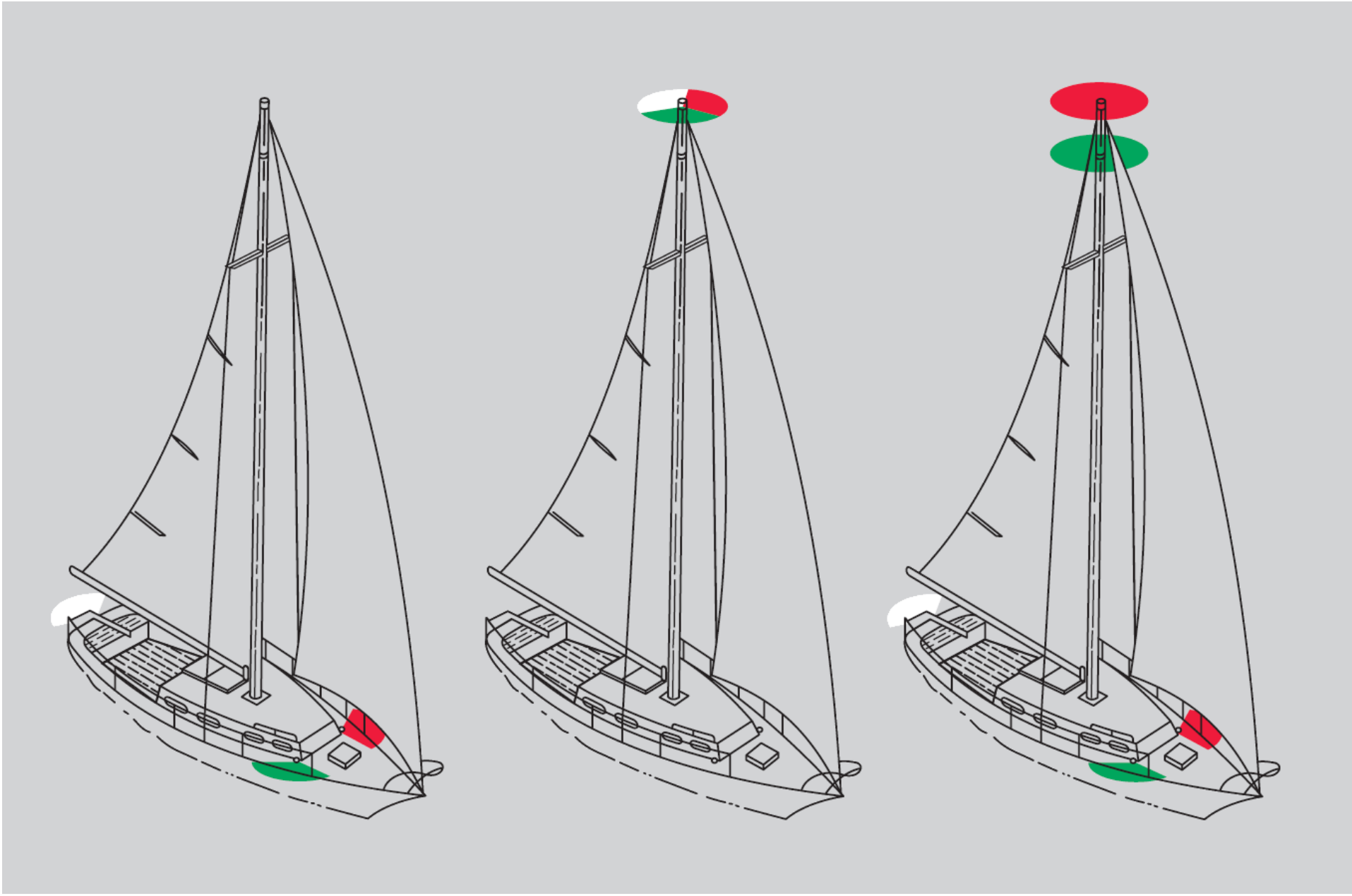
Navigation Rules

Rule 25 – Sailing Vessels Underway

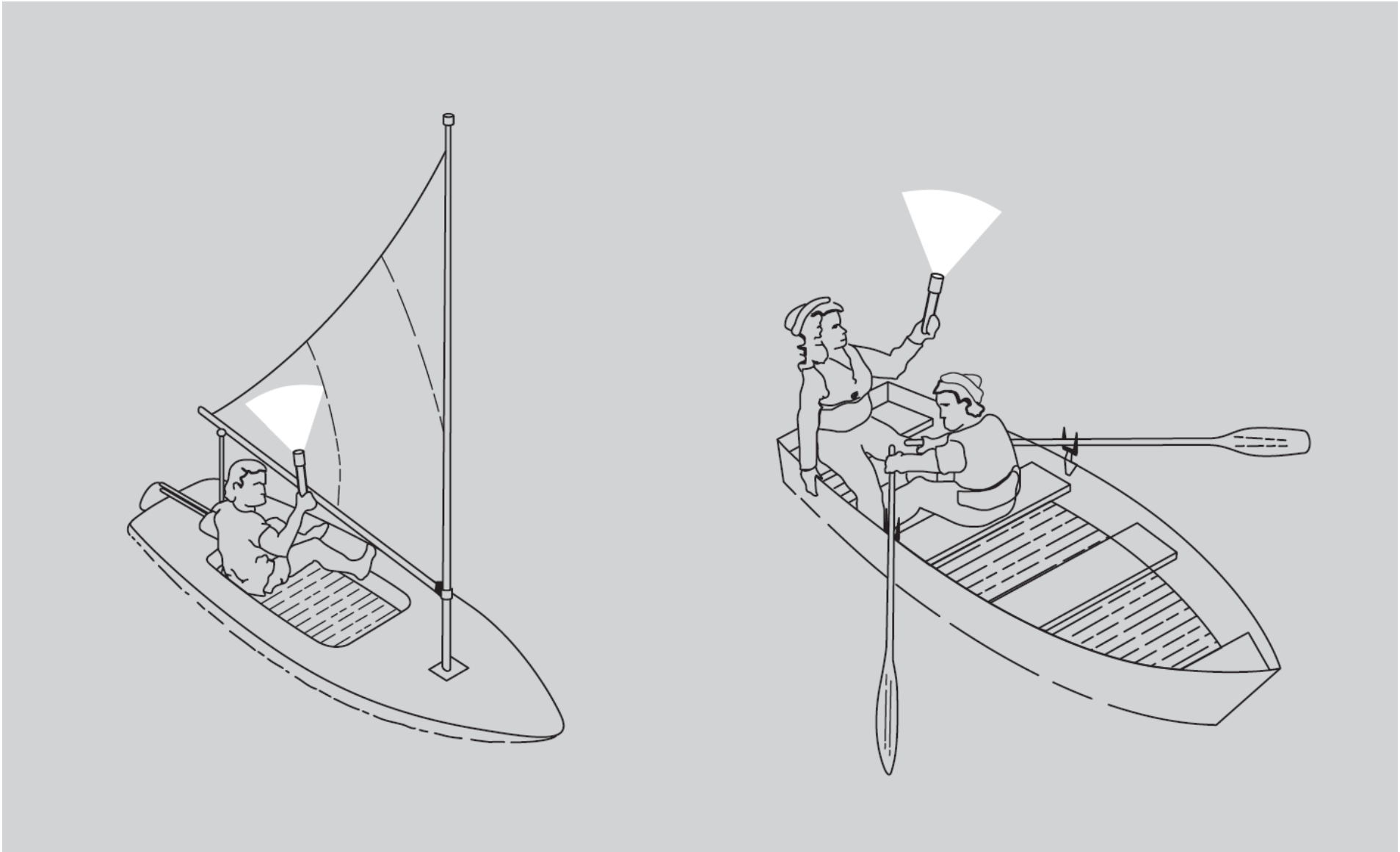
- Sailboats must have:
  - Sidelights
  - Sternlight
- The above can be replaced by a tri-color light at the top of the mast.
- Optionally, two all-round lights, red over green, can be at the top of the mast (but cannot be used with tri-color).

- Vessels under oars may have sidelights and sternlight
- Sailboats under 7m or vessels under oars can just use a flashlight.

Navigation Rules

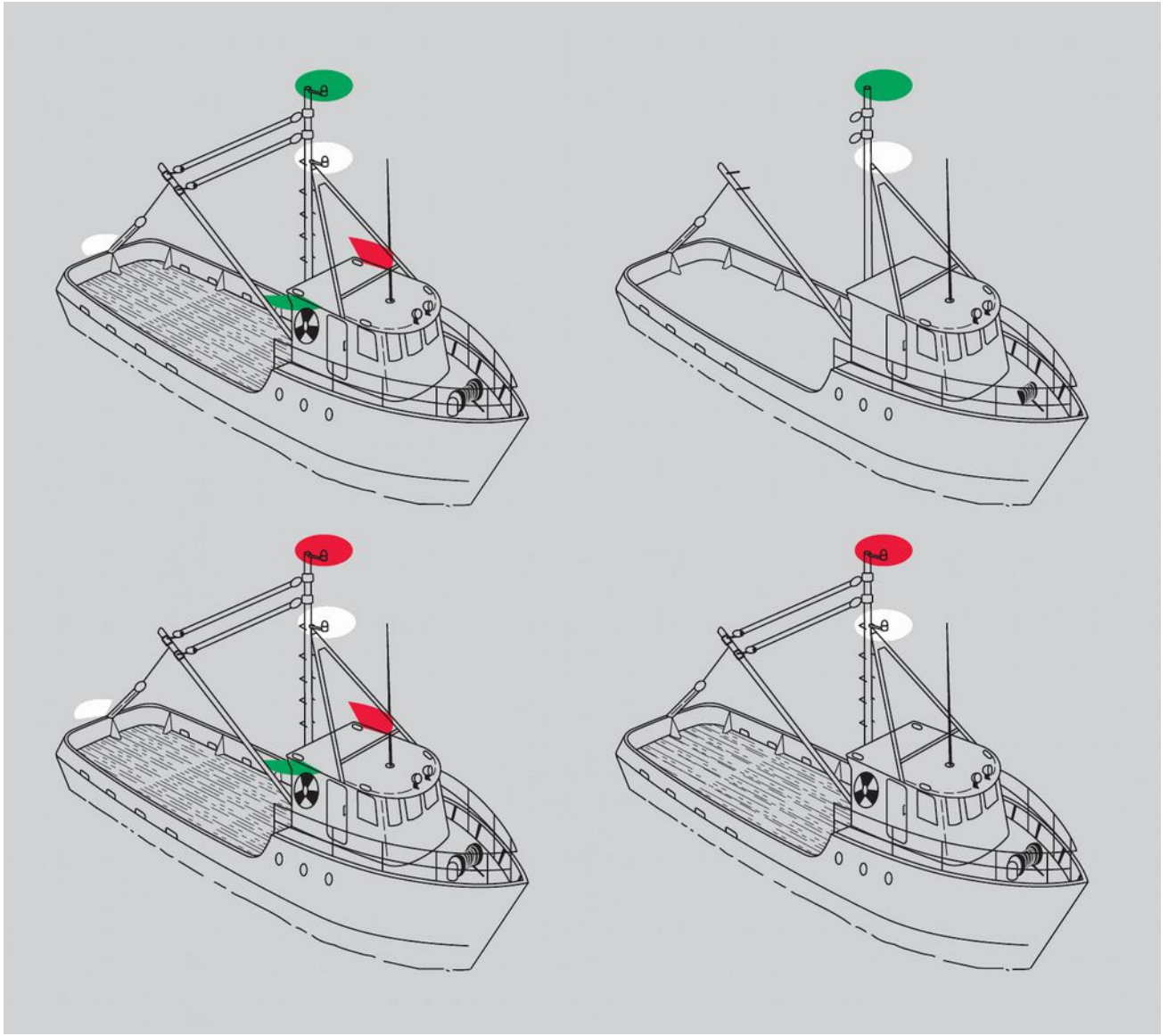


Navigation Rules



Navigation Rules

Rule 26 – Fishing Vessels

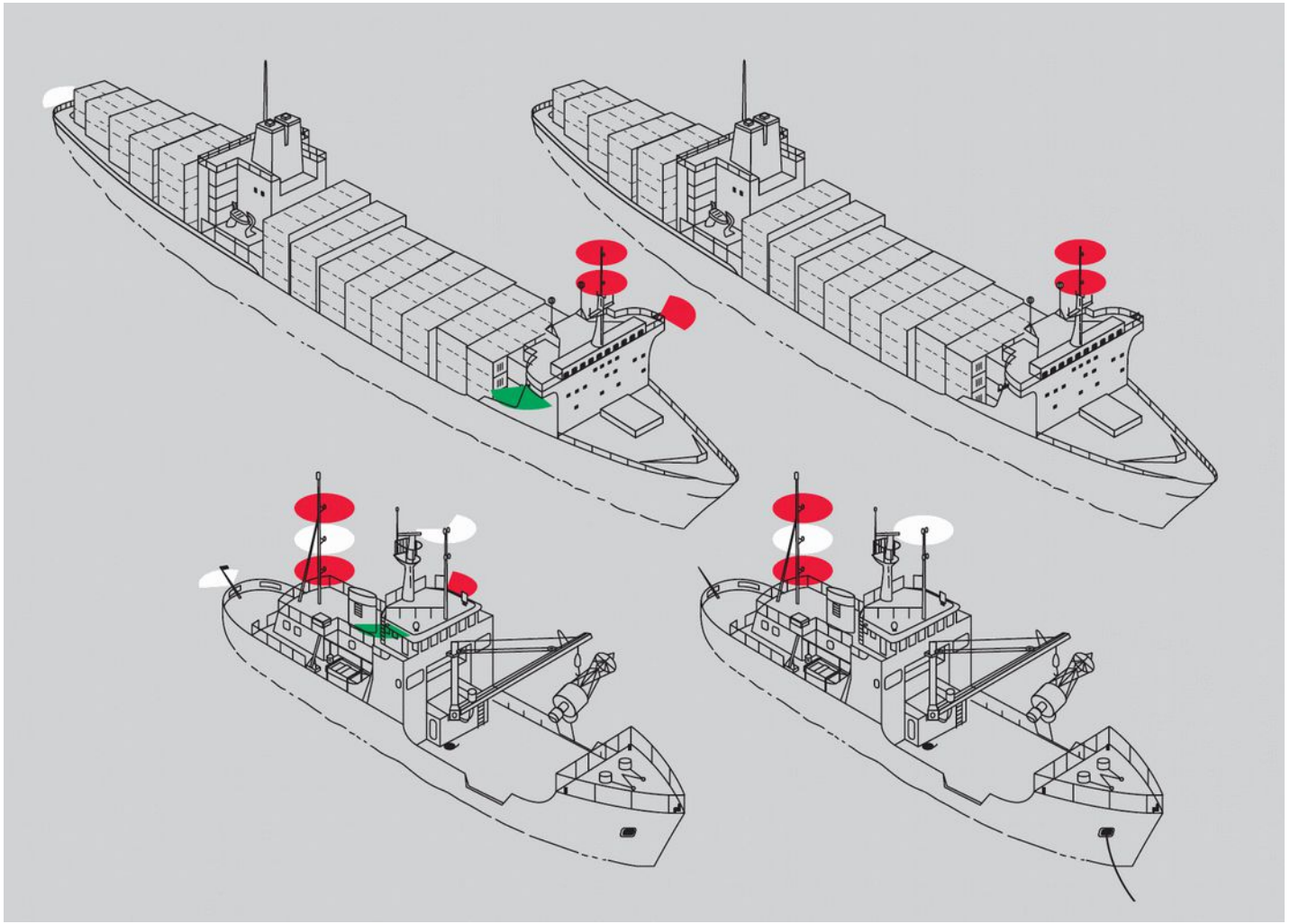


Vessels engaged in trawling (underway and not underway)

Vessels engaged in fishing other than trawling (underway and not underway)

Navigation Rules

Rule 27 – Vessels Not Under Command or Restricted in Ability to Maneuver



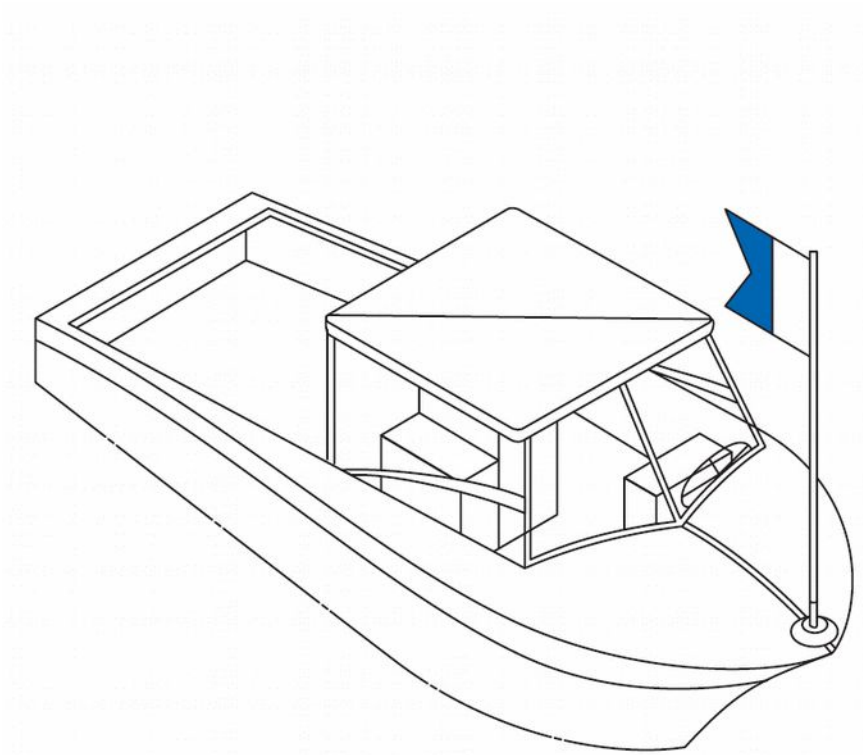
Vessels not under command (underway and not underway)

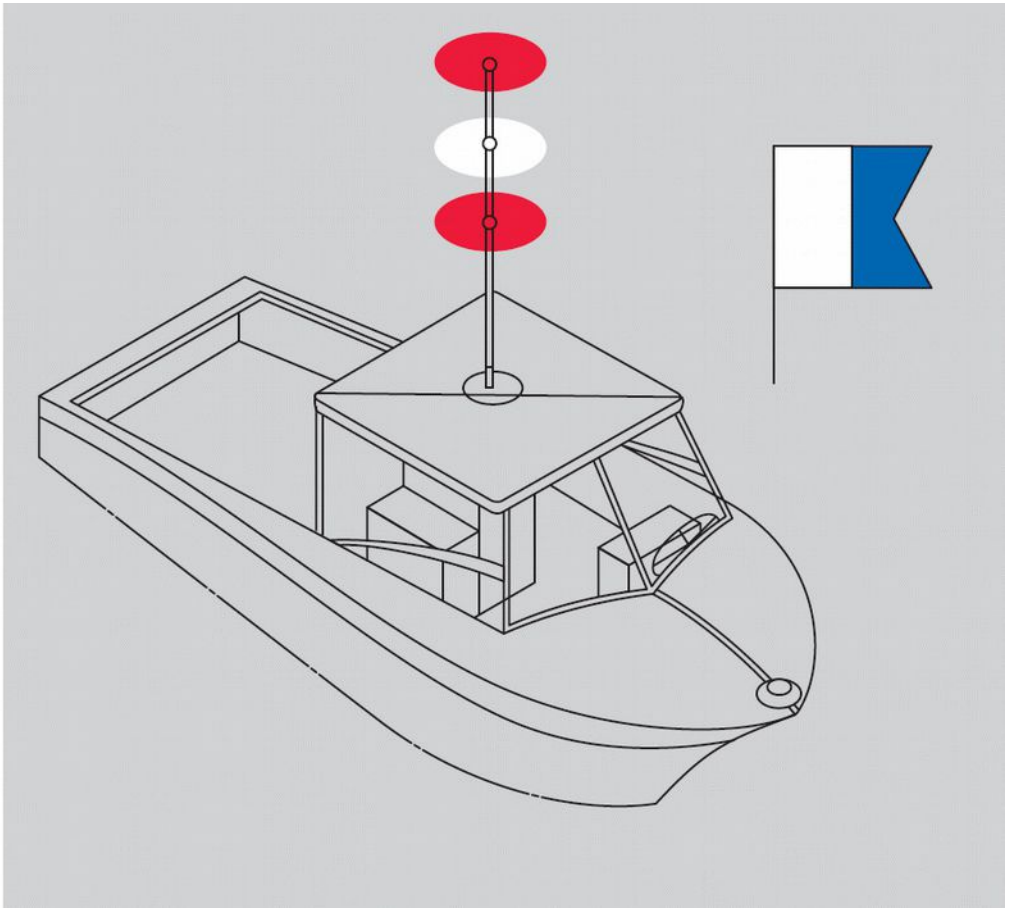
Vessels restricted in their ability to maneuver (underway and not underway)

Navigation Rules

Rule 27 – (continued)

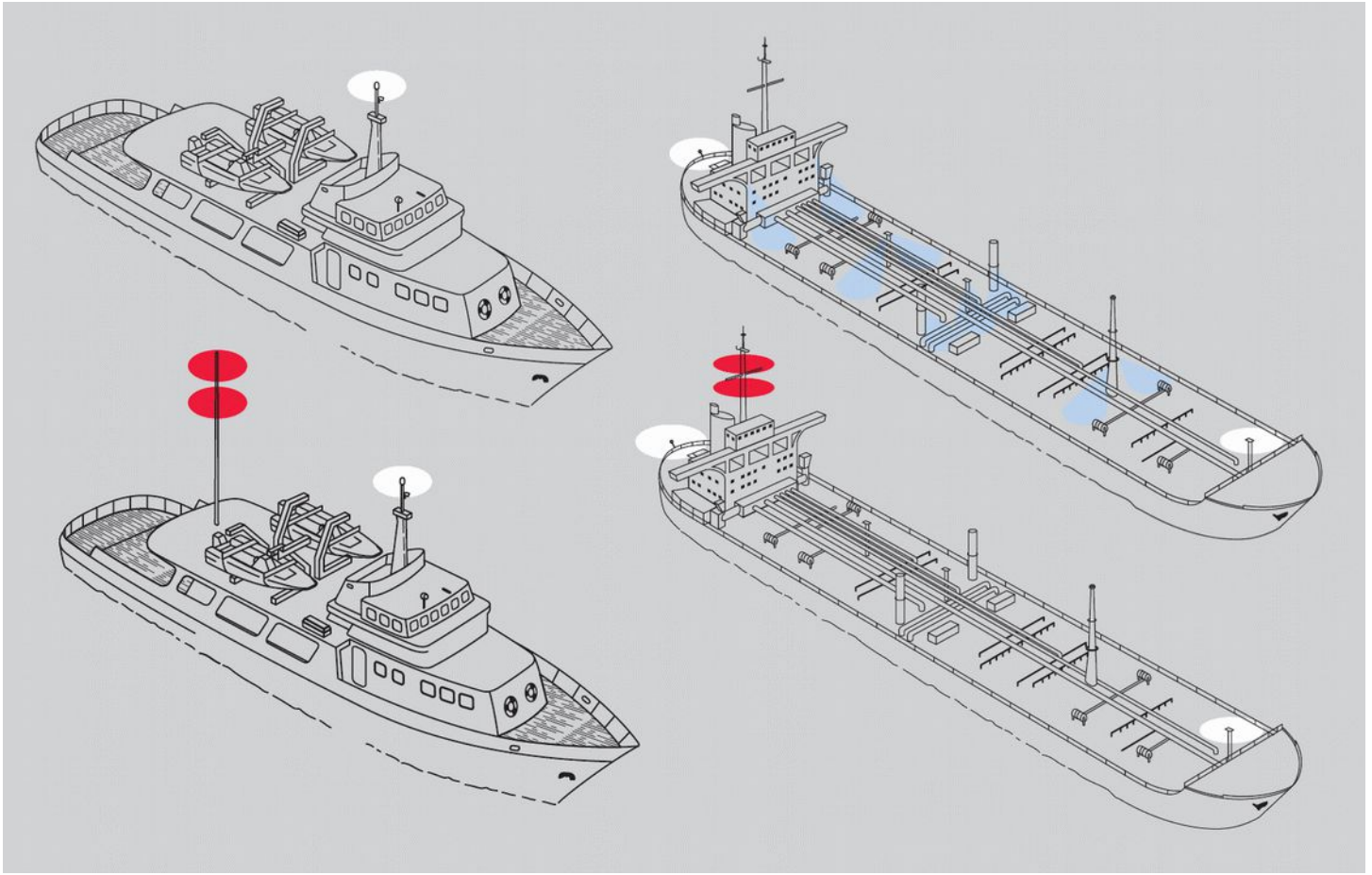
- Vessels engaged in diving operations





Navigation Rules

Rule 30 – Vessels at Anchor or Aground



Vessels at anchor (<50m and >50m)

Vessels aground (<50m and >50m)

Navigation Rules

Rule 32 – Sound & Light Signals - Definitions

- Whistle
- Short blast – 1 second
- Prolonged blast – 4 to 6 seconds

Rule 33 – Equipment for Sound Signals

- Vessel longer than 100m: whistle, bell and gong
- 12m to 100m: whistle and bell
- Shorter than 12m: some means of making an efficient sound signal

Navigation Rules

Rule 34 – Maneuvering and Warning Signals

- Inland: Head-on or crossing vessels
  - One short blast: I intend to leave you to my port side.
  - Two short blasts: I intend to leave you to my starboard side.
  - If in agreement, the other vessel will echo back the whistle blasts. If not, they will sound five or more rapid whistle blasts.
- International:
  - One short blast: I am altering my course to starboard
  - Two short blasts: I am altering my course to port

Navigation Rules

Rule 34 – Maneuvering and Warning Signals

- Inland: Overtaking:
  - Same as meeting or crossing.
- International: In a narrow channel:
  - Two long, one short blast: I intend to overtake you on your starboard side.
  - Two long, two short blasts: I intend to overtake you on your port side.
  - If in agreement, the other vessel answers back: one long, one short, one long, one short.

Navigation Rules

Rule 34 – Maneuvering and Warning Signals

- Three short blasts means I am backing up.
- At any time, if there is disagreement, confusion or danger, sound the danger signal: 5 or more rapid blasts.
- When approaching a bend in a channel or an area of obscured visibility, one prolonged blast.
- Inland only: when a power vessel is leaving a dock, one prolonged blast
- Inland only: one or two short blasts can be substituted by calling on the radio.

Navigation Rules

Rule 35 – Sound Signals in Restricted Visibility

- Power vessel making way: one prolonged blast every 2 minutes
- Power vessel underway but not making way: two prolonged blasts every 2 minutes
- Vessel not under command, restricted in ability to maneuver, engaged in towing, engaged in fishing while at anchor, or a sailboat: one prolonged and two short blasts every two minutes.
- Vessel at anchor: ring bell rapidly for 5 seconds every minute.

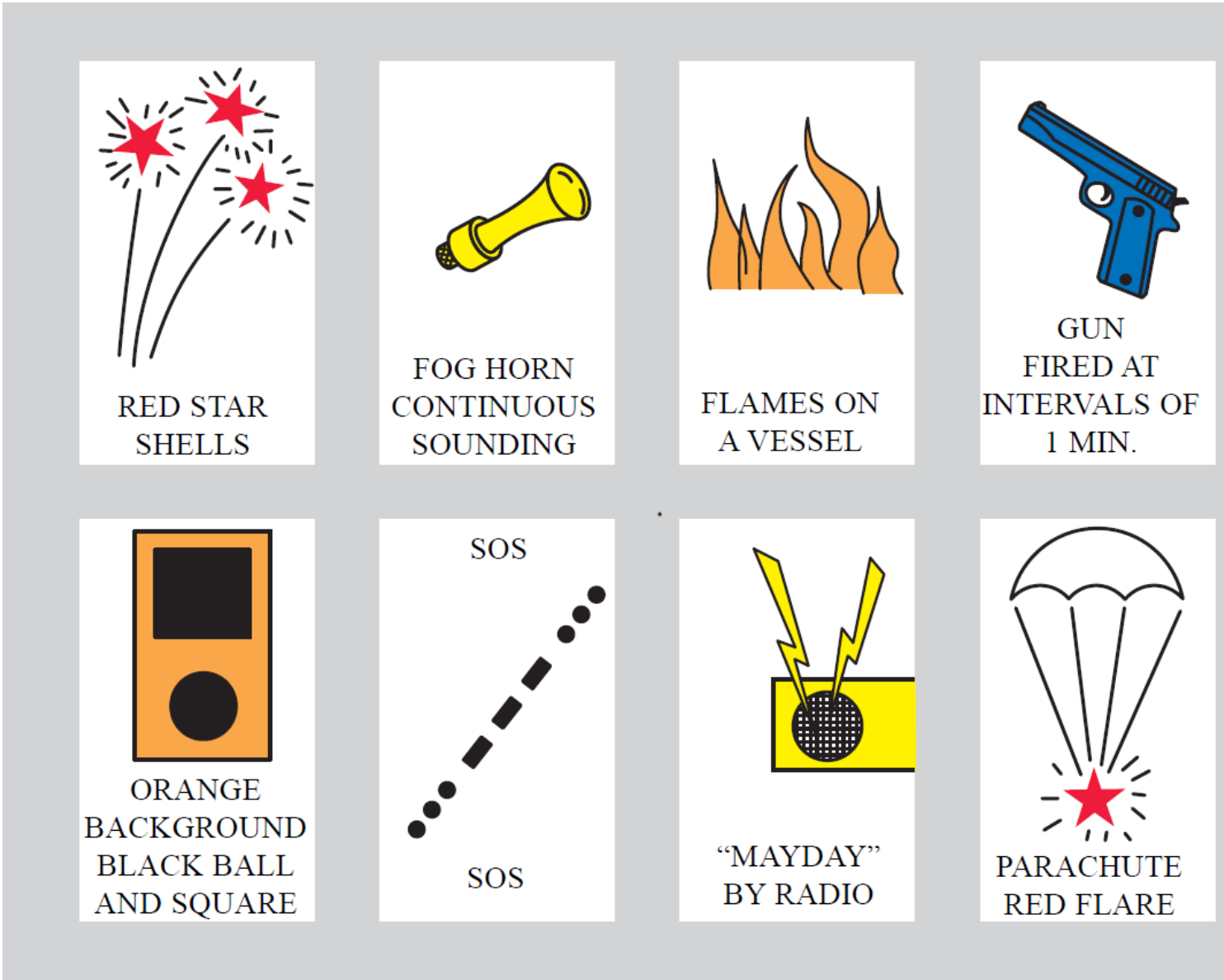
Navigation Rules

Rule 35 – Sound Signals in Restricted Visibility

- Power vessel making way: one prolonged blast every 2 minutes
- Power vessel underway but not making way: two prolonged blasts every 2 minutes
- Vessel not under command, restricted in ability to maneuver, engaged in towing, engaged in fishing while at anchor, or a sailboat: one prolonged and two short blasts every two minutes.
- Vessel at anchor: ring bell rapidly for 5 seconds every minute.

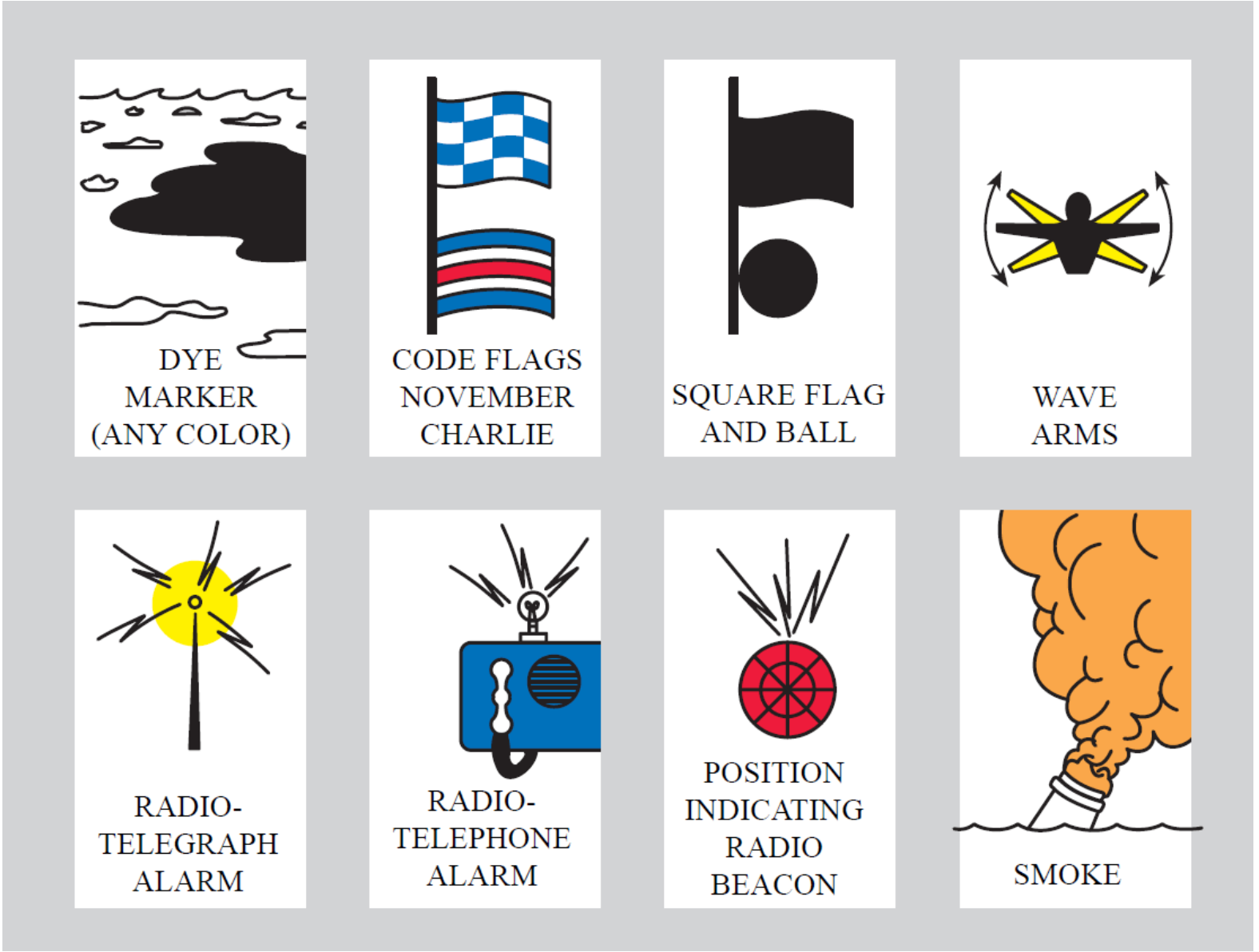
Navigation Rules

Rule 37 – Distress Signals



Navigation Rules

Rule 37 – Distress Signals



Satellite Navigation

Satellite Navigation

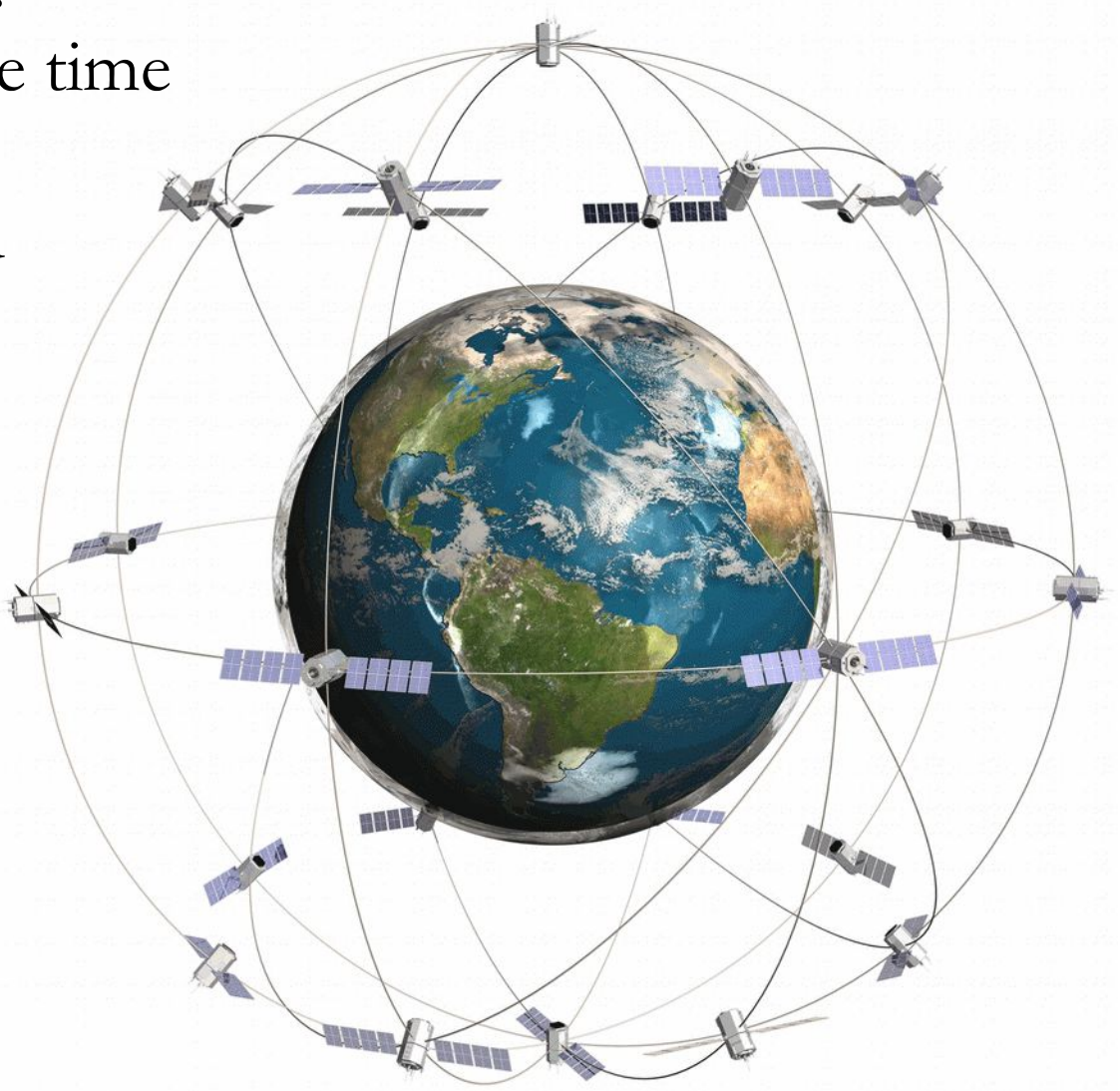
Global Positioning System (GPS)

- Built by the U.S. Government and maintained by the U.S. Department of Defense.
- Originally conceived as a military system; now considered a "dual-use" system (military and civilian).
- First satellite launched in 1978.
- Ten more satellites launched by 1985.
- First consumer hand-held receivers sold in 1989.
- Used heavily in the first Gulf War (1990-1991).
- Declared to be fully operational in April 1995.
- "Selective Availability" disabled in May 2000.

Satellite Navigation

Global Positioning System (GPS)

- System of 24+ satellites.
- Satellites transmit precise time and position data.
- Receivers on Earth need data from four satellites.
- Receivers triangulate their positions.
- Accurate to ±10m.
- Works anywhere on Earth in any weather.



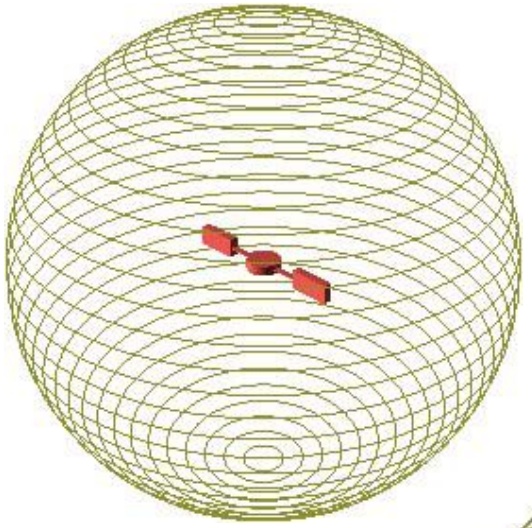
Satellite Navigation

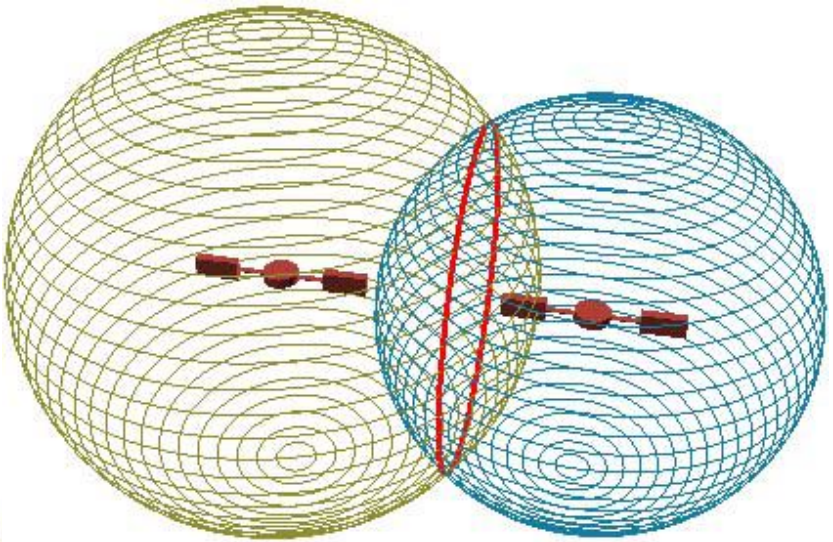
Global Positioning System (GPS)

- Satellites transmit very accurate time and position data.
- Radio signals travel at the speed of light: 299,792,458 m/s.
- If you know how long it takes the signal to reach you, you know exactly how far away the satellite is.
- If you know how far away three satellites are, you can determine your 2D position on the earth.
- If you know how far away four satellites are, you can determine your 3D position on the earth.

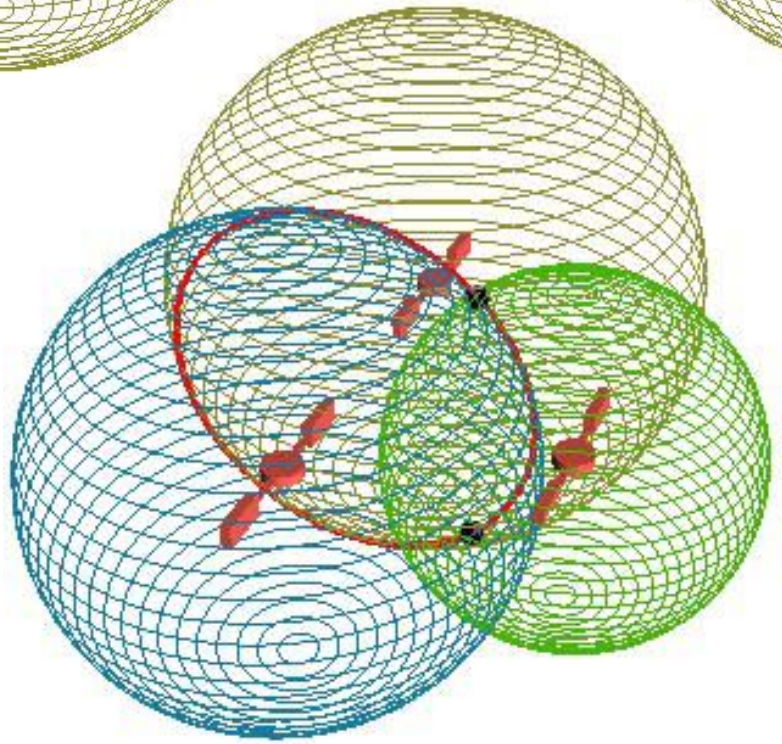
Satellite Navigation

One sphere of position.





Two spheres of position create a circle of position.



Three spheres of position reduce to two points.

Satellite Navigation

Sources of GPS Position Error

- Signal arrival time measurement: ±10 nS → ±3m
- Atmospheric effects: ±5m
- Ephemeris errors (satellite position): ±2.5m
- Satellite clock errors: ±2m

Accuracy is better than 10m 95% of the time.

Satellite Navigation

GPS Accuracy Enhancement

- Differential GPS (DGPS)
  - Uses reference stations on land with known positions.
  - Reference station determines difference between its true position and the calculated GPS position.
  - The error information is transmitted to GPS receivers which combine it with their own GPS data to provide a more precise location.
  - Accuracy can be 1-5m.
  - The accuracy decreases with distance from the reference station. Range is about 200 km.

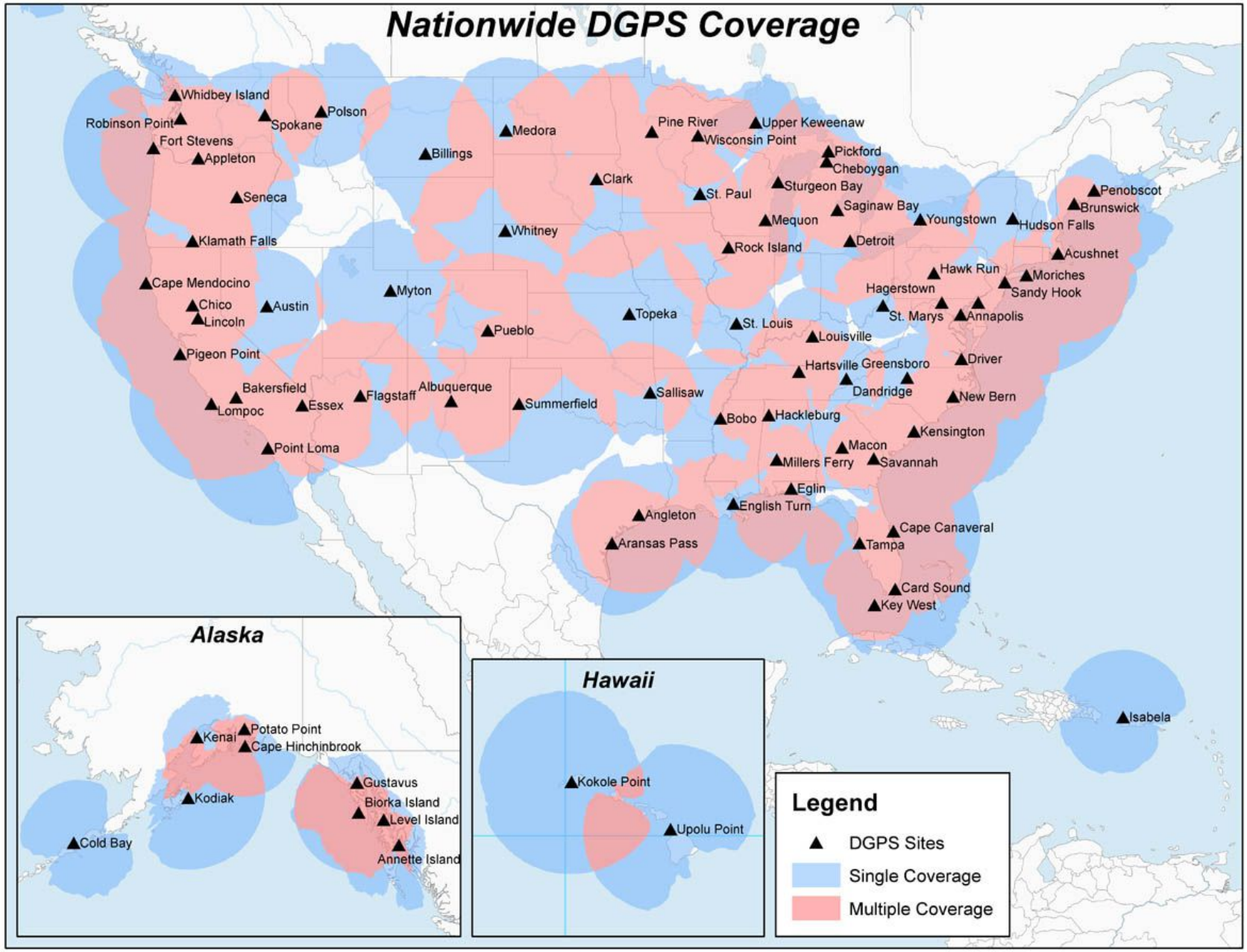
Satellite Navigation

GPS Accuracy Enhancement

- Differential GPS (DGPS)
  - The U.S. operates about 80 reference stations:
    - US Coast Guard (Maritime)
    - US Army Corp Engineers (Rivers)
    - NDGPS (Inland)

  - Canadian DGPS
  - European DGPS Network
  - 47 countries around the world operate DGPS systems

Satellite Navigation



Satellite Navigation

GPS Accuracy Enhancement

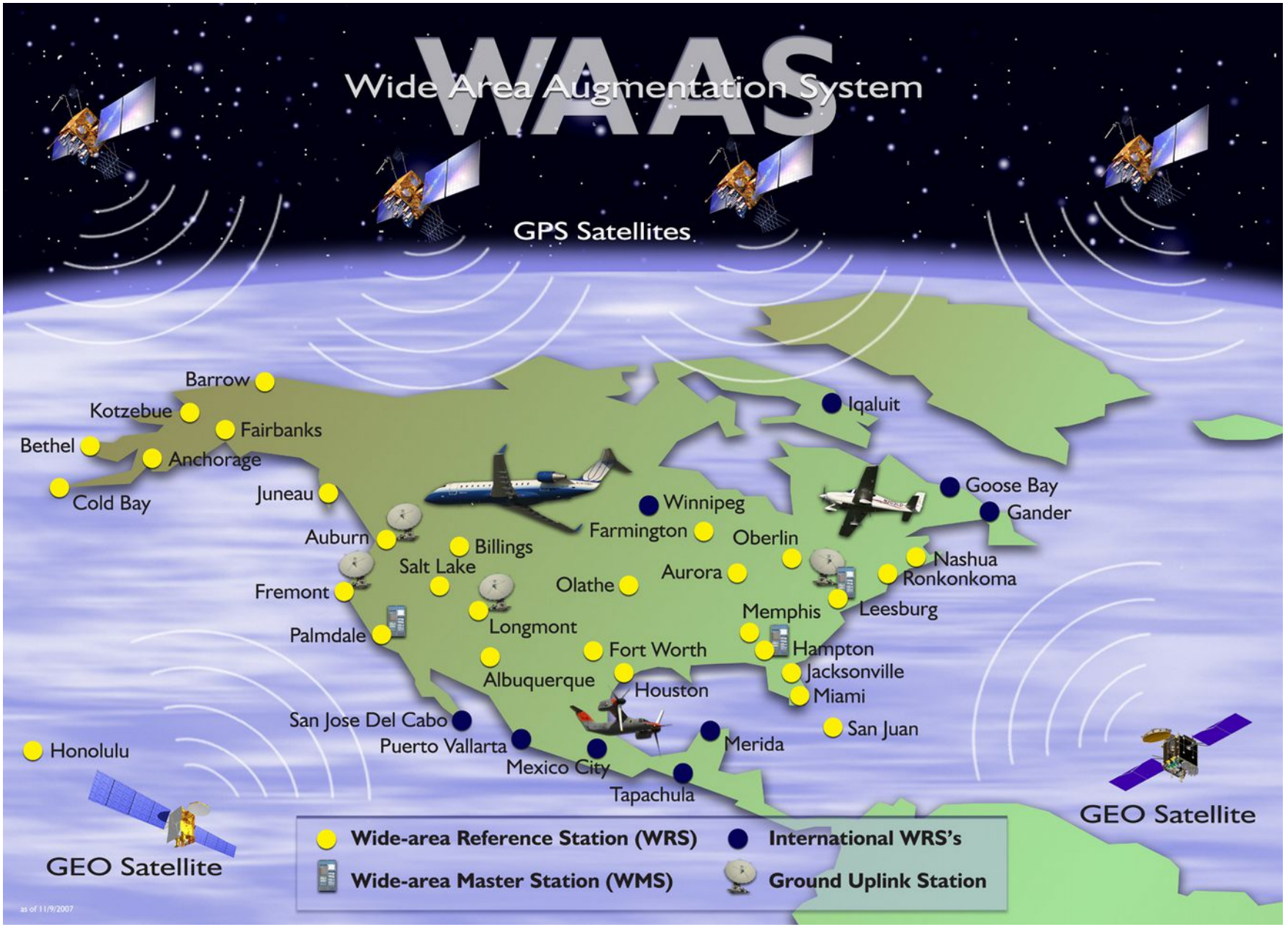
- Differential GPS (DGPS)
  - Transmits at 283-325 kHz
  - Requires a separate receiver and antenna from GPS
  - Some products have DGPS integrated into their GPS receivers.

Satellite Navigation

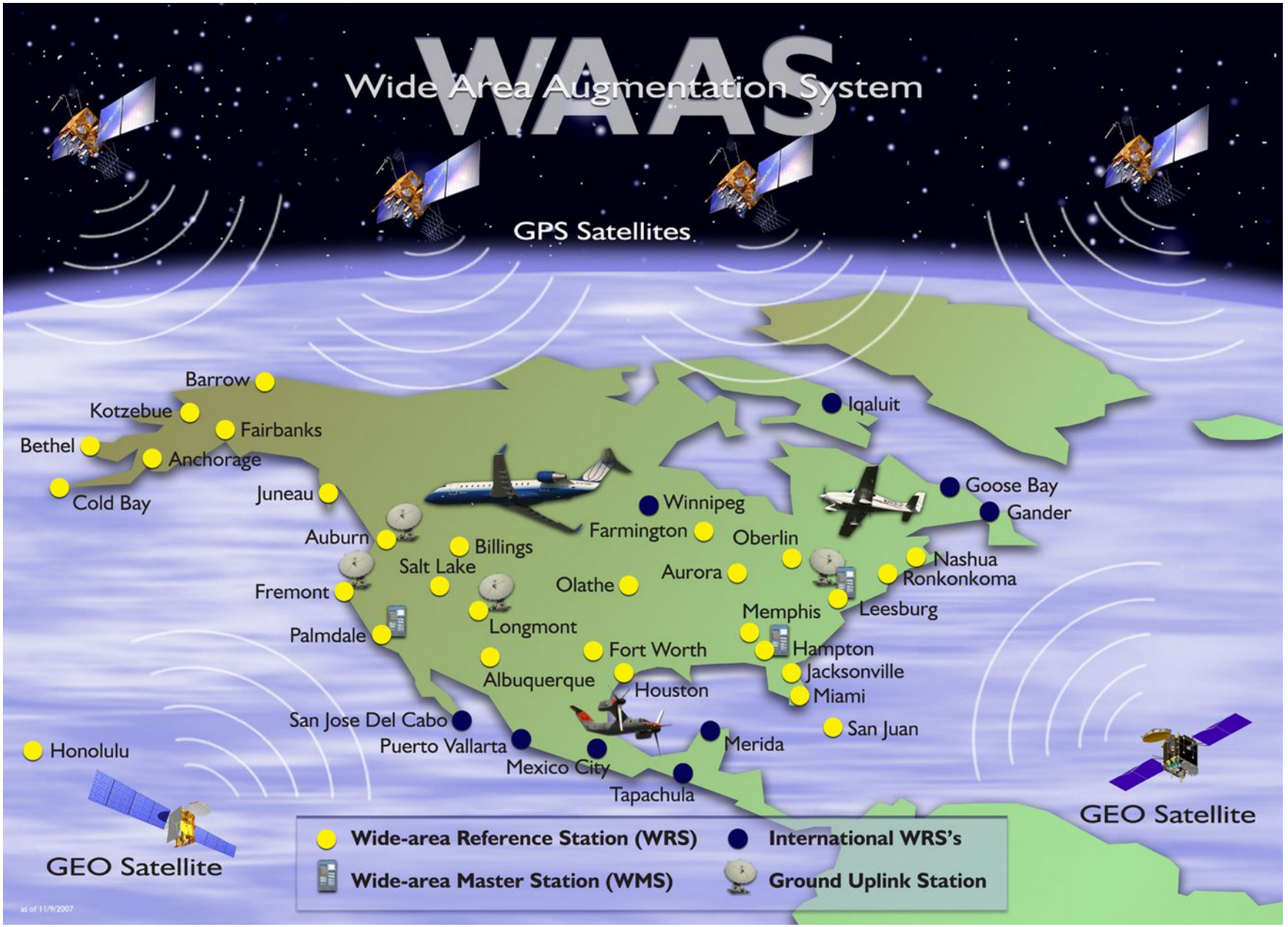
GPS Accuracy Enhancement

- Wide Area Augmentation System (WAAS)
  - Similar to DGPS.
  - Developed by the FAA for aircraft.
  - Uses a network of ground-based reference stations.
  - The correction data is then sent to geostationary satellites.
  - The satellites transmit the error corrections on the same frequency as GPS.
  - Typical accuracy is 2-3m.

Satellite Navigation

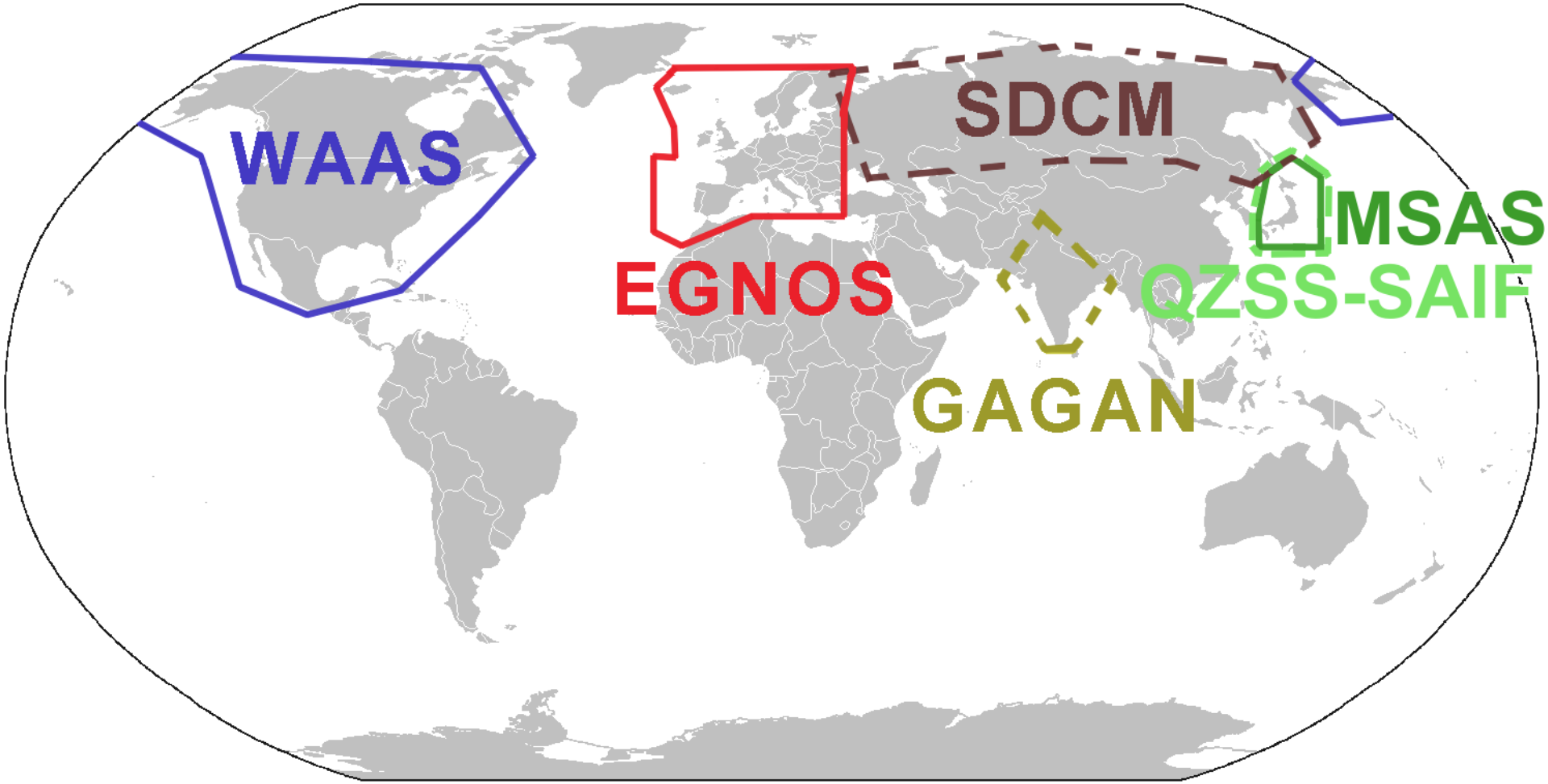


Satellite Navigation



Satellite Navigation

Satellite Based Augmentation Systems (SBAS)



Satellite Navigation

Other Global Navigation Satellite Systems

- GLONASS – Soviet/Russian System (since 1995)
- Galileo – European (2017-2020)
- BeiDou – Chinese System (2012-2020)
- IRNSS – Indian System (2016)

Satellite Navigation

GPS Chartplotters

- Portable vs. fixed
- Internal vs. external antenna.
- Different chart options.
- Navigation features (i.e. VMG?)

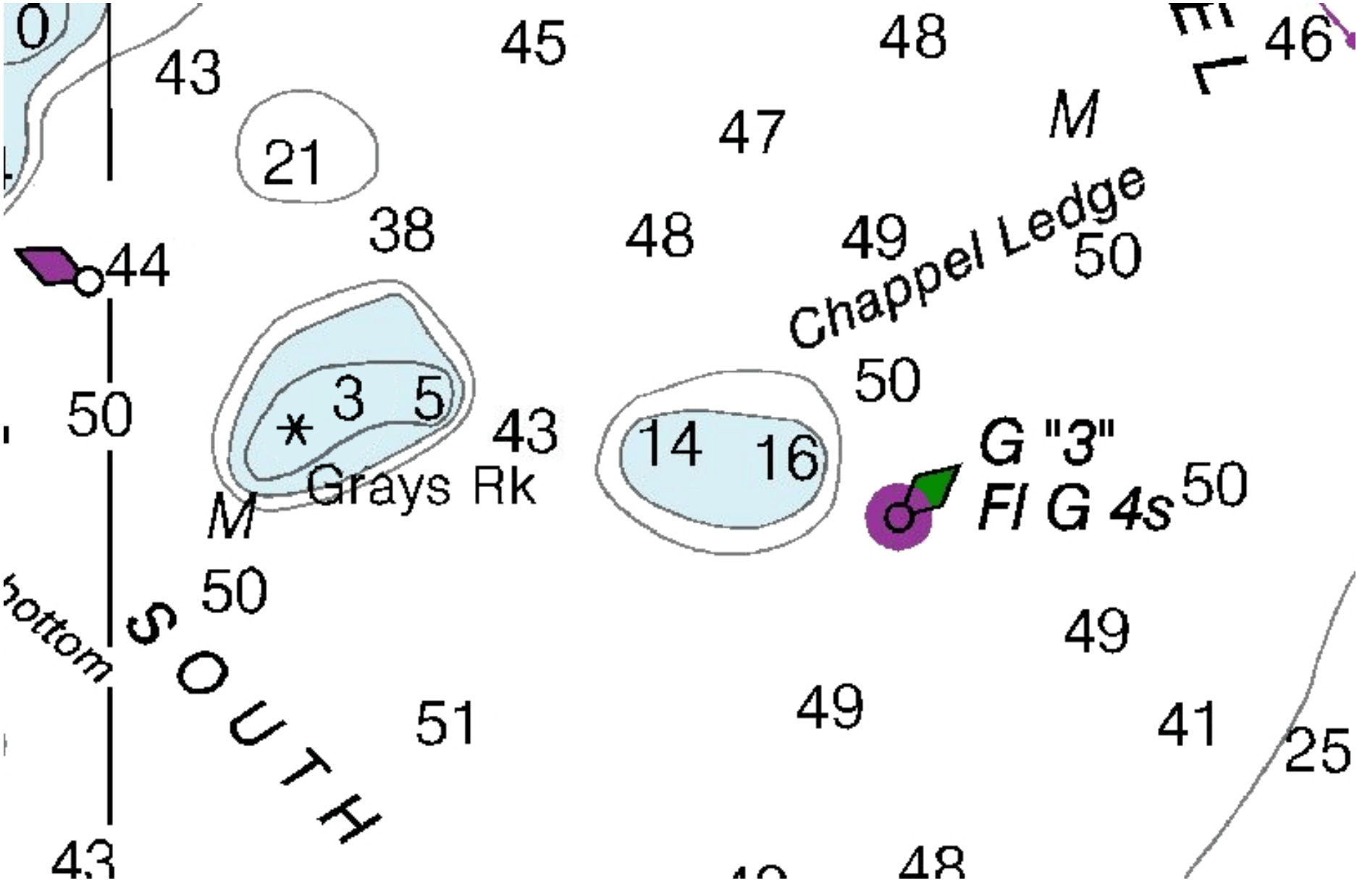
Satellite Navigation

GPS Chartplotters

- Interface with other devices
  - Depth sounder
  - Wind instruments
  - Electronic compass
  - VHF radio (DSC)
  - AIS
- NMEA-0183 vs. NMEA-2000

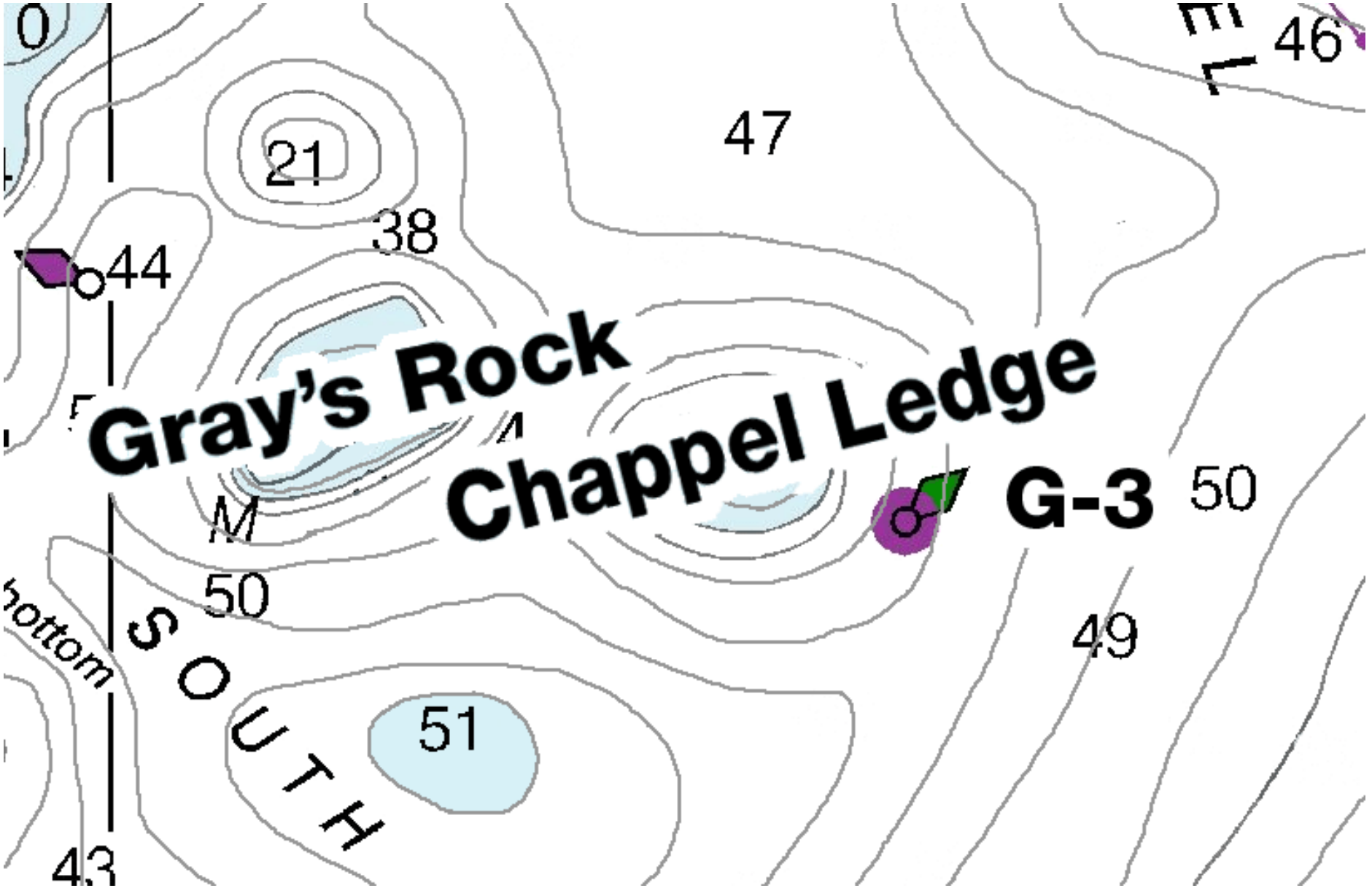
Satellite Navigation

GPS Chartplotters



Satellite Navigation

GPS Chartplotters



AIS

Automatic Identification System

- Tracking system for ships.
- Transmitters required on large commercial vessels.
- Digital data transmitted on VHF radio frequencies.
- Includes data about the vessel:
  - Name of vessel
  - Length and width
  - Latitude and longitude
  - Heading
  - Speed
  - Destination
  - Type of vessel
  - et al.

AIS

Automatic Identification System

- Transceivers receive data from other ships.
- They re-broadcast that data along with their own.
- Transceivers are also being placed on aids to navigation.
- Range is limited by VHF frequencies: 10-20 nm.

- AIS units can have integrated displays, or can connect to a chartplotter.
- Chartplotters may have software to predict collisions with nearby ships.

Online Resources

http://navcen.uscg.gov/
http://tidesandcurrents.noaa.gov/
http://mailman.mit.edu/mailman/listinfo/bluewater

Further Reading

Chapman Piloting and Seamanship
By Jonathan Eaton
Annapolis Book of Seamanship
By John Rousmaniere
Piloting and Dead Reckoning
By Capt. H.H. Shufeldt and G.D. Dunlap
American Practical Navigator (BOWDITCH)
https://msi.nga.mil/NGAPortal/MSI.portal