# *Don't Even Sink About It!*

**Lesson Time :** 90 minutes
**Grade Level :** 9-12
**Vocabulary:** mass, acceleration, gravity, matter, displacement, draft, deadweight, tonnage

**Summary**

Does a can of soda float? Does salt water really make that much difference? What's a Plimsoll mark? Buoyancy can be a difficult concept for students. It's all about density! With this hands-on introduction to teaching buoyancy, students work through activities and demonstrations that use online resources and ocean observing systems data to investigate the buoyancy considerations of commercial shipping.

**Objectives**

- Identify factors that affect the ability of an object to float.
- Explain the relationship between buoyancy and density.
- Describe the role of salinity and temperature in water density.
- Define the attributes by which cargo ships are classified.
- Evaluate real-time and archived water depth data.

**Introduction**

Why do we wear PFDs (personal flotation devices, also known as life jackets) when we ride on a boat? How is a ship weighing 647,995 tons when fully loaded with petroleum, able to float with no problem? It all has to do with buoyancy.

Buoyancy is the upward force exerted on an object by the surrounding fluid (in most cases, water) in which the object is immersed.

Buoyancy acts against the force of gravity. If the density of the object is greater than that of the surrounding fluid, the object sinks. If the densities are equal, the object is neutrally buoyant and hovers in the fluid. If the density of the object is less than that of the surrounding fluid, the object floats.

So, although the human body can typically float in water because of the air in the lungs, a person wearing a properly-fitting, well-maintained PFD, the density of which is extremely low, is practically guaranteed to float.

Density is defined as the mass per unit volume of an object (D = M / V). Remember that mass is not the same as weight. A small but heavy object, such as a lead fishing sinker, is denser than a lighter object of the same size, such as a cork. The same holds for a bowling ball vs. a soccer ball. Both are relatively the same size, however, the bowling ball has much more matter. Mass is how much matter is in an object and is measured in kilograms (kg). Weight is the size of the gravitational pull on an object, and is measured in units of force, such as (kg•m/s2), which is usually simplified to just kg. Weight is calculated by multiplying mass and acceleration due to gravity.

Different fluids have different densities. Since oil is less dense than water it floats on water.

The density of fluid is affected by several variables, including temperature and salinity. As fluid temperature increases, its density decreases. Conversely, as fluid's salinity increases, so does its density. Therefore, colder salt water will sink below warmer, freshwater. Because saltwater is denser (1025 kg/m3) than fresh (1000 kg/m3), objects, including humans, are better able to float in saltwater.

So how exactly does a huge cargo ship stay positively buoyant, even when fully loaded? The key is to ensure that the volume of the ship is large enough to displace the mass of the ship. In the 3rd century BC, the Greek mathematician Archimedes realized that when he got into his bathtub, his body displaced the water making it rise and spill out of the tub. His discovery led to two laws of buoyancy that are still the basis of today's shipbuilding. His first law states that any floating object displaces a volume of water whose mass is equal to the mass of the object. The second law describes the effect a boat's shape has on how well it floats.

In addition to its shape, another important component of a commercial ship is the Plimsoll mark. Named for Samuel Plimsoll, these markings are not only painted, but permanently welded mid-ship onto both sides of a ship's hull. This important visual cue helps ensure the ship is loaded evenly and not overloaded for the water conditions through which the ship will be sailing. Safety is the main premise behind the Plimsoll mark.

The Plimsoll mark is very easy to use and effective in keeping ships and their crews safe. A ship is loaded according to the type of water in which it is being loaded. If loaded until the water line reaches the appropriate Plimsoll line, it can safely travel through all of the different densities of water on the planet! If the ship is loaded beyond the correct line, its chances of a safe voyage are lessened. For example, if a ship in Norfolk, VA is loaded in January to the "F" line and travels to the much warmer (and thus, less dense) waters of Puerto Limon, Costa Rica, the ship will be floating dangerously low; whereas, if the ship is properly loaded to the "W" line, it will maintain a safe floating height when it sails into the southwest Caribbean.

## Data Activity

### *A. Investigating Ship Attributes*

So how are giant cargo ships able to float? First, we need to explore how big these ships really are.

Ships can be classified in several different ways according to their different attributes, including their: volume, length, draft (amount of ship below the water line) and cargo capacity. Cargo capacity is typically measured in TEUs, or twenty-foot equivalent units, which represents the number of 20-foot containers a ship can hold.

To explore these attributes, let's look at them using a cargo ship that is infamous among oceanographers, the M/V (motor vessel) Ocean Hope, formerly the M/V Hansa Carrier. In 1990, the Hansa Carrier encountered rough seas in the Pacific Ocean on its way from Korea to the United States and lost 21 of its 40-foot containers. Loaded in 5 of these containers were Nike shoes – over 80,000 of them – which subsequently contributed to an unplanned oceanography experiment that is still active today.

- Use Figures 1a and b to fill in Table 1.

***B. Understanding the Plimsoll Mark***

Using the information learned above, fill in the Plimsoll mark worksheet and answer the following questions.

1. In terms of density, why would a ship float lower in "T" water than in "W" water?
2. The ship in Figure 2 is being loaded in Philadelphia, PA (fresh water) for its trip to Miami, FL, has it been overloaded with cargo? How do you know?

Use Figures 3a-c to answer the following questions.

1. The ship in Figure 3a just left port (tropical freshwater) after being loaded with cargo, why will the captain's boss be upset with him? Why is this a potentially dangerous situation?
2. What is wrong with the ship in Figure 3b? Can you offer some suggestions as to why this happened?
3. What is the problem in Figure 3c? How can it be fixed?

***C. Hindcasting (evaluating archived data) Accessibility of the York River, VA by the M/V Ocean Hope***

The *M/V Ocean Hope* does not sail in the York River, but this vessel serves as a good example of a typical large ocean-going vessel, so we will use it in the following activities. Using archived data sets from the VIMS NOMAD buoy, located at the mouth of the York River, you will determine whether the river is deep enough for the M/V Ocean Hope to enter and deliver its cargo. The NOMAD buoy measures a suite of abiotic parameters including wave height, wave period, salinity and water depth.

Refer to your Table 1 of vessel attributes and view Figure 4, a graph of mean water depth data from the week of October 29 to November 5, 2007.

From the figure:

1. What is the range in water depth?
2. Why does the water depth increase and decrease daily?
3. On what day was the water the deepest?
4. On what day was the water the shallowest?
5. Provided the M/V Ocean Hope was loaded properly, could it enter the York River whenever it wanted during the week shown?
    - If not, is there any point during the week that the ship could enter the river and not scrape the bottom (water depth > 10.6m)? If so, when?
    - For each date, how much clearance would there be between the hull of the ship and the sea floor?
6. The average temperature and salinity of the York River during this time period were 13.8$^oC$ and 22.8 ppt, respectively. If the M/V Ocean Hope was loaded properly in its departure port and had enough water to sail in the York, where would the water line be on its Plimsoll mark?

Now view Figure 5, a graph of the mean water depth data from the year beginning on November 5, 2006.

1. What is the range in water depth?
2. During what month was the water the deepest?
3. During what month was the water the shallowest?
4. During what season is the *M/V Ocean Hope* most likely to encounter water deep enough to enter the York River?
    - Formulate a hypothesis to explain this observation.
    - The U.S. Coast guard stipulates that in order for a ship to enter a channel or port, there must be 2-3 feet of water between the bottom of ship's hull and the sea floor. With this regulation in mind, is the water at the mouth of the York River ever deep enough for the M/V Ocean Hope to legally enter?
      *Note: You must convert the depth from meters to feet (1 foot = 0.305 meters)*

***D. Nowcasting (evaluating real-time data) Accessibility of the York River, VA by the M/V Ocean Hope***

We will now evaluate real time water data at the mouth of the York River.

Go to the Virginia Estuarine & Coastal Observing System (VECOS) homepage (www.vecos.org) and click on the VECOS Physical Realtime Sites link in the Links section of the left hand side navigation menu.

Click on the red balloon at the mouth of the York River, Station YRK000.00B. The data that you see is the most recent data report from this buoy.

1. When were these data reported?
2. When these data were reported, what was the mean water depth?
3. Is the river deep enough for the M/V Ocean Hope to enter the York River?
4. Is the river deep enough for the M/V Ocean Hope to legally enter in the eyes of the U.S. Coast Guard?

Using the VECOS buoy Station YRK005.67B, which is further up the York River at Gloucester Point, VA, answer the following:

1. What is the current salinity and water temperature at this location?
2. If the M/V Ocean Hope was loaded properly in its departure port and had enough water to sail in the York, where would the water line be on its Plimsoll mark?
3. Given the current temperature and salinity measurements at Gloucester Point, calculate the density using the density calculator found at http://gyre.umeoce.maine.edu/physicalocean/Tomczak/Utilities/density.html (in situ pressure is 101kPa).

Temperature (C):
Salinity (ppt):

The note at the bottom of the density calculator states, "Add 1000 to the result to obtain density in kg $m^{-3}$." These are the same units the Rutgers glider density plots are reported in the Extension activity. How does the current density in the York compare to the density of the waters off New Jersey and the Delmarva Peninsula?

Current York River Density (kg m-3):
Comparison to the Rutgers plots:

Activities III and IV demonstrate just how useful coastal and ocean observing systems are to the commercial shipping industry. Shippers are now able to check the water depth, water currents, wind speed, salinity and tide regimes for major ports all over the world, from all over the world. This has vast economic impacts as ships now know exactly when they can and cannot enter their destination port; eliminating dangerous guess work and time spent at anchor waiting for the proper conditions.

**Discussion**

- As you know, 2005 was a year of high water temperatures. How do the years 2006-2008 compare to 2005?
- What trend, if any, do you see in the number of DHWs over the 2005-2008 period? Is this a long enough period to determine a trend? If not, how long a period would you suggest?
- Based on the 2005-2008 data, what would you expect to see for water temperatures in San Juan, PR for 2009? What about 2019 and 2025? (*Hint: Access the San Juan, PR NOAA buoy data to see the current water temperature.*)
- Over the next few decades, if water temperatures continue to remain high for long periods of time at a stretch (resulting in significant DHWs per year), how do you think this will affect coral reefs? What impact would this have on the ecosystem? On the local economy?

*This lesson was written by staff educators at the Bridge Ocean Education Resource Center in collaboration with Virginia Sea Grant. If reusing, presenting, or adapting this lesson please credit the Bridge Ocean Education Resource Center and include the URL below.*

# Bridge Buoyancy DATA: “Don’t Even Sink About It!”

## Figure 1. Listings of attributes of the M/V Ocean Hope.

Figure 3a from http://www.ariesmaritime.com/fleet/cargo-vessels/container-ship-ocean_hope.php. Figure 3b from http://containerinfo.co.ohost.de/vessel_8717518.html.

a.


| NAME: | M/V "OCEAN HOPE" |
|---|---|
| BUILT IN: | GERMANY, 1989 |
| IMO NO. : | 8717518 |
| FLAG: | MARSHALL ISLANDS |
| DWT: | 26,089 MT on 10.52 m |
| GROSS / NET: | 18,037/10,484 MT |
| TEU INTAKE: | 1,799 units (20x8ftx8ft6inch) |
| TYPE: | GEARED CELLCULAR CONTAINER VESSEL (bv 1800) |
| MAIN ENGINE: | MAN /B+W 7l60mc 16,199 BHP with shaft generator on but no reefer containers on board speed abt 19.0 kts on abt 48 MT HFO consumption. |

b.

OCEAN HOPE

IMO number: 8717518
owner: Leonhardt & Blumberg
shipyard: Bremer Vulkan AG - Schiffbau, Germany
engine type: 7L60MC
overall length (m): 176,50
maximum TEU capacity: 1799
deadweight (ton): 26.366
exname 1: CALIFORNIA CARRIER

1st name: HANSA CARRIER
operator:
yard / hull number: 1083
power output (KW): 12.180
overall beam (m): 27,50
container capacity at 14t (TEU): 1330
gross tonnage (ton): 18.037
exname 2:

flag / nationality: Marshall Islands
completion year: 1989
engine design: B&W
maximum speed (Kn): 18,0
maximum draught (m): 10,5
reefer containers (TEU): 70
handling gear: 3 x 40
exname 3:

http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1207.html

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## Table 1. Attributes of the M/V *Ocean Hope*.

| Attribute | M/V Ocean Hope |
|---|---|
| Flag/Nationality | |
| Length (m) | |
| TEU capacity | |
| Draft (m) | |
| Deadweight (metric tons) | |
| Gross Tonnage (metric tons) | |
| Net Tonnage (metric tons) | |
| Max Speed (knots) | |

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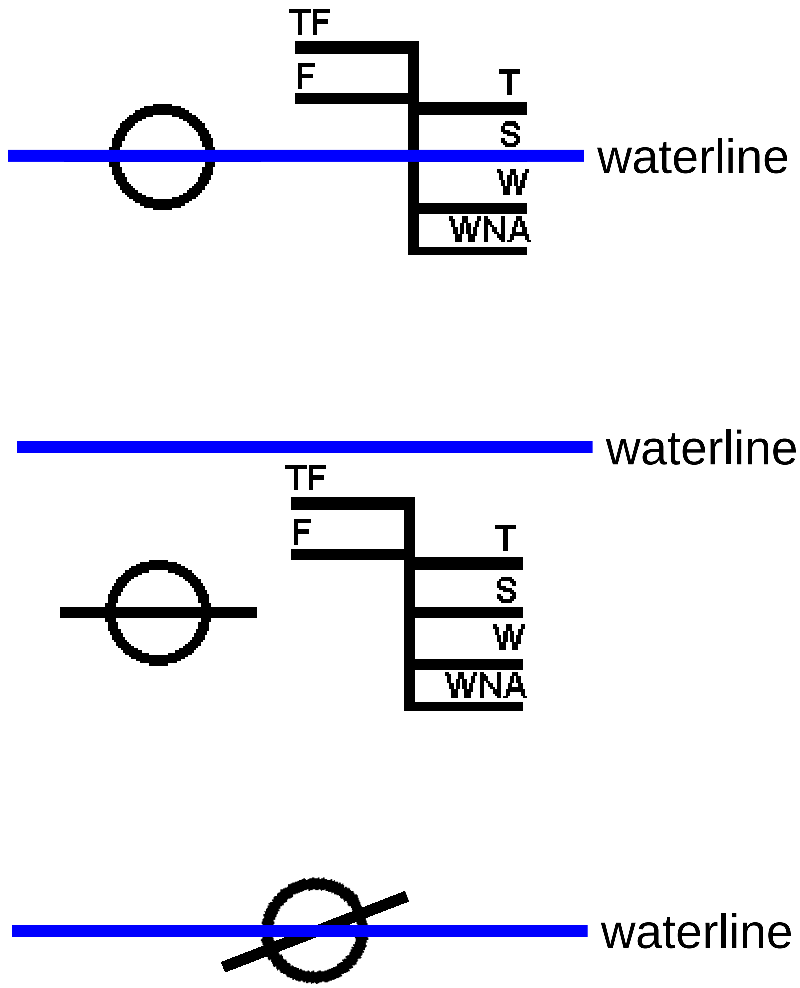
Figure 3. Different applications of the Plimsoll mark. In each figure, assume the bow (front) of the ship is to the *left*, and the stern (rear) of the ship is to the *right*.

a.

b.

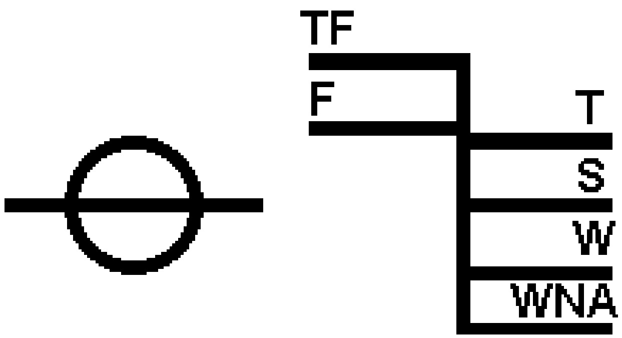
c.




http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1207.html

## Bridge Buoyancy DATA: “Don’t Even Sink About It!”

### Plimsoll Mark Worksheet




TF = ____________________________

F = ____________________________

T = ____________________________

S = ____________________________

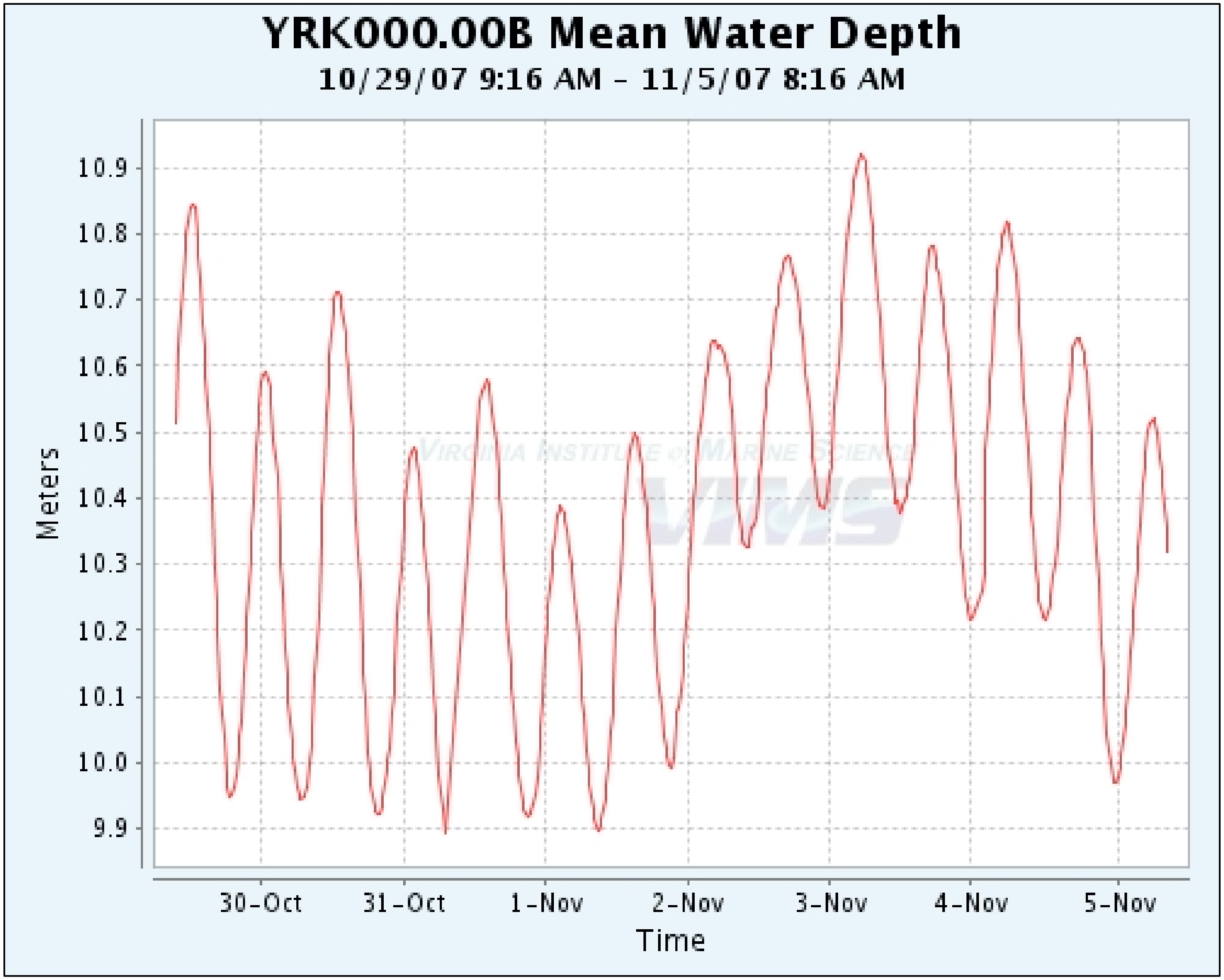
W = ____________________________

WNA = __________________________

http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1207.html

## Bridge Buoyancy DATA: "Don't Even Sink About It!

Figure 4. Mean water depth at the mouth of York River, VA during the week of 29 October to 5 November, 2007

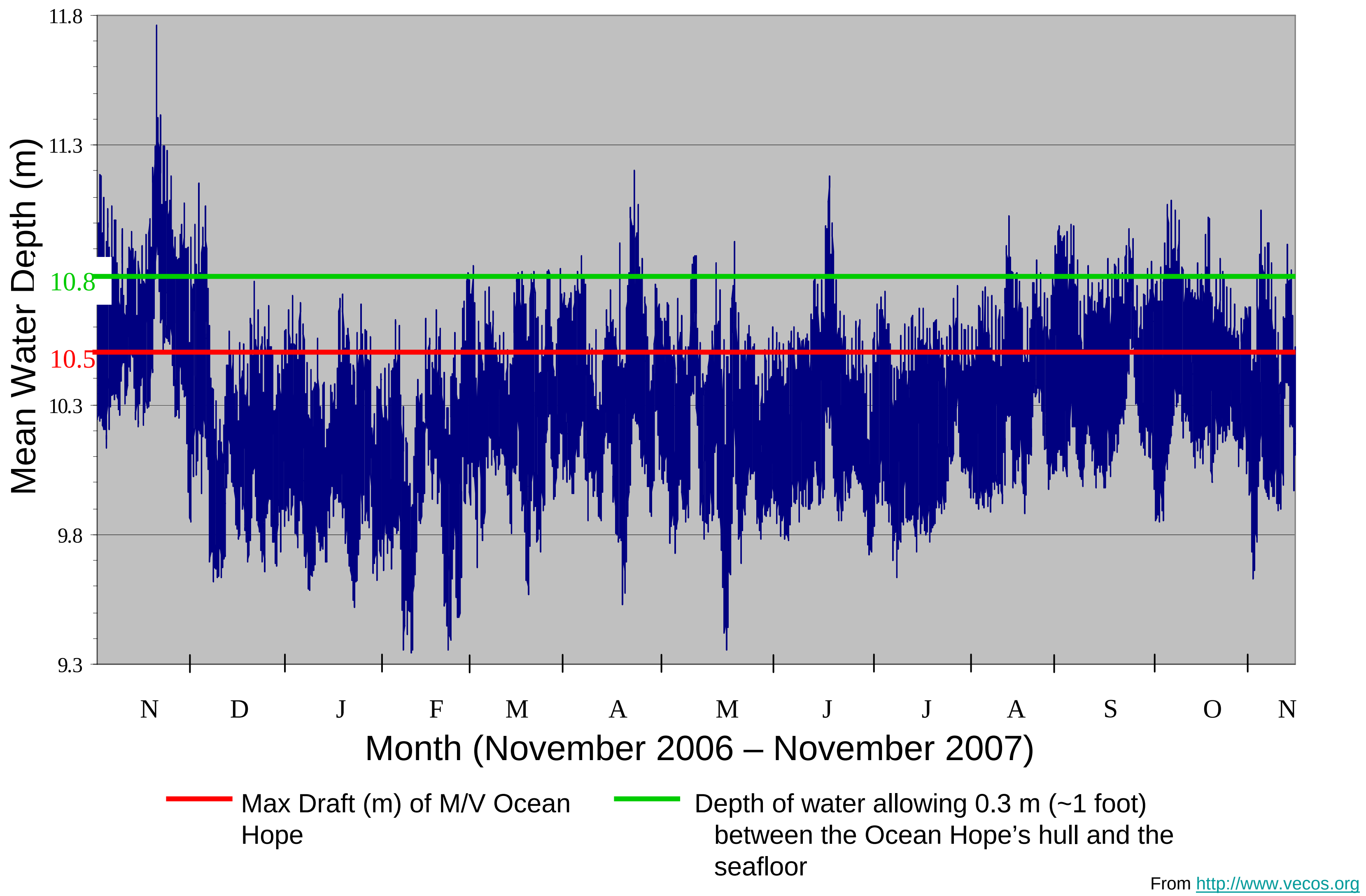



From http://www.vecos.org

http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1207.html

# Bridge Buoyancy DATA: "Don't Even Sink About It!"

Figure 5. Mean water depth at the Mouth of the York River, VA for November 2006-November 2007




http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1207.html