Document ID: 02_23_99_1
Date Received: 1999-02-23 **Date Revised**: 1999-04-27 **Date Accepted**: 1999-05-05
Curriculum Topic Benchmarks: M4.3.4, M4.3.17, M4.3.10, M1.3.9, M1.3.10, M3.3.9
Grade Level: [6-8] Middle School
Subject Keywords: volume, area, depth, height, oil, coast, gallons, meters, tons, yards, units
Rating: moderate

Coastal Threat: A Story In Unit Conversions

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On February 4, 1999, the 639-foot freighter New Carissa became grounded near Coos Bay on the Oregon coast. Aboard the ship were 400,000 gallons of bunker fuel, threatening to leak from the fractured hull and damage the state's fragile beach habitats. With an approaching storm increasing the chances of a disastrous spill, authorities decided to set the ship afire, a choice not without controversy and risks of its own. An oceanographer friend and I became curious about the extent of the disaster associated with the potential spill. 400,000 gallons is equivalent to 400,000 milk jugs –- a lot of milk. But how much space does 400,000 gallons really take up? Some simple arithmetic can help put the quantity in perspective.

The New Carissa held approximately 400,000 gallons of oil and diesel fuel. A table of units, available in many text or reference books, provides the relationship between one unit, in this case a volume measurement in U.S. liquid gallons, and another. For this example, we choose to express the New Carissa's fuel quantity in terms of the MKS volume measurement of cubic meters (m^3). The table below contains this conversion relation as well as others that may be useful in this exercise.

Table of Conversion Relations:

VOLUME	AREA	LENGTH
1 US liq gallon = 0.003785 m^3	1 km^2 = 1,000,000 m^2	1 inch = 25.4 mm
1 liquid ton = 2.831685 m^3	1 m^2 = 1.19596 yd^2	1 km = 0.62137 miles
1000 cm^3 = 1 l (liter)		1 meter = 1.0936 yards
1 ml = 0.001 mm^3		1 yard = 36 inches

We write the conversion relation as 0.003785 cubic meters per 1 gallon, or 0.003785 m^3/ 1 gallon.

Therefore, 400,000 gallons × 0.003785 cubic meters/1 gallon = 1514 cubic meters.

Note that the units we wish to convert *from* are in the denominator of the conversion relationship whereas the units we wish to convert *to* are in the numerator. This "cancels" the gallons units and leaves us with our desired measure of cubic meters.

So how much space would 1514 cubic meters actually occupy? We know that Volume = Length × Width × Height and for this example will allow the length, width, and height to all be equal. Then the cube root of 1514 equals 11.48 and gives the dimensions of the space occupied by the oil: 11.48 meters × 11.48 meters × 11.48 meters.

According to containment experts, the oil would form a layer 1/100 of an inch (0.254 mm) thick on the surface of the water. To truly understand the scope of this disaster, we are interested in calculating the area covered by such a layer. If we divide Volume by Height we obtain a measurement of Area. To do this calculation we must first express our 0.254-mm height in terms of meters:

0.254 mm × 1 meter/1000 mm = 0.000254 meters.

Then, AREA = 1514 m^3/ 0.000254 m = 5,960,630 m^2(or square meters).

If we assume that the extent of the oil has equal length and width, we can find these dimensions by taking the square root of 5,960,630. We find that the 400,000-gallon volume will cover an area 2,441 meters × 2,441 meters with a layer of oil 0.254 mm deep. Since 1 meter is equal to 1.0936 yards, the area affected by the oil is 2,670 yards × 2,670 yards -- a region approximately the length of 27 football fields on each side. In actuality, the oil would not have been distributed in a perfect square, but would have all washed onto the shore, carried by ocean waves and currents. NOAA scientists estimated that the impacted area of the coast could have been on the order of 50 to 100 miles!

Activity: Similar calculations of units can be applied first hand using your own freighter (a cup or beaker of water) and ocean (try a cookie sheet with edges). In this case, the area over which the "oil" will spread (the dimensions of the cookie sheet) can be measured. Knowing the amount of oil (or water) originally in the beaker will allow students to calculate the depth of water expected to be measured in the cookie sheet, which they can then verify with a ruler. Similarly, measurement of the depth of water would allow computation of the volume of liquid poured from the beaker. The following example also demonstrates how we can create our own scale conventions to further illustrate measurement quantities. For instance, at a 1/10,000 scale,
1 cm = 1 km of coastline and 1 milliliter of water = 100 liters of "oil". This type of scaling allows us to create our own mini-ocean to replicate the spill.

Example:

Dimensions of "basin": 42 cm by 30 cm
Depth of water in basin: 10 mm
Volume of water "spilled": 420 mm × 300 mm × 10 mm = 1,260,000 mm^3
1 mm^3 = 0.001 ml, so volume spilled equals 1260 ml (126,000 liters of oil to cover a 42 km × 30 km area, according to the scaling convention above).

There are many opportunities for creativity here: the fluid does not have to be water, and the "basin" could be much larger than a cookie sheet. To give students a more realistic view of how the oil would spread out over a surface, a basin could be created on a flat area of the school yard using a plastic sheet and boards. A 1/100-scale would mean that the New Carissa spill could be represented using an area about 24.41 meters on a side.

Unit conversion calculations can answer a variety of questions in our everyday lives. Here are some additional examples:

For the case above, let the amount of fuel leaking from the New Carissa equal 1,000,000 gallons. If the oil forms a layer 0.25-mm thick along a 12-meter wide section of shoreline, what is the length of shoreline affected by the spill? Express the answer in kilometers and miles.

Solution: 1,000,000 gallons × 0.003785 m^3/1 gallon = 3785 m^3

0.25 mm × 1 m/1000 mm = .00025 m (depth of oil in meters)
3785 m^3/0.00025 m = 15,140,000 m^2 (area covered by oil)
15,140,000 m^2/12 m = 1,261,670 m (length of shoreline affected)

1,261,670 m × 1 km/1000 m =**1,261.67 km**

1,261.67 km × 0.62137 miles/1 km = **783.96 miles**

1. Suppose you wish to add a layer of top soil 1 inch deep to a 15 meter × 13 meter area of your backyard. Top soil is sold by the cubic yard: how many cubic yards would you need?

   Solution: 15 m × 13 m = 195 m^2 (area of yard in square meters)

   195 m^2 × 1.19596 yd^2/1 m^2= 233 yd^2 (area of yard in square yards)

   1 inch × 1 yard/36 inches = 0.0278 yards (depth of top soil in yards)

   233 yd^2 × 0.0278 yd = 6.48 cubic yards (volume of top soil needed)
   Amount to purchase: **7 yd^3**

2. What would be the depth (height) of water over a 2 square kilometer flood-prone area if a break in a dam released 535,000 tons of water? Express your answer in centimeters.

   Solution: 535,000 tons × 2.8317 m^3 /1 ton = 1,514,960 m^3

   2 km^2 × 1,000,000 m^2/1 km^2 = 2,000,000 m^2
   1,514,960 m^3/ 2,000,000 m^2 = 0.757 m

   0.757 m×100 cm/1 m = **75.7 cm**

References:

"*Burning ship splits up*", Florangela Davis and Ross Anderson, Seattle Times, 2-12-99.

On-line **archives of New Carissa news** articles:
http://www.deq.state.or.us/hub/Carissa.htm.
http://www.oregonlive.com/special/archives/newcarissa_9902.html.

An excellent source for **unit conversion relations**:
http://www.webcom.com/%7Elegacysy/convert2/convert_old.html.