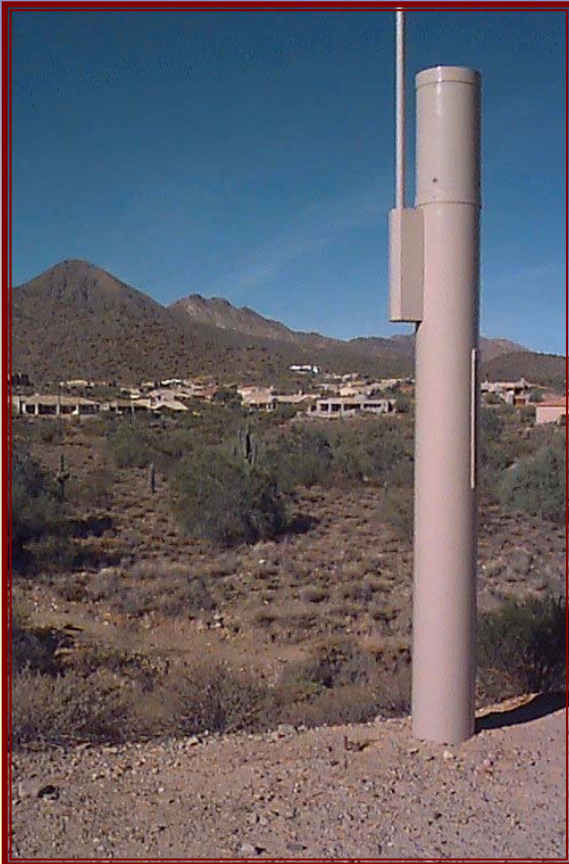


# *Flood Control District of Maricopa County*

## **Flood Physics**



**Steve Waters**

Senior Hydrologist

Flood Warning / Water Quality Branch

Engineering Division



# Physics of Stream Forces

- Moving water exerts pressure on objects.

$$\text{Pressure} = k(\text{constant}) \times (\text{Velocity})^2$$

- Pressure on an area becomes a force.

$$\text{Force} = (\text{pressure} \times \text{area})$$

water depth  greater area  greater the force

- Surface becomes slippery  (reduced friction force)

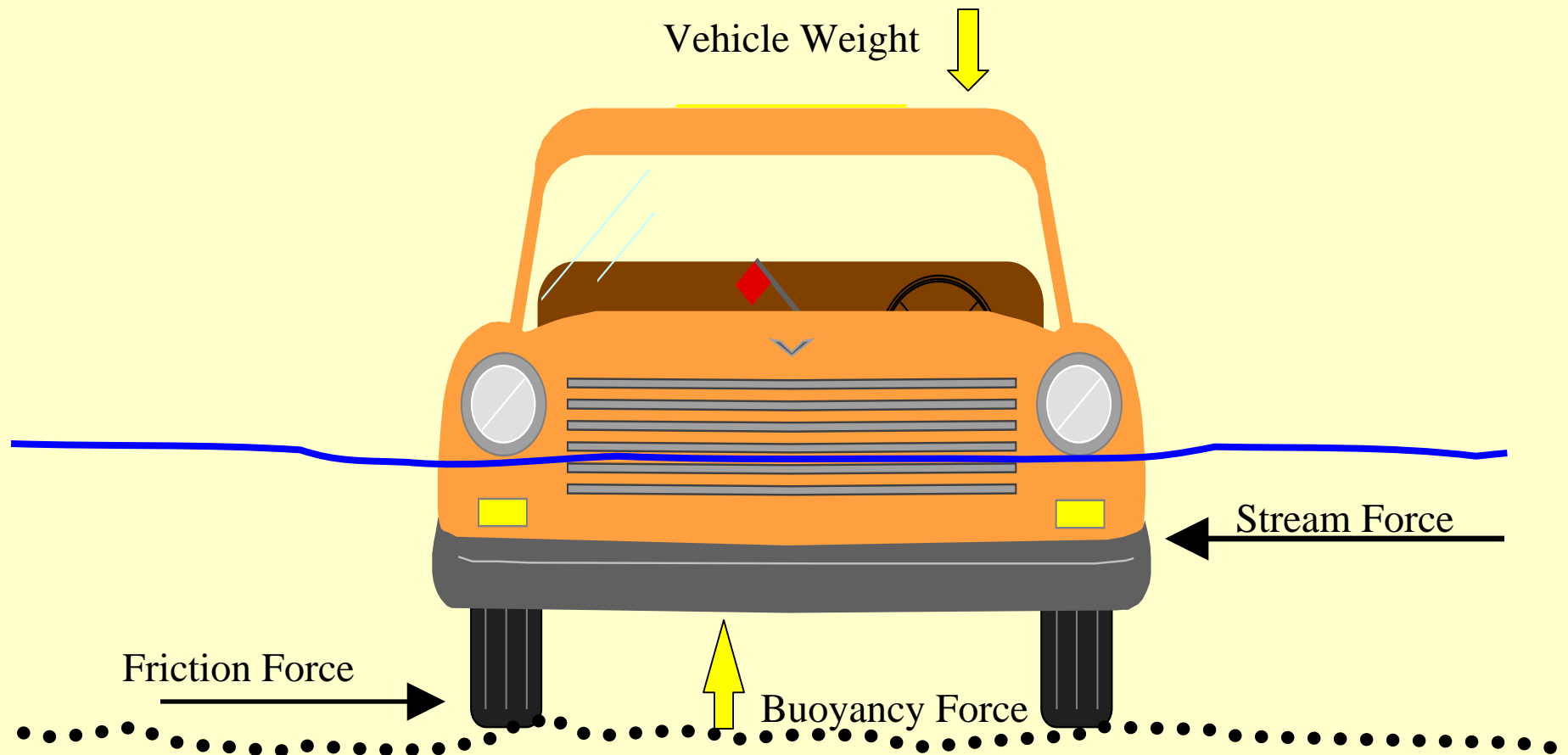
# Archimedes' Principle

The buoyant force on an object is equal to the weight of the fluid displaced by that object



# Forces on Vehicles Crossing Streams

**The car will float downstream when:  
Stream Force > Friction Force**



# Some Water Physics Facts

- Water weighs 62.4 pounds/cubic foot, and cars displace a lot of it
- The pressure exerted by moving water increases with the square of its velocity
- Water, sand and mud reduce the frictional forces that hold a car in place
- Water clarity and lighting conditions conceal the condition of the roadway beneath you

# From the FEMA Web Page

## Flash Floods: How Can a Foot or Two of Water Cost You Your Life?

Nearly *half* of all flash flood fatalities are auto related!



Water weighs 62.4 lbs. per cubic foot and typically flows downstream at 6 to 12 miles an hour.



When a vehicle stalls in the water, the water's momentum is transferred to the car. For each foot the water rises, 500 lbs. of lateral force are applied to the car.



But the biggest factor is buoyancy. For each foot the water rises up the side of the car, the car displaces 1,500 lbs. of water. In effect, the car weighs 1,500 lbs. less for each foot the water rises.



**Two feet of water will carry away most automobiles.**

# Fighting a Losing Battle



- Width: 5.5 feet
- Length: 14 feet
- Ground Clearance: 10 inches
- Weight: 3,400 pounds

However, 1 foot of water displaced by this vehicle weighs:  
(5.5' x 14' x 1' x 62.4 lbs./cu.ft.) = 4,805 pounds

# Something a Little Bigger

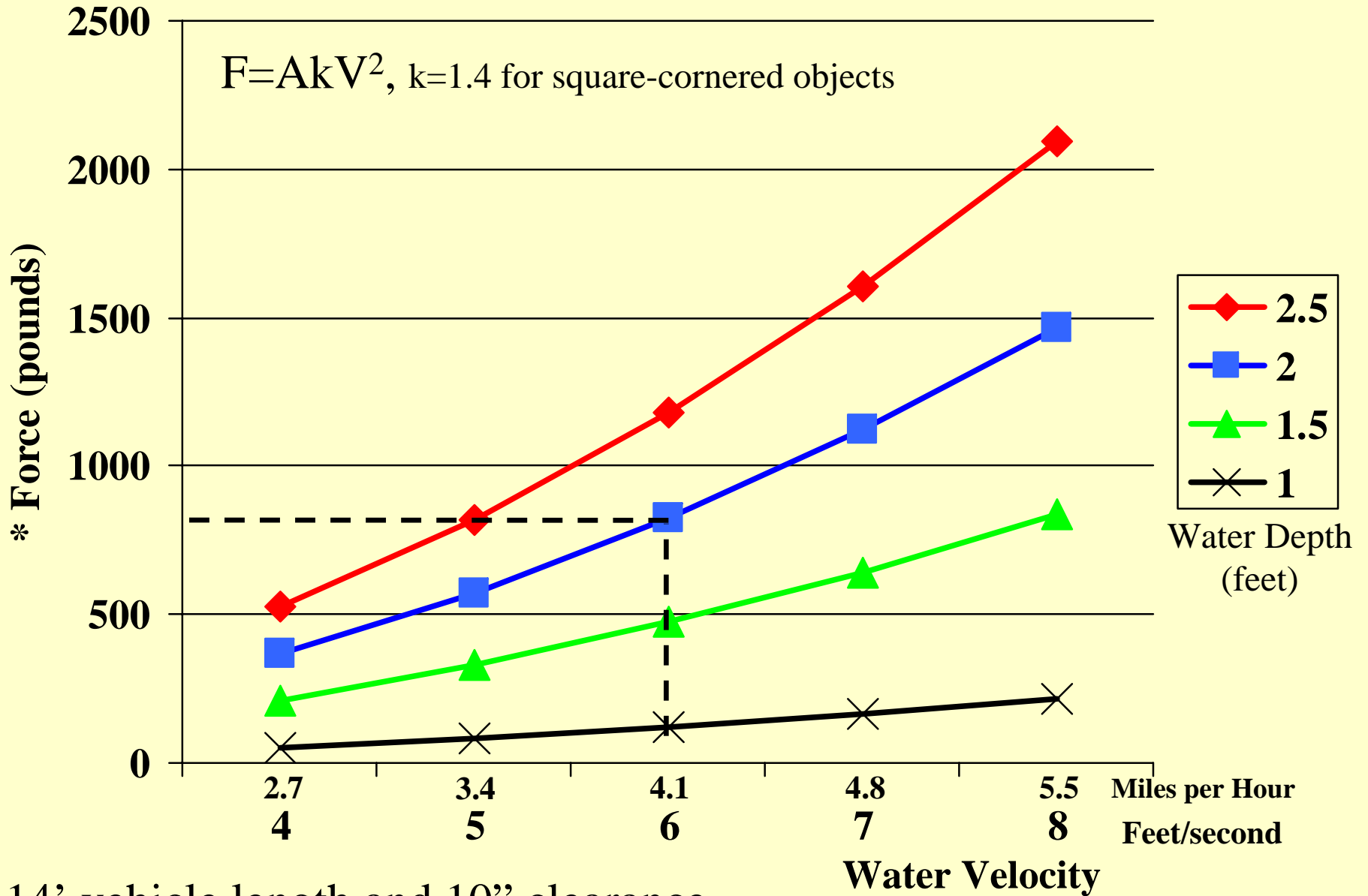


- Width: 6 feet
- Length: 18 feet
- Ground Clearance: 18 inches
- Weight: 5,040 pounds

1 foot of water displaced by this vehicle weighs:  
(6' x 18' x 1' x 62.4 lbs./cu.ft.) = 6,739 pounds

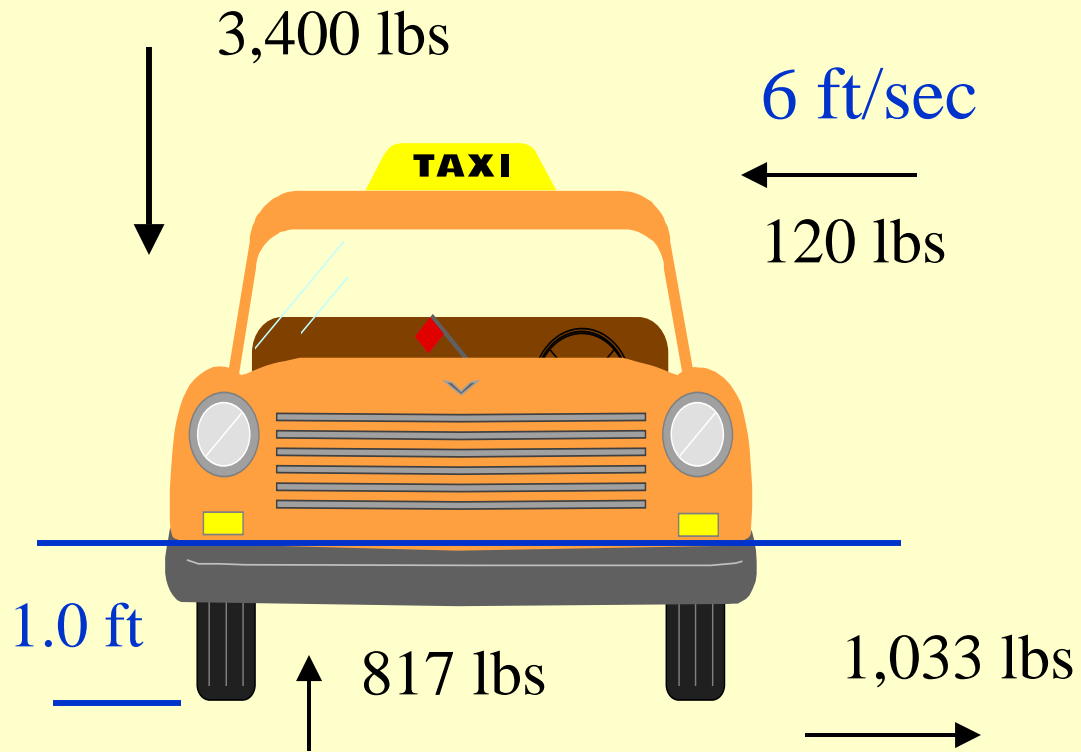


# Stream Forces on Vehicles



\* 14' vehicle length and 10" clearance

# Water Depth: 1 foot



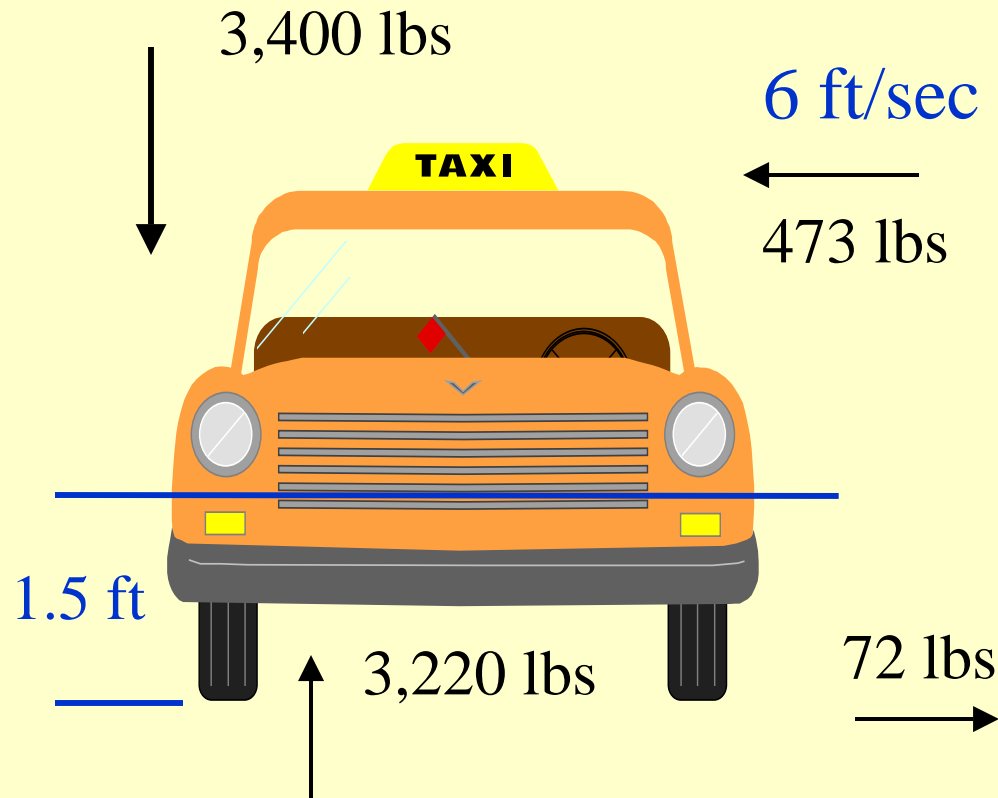
- Width: 5.5 feet
- Length: 14 feet
- Clearance: 10 inches
- Weight: 3,400 pound
- Net Depth = 0.17 feet

Net Weight :  $3,400 \text{ lbs} - 817 \text{ lbs} = 2,583 \text{ lbs}$

Friction Force:  $0.4 \times 2,583 \text{ lbs} = 1,033 \text{ lbs}$

1,033 lbs is greater than the 120 lbs of stream force, so the vehicle stays put

# Water Depth: 1.5 feet



- Width: 5.5 feet
- Length: 14 feet
- Clearance: 10 inches
- Weight: 3,400 pound
- Net Depth = 0.67 feet

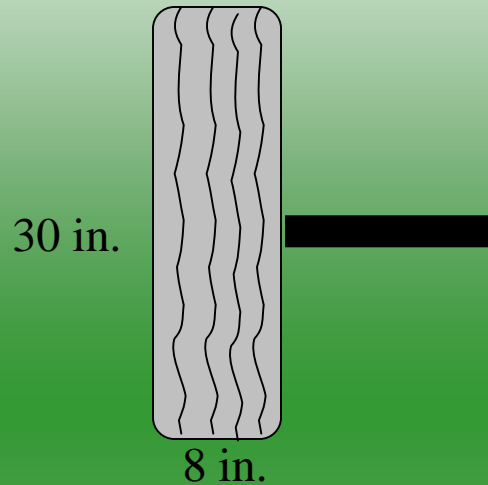
Net Weight :  $3,400 \text{ lbs} - 3,220 \text{ lbs} = 180 \text{ lbs}$

Friction Force:  $0.4 \times 180 \text{ lbs} = 72 \text{ lbs}$

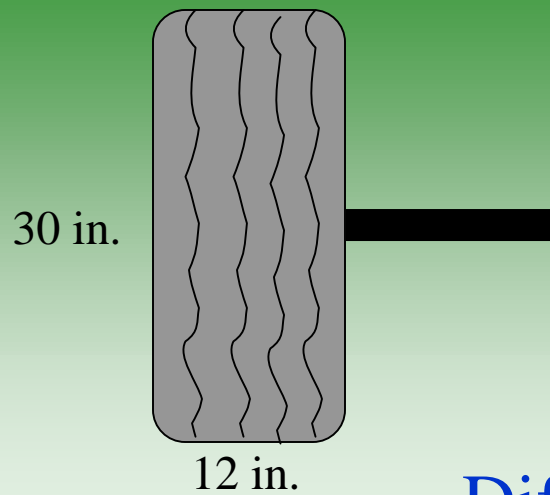
72 lbs is less than the 473 lbs of stream force, so the vehicle moves downstream

# Something Else to Think About

## Buoyancy and Tire Size



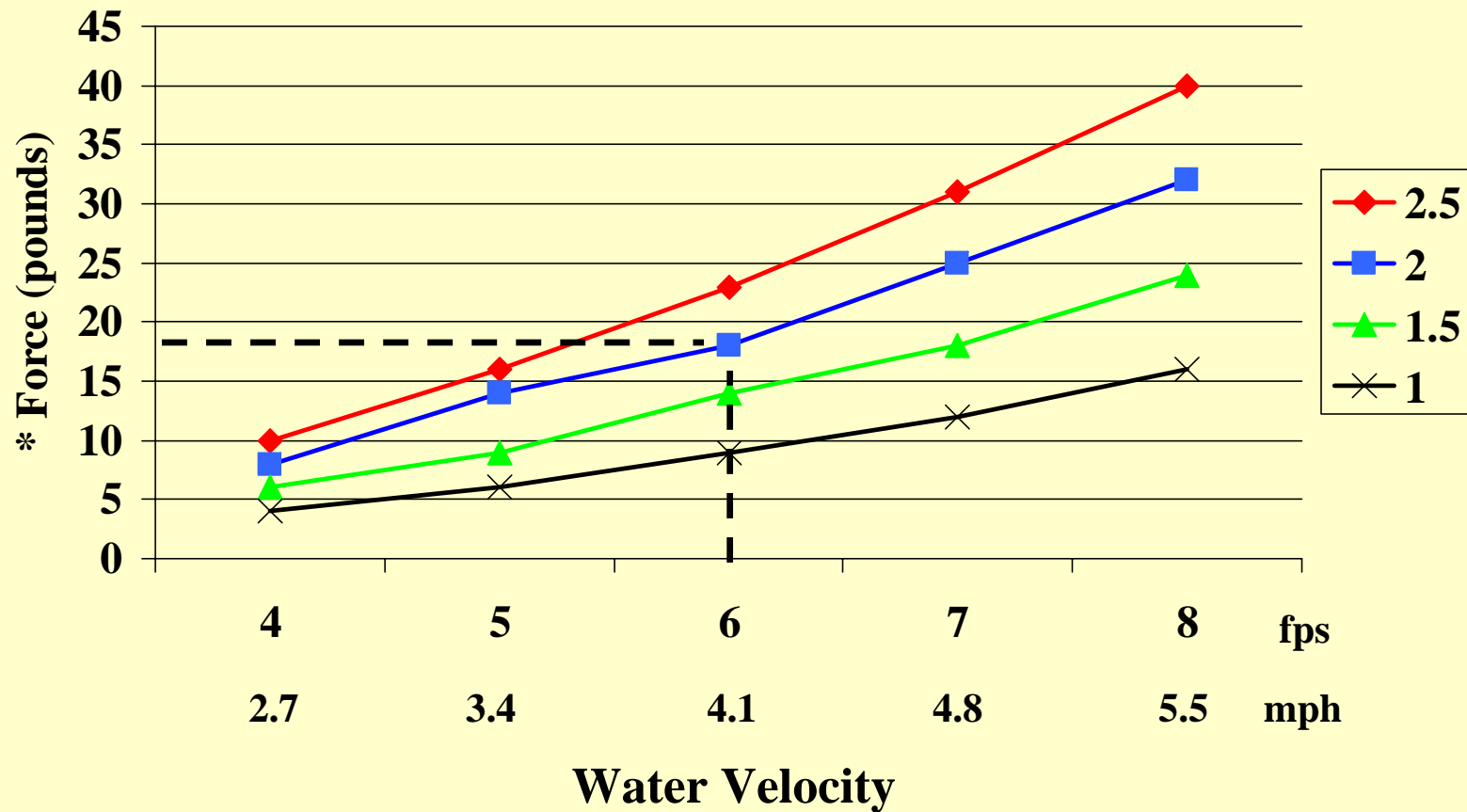
$$\begin{aligned}\text{Volume} &= 3.27 \text{ ft}^3/\text{tire} \times 4 = 13.09 \text{ ft}^3 \\ 13.09 \text{ ft}^3 &* 62.4 \text{ lbs/ft}^3 = 816.2 \text{ lbs}\end{aligned}$$



$$\begin{aligned}\text{Volume} &= 4.91 \text{ ft}^3/\text{tire} \times 4 = 19.64 \text{ ft}^3 \\ 19.64 \text{ ft}^3 &* 62.4 \text{ lbs/ft}^3 = 1,225.2 \text{ lbs}\end{aligned}$$

Difference is 409 lbs. added buoyant force

# Stream Forces on Humans



\* Force on each leg

# Flood Safety

## ↓ Judgement

- ↓ If You Absolutely Must Cross a Flooded Stream...
- ↓ Enter slowly, watch the depth and back out if the front axle is submerged
- ↓ If your vehicle stalls in the wash, and upstream weather conditions are bad, abandon the vehicle and get to shore

# Flood Safety

↓ Remember...



↓ Floodwaters can conceal a damaged roadway

↓ Flash Floods rarely last more than an hour

↓ Don't trade an hour for a lifetime