INFILTRATOR
water technologies

Pipes, Pores, and Other Pathways
Hydraulic Engineering Principles for Onsite Installers

David Lentz, P.E.

Important Disclaimer

The materials being presented represent the presenter's opinions, and do NOT reflect the opinions of NOWRA.

Solids, Liquids, and Gases

Solid

Liquid

Gas

Solids, Liquids, and Gases

Solid

Fluids

Liquid

Gas

https://slideplayer.com/9420942/33/images/slide_1.jpg

Solids, Liquids, and Gases

Solid

Hydraulics

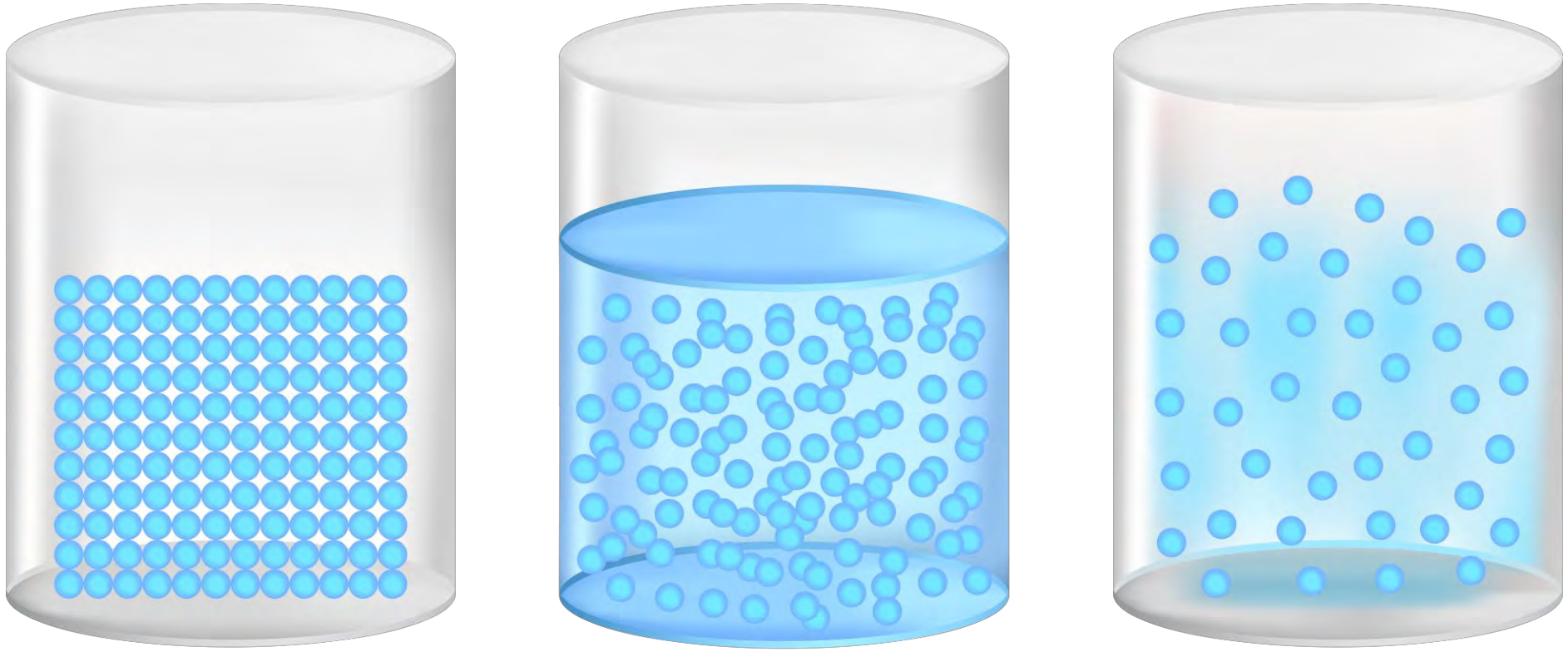
Liquid

Pneumatics

Gas

https://slideplayer.com/9420942/33/images/slide_1.jpg

What's the Molecular Difference?



SOLID LIQUID GAS

Today's Topic - Hydraulics

Hydraulics

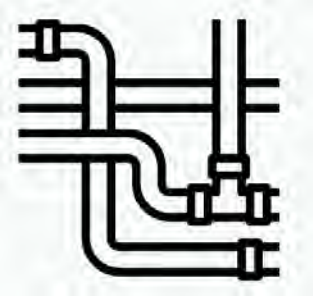
Liquid

https://slideplayer.com/9420942/33/images/slide_1.jpg

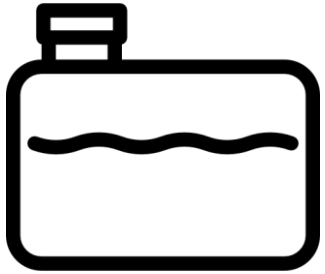
Hydraulics Throughout the Onsite System

What are we Going to Cover?

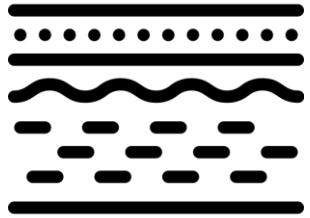
Pipes



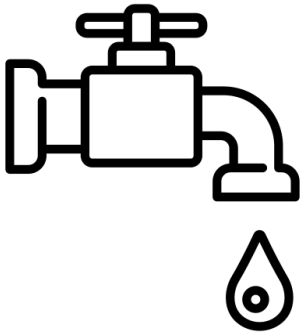
Septic Tank



Drainfield



Daily Flow

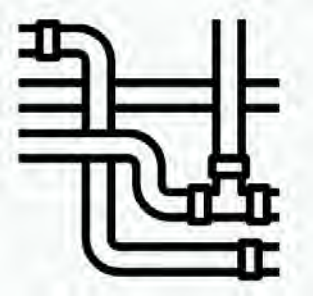


Stormwater

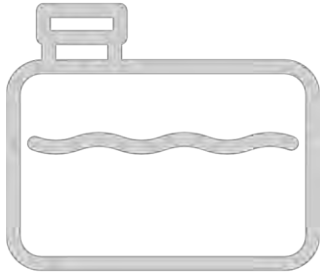
Equipment

What are we Going to Cover?

Pipes



Septic Tank



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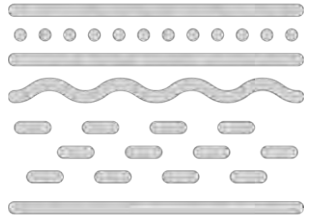
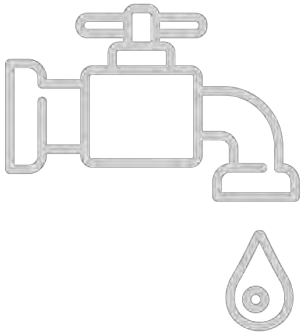


Daily Flow

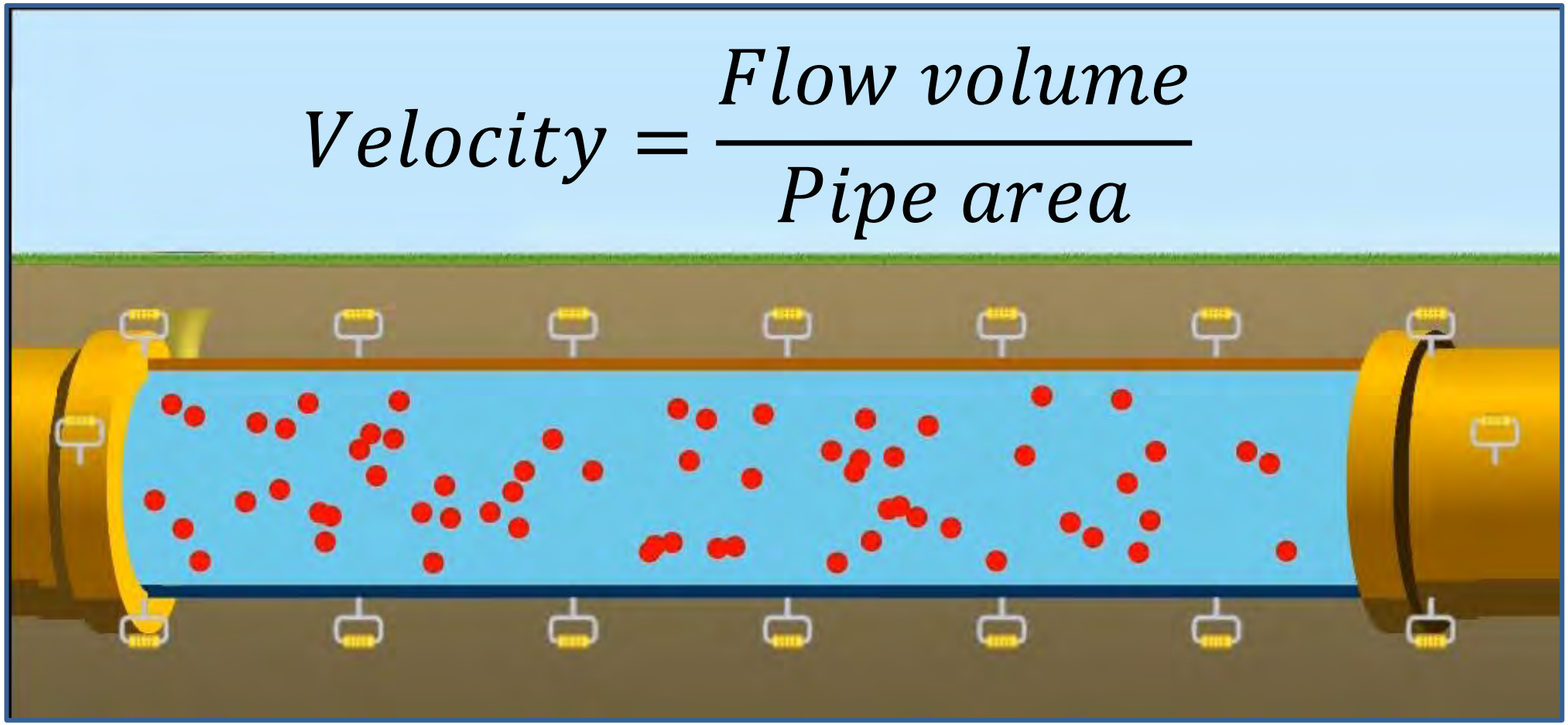


Stormwater

Equipment

Increasing Diameter Decreases Velocity

$$Velocity = \frac{Flow\ volume}{Pipe\ area}$$

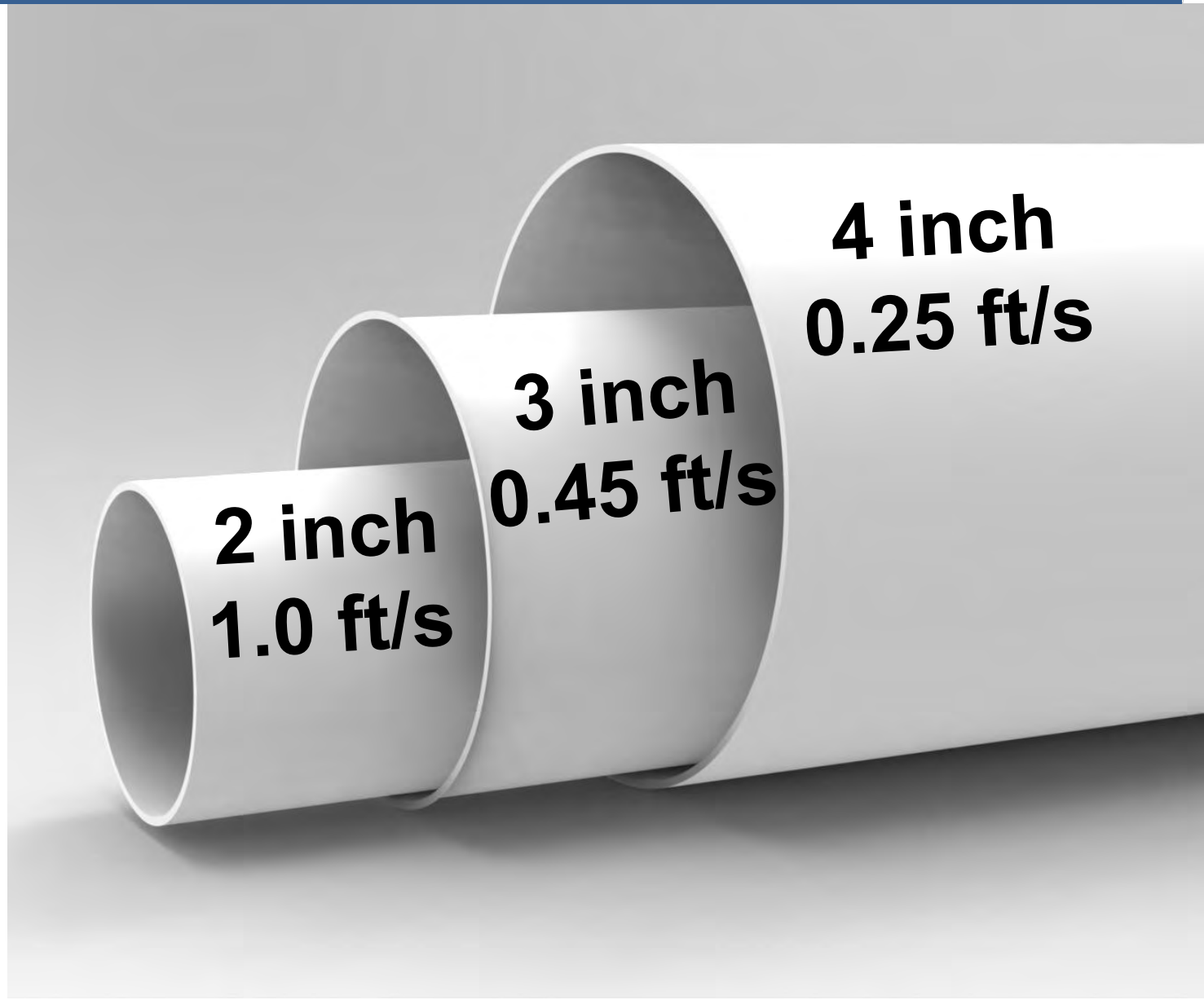


As pipe diameter increases, velocity decreases

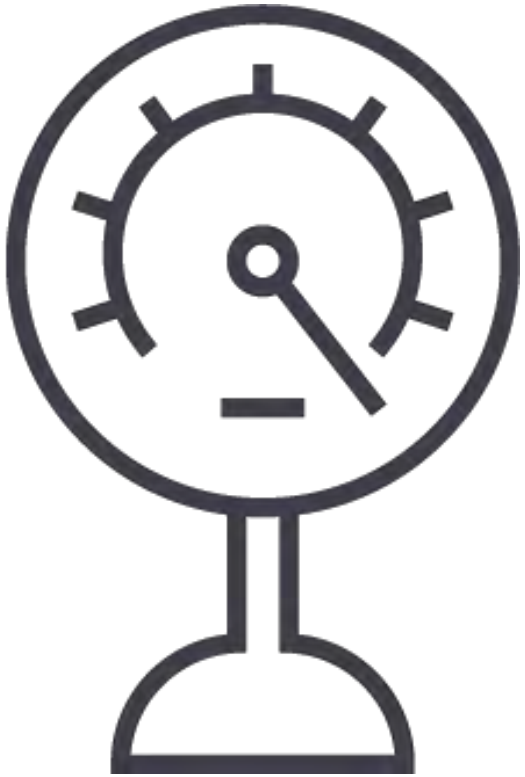
https://phet.colorado.edu/sims/cheerpj/fluid-pressure-and-flow/latest/fluid-pressure-and-flow.html?simulation=fluid-pressure-and-flow

Flow Rate: V = Q ÷ A

If the flow rate is 10 gpm, how does velocity change?



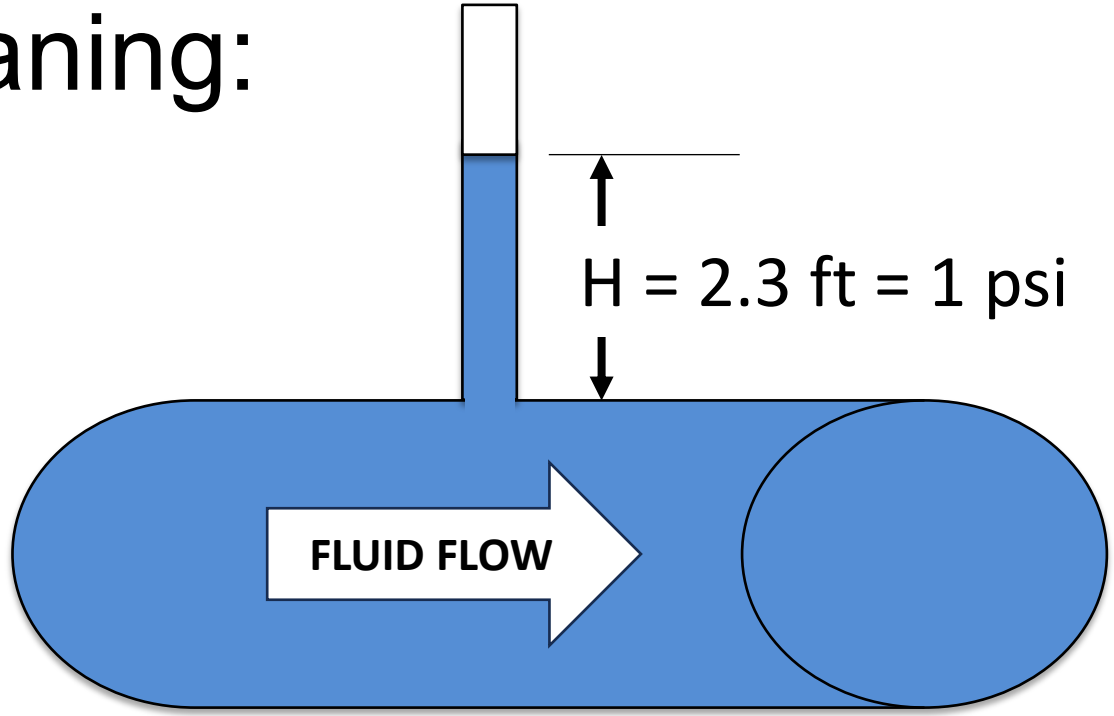
What Happens to Water Pressure?



Water Pressure Terms

Common terms, same meaning:

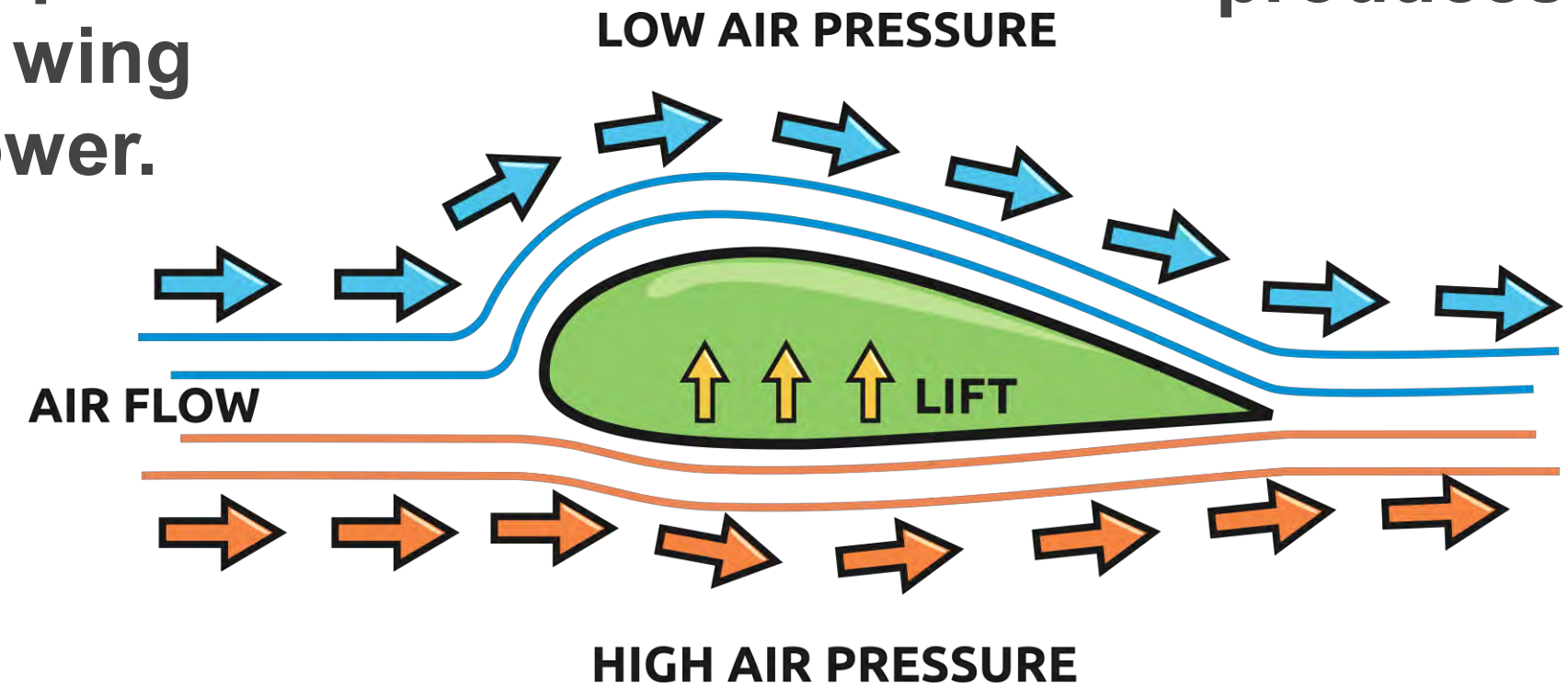
- Pressure
- Head
- Static pressure head
- Water column



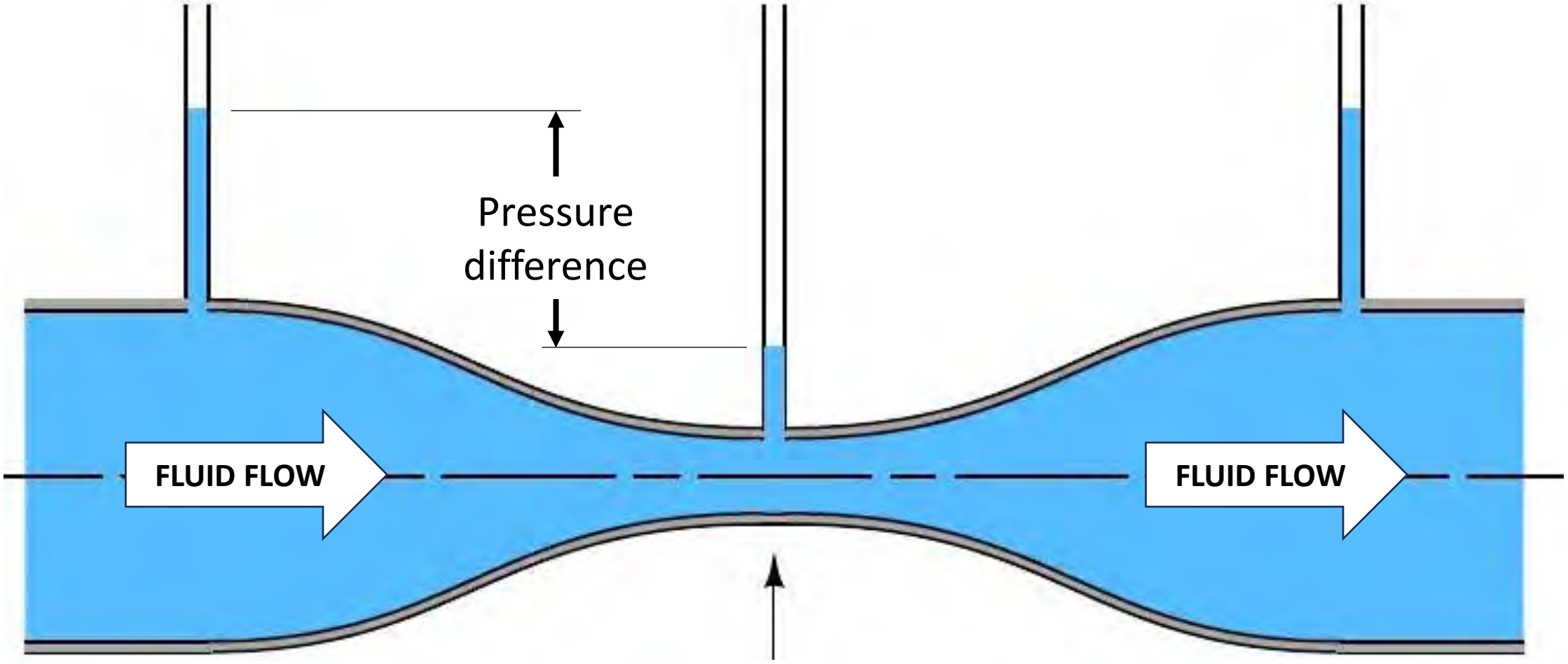
Bernoulli Effect – How Planes Fly

An airplane wing is shaped so that air flows faster over the upper part of the wing than the lower.

This results in a pressure difference that produces lift.

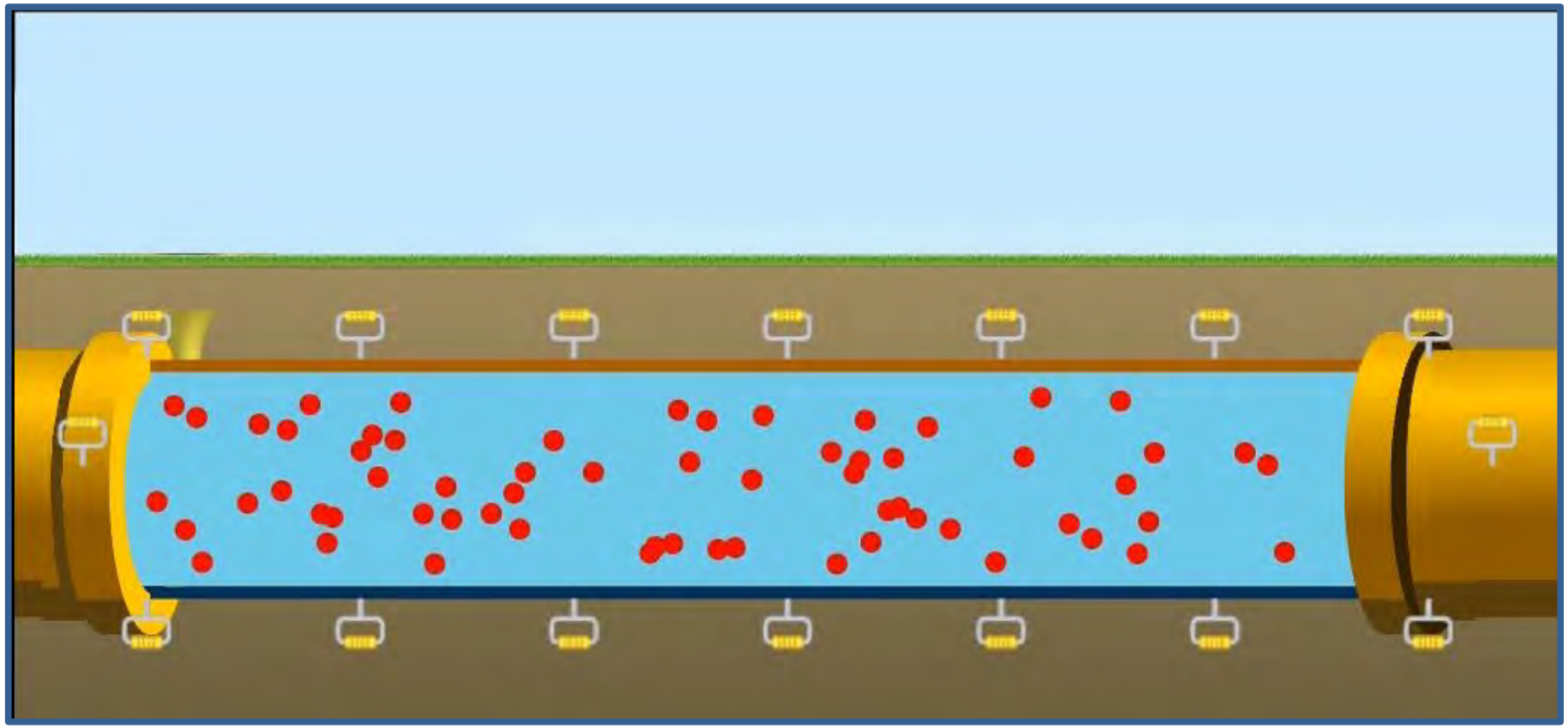


What About Pressure in a Pipe?



https://instrumentationtools.com/flow-directly-proportional-square-root-delta-p/

Increasing Diameter Increases Pressure



Lower Pressure

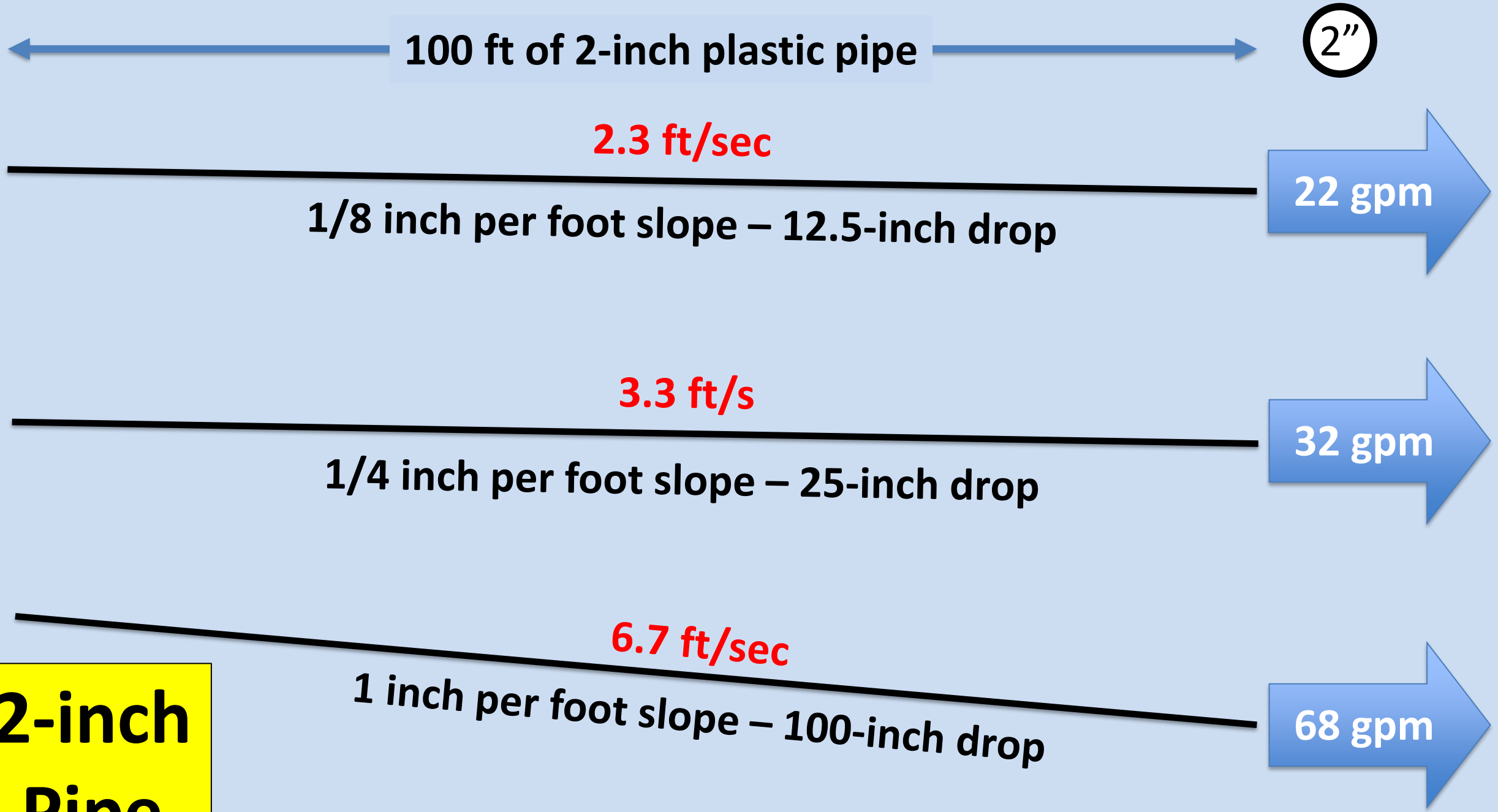
Higher Pressure

https://phet.colorado.edu/sims/cheerpj/fluid-pressure-and-flow/latest/fluid-pressure-and-flow.html?simulation=fluid-pressure-and-flow

How Does Pipe Slope Affect Flow?

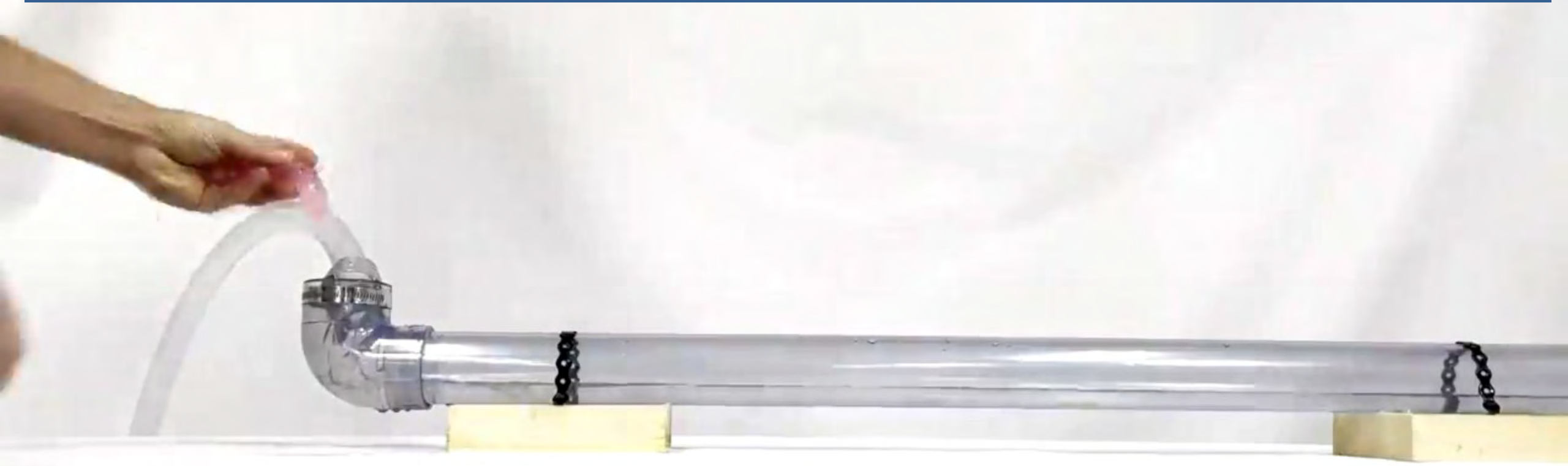
https://pcionline.com/magazine/2020/july-2020-vol-247-no-7/features/construction-of-pipelines-in-steep-terrain-with-cable-crane-systems


http://www.youtube.com/watch?v=UpHOkHxpTvQ



https://www.omnicalculator.com/physics/pipe-flow

Reason for Minimum Cleaning Velocity

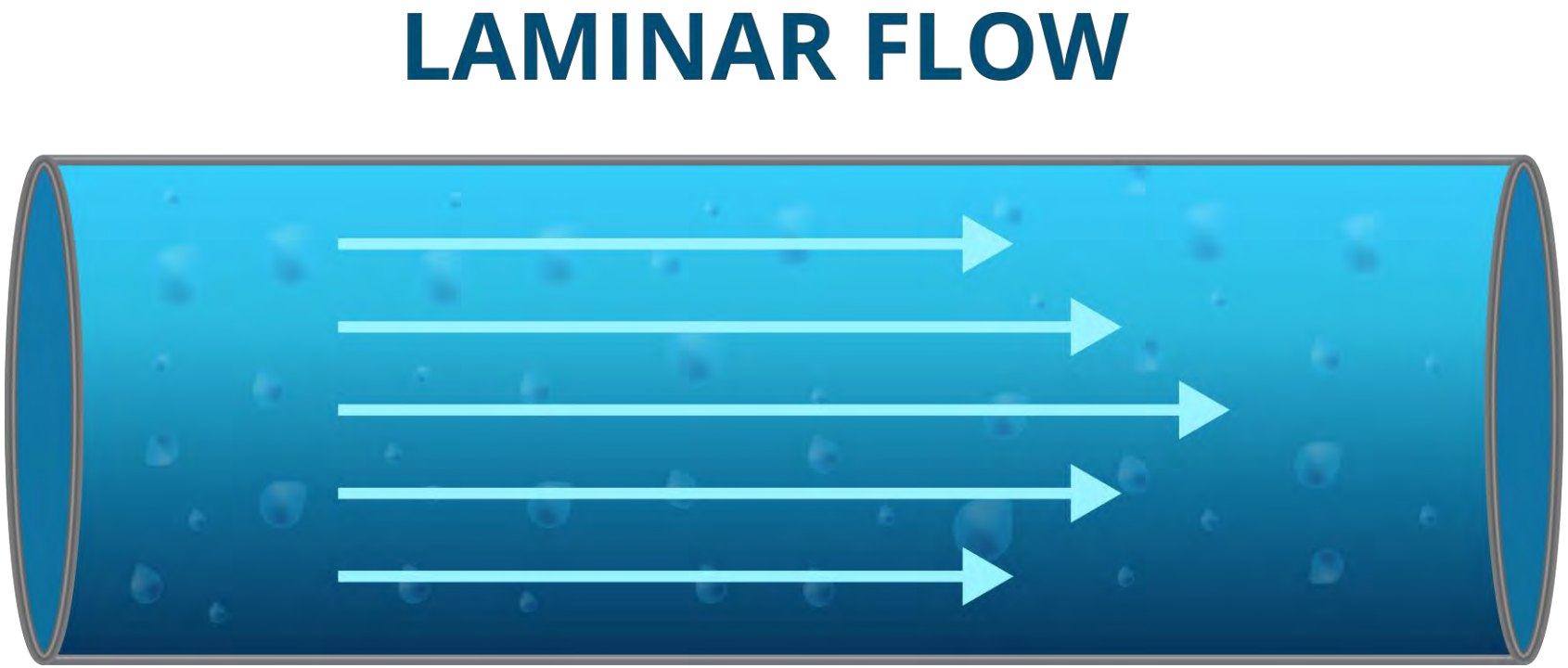


https://www.youtube.com/watch?v=UpHOkHxpTvQ

Reason for Minimum Cleaning Velocity

https://www.youtube.com/watch?v=UpHOkHxpTvQ

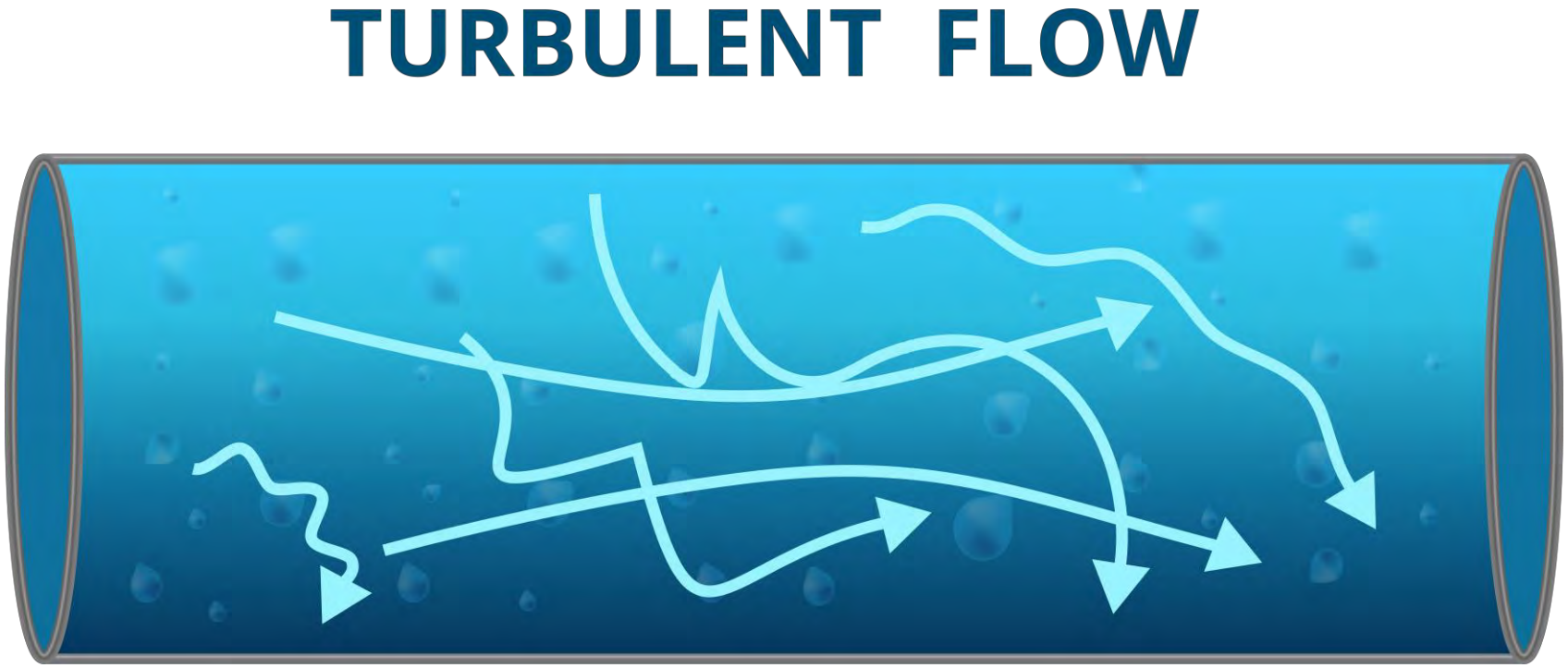
Pipe Velocity Profile – Laminar Flow



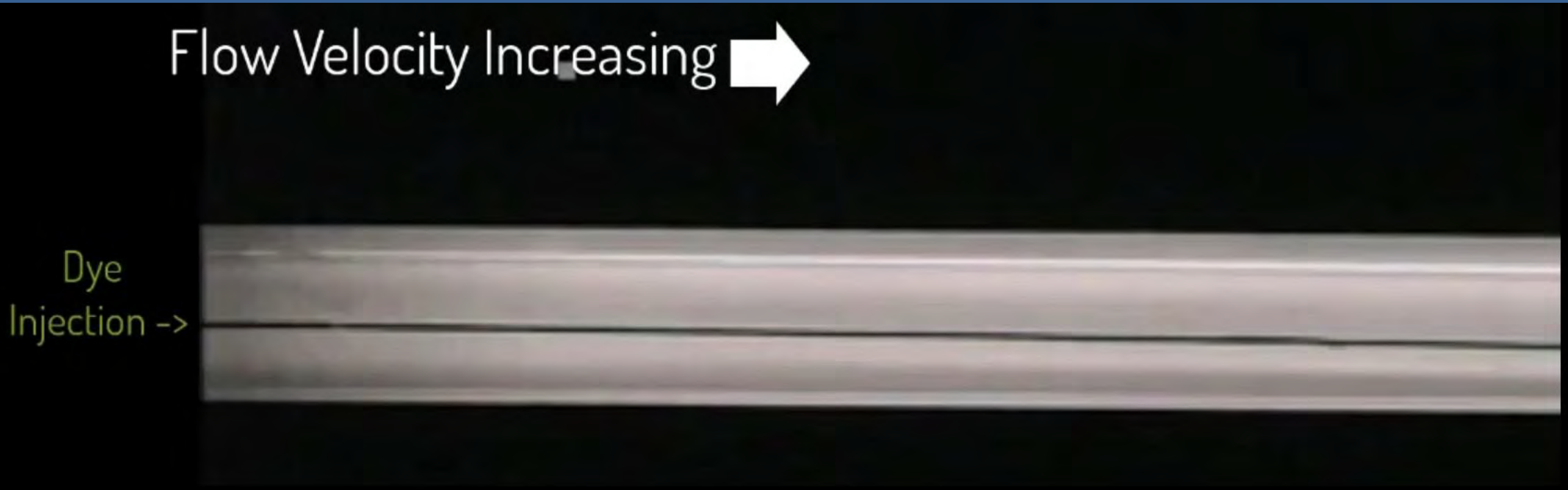
- Velocity increases from wall toward centerline
- Lowest velocity at wall, where solids accumulate

Pipe Velocity Profile – Turbulent Flow

- Velocity more uniform across pipe diameter
- Higher velocity at wall than laminar flow



Laminar to Turbulent Flow



Energy/Head Loss Types

Major

Caused by pipe

Frictional resistance between pipe and fluid

Minor

Caused by fittings

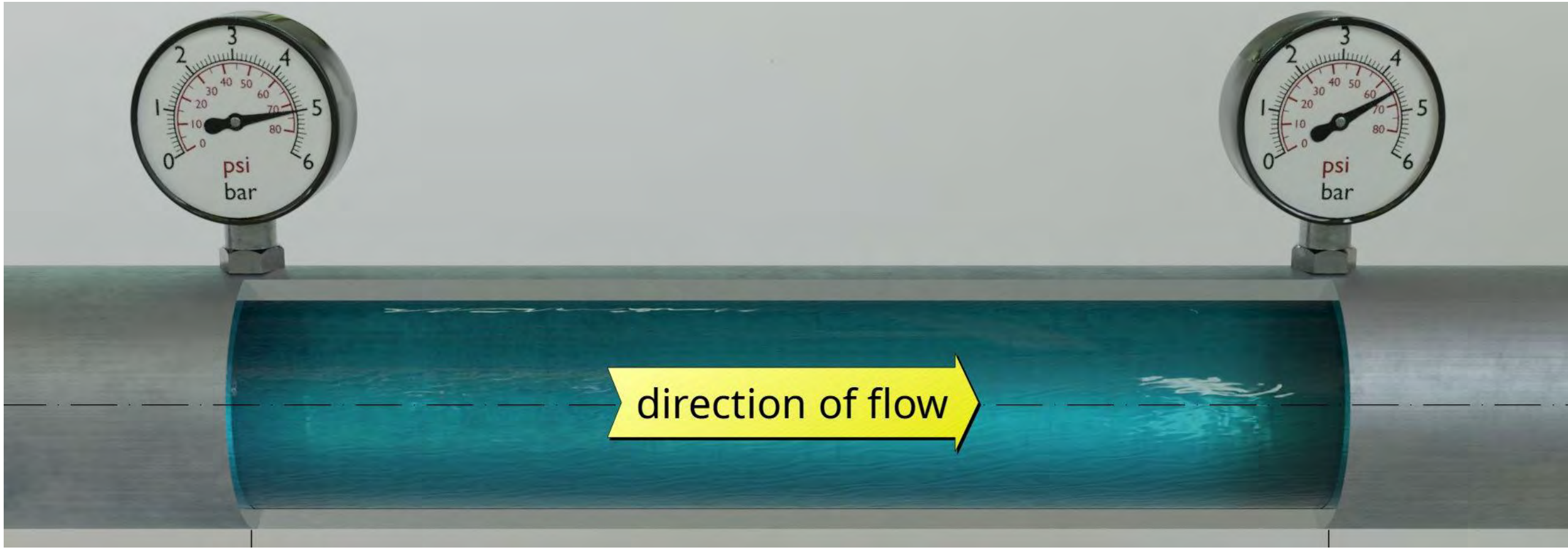
Direction change due to geometry or velocity change

Major Loss – Pipe Roughness

Rougher pipe = Greater head loss

https://www.cpesupply.com/835174/product/n/ads-1020flexdoublewall

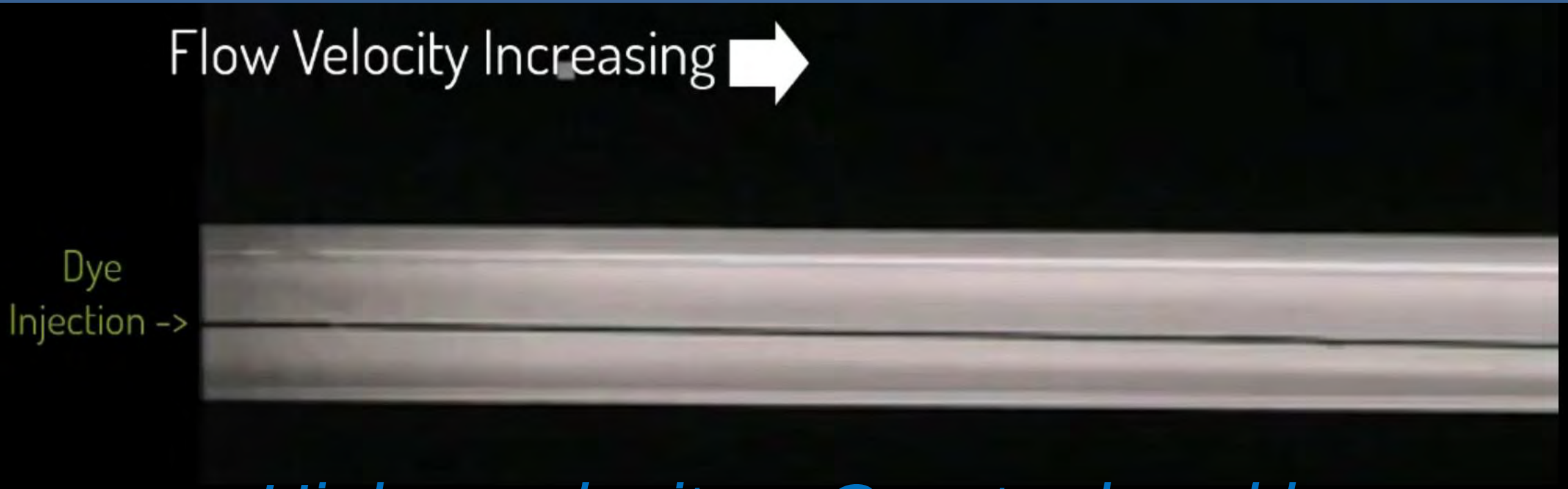
Major Loss – Pipe Length



Longer pipe = Greater head loss

https://www.tec-science.com/mechanics/gases-and-liquids/hagen-poiseuille-equation-for-pipe-flows-with-friction/

Major Loss – Water Velocity



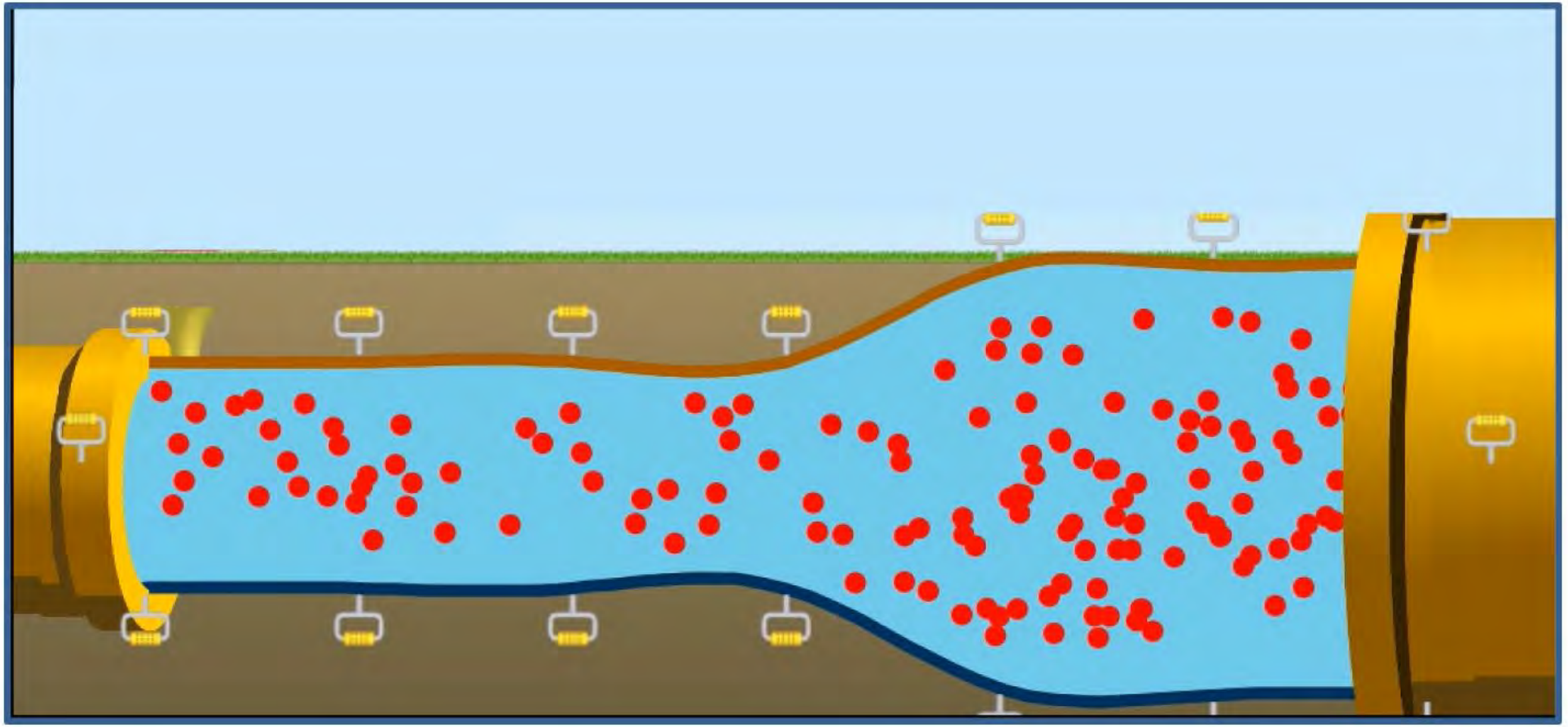
Higher velocity = Greater head loss

$(4\ ft/sec)^2 = 16$

$(8\ ft/sec)^2 = 64$

Fourfold increase by doubling velocity

Major Loss – Pipe Diameter

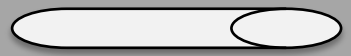


Smaller diameter = Greater head loss

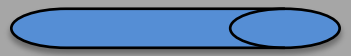
https://www.youtube.com/watch?v=kppxoA3gWco

Major Loss – Effect of Pipe Diameter

1-Inch-Diameter Pipe



Water contact surface area = 37 in^2/ft

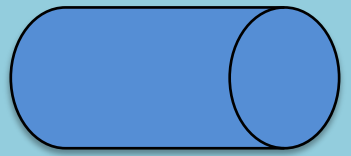


Water volume inside pipe = 0.041 gal/ft

$$\frac{\text{Surface area}}{\text{Water volume}} = \mathbf{919\ in2/gal}$$

4-Inch-Diameter Pipe

Water contact surface area = 150 in^2/ft

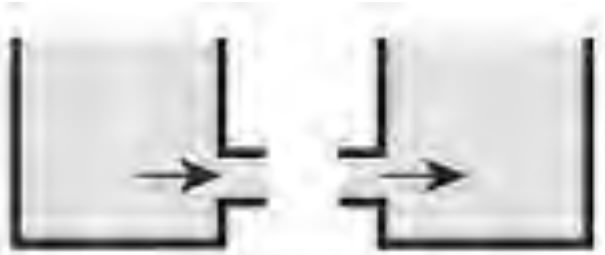


Water volume inside pipe = 0.65 gal/ft

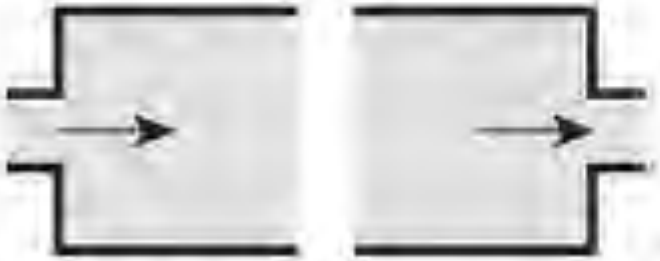
$$\frac{\text{Surface area}}{\text{Water volume}} = \mathbf{231\ in2/gal}$$

Higher pipe wall-water contact means greater head loss

Minor Loss Examples

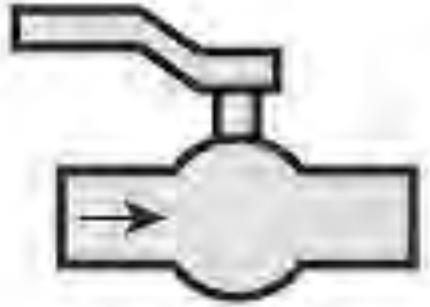


Entrances and Exits



Sudden expansions and contractions

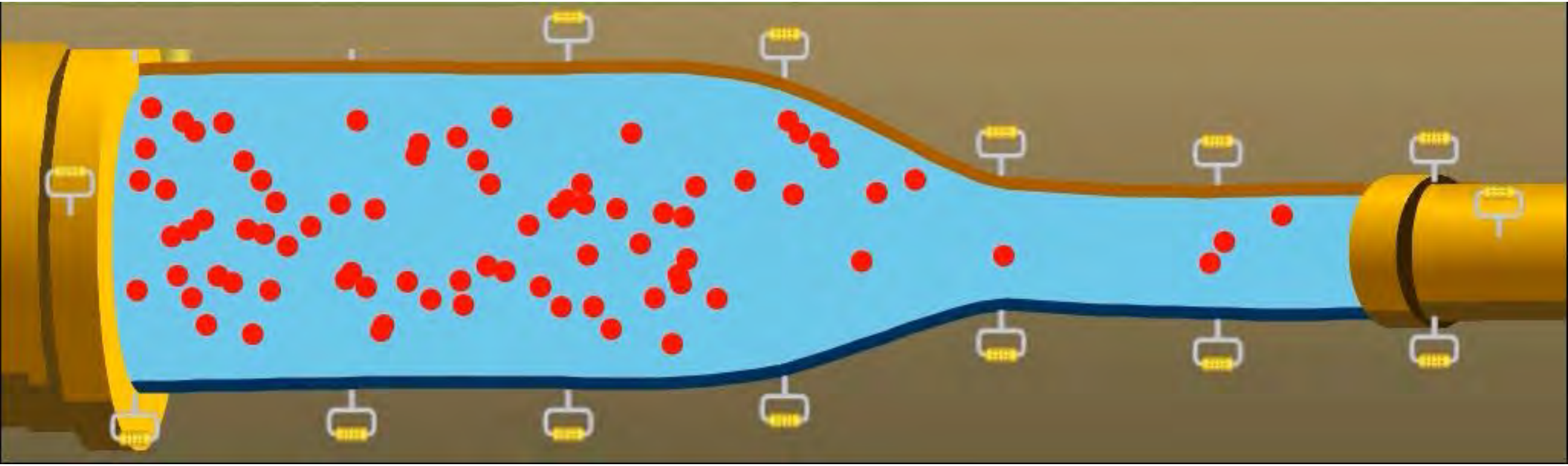
Gradual expansions and contractions



Valves

Bends and fittings

Minor Loss Example



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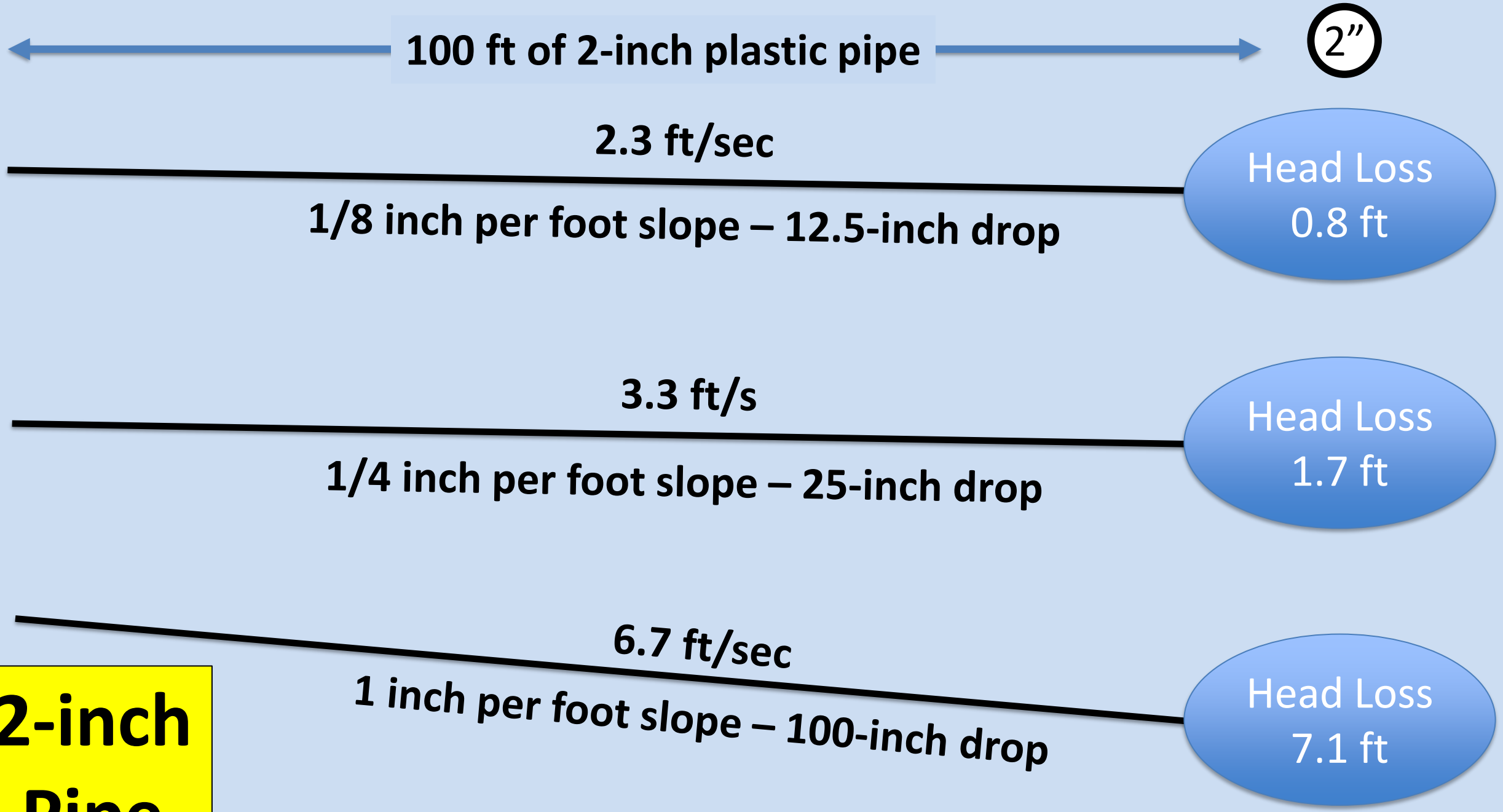

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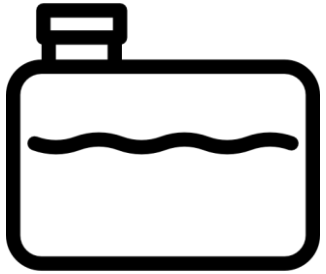
https://www.youtube.com/watch?v=uXTw8NlOFuI


https://www.youtube.com/watch?v=uKTw8NIOFtI

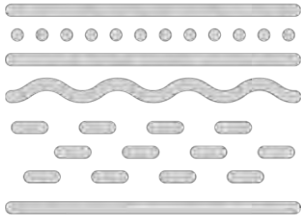
What are we Going to Cover?

Pipes

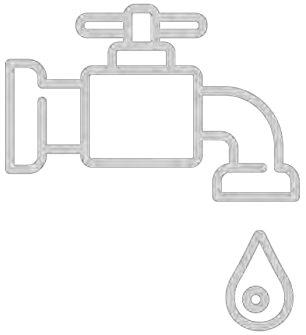
Septic Tank



Drainfield



Daily Flow

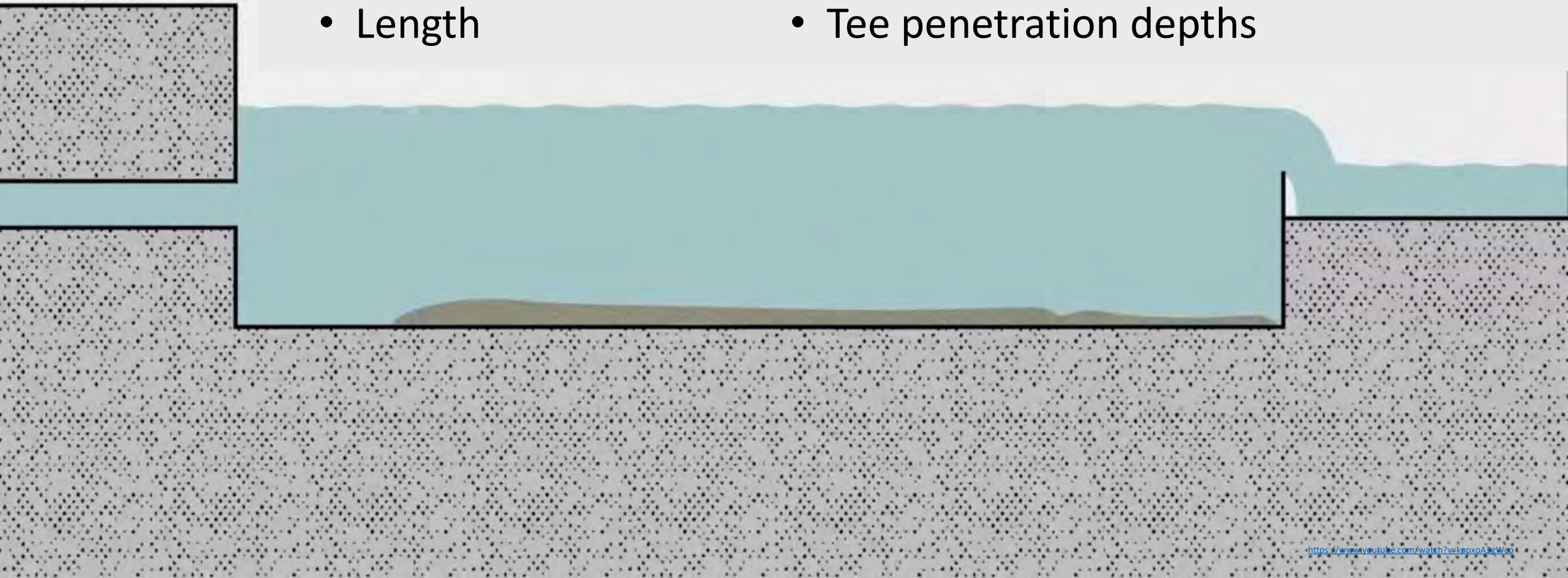


Stormwater

Equipment

Common Septic Tank Design Principles

- Liquid depth
- Volume
- Length
- Length-to-width ratio
- Two compartments
- Tee penetration depths



High Flow Reduces Residence Time

Normal Flow

- **4 residents with average flow**
- Resident flow = 280 gal/day
- Tank = 1,000 gal

$$\frac{\text{Tank volume}}{\text{Daily flow}} = \mathbf{3.5\ days}$$

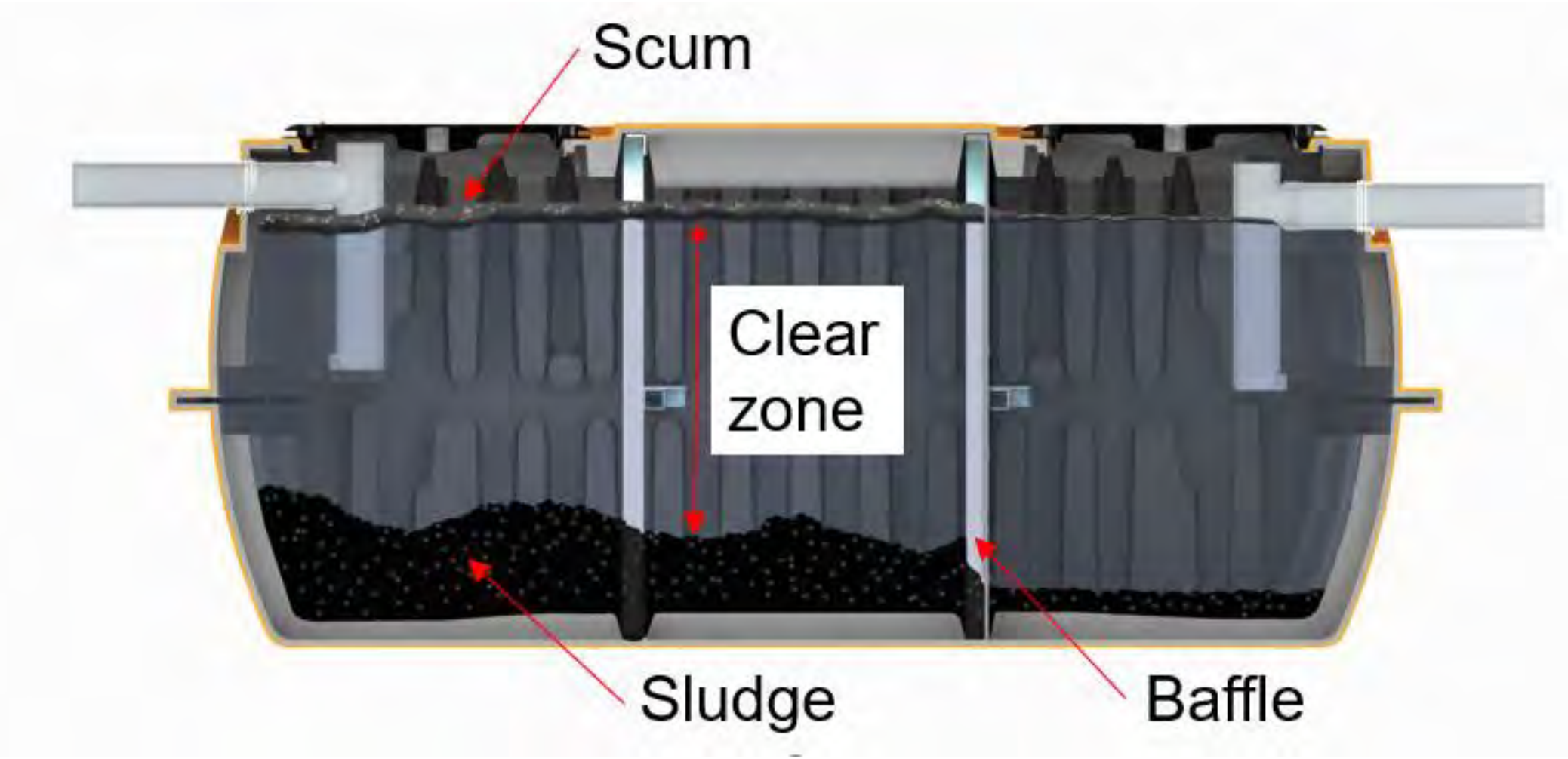
High Flow

- **4 average residents + home daycare**
- Resident flow = 280 gal/day
- Daycare flow = 280 gal/day
- Tank = 1,000 gal

$$\frac{\text{Tank volume}}{\text{Daily flow}} = \mathbf{1.8\ days}$$

Effluent time in tank reduced by high flow

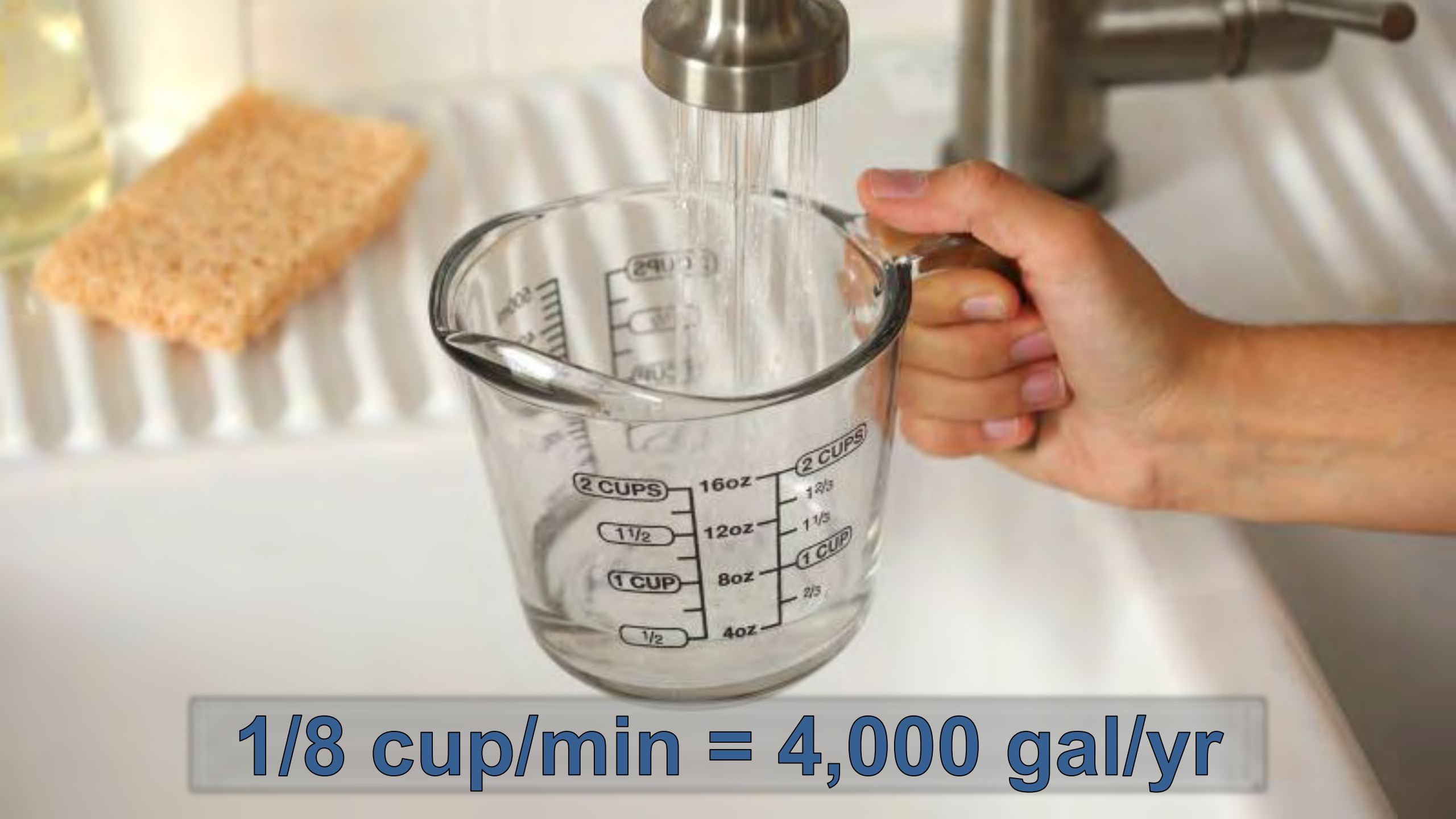
Reason to Pump Tank – Remove Solids



Pump Every 2 to 5 Years

Plumbing Check

Plumbing Check

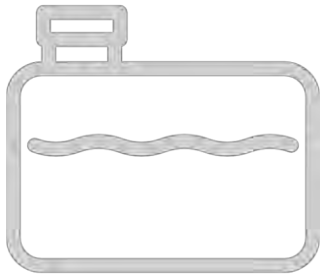


1/8 cup/min = 4,000 gal/yr

What are we Going to Cover?

Pipes

Septic Tank



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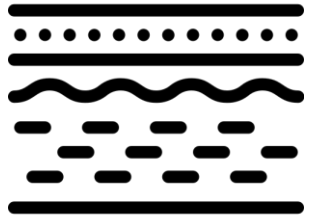
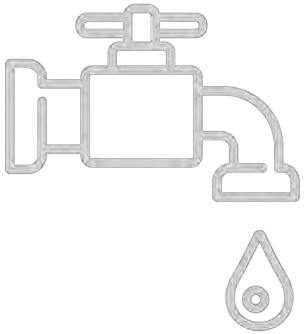


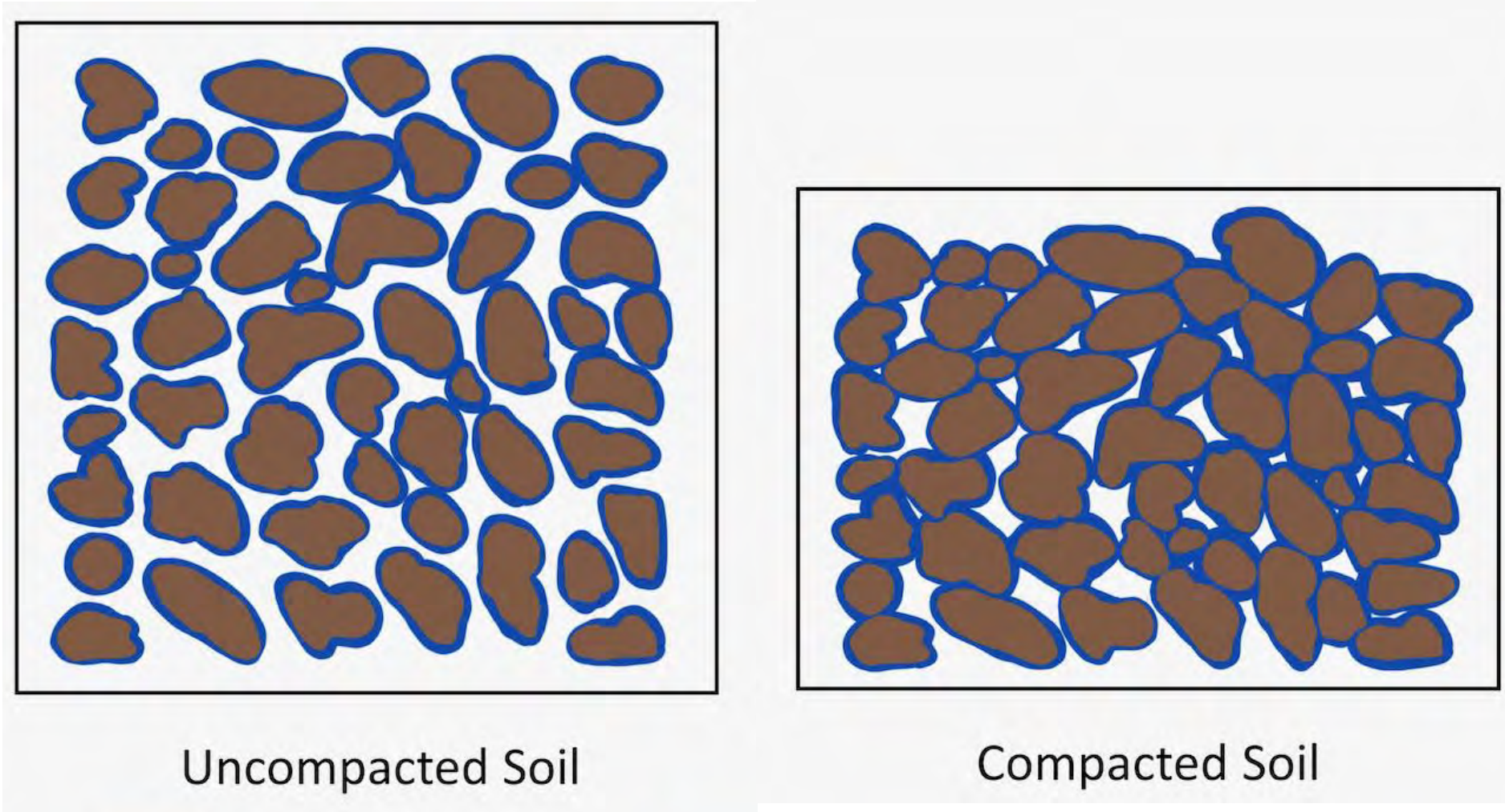
Daily Flow



Stormwater

Equipment

Soil Pore Structure



sk.ca/soilscience/chapter/soil-physics/

Fine Rounded Sand

https://www.sandatlas.org/desert-sand/

Clay Mineral

https://www.geo-ceramic-laboratory.com/geo-ceramic-laboratory/clay-mineralogy/

Subsurface Effluent Flow Modeling

NC STATE UNIVERSITY

Lateral Movement of Water in the Capillary Fringe Under Drainfields, Amoozegar, et. al., North Carolina State University

Combined Treatment and Dispersal System

Clogged Drainfield – Solids

Clogged Drainfield – Motor Oil

Clogged Drainfield – Papier-Mâché

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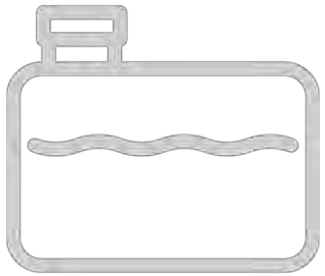

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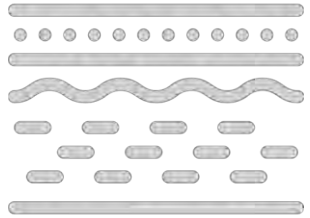

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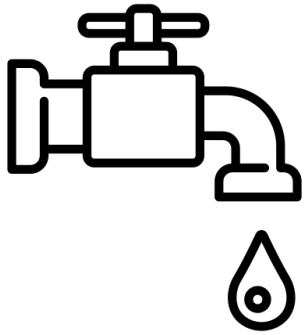
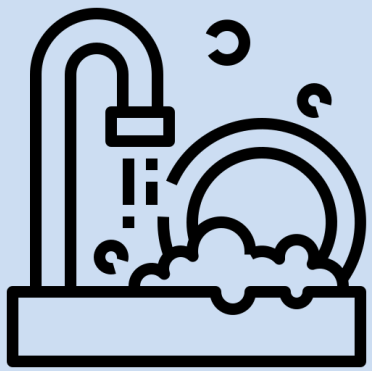
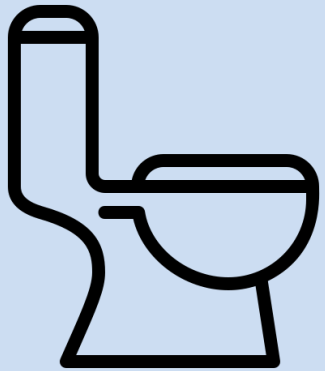


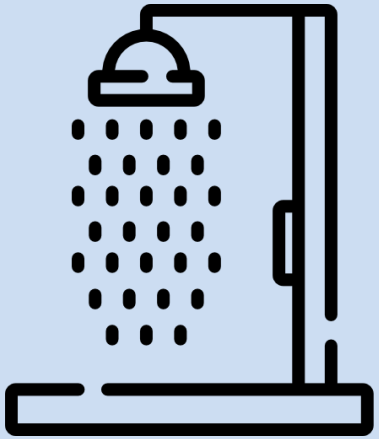
Stormwater

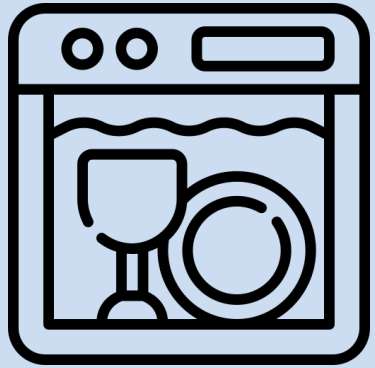
Equipment

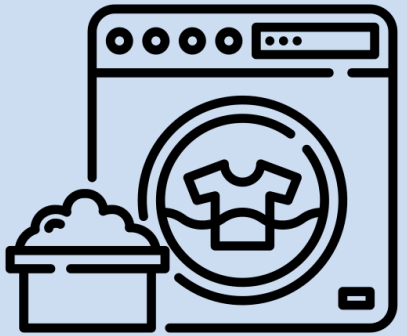
Primary Sources of Residential Flow







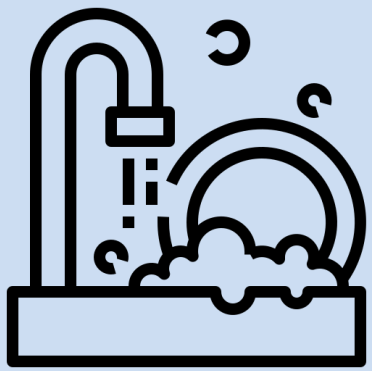




https://www.flaticon.com/

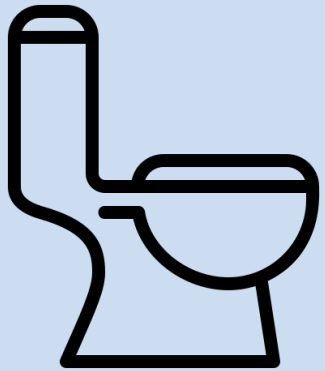
https://www.aquasana.com/info/what-is-a-typical-home-water-flow-rate-pd.html#:~:text=Dishwasher%3A%202%2D4%20GPM,Washing%20machine%3A%203%2D5%20GPM

Kitchen Sink



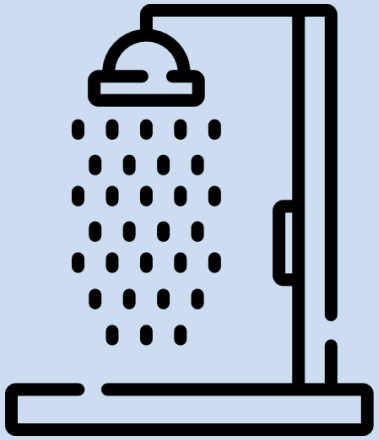
2 to 3 gpm

Toilet



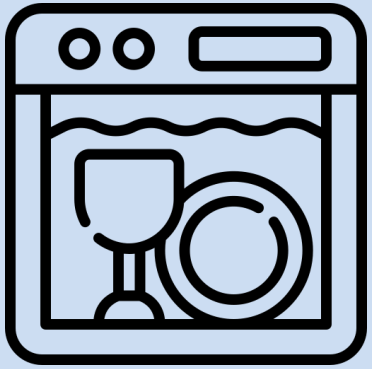
2 gpm

Shower



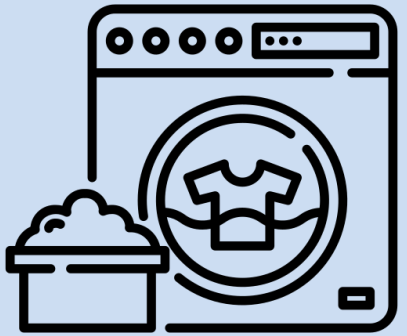
2 to 3 gpm

Dishwasher



2 to 4 gpm

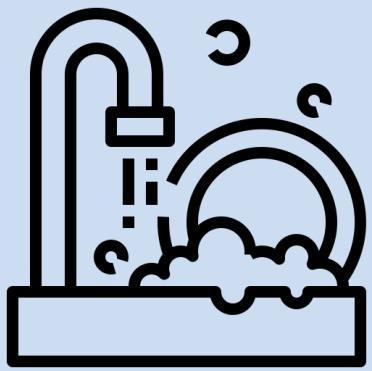
Clothes Washer



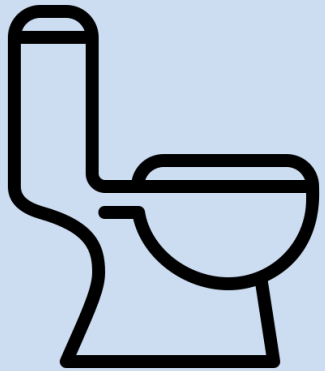
3 to 5 gpm

https://www.flaticon.com/

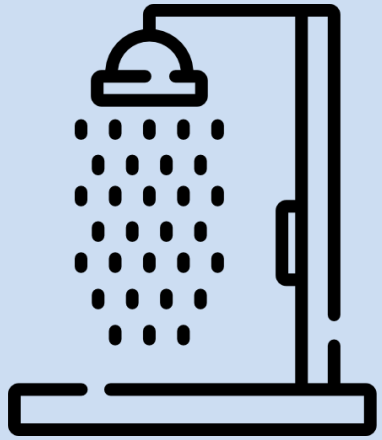
Total Simultaneous Flow ~ 17 gpm



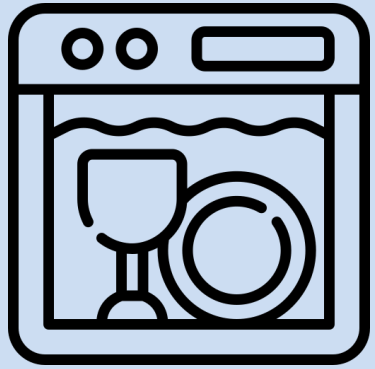
2 to 3 gpm



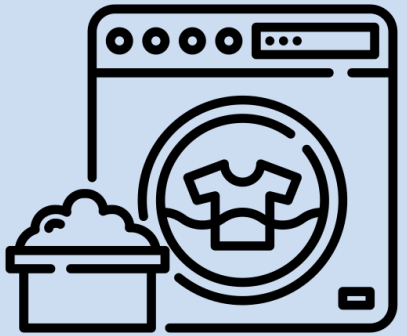
2 gpm



2 to 3 gpm



2 to 4 gpm



3 to 5 gpm

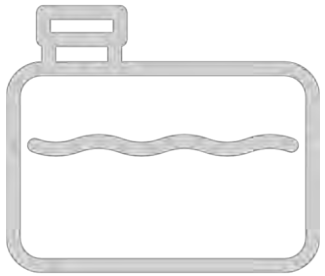
https://www.flaticon.com/


JUN 6 2007

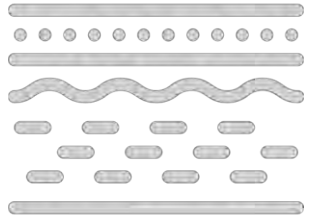
What are we Going to Cover?

Pipes

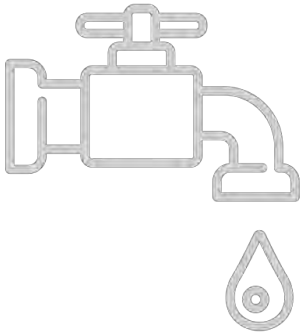
Septic Tank



Drainfield



Daily Flow



Stormwater

Equipment

https://www.youtube.com/watch?v=bmRYYeIqT3w&t=2s

Gallons per acre of water produced by a 1-inch rain event:

A. 7,000
B. 17,000
C. 27,000
D. 270,000

Raindrop Trivia

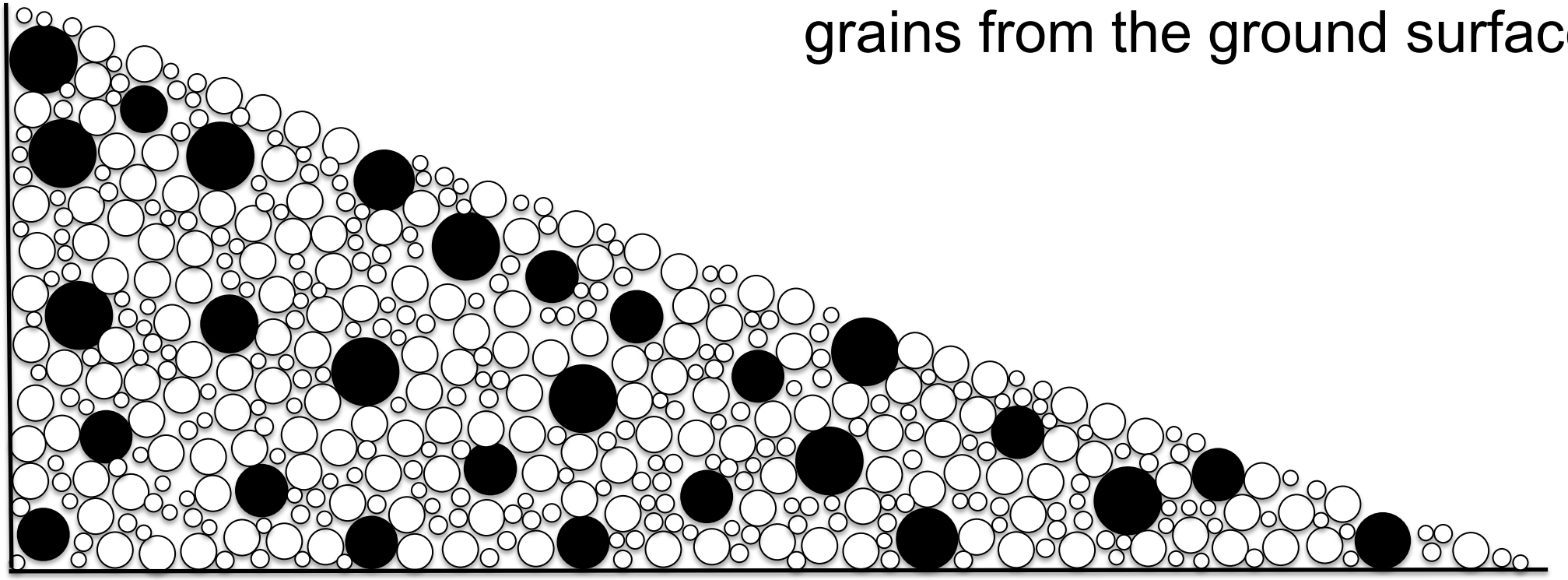
- 2 to 5 millimeters in diameter
- 20 mph impact velocity
- 18,000 drops/sf in a storm
- 784,000,000 drops/acre in a storm

https://water.usgs.gov/edu/activity-howmuchrain.php

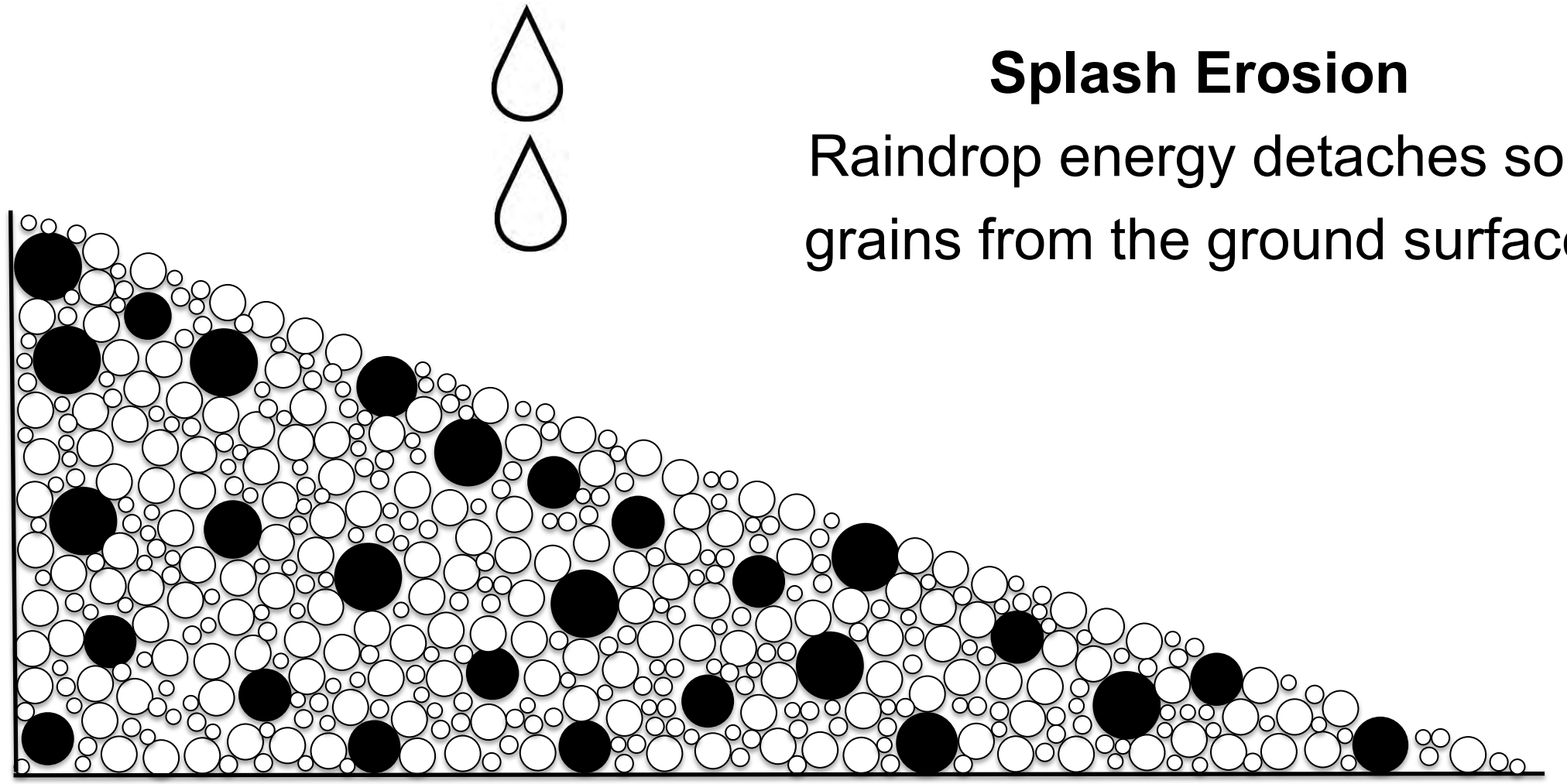
Raindrop Erosion Mechanism

Splash Erosion

Raindrop energy detaches soil grains from the ground surface



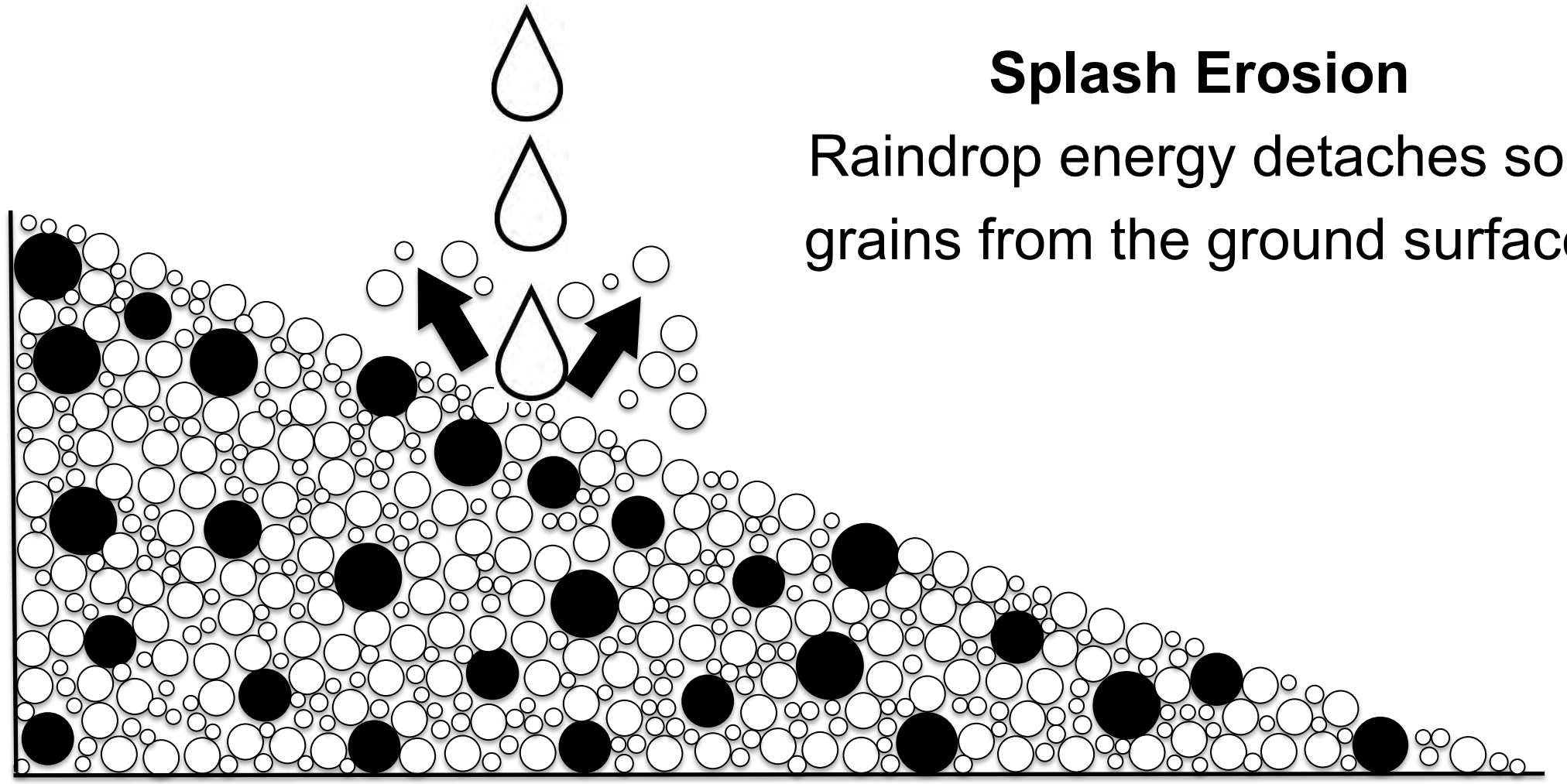
Raindrop Erosion Mechanism



Splash Erosion

Raindrop energy detaches soil grains from the ground surface

Raindrop Erosion Mechanism



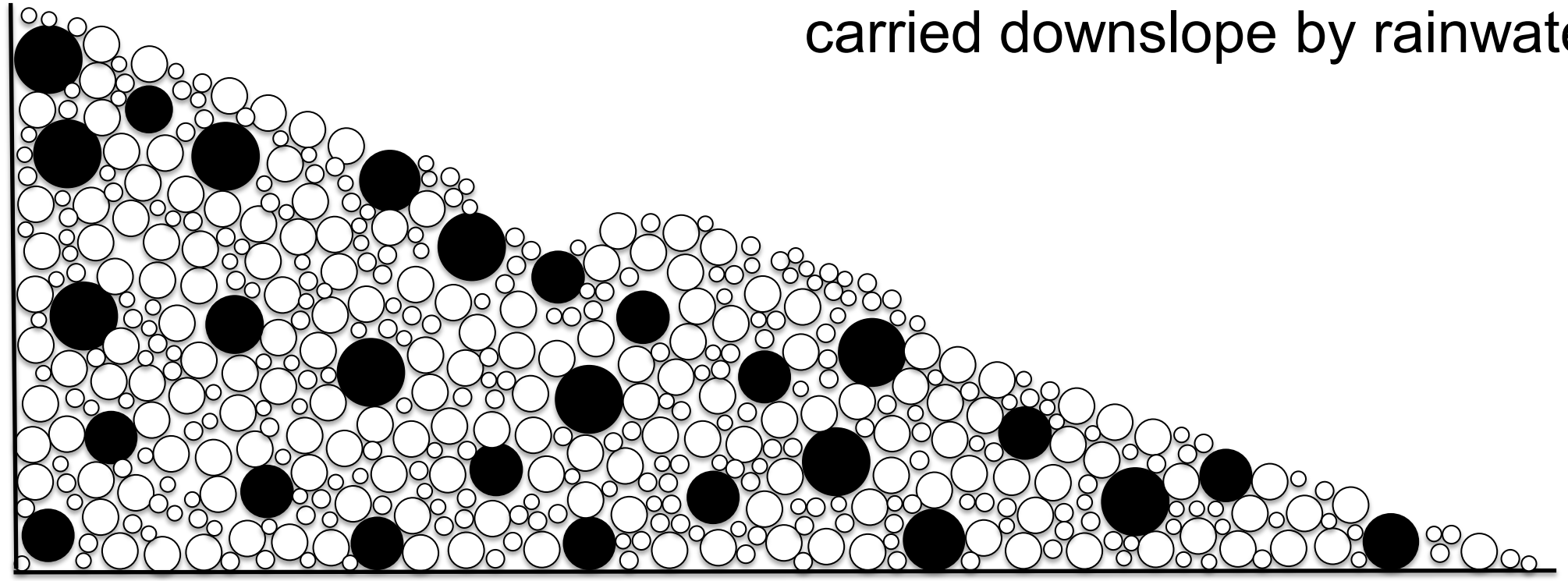
Splash Erosion

Raindrop energy detaches soil grains from the ground surface

Raindrop Erosion Mechanism

Sheet Erosion

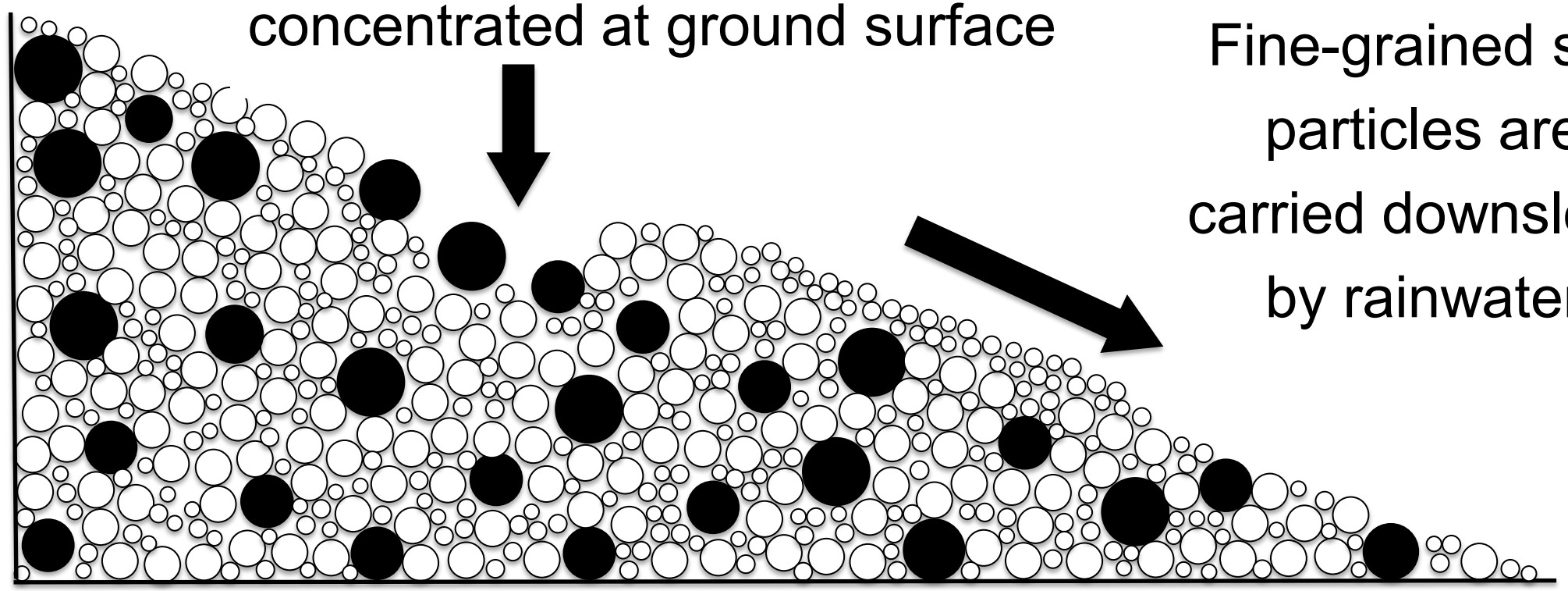
Fine-grained soil particles are carried downslope by rainwater



Raindrop Erosion Mechanism

Armor Layer Formation

Coarse soil grains concentrated at ground surface



Sheet Erosion

Fine-grained soil particles are carried downslope by rainwater

Why is Soil Erosion a Concern?

- Loss of organic topsoil inhibits vegetation
- Loss of soil structure and permeability
- Loss of minimum system cover depth
- Eroded soil grains transported elsewhere

Sheet Erosion

https://www.nrdc.org/stories/soil-erosion-101#water/

Rill Erosion

https://www.nrdc.org/stories/soil-erosion-101#water/

Gully Erosion

https://www.nrdc.org/stories/soil-erosion-101#water/

Vegetation Inhibits Erosive Forces

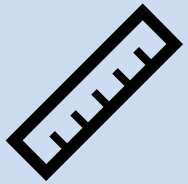
Erosion Control Best Practices

- Vegetate disturbed soil surfaces
- Mulch seeded area
- Keep slopes shallow
- Preserve natural vegetation
- Promote a deep root system


https://www.youtube.com/watch?v=9u05_c0bkQ

UNIVERSAL SOIL LOSS EQUATION

R - Rainfall and Runoff



L - Slope Length

K - Soil Erodibility

P - Support Practice

C - Crop Management

S - Slope Steepness

$$A = R \times K \times L \times S \times C \times P$$

Unstabilized – Heavy Erosion

Soil Loss = 3.5 Triaxles Per Year!

Seeded – Less Erosion

Soil Loss = 0.75 Triaxles Per Year

https://www.flaticon.com/

Uncontrolled Erosion – One Storm

Erosion Control Blanket

https://www.millbornseeds.com/erosion-control/blankets/


Coir
Log


Filter
Sock

Check Dams

Retaining Wall

https://www.lowes.com/n/how-to/control-erosion-in-the-landscape

Hardscaping

https://renogreen.com/reno-landscaping-services/xeriscaping-in-northern-nevada/

What are we Going to Cover?

Pipes

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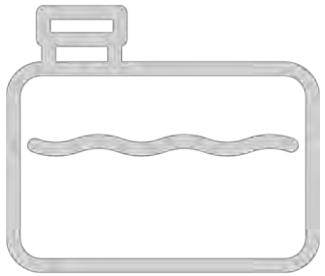

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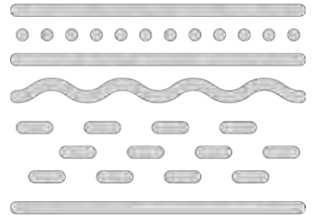
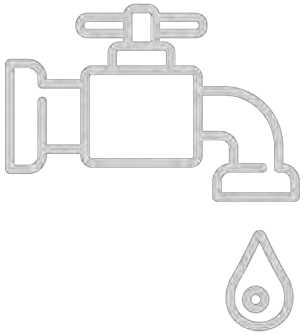
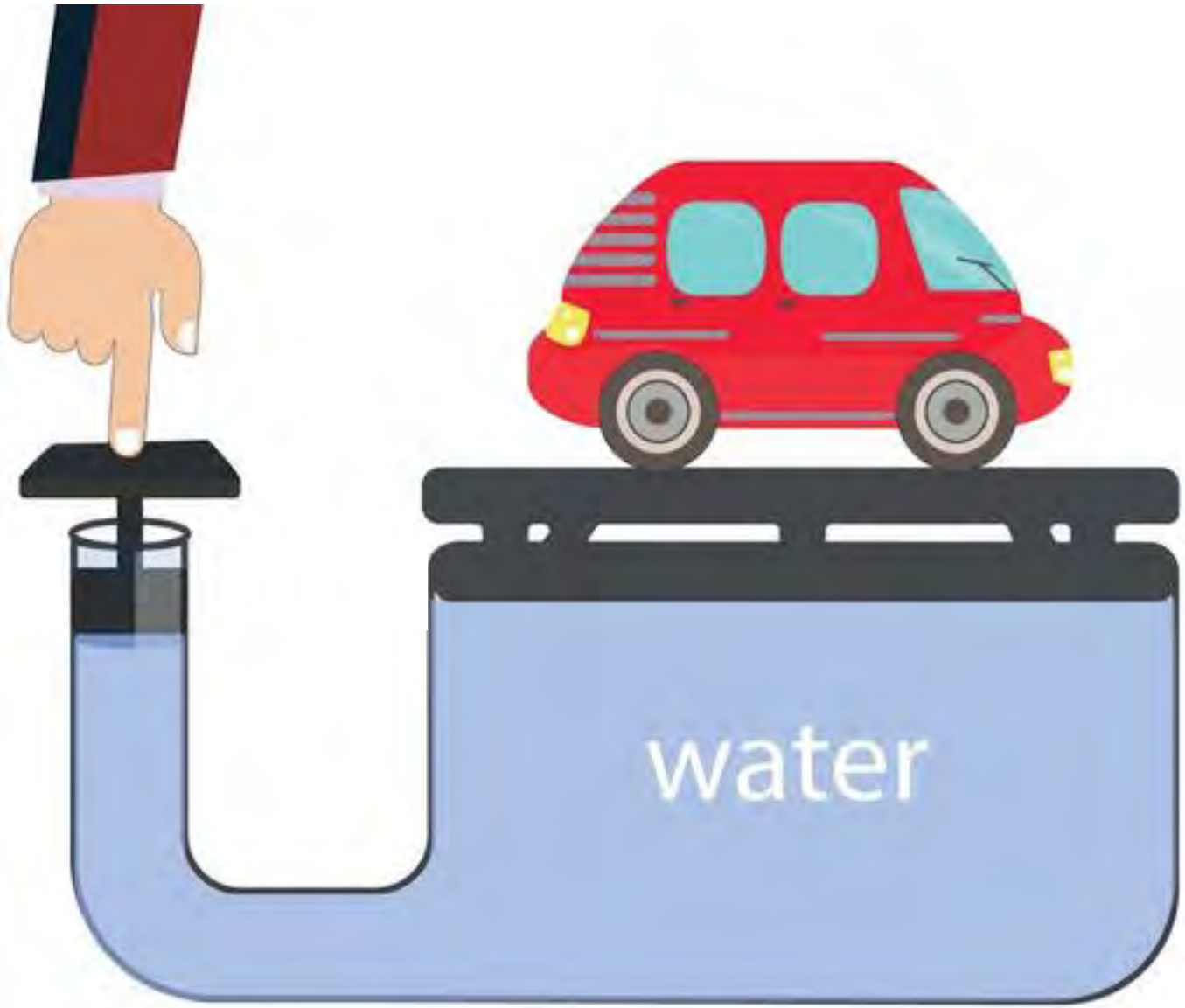


Daily Flow



Stormwater

Equipment



https://www.careers360.com/premium/how-to-prepare-pascal-law-in-physics-for-jee-main-neet

Open System Pressure Varies

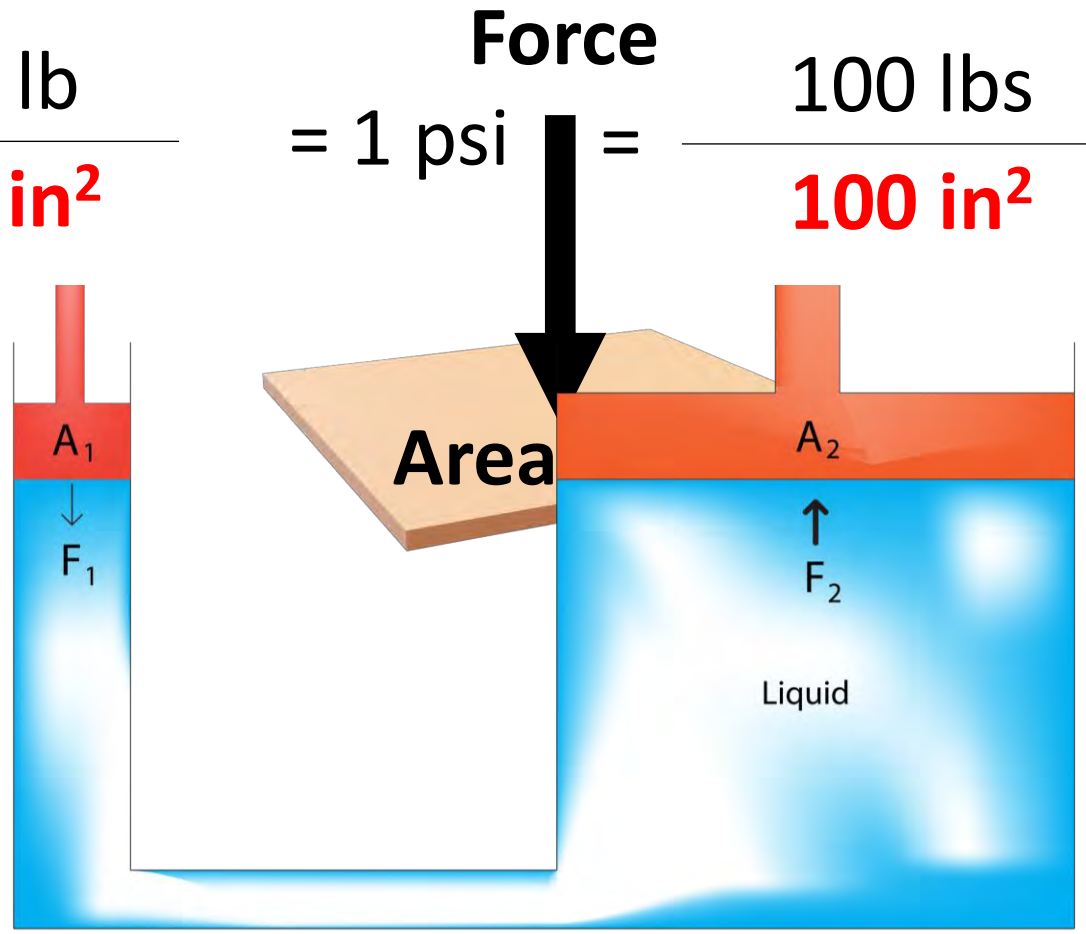
Closed System Pressure Constant

Uniform pressure exists everywhere in a closed system

Equipment Hydraulics

$$\frac{\text{Force}}{\text{Area}} = \text{Pressure} = \frac{\text{Larger Force}}{\text{Larger Area}}$$

$$\frac{1\text{ lb}}{1\text{ in}^2} = 1\text{ psi} = \frac{100\text{ lbs}}{100\text{ in}^2}$$



Force multiplier is 100

Concepts to Take With You

- Fluid flow affects many aspects of onsite systems
- Fluid flow is affected by pipe type, size, and shape
- Fluid creating friction reduces energy and causes head loss
- Fluid changing direction reduces energy and causes head loss
- The open soil pore network keeps a drainfield functioning
- Mitigating soil erosion is about controlling precipitation energy

Questions?

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www.infiltratorwater.com