WATER TREATMENT OPERATION

Exam Preparation Training

NEVADA RURAL WATER ASSOCIATION

OBJECTIVE

Basic objective of a water operator?

To provide drinking water that is…

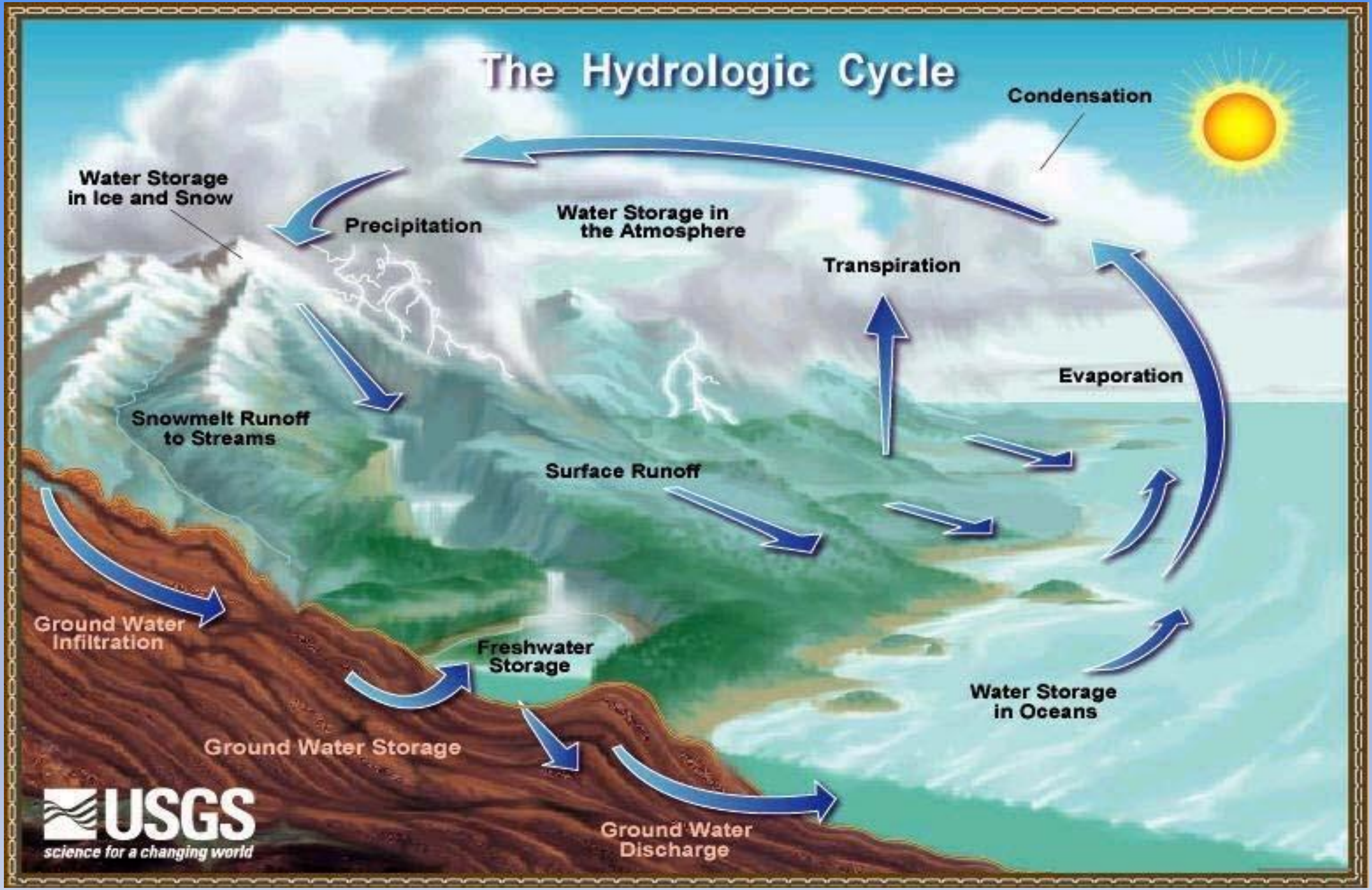
Safe

Aesthetically Pleasing

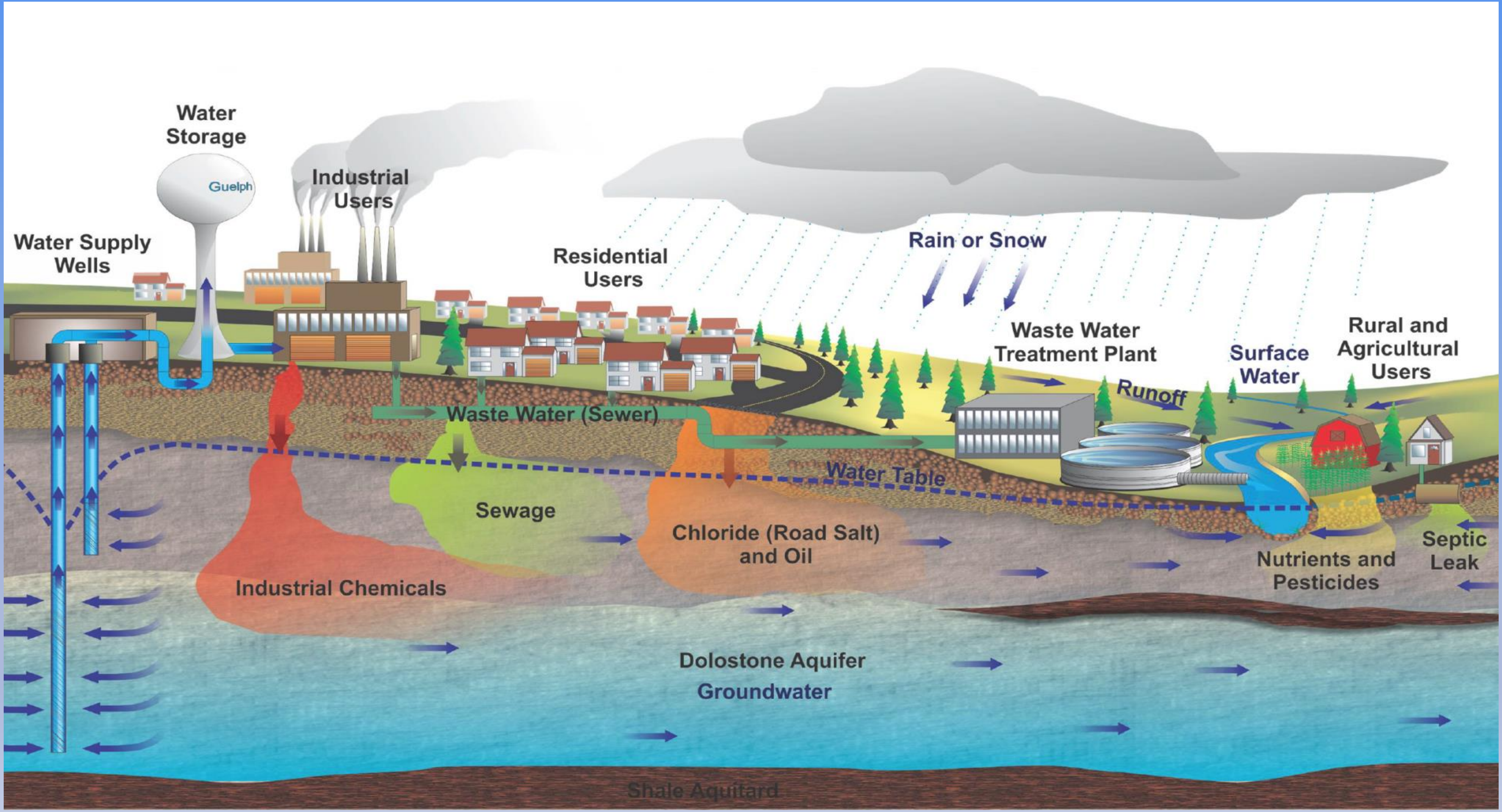
Reasonable Cost

SAFE, AESTHETICALLY PLEASING, AND…

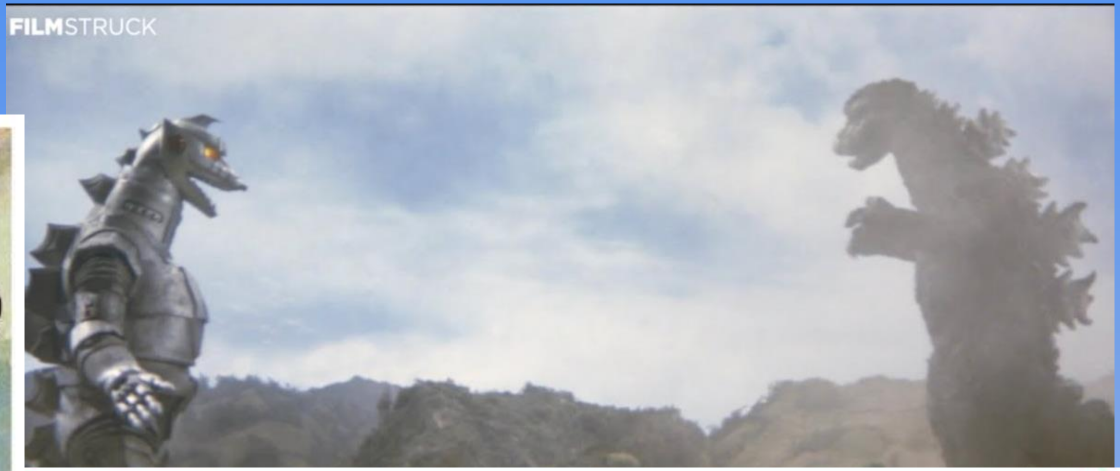
WHERE DOES IT COME FROM?

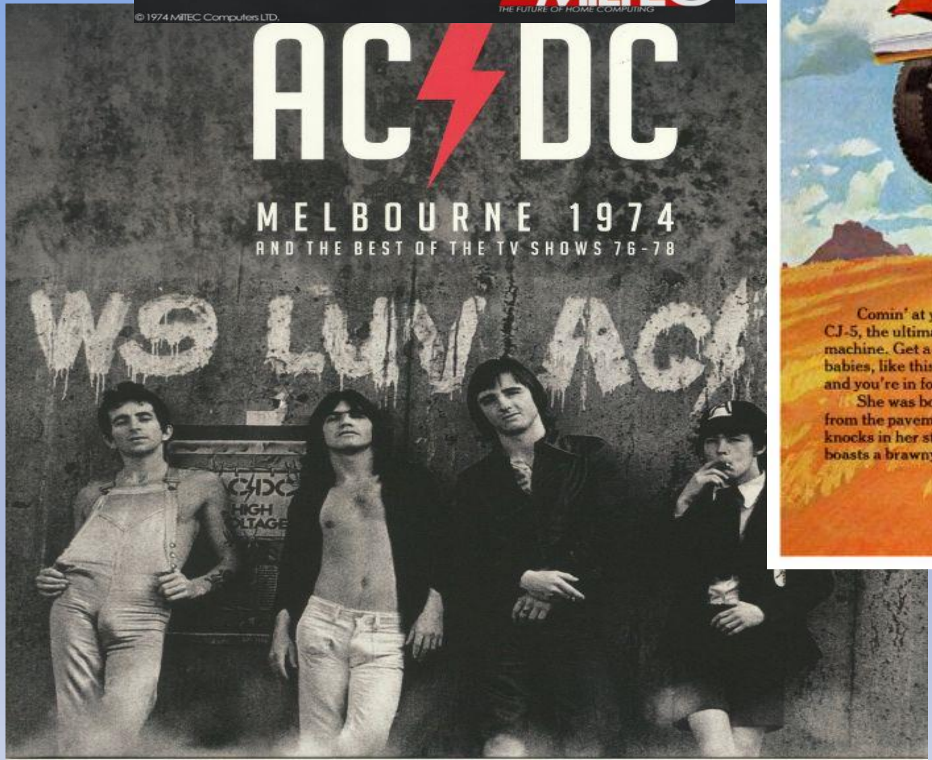


WHY DO WE NEED TO TREAT?



WHAT HAPPENED IN 1974?





1974 SAFE DRINKING WATER ACT

Set national standards regulating 23 contaminants in drinking water.

Required PWS to monitor and report levels of identified contaminants.

Gave states lead role in implementation and enforcement.

- Primacy

Requires certified and licensed operators!

...1986

Set deadlines for establishment of 83 MCLs (60 new)

Established uniform guidelines specifying two treatment techniques:

Filtration and Disinfection

Greater emphasis on enforcement

Penalties for tampering with drinking water supplies

Protection of groundwater sources:

- Wellhead Protection Program & Critical Aquifer Protection Program

AND 1996

Officially defines PWS categories.

Research (arsenic, lead, disinfection byproducts, etc.)

"Best available science in decision making".

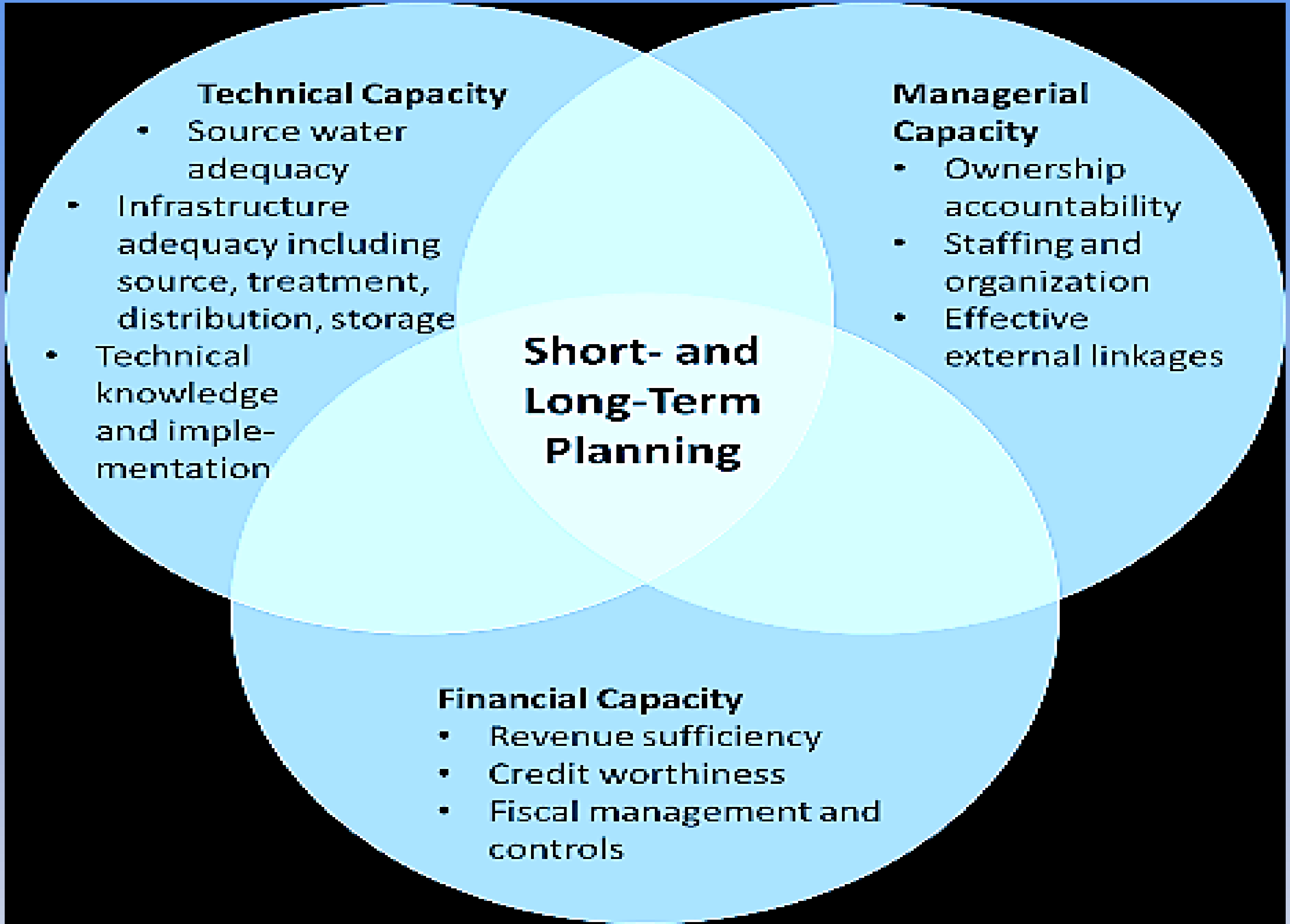
Refines public notification rules.

Drinking Water State Revolving Loan Funds

Capacity Development (TMF)

- Technical Managerial Financial

TECHNICAL MANAGERIAL FINANCIAL CAPACITY



SDWA WATER TREATMENT REGULATIONS

1989 Surface Water Treatment Rule (SWTR)

1998 Interm Enhanced Surface Water Treatment Rule (IESWTR)

1998 Stage 1 Disinfectant and Disinfection Byproduct Rule (Stage 1 DBPR)

2001 Filter Backwash Recycling Rule (FBRR)

2002 Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)

2006 Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

2006 Stage 2 Disinfectant and Disinfection Byproduct Rule (Stage 2 DBPR)

SURFACE WATER TREATMENT RULE (SWTR) JUNE 1989

- Applies to all public water systems (PWSs) using surface water sources or ground water sources under the direct influence of surface water (GWUDI)
- Requires most water systems to filter and disinfect water from surface water sources or GWUDI
- Establishes maximum contaminant level goals (MCLGs) for viruses, bacteria and Giardia lamblia
- Includes treatment technique (TT) requirements for filtered and unfiltered systems to protect against adverse health effects of exposure to pathogens

INTERIM ENHANCED SURFACE WATER TREATMENT RULE (IESWTR) DECEMBER 1998

- Applies to all public water systems using surface water, or GWUDI, that serve 10,000 or more persons
- Sets a maximum contaminant level goal (MCLG) of zero for Cryptosporidium
- Sets a 2-log Cryptosporidium removal requirements for systems that provide filtration
- Requires that watershed protection programs address Cryptosporidium for system that are not required to provide filtration

INTERIM ENHANCED SURFACE WATER TREATMENT RULE (IESWTR) DECEMBER 1998

- Requires certain public water systems to meet strengthened filtration requirements
- Establishes requirements for covers on new finished water reservoirs
- Requires sanitary surveys, conducted by states, for all surface water systems regardless of size
- Requires systems to calculate levels of microbial inactivation to address risk trade-offs with disinfection byproducts

FILTER BACKWASH RECYCLING RULE (FBRR) JUNE 2001

- Applies to all public water systems using conventional or direct filtration to treat surface water, or GWUDI, regardless of size
- Requires public water systems (PWSs) to review their backwash water recycling practices to ensure that they do not compromise microbial control
- Requires recycled filter backwash water to go through all processes of a system's conventional or direct filtration treatment.

LONG TERM 1 ENHANCED SURFACE WATER TREATMENT RULE (LT1ESWTR) JANUARY 2002

- Applies to all public water systems using surface water, or GWUDI, serving fewer than 10,000 persons
- Sets a maximum contaminant level goal (MCLG) of zero for Cryptosporidium
- Sets a 2-log Cryptosporidium removal requirements for systems that filter
- Requires that watershed protection programs address Cryptosporidium for system that are not required to provide filtration

LONG TERM 1 ENHANCED SURFACE WATER TREATMENT RULE (LT1ESWTR) JANUARY 2002

- Requires certain public water systems to meet strengthened filtration requirements
- Requires systems to calculate levels of microbial inactivation to address risk trade-offs with disinfection byproducts

LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE (LT2ESWTR) JANUARY 2006

- Applies to all PWSs that use surface water or GWUDI
- Targets additional Cryptosporidium treatment requirements to higher risk systems
- Requires provisions to reduce risks from uncovered finished water storage facilities
- Provides provisions to ensure that systems maintain microbial protection as they take steps to reduce the formation of disinfection byproducts

EPA DRINKING WATER QUICK REFERENCE GUIDES

https://www.epa.gov/dwreginfo/drinking-water-rule-quick-reference-guides#stage2qrg

EPA United States Environmental Protection Agency

Comprehensive Surface Water Treatment Rules Quick Reference Guide: Systems Using Conventional or Direct Filtration

Overview of the Rules

Title	**Surface Water Treatment Rule** (SWTR) - 40 CFR 141.70-141.75 **Interim Enhanced Surface Water Treatment Rule** (IESWTR) - 40 CFR 141.170-141.175 **Filter Backwash Recycling Rule** (FBRR) - 40 CFR 141.76 **Long Term 1 Enhanced Surface Water Treatment Rule** (LT1ESWTR) - 40 CFR 141.500-141.571
Purpose	Improve public health protection through the control of microbial contaminants, particularly viruses, *Giardia*, and *Cryptosporidium*.
General Description	The **Surface Water Treatment Rules**: ➤ Applies to all public water systems (PWSs) using surface water or ground water under the direct influence of surface water (GWUDI), otherwise known as **"Subpart H systems."** ➤ Requires all Subpart H systems to disinfect. ➤ Requires Subpart H systems to filter unless specific filter avoidance criteria are met. ➤ Requires individual filter monitoring and establishes combined filter effluent (CFE) limits. ➤ Applies a treatment technique requirement for control of microbials.

Overview of Requirements

The purpose of this table is show how the requirements for the IESWTR and LT1ESWTR build on the existing requirements established in the original SWTR.

APPLICABILITY: PWSs that use surface water or ground water under the direct influence of surface water (Subpart H) that practice conventional or direct filtration.		**Final Rule Dates**			
		SWTR 1989	**IESWTR 1998**	**LT1ESWTR 2002**	**FBRR 2001**
Population Served	$\geq$10,000	✓	✓		✓
	< 10,000	✓	N/A (except for sanitary survey provisions)	✓	✓
Regulated Pathogens	99.99% (4-log) removal/inactivation of viruses	✓	Regulated under SWTR	Regulated under SWTR	Regulated under SWTR
	99.9% (3-log) removal/inactivation of *Giardia lamblia*	✓	Regulated under SWTR	Regulated under SWTR	Regulated under SWTR
	99% (2-log) removal of Cryptosporidium		✓	✓	Regulated under IESWTR & LT1ESWTR
Residual Disinfectant Requirements	Entrance to distribution system ($\geq$0.2 mg/L)	✓	Regulated under SWTR	Regulated under SWTR	
	Detectable in the distribution system	✓	Regulated under SWTR	Regulated under SWTR	
Turbidity Performance Standards	Combined Filter Effluent	✓	✓	✓	
	Individual Filter Effluent		✓	✓	
Disinfection Profiling & Benchmarking	Systems must profile inactivation levels and generate benchmark, if required		✓	✓	
Sanitary Surveys (state requirement)	CWS: Every 3 years NCWS: Every 5 years		✓	Regulated under IESWTR	
Covered Finished Reservoirs/Water Storage Facilities (new construction only)			✓	✓	
Operated by Qualified Personnel as Specified by State		✓	Regulated under SWTR	Regulated under SWTR	Regulated under SWTR

(CWS) Community Water System (NCWS) Non-community Water System

Turbidity

There are two ways turbidity is measured: **Combined Filter Effluent (CFE)** and **Individual Filter Effluent (IFE)**.

Turbidity: Monitoring and Reporting Requirements

Turbidity Reporting Requirements *(Reports due by the 10th day of the following month the system serves water to the public.)*	**Monitoring/ Recording Frequency**	**SWTR As of June 29, 1993**	**IESWTR $\geq$ 10,000 people As of January 1, 2002**	**LT1ESWTR < 10,000 people As of January 1, 2005**
CFE 95% Value Report total number of CFE measurements and number and percentage of CFE measurements $\leq$ 95th % limit.	At least every 4 hours*	$\leq$ 0.5 NTU	$\leq$ 0.3 NTU	$\leq$ 0.3 NTU
CFE Maximum Value Report date and value of any CFE measurement that exceeded CFE maximum limit.	At least every 4 hours*	5 NTU Contact state within 24 hours	1 NTU Contact state within 24 hours	1 NTU Contact state within 24 hours
IFE Monitoring Report IFE monitoring conducted and any follow-up actions.	Monitor continuously every 15 minutes	None	Monitor–exceedances require follow-up action	Monitor–exceedances require follow-up action. Systems with 2 or fewer filters may monitor CFE continuously in lieu of IFE.

*Monitoring frequency may be reduced by the state to once per day for systems serving 500 or fewer people.

IFE Follow-Up and Reporting Requirements

Condition	**IESWTR ($\geq$ 10,000)**			**LT1ESWTR (< 10,000) ****		
	Action	**Report**	**By**	**Action**	**Report**	**By**
2 consecutive recordings >0.5 NTU taken 15 minutes apart at the end of the first 4 hours of continuous filter operation after backwash/offline:	Produce filter profile within 7 days (if cause not known)	➤ Filter # ➤ Turbidity value ➤ Date ➤ Cause (if known) or report profile was produced	10th of the following month			
2 consecutive recordings > 1.0 NTU taken 15 minutes apart:	Produce filter profile within 7 days (if cause not known)	➤ Filter # ➤ Turbidity value ➤ Date ➤ Cause (if known) or report profile was produced	10th of the following month		➤ Filter # ➤ Turbidity value ➤ Date ➤ Cause (if known)	10th of the following month
2 consecutive recordings > 1.0 NTU taken 15 minutes apart at the same filter for **3 months in a row**:	Conduct filter self-assessment within 14 days	➤ Filter # ➤ Turbidity value ➤ Date ➤ Report filter self-assessment produced	10th of the following month	Conduct a filter self-assessment within 14 days. Systems with 2 filters that monitor CFE in lieu of IFE must do both filters.	➤ Date filter self-assessment triggered & completed	10th of the following month (or within 14 days of filter self-assessment being triggered if triggered in last 4 days of the month)
2 consecutive recordings > 2.0 NTU taken 15 minutes apart at the same filter for 2 months in a row:	Arrange for CPE within 30 days & submit report within 90 days	➤ Filter # ➤ Turbidity value ➤ Date Submit CPE report	10th of the following month 90 days after exceedance	Arrange for CPE within 60 days & submit CPE report within 120 days	➤ Date CPE triggered Submit CPE report	10th of the following month 120 days after exceedance

** Systems serving fewer than 10,000 people must begin complying with these requirements beginning January 1, 2005.

IFE performance is measured in systems using conventional or direct filtration. The performance of each individual filter is critical to controlling pathogen breakthrough. The **CFE** turbidity results may mask the performance of an individual filter since the individual filter may have a turbidity spike of a short duration not detected by 4 hour CFE readings.

The IESWTR and LT1ESWTR created more stringent CFE turbidity standards and established a new IFE turbidity monitoring requirement to address *Cryptosporidium*. These new turbidity standards assure conventional and direct filtration systems will be able to provide 2-log *Cryptosporidium* removal.

Disinfection

Disinfection must be sufficient to ensure that the total treatment process (disinfection plus filtration) of the system achieves at least:

- 99.9% (3-log) inactivation and/or removal of *Giardia lamblia*.
- 99.99% (4-log) inactivation and/or removal of viruses.

Cryptosporidium must be removed by filtration and no inactivation credits are currently given for disinfection. Systems must also comply with the maximum residual disinfectant level (MRDL) requirements specified in the Stage 1 Disinfectants/ Disinfection Byproducts Rule (Stage 1 DBPR).

Residual Disinfectant Monitoring and Reporting Requirements

Location	**Concentration**	**Monitoring Frequency**	**Reporting (Reports due 10th of the following month)**
Entry to distribution system.	Residual disinfectant concentration cannot be < 0.2 mg/L for more than 4 hours.	Continuous, but states may allow systems serving 3,300 or fewer persons to take grab samples from 1 to 4 times per day, depending on system size.	Lowest daily value for each day, the date and duration when residual disinfectant was < 0.2 mg/L, and when state was notified of events where residual disinfectant was < 0.2 mg/L.
Distribution system - same location as total coliform sample location(s).	Residual disinfectant concentration cannot be undetectable in greater than 5% of samples in a month, for any 2 consecutive months. Heterotrophic plate count (HPC) $\leq$ 500/mL is deemed to have detectable residual disinfectant.	Same time as total coliform samples.	Number of residual disinfectant or HPC measurements taken in the month resulting in no more than 5% of the measurements as being undetectable in any 2 consecutive months.

LOG INACTIVATION

Log Removal Value (LRV) is a measure of the ability of a treatment processes to **remove or inactivate** pathogenic microorganisms.

Determined by taking the **logarithm of the ratio of pathogen concentration** in the **influent and effluent water** of a treatment process.

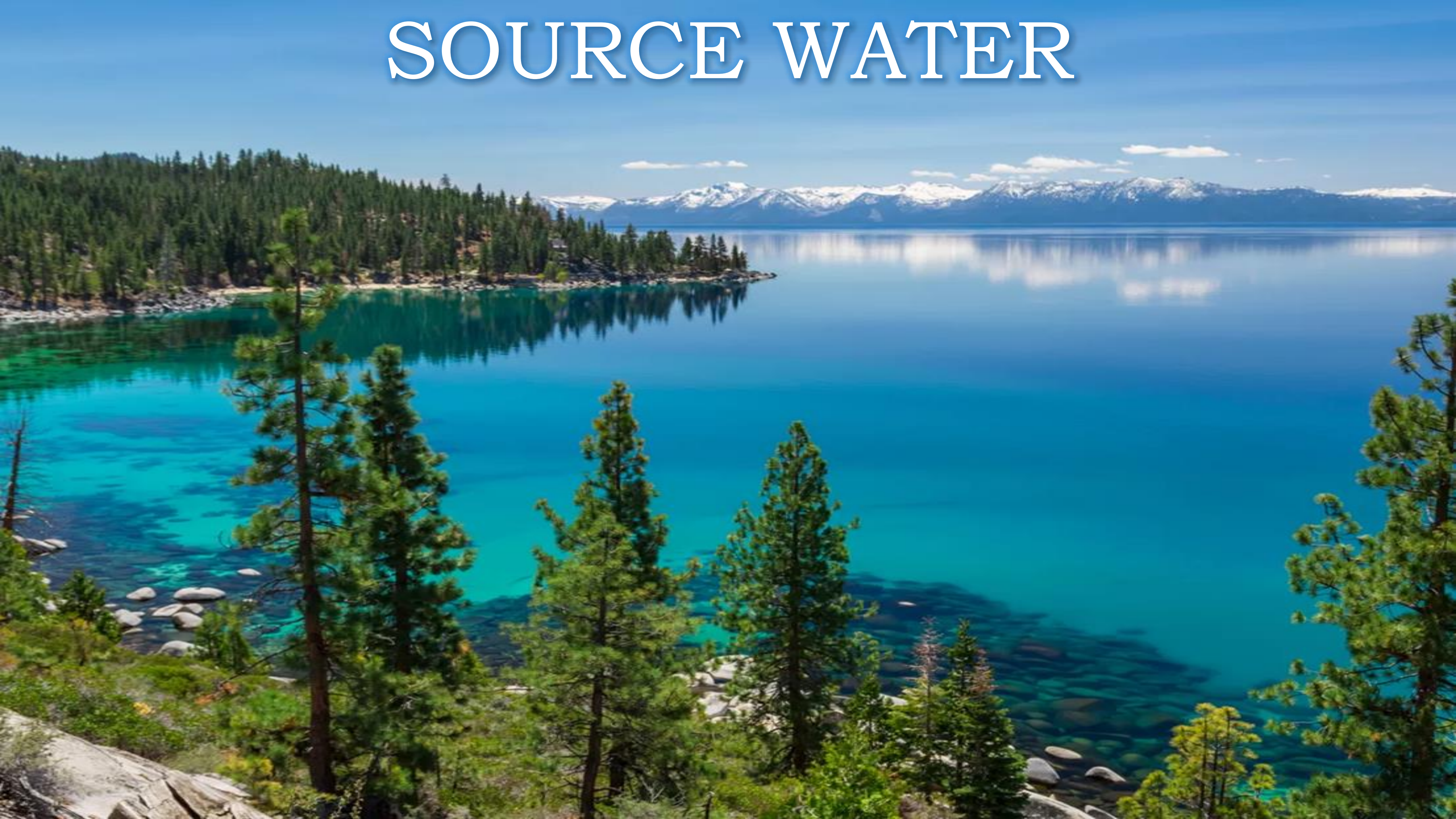
Log inactivation relates to % **inactivation.**

1-log inactivation = 9 out of 10 = 90% inactivation

2-log inactivation = 99 out of 100 = 99% inactivation

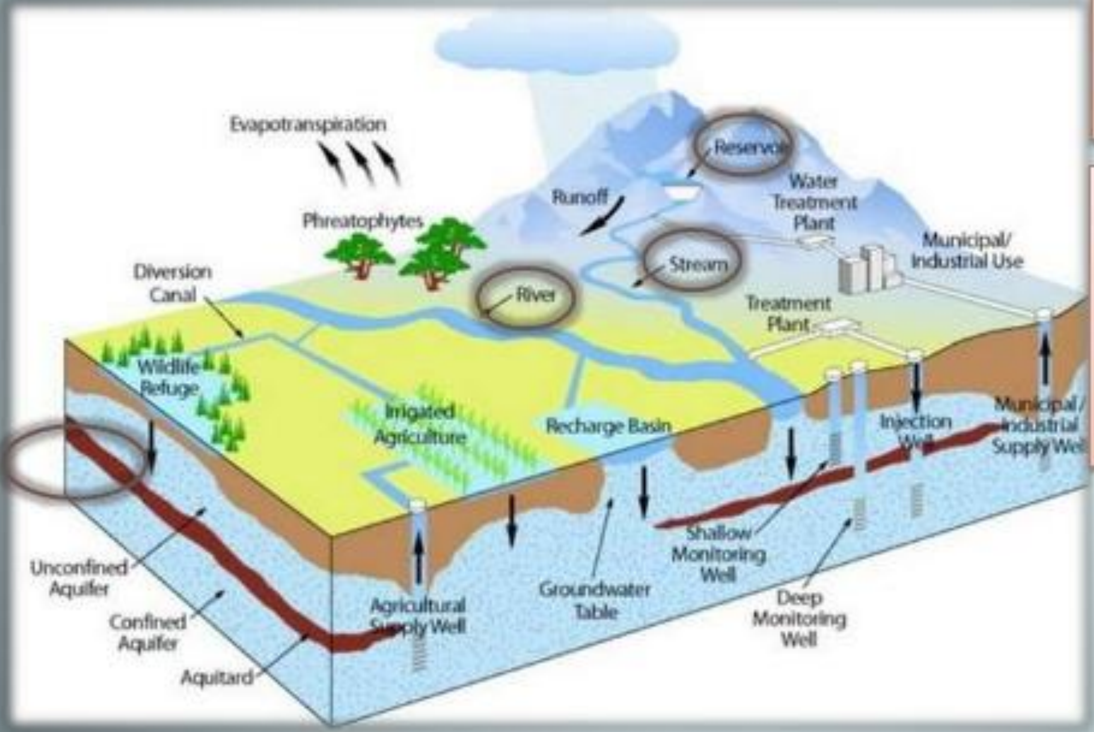
3-log inactivation = 999 out of 1,000 = 99.9% inactivation

4-log inactivation = 9,999 out of 10,000 = 99.99% inactivation


SOURCE WATER

SOURCE WATER

SOURCES OF WATER:



SURFACE SOURCES:

1. Streams
2. Lakes
3. Ponds
4. Rivers
5. Reservoirs
6. Stored rain water and cisterns

GROUND SOURCES:

1. Springs
2. Wells

Carson River Watershed

Carson River Watershed

- Encompasses apx. 3,966 square miles (6,382 kilometers)
- Carson River 184 miles long (296 km)
- Current population estimation125,000
  - Range from 200 people in Markleeville to 50,000 in Carson City
- Was predicted to reach over 457,000 by 2050

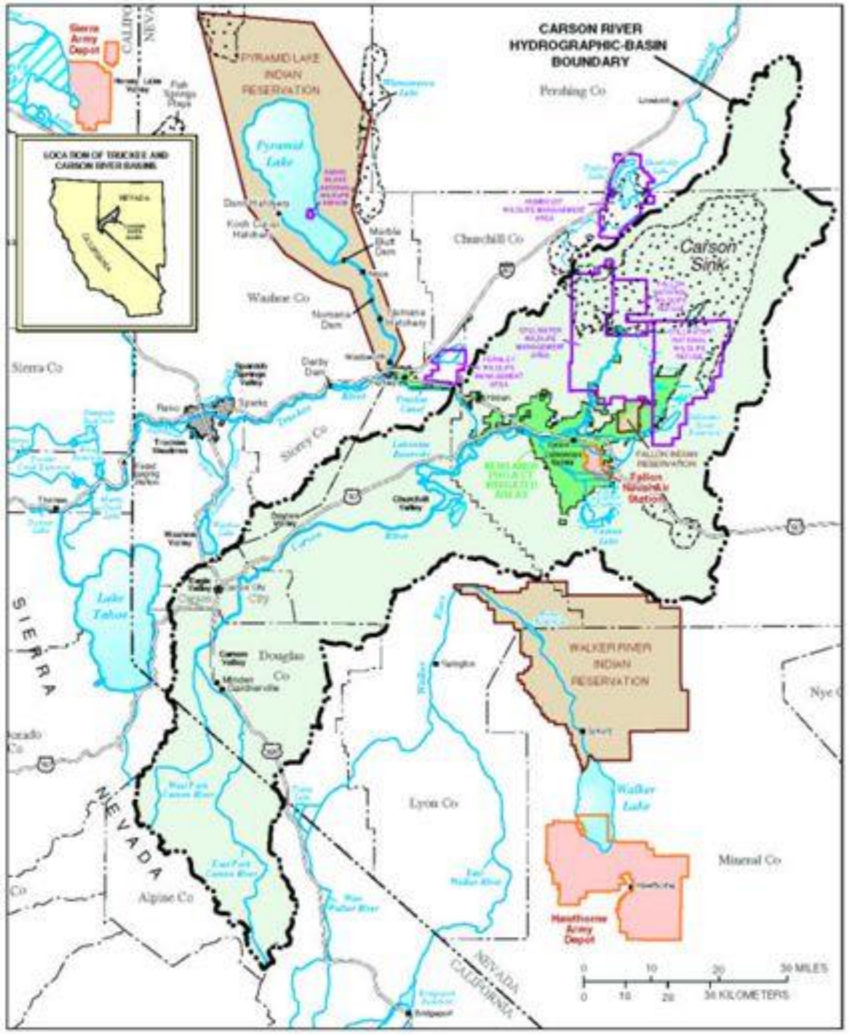
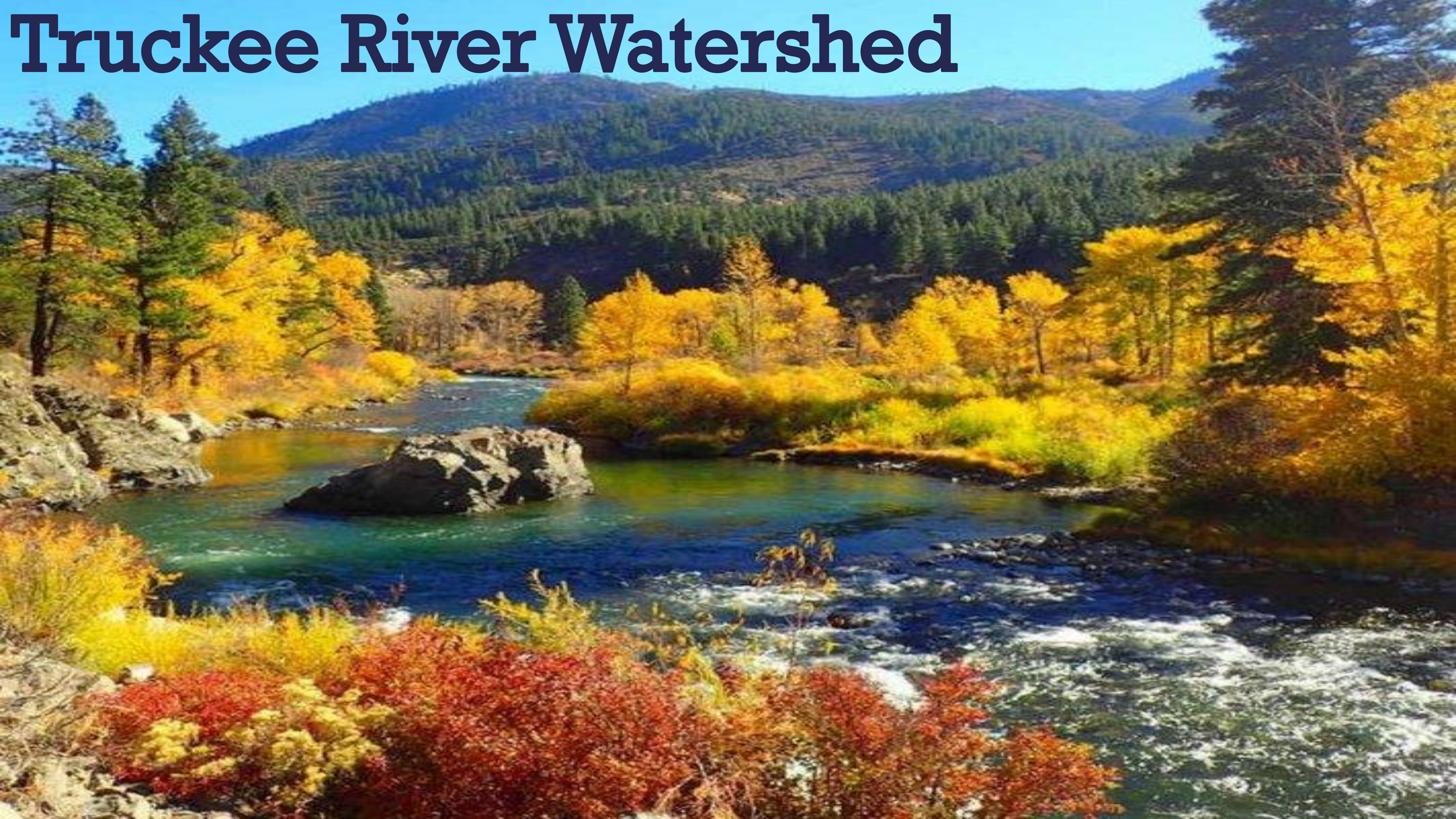
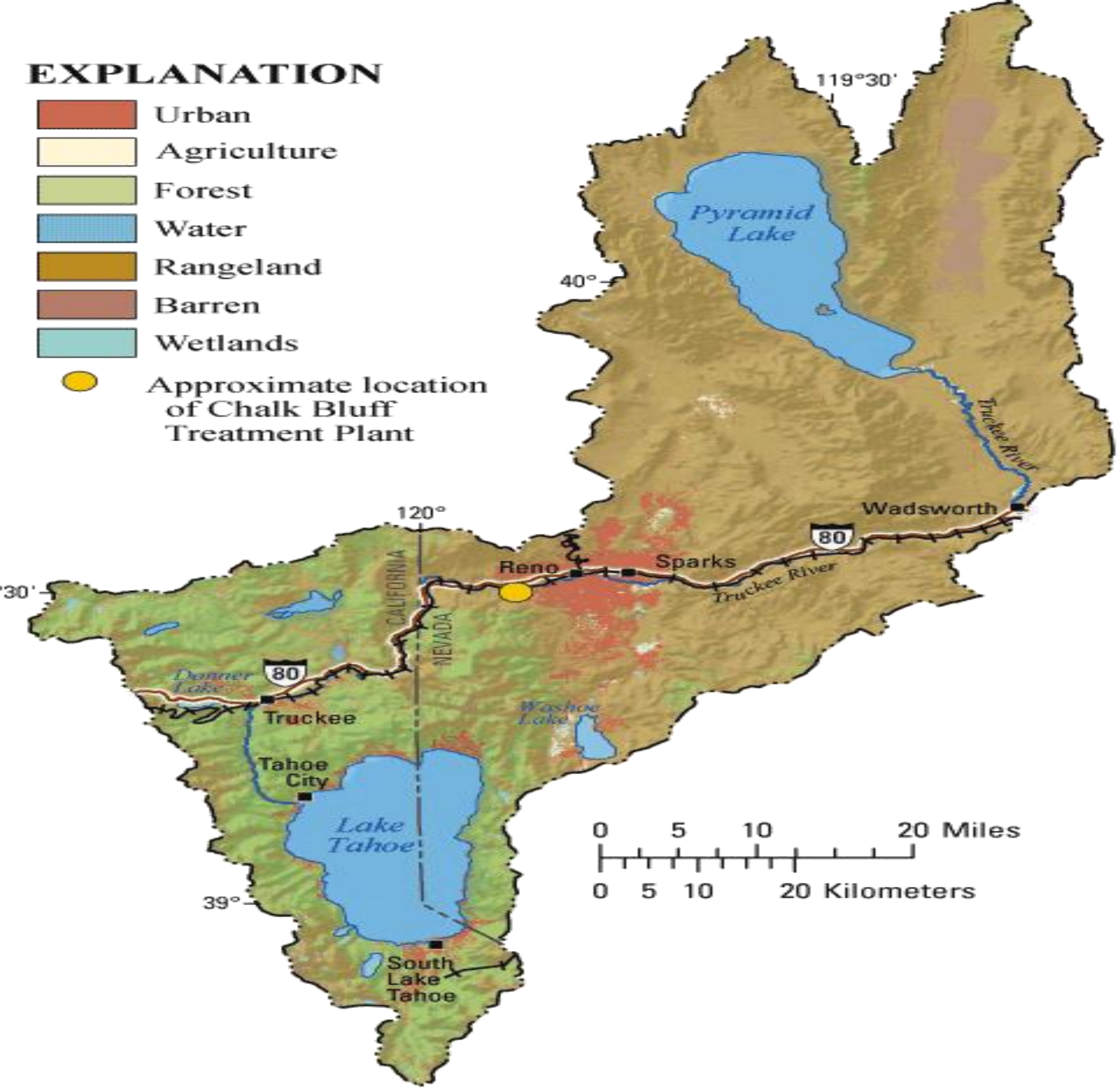


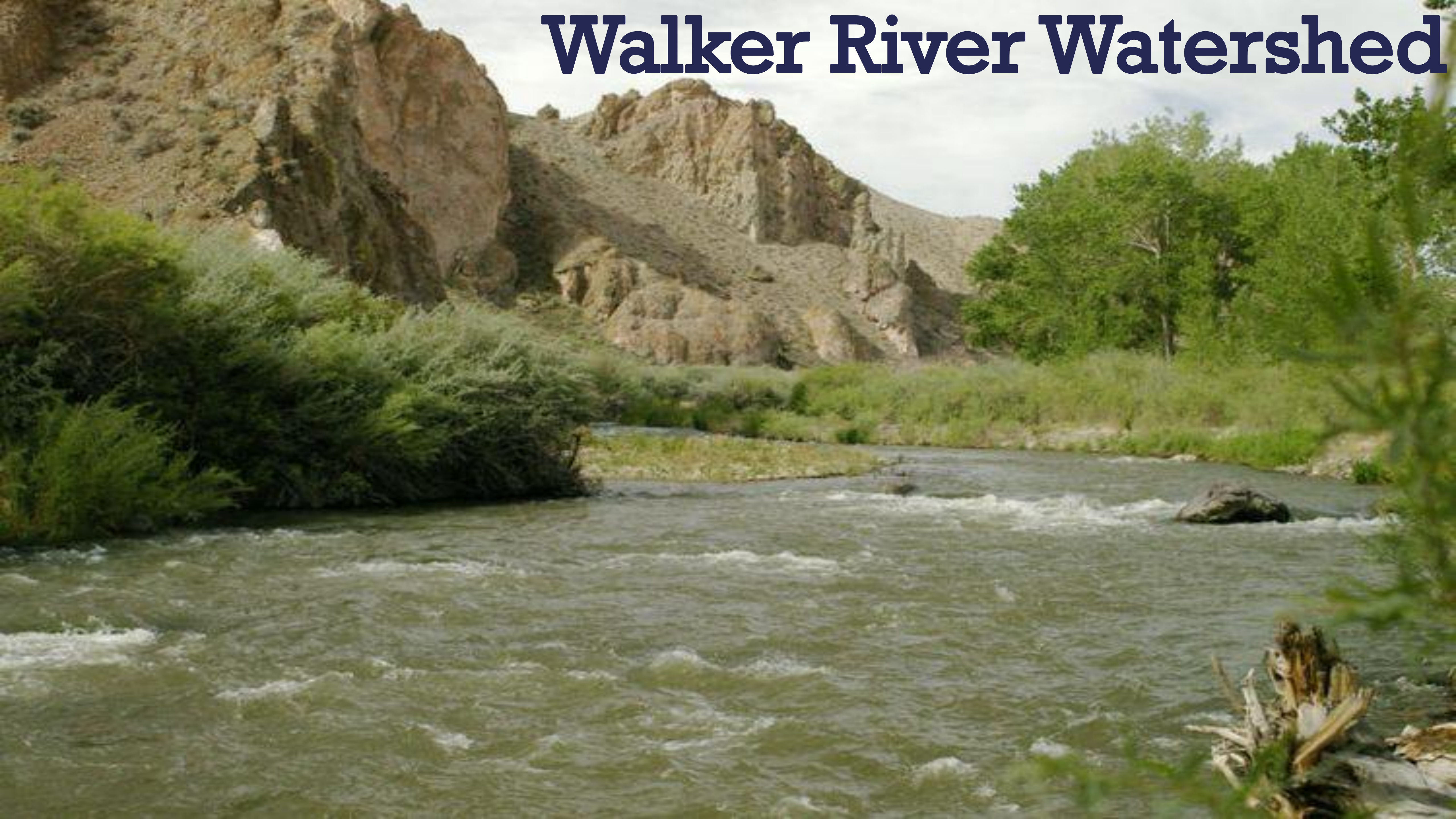
Figure1. USGS hydrologic features map of the Carson River watershed and surroundings.

Truckee River Watershed

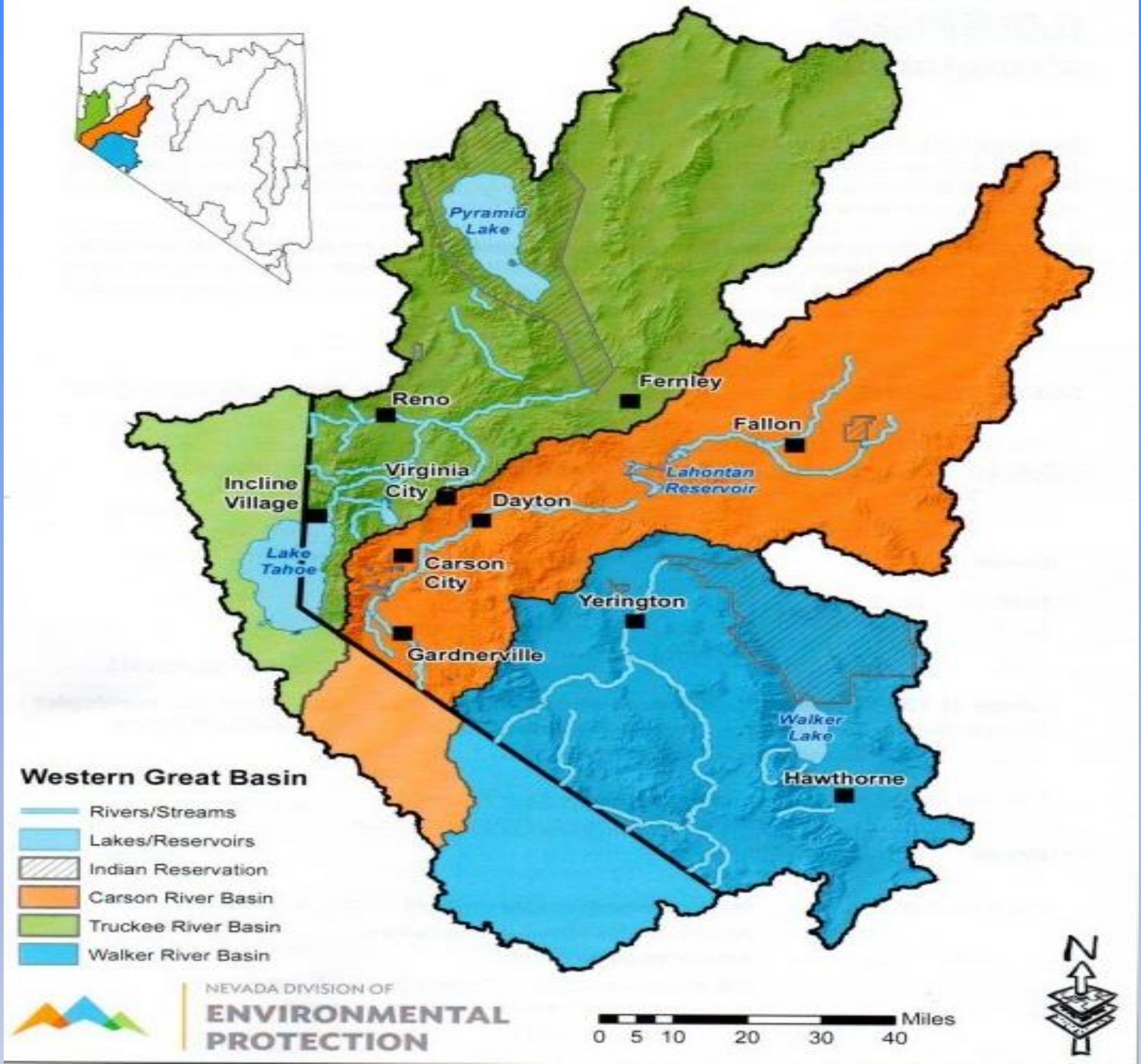



EXPLANATION
Urban
Agriculture
Forest
Water
Rangeland
Barren
Wetlands
Approximate location of Chalk Bluff Treatment Plant
119°30'
Pyramid Lake
40°
Truckee River
Wadsworth
80
120°
Reno
Sparks
Truckee River
39°30'
CALIFORNIA
NEVADA
Donner Lake
80
Truckee
Washoe Lake
Tahoe City
Lake Tahoe
39°
South Lake Tahoe
0 5 10 20 Miles
0 5 10 20 Kilometers

Walker River Watershed



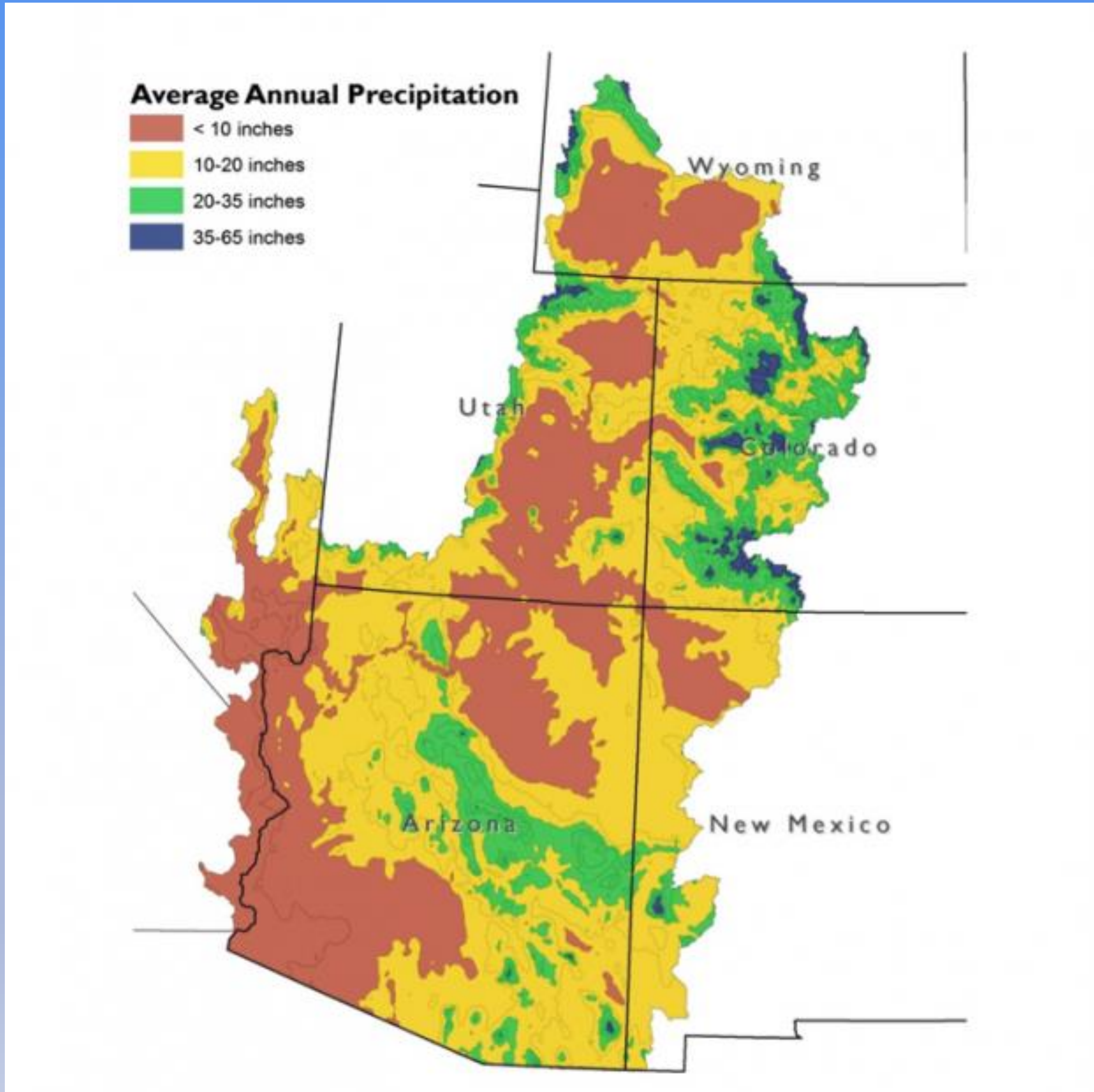

Carson River
9277 ft
Training Area
Austin Hwy
US Naval
Reservation
Target Area
Lake Tahoe
CARSON RANGE
Carson City
Carson City (City)
Naval Air
Station Fallon
Bombing
Lyon
Weber Reservoir
Walker River
Reservation
Douglas
Eldorado
National
Forest
East Walker River
West Walker River
IONE VALLEY
East Fork Carson River
Walker Lake
10376 ft
Topaz Lake
Toiyabe
National
Forest
Alpine
Hawthorne
Army Depot
11286 ft
Hawthorne
Mineral
WASSUK RANGE
Stanislaus
National
Forest
Bridgeport
Reservoir
Strawberry
NEVADA
CALIFORNIA
Tuolumne
Mono
Lake
5827 ft
Mono


Pyramid Lake
Fernley
Reno
Fallon
Lahontan Reservoir
Virginia City
Incline Village
Dayton
Lake Tahoe
Carson City
Yerington
Gardnerville
Walker Lake
Hawthorne
Western Great Basin
Rivers/Streams
Lakes/Reservoirs
Indian Reservation
Carson River Basin
Truckee River Basin
Walker River Basin
NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION
0 5 10 20 30 40 Miles
N

Colorado River Watershed

Colorado River Watershed

Colorado River Watershed



SURFACE WATER RESERVOIRS

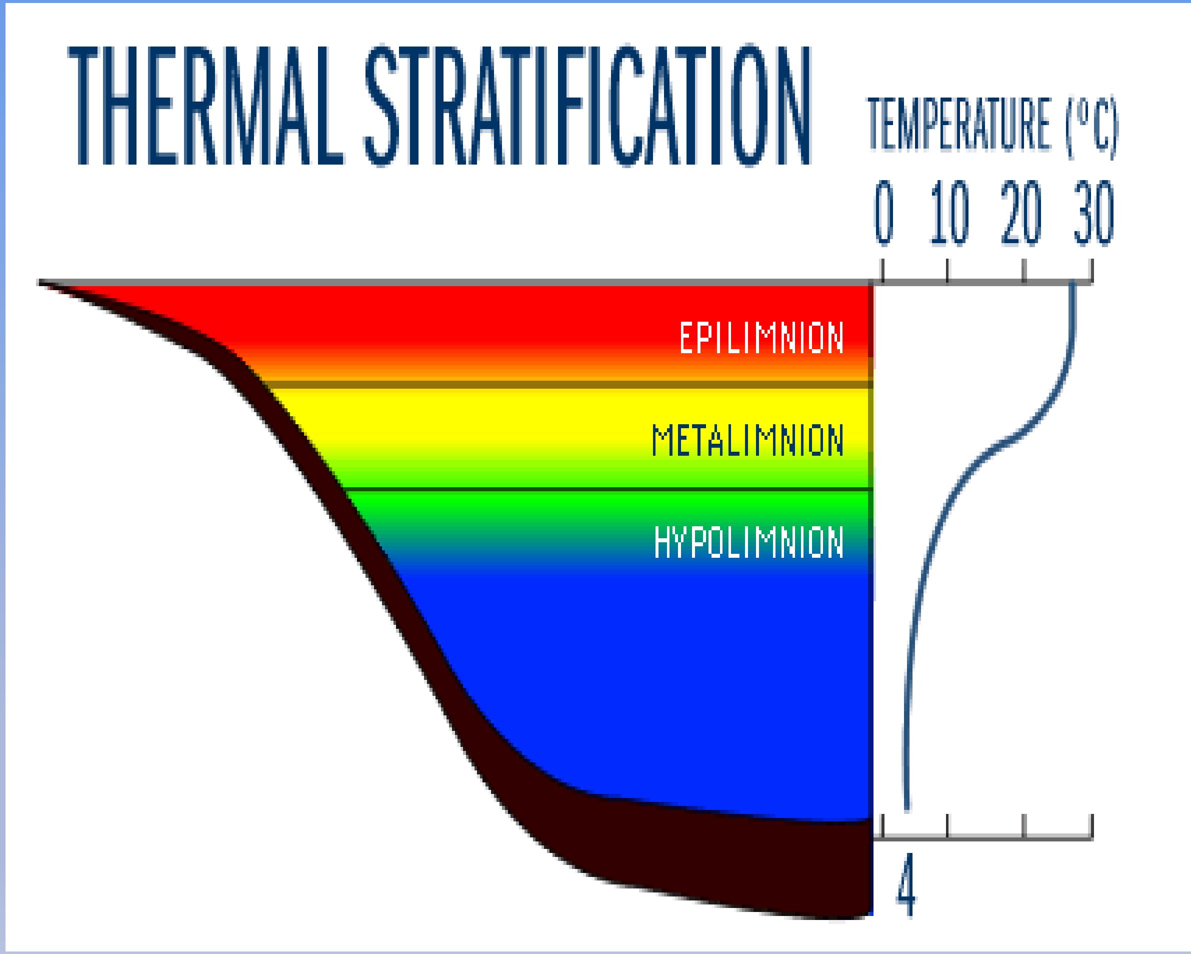
RESERVOIR LAYERS

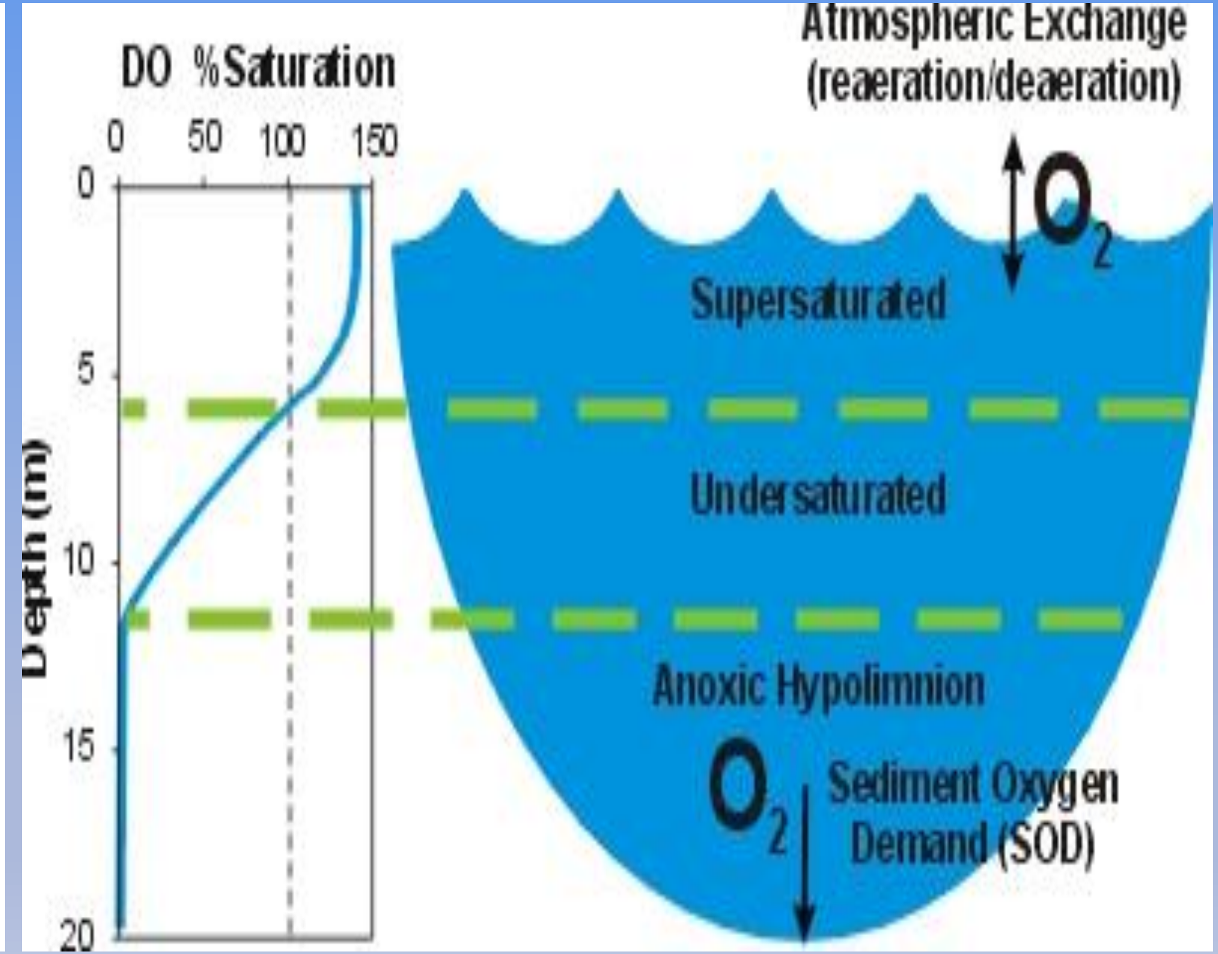
Epilimnion- upper layer that circulates warm water where dissolved oxygen concentrations are moderate to high

Thermocline (Metalimnion)- separates upper an lower layers

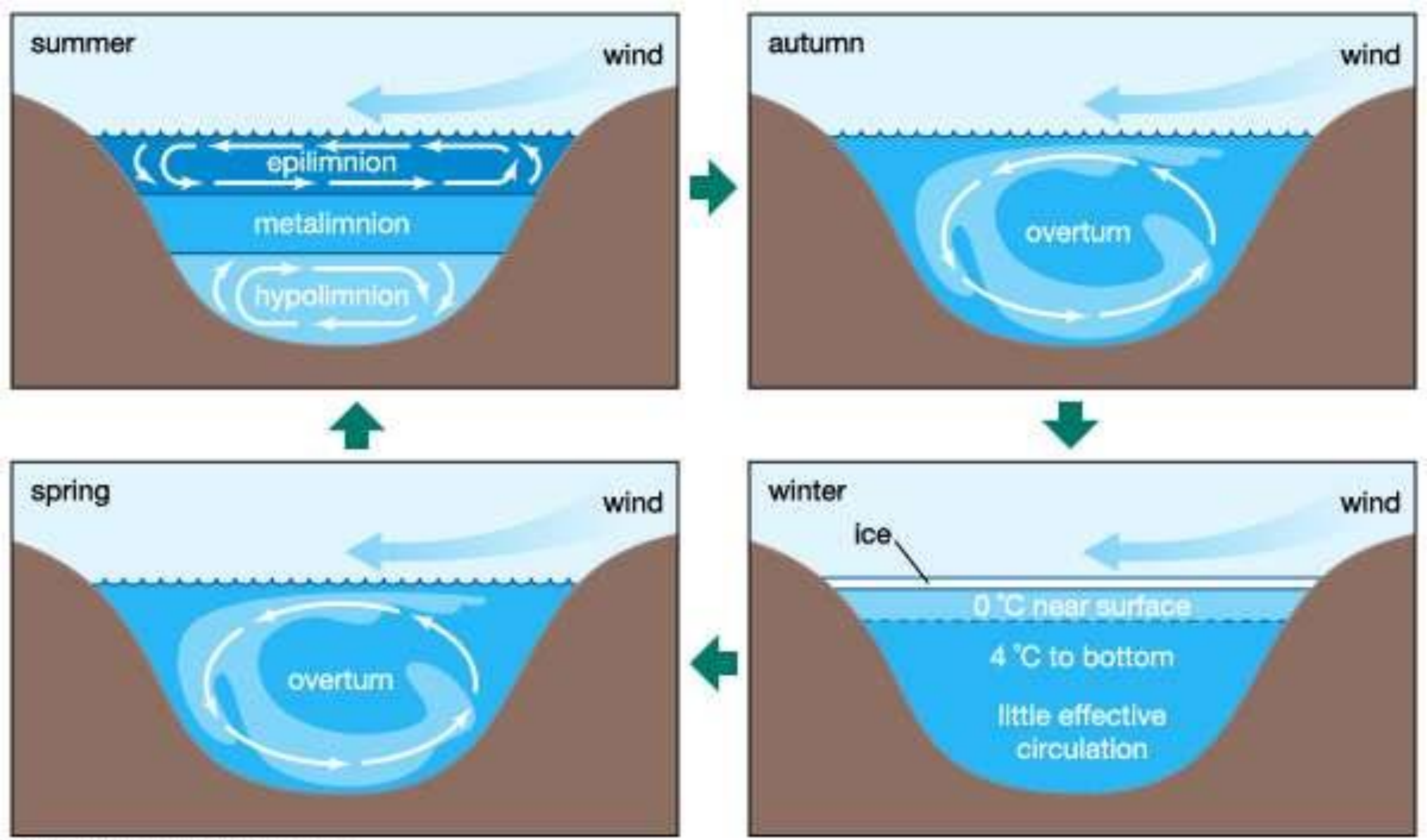
Hypolimnion- a cold, deep-water, non-circulating layer in which oxygen is low or absent

RESERVOIR STRATIFICATION





SURFACE RESERVOIR SEASONS



ALGAE

Algae Control

Algaecide

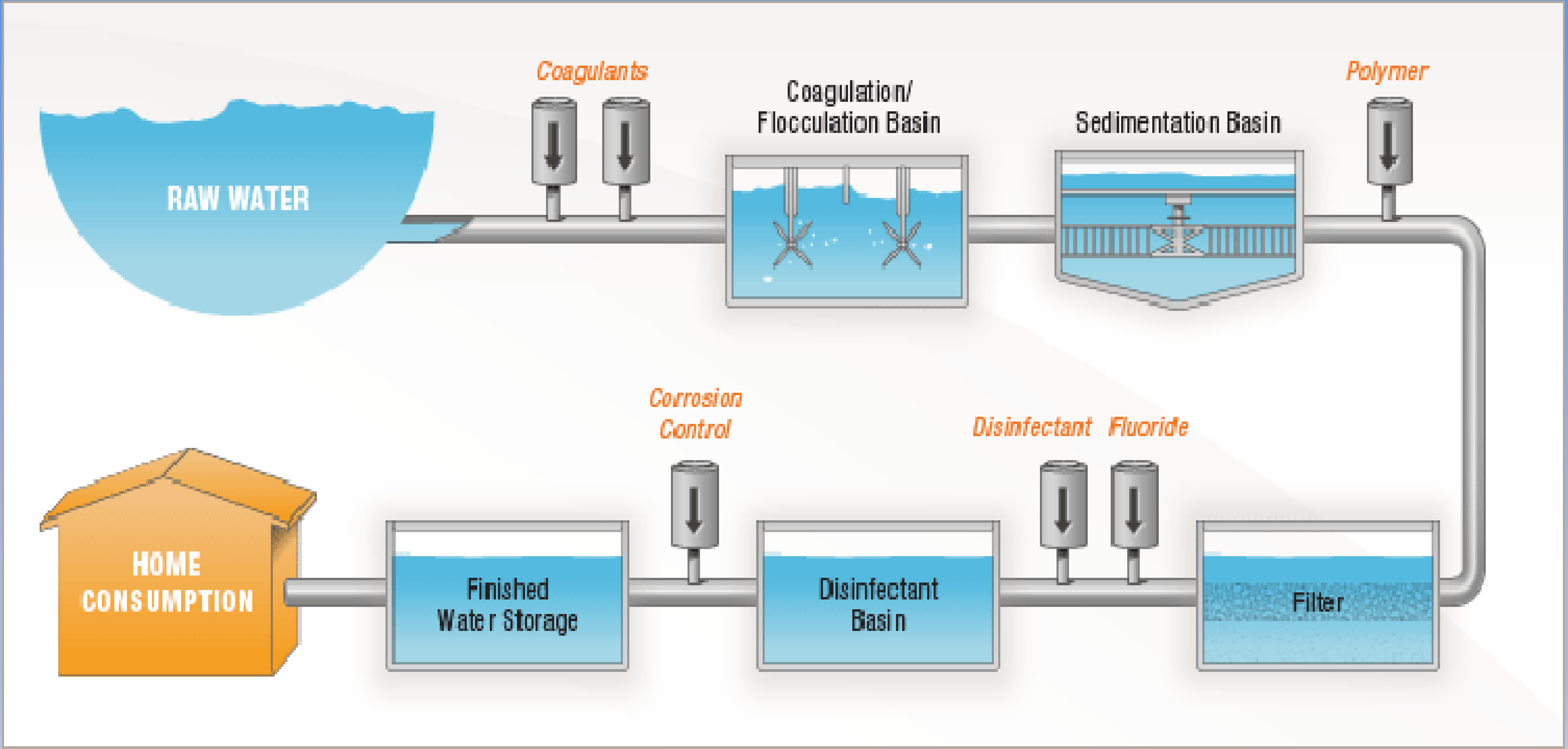
- Copper Sulfate ($CuSO_4$) is most common
- Cost ~ $10/acre per application
- Very short lived. Reacts with minerals and precipitates. May require multiple applications.
- Toxic to fish.
- Killing algae will release internal T&O/toxic compounds. $CuSO_4$ should only be used to prevent algae blooms.

HOW DO YOU APPLY THE COPPER SULFATE?

INVASIVE SPECIES

WHAT CAN A FEW MUSSELS DO ANYWAY?

CONVENTIONAL SURFACE WATER TREATMENT



CONVENTIONAL TREATMENT PROCESS

Screens and Pre-Sedimentation

- Remove debris and larger particles

Pre-Disinfection

- Kills pathogens
- Controls taste and odors.
- Process removes dead pathogens
- Pre-Chlorination
- Possible problems with DBP's
- UV and Ozone instead
  - No Residual

CONVENTIONAL TREATMENT PROCESS

Chemicals

- Assist with the process of Coagulation/Flocculation

Flash mixer

- Mixes chemicals with water

Coagulation/flocculation

- Slowly mixes the chemical and particles together.

Sedimentation

- Settle out particles

CONVENTIONAL TREATMENT PROCESS

Filtration

Adsorption and Mechanical

Post-Treatment Disinfection

Chlorination = Leaves residual throughout the system

Disinfectant Basin

Contact Time

Post-Treatment Chemistry

Alkalinity, Fluoride

SCREENS

<u>Coarse Screens</u>

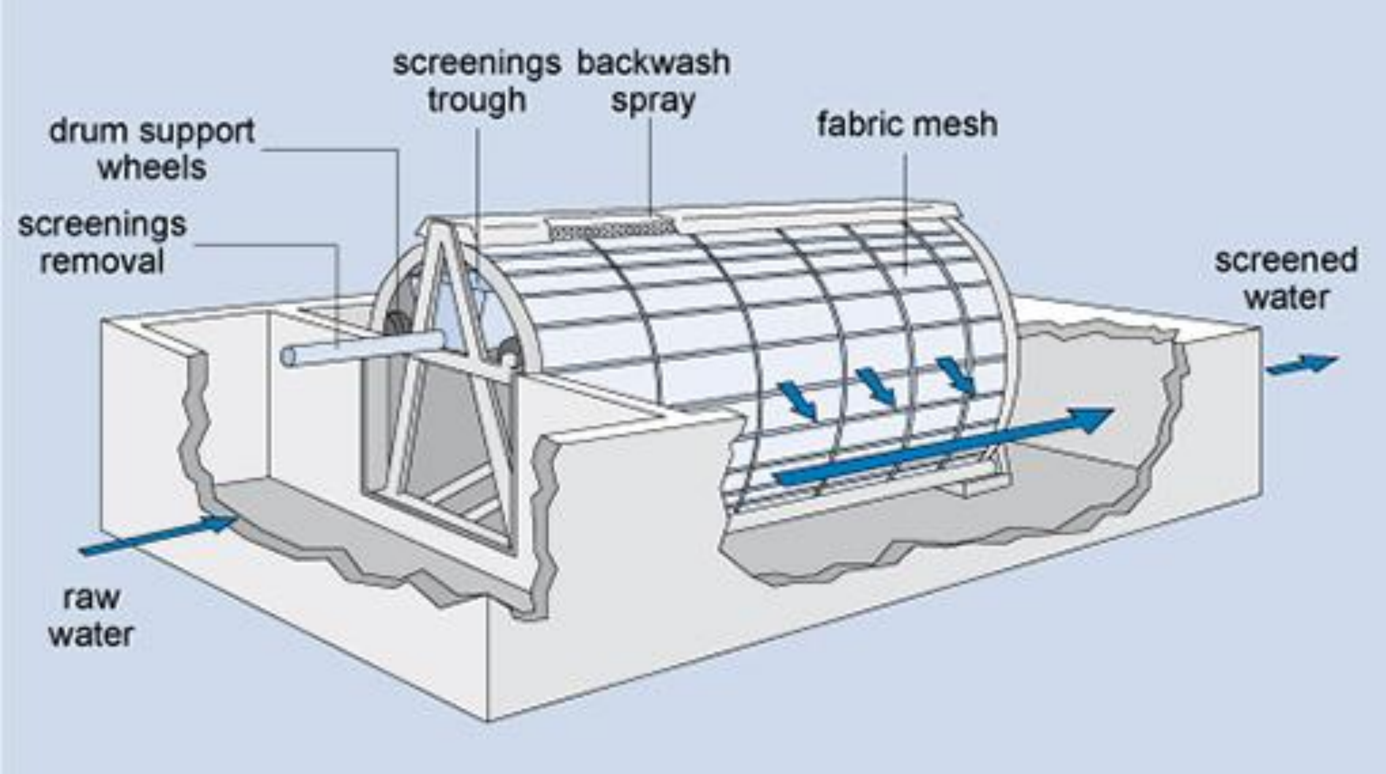
Steel bars 2-6 inches apart for larger debris.

Set at 60 degree angle for easier raking.

SCREENS

<u>Micro-Strainer</u>

Rotating drum of very small stainless steel mesh (.0005 inches)



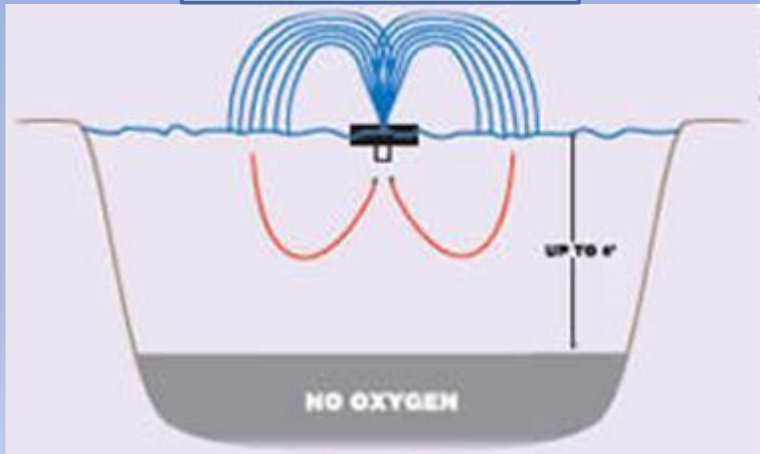
PRE-SEDIMENTATION

- Removal of debris
- Helps control impact of changing raw water
- Impoundments are types of pre-sedimentation systems

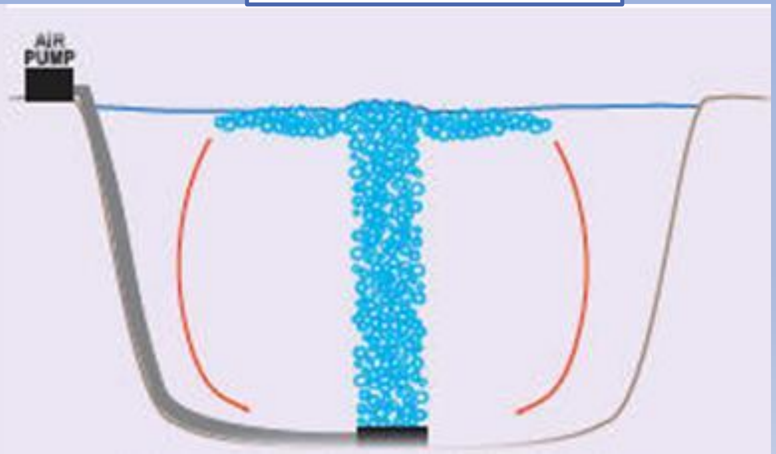
AERATION

- Removes dissolved gases like CO_2
- Removes dissolved metals such as <u>iron and manganese</u>
- Releases volatile chemicals

Cascade Aerator



Fountain Aerator

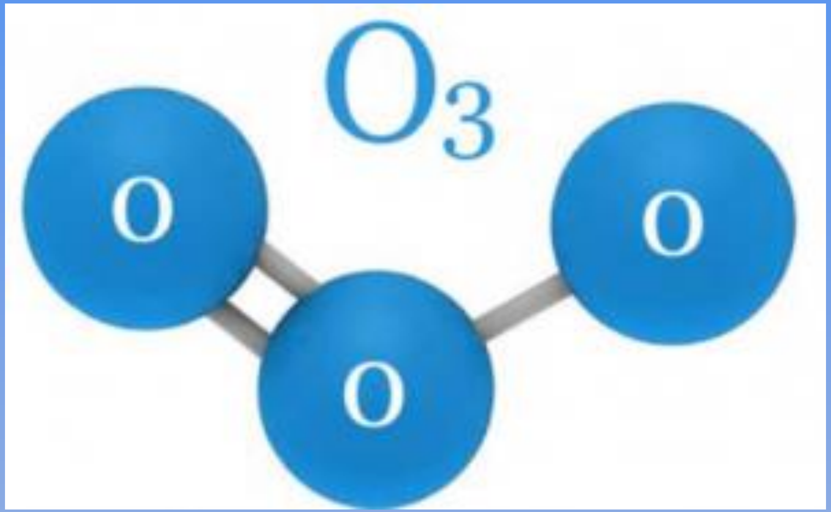


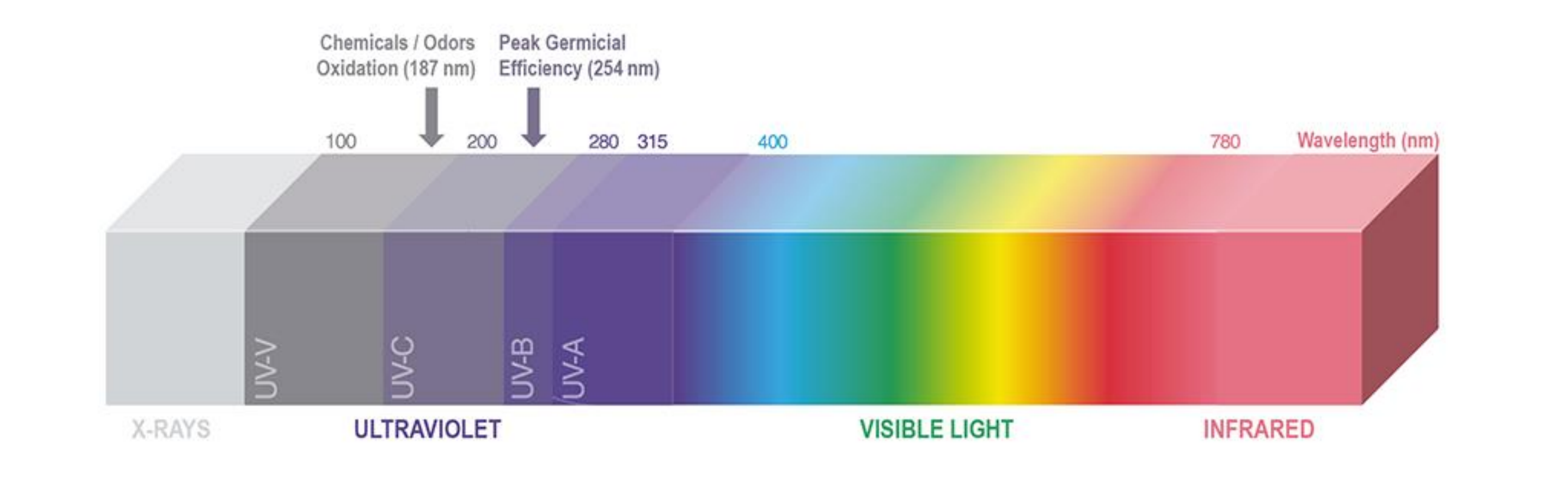
Diffuser Aerator

PRE-DISINFECTION

Chlorine Alternatives

- Ozone
- Ultraviolet Light





OXIDATION

Oxidation is any chemical reaction that involves the moving of electrons. Specifically, it means the substance that gives away electrons is oxidized.

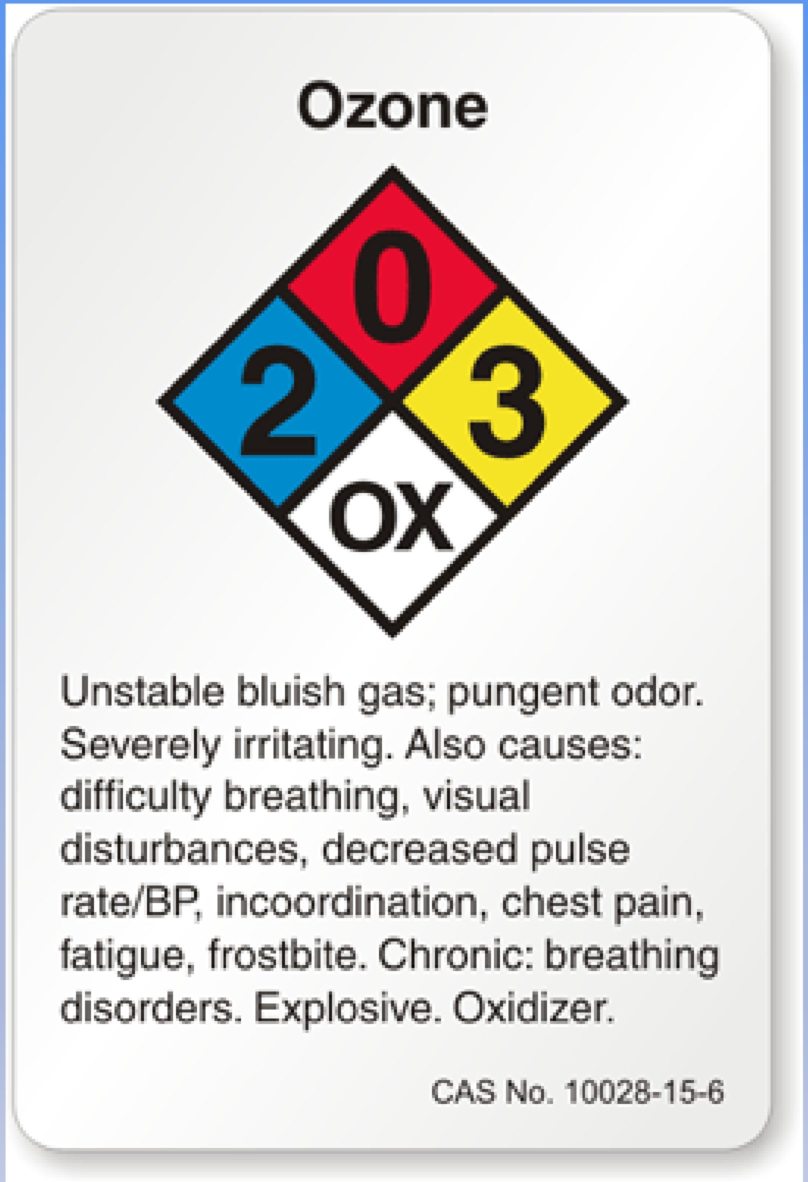
Oxidizing Reagent	Oxidizing Potential
Ozone	2.00
Hypobromous acid	1.59
Chlorine dioxide	1.50
Hypochlorus acid	1.49
Monochloramine (acidic)	1.47
Chlorine	1.36
Oxygen	1.23
Bromine	1.09
Hypochlorite	0.94
Monochloramine (basic)	0.74

WHAT IS OZONE?

Natural component of the earth's upper atmosphere, where it is primarily formed photo chemically.

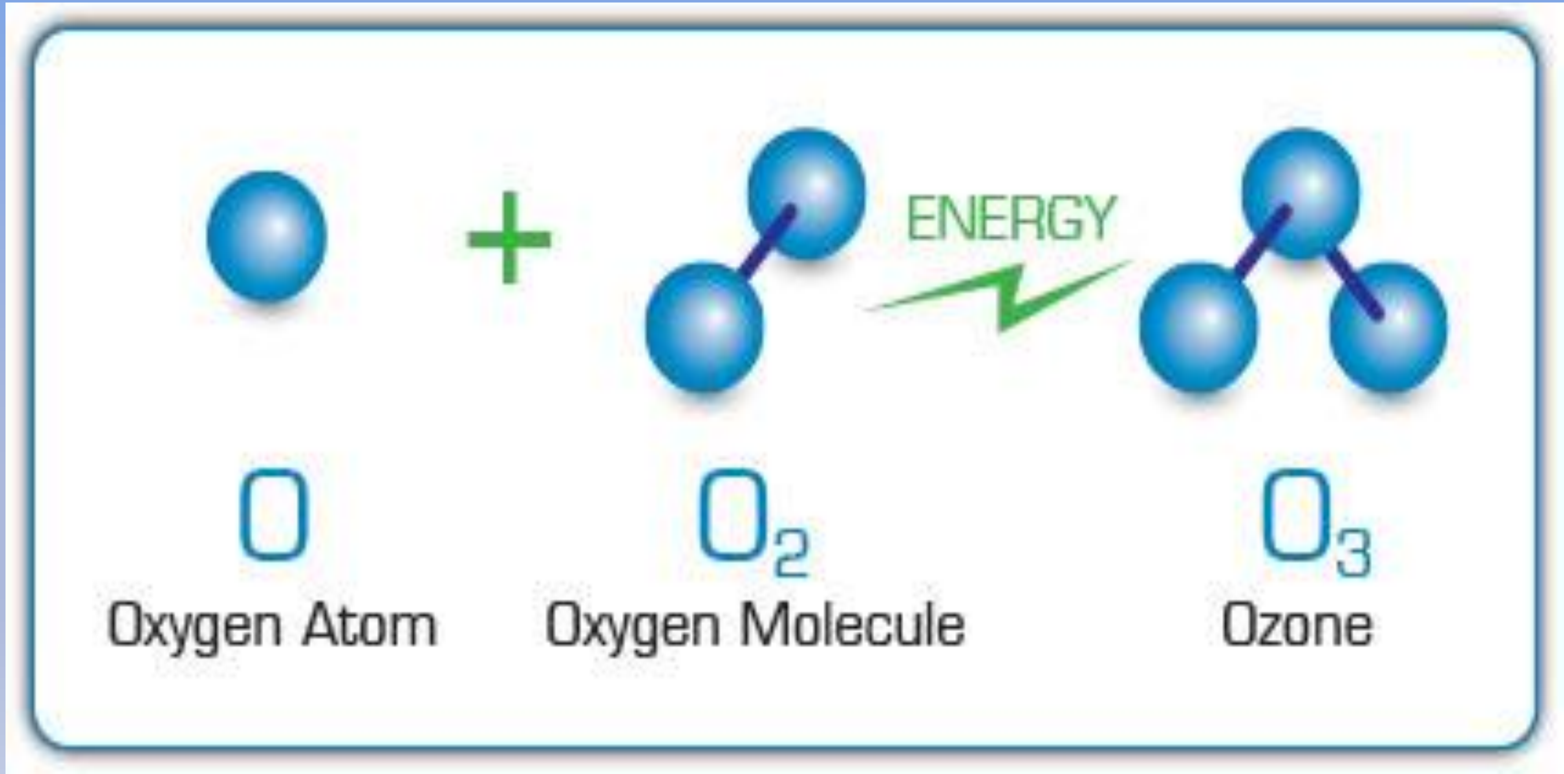
The reason the sky is blue.

Doesn’t leave a lasting residual.

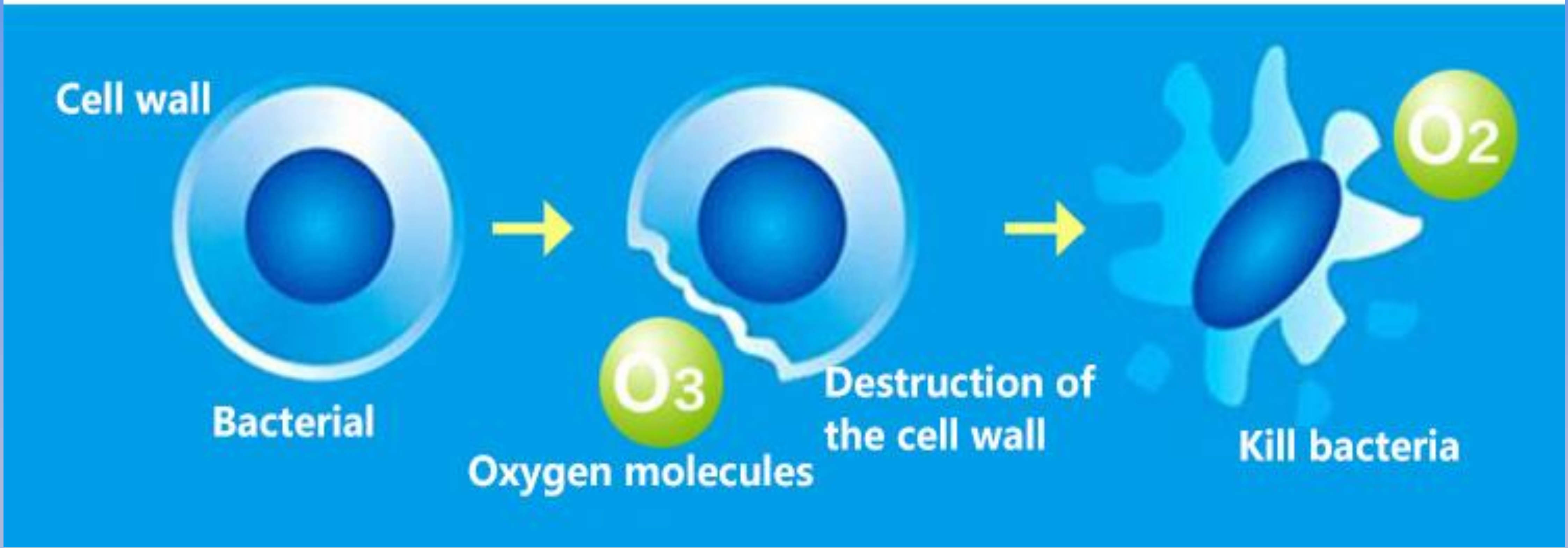


OZONE

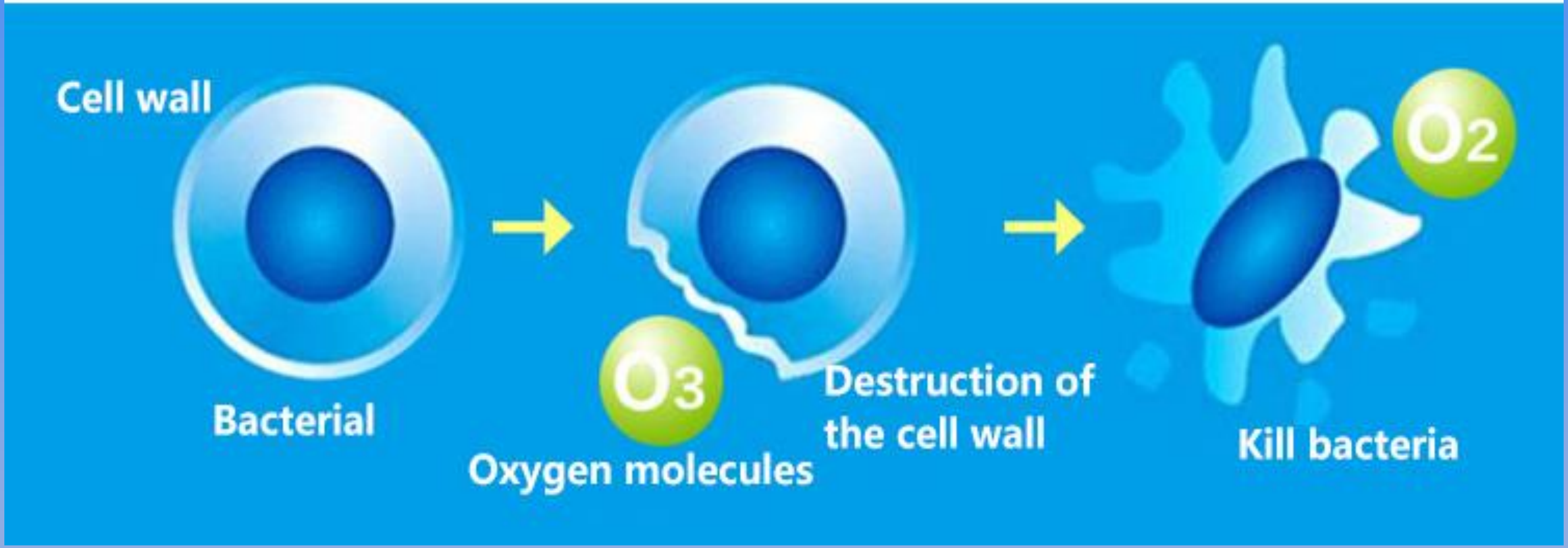
Oxygen (O2) molecules are dissociated by an energy source (6 to 20 kilovolts) into oxygen atoms which collide with another oxygen molecule to form ozone (O3).

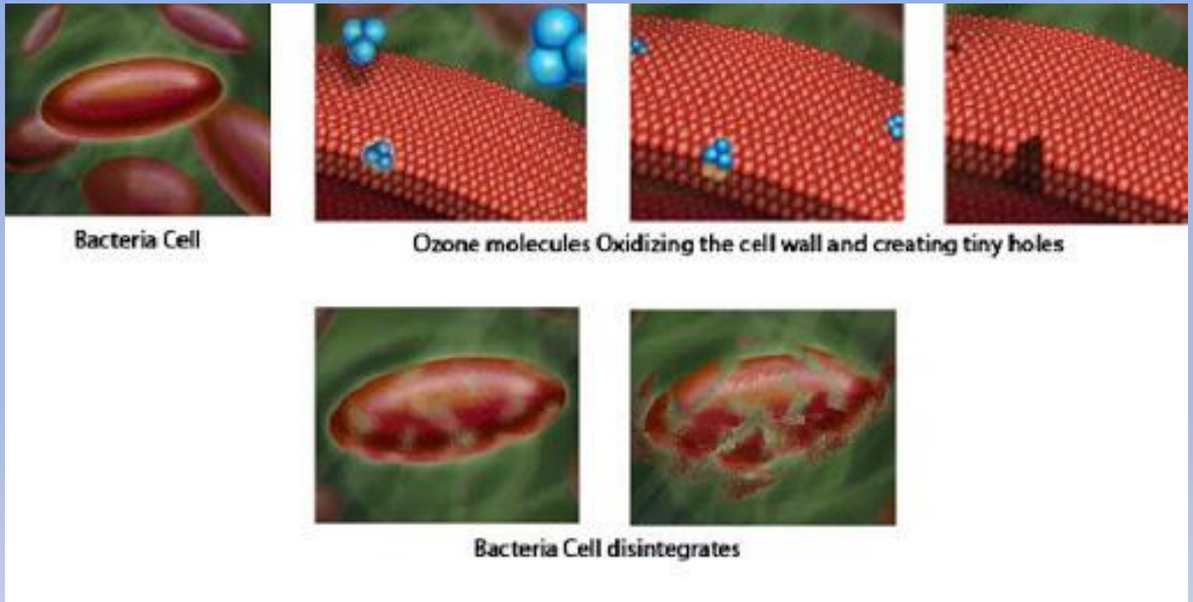


OZONE

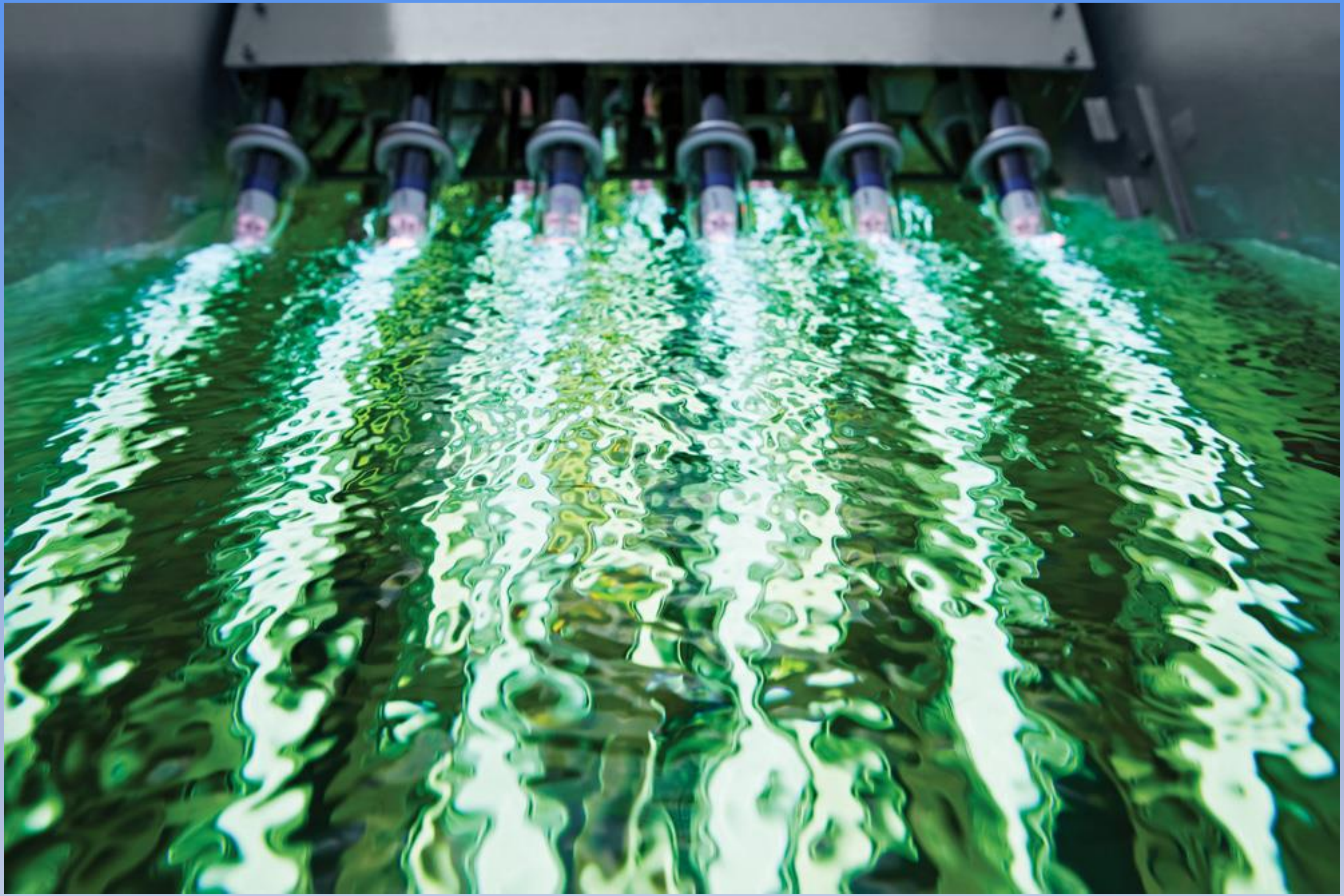

Cell wall
Bacterial
O3
Oxygen molecules
Destruction of
the cell wall
O2
Kill bacteria

OZONE


Cell wall
Bacterial
O3
Oxygen molecules
Destruction of
the cell wall
O2
Kill bacteria


Bacteria Cell
Ozone molecules Oxidizing the cell wall and creating tiny holes
Bacteria Cell disintegrates

ULTRAVIOLET LIGHT (UV)



UV

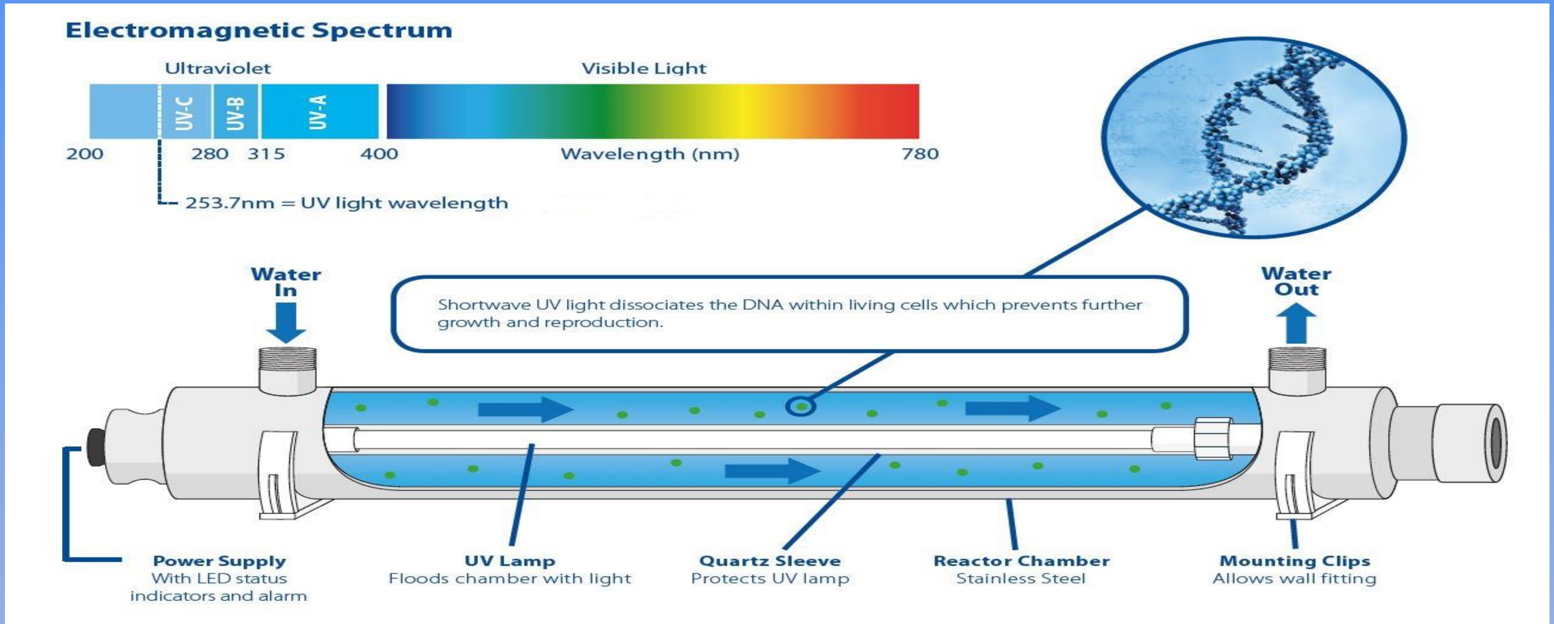
Is the only method of disinfection that does not alter:

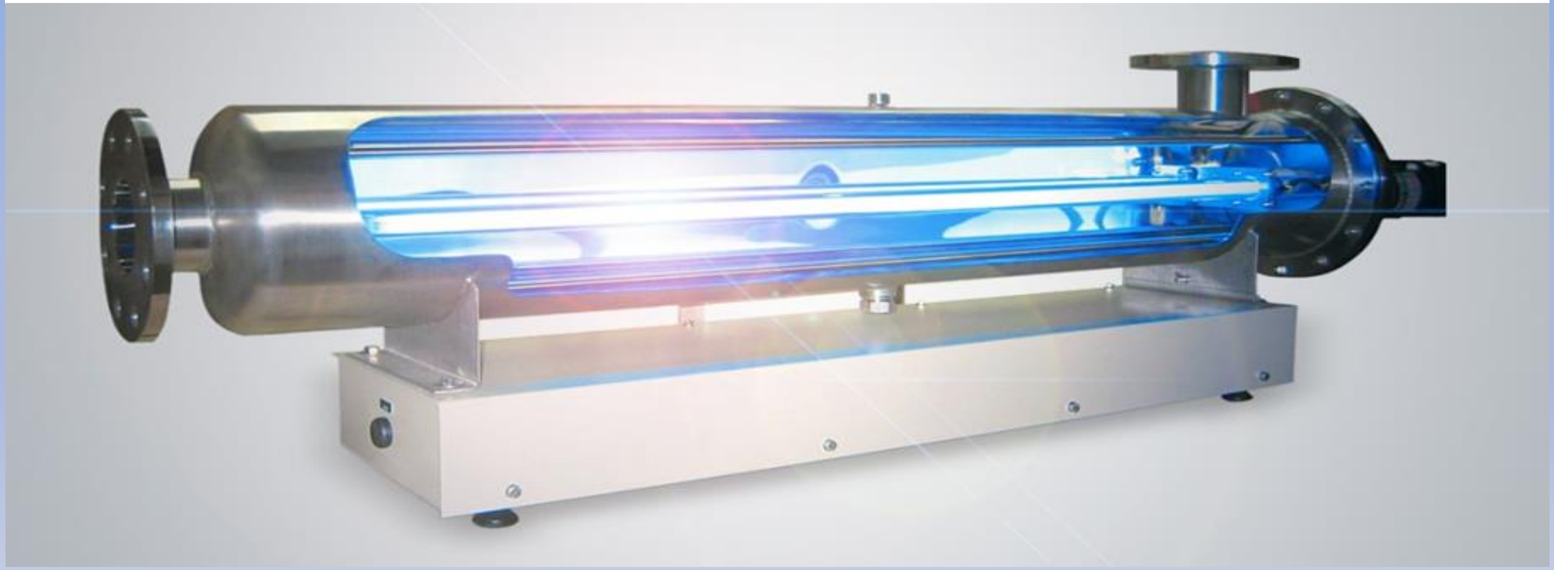
the pH

taste

the chemical composition of water.

UV


Electromagnetic Spectrum
Ultraviolet
Visible Light
UV-C
UV-B
UV-A
200
280
315
400
Wavelength (nm)
780
253.7nm = UV light wavelength
Water In
Shortwave UV light dissociates the DNA within living cells which prevents further growth and reproduction.
Water Out
Power Supply
With LED status indicators and alarm
UV Lamp
Floods chamber with light
Quartz Sleeve
Protects UV lamp
Reactor Chamber
Stainless Steel
Mounting Clips
Allows wall fitting

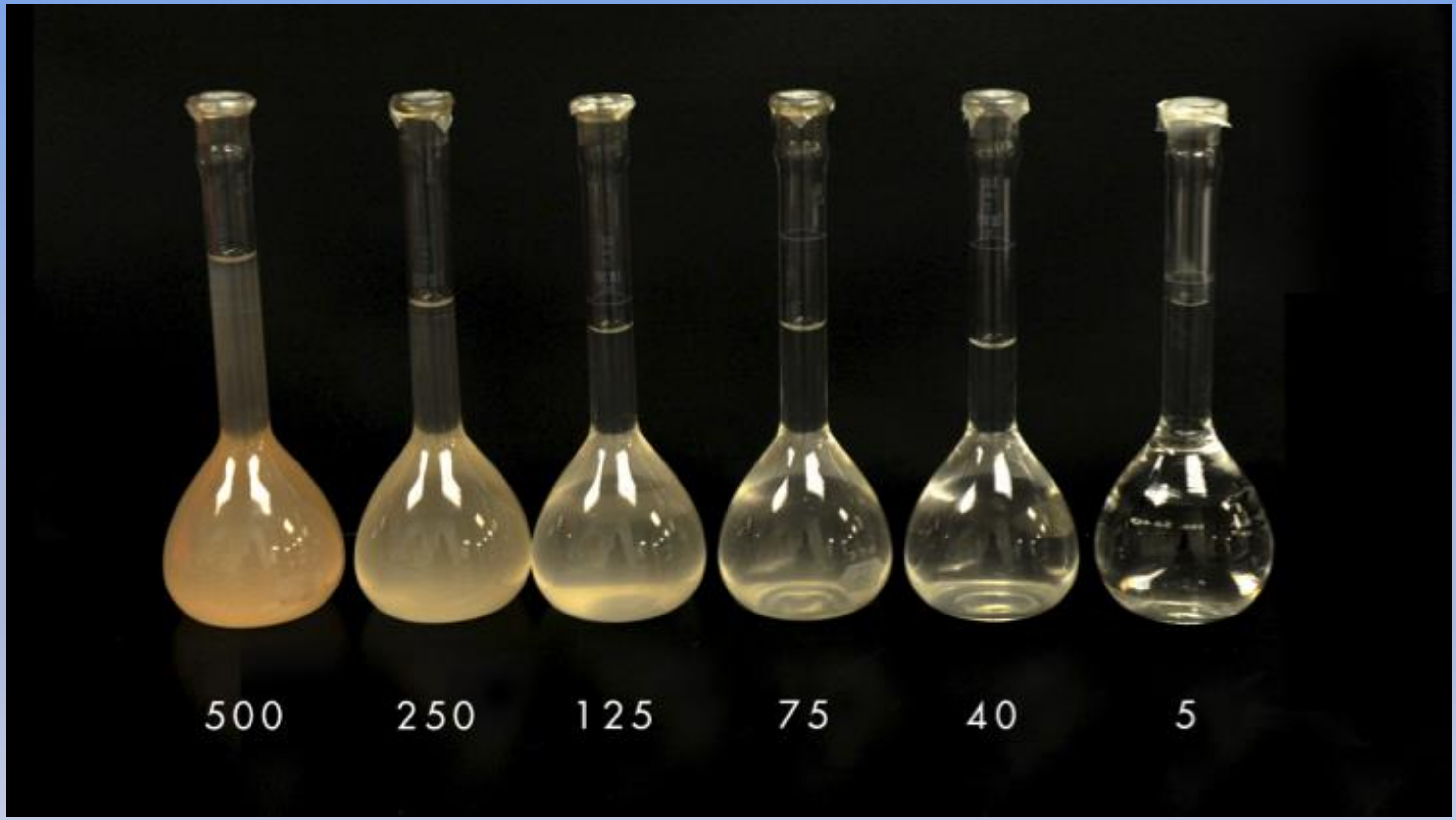


UV

Operates best when:

<u>Suspended Solids:</u> <10 – 15 mg/L

<u>Turbidity:</u> <5 – 10 NTU.



COAGULATION AND FLOCCULATION

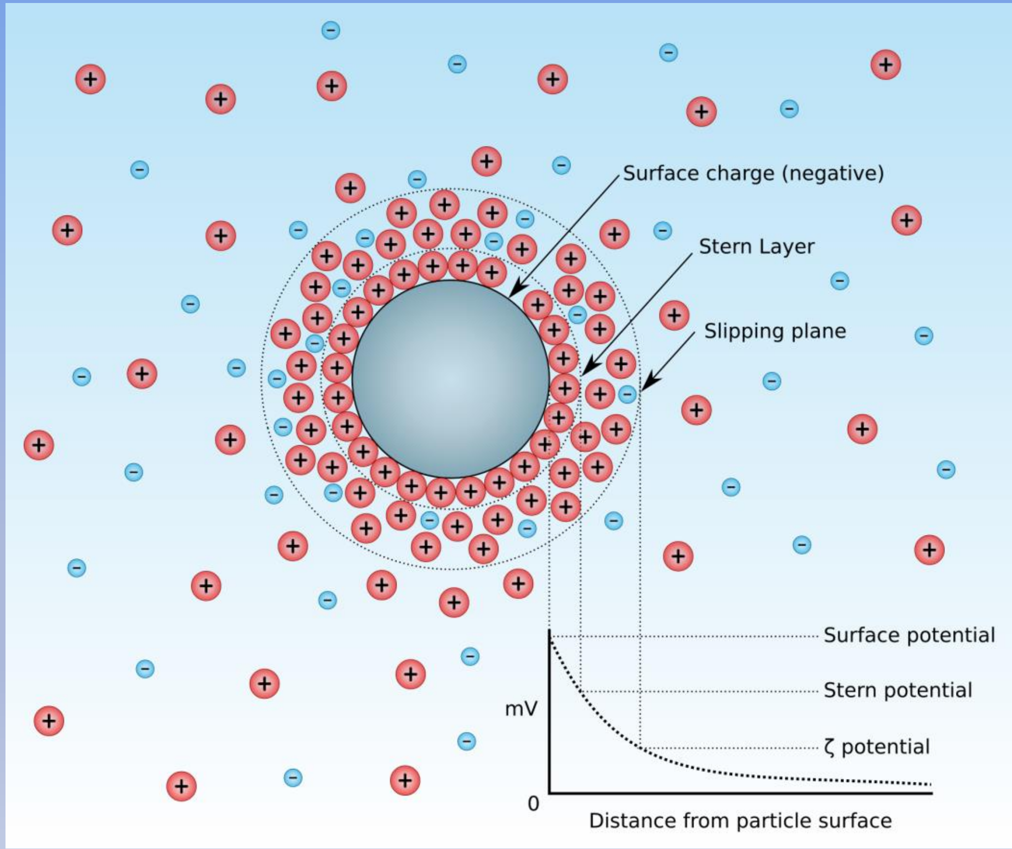
American Water Work WSO Treatment Operator Grade 1 Video: Coagulation and Flocculation

https://www.youtube.com/watch?v=GVCWwWCLY7w&list=PL9NfaH39Z9FIp1MpK3hYudNAVp5BA54sR&index=20

COAGULATION

Zeta Potential

The repelling force that keeps particles separated



COAGULATION

Coagulation

Is the adding & rapid mixing of chemical coagulants in water to reduce turbidity prior to filtration

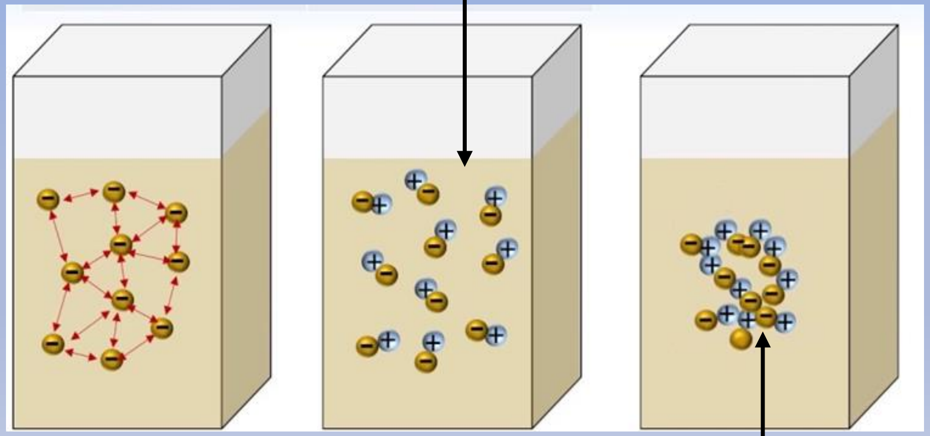
Is a chemical reaction between coagulant, turbidity, & alkalinity.

Neutralizes negative (-) charges

Stability behavior of a colloid depending on zeta potential

Zeta potential (mV)	Stability behavior
0 to ±5	Rapid coagulation or flocculation
±10 to ±30	Developing instability
±30 to ±40	Moderate stability
±40 to ±60	Good stability
>61	Excellent stability

Add Positively Charged Chemical



Zeta Potential

Create Floc

FLOCCULATION

Flocculation is a process that form floc to settle out impurities in the water & reduce turbidity prior to filtration

Floc grows with the collision of the particles

Troubleshooting

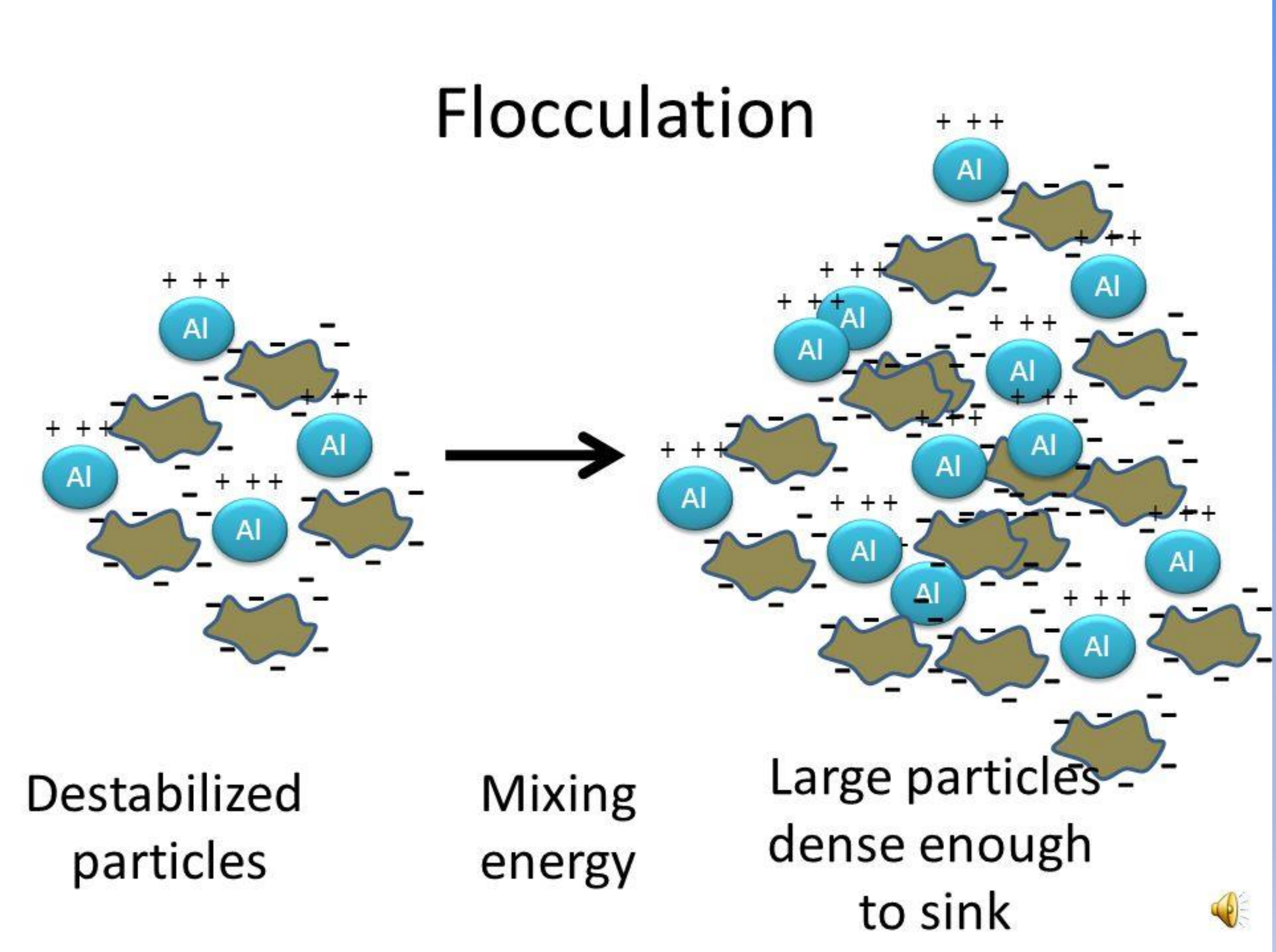
Paddle speed: -too slow floc will settle prematurely

- too fast floc will break apart

Velocity through basin: achieve optimal speed for system

Short circuiting: "In and Out" Not enough detention time

FLOCCULATION

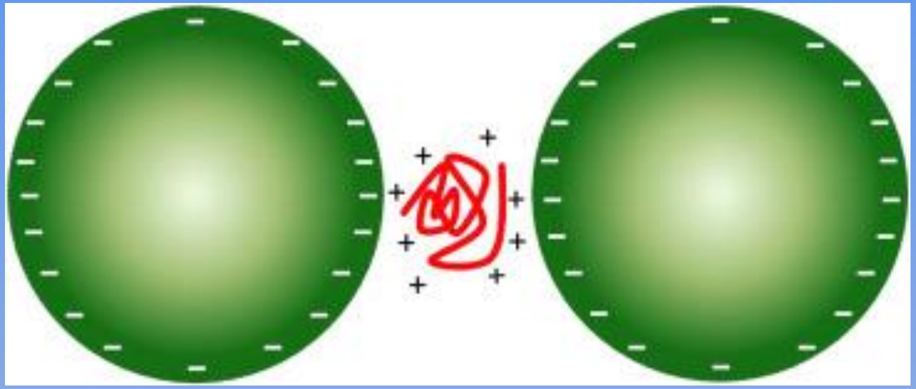


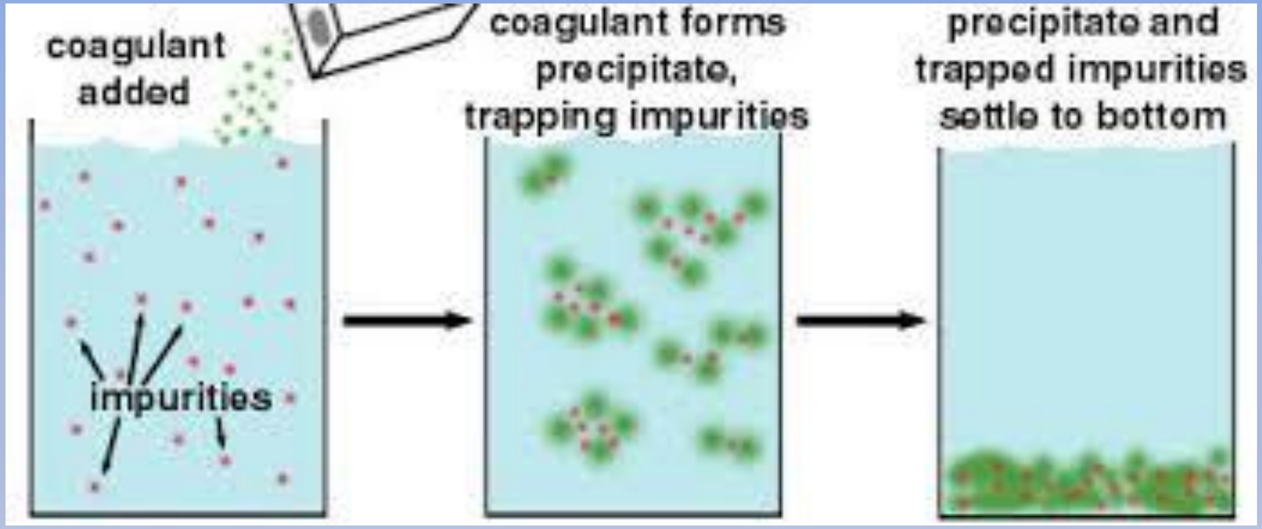
PRIMARY COAGULANTS

Aluminum sulfate
Ferrous sulfate
Ferric sulfate
Cationic polymer
Calcium hydroxide
Calcium oxide
Sodium aluminates

COAGULANT AIDS

- Calcium hydroxide
- Calcium oxide
- Sodium aluminates
- Bentonite
- Calcium carbonate
- Sodium silicate
- Anionic polymer
- Nonionic polymer





JAR TESTS TO FIND THE OPTIMUM

American Water Works WSO Treatment Operator Grade 1

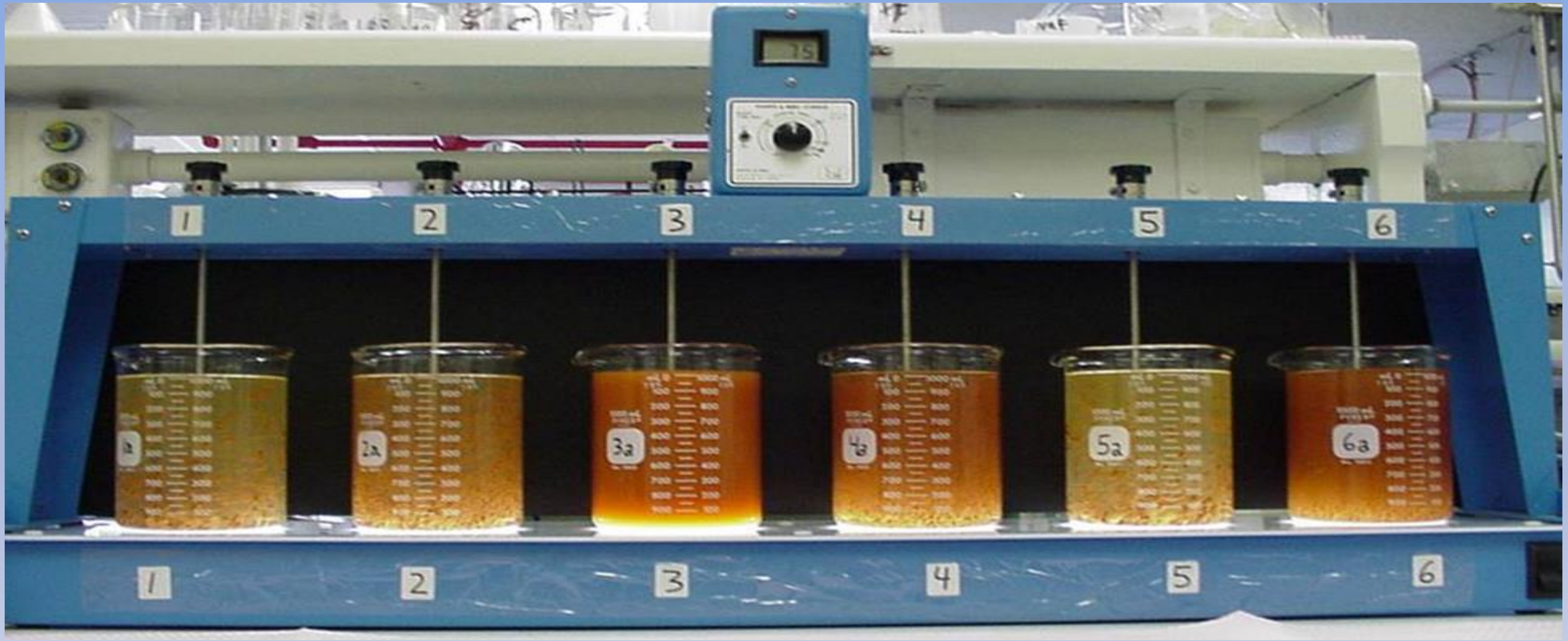
Video: Jar Testing

https://www.youtube.com/watch?v=_OcBSQYfKWE&list=PL7BpwzCwK105B06OqorTUeW6Ts3UcNFmF&index=9

JAR TESTS TO FIND THE OPTIMUM

Laboratory procedure to determine the optimum pH and coagulant chemical dosage.

Simulates coagulation and flocculation process on a smaller scale.



JAR TESTS – EXAMPLE PROCEDURE

Label six beakers (jars) #1-6.

Fill each beaker with 1000mL (1L) of the sample water.

Place beakers in jar test apparatus.

Beaker #1 add 0mL coagulant (control)

Beaker #2 add 2mL coagulant (2mg/L)

Beaker #3 add 5mL coagulant (5mg/L)

Beaker #4 add 10mL coagulant (10mg/L)

Beaker #5 add 15mL coagulant (15 mg/L)

Beaker #6 add 20mL coagulant (20 mg/L)

JAR TESTS – EXAMPLE PROCEDURE

- Mix beakers at approximately 100 rpm for 1 minute.
- Note the condition of the floc during rapid mix coagulation.
- Turn mixing speed down to 25-35 rpm for 15-20 minutes.
- Note the condition of the floc every 5 minutes on data sheet.
- Determine which dosage has best floc time and most settled.
- Test turbidity of each beaker at end and record on data sheet.
- Use the optimal dosage determined for treatment.
- *May need further tests with different pH levels.

JAR TESTS – RESULTS TABLE

A jar test was done for ferric chloride (Table 1.0) and alum (Table 2.0) by varying the pH.

(i) Identify the optimum pH and describe the type of coagulation that will occur at optimum pH.

(ii) Explain the highest turbidity observed for each coagulant.

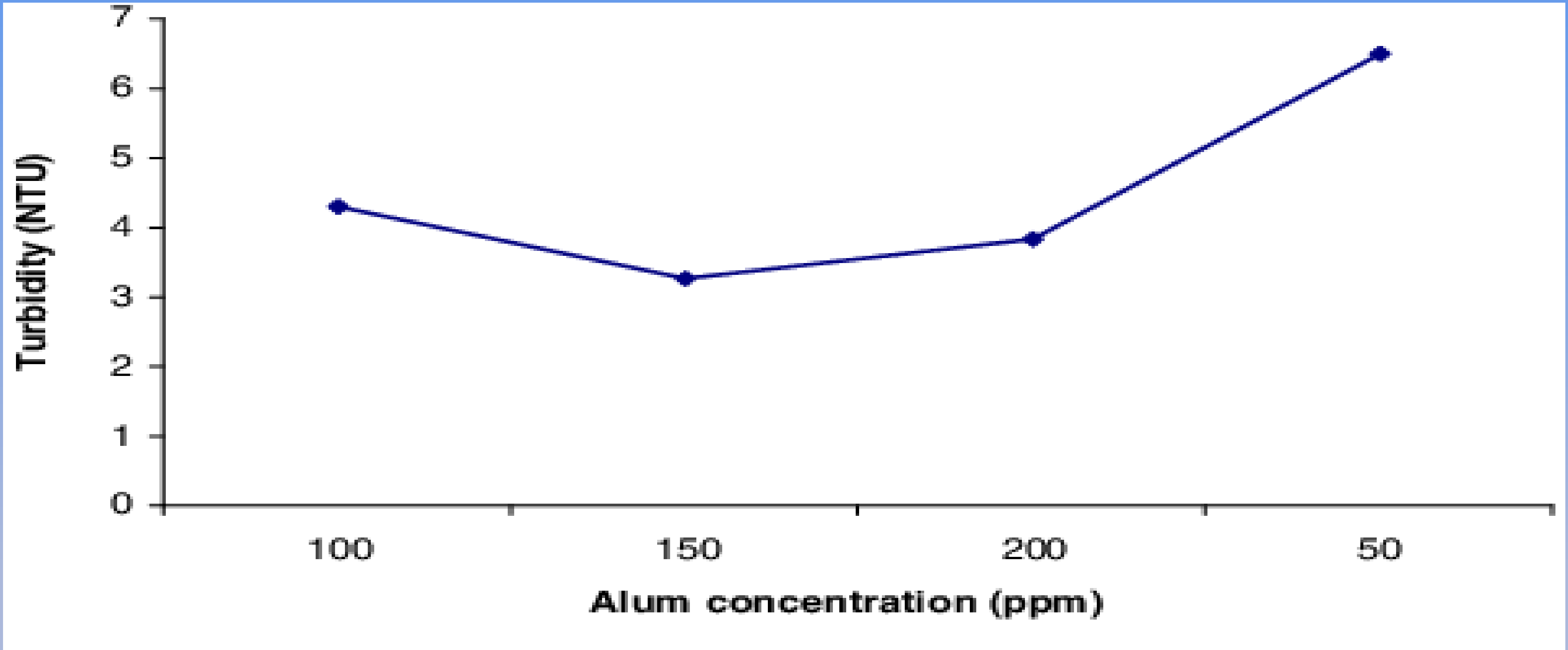
Table 1.0 Jar test results for ferric chloride addition

Jar #	1	2	3	4	5	6
pH	5.5	6	6.5	7	7.5	8
$FeCl_3$ (mg/L)	50	50	50	50	50	50
Turbidity (NTU)	40	10	15	20	22	23

Table 2.0 Jar test results for alum addition

Jar #	1	2	3	4	5	6
pH	5.5	6	6.5	7	7.5	8
Alum (mg/L)	50	50	50	50	50	50
Turbidity (NTU)	50	45	40	10	20	30

JAR TEST – RESULTS GRAPH



SEDIMENTATION

American Water Works Treatment Grade 1 Video: Sedimentation and Clarifiers.

https://www.youtube.com/watch?v=PPYXKHxDDsk&index=6&list=PL7BpwzCwK105B06OqorTUeW6Ts3UcNFmF

SEDIMENTATION

Particle Size (mm)	Particle Size (microns)	Order of Size	Time Required to Settle (sg = 2.65)	Time Required to Settle (sg = 1.2)
10	10000	Gravel	0.4 sec	1.2 sec
1	1000	Coarse Sand	3.0 sec	9 sec
0.1	100	Fine Sand	34 sec	5 min
0.01	10	Silt	56 min	8 hours
0.001	1	Bacteria	4 days	32 days
0.0001	0.1	Colloidal	1 year	9 years
0.00001	0.01	Colloidal	> 50 years	> 50 years
0.000001	0.001	Colloidal	> 50 years	>50 years

SEDIMENTATION

Allows solids to settle out before filtration

Sedimentation - With Settling Tubes

As required by drinking water rules and **manufacturer's specifications.**

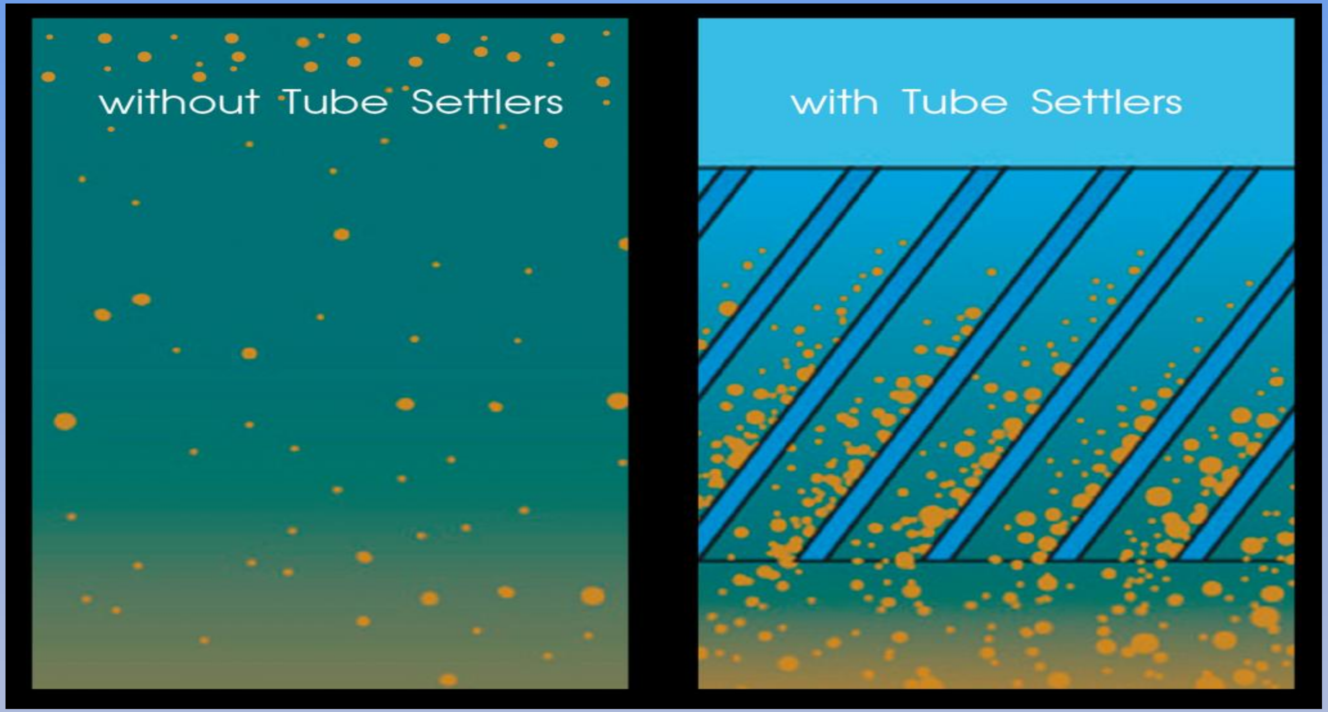
Sedimentation - Without Settling Tubes (typical parameters)

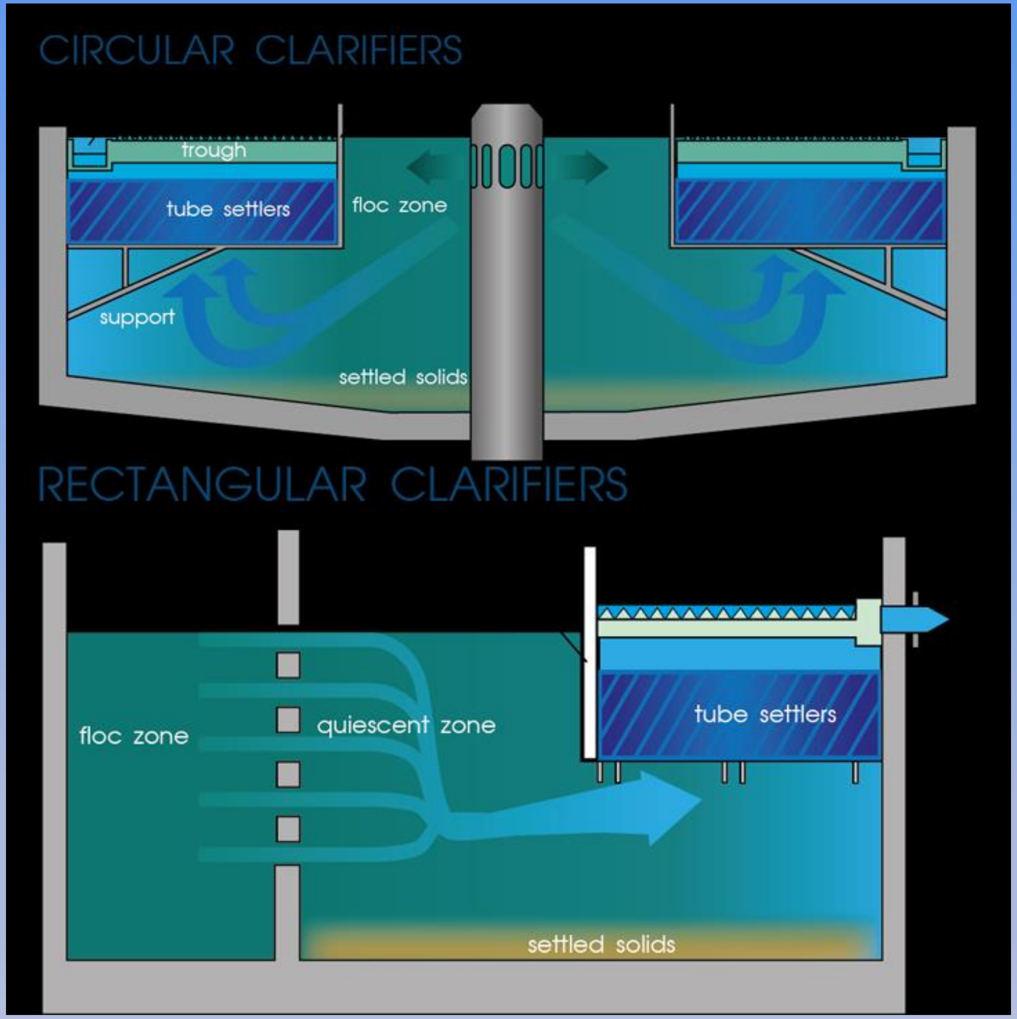
2 hours detention time

WLR (weir loading rate) <20,000 gpd/ft weir length

0.5 fpm velocity and 8 to 12 ft depth

SEDIMENTATION WITH TUBES





SEDIMENTATION TROUBLESHOOTING

<u>Short circuiting:</u> "In & Out" Low detention time

<u>Temperature:</u> Lower Temp = Lower Sedimentation Rate

<u>Working properly:</u> Turbidity In vs Turbidity Out

<u>Wind currents:</u> "Stir it up"

<u>Velocity</u>: Increase in flow = Decrease in settling

<u>Floating materials:</u> Sign that parameters are off

<u>Sludge accumulation and removal:</u> Need to clean out to settle more.

<u>Noisy drive chain:</u> Time for mechanical maintenance.

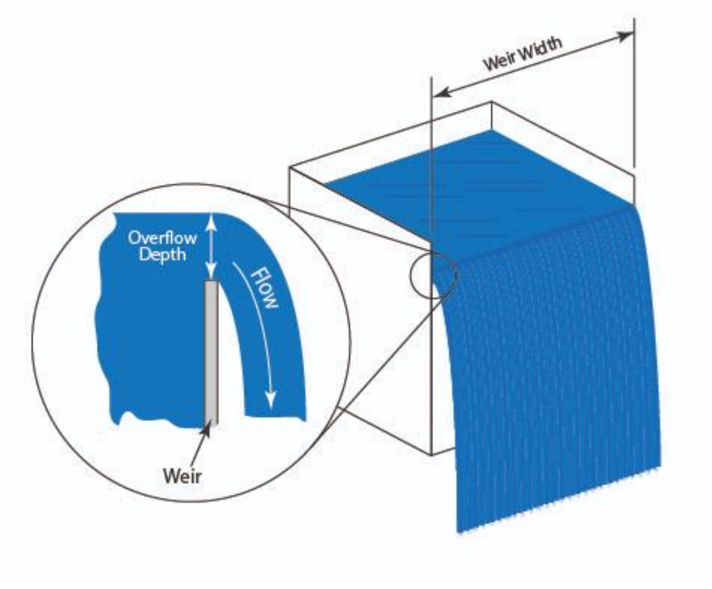
WEIR

WEIR

An obstruction in the flow path of an open channel.

Causes increase in water depth.

Height of water above top of weir used for flow rate.



$$\text{Weir Overflow Rate(gpd/ft)} = \frac{\text{Flow(gpd)}}{\text{Weir Length(ft)}}$$

WEIR LOADING RATE

American Water Works Treatment Grade 2 Video:

Weir Loading Rate

https://www.youtube.com/watch?v=4ro6Q9d87kk&list=PL7BpwzCwK105B06OqorTUeW6Ts3UcNFmF&index=11

FILTRATION

American Water Works Treatment Grade 1 Video:
Filtration and Filtration Processes.

https://www.youtube.com/watch?v=hAWTb4Xu5x0&list=PL7BpwzCwK105B06OqorTUeW6Ts3UcNFmF&index=7

FILTRATION SYSTEMS

Conventional Treatment

Coagulation
Flocculation
Sedimentation
Filtration

Non-conventional

Direct filtration

*No: Sedimentation

Slow sand filter

*No: Chemicals

Flash mixing
Coagulation
Flocculation
Sedimentation

FILTRATION

Percolation: movement of liquid through porous materials

Determine flow thru filter: Close inlet valve & measure drop in the water level over time.

Head Loss Gauge: measures pressure drop as water passes thru the filter

Terminal Head Loss: water can no longer be filtered

FILTRATION

Types

Mechanical filter: large particles stuck in media

Adsorbtion filter: particles stick to the media

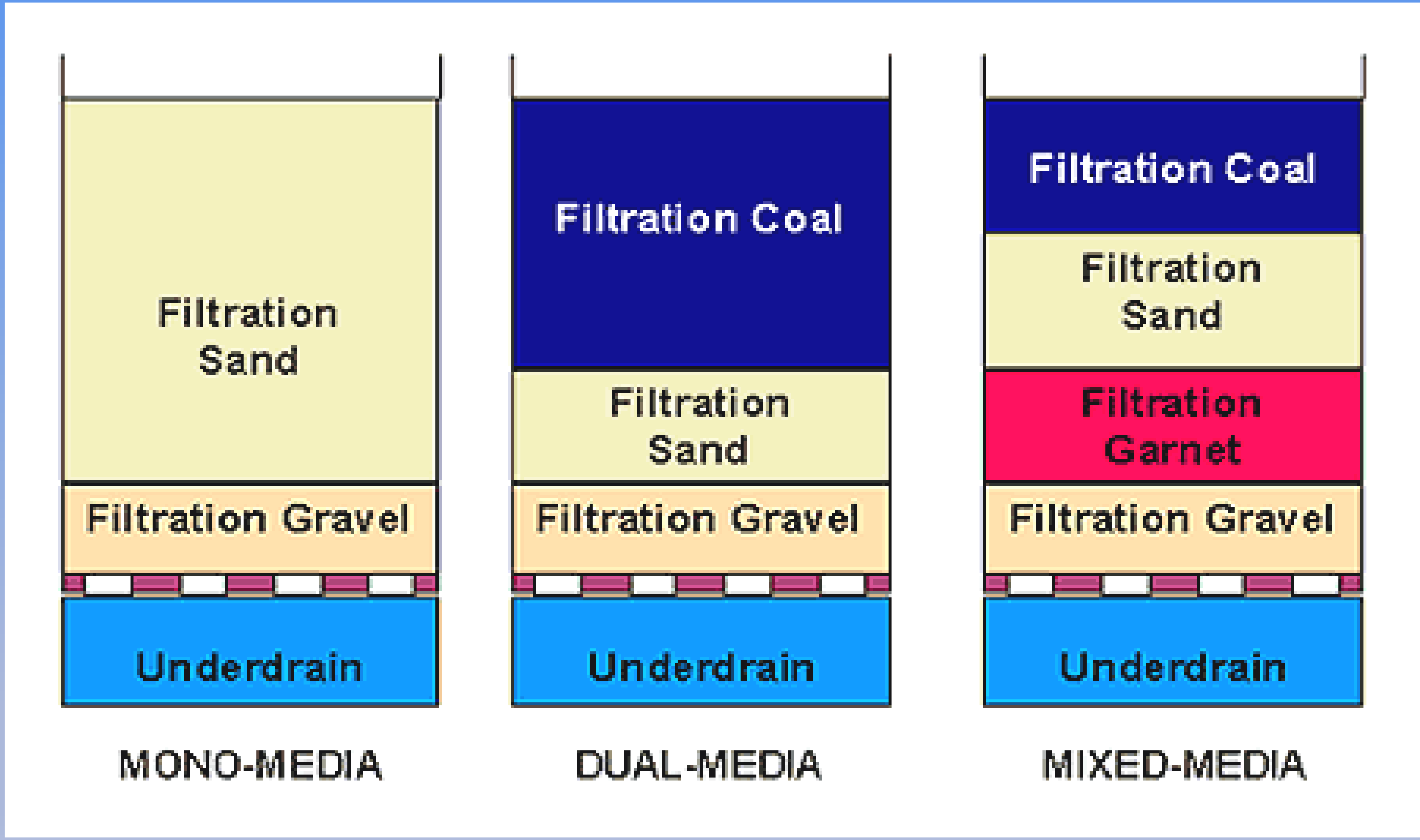
Slow sand- flow rate .015-0.15 gpm/ft^2

Rapid sand- flow rate 0.6-6.0 gpm/ft^2

Mixed media- 3.0-7.0 gpm/ft^2

Filter Loading Rates are defined as gallons of water applied to each square foot of filter surface area (gal/ft^2)

FILTRATION MEDIA DESIGNS



FILTER MEDIA TYPES

Anthracite

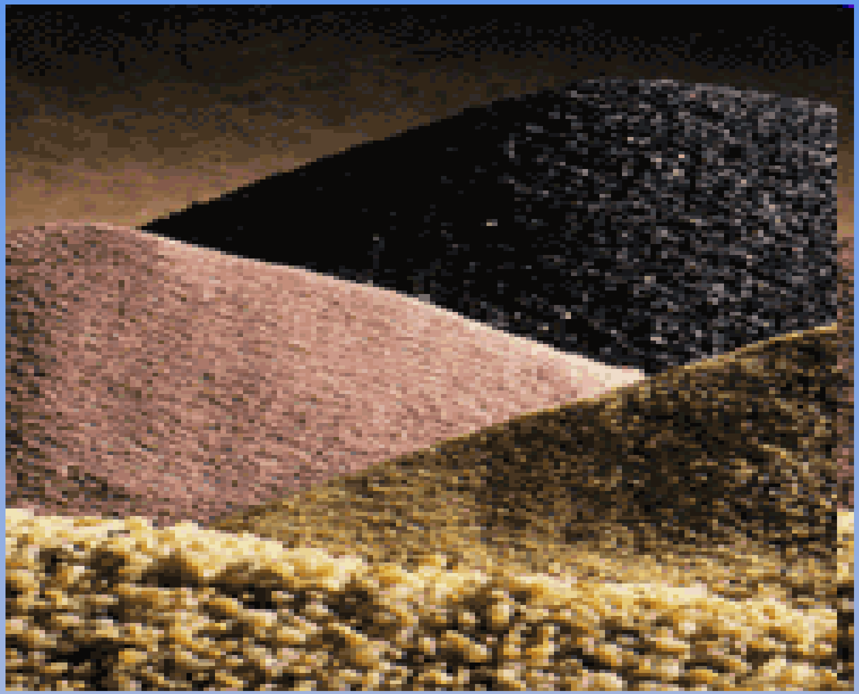
Granular Activated Carbon

Silica Sand

Garnet Sand

Green Sand –manganese oxide

iron and manganese removal

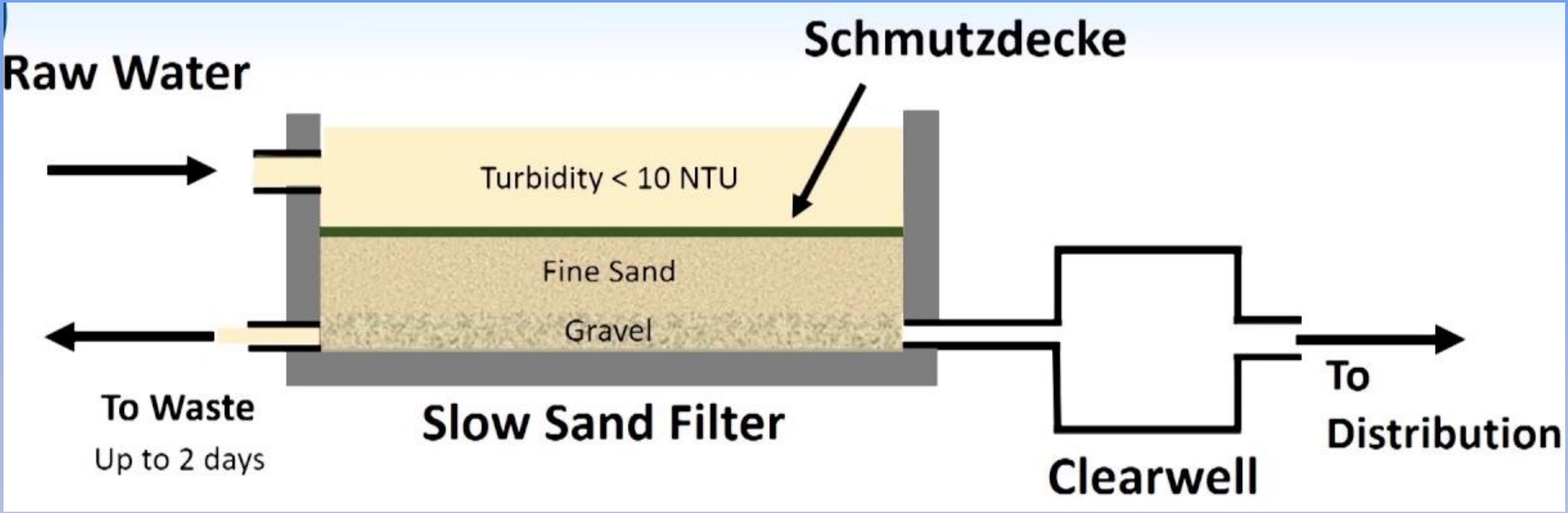


Measured by sieve analysis to determine size

Settle by specific gravity

SLOW SAND FILTER

<u>Schmutzdecke:</u> is a hypogeal biological layer formed on the surface of a slow sand filter.



FILTER BACKWASH

American Water Works Treatment Grade 2 Video:
Filter Backwash

https://www.youtube.com/watch?v=gVCZhR7kGBU&index=20&list=PL9NfaH39Z9FLFKEbYVaRNYPysEBR408DG

FILTER BACKWASH

Backwash initiated when:

Head loss is so high that filtration rate is too low.

Floc starts to break through the filter and turbidity in the filter effluent increases.

A filter run exceeds a given time of operation.

Filter is taken out of service, it must always be backwashed prior to being put back on-line.

FILTER BACKWASH

Typical Procedure for Media Beds:

1. Stop inflow
2. Drain water in filter to 6-10 inches below surface.
3. Initiate Surface Wash (Air or Water) for 1-2 minutes
4. Open backwash valve to pump finished water backwards through media at slow rate.
5. Shut off surface wash
6. Increase backwash flow to around 10-20gpm/ft^2 or until the bed has expanded 20-30%
   (make certain not to lose media over trough walls)
7. Once backwash water clear then slow backwash rate to allow for media restratification.
8. Shut backwash valve and place back in service.

FILTRATION TROUBLESHOOTING

Mud Balls

Solids accumulate within a filter and agglomerate into a ball of solids combined with the filter media.

Masses block the passage of water, causing higher velocity filtration and uneven distribution.

Improper surface washing or backwashing

Cracking

Septic smell

FILTRATION TROUBLESHOOTING

Air binding

Pressure in the filter becoming negative during operation.

Causes the air dissolved in the water to come out of the solution and become trapped in the filter.

Results in resistance and short filter runs.

FILTRATION TROUBLESHOOTING

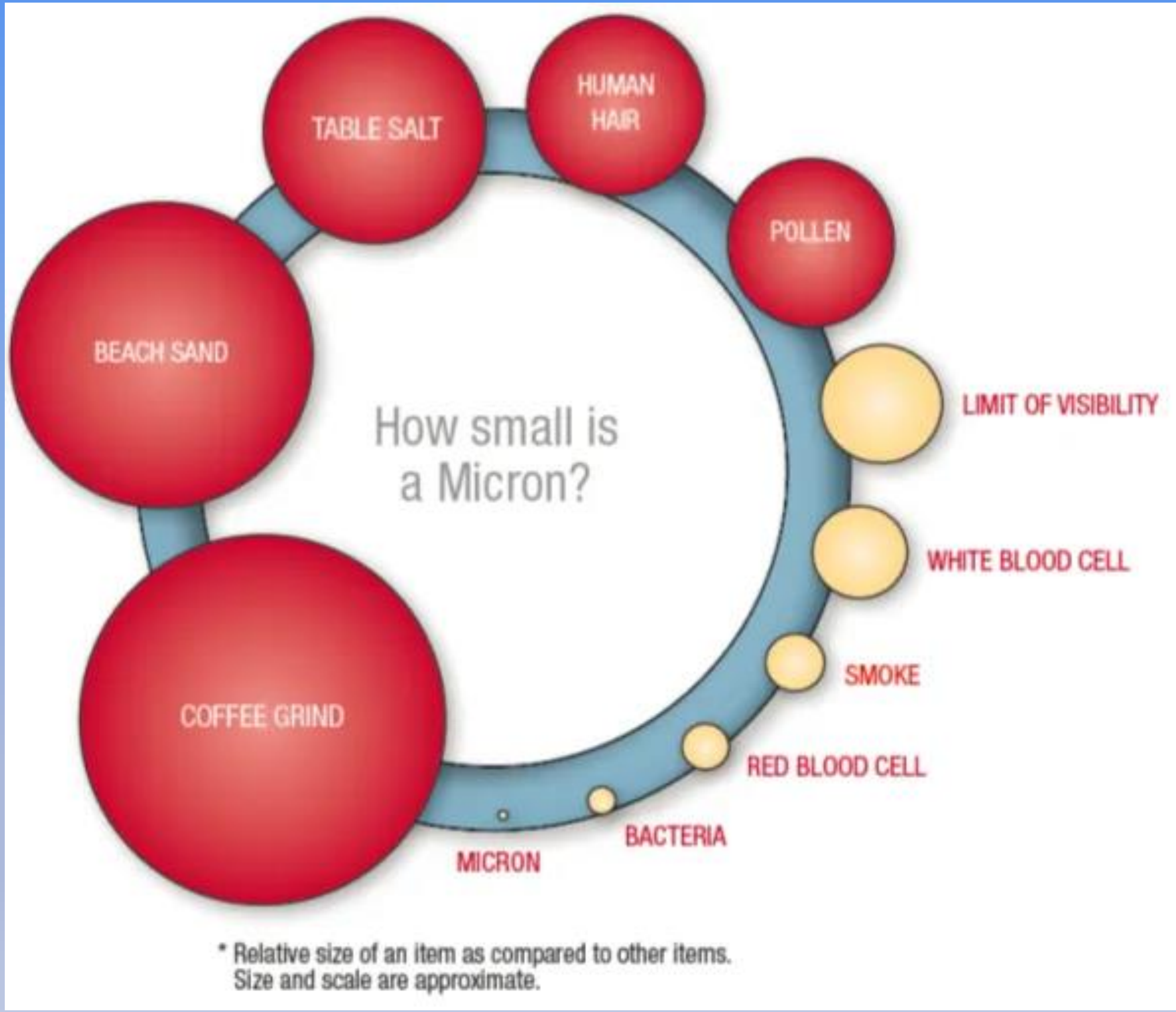
Air binding

Pressure in the filter becoming negative during operation.

Causes the air dissolved in the water to come out of the solution and become trapped in the filter.

Results in resistance and short filter runs.

MEMBRANE FILTRATION



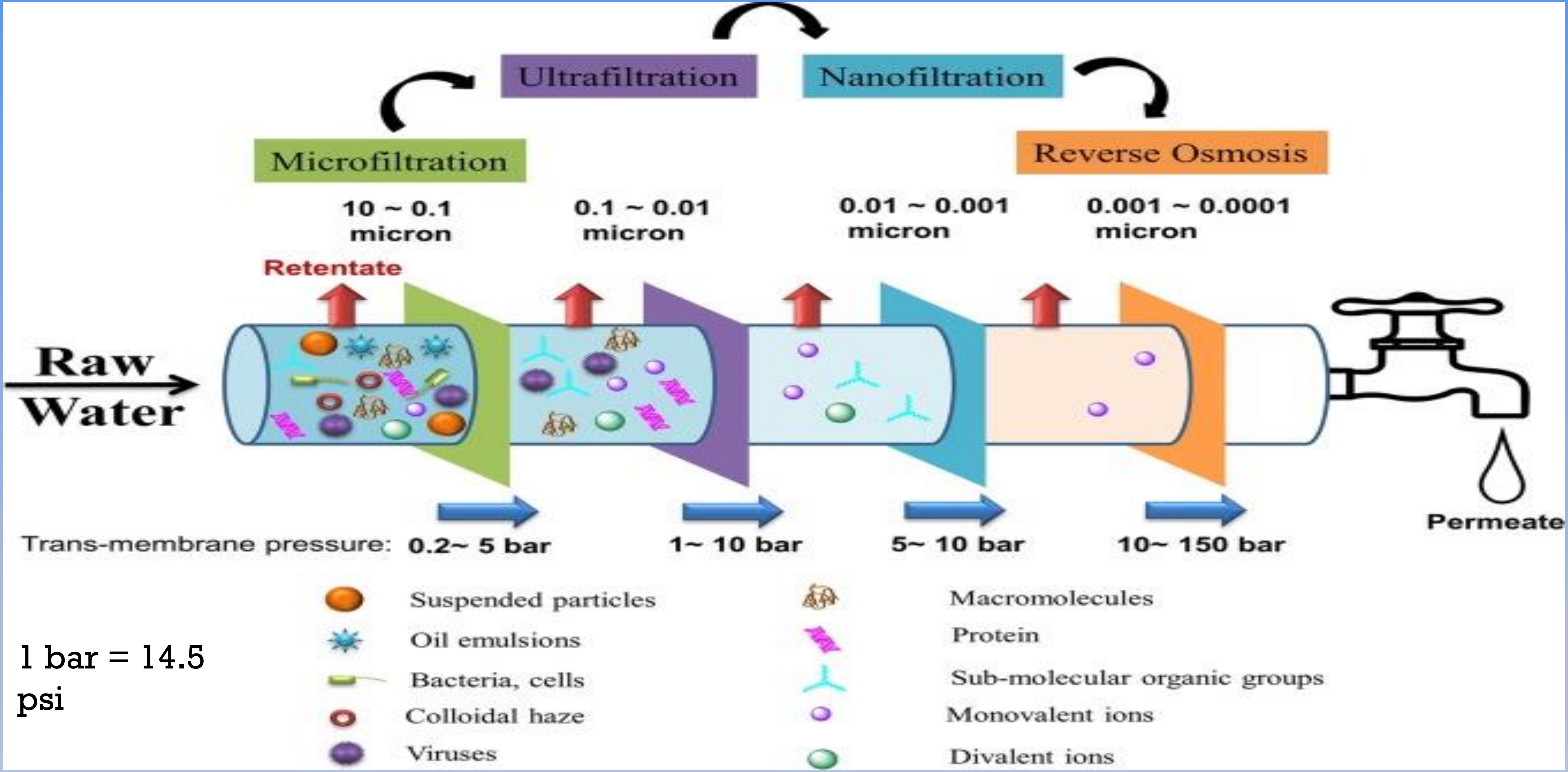
MEMBRANE FILTRATION

American Water Works WSO Treatment Operator Grade 1

Video: Membranes.

https://www.youtube.com/watch?v=Ki8LmnPt6qE&list=PL7BpwzCwK105B06OqorTUeW6Ts3UcNFmF&index=8

MEMBRANE FILTRATION



1 bar = 14.5 psi

MEMBRANE FILTRATION

Sieving Processes require 10-50 psi

Micro Filtration (MF)

.1 Micron Pore Size

Removes: suspended matter, bacteria, turbidity, algae, fungi, and protozoa like Giardia and Cryptosporidium.

Does Not Remove: Viruses, Disinfection Byproduct Precursors, Inorganic Chemicals, Natural Organic Matter.

MEMBRANE FILTRATION

Sieving Process requires 10-50 psi

Ultra Filtration (UF)

- .01 Micron Pore Size

- Removes: all MF plus viruses

- Does Not Remove: Inorganic Chemicals like Chloride and Nitrates, and Metals.

MEMBRANE FILTRATION

Semi-Permeable Desalination Membranes

No pores, water diffuses across molecular membrane.

Nano Filtration (NF)

Requires 75 to 250 psi

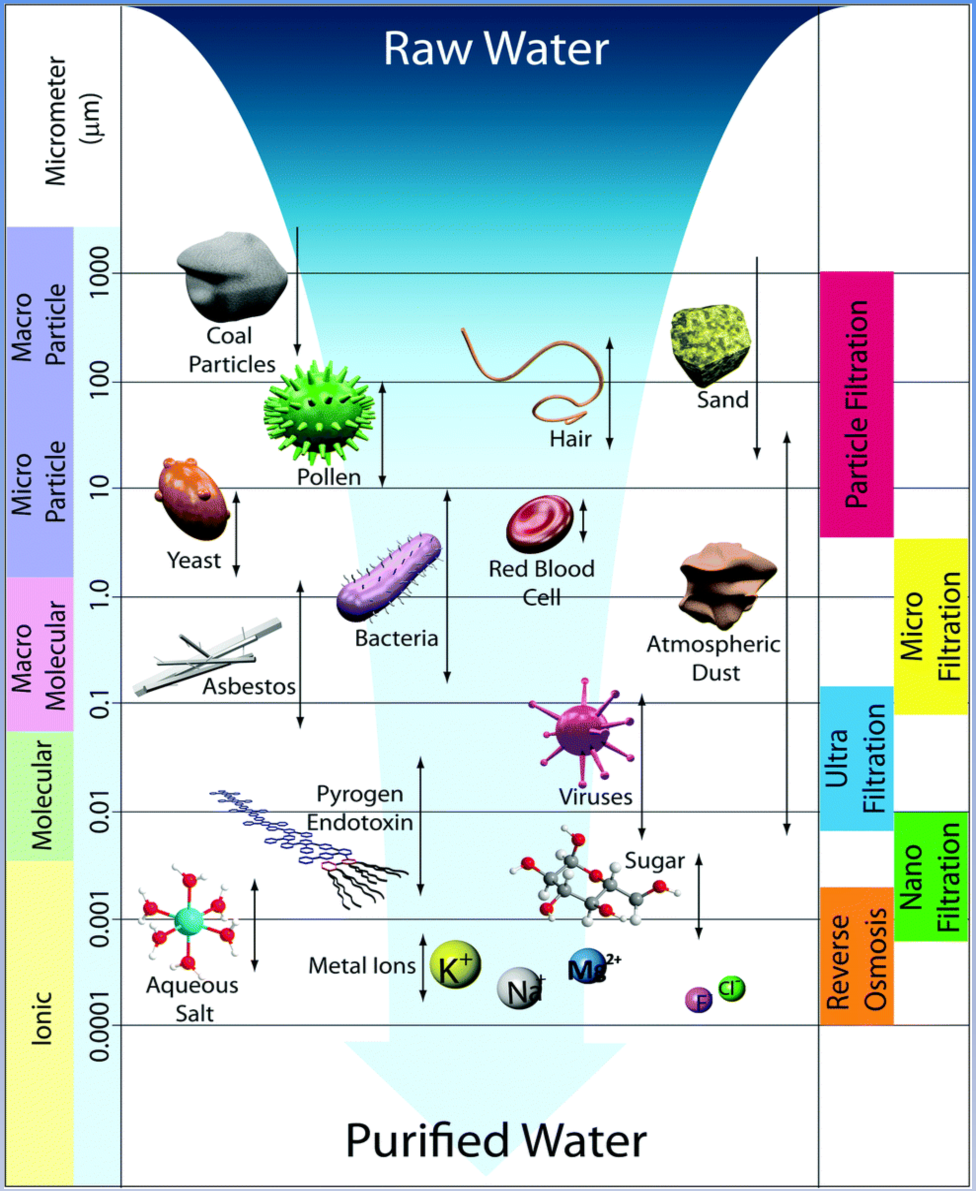
Removes: all UF plus most Natural Organic Matter, DBP Precursors, Micro-organisms, Organic Compounds like Pesticides

Reduces: Calcium and Magnesium as well as Color.

MEMBRANE FILTRATION

- Semi-Permeable Desalination Membranes
  - No pores, water diffuses across molecular membrane.
- Reverse Osmosis (RO)
  - Can require up to 1200psi!
  - EPA "Best available method for removing inorganic chemicals".
  - Removes: Nitrates
  - Used for Desalination
  - Approved for Reuse Applications "Toilet to Tap"

FILTRATION



Pressure Required

1 psi +

10-50 psi

75-250 psi

1200 psi

POST TREATMENT DISINFECTION

Chlorine used because:

- Low Cost
- Ease of Use
- Leaves a Residual

5 PRINCIPLES OF CHLORINE DISINFECTION

Concentration

Contact time

Temperature of the water

pH of the water

Foreign substances in the water

CONCENTRATION & CONTACT TIME

Chlorine concentration down then contact time up

Longer detention times = higher bacteria kill rates

A minimum of 0.2 mg/L residual:

- leaving the chlorination station
- maintained at the extremities of the distribution system

Chlorine penetrates the cell wall to kill pathogens

- More time to penetrate = More time to kill

Ct Calculation = (Chlorine Concentration, mg/L)(Time, min)

DETENTION TIME (DT)

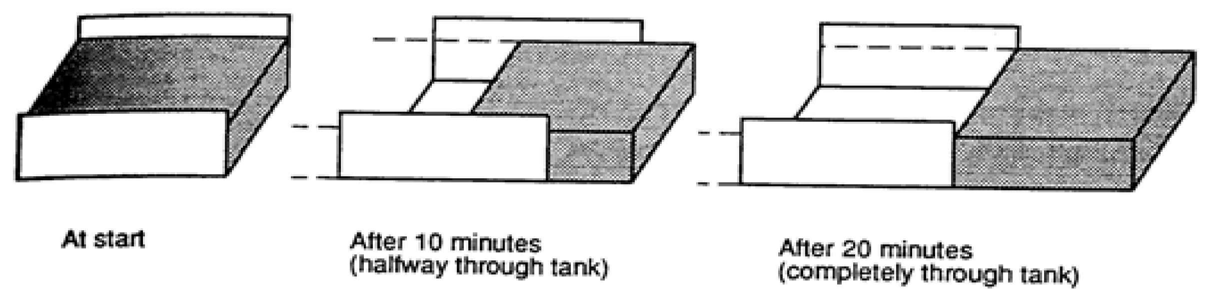
The calculated time required for a given amount of water or wastewater to pass through a tank at a given rate of flow.

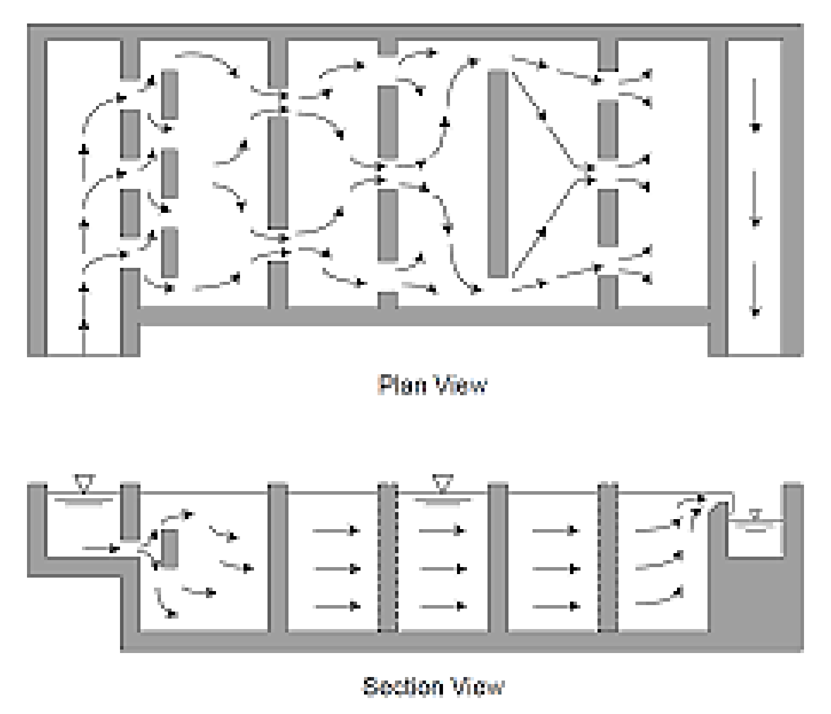
The actual time in hours, minutes, or seconds that a small amount of water is in a settling basin, flocculating basin, or rapid-mix chamber.

In storage reservoirs, detention time is the length of time entering water will be held before being drafted for use.

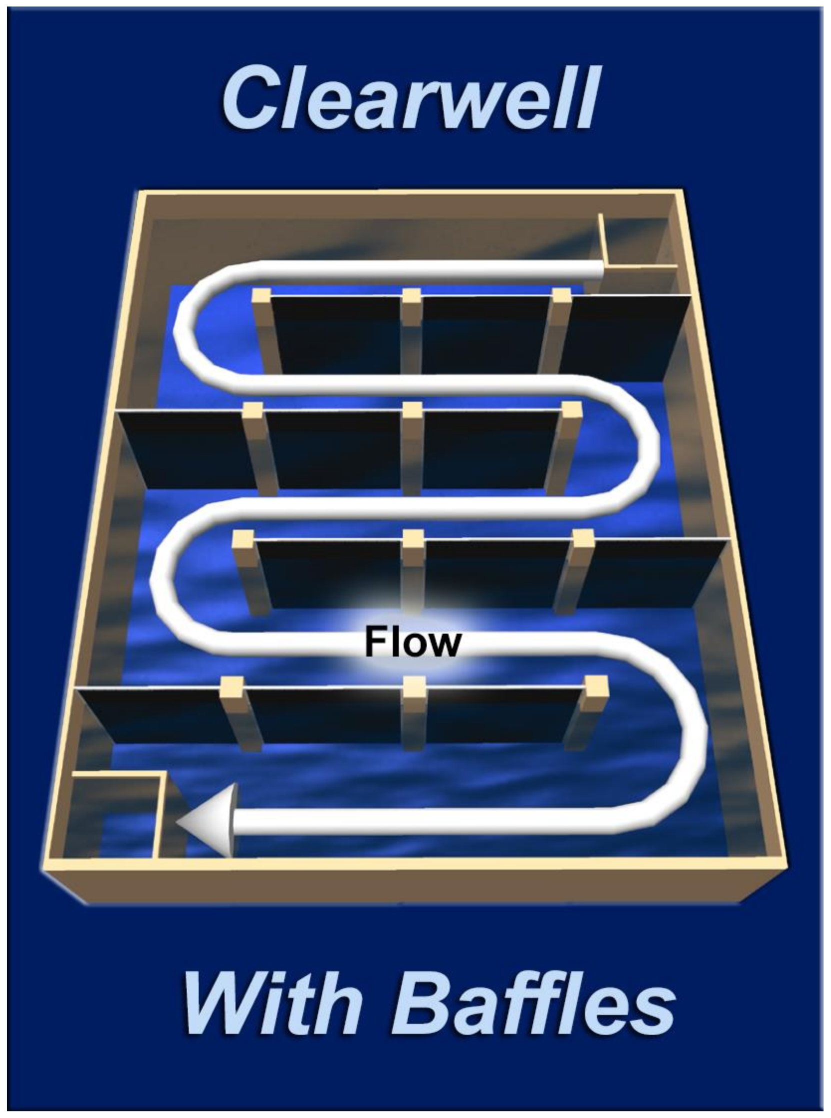
$$Dt\ (day) = \frac{\text{Basin Volume, gal}}{\text{Flow gal/day}}$$

DETENTION TIME & CHLORINE BASIN





DETENTION TIME AND CLEAR WELLS



TEMPERATURE

Low temperatures the bacteria kill rate is lower

Chlorine residual will remain longer in cold water

Chlorine dosages should be adjusted with changes in water temperatures

Higher temperatures cause faster rates of THM formation

PH

pH should be checked routinely

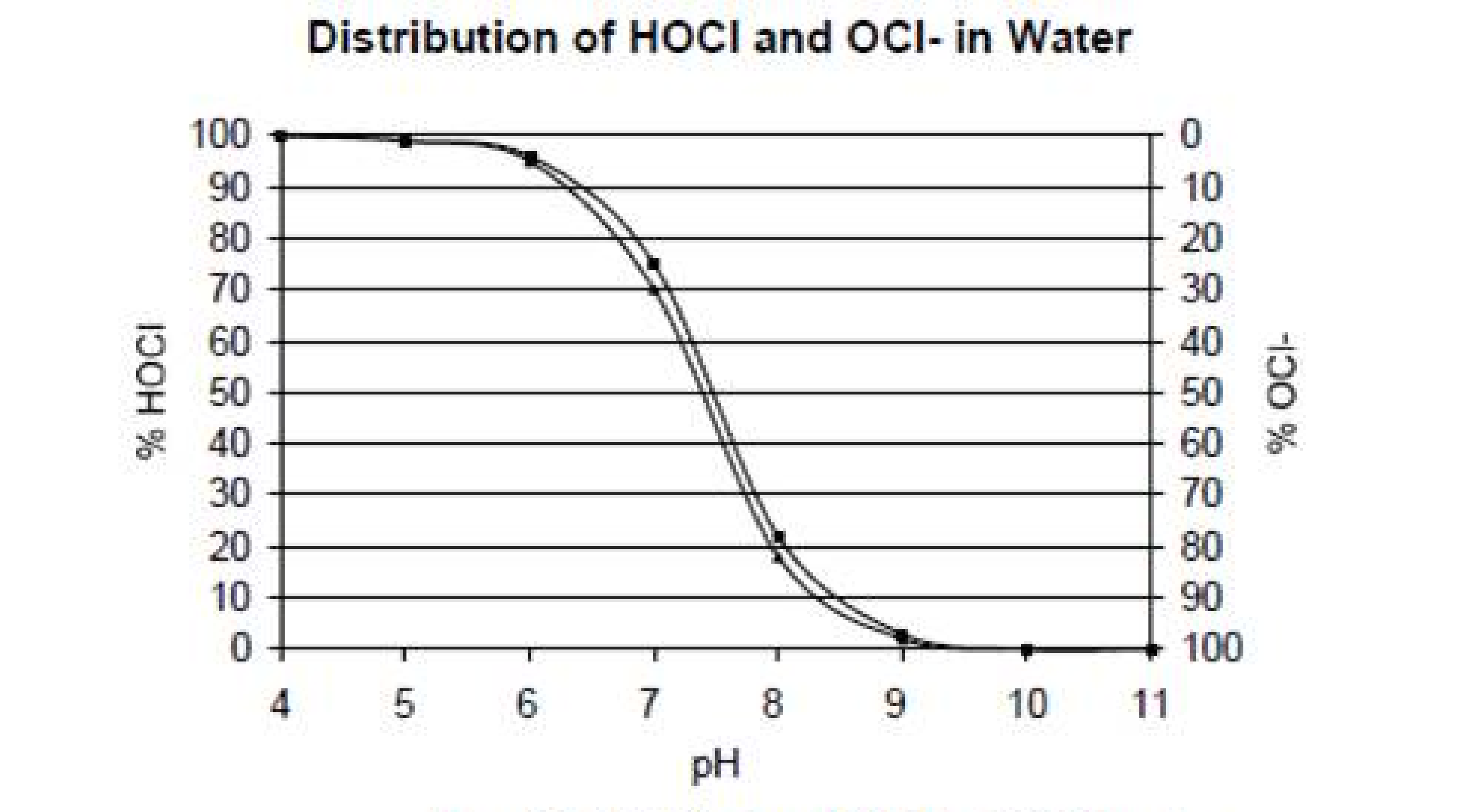
If the pH of the water system is raised for corrosion control, then the chlorine dose needs to be raised to maintain an effective kill level. Why?

Lower pH=Hypochlorous acid HOCL Free Cl Stronger disinfectant

Higher pH=Hypochlorite Ion (OCl^{-}) Free Cl

Weaker disinfectant

PH VERSES HOCL AND OCL-



TURBIDITY

Can mask the bacteria

Chlorine is effective only if it comes in contact with bacteria

Can prevent good contact time and protect pathogens

NEPHELOMETRIC TURBIDITY UNIT (NTU)

Nephelometer = Measures reflected light (90°)

Greater NTU = Dirtier Water

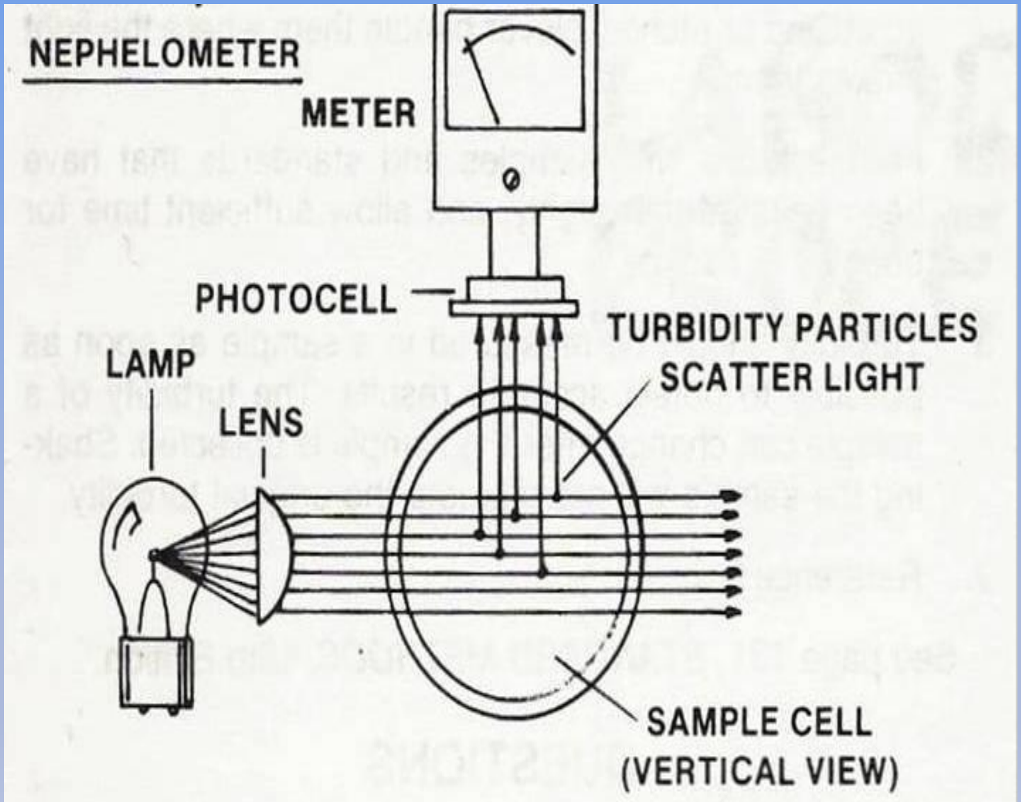


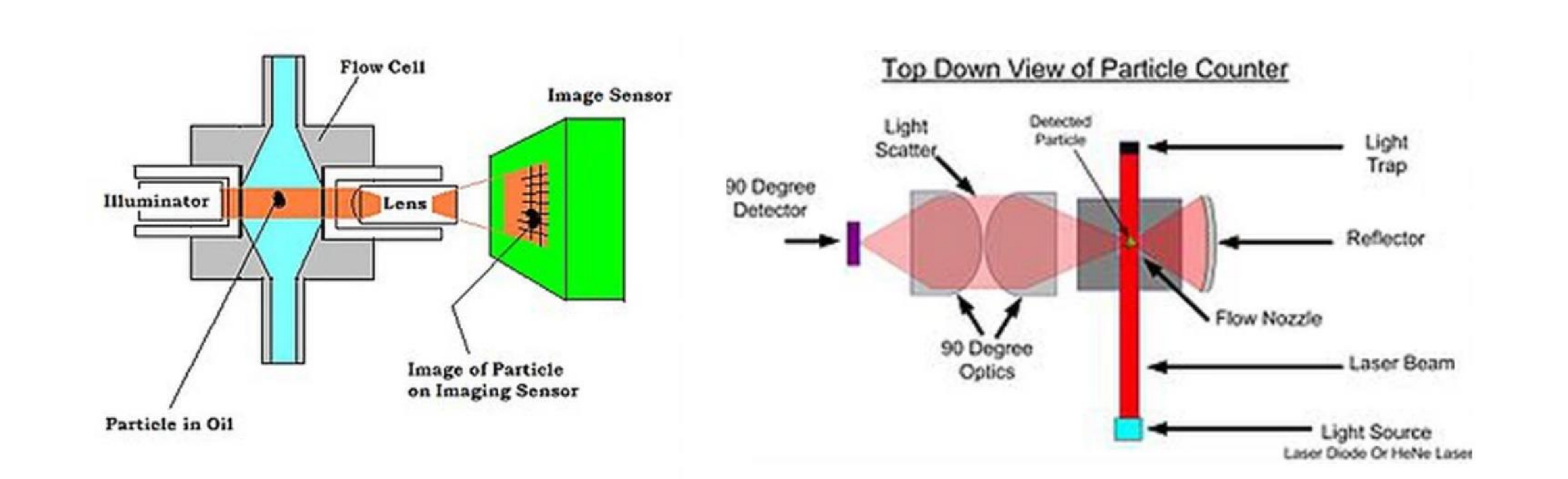
Fig. 7.19 Nephelometer

(Permission of Hach Company)

PARTICLE COUNTER

The method used to measure the cloudiness of the water – the amount and the size of particles.

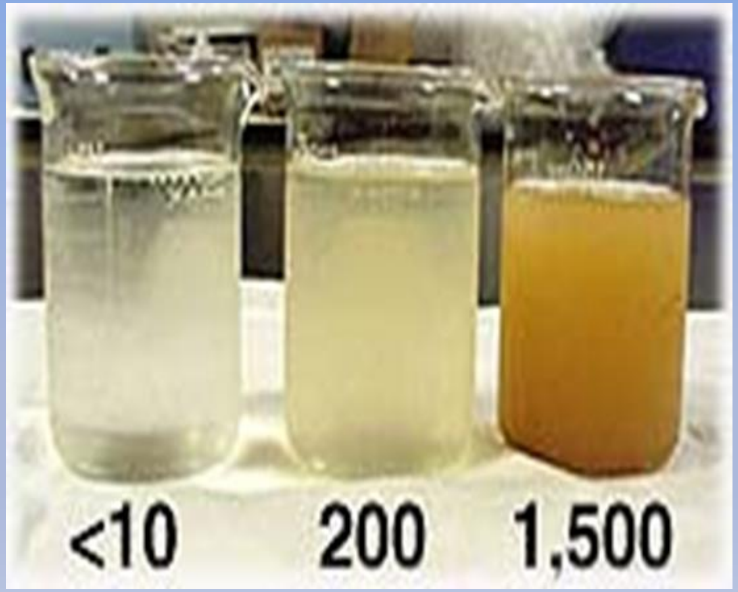
The dirtier the water, the greater the possibility of microbiological contamination.



TURBIDITY AND SWTR

Must never be higher than 1.0 NTU

Samples for turbidity must be less than 0.3 NTU in at least 95 percent of samples in any month.

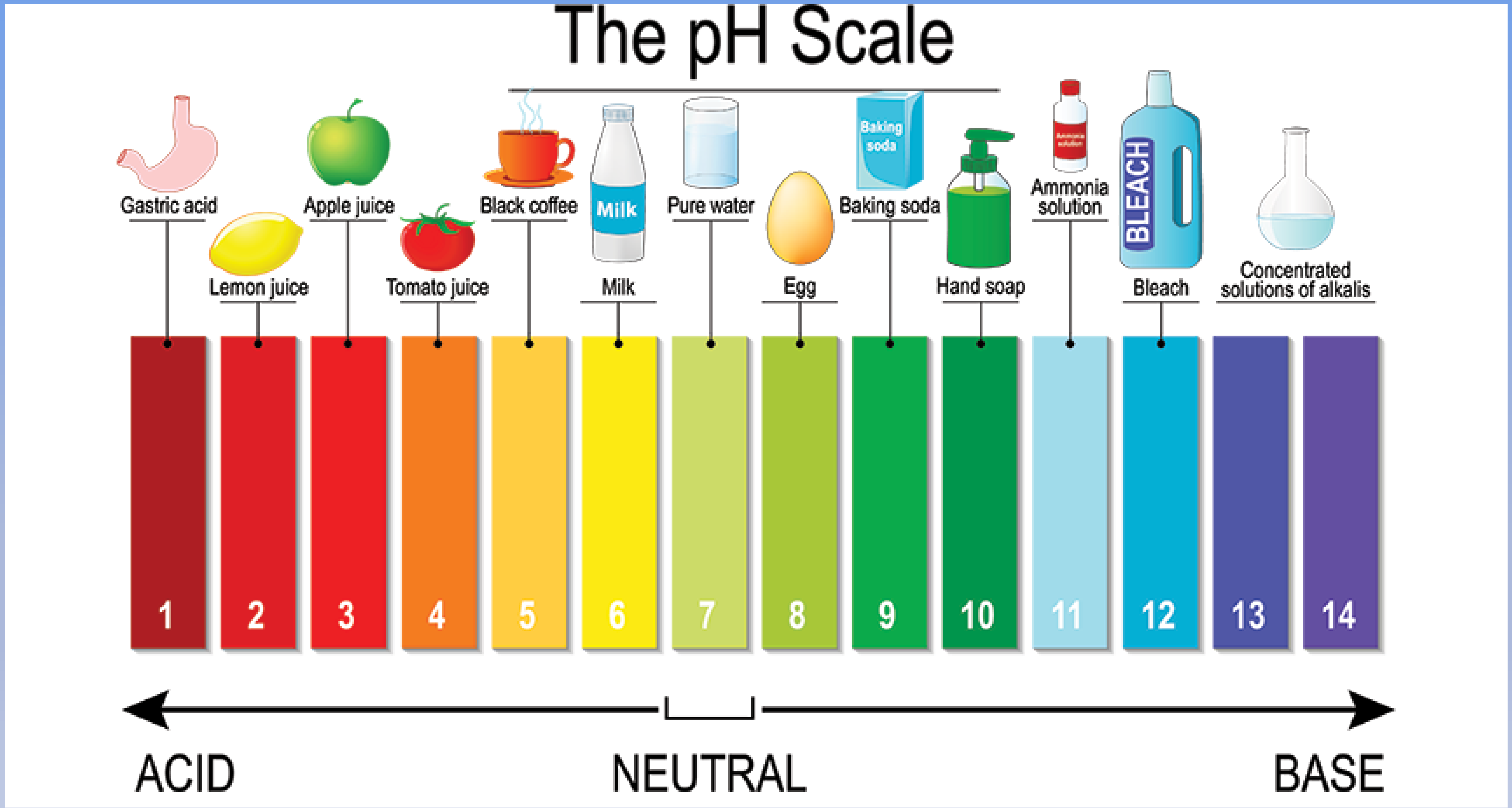


POST TREATMENT CHEMICAL ADJUSTMENT

- pH
- Alkalinity
- Fluoride

PH

- pH: refers to the basic or acidic conditions of the water.



ALKALINITY

A measurement of the water's capacity to neutralize an acid

Alkalinity is determined by titrating to an end point with a pH meter or the use of the methyl orange test using sulfuric acid

Affects the coagulation process

Insoluble calcium carbonate compounds cause build up of scale

Hardness expressed as mg/L in CaCO3 Calcium Carbonate, to be considered soft should be 0 to 50 mg/L

FLUORIDE

Fluoride shall not exceed 4 mg/L

If fluoride levels exceed 2 mg/L, the water system must notify the public.

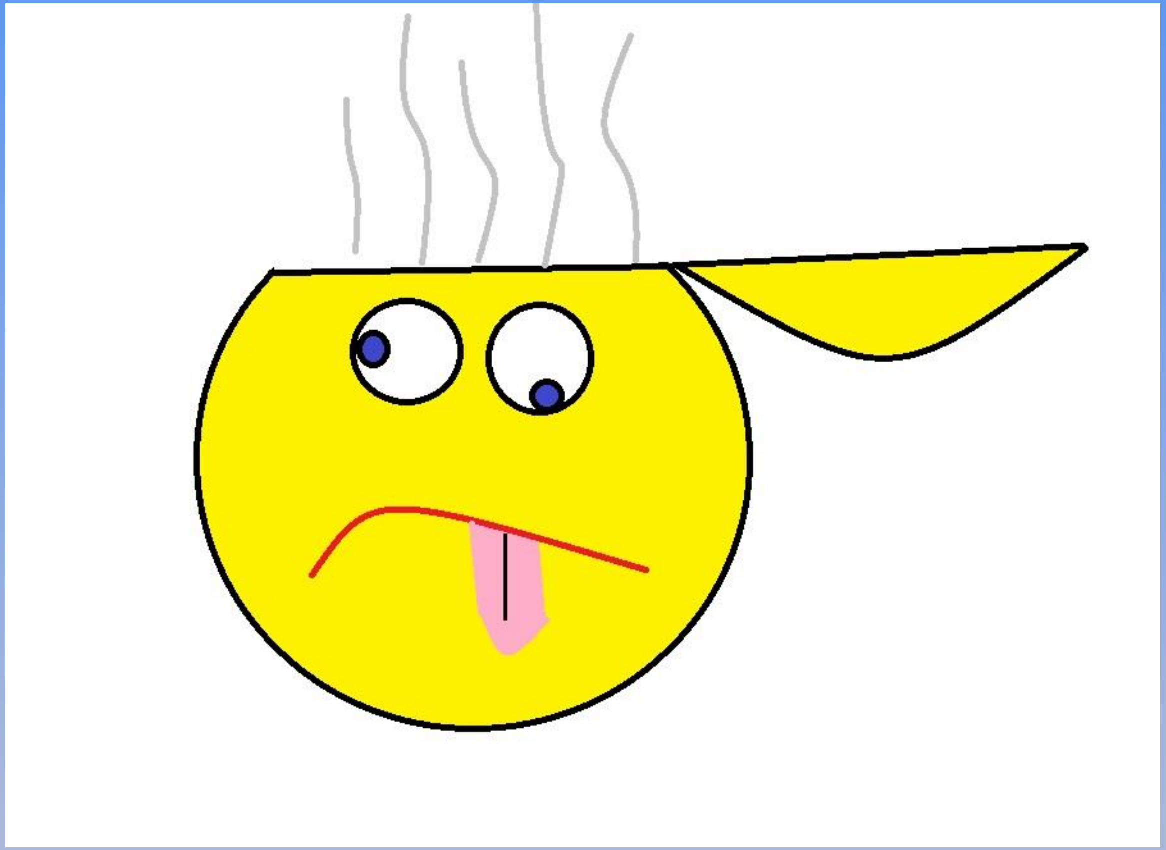
Water system must notify the public in their first set of water bills after the violation

Must provide specific health effects language

OVER FEEDING FLUORIDE

Can Mottle Teeth

THE END



MATH TIME

Velocity

What is the velocity, in feet per second, of water traveling through a 36-inch pipe when your flow is 6.5 MGD?

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, ft}^3\text{/sec}}{\text{Area, ft}^2}$$

$$\text{Velocity, ft/sec} = \frac{\text{Distance, ft}}{\text{Time, sec}}$$

Velocity

What is the velocity, in feet per second, of water traveling through a 36-inch pipe when your flow is 6.5 MGD?

Known

Flow Rate = 6.5 MGD = 10.1 ft^3/sec
Pipe Diameter = 36” or 3 ft

Unknown

Velocity in fps?

6.5 MG	1,000,000 gal	1 ft^3	1 day	1 min	6,500,000 ft^3
1 day	1 MG	7.48 gal	1440 min	60 sec	646,272 sec

Velocity

What is the velocity, in feet per second, of water traveling through a 36-inch pipe when your flow is 6.5 MGD?

Known

Flow Rate = 6.5 MGD = 10.1 ft^3/sec

Pipe Diameter = 36" or 3 ft

Pipe area? 7.1 ft^2

Unknown

Velocity in fps?

(dia, ft)(dia, ft)(.785) = Area, ft^2

(3 ft)(3 ft)(.785) = 7.1 ft^2

Velocity

What is the velocity, in feet per second, of water traveling through a 36-inch pipe when your flow is 6.5 MGD?

$$\text{Velocity, ft/sec} = \frac{\text{Flow Rate, ft}^3\text{/sec}}{\text{Area, ft}^2}$$

$$\text{Velocity, ft/sec} = \frac{10.1\ \text{ft}^3\text{/sec}}{7.1\ \text{ft}^2} = 1.42\ \text{fps}$$

Flow

Water is moving through a 24 inch pipe at 5 feet per second. What is the flow rate in gallons per minute?

Known

Pipe Diameter = 24 in or 2 ft
Velocity = 5 fps

Unknown

Flow Rate in gpm?

Flow Rate, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)

Flow

Water is moving through a 24 inch pipe at 5 feet per second. What is the flow rate in gallons per minute?

Known

Pipe Diameter = 24 in or 2 ft
Velocity = 5 fps

Area of Pipe, $ft^{2?}$ = 3.14 ft^2

(dia, ft)(dia, ft)(.785) = Area, ft^2

(2 ft)(2 ft)(.785) = 3.14 ft^2

Unknown

Flow Rate in gpm?

Flow

Water is moving through a 24 inch pipe at 5 feet per second. What is the flow rate in gallons per minute?

Known

Pipe Diameter = 24 in or 2 ft
Velocity = 5 fps
Area of Pipe, ft^2 = 3.14 ft^2

Unknown

Flow Rate in gpm?

Flow Rate, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)

Flow Rate, ft^3/sec = (3.14 ft^2)(5 ft/sec) = 15.7 ft^3/sec

15.7 ft^3	7.48 gal	60 sec
1 sec	1 ft^3	1 min

= 7046 gpm

Detention Time

What is the detention time in hours through a 52 ft. diameter clarifier that is 8 ft high when the flow is 1.0 MGD?

Known

Diameter 52 ft
Height 8 ft
Flow 1.0 MGD

Unknown

Detention Time Hours?

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

Detention Time

What is the detention time in hours through a 52 ft. diameter clarifier that is 8 ft. high when the flow is 1.0 MGD?

Known
Diameter 52 ft
Depth 8 ft
Flow 1 MGD

Unknown
Detention Time Hours?

Clarifier Volume? = .127 MG

Volume = (dia, ft)(dia, ft)(.785)(depth, ft)(7.48gal/ft^3)

Volume = (52ft)(52ft)(.785)(8ft)(7.48gal/ft^3)

= 127,019 gal or .127 MG

Detention Time

What is the detention time in hours through a 52 ft. diameter clarifier that is 8 ft. high when the flow is 1.0 MGD?

Known

Diameter 52 ft

Depth 8 ft

Flow 1 MGD

Clarifier Volume .127 MG

Unknown

Detention Time Hours?

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}}$$

$$\text{Detention Time} = \frac{.127\ \text{MG}}{1.0\ \text{MGD}}$$

Detention Time = .127 Days

$$\frac{.127\ \text{Days} \times 24\ \text{Hours}}{1.0\ \text{Day}} = 3\ \text{Hours}$$

Filter Loading Rate

If a treatment plant had two filters that measured 20 ft. in diameter and 6 ft. deep and the daily flow to this plant was 1.1 MGD, what is the filter loading rate in gpm per square foot?

Known

Diameter 20 ft
Depth 6 ft
Flow 1.1 MGD
TWO FILTERS!!!

Unknown

Filter Loading Rate gpm/ft^2?

$$\text{Filter Loading Rate, gpm/ft}^2 = \frac{\text{Flow gpm}}{\text{Filter area (ft}^2\text{)}}$$

Filter Loading Rate

If a treatment plant had two filters that measured 20 ft. in diameter and 6 ft. deep and the daily flow to this plant was 1.1 MGD, what is the filter loading rate in gpm per square foot?

<u>Known</u>

Diameter 20ft

~~Depth 6ft~~

Flow 1.1 MGD

TWO FILTERS!!!!

Filter area (ft^2) = 628 ft^2

<u>Unknown</u>

Filter Loading Rate gpm/ft^2?

Area = (dia, ft)(dia, ft)(.785ft)

Area = (20 ft)(20 ft)(.785) = 314 ft^2

314 ft^2 x 2 = 628ft^2

Filter Loading Rate

If a treatment plant had two filters that measured 20 ft. in diameter and 6 ft. deep and the daily flow to this plant was 1.1 MGD, what is the filter loading rate in gpm per square foot?

Known

Diameter 20ft

Flow 1.1 MGD = 763.89gpm

TWO FILTERS!!!!

Filter area (ft^2) =628 ft^2

Unknown

Filter Loading Rate gpm/ft^2?

$$\frac{1.1\ \text{MG}}{1\ \text{Day}} \times \frac{1{,}000{,}000\ \text{gal}}{1.0\ \text{MG}} \times \frac{1\ \text{Day}}{1440\ \text{min}} = 763.89\text{gpm}$$

Filter Loading Rate

If a treatment plant had two filters that measured 20 ft. in diameter and 6 ft. deep and the daily flow to this plant was 1.1 MGD, what is the filter loading rate in gpm per square foot?

Known

Diameter 20ft
Flow 1.1 MGD = 763.89 gpm
TWO FILTERS!!!
Filter area (ft^2) = 628 ft^2

Unknown

Filter Loading Rate gpm/ft^2?

$$\text{Filter Loading Rate, } gpm/ft^2 = \frac{763.89 gpm}{628 ft^2}$$

$$\text{Filter Loading Rate, } gpm/ft^2 = 1.22 gpm/ft^2$$

Feed Rate (Pounds Formula)

$$\text{Lbs/day} = \frac{(\text{Dose, mg/L})\ (\text{Flow, MGD})\ (8.34\ \text{lbs/gal})}{\text{Purity, expressed as a decimal}}$$

<u>Chlorine % Purity</u>

Cl_2 = 100% or 1.0

$Ca(OCl)_2$ = 65% or 0.65

NaOCl = 12.5% or .125

Feed Rate (Pounds Formula)

If the flow to your treatment plant is 5.0 MGD and you want to dose it at .60 mg/L of Cl_2, how many pounds per day will you be using?

$$\text{Lbs/day} = \frac{(\text{Dose, mg/L})\ (\text{Flow, MGD})\ (8.34\ \text{lbs/gal})}{\text{Purity, expressed as a decimal}}$$

$$\text{Lbs/day} = \frac{(.60\ \text{mg/L})\ (5.0\ \text{MGD})\ (8.34\ \text{lbs/gal})}{1.0}$$

Lbs/day = 25.02

Feed Rate (Pounds Formula)

If the flow to your treatment plant is 5.0 MGD and you want to dose it at .60 mg/L of Cl_2, how many pounds per day will you be using?

Cl_2 100% Lbs/day = 25.02 lbs

$Ca(OCl)_2$ 65% Lbs/day = $\frac{25.02}{.65}$ = 38.49 lbs

NaOCl 12.5% Lbs/day = $\frac{25.02}{.125}$ = 200.16 lbs

Feed Rate (Pounds Formula)

Specific Gravity of NaOCl from SDS is 1.2 and the weight of pure water is 8.34 lbs/gallon so…

1.2 x 8.34 lbs/gallon = 10.2 lbs NaOCl solution/gallon

$$\frac{200.16 \text{ lbs NaOCl}}{10.2 \text{ lbs NaOCl/gallon}} = 19.62 \text{ gallons}$$