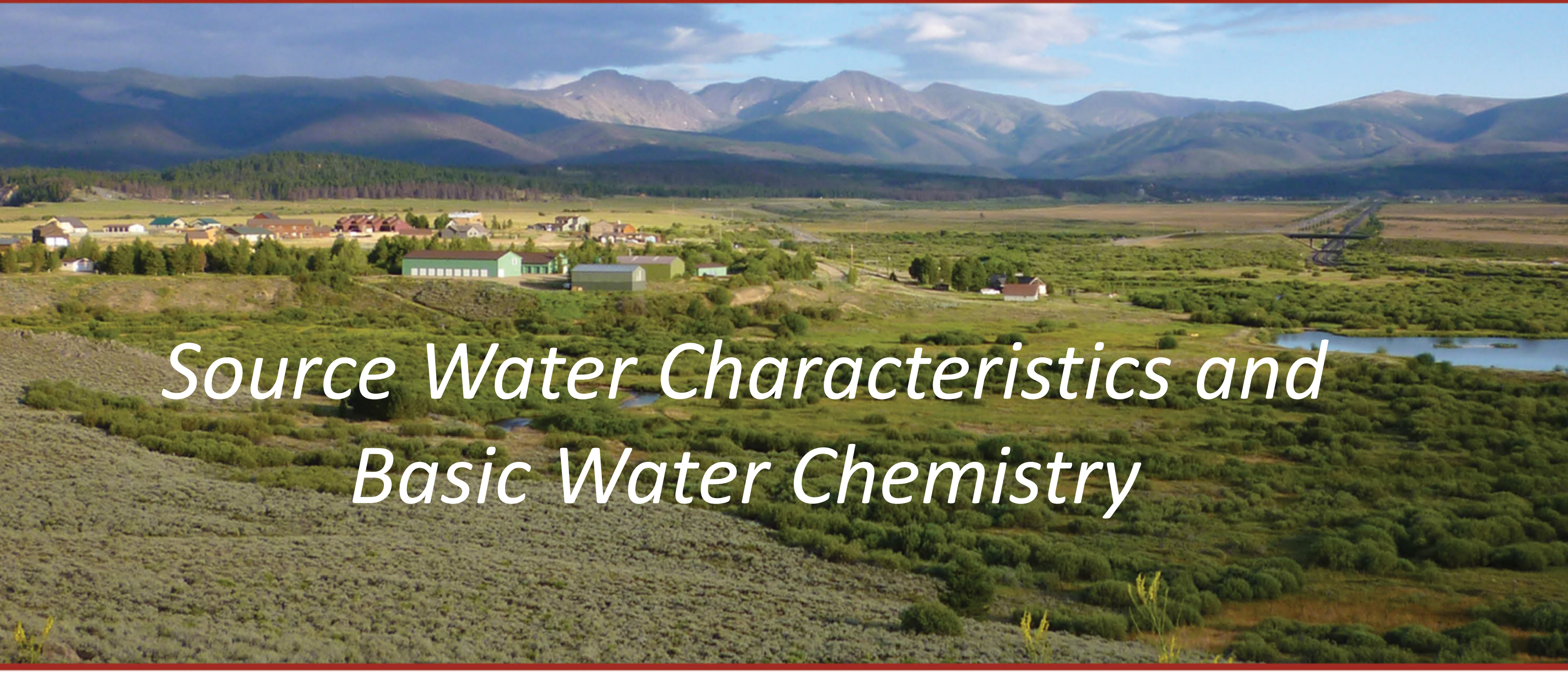






Source Water Characteristics and Basic Water Chemistry

Daniel B. Stephens & Associates, Inc.

What is the main, most important reason for having a trained, certified water system operator?

PROTECT PUBLIC HEALTH

Safe Drinking Water Act (SDWA)

- 1974: U.S. Environmental Protection Agency (EPA) was mandated to identify the constituents in drinking water that cause adverse health effects.
- 1977: National interim primary drinking water regulations were established.
- 1979: Trihalomethanes (TTHMs) started being regulated. TTHMs are organic compounds formed during the disinfection process, and are considered carcinogens.
- 1986: EPA was mandated to specifically regulate microbiological constituents, inorganic and organic compounds, and radioactivity.

Safe Drinking Water Act (SDWA) (cont.)

- 1996: More amendments established that looked at preventive approaches to safe drinking water, improving consumer education (CCRs) and funding for states and local water systems.
- Congress intended that the SDWA would be a partnership between states, the EPA, and local water utilities.
- By accepting primary enforcement responsibility (primacy), New Mexico implements the law within the state. Water utilities have to meet the requirements of the law, thereby providing day-to-day surveillance of water supplies.

1870–1880s	1890s	1908	1915	1917
Scientists demonstrate that microorganisms can cause disease.	First application of chlorine disinfectants to water facilities in England.	First application of chlorine disinfectants to U.S. municipal water facilities in Jersey City and Chicago.	First U.S. drinking water bacterial standard.	Chlorination first used in the U.S. and Canada.

1918	1925	Early 1960s	1970s	1972
Over 1,000 U.S. cities employ chlorine disinfection.	U.S. drinking water bacterial standard becomes more stringent.	More than 19,000 municipal water systems operate throughout the U.S.	Chlorine dioxide begins to gain acceptance as a drinking water disinfectant.	Passage of the U.S. Clean Water Act for restoring and maintaining surface water quality.

1974	1996	2000...
Passage of the U.S. Safe Drinking Water Act; the US Environmental Protection Agency is given authority to set water quality standards which states must enforce.	Amendments to the U.S. Safe Drinking Water Act extend existing law to recognize: source water protection, operator training, funding for water system improvements, and public information.	Disinfection By-Product Rule

Maximum Contaminant Level (MCL)

- The maximum permissible amount of a contaminant in water delivered to a user of a public water system.

Contaminants

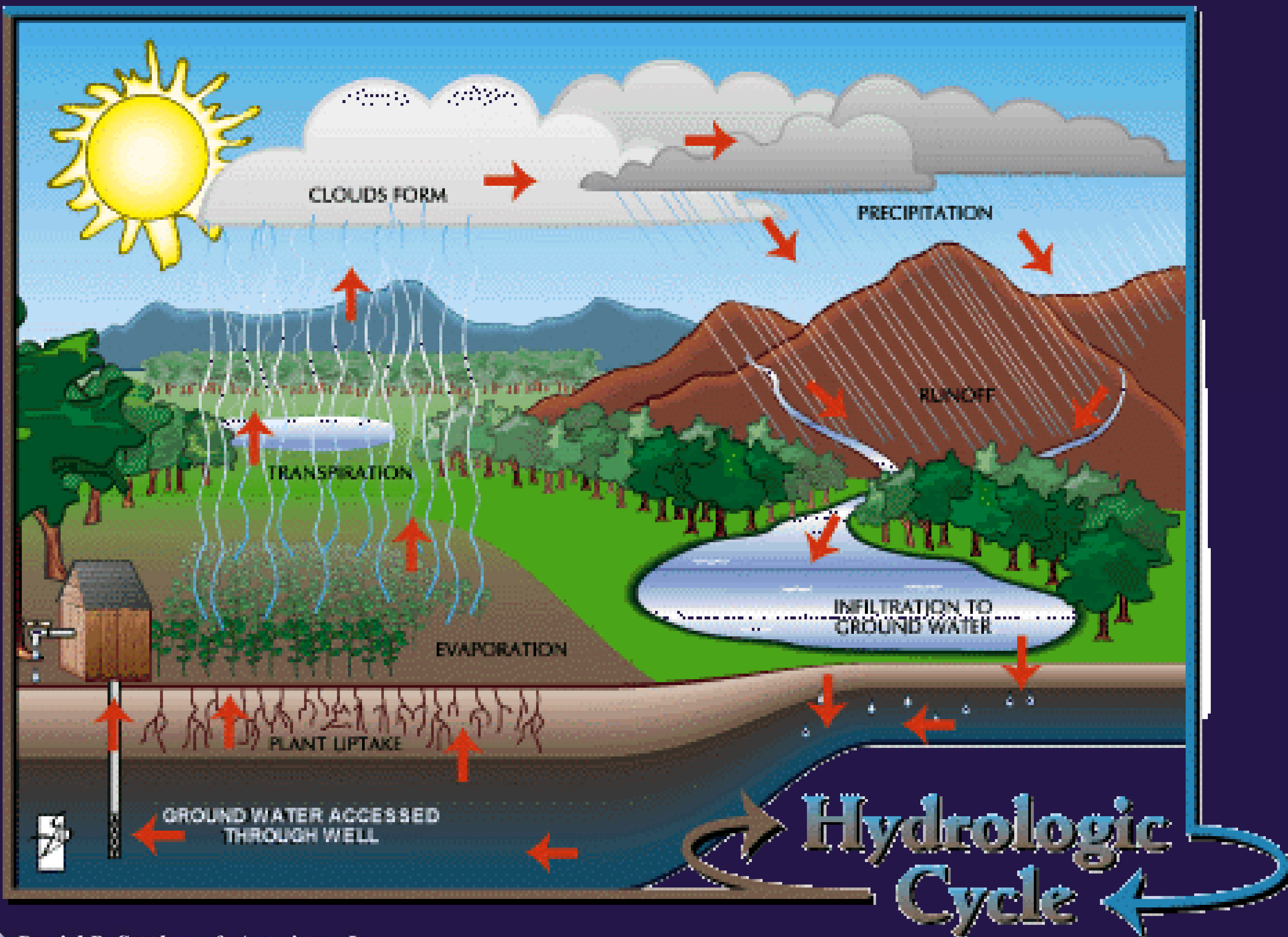
- Primary standards
  - Known acute or chronic health effects
- Secondary standards
  - Associated impacts that are not directly related to health, such as taste and staining

Primary Contaminants

- Pathogens: bacteria, viruses, protozoa
- Turbidity
- Organics: DBPs, VOCs, SOCs
- Metals, including lead and copper
- Radiological constituents
- Inorganics: cyanide, fluoride, nitrate

Secondary Contaminants

- Iron, manganese
- Hardness: calcium, magnesium
- Sulfate
- pH
- Aluminum
- Fluoride


CLOUDS FORM
PRECIPITATION
RUNOFF
TRANSPIRATION
INFILTRATION TO GROUND WATER
EVAPORATION
PLANT UPTAKE
GROUND WATER ACCESSED THROUGH WELL
Hydrologic Cycle

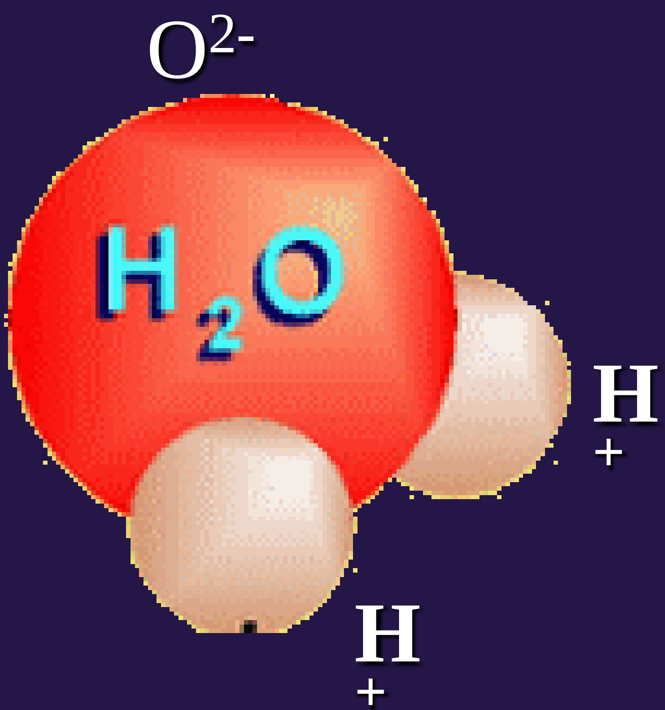
Source Water

- Groundwater: drilled wells, springs
- Surface water: lakes, rivers, streams
- Groundwater under the direct influence of surface water (GUDISW): shallow wells influenced by surface water

Is groundwater "better" than surface water?

Water: "The Universal Solvent"

- Solids
- Microorganisms
- Gases
- Chemicals
- Minerals



Common Groundwater Characteristics

- Iron
- Manganese
- Fluoride
- Calcium
- Sulfate
- Magnesium
- Arsenic
- Hydrogen sulfide
- Nitrate
- Radiological contaminants

Common Surface Water Characteristics

- Turbidity
- Biological
- Chemical
- Physical
- Living organisms
- Radiological contaminants
- Industrial/commercial
- Sediment
- Decaying animals/ vegetation
- Hydrocarbons

Surface water changes depending on human activity, climate changes, and seasonal disturbances.

GUDISW

- Groundwater under the direct influence of surface water
- Shallow wells and springs that are recharged by surface water
- Can contain the same impurities as surface water, which leads to more complex treatment methods

Influenced by surface water?

- Is water quality same as for lake?
- Does turbidity increase/ decrease with lake level?
- Does well level increase/ decrease with lake level?
- Is *Cryptosporidium* or *Giardia* present?

Source Water Characteristics

- *Physical characteristics:* can be seen, smelled, or tasted; generally the basis of customer complaints - turbidity, taste/odor, color, temperature.
- *Chemical characteristics:* can be organic, inorganic, radioactive; include pH. Health effects can be acute or chronic. Include chemicals that affect aesthetics.
- *Biological characteristics:* microorganisms living in the water.

Inorganic NPDWR Contaminants

- Mostly heavy metals (by RCRA definition), but also include other non-carbon-based chemicals
  – 15 contaminants
  – May enter water supply naturally through groundwater formations or from mining runoff and industrial discharges

Inorganic Contaminant	MCL (mg/L)
Antimony	0.006
Arsenic	0.010
Barium	2
Beryllium	0.004
Cadmium	0.005
Chromium	0.1
Cyanide (as free Cyanide)	0.2
Mercury	0.002
Selenium	0.05
Thallium	0.002
Copper	*1.3* Action level*
Lead	*0.015* Action level*
Nitrate (as N) – Acute (chemical)	10
Nitrite (as N)	1
Total Nitrate/Nitrite (as N)	10
Fluoride	*2.0 Secondary MCLG* *4.0 Violation*
Turbidity – Acute (physical)	0.3 NTU in 95% of samples 1 NTU maximum
Asbestos	7,000,000 Fibers/L

Turbidity

- An acute physical health hazard...why?
  - The cloudy appearance of water is caused by the presence of suspended or colloidal matter
  - Causes problems with
    - Taste
    - Odor
    - Hiding place for microorganisms
    - Interference with disinfection
- Measured in nephelometric turbidity units (NTU)

Organic NPDWR Contaminants

- 51 contaminants
  - Herbicides and insecticides, primarily used in agricultural applications
  - Organic solvents used industrial applications
  - Organic by-products of industrial processes
  - Chemical by-products from chlorination of drinking water

Organic NPDWR Contaminants (cont.)

- Sources of contamination include
  - Runoff from agricultural spraying
  - Industrial discharges
  - Accidental spills
  - Improper disposal of hazardous wastes

Organic Contaminants

Contaminant	MCL (mg/L)	Contaminant	MCL (mg/L)
Acrylamide	TT[1]	Lindane	0.0002
Alachor	0.002	Methoxychlor	0.04
Atrazine	0.003	Oxamyl (Vydate)	0.2
Benzene	0.005	Polychlorinated byphenyls (PCBs)	0.0005
Benzo(a)pyrene	0.0002	Pentechlorophenol	0.001
Carbofuran	0.04	Picloram	0.5
Carbon Tetrachloride	0.005	Simazine	0.004
Chlordane	0.002	Styrene	0.1
Chlorobenzene	0.1	Tetrachloroethylene	0.005
2,4-D	0.07	Toluene	1
Dalapon	0.2	Toxaphene	0.003
DBCP	0.0002	Trichloroethylene	0.005
o-Dichlorobenzene	0.6	2,4,5-TP (Silvex)	0.05
p-Dichlorobenzene	0.075	1,2,4-Trichlorobenzene	0.07
1,2-Dichloroethane	0.005	1,1,1-Trichloroethane	0.2
1,1-Dichloroethylene	0.007	1,1,2-Trichloroethane	0.005
cis-1,2-Dichloroethylene	0.07	Vinyl chloride	0.002
trans-1,2-Dichloroethylene	0.1	Xylenes (total)	10
Dichlormethane	0.005		
1,2-Dichloropropane	0.005		
Di(2-ethylhexyl) adipate	0.4		
Di(2-ethylhexyl) phthalate	0.006		
Dinoseb	0.007		
Dioxin	0.00000003		
Diquat	0.02		
Endothall	0.1		
Endrin	0.002		
Epichlorohydrin	TT[1]		
Ethylbenzene	0.7		
Ethylene dibromide	0.00005		

[1] – TT refers to approved Treatment Technology rather than MCL

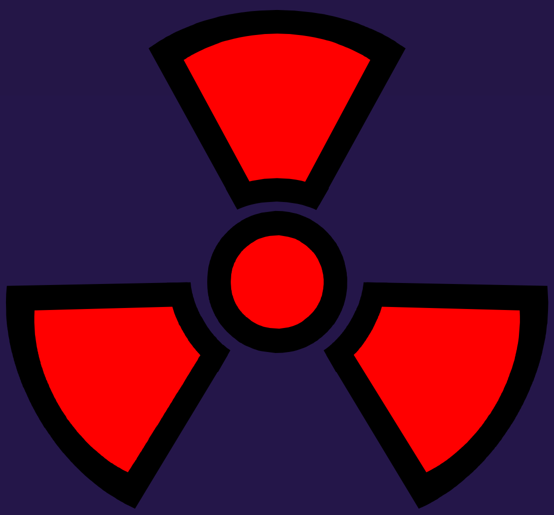
Radiological NPDWR Contaminants

- Most radioactive substances occur naturally in groundwater and in some surface supplies.
- Some man-made substances may also enter drinking water supplies from processing facilities, mining areas, and nuclear power plants.
- Radioactive material is constantly disintegrating until an element with a stable nucleus is created

The 4 contaminants include:

Contaminant	MCL
Radium 226 and 228	5 pCi/L
Gross Alpha Activity	15 pCi/L
Gross Beta Activity (man-made) or	4 millirem/yr, 50 pCi/L
Uranium	30 µg/L (ppb)

RADIOLOGICAL CONTAMINANTS

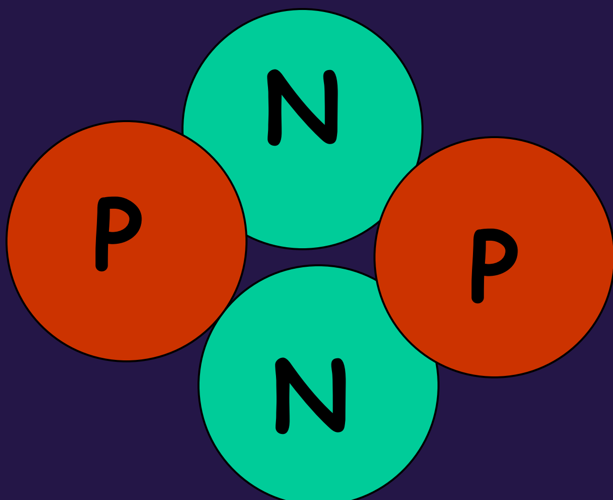


All are carcinogens or mutagens

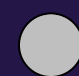
Most measured in picocuries per liter (pCi/L)

1 pCi/L = 2.2 disintegrations/min

Helium nucleus: 2 protons + 2 neutrons



Alpha particle



Beta particle: high speed electron

Gamma ray

Household <u>radon</u> can be a problem in some counties of New Mexico

Radon

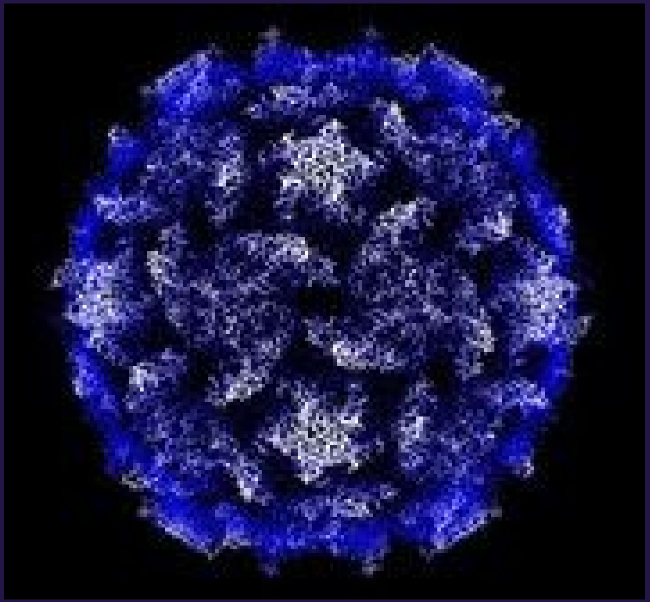
Uranium → Radium

Biological Characteristics of Water

- Disease-causing organisms are called pathogens.
- Waterborne pathogens include
  - Viruses
  - Bacteria
  - Protozoa

Biological Characteristics of Water (cont.)

- Viruses
  - 0.02 to 0.25 microns in diameter
    - Midgets of the microbial world
  - Difficult to destroy by normal disinfection practices
  - Need a host



Polio virus

Biological Characteristics of Water (cont.)

- Diseases caused by viruses
  - Viral gastroenteritis
  - Smallpox
  - Poliomyelitis
  - Infectious hepatitis
  - SARS

Biological Characteristics of Water (cont.)

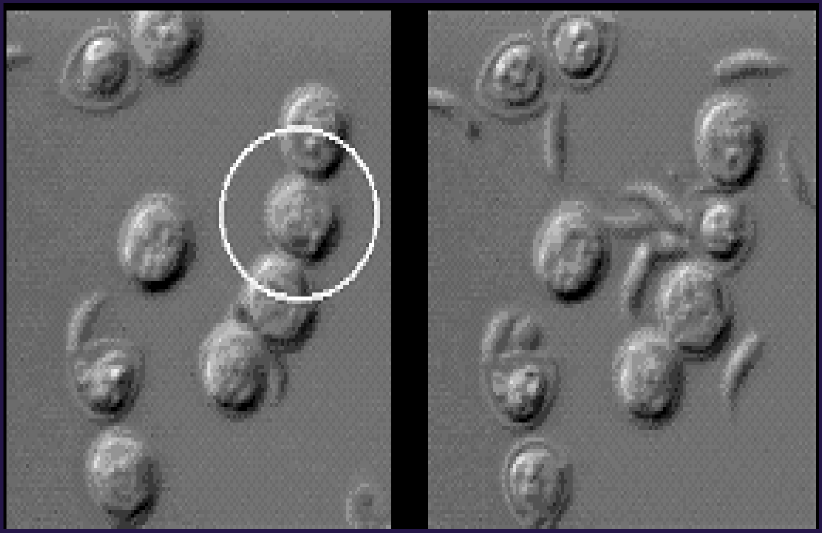
- Bacteria
  - Single-celled organisms ranging in size from 0.5 to 2 microns wide and 1 to 10 microns long
    - It would take 1,000 bacteria lying side by side to reach across the head of a straight pin.
  - The most common type of microorganisms in water

Biological Characteristics of Water (cont.)

- Diseases caused by bacteria
  - Typhoid fever
  - Gastroenteritis
  - Cholera
  - Tetanus
  - Botulism

Biological Characteristics of Water (cont.)

- Protozoa
  - One-celled animal-like organism
  - Giants of the microbial world: range from 10-20 microns to 400-500 microns
  - Grouped by locomotion system



Cryptosporidium

Protozoa go through a life cycle that includes the resting or cyst phase; in this phase, they are hard to kill with chlorine.

Biological Characteristics of Water (cont.)

- Diseases caused by protozoa
  - Giardiosis ("beaver fever")
  - Cryptosporidosis
  - Amoebic dysentery

Indicator Organisms

- Coliform bacteria
  - Organism that provides the first "clue" of possible presence of pathogens in water supply
- Fecal coliform
  - Originates from the intestinal tracts of warm-blooded animals
  - Indicates presence of contamination from fecal matter

National Secondary Drinking Water Standards

- Secondary maximum contaminant level goal (SMCLG) examples
  - Total dissolved solids 500 mg/L
  - Chloride 250 mg/L
  - Sulfate 250 mg/L
  - Iron 0.3 mg/L
  - Manganese 0.05 mg/L
  - pH 6.5 - 8.5
- Not enforceable
- Goals or guidelines for states

Taste and Odor

- Can be caused by area geology (gases such as hydrogen sulfide), algae (earthy/musty), iron/ manganese (rusty)
- Difficult to quantify
  - Usually determined by a panel
  - Subjective testing
- Generate many customer complaints
- Odor reported as threshold odor number (TON)
- Is it the garbage disposal, sewer gas trap?

Color

- True color = dissolved or suspended organic material caused by once-living plants or animals
- Apparent color = suspended colloidal oxidized iron and manganese
- Aesthetically displeasing
- Can react with disinfectants to form disinfection by-products (DBPs)
- Determined by comparing water to color standards
- Reported as color units

Color Removal

- Reduce pH to between 3.5 and 5.5 (before other processes that require higher pH)
- Causes color compounds to settle out as gelatin-like (slimy) solid
- Oxidation with chloride, ozone, potassium permanganate

pH: Power of Hydrogen

- The measurement of hydrogen ion (H^+) or acid concentration of a fluid
  - Water considered acidic when it has more hydrogen ions than hydroxide ions (OH^-)
  - Water considered basic when it has more hydroxide ions than hydrogen ions
- Chemicals that add hydrogen ions: Hydrochloric acid (HCl), sulfuric acid (H_2SO_4), nitric acid (HNO_3), carbonic acid (H_2CO_3)
- Chemicals that add hydroxide ions: Sodium hydroxide ($NaOH$), calcium hydroxide ($Ca(OH)_2$), magnesium hydroxide ($Mg(OH)_2$)

pH: Power of Hydrogen (cont.)

- pH of water is measured on a scale that reads from 0 to 14, where 7 is neutral

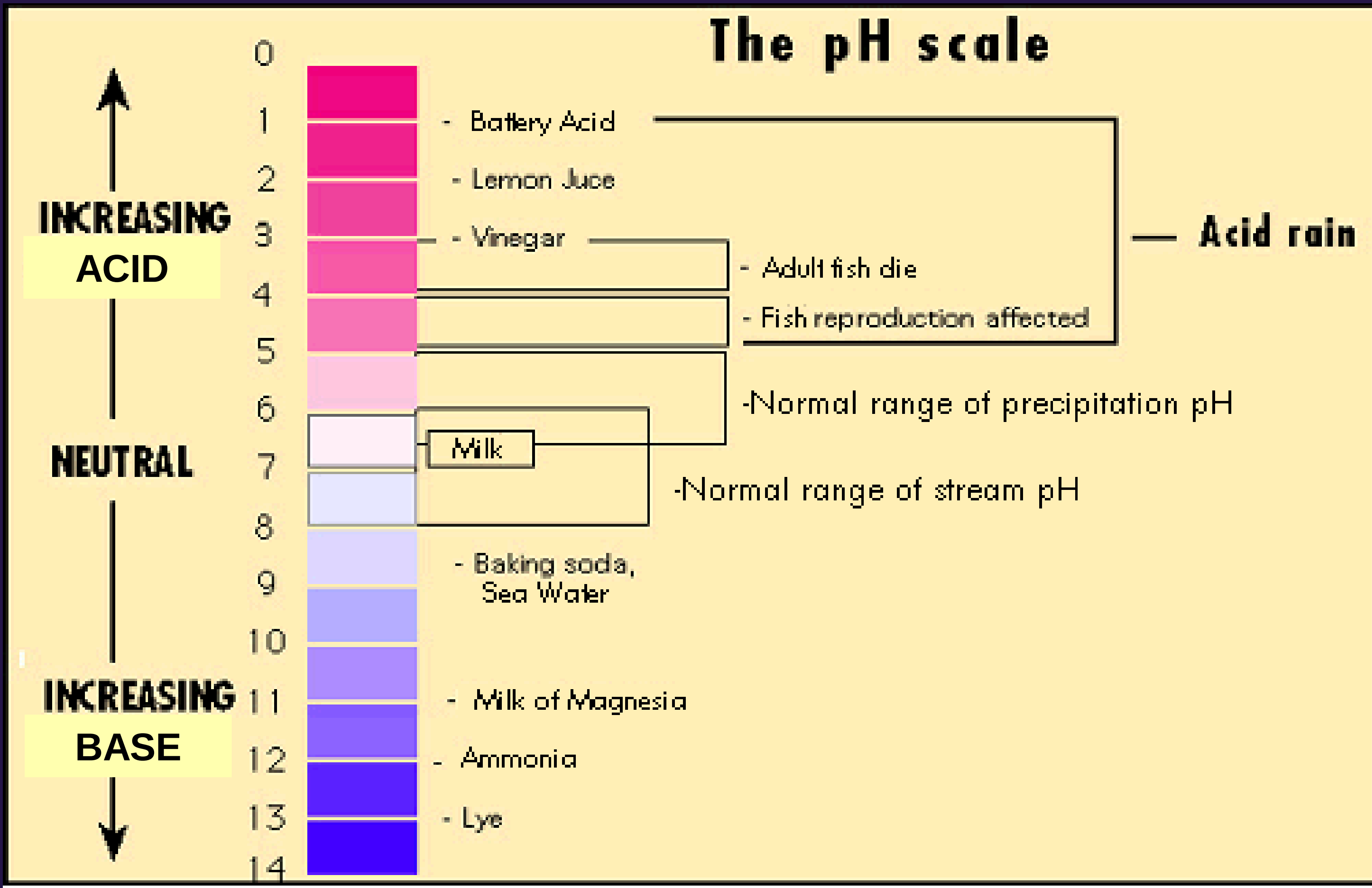
pH SCALE

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

More Acid ← **Neutral** → **More Basic**

- For every whole-number pH change, the strength of the acid or base properties of the fluid will change by a factor of 10
  - pH of 9 to pH of 10 becomes 10 times more basic
  - pH of 5 is 10 times more acidic than water at a pH of 6

pH: Power of Hydrogen



Concentration of Hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH= 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Gastric Acid Vineger
10,000	pH = 3	Grapefruit, Orange Juice, Soda
1,000	pH = 4	Acid rain Tomato Juice
100	pH = 5	Soft drinking water Black Coffee
10	pH = 6	Urine Saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Sea water
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake Milk of Magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH =13	Bleaches Oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

Hardness

- Caused by calcium and magnesium
- Hard water: requires a lot of soap to produce any suds
- Soft water: reacts with soap to produce a slimy residue

Soft water = 0 to 75 mg/L

Moderate = 75 to 150 mg/L

Hard = 150 to 300 mg/L

Very hard = Over 300 mg/L

Hardness (cont.)

- What are the major problems associated with hard water?
  - Calcium carbonate build-up in pipes and plumbing fixtures

Hardness (cont.)

- What is the major problem associated with soft water?
  - With no hardness, pipes have no coating, leaving them at risk for corrosion

Corrosivity

- Tendency of water to dissolve metal
  - Corrosive water can bring metals such as lead and copper into solution
- Based on:
  - pH
  - Hardness
  - Alkalinity
  - Temperature
  - Total dissolved solids

Iron and Manganese

- Iron: reddish brown color, can stain clothes and plumbing fixtures
- Manganese: brownish, blackish color, also stains clothes and plumbing fixtures
- Iron and manganese are considered nuisance constituents in water
  - Can also cause some taste and odor problems

Iron and Manganese Removal

- Aeration
- Ion exchange
- Sequestering agents - polyphosphates such as sodium hexametaphosphate (Calgon)
- Potassium permanganate/greensand
- Cartridge filters
- Addition of chlorine followed by cartridge filtration

Dissolved Gases

- Dissolved gases found in water may include
  - Oxygen: bubbles in the water
  - Carbon dioxide
  - Methane gas: tastes like garlic, explosive
  - Hydrogen sulfide: smells like rotten eggs
  - Radon: suspected carcinogen

What are some pollutants and contaminants you may find in your surface water source?

- Wastewater treatment effluent
- Animal wastes
- Industrial discharges
- Recreational contaminants (boats, wave runners)
- Surface water runoff flowing into the water source can pick up many types of contaminants

Surface water requires more complex treatment processes to make it safe for public consumption.

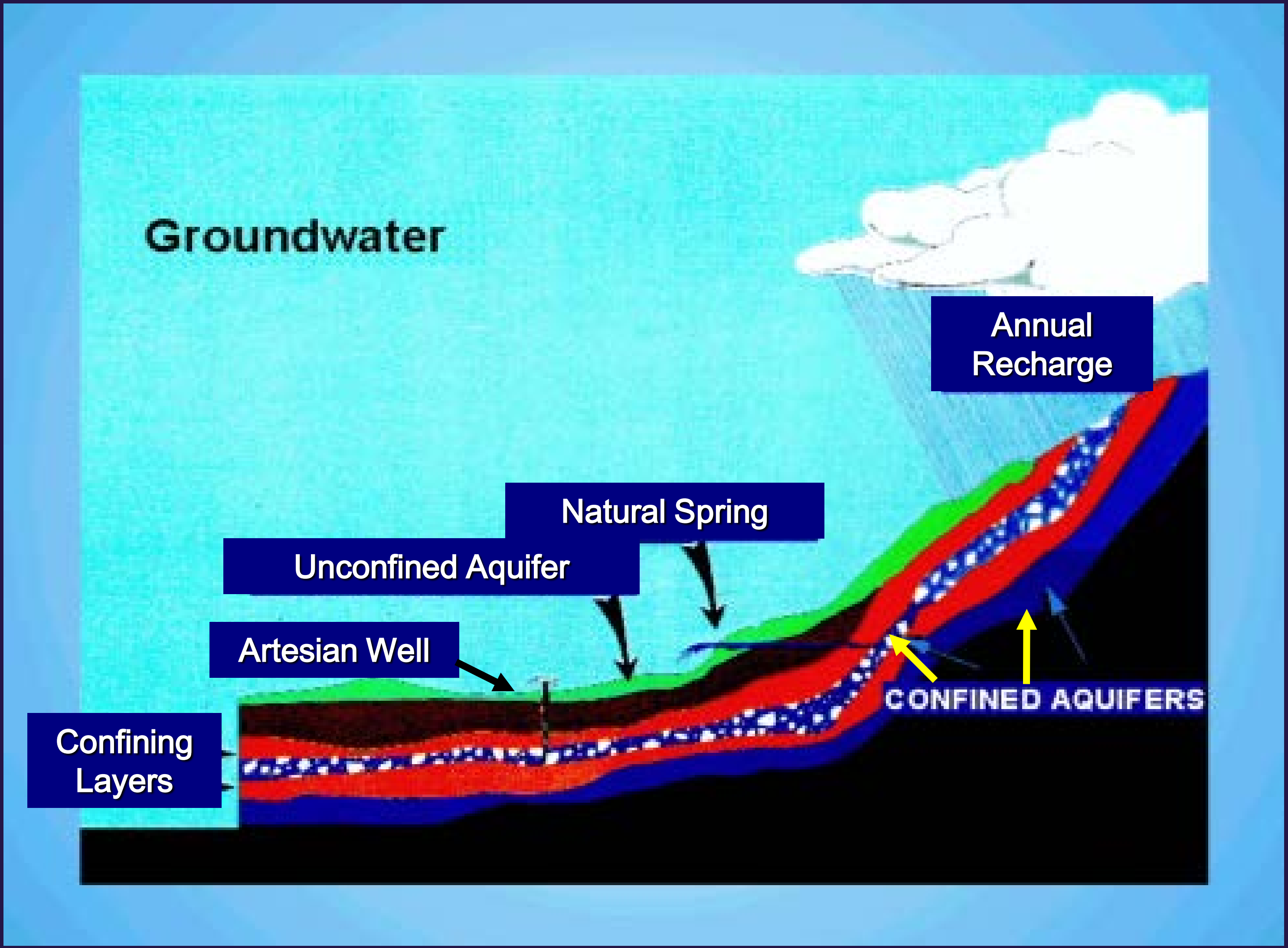
What are some protective measures that can be taken for surface water?

- Educate people
- Try to keep potential contaminants out of the surface water
  - Fence off
  - Zoning laws

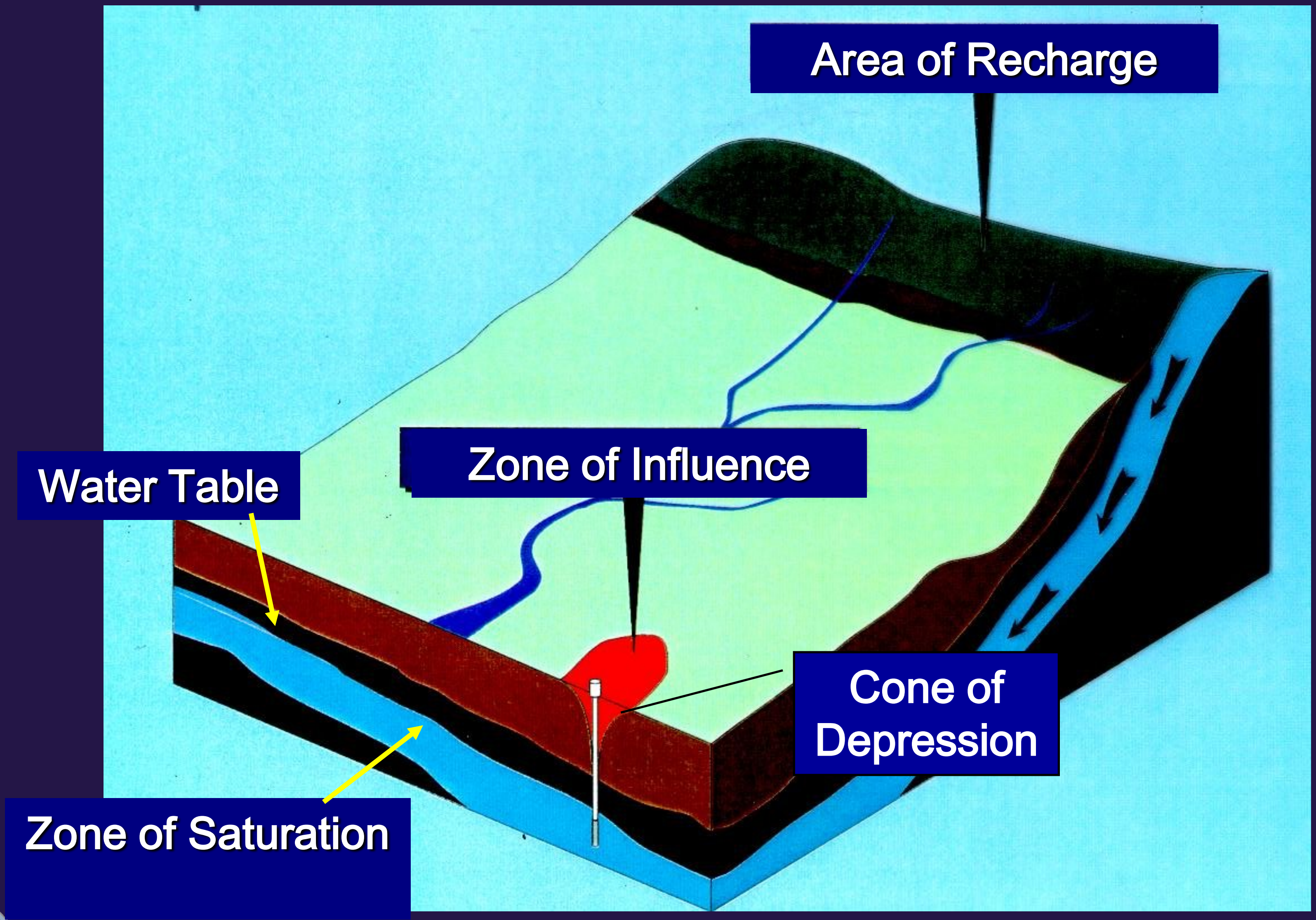
Drinking Water Protection Program

- Source water assessment
  - A report or study that identifies factors that can affect the source water quality and how to mitigate them
- Groundwater protection
  - Establishes minimum separation distances between drinking water sources and potential sources of contamination
- Wellhead protection
  - Designed to prevent contamination in and around the area of the well

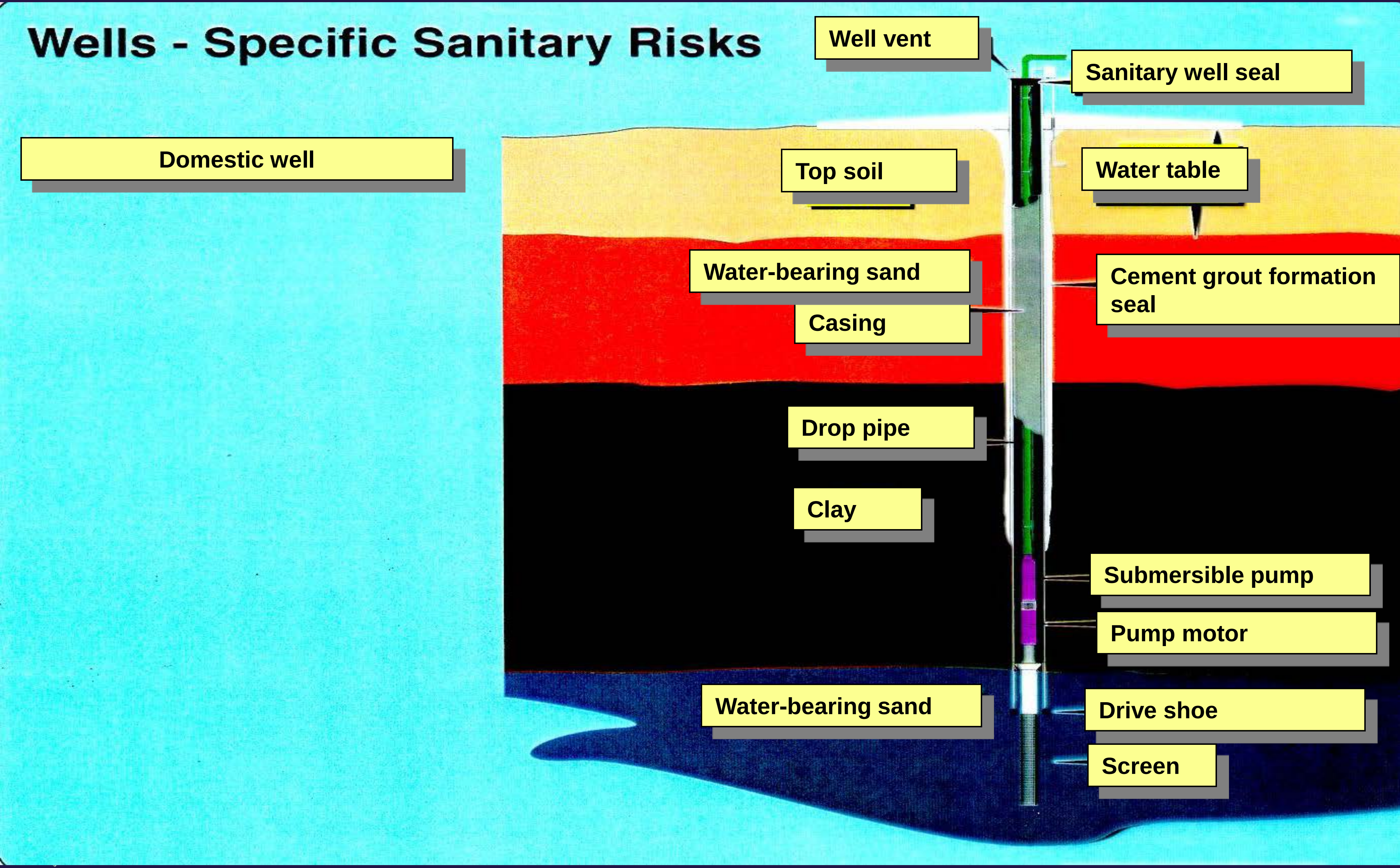
Aquifer Classification



Well Site Anatomy



Well Components



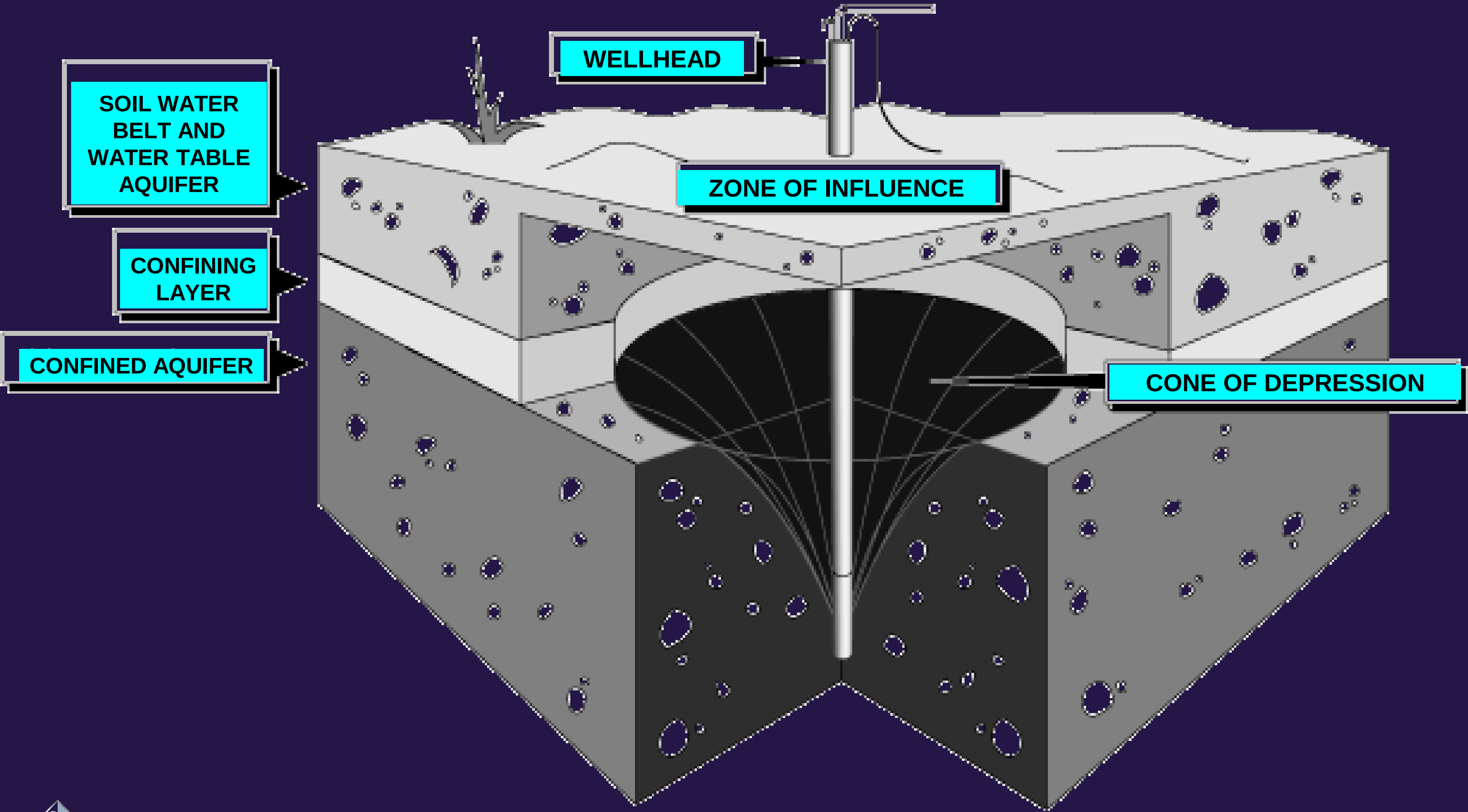
Well Log

- A written report produced by the well driller during drilling
  - Description of material (soil, rock, or ice) encountered during drilling
  - Depths at which material occurred
  - Depth to groundwater
  - Total well depth
  - Length, diameter, wall thickness, and type of casing
  - Location and type of casing perforations or screen
  - Location and type of grouting

Wellhead Protection Program

- What are some protective measures that can protect wells from pollutants?
  - Keep the wellhouse clean.
  - Do not store lawnmowers, weed eaters, paint, or anything else that can contaminate your well in the wellhouse.
  - Make sure the sanitary seal is secure and no contaminants can get into the well.
  - If you do not have a wellhouse, protect your well from contamination by not allowing old cars, snow machines, or wheelers to park near the wellhead. Old vehicles tend to leak oil, transmission fluid, brake fluid, and antifreeze.

Wellhead Protection Area



Well Abandonment

- An abandoned well poses a contamination threat to the aquifer in which it is drilled.
  - The open well casing serves as a direct conduit for contaminants to enter the aquifer.
  - Contamination of an abandoned well can lead to contamination of other wells drilled in the same aquifer.
- OSE & NMED has well abandonment procedures available to the public.