Water and Wastewater Treatment Sharing

OTCO Procrastinators' Workshop

Columbus – December 10, 2015

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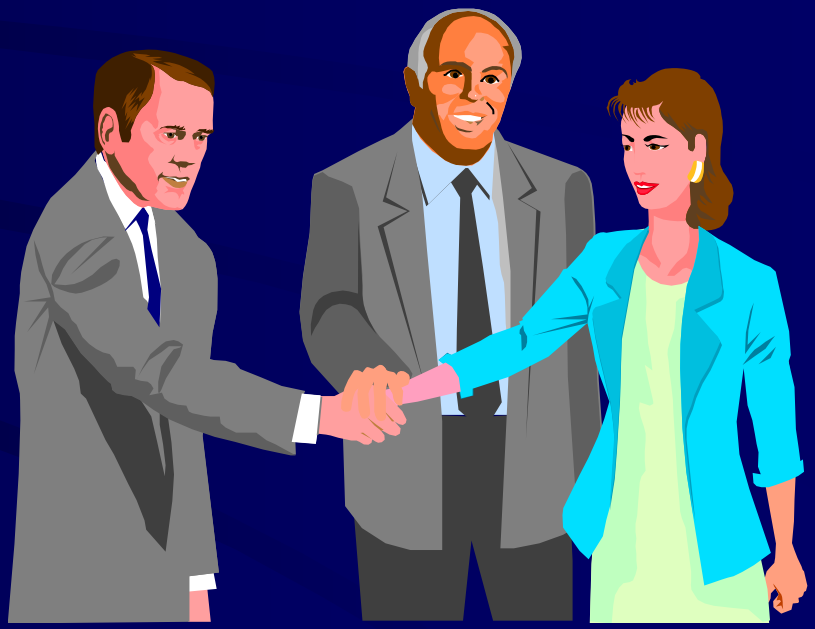
MWH Americas

Goals of this Presentation

- Share the water side with the wastewater side, and vice versa
- Create a spirit of understanding between our water & wastewater communities
- Continue to merge our water & wastewater hydrologic cycles



Items to be Discussed in this Presentation

- **Part 1**
  - Water Sources, Treatment & Distribution
- **Part 2**
  - Wastewater Collection & Treatment
- **Part 3**
  - Continuing to Merge our Water and Wastewater Hydrologic Cycles

PART 1

Water Sources, Treatment and Distribution

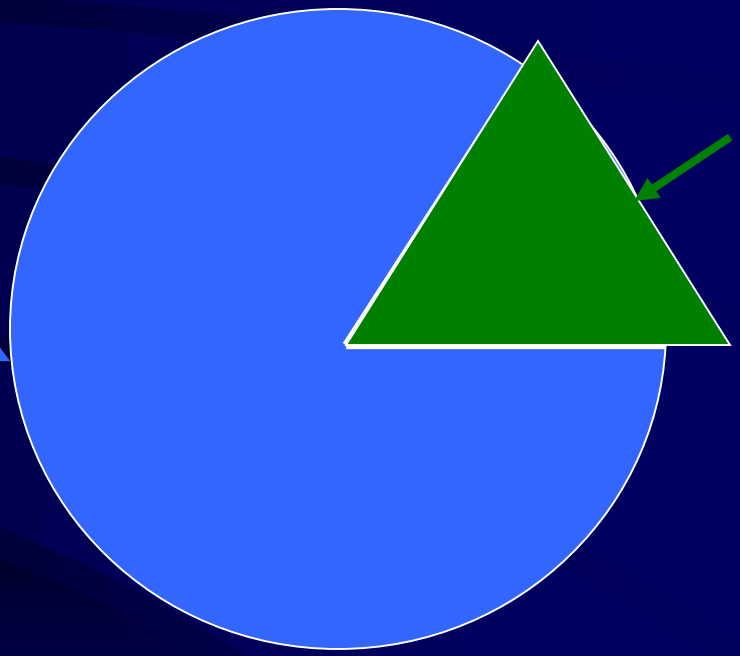
Items to be Discussed in the Water Segment

- **Water on Planet Earth**
- **Water Sources**
  - Sources of Fresh Water
  - What can be Found in these Water Sources?
- **Water Treatment**
  - Surface water
  - Ground water
- **Water Distribution**
  - Conveyance
  - Storage

Water on Planet Earth

Abundance of Water on Planet Earth

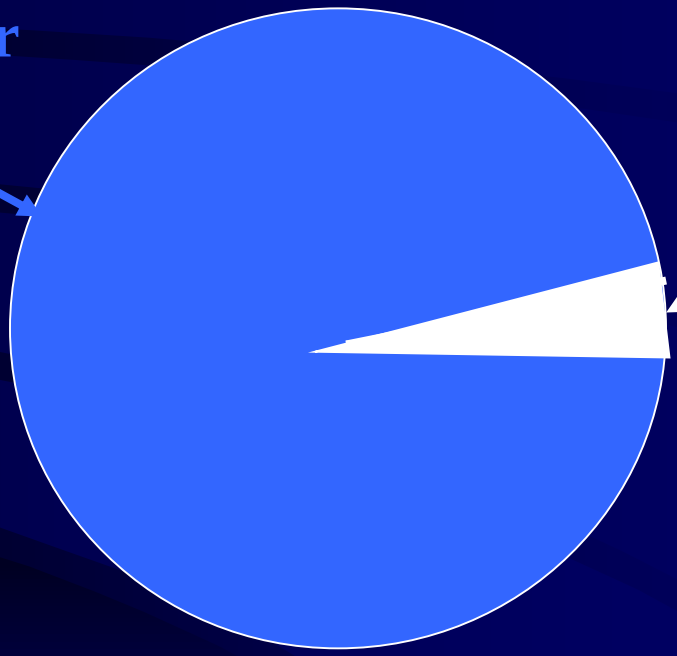
80% of the earth's surface is covered with water



20% is land

Abundance of Water on Planet Earth (cont)

97% of the water on earth is salt water (i.e., found in the oceans)

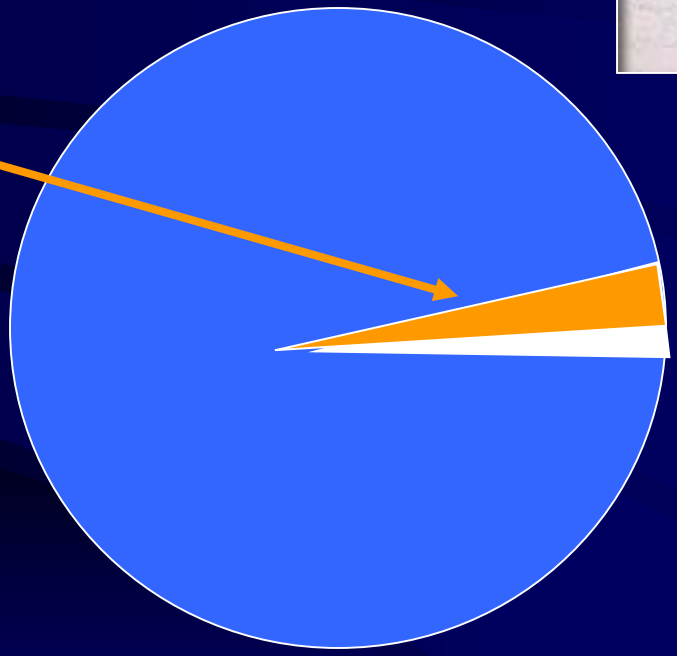


3% of the water is fresh water

Fresh water is source water that can be treated cost-effectively to produce drinking water.

Abundance of Water on Planet Earth (cont)

67% of the fresh water on earth is glacier ice at the North and South Poles



Less than 1% of the water on earth is fresh water that we can use

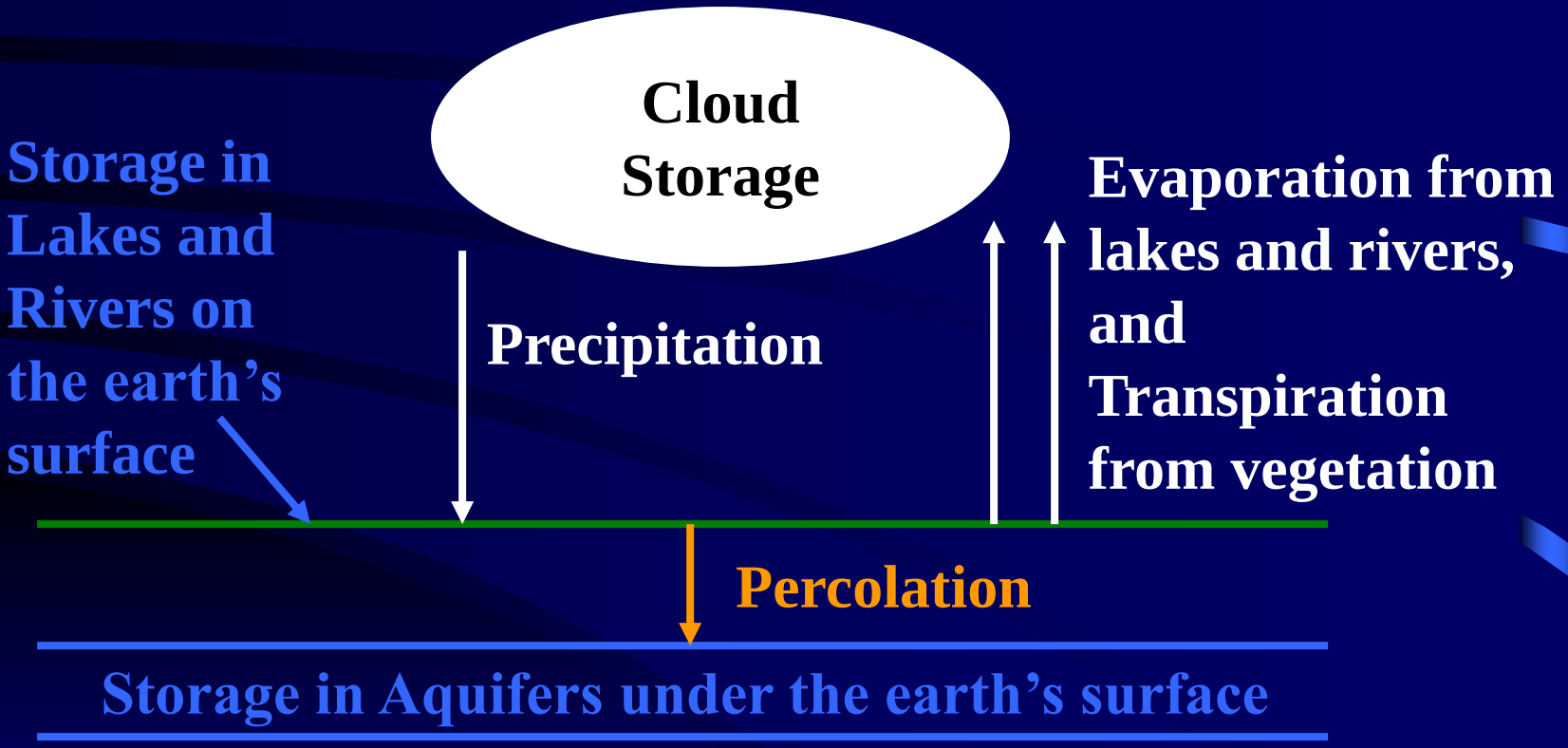
Role of Water on Planet Earth

- **What if there wasn't any water on earth ?**
  - There wouldn't be any trees … or animals … or humans.
  - Next to the air we breathe, water is our most important need.
  - **Without water the earth would look like the moon.**

Importance of Water to Us

- The human body is 70% water.
- Every system in our body uses water:
  - water makes up 83% of our blood
  - water transports our body wastes
  - water lubricates our body joints
  - water keeps our body's temperature stable
  - water is a part of cells, which make up all living things
- **Human beings can live for several weeks without food, but for only a few days without water.**

The Water Hydrologic Cycle



Water System

- **An overall water system consists of three principal elements:**

1 **Source water** **(i.e., ground or surface water)**

2 **Treatment plant** **(i.e., to convert fresh water into drinking [finished] water)**

3 **Distribution system** **(i.e., to convey finished water to customers)**

Water Sources

Sources of Fresh Water

- **Surface Water sources**
  - lakes
  - reservoirs (i.e., engineered lakes)
    - on river (i.e., dam on river)
    - off river (i.e., pump to up-ground reservoirs)
  - rivers

- **Ground Water sources**
  - shallow aquifers near the earth's surface
  - deep aquifers far below the earth's surface

What can be Found in the Water from Surface Water Sources ?

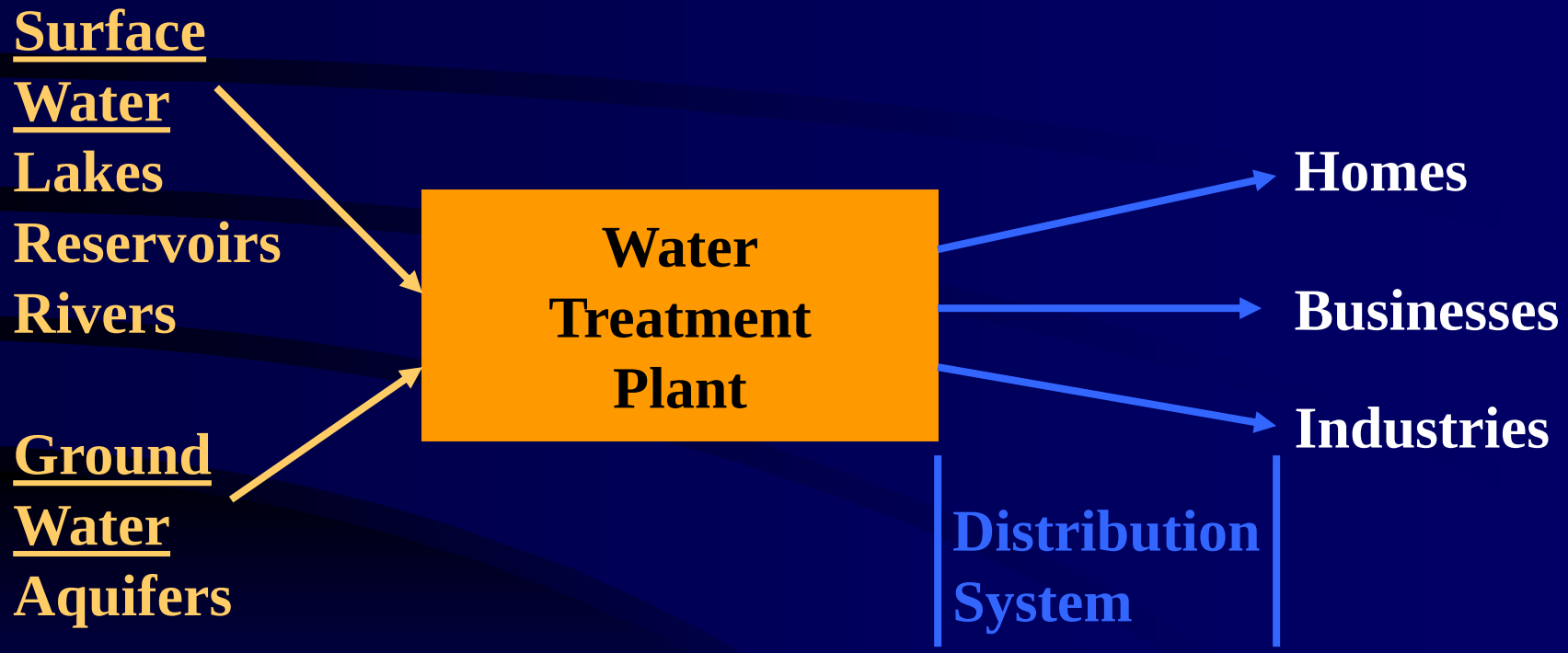
- Particulate Matter (turbidity-causing particles)
  - Inorganic materials (**lots of** clay, silt, etc.)
  - Organic materials (**protozoa - e.g., *Giardia* and *Crypto*, algae**, bacteria, viruses, etc.)
- Dissolved Matter
  - Inorganic materials (taste and odor [decayed vegetation and algal by-products], color [humic substances complexed with iron], IOCs, etc.)
  - Organic materials (harmful algal toxins, SOCs, etc.)

What can be Found in the Water from Ground Water Sources ?

- Particulate Matter (turbidity-causing particles)
  - Inorganic materials (**some** clay, silt, etc.)
  - Organic materials (bacteria and viruses)
- Dissolved Matter
  - Inorganic materials (hardness [calcium and magnesium], color [iron and manganese], IOCs, etc.)
  - Organic materials (SOCs, **VOCs**, etc.)
  - Radionuclides (radon, etc.)
- Dissolved Gases (hydrogen sulfide, carbon dioxide, methane, etc.)

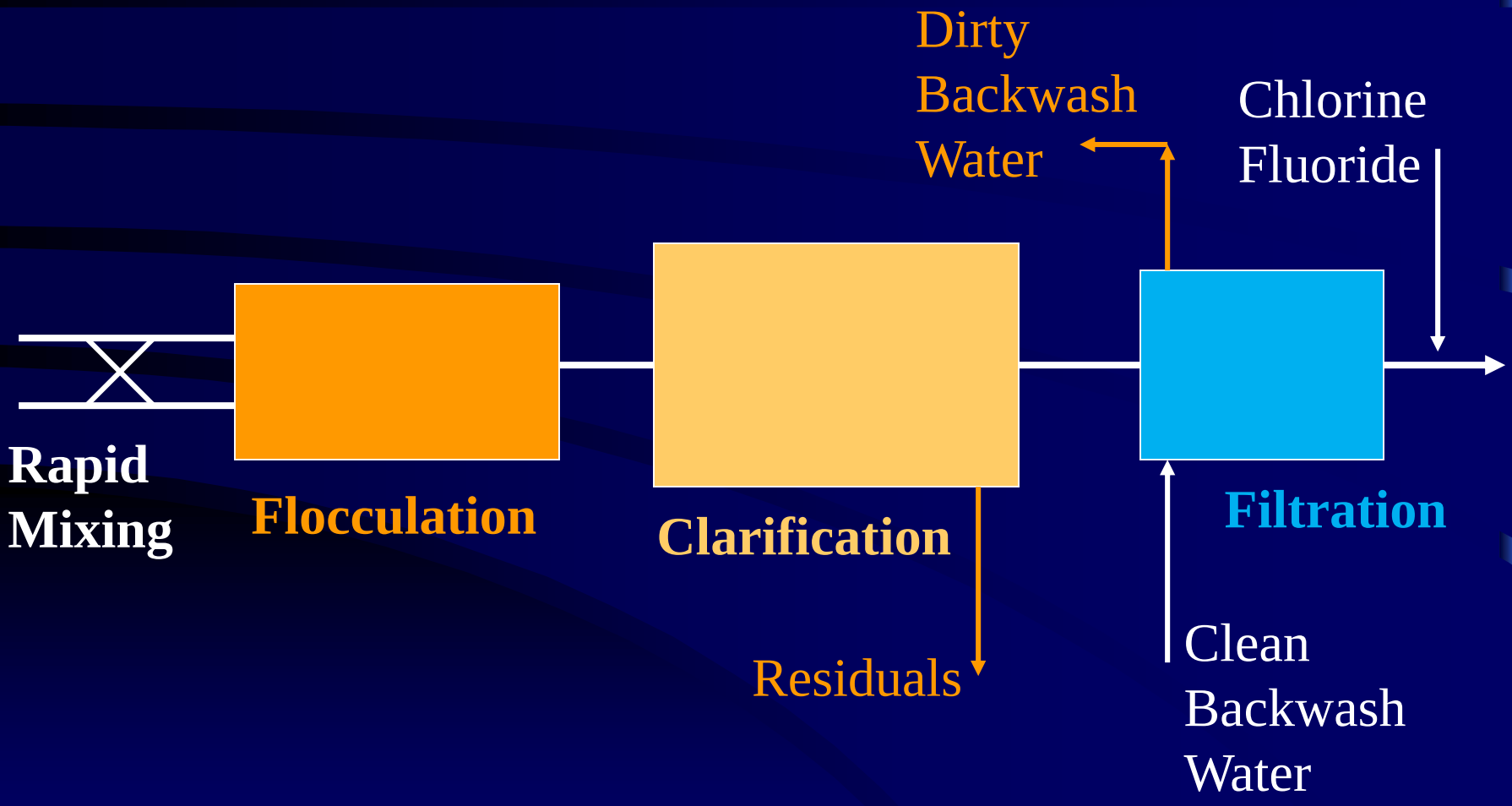
Water Treatment

How is Fresh Water Made Safe to Drink ?

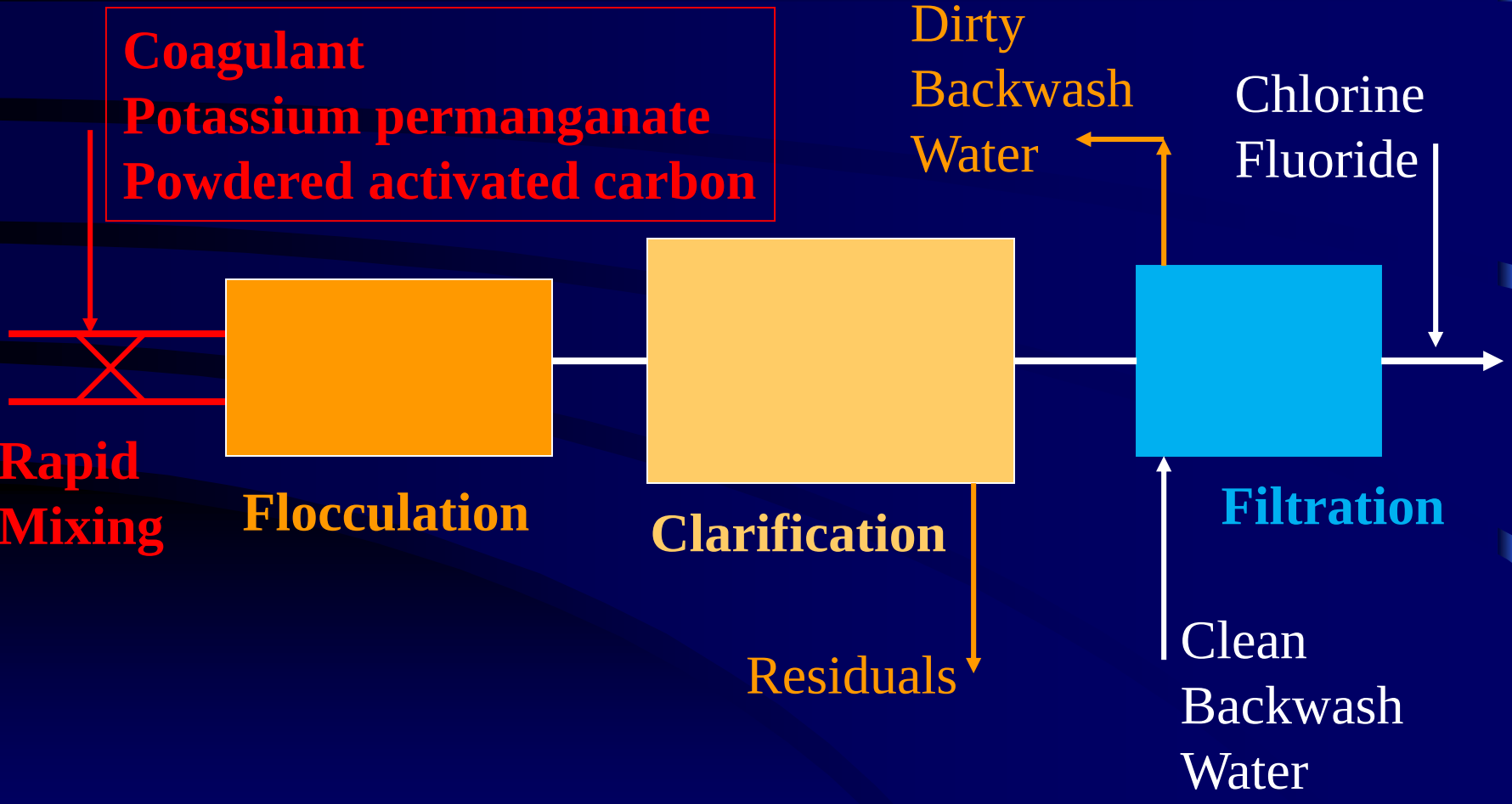


Fresh water is collected from Surface and Ground Water Sources, processed at a Water Treatment Plant to produce drinking water, and is distributed through pipes to the Customers.

How is Water Processed at Water Treatment Plants ?



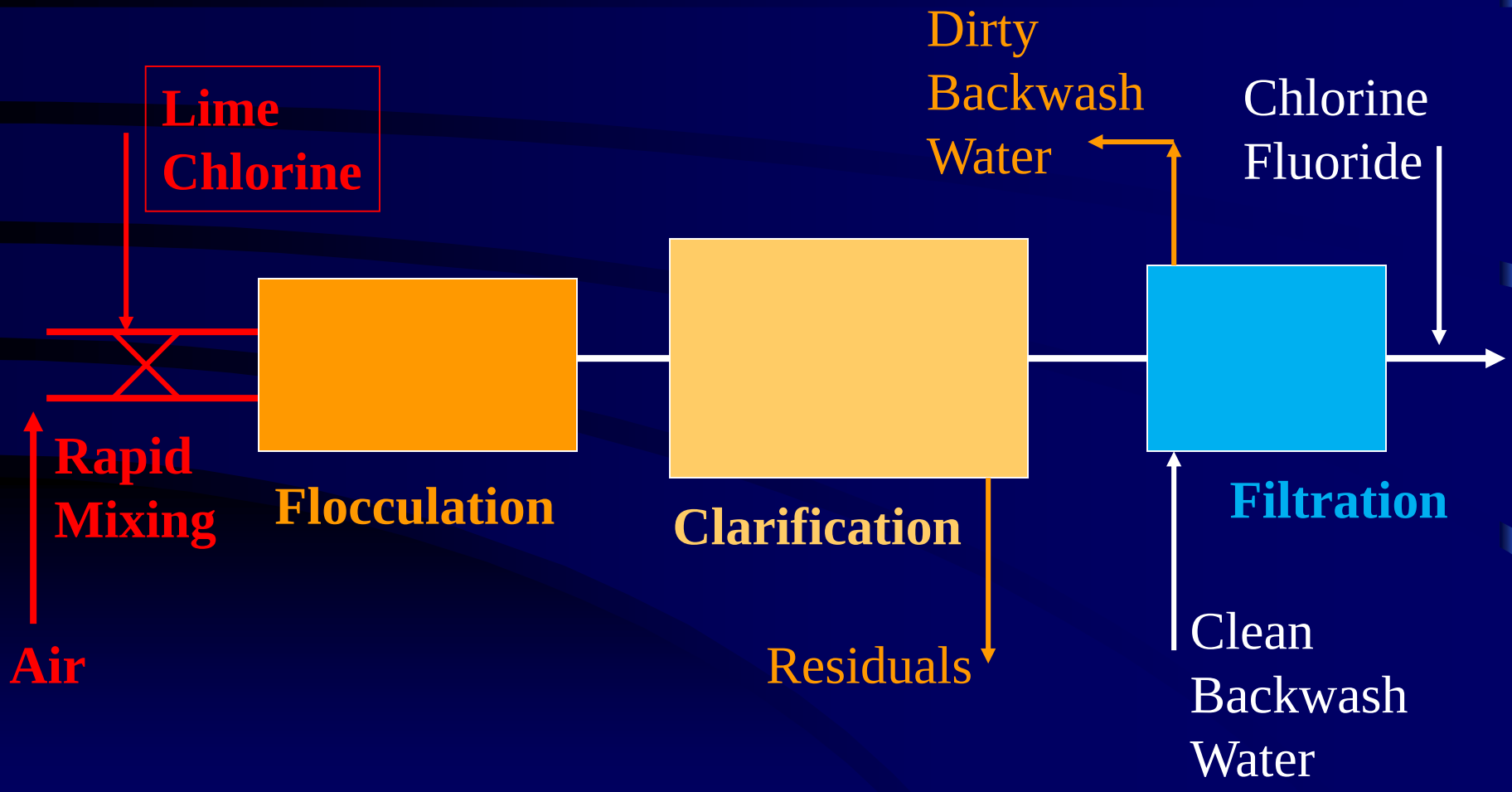
How is Water First Processed at a Surface Water Treatment Plant ?



How is Water First Processed at a Surface Water Treatment Plant ?

- Rapid Mixing - Used to disperse chemicals (e.g., a coagulant, and potassium permanganate or powdered activated carbon) into the water.
  - Coagulant is used to change the little particles so they'll stick together during Flocculation.
  - Potassium permanganate, or Powdered activated carbon, are used to oxidize or adsorb taste-and-odor causing materials.

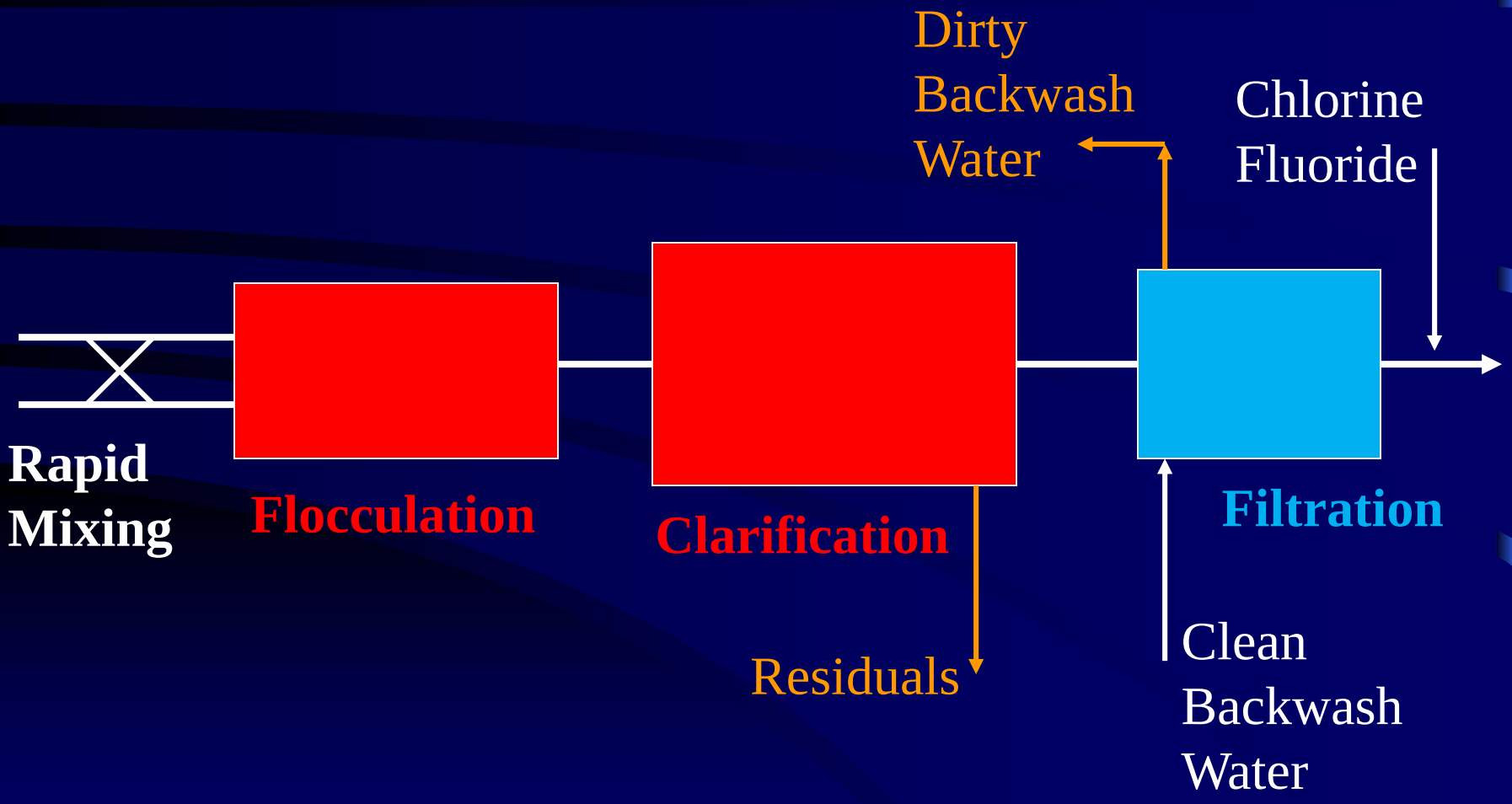
How is Water First Processed at a Ground Water Treatment Plant ?



How is Water First Processed at a Ground Water Treatment Plant ?

- Air is passed through the water to remove dissolved gases (e.g., carbon dioxide).
- Rapid Mixing - Used to disperse chemicals (e.g., lime and chlorine) into the water.
  - Lime is used to change the dissolved, hardness-causing substances (calcium and magnesium) into particles for processing during Flocculation.
  - Chlorine is used to change the dissolved, color-causing substances (iron and manganese) into particles for processing during Flocculation.

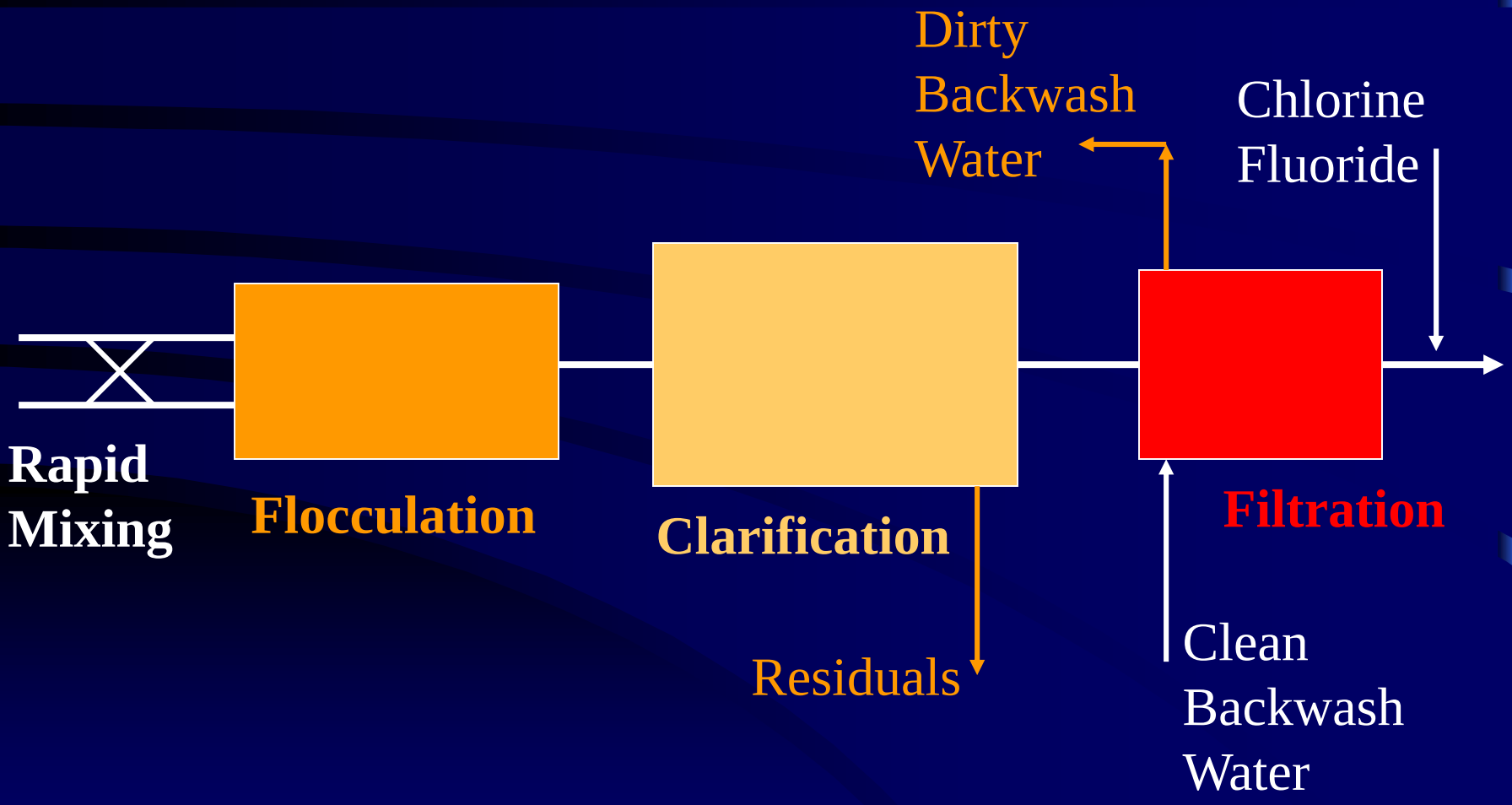
How is Water Further Processed at Both Water Treatment Plants ?



How is Water Further Processed at Both Water Treatment Plants ?

- Flocculation - Used to gently mix the water.
  - The little particles bounce into each other; forming large particles for easier removal during Clarification and Filtration.
- Clarification - Used to remove the large particles.
  - The large particles settle to the bottom of the clarifier.
  - The large particles that are settled on the bottom are periodically removed from the clarifier as residuals.

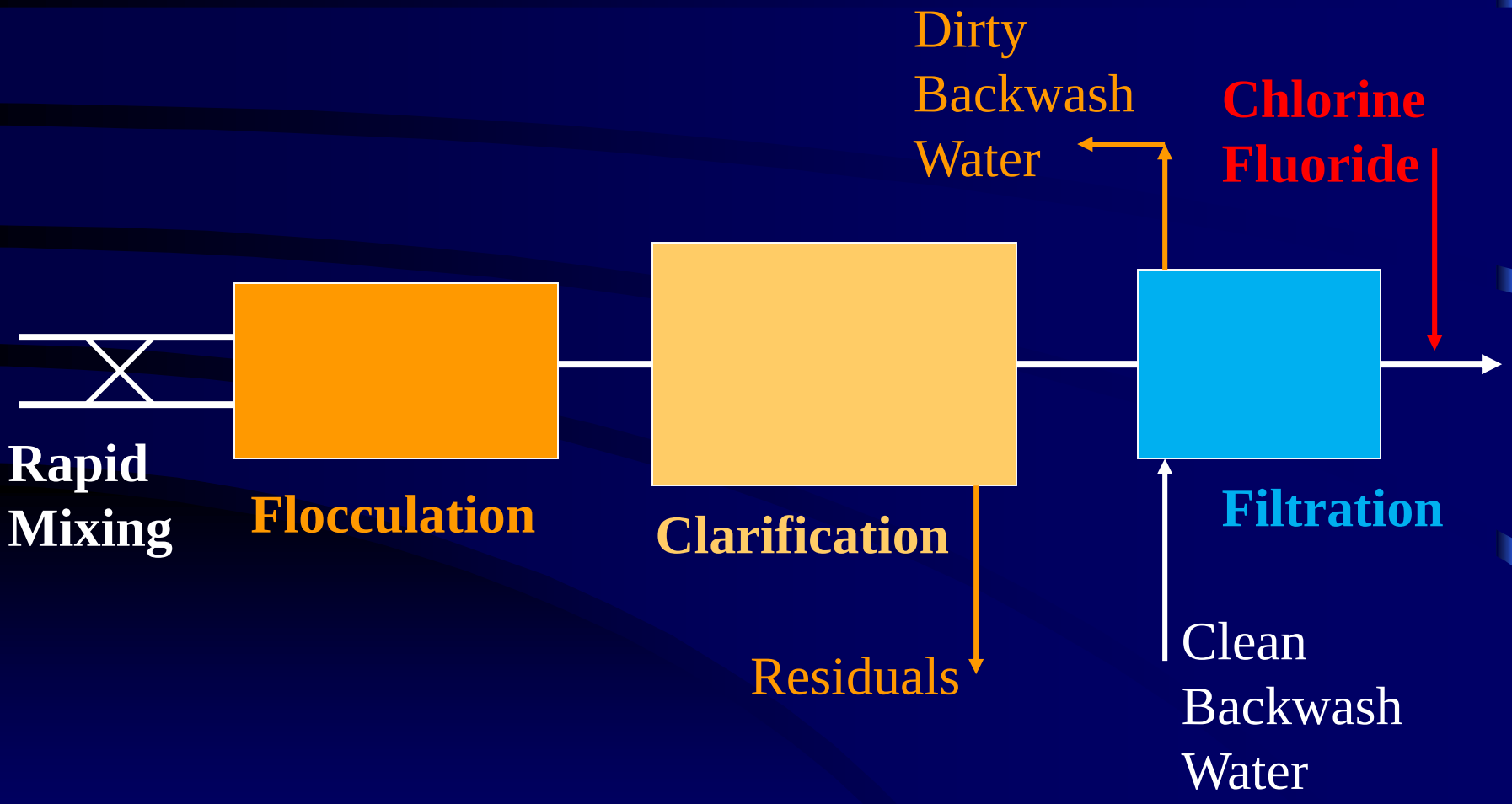
How is Water Further Processed at Both Water Treatment Plants ?



How is Water Further Processed at Both Water Treatment Plants ?

- Filtration - Used to remove the small particles that escape clarification.
  - The small particles are stored (trapped) in the Filter as the water passes down through sand.
  - Clean water is periodically passed up through the sand (called backwashing) to dislodge the trapped particles and remove them as dirty backwash water.

How is Water Further Processed at Both Water Treatment Plants ?



How is Water Further Processed at Both Water Treatment Plants ?

- Chlorine is added to the filtered water to kill any microorganisms that may have passed through the Filter, **and** to keep the water safe as it passes through the distribution system to the customers.
- Fluoride is added to the filtered water to help prevent dental caries (cavities), particularly in children.

Some of the Latest Water Treatment Technologies are . . .

- Intermediate ozone and biologically-active filtration (BAF)
- Intermediate ozone and biologically-active carbon (BAC) filtration
- Intermediate ozone with hydrogen peroxide as an advanced oxidation process (AOP)
- Membranes (micro, ultra, nano and RO)
- Post-filter granular activated carbon (GAC) adsorption
- Post-filter UV disinfection
- Post-filter UV with hydrogen peroxide as an AOP

How do We Know Our Drinking Water is Safe ?

- Drinking water distributed to customers from public, water treatment plants must meet Drinking Water Regulations:
  - 1974 Safe Drinking Water Act (SDWA)
  - 1986 Amendments to the SDWA
  - 1996 Amendments to the SWDA
- Water leaving the water treatment plant, and in the distribution system, must be regularly monitored for over 100 potential contaminants.

Primary Regulations Since 1986 Amendments

1. Fluoride - Phase IIA,
2. Volatile Organic Chemicals (VOCs) - Phase I,
3. Total Coliform Rule (TCR),
4. Surface Water Treatment Rule (SWTR),
5. SOCs & IOCs - Phase II,
6. Lead & Copper Rule (LCR),

   and

7. SOCs & IOCs - Phase V.

Primary Regulations Since 1996 Amendments

1. Information Collection Rule (ICR),

2. Stage 1 of the Disinfectants/Disinfection By-Products Rule (D/DBPR),

3. Interim Enhanced SWTR (InterimESWTR),

4. Radionuclides – Phase III,

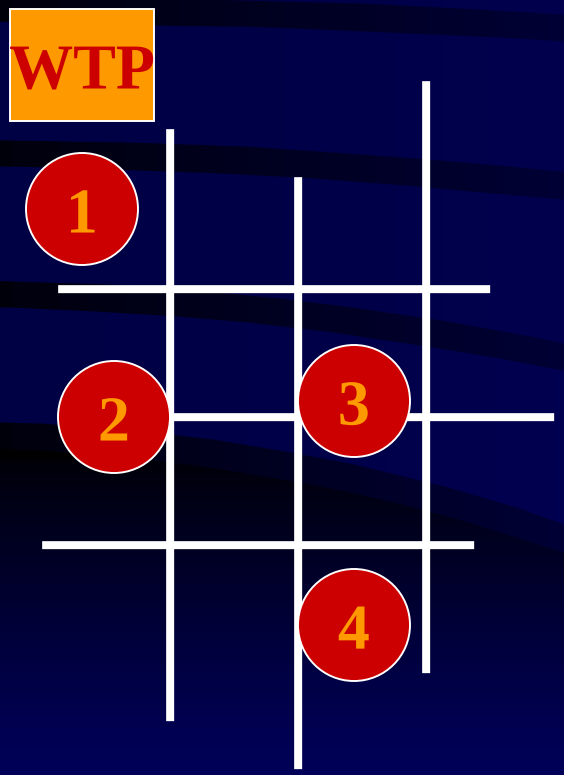
Primary Regulations Since 1996 Amendments (cont)

5. Arsenic,
6. Filter Backwash Recycling Rule (FBRR),
7. Long-Term 1 ESWTR (LT-1-ESWTR),
8. Stage 2 of the DBPR (Stage-2-DBPR),
9. Long-Term 2 ESWTR (LT-2-ESWTR), and
10. Ground Water Rule (GWR).

Revisiting Total Coliform Rule, Lead & Copper Rule, etc.

Running Annual Avg. (RAA) vs. Locational (LRAA)

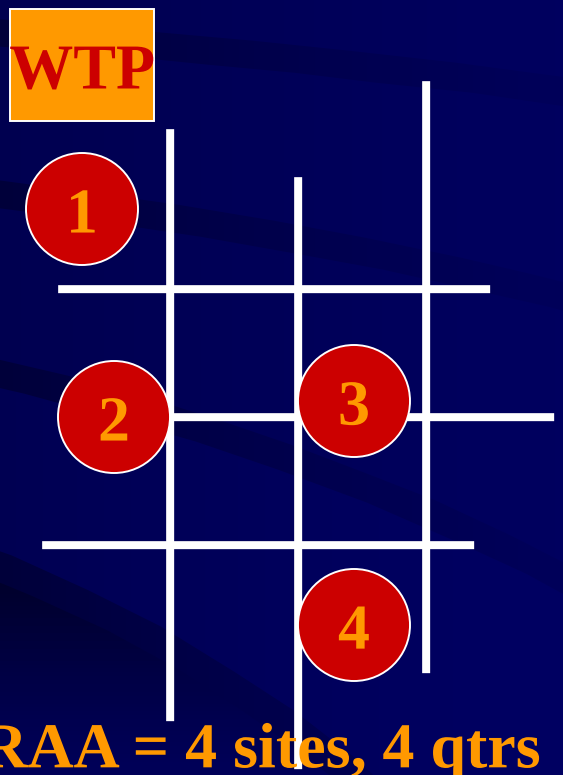
Stage-1-D/DBPR



RAA = 4 sites, 4 qtrs

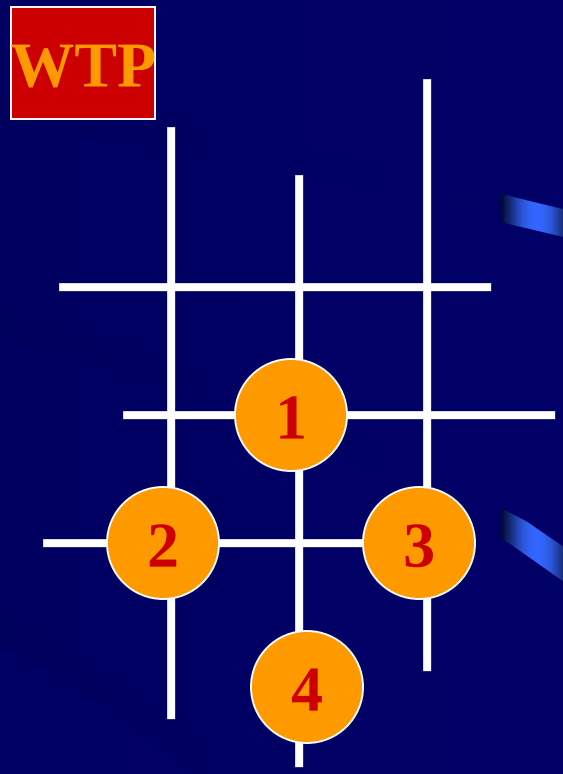
Stage-2-DBPR

Phase I



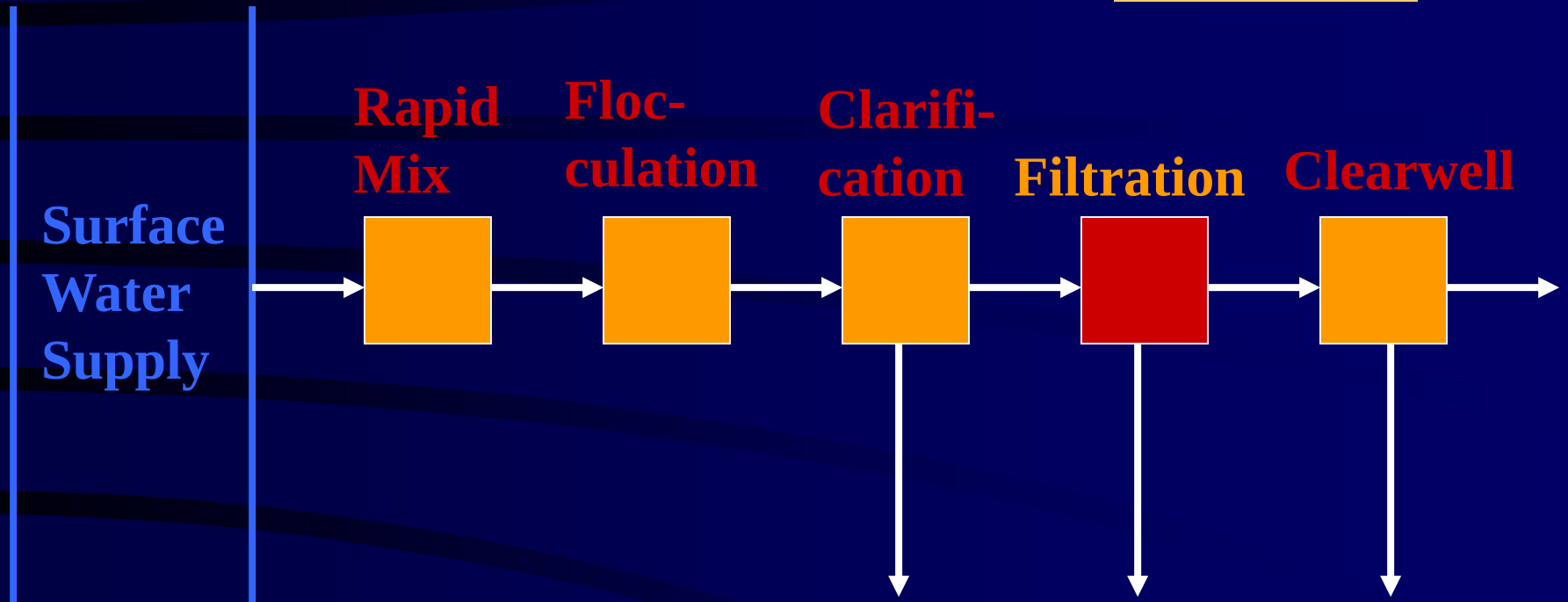
RAA = 4 sites, 4 qtrs
LRAA = each site, 4 qtrs

Phase II

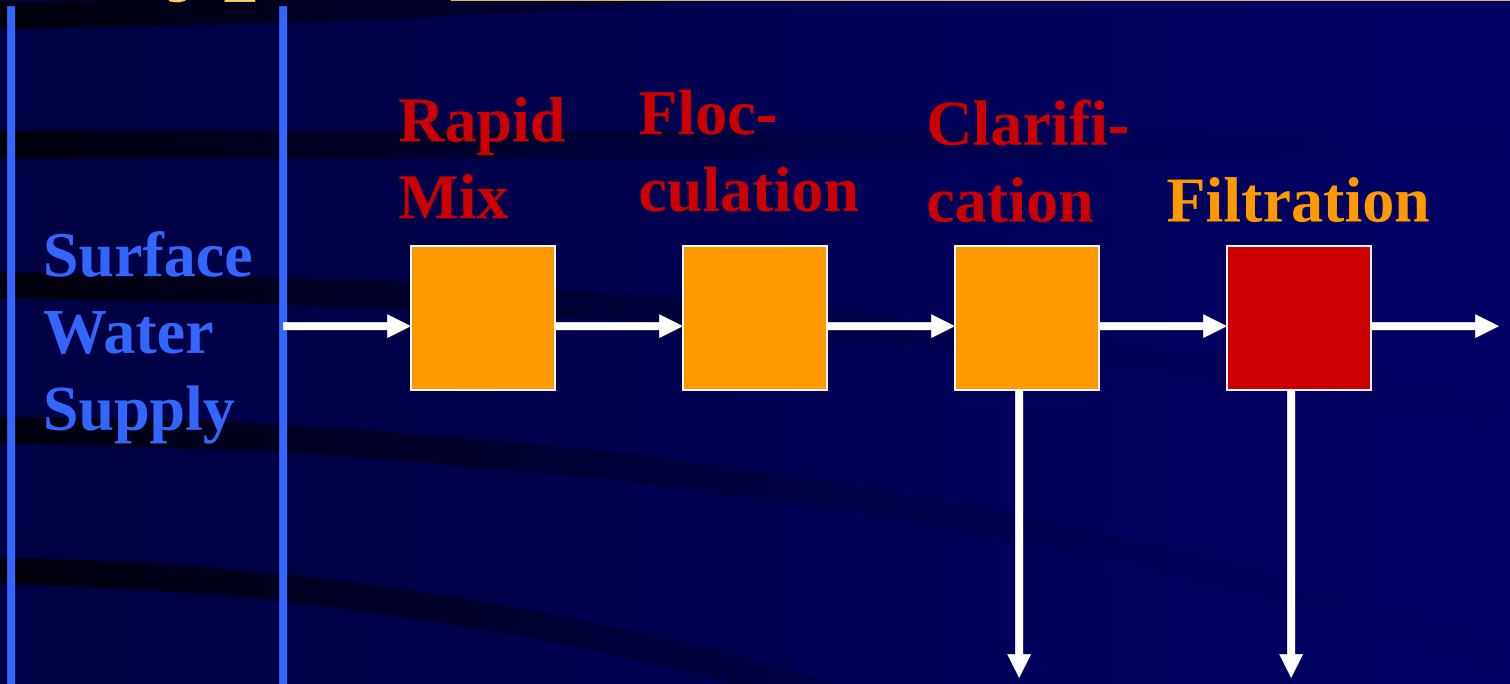


LRAA = each IDSE site (1+), 4 qtrs

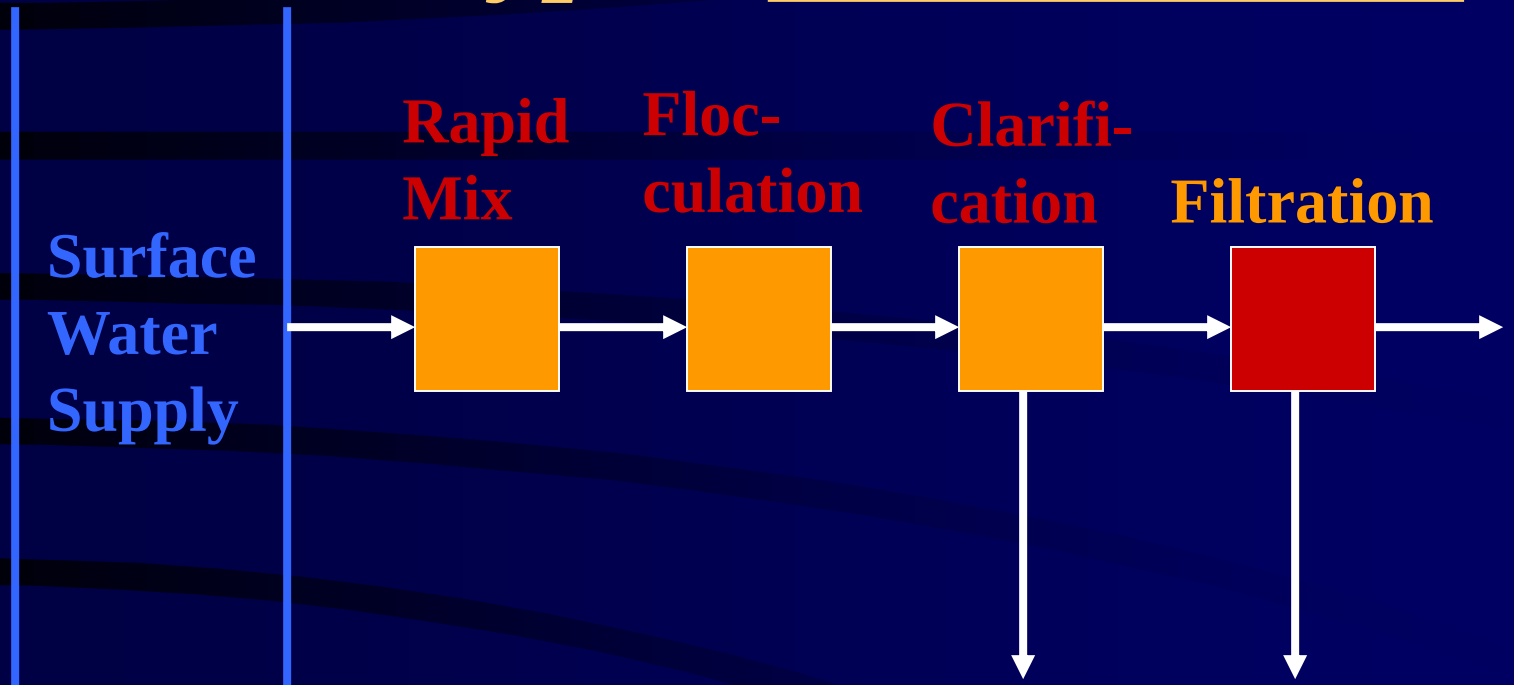
Giardia and Viruses: SWTR



Crypto: IESWTR & LT-1-ESWTR



Crypto: LT-2-ESWTR



Water Distribution

Finished-water Demands (cont)

- Typical ratios (i.e., unitless quantities) of these various finished-water demands for communities are:

$$\frac{\text{ADD}}{\text{Min. DD}} = 1.2 \text{ to } 1.5$$

$$\frac{\text{MDD}}{\text{ADD}} = 1.2 \text{ to } 2.5$$

$$\frac{\text{PHD}}{\text{MDD}} = 1.3 \text{ to } 2.0$$

Finished-water Demands

- The demand for finished water comes from three major sources:
  - homes
  - businesses
  - industries
- And, also from:
  - fire hydrants
  - public buildings,
  - etc.

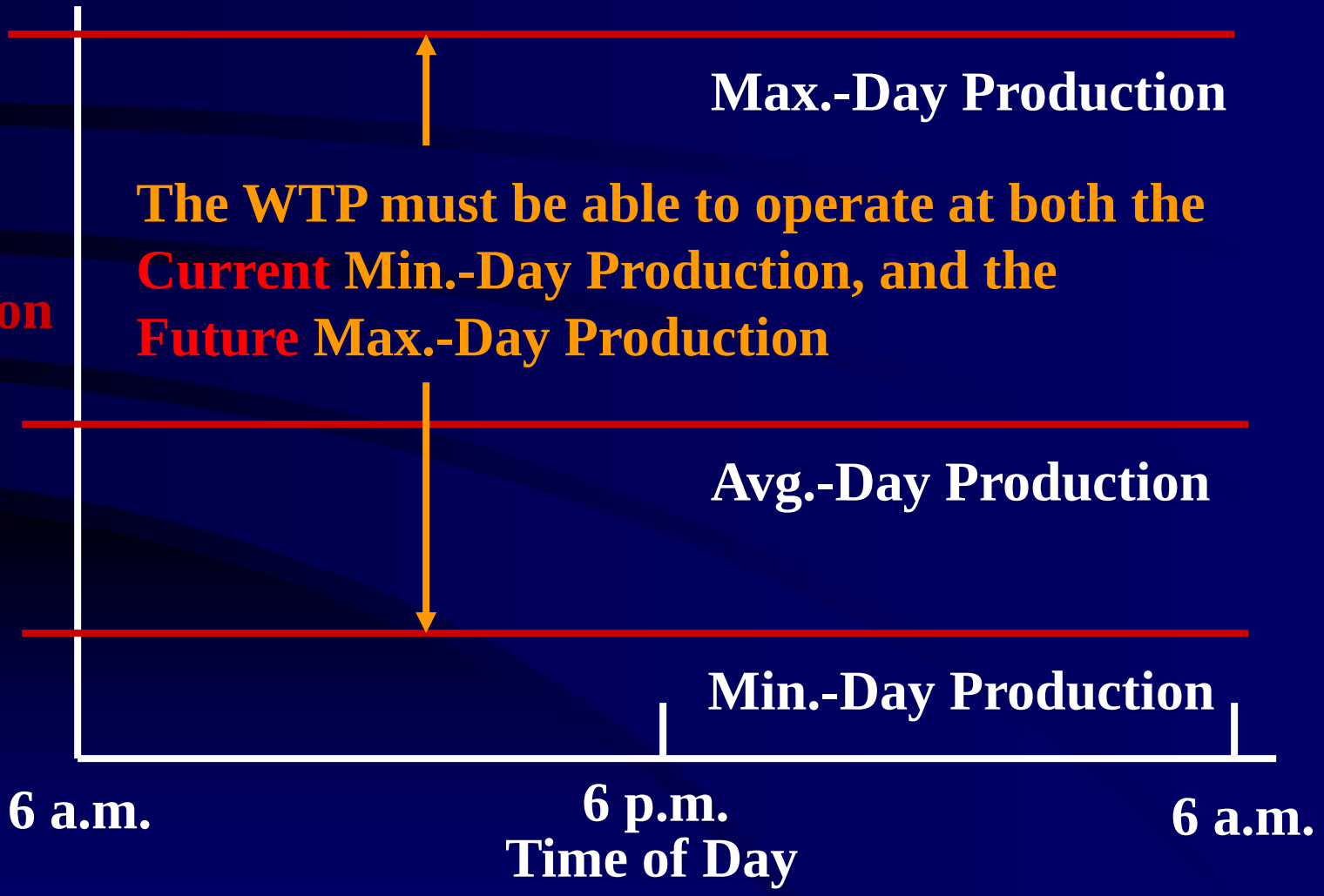
Finished-water Demands (cont)

- Water demands in the distribution system vary throughout **the year**
  - Minimum-day demand (Min. DD)
  - Average-day demand (ADD)
  - Maximum-day demand (MDD)
- Water demands in the distribution system also vary throughout **each day**
  - Minimum-hour demand (MHD)
  - Peak-hour demand (PHD)

Role of the Water Treatment Plant

- The Source facilities and the WTP are expensive elements of a water system, so the goal is to make these items as small as possible (i.e., don't want to satisfy peak-hour demands (PHDs) **directly** from the WTP)
- Also, finished water leaving the WTP must meet requirements of the applicable Drinking Water Regulations (i.e., want to operate the WTP at a **fairly-constant rate**)

Hydraulic Role of Water Treatment Plant



Production

- The rate at which finished water leaves the WTP
  - Water demand (residential, industrial, public use, etc.)

  AND
  - Unaccounted for water
  - Inaccurate meters
  - Etc.

Ref. Ohio EPA Approved Capacity Document

Distribution System (cont)

- **The Water Distribution system consists of two principal elements:**

1 **Conveyance facilities (i.e., underground piping)**

2 **Storage facilities (i.e., overhead and ground-level tanks)**

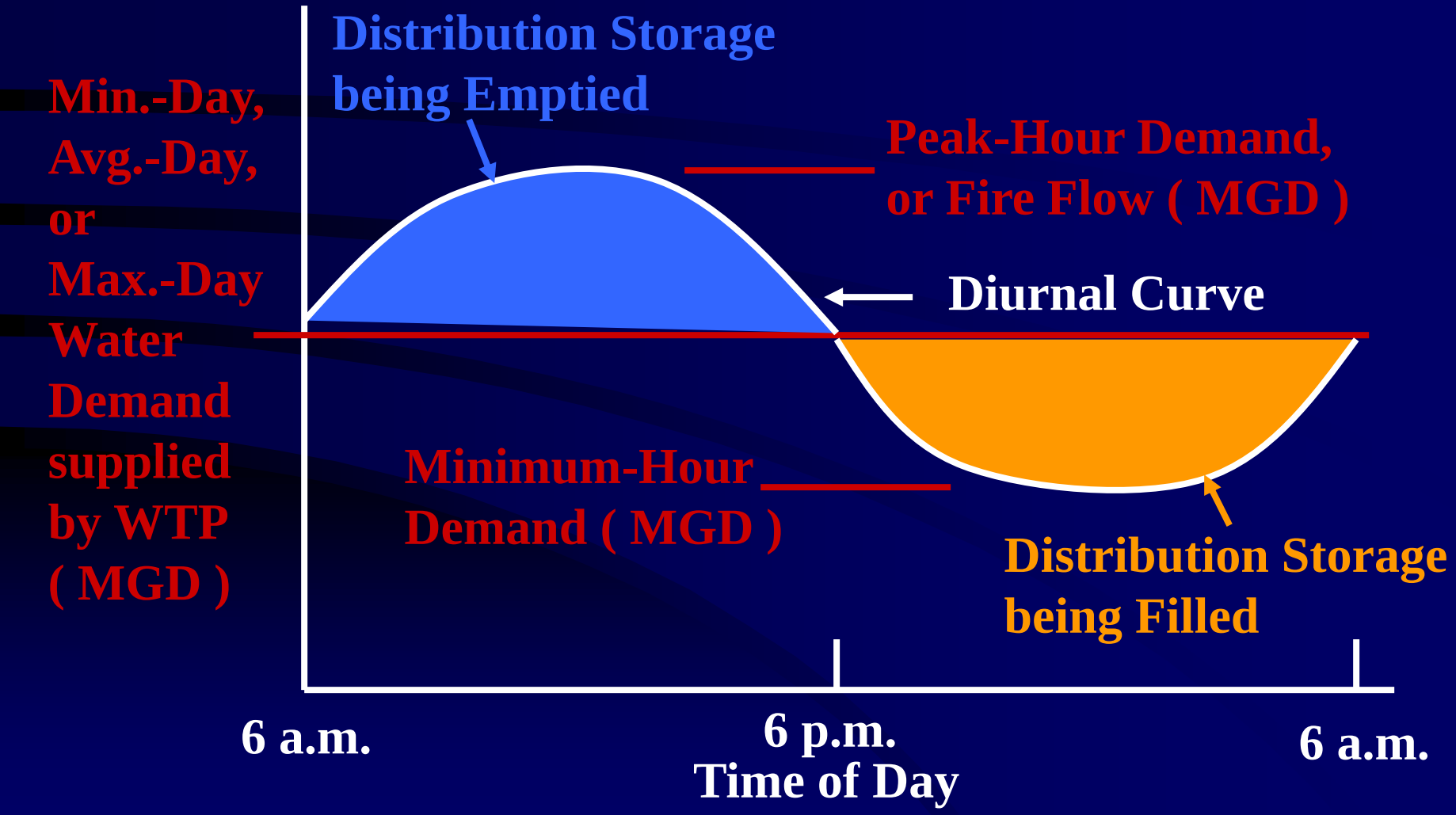
Hydraulic Role of Distribution Piping

- Distribution system demands are exerted instantaneously:
  - at the customer service connections, and
  - at fire hydrants

Hydraulic Role of Distribution Piping (cont)

- **Distribution piping** needs to be large enough to deliver water at a rate and pressure that meets these instantaneous peak demands:
  - peak-hour demands in larger cities, and
  - fire-flow requirements in smaller cities

Daily Hydraulic Role of Distribution-Storage Facilities



Items Discussed in the Water Segment

- **Water on Planet Earth**
- **Water Sources**
  - Sources of Fresh Water
  - What can be Found in these Water Sources?
- **Water Treatment**
  - Surface water
  - Ground water
- **Water Distribution**
  - Conveyance
  - Storage

PART 2

Wastewater Collection & Treatment

Wastewater Collection

Residential and industrial WWs
Sanitary, storm and combined sewers
Hydrographs and pollutographs
Attenuation

Residential and Industrial WWs

- The WW introduced to a municipal collection system is mainly from either residential or industrial sources.
- **Residential sources** introduce pollutants such as biochemical oxygen demand (BOD) and suspended solids (SS).
- In addition to BOD and SS - **Industrial sources** introduce pollutants such as oils and greases, heavy metals and toxic chemicals.

Sanitary, Storm and Combined Sewers

- Municipal, **sanitary sewers** convey residential WW and pre-treated industrial WW.
- Municipal, **storm sewers** convey storm water from precipitation events.
- Municipal, **combined sewers** convey both:
  - residential and pre-treated industrial WWs, and
  - storm water.

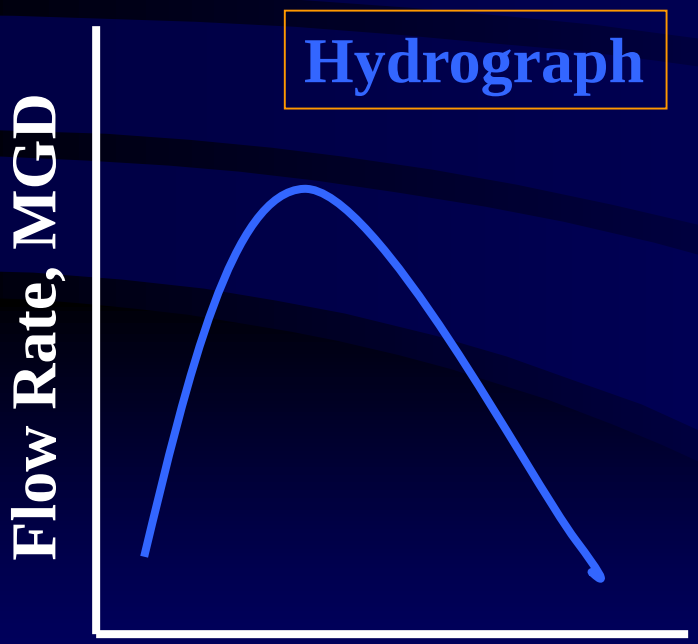
Sanitary, Storm and Combined Sewers (cont)

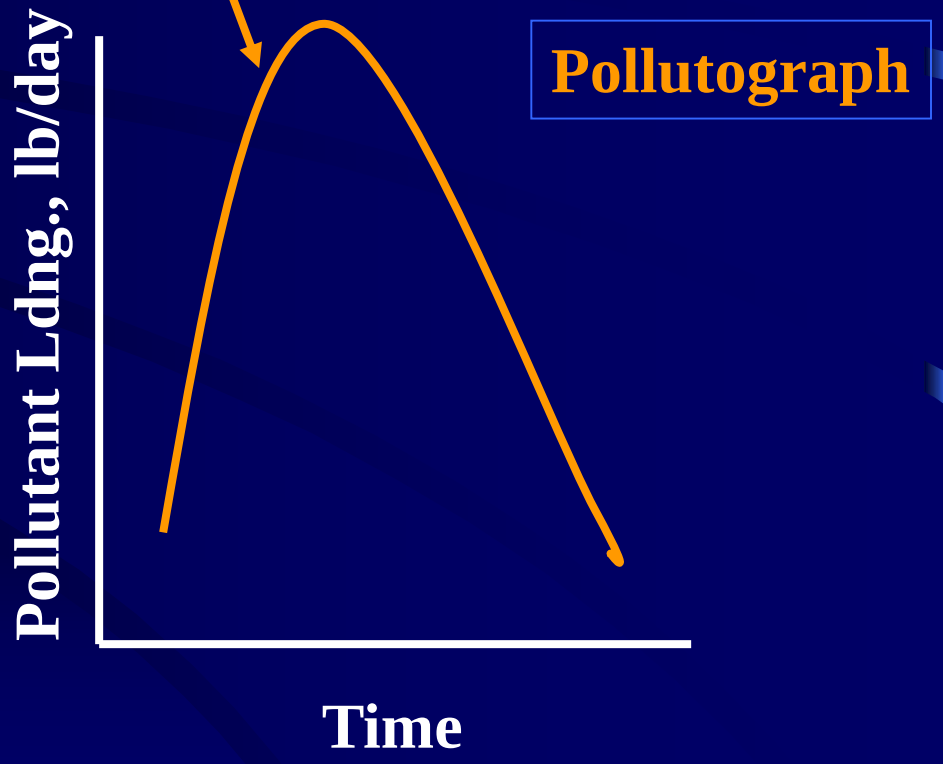
- Overloaded sanitary sewers can result in dry-weather and wet-weather **SSOs** : dry-weather ones are to have been eliminated.
- Overloaded combined sewers result in **CSOs** - emphasis is to convey all WWs to a WWTP for processing prior to discharge to a water body.
- Combined sewers complicate the picture because WW and storm water are generally conveyed to the WWTP for processing.

Hydrographs and Pollutographs

- The WW flow rate, MGD, and pollutant concentration, mg/L, arriving at a WWTP are not constant with time.
- Both the WW's flow rate and pollutant concentration vary in a sanitary sewer system.
- Both vary even more in a combined sewer system (i.e., particularly the flow rate - based on the influence of precipitation events).

Hydrographs and Pollutographs (cont)





Attenuation

- The WWTP operates best at a fairly even flow rate and pollutant loading.
- **Attenuation** levels out (or equalizes) the varying flow rates and pollutant loadings arriving at the WWTP.
- **Attenuation** is accomplished:
  - In the collection system (in sewers and off-line storage tanks), or
  - At the influent to the WWTP (in storage tanks).

Wastewater Treatment

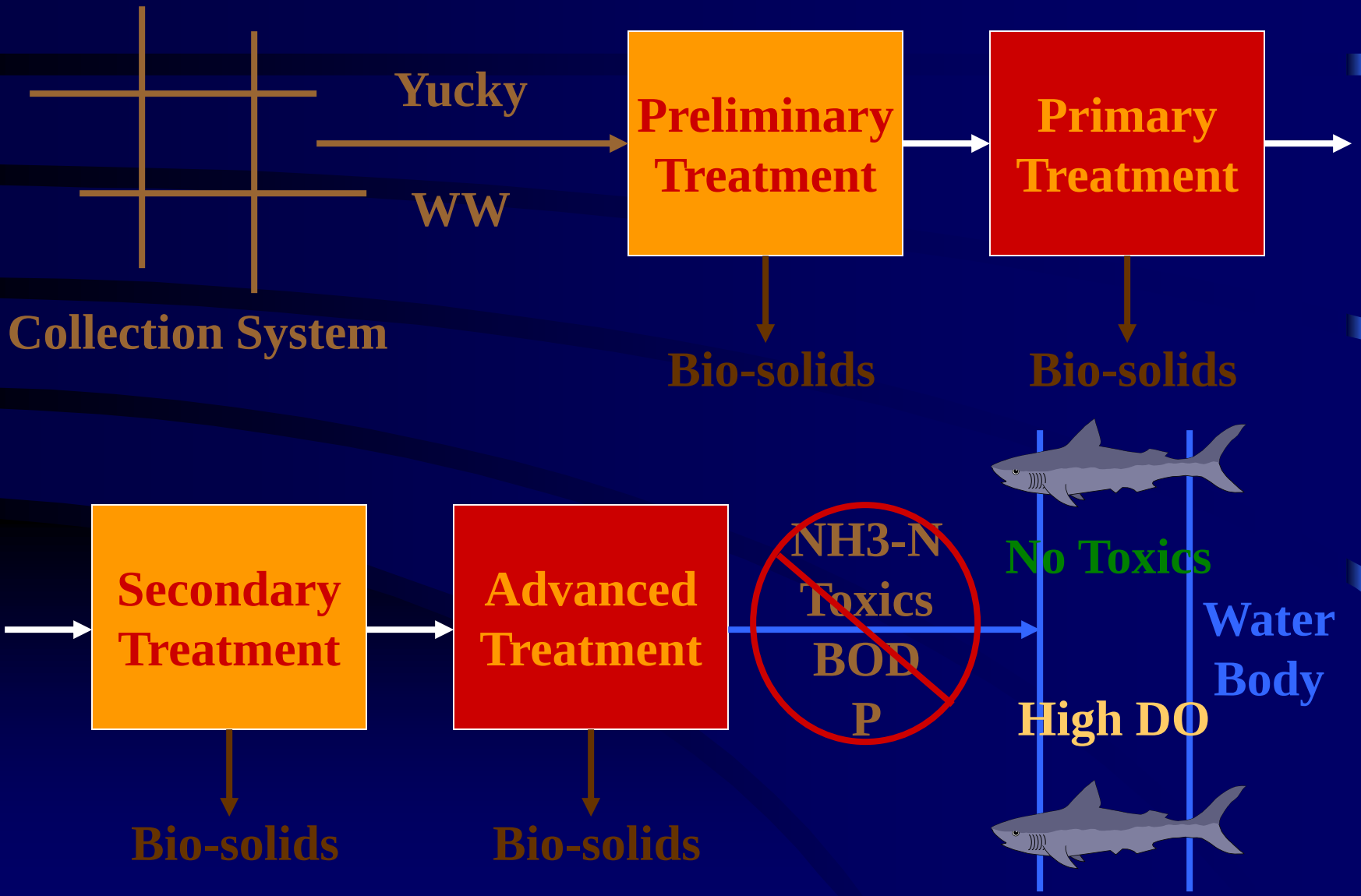
Preliminary treatment

Primary treatment

Secondary treatment

Advanced treatment

WWTP (or POTW)


Yucky
WW
Collection System
Preliminary Treatment
Primary Treatment
Bio-solids
Bio-solids
Secondary Treatment
Advanced Treatment
NH3-N
Toxics
BOD
P
No Toxics
Water Body
High DO
Bio-solids
Bio-solids

WWTP (cont)

So …

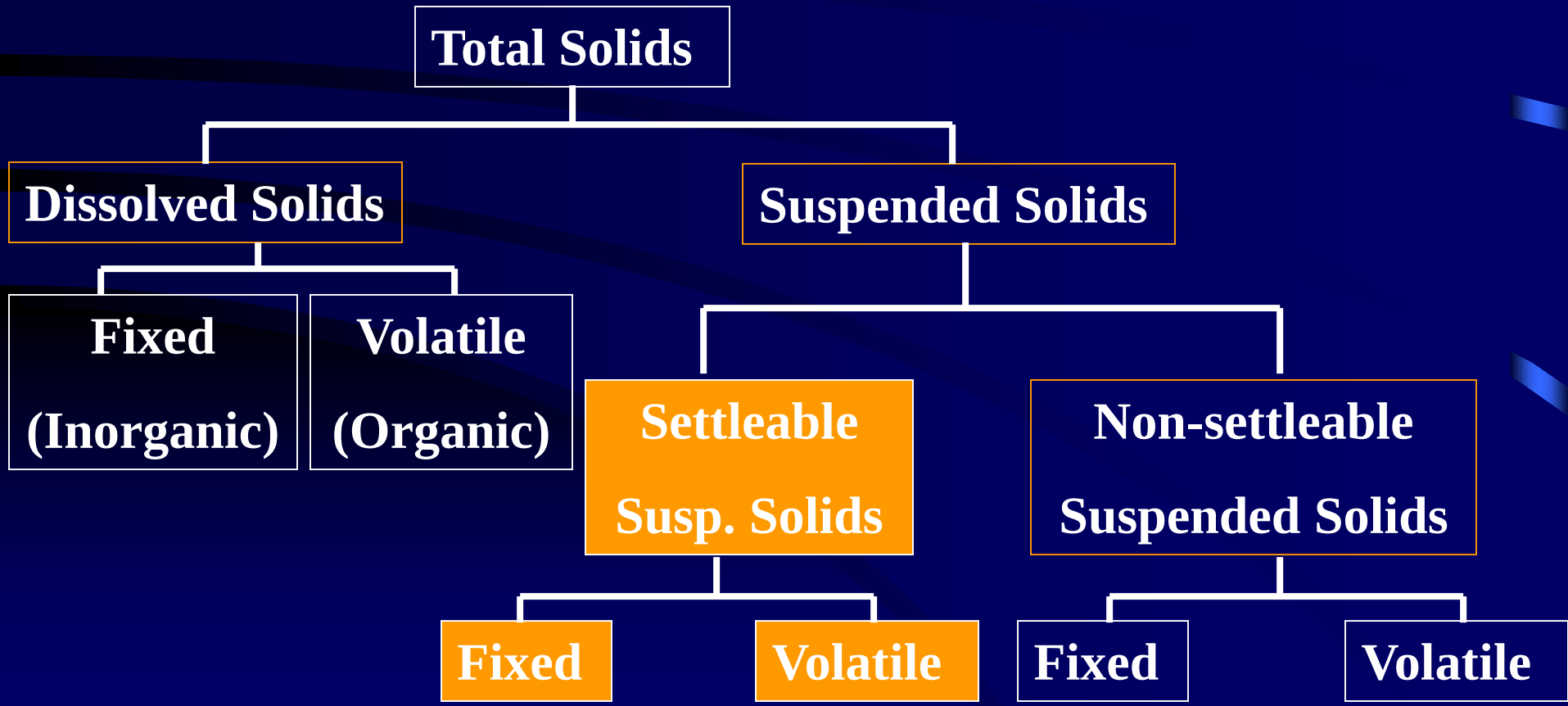
Let's Follow the WW Through a WWTP

Preliminary Treatment

- **Targeted Pollutant:** Remove floatables, and abrasive or large objects that could damage equipment in the WWTP
- **Processes:**
  - Screening (manual bar racks, mechanical bar racks, comminutors, barminutors and fine screens)
  - Grit removal (detritus tanks, grit channels and aerated grit chambers)

Primary Treatment

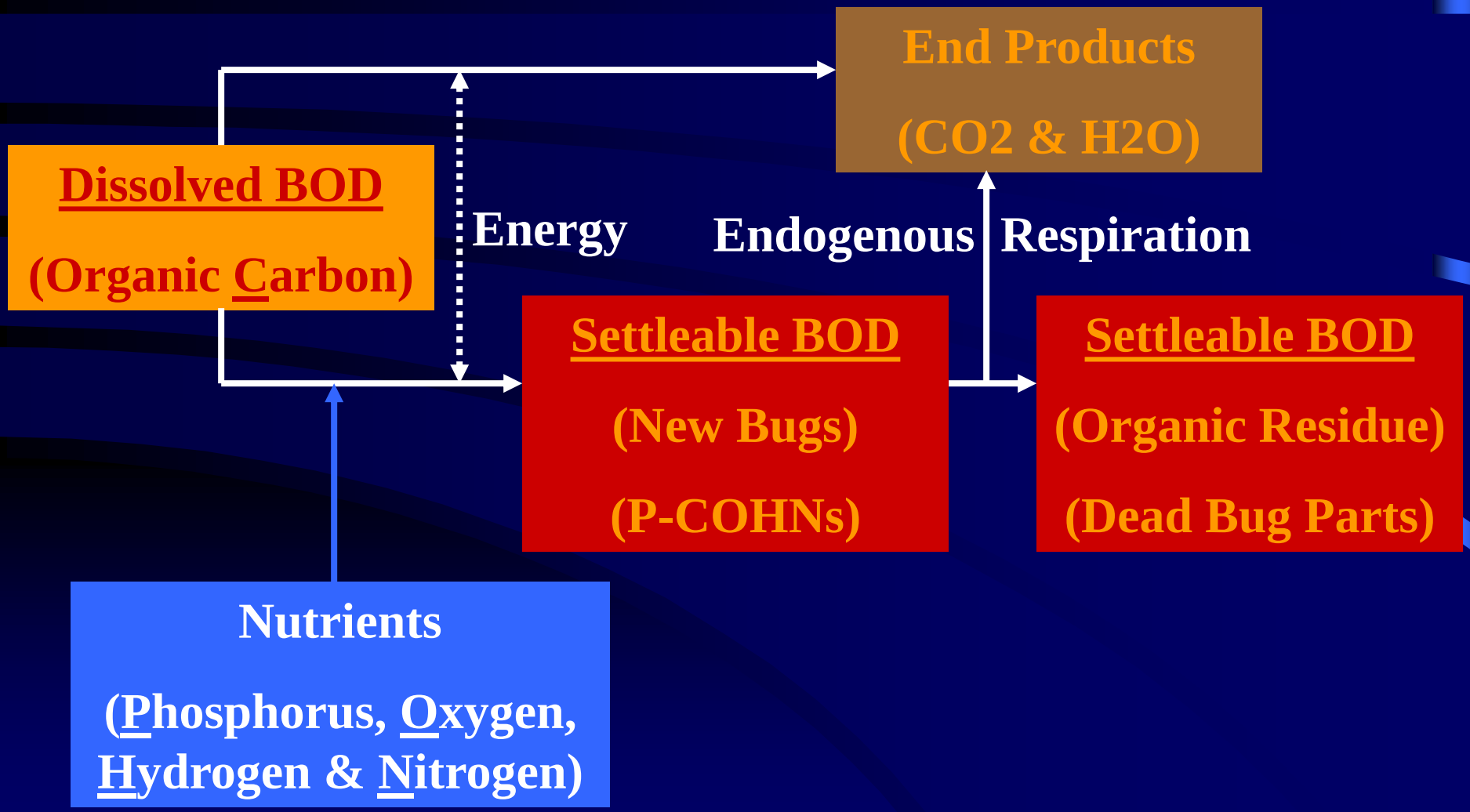
- **Targeted Pollutant:** Settle the settleable suspended solids in a Primary Settling Tank



Secondary Treatment

- **Targeted Pollutant:** Convert dissolved Biochemical Oxygen Demand (BOD) to settleable BOD (i.e., Bugs) in a Biological Reactor so it can be removed
- **Processes:**
  - Attached-growth biological reactors
    - Trickling filters
    - Rotating biological contactors (RBCs)
  - Suspended-growth biological reactors
    - Activated sludges (conv., ext.-aer., step-aer., etc.)

Secondary Treatment (cont)

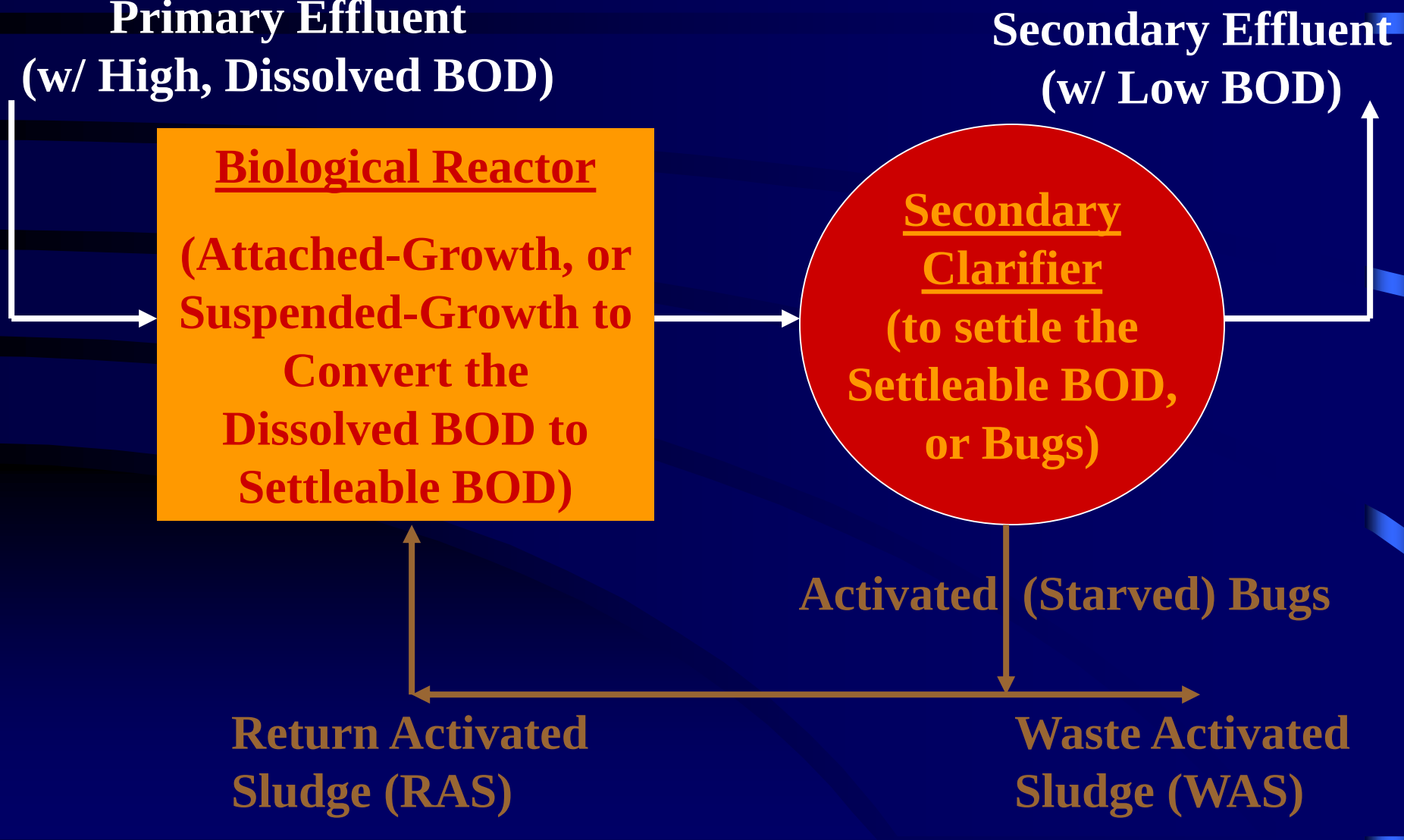


Secondary Treatment (cont)

- Biological reactor converts the dissolved Biochemical Oxygen Demand (BOD) to settleable BOD (i.e., Bugs)

- Secondary, or final clarifier, settles this settleable BOD for:
  - recycling as RAS, or
  - removal as WAS

Secondary Treatment (cont)



Advanced Treatment

- **As part of Primary or Secondary Treatment**
  - Coagulant addition to precipitate Phosphorus
  - Nitrification to biologically convert soluble Ammonia-N to Nitrite, and then to biologically convert the Nitrite to Nitrate (aerobic)
  - De-nitrification to biologically convert soluble Nitrate to Nitrogen gas (anaerobic)

Advanced Treatment (cont)

- **As a separate Tertiary Treatment**
  - Lime addition to convert soluble ammonia-N (NH3-N) to ammonia gas (NH4), and Aeration to remove the ammonia gas
  - Filtration to remove additional suspended solids [both fixed (inorganic) and volatile (organic)]
  - Chlorination to kill fecal coliforms before the effluent discharges to a receiving body of water
  - De-chlorination to remove excess chlorine

Items Discussed in the Wastewater (WW) Segment

- **Wastewater Collection**
- **Wastewater Treatment**

PART 3

Merging the Water and Wastewater Hydrologic Cycles

Six-stage Water & Wastewater Hydrologic Cycle

- Stage One – Precipitation and Travel
  - Surface and ground water
- Stage Two – Source Water Use
  - Cooling towers, irrigation, etc.
- Stage Three – Withdrawal and Water Treatment
  - Surface and ground water
- Stage Four - Treated Water Use and Reuse
- Stage Five – Release and Wastewater Treatment
- Stage Six – Evaporation and Transpiration

Moving Towards IPR and DPR

- Indirect Potable Reuse (IPR) uses the environment (river or aquiver) as a buffer between treated wastewater and the point of water treatment

- Direct Potable Reuse (DPR) eliminates the release to the environment

Items Discussed in the Water and Wastewater Hydrologic Cycle Segment

- **Six-stage W/WW Hydrologic Cycle**
- **Moving Towards IPR and DPR**

So . . . . Do we start to do sophisticated treatment at the effluent end of the WWTP or the influent end of the WTP?

Items Discussed in this Presentation

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