CornellEngineering
Civil and Environmental Engineering

CEE 4540

Sustainable municipal drinking water treatment

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Dissolved Air Floatation Overview

Process Overview

- Conventional DAF
- High Rate DAF
- In-Filter DAF/F

DAF Applications

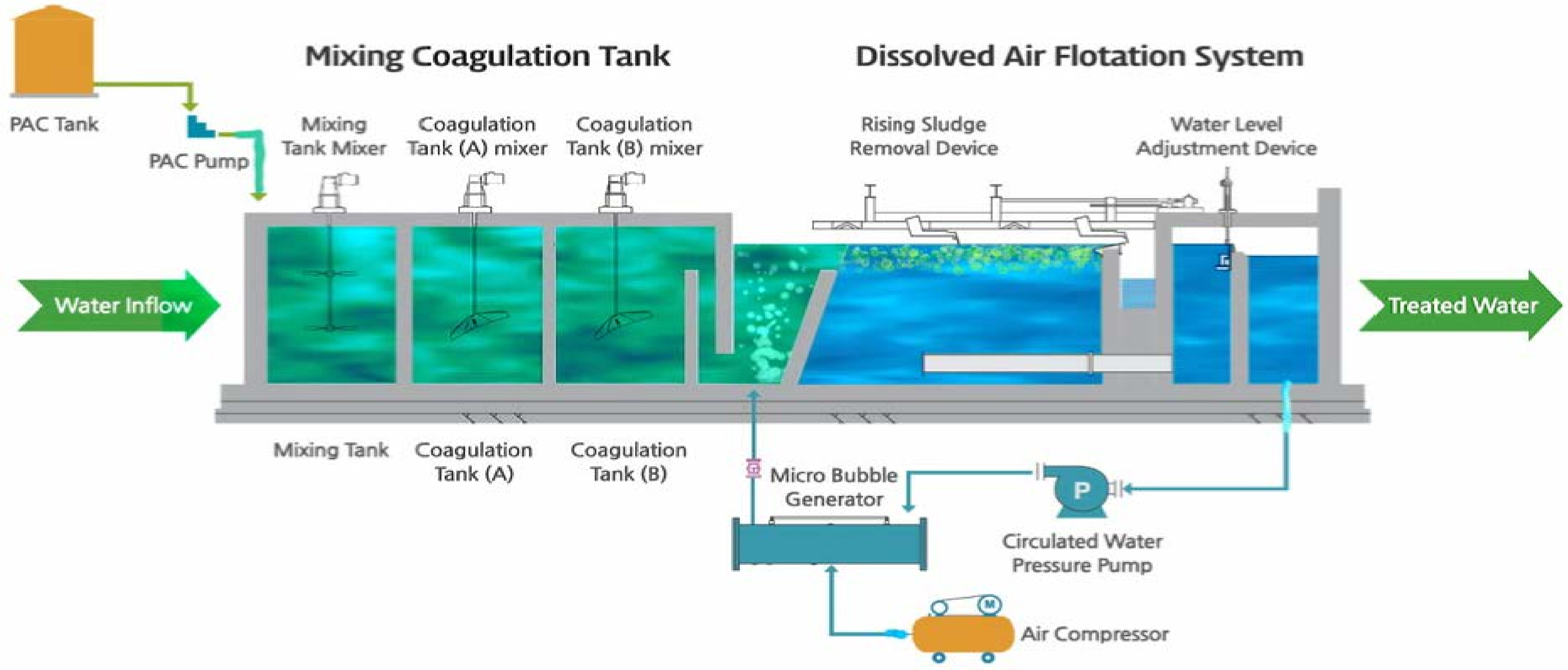
Conventional vs. High Rate DAF

- Design Considerations
- Cost Issues

Case Studies

- 400 ML/d Deacon Reservoir WTP, Winnipeg
- 155 ML/d Duteau Creek WTP, Vernon, BC
- 115 ML/d Penticton WTP, Penticton, BC

How Dissolved Air Floatation Work?



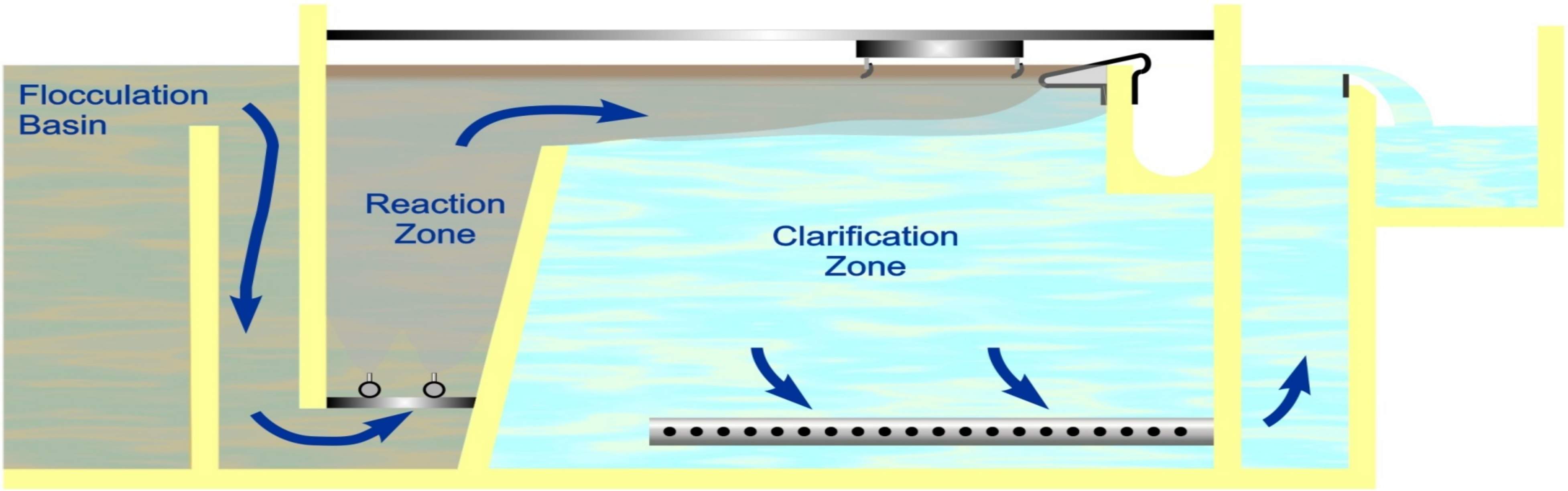
Main Components of a DAF System

- The DAF Basin
- Recycle Systems
- Float (Sludge) Removal systems
- Clarified Water (subnatant) withdrawal

Examples of DAF Applications

What is Dissolved Air Floatation, or DAF ?

- A solid/liquid separation process used for primary clarification or for sludge thickening Uses small air bubbles (20 - 100 microns) to separate coagulated / flocculated particles from raw water by floating them to the surface
- Developed in early 1960’s in Europe and gained popularity in US in late 1980’s



Where is DAF used now?

Clarification of algae laden waters:

- Best Available Technology for algae removal
- Generally achieve 90 – 95% removal

Clarification of low to moderate turbidity (≤ 100 NTU) lakes and reservoirs

Clarification of highly colored waters

- Ideal for low density solids
- Don't try to float heavier silts

Emerging DAF Applications

Increasing interest in use for residuals handling – Clarification of backwash wastes

- Granular Media Filtration – Westbank, BC
- Membrane Filtration – City of Kamloops, BC

Pre-treatment for membrane filtration

- Low or no polymer usage is a major plus
- DAF can pay for itself in membrane design & operation

DAF Retrofits of poorly performing sedimentation basins

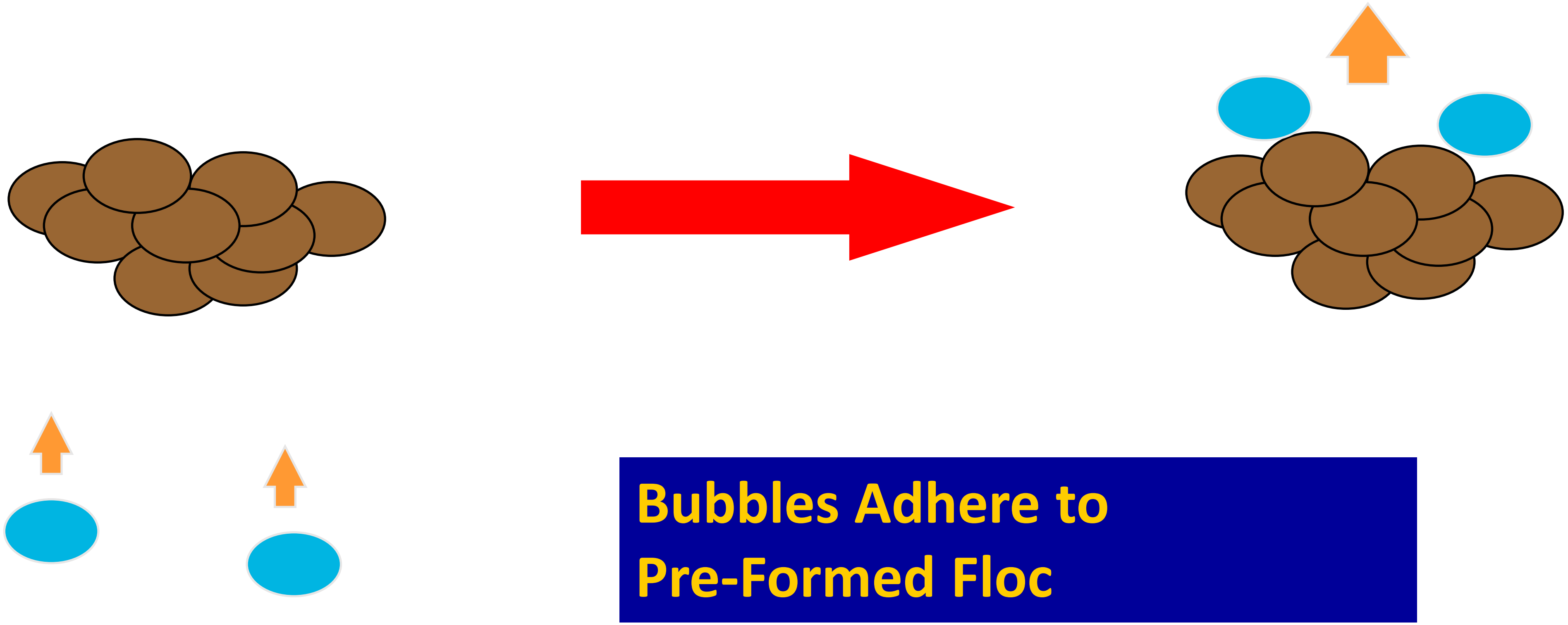
Pre-Treatment for Seawater Desalination

Fundamental Principals of DAF

- The attraction between floc and bubbles is the key to the process
- What causes the flocs and bubbles to stick together ?
  - Electrostatic attraction
  - Entrapment of bubbles
- Microbubbles of 20 – 100 microns nominal diameter provide “ideal” performance

Bubble-Floc Attachment - Mechanism No. 1

– This type of attachment bonding could be weaker since bubbles could “detach”

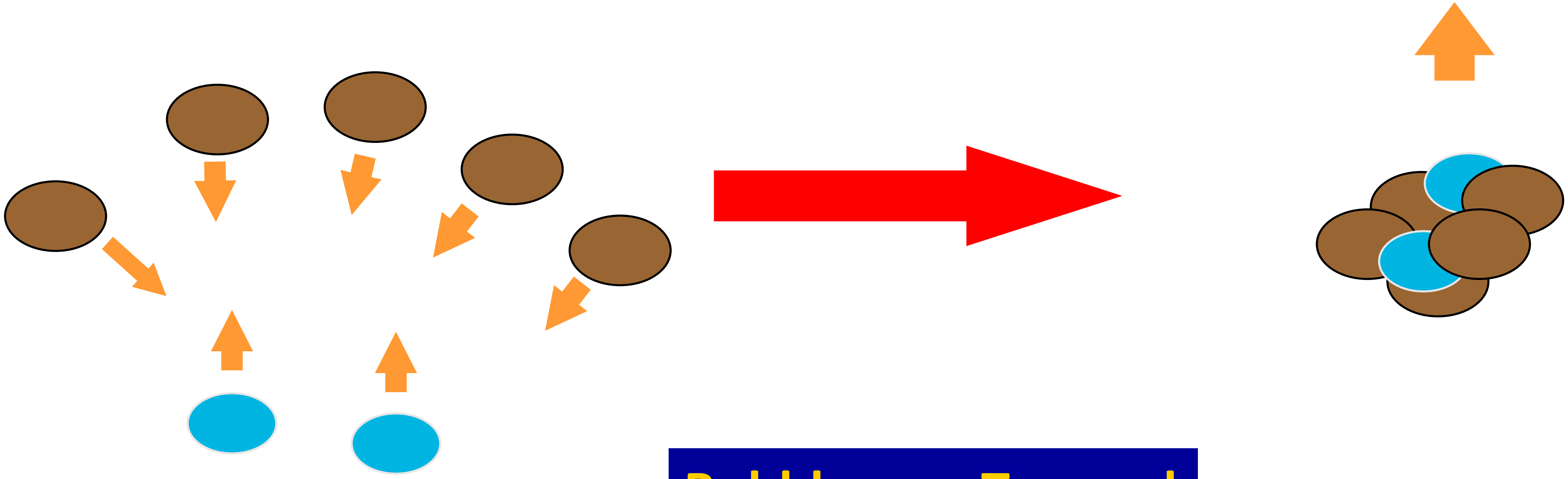


Bubble-Floc Attachment - Mechanism No. 2

- This type of bonding is more secure; not easy for bubbles to escape

Bubble-Floc Attachment - Mechanism No. 3

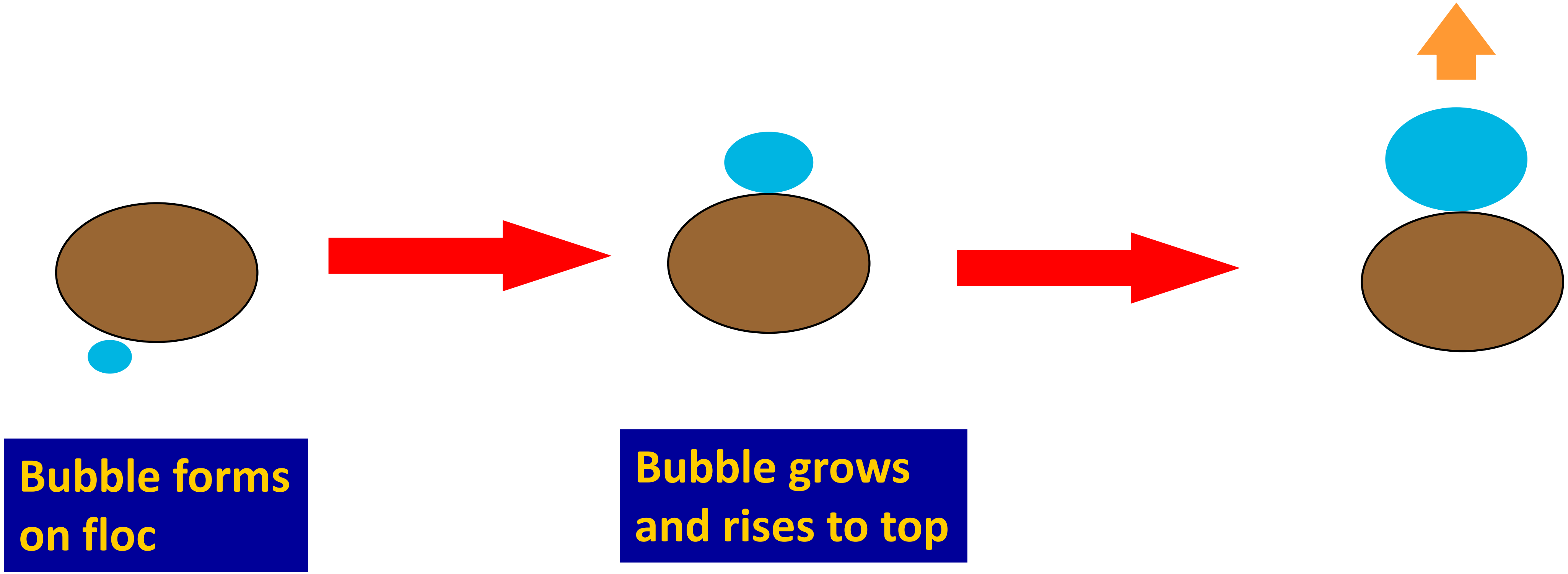
– This is also a strong bubble attachement



Bubbles are Trapped as Floc Forms

Bubble-Floc Attachment – Mechanism No. 4

- Bubble attachment strength is medium



Detachment Mechanisms

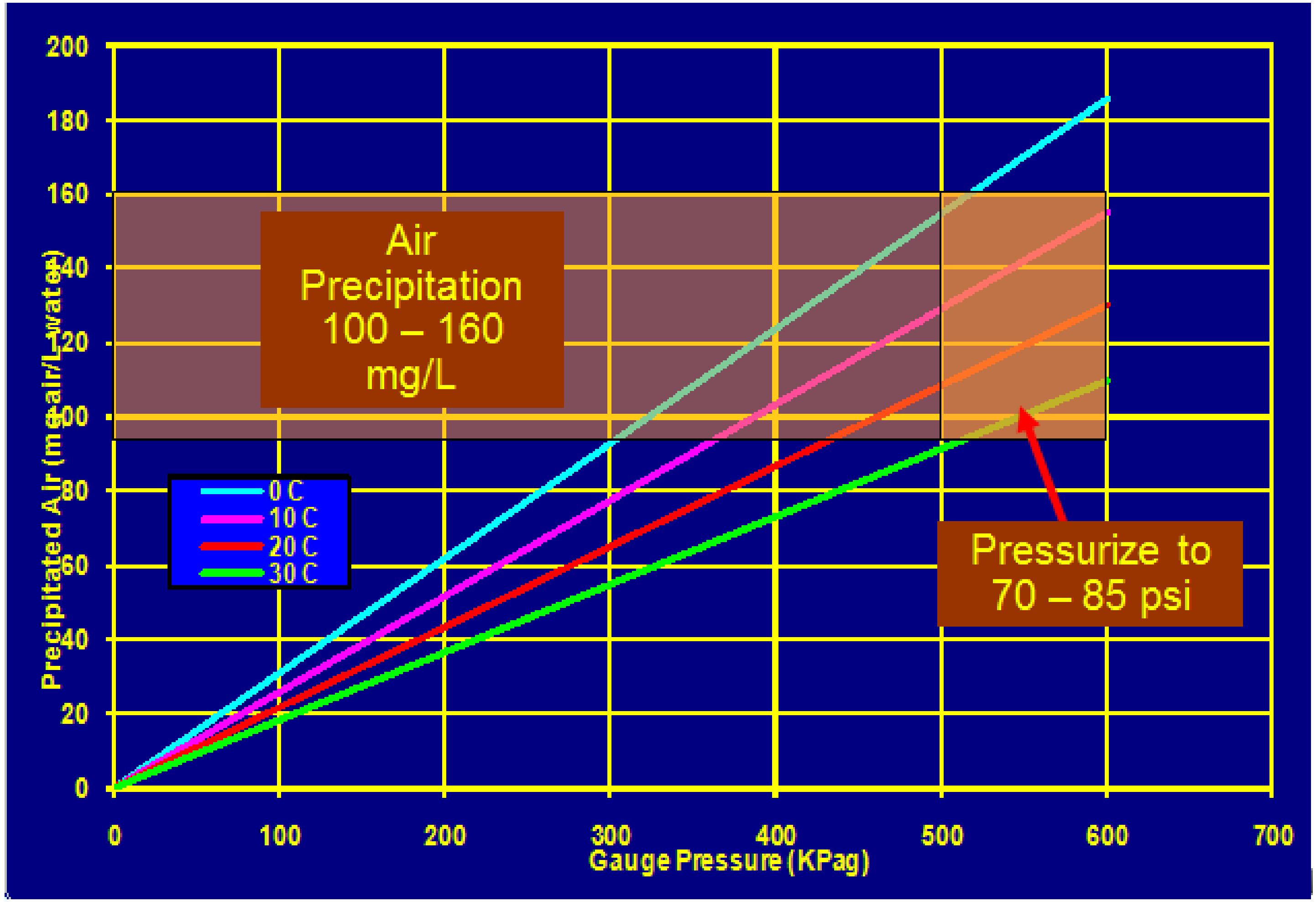
- Bubble-Floc Detachment can also occur:
  - Flocs too large
  - Excessive turbulence
  - Mechanical Disturbance (e.g. Scraper)
  - Excessive Float Retention
  - Charge Repulsion
  - Float Scour

Helpful Characteristics of Small Bubbles

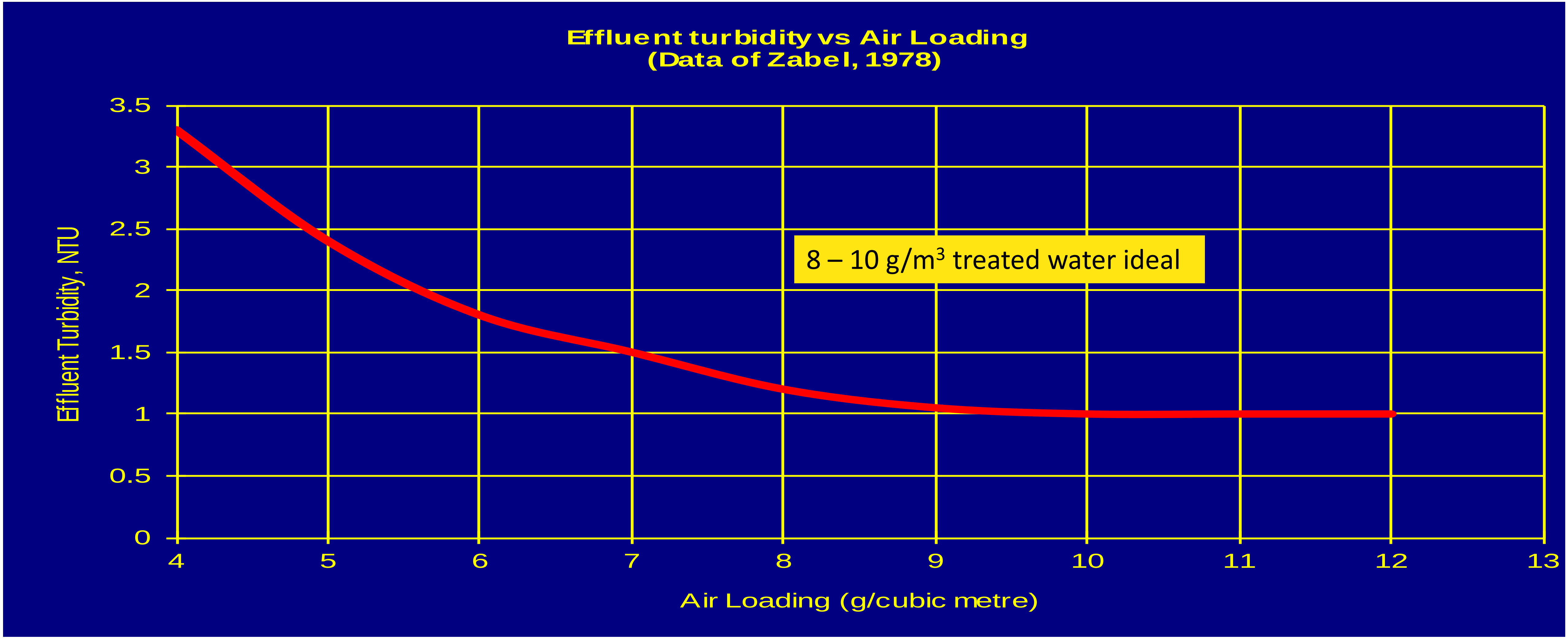
- Slow rise velocities
- High Surface Area - to Volume Ratio - Plenty of Area for Attachment
- They cause minimal turbulence on the way up
- Not wasteful of Air (which requires energy to produce)
- They do not disturb the float layer

Theoretical Air Precipitation vs. Pressure

- Higher pressure = more dissolved air (air precipitation)
- Lower temperature = more dissolved air



How Much Air is Enough ?



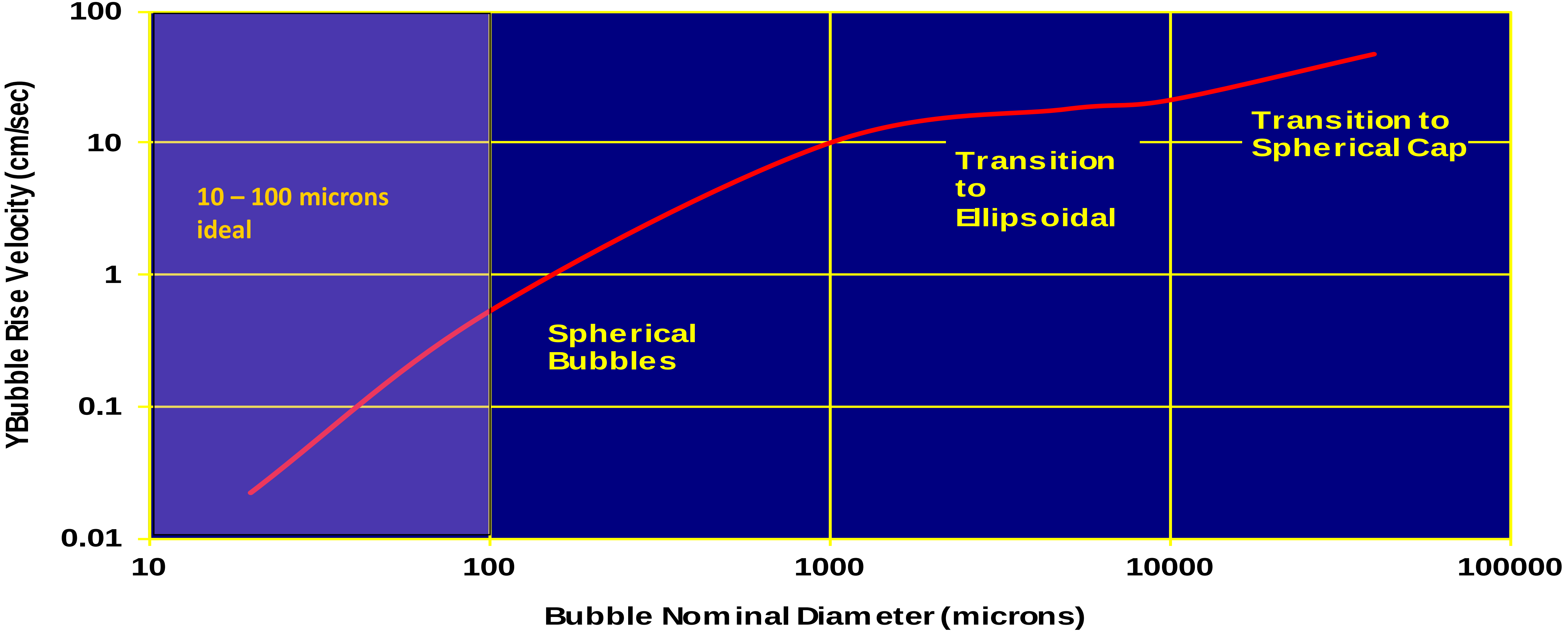
Why are micro-bubbles so important ??

- They rise slowly, providing gentle flotation with minimal turbulence
  - Improved chances for floc-bubble attachment
  - Discouraged floc-bubble separation during flotation
  - Minimal disruption to float layer
- High Surface Area - to Volume Ratio - Plenty of Area for Attachment
- Efficient Use of Air


Typical view of Bubble Cloud
Note that the bubbles are invisible to the naked eye – “Milky” Water

Greenville, South Carolina

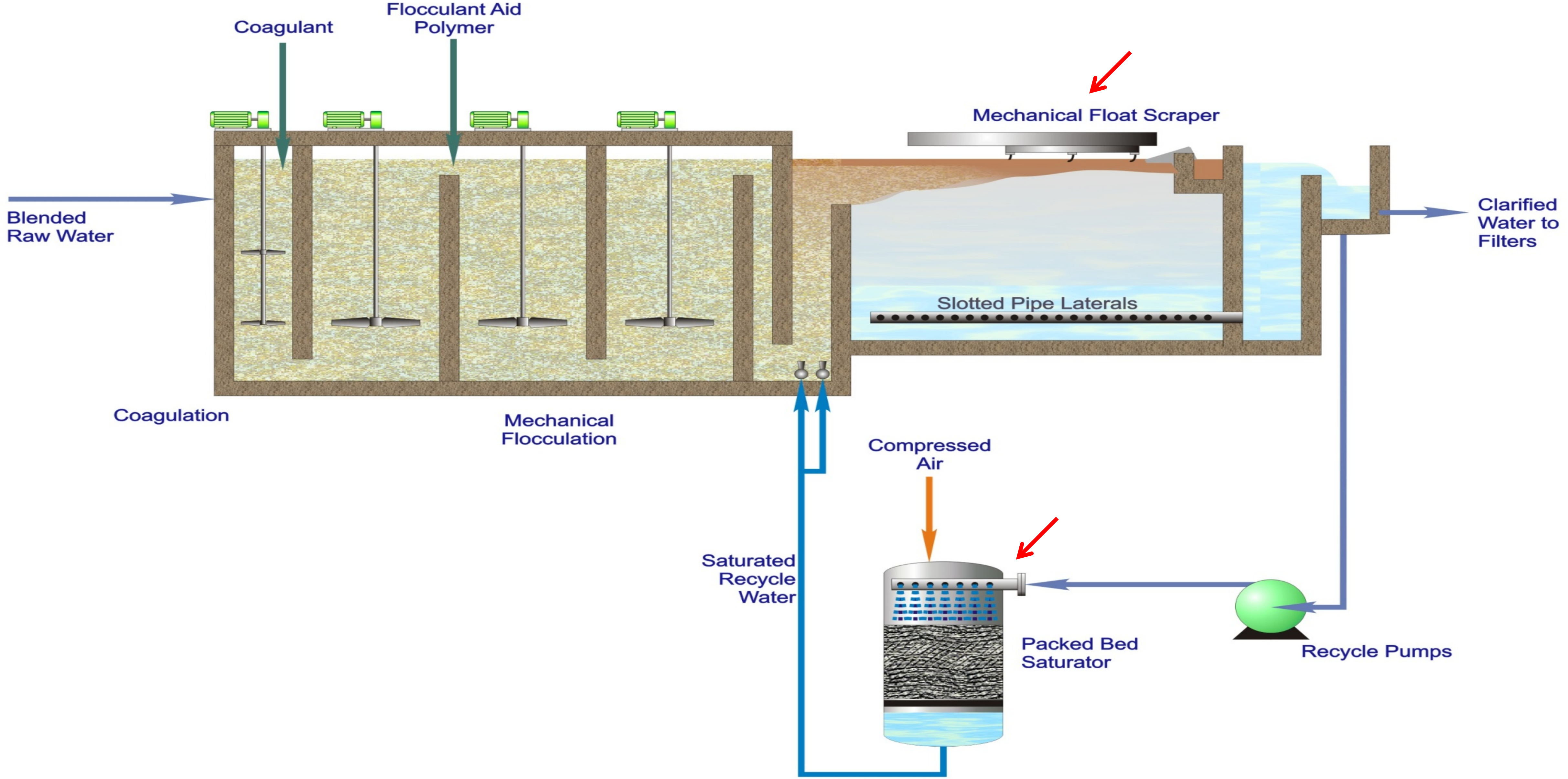
Bubble Rise Velocity



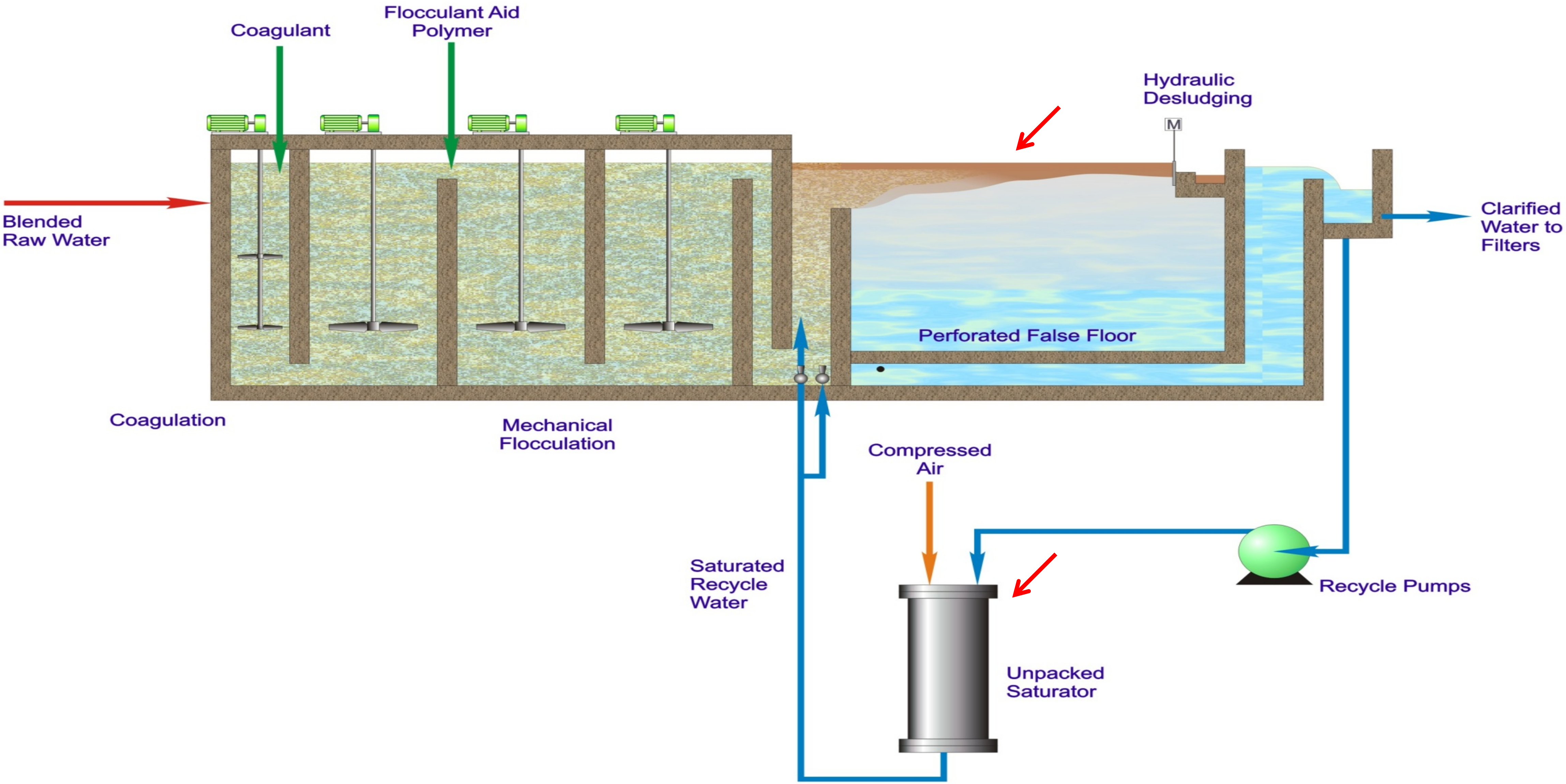
Ideal Bubble Characteristics

- Lots of them !!!!
- Spherical bubble, with laminar flow
- Gentle flow does not break up floc-bubble pairs
- Nominal Diameter: 20 - 100 microns
- Typical Rise Rate 1 cm/sec, 36 m/hr
- Bubble must rise faster than water flows down !!!!

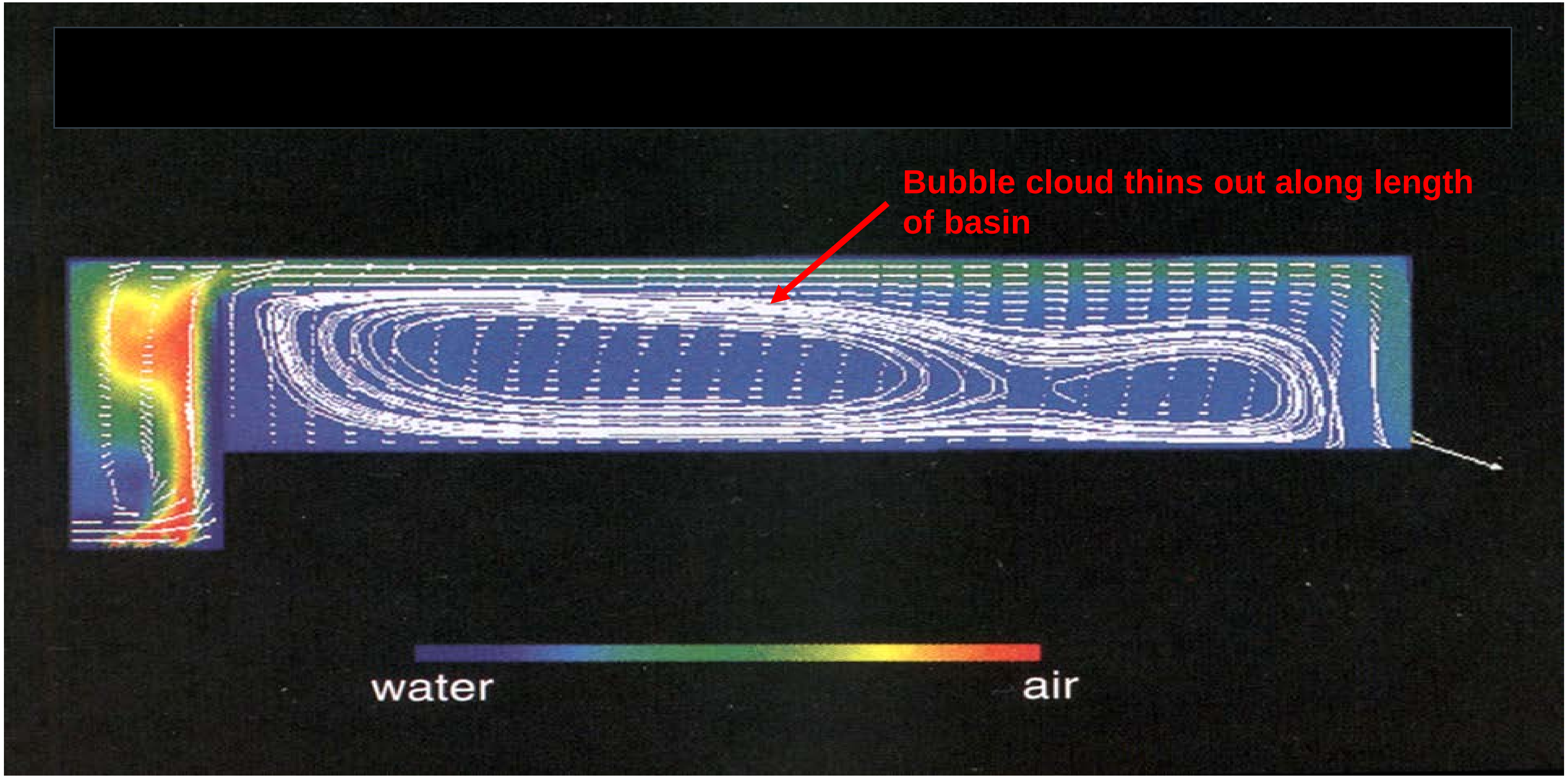
Process Schematic – Conventional DAF



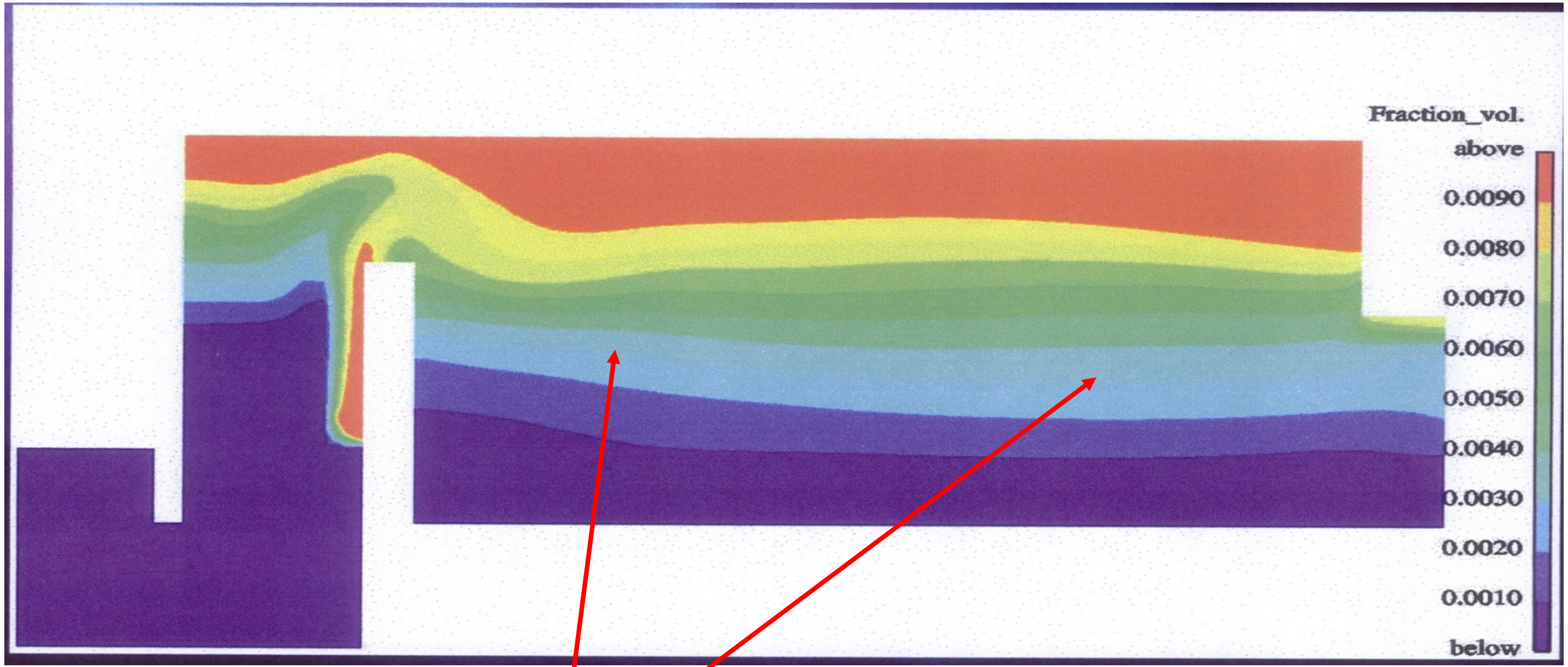
Process Schematic – High Rate DAF (AquaDAF)



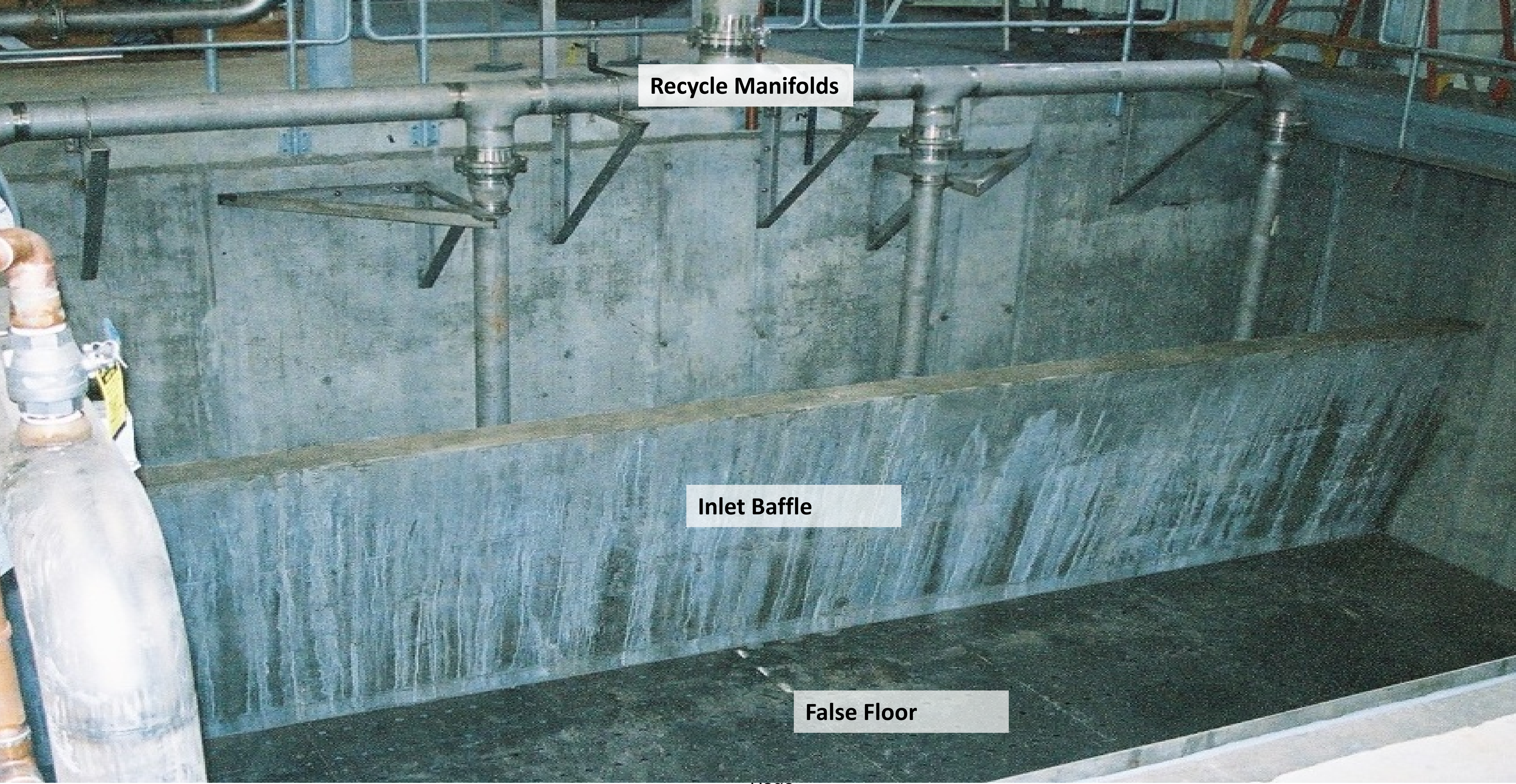
Hydraulic (CFD) Model: Conventional DAF Basin



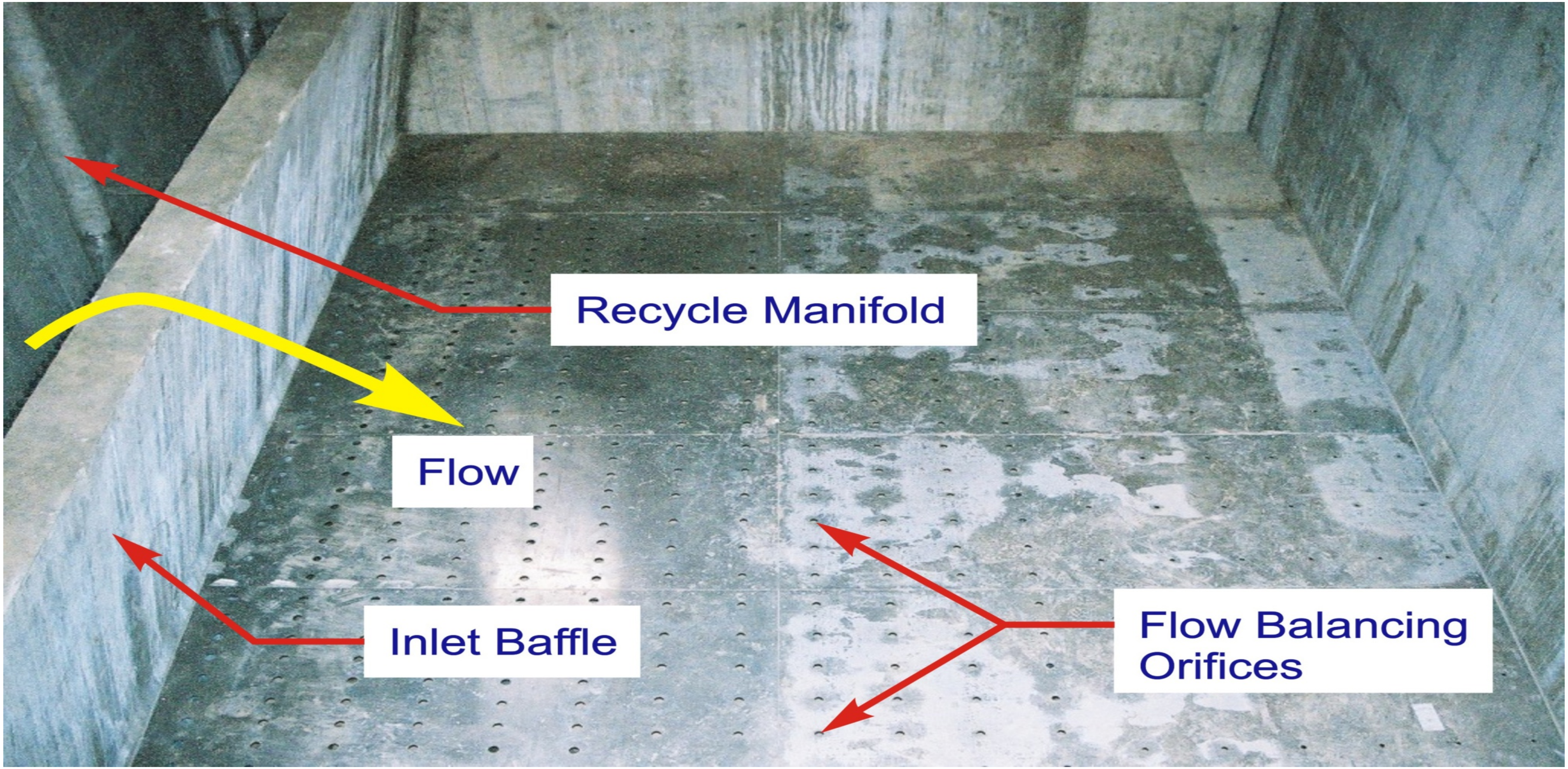
Hydraulic (CFD) Modeling: High Rate DAF Basin



Note the uniform bubble blanket

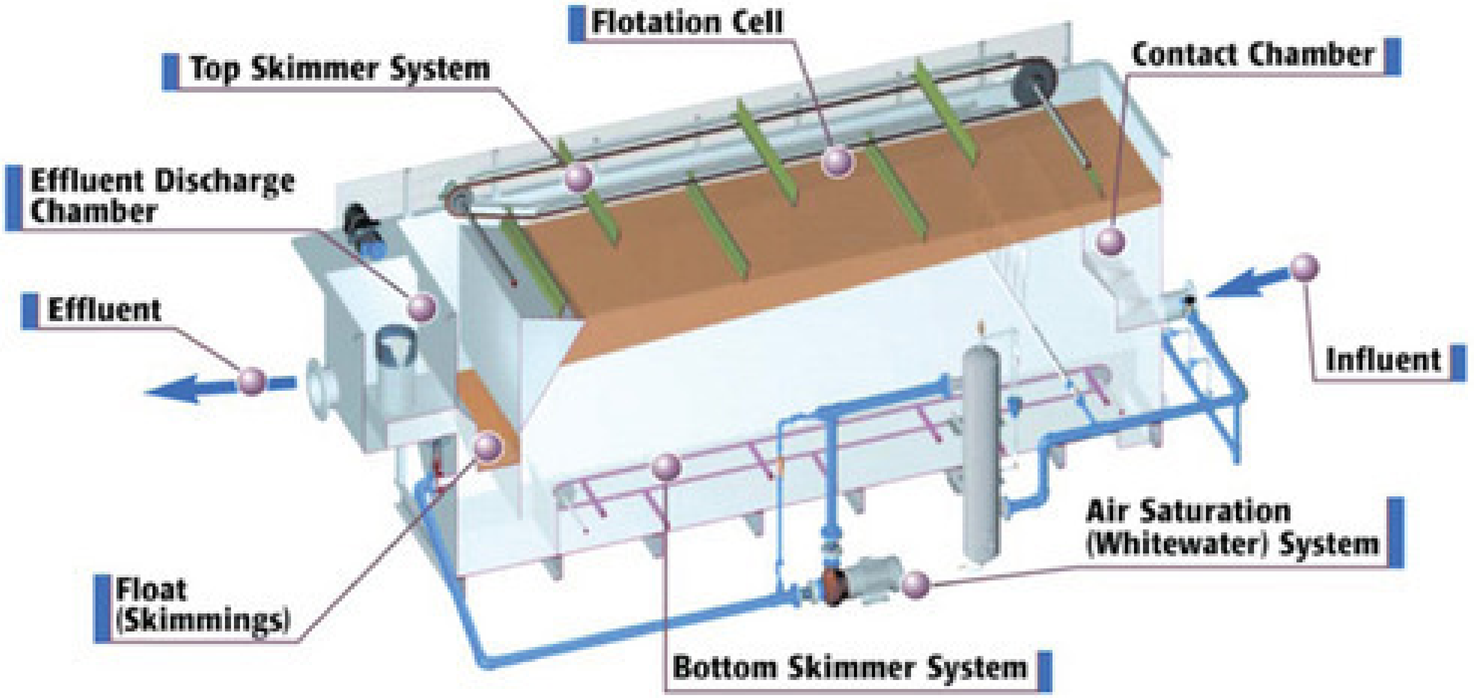

Recycle Manifolds
Inlet Baffle
False Floor

False Floor introduces more head loss than perforated pipe laterals



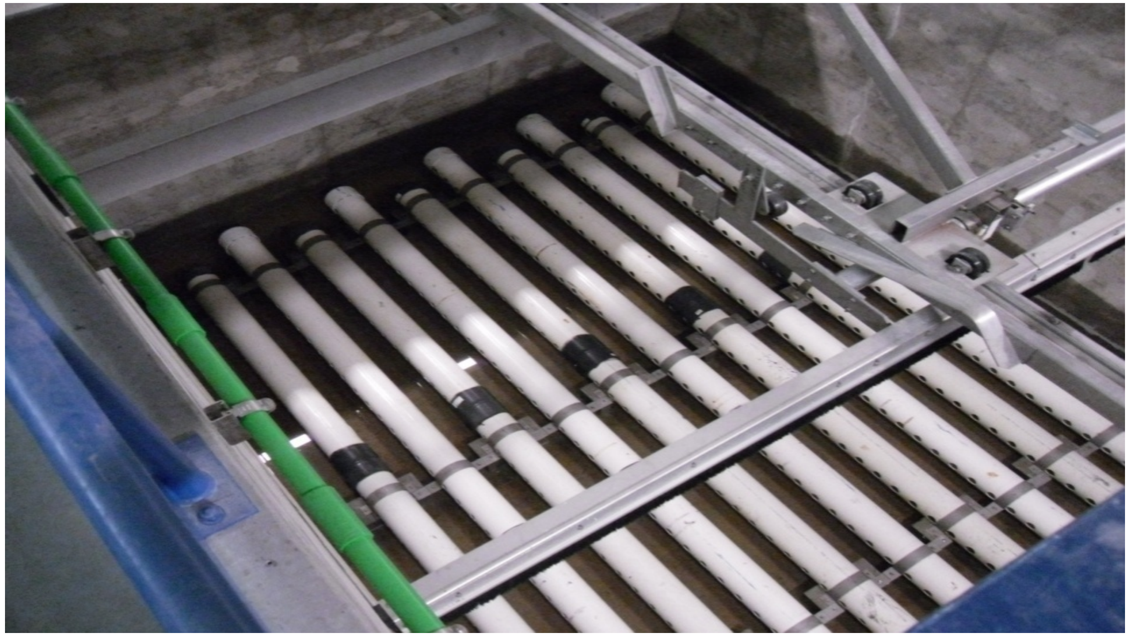
Review of the DAF Design

- On the effluent end the skimmer pulls the collected surface material (Float) up an inclined “beach plate” and into an internal float hopper.
- The beach is sloped to allow for efficient removal of float material by the skimmer wiper.



High Rate DAF – Design Considerations

- ClariDAF – Traditional effluent lateral design
- Beach design important to allow for level variation
- Deeper basin



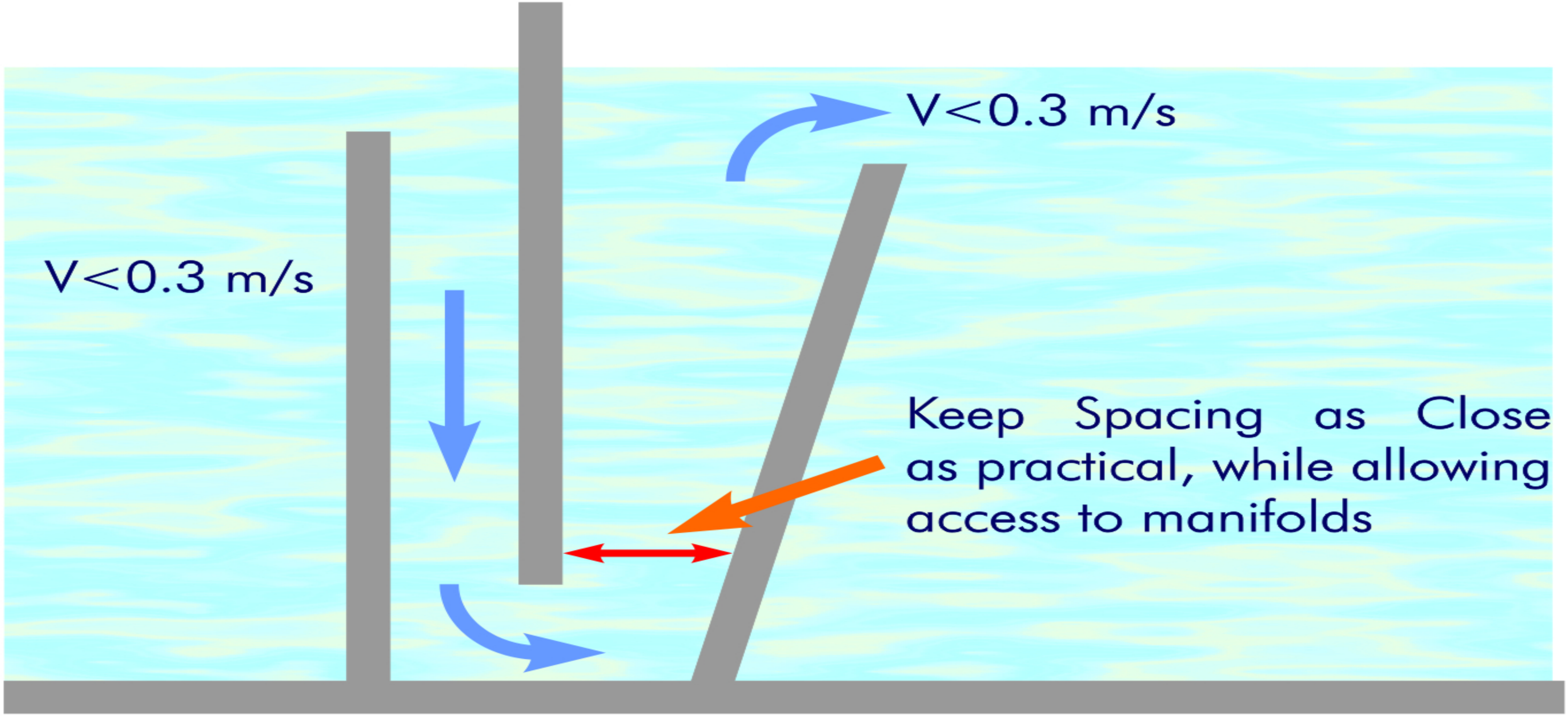
DAF Basin Design Considerations

- Conventional DAF Design:
  - Surface Loading Rates: 8 – 16 m/hr (3.3 – 6.6 usgpm/ft^2)
- High Rate DAF Design
  - Surface Loading Rates: 20 – 40 m/hr (8.2 – 16.4 usgpm/ft^2)
  - Lamella plates have been used for even higher rates in some cases
- Specific basin geometry varies depending on type of DAF used
  - Conventional DAF basins should have an L/W ratio > 1, and be no more than 11 m long
  - Geometry less important for High Rate DAF as substant removal is more even

Reaction Zone Design

- Poor design of Reaction Zone the most common causes of poor performance
  - Short circuiting
  - Poor air-bubble contact
- Desire intimate mixing of flocs and bubbles
- Reaction Zone should be filled with bubbles
- Allow minimum retention time for floc-bubble interaction

Reaction Zone Design
Key Distances




AIR VESSELS
LLESTRI AER
Air Inlet
Water Inlet
Level Control
Recycle out

Float (Sludge) Removal Systems

- There are two basic types:
  - Hydraulic removal systems
  - Mechanical scraper systems
- Hydraulic systems are mechanically less complex, and cheaper to install
- Mechanical scrapers produce significantly thicker sludge (1-3% versus 0.5% for hydraulic)
- Selection of preferred type should be case specific, and consider the ultimate fate of the sludge
  - Hydraulic desludging usually preferred for sewer discharge
  - Mechanical desludging often more cost effective if on-site sludge handling is part of the plant

Hydraulic Desludge in Progress

– Float concentration increased by shortening desludge time, using sidewalls sprays, and increasing overflow rate