Emerging Technologies for Nutrient Removal

Puget Sound Nutrient Forum

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Presenters:

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Introduction

- The results of the first phase of the Salish Sea modeling work indicate that human sources of nutrients are having a significant impact on dissolved oxygen in Puget Sound
- The model has also shown that reducing nutrient loads from municipal wastewater treatment plants would provide significant progress toward meeting the dissolved oxygen water quality standards in the Sound.
- Innovative and sustainable nutrient reduction technologies and strategies will be needed to meet water quality standards and accommodate projected population growth in the region while at the same time being affordable and limiting or reducing adverse impacts on climate change.

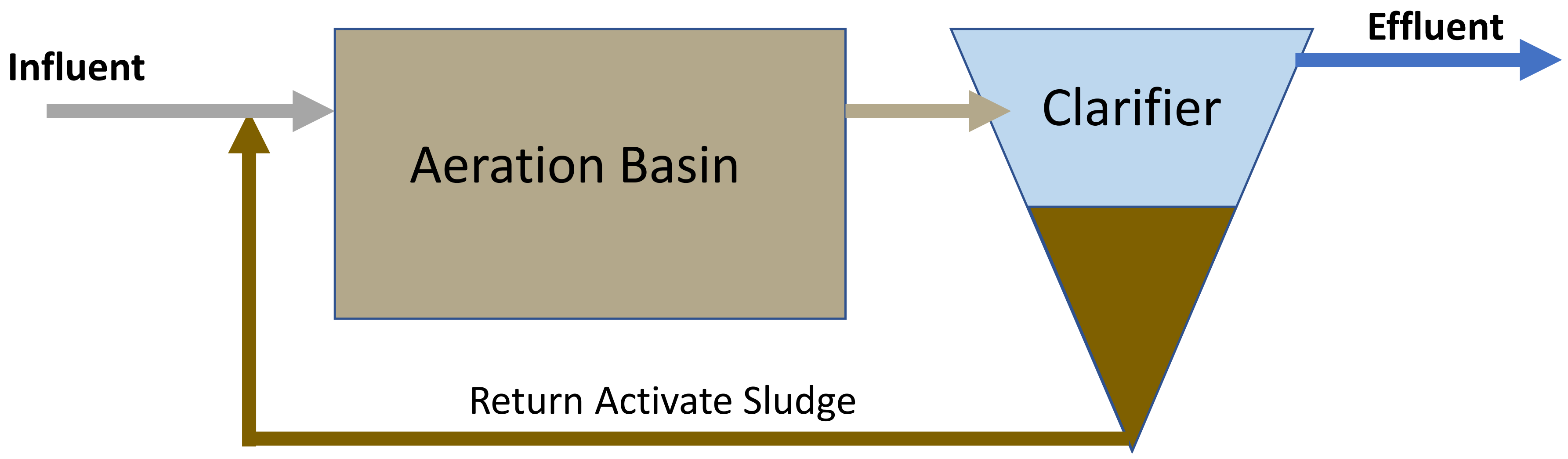
Overview of Biological Nitrogen Removal using Conventional Activated Sludge Treatment

- Activated Sludge for Secondary Treatment without Nitrification (typical of many WWTPs discharging to Puget Sound)

- Activated Sludge with Nitrification reduces effluent ammonia but not Total Inorganic Nitrogen (TIN)

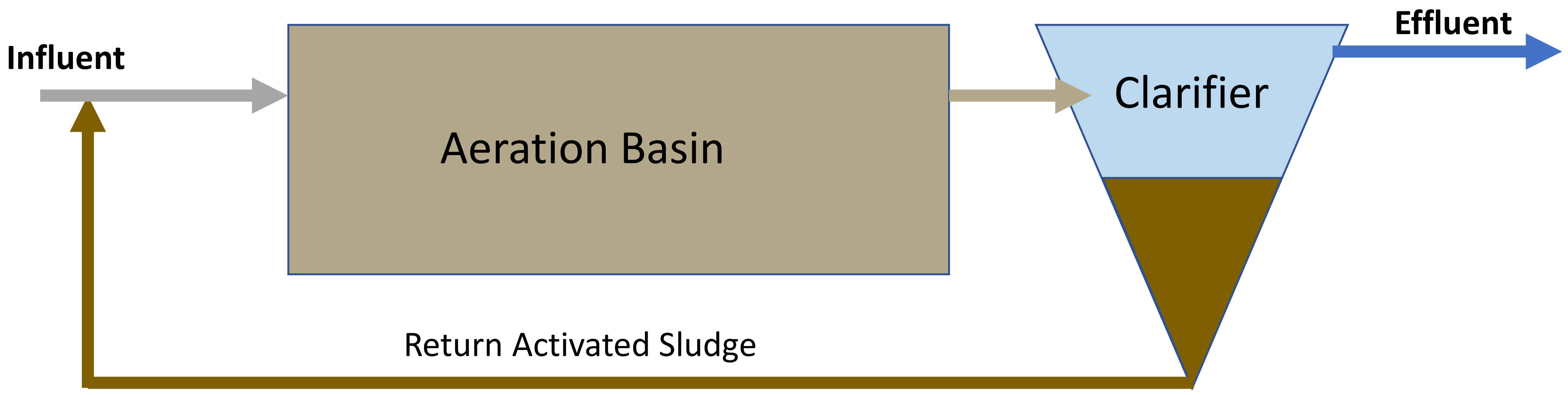
- Activated Sludge with Nitrification and Denitrification

Activated Sludge Secondary Treatment (for BOD and TSS)



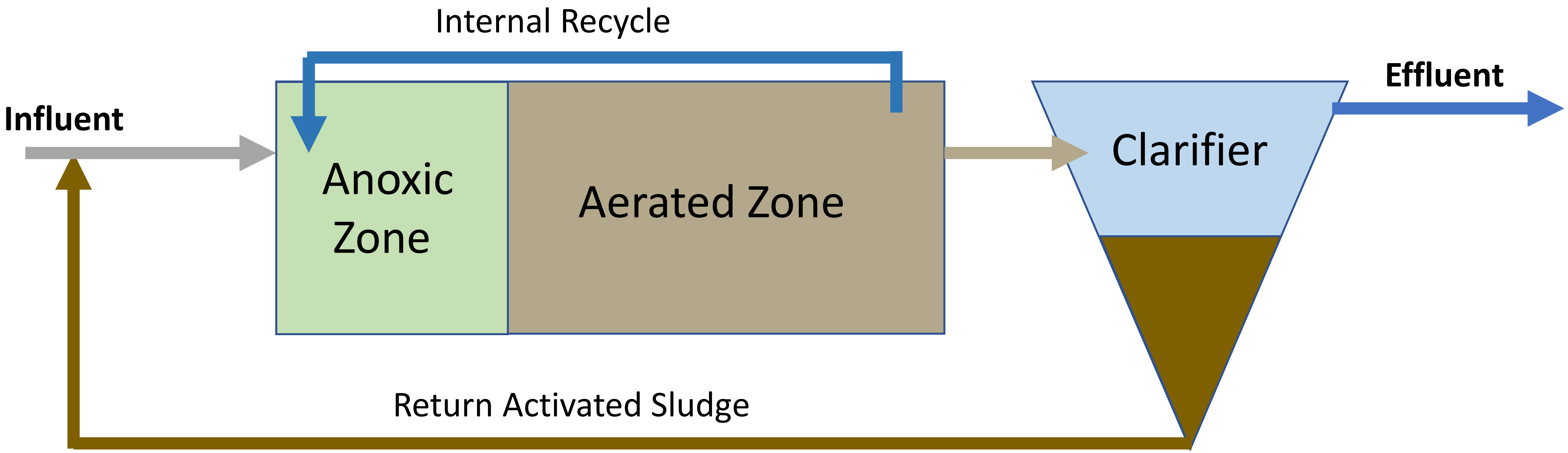
- Influent contains BOD, NH_3, and organic nitrogen.
- Solids retention time (SRT) in Aeration Basin is not long enough to support nitrification.
- Most of the inorganic nitrogen in the effluent will be in the form of NH_3.

Activated Sludge with Nitrification



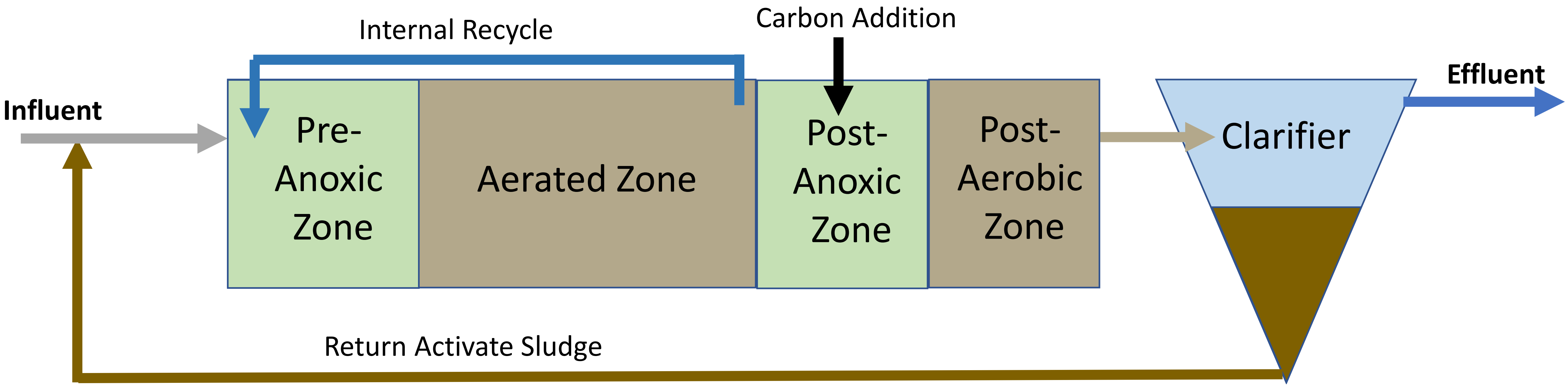
- Influent contains BOD, NH_3, and organic nitrogen.
- Aeration Basin is larger than for Secondary Treatment to provide longer SRT.
- Most of the inorganic nitrogen in the effluent will be in the form of nitrate (NO_3^-).
- TIN in the effluent is similar to the TIN in secondary effluent without nitrification.

Activated Sludge with Nitrification and Denitrification



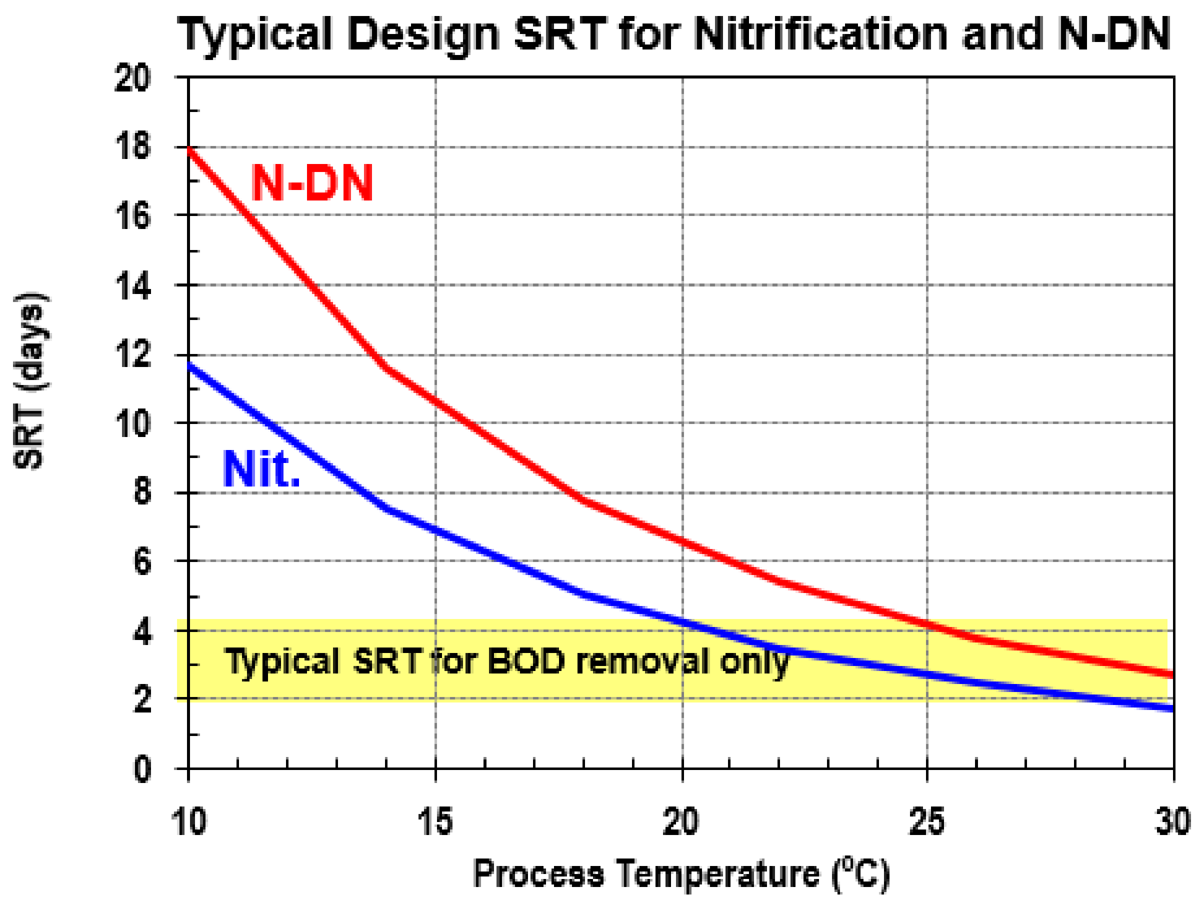
- Influent contains BOD, NH_3, and organic nitrogen.
- Aerated Zone is large enough to support nitrification
- Internal recycle brings nitrate into the Anoxic where it is denitrified using influent BOD.
- Effluent contains reduced levels of total inorganic nitrogen (TIN)

Activate Sludge with Advanced Nitrification and Denitrification



Additional tanks and carbon addition may be needed to meet low TIN limits (e.g. <3mg/L)

Aerobic solids retention time (SRT) and volume is controlled by NITRIFICATION needs



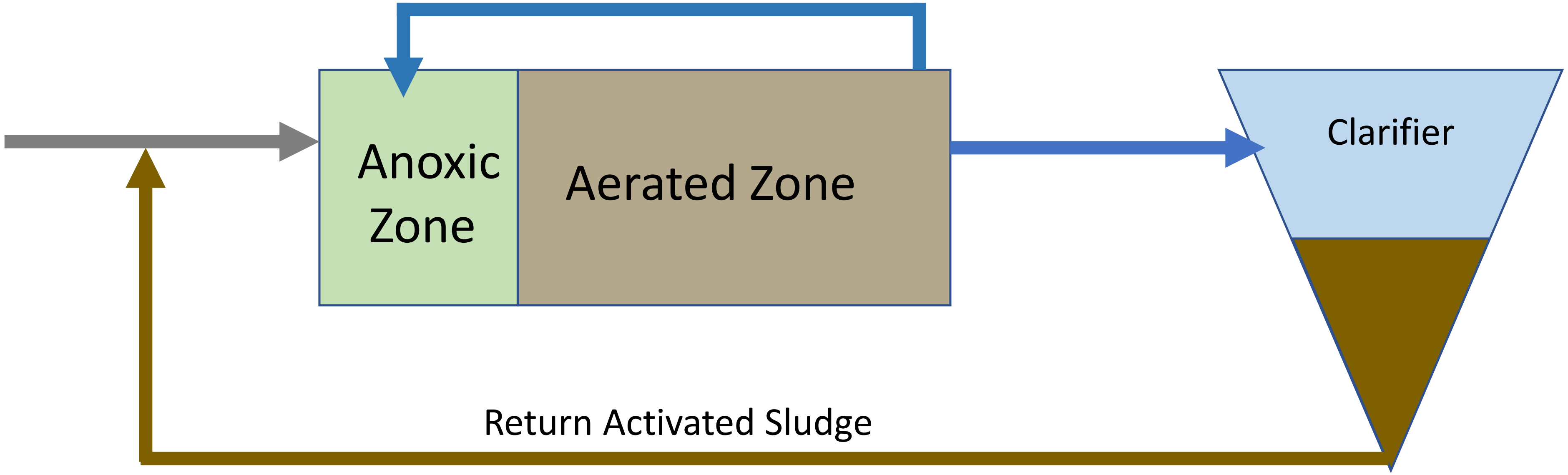
- Lower temperatures requires longer SRT
- Lower NH4+ requires longer SRT
- Longer SRT increases aerobic volume needed
- Higher influent BOD – greater volume
- Higher MLSS – less volume

Settleability of the activated sludge mixed liquor is a limiting factor in determining WWTP capacity

- Upgrades to flocculant activated sludge plants designed for only secondary treatment will in most cases require substantial increases in aeration basin volumes and clarifier capacity to enable them to achieve needed reductions in TIN.
- Settleability of mixed liquor is expressed as Sludge Volume Index (SVI) where a lower SVI value indicates better settling.
- Typical design for flocculant activated sludge assumes an SVI of 150 mL/gram.
- SVIs lower than 150 are possible with flocculant activated sludge but difficult to maintain consistently.
- SVIs of 200 or higher commonly occur due to sludge bulking caused by filamentous bacteria.
- Upgrades using conventional flocculant activated process will therefore be costly to construct and in many cases insufficient space is available at existing sites to install the additional tankage and related equipment which would be needed.

Benefits of increasing the density of active biomass

Aeration basin capacity in terms of BOD and NH_3 loading is roughly proportional to the mass of mixed liquor suspended solids (MLSS) in the reactors



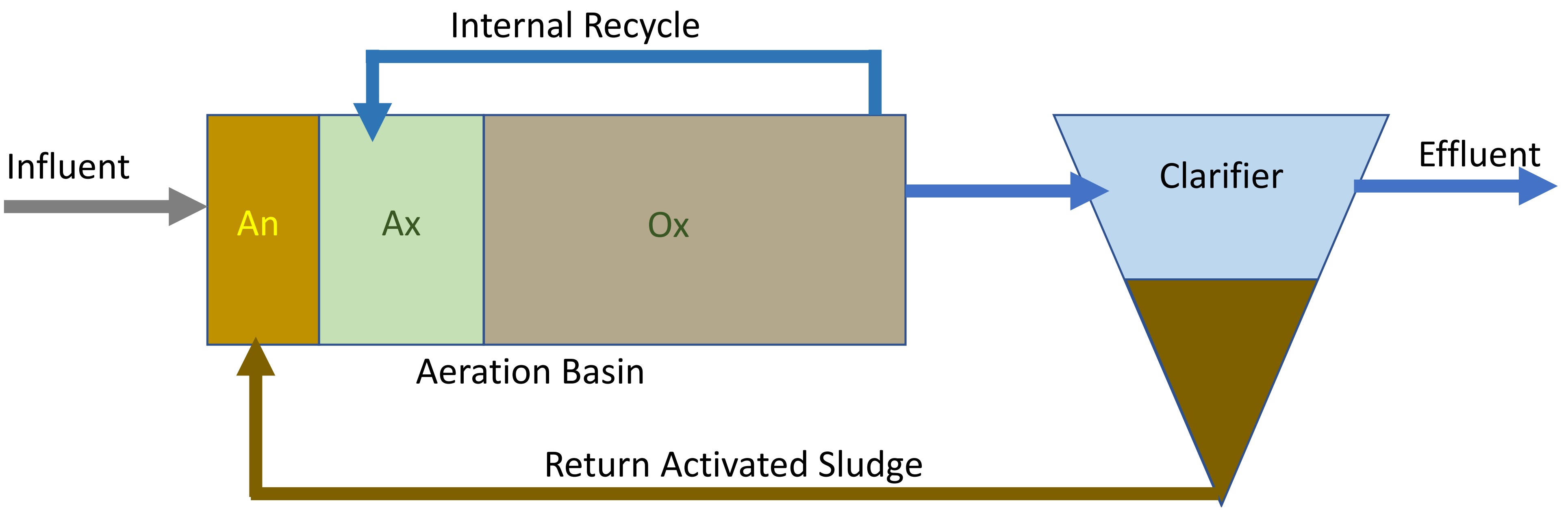
For an existing activated sludge system designed around an SVI of 150, the capacity can be approximately doubled if the SVI can be reliably maintained at 75.

Options for increasing the density of active biomass

- **Membrane bioreactors (MBRs)** - can be used to increase mixed liquor concentrations and reduce reactors volumes since membrane separation does not rely on gravity settling. Disadvantages include high capital cost, high life cycle costs, and high energy consumption.
- **Integrated fixed film activated sludge (IFAS)** - the addition of plastic or other media to aeration basins to support fixed film growth in addition to suspended growth. The benefits of IFAS must be weighed against the cost of the media, the associated media handling systems, and other considerations.
- **Membrane aerated bioreactors (MABRs)** - a new technology which may be promising for some applications, but it is a technology which is still at the pilot testing and demonstration project stage.
- **Modify the bacterial selection processes** to fundamentally change the structure and function of the microbial communities from those that predominate in conventional flocculant activated sludge systems.

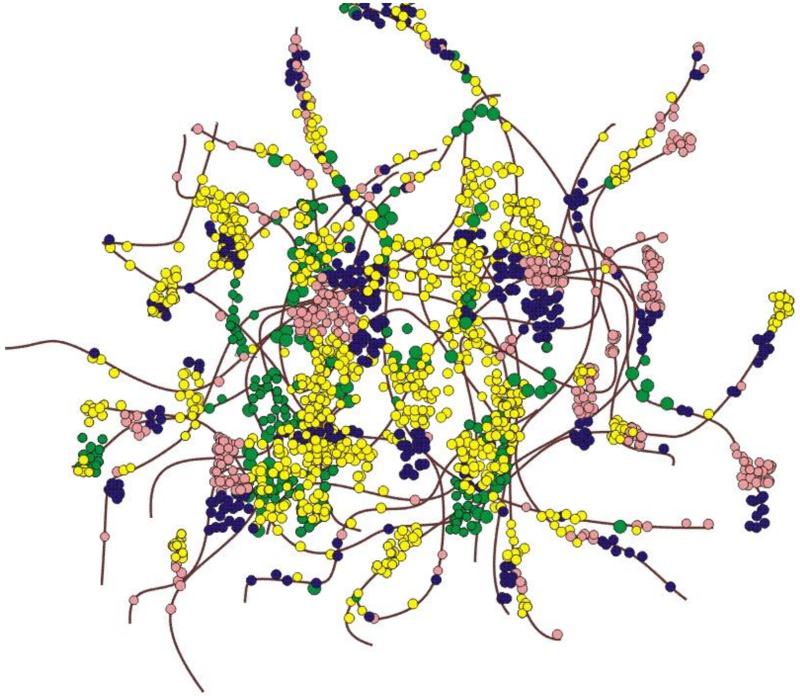
Anaerobic Selectors and Phosphorus Accumulating Organism (PAOs)

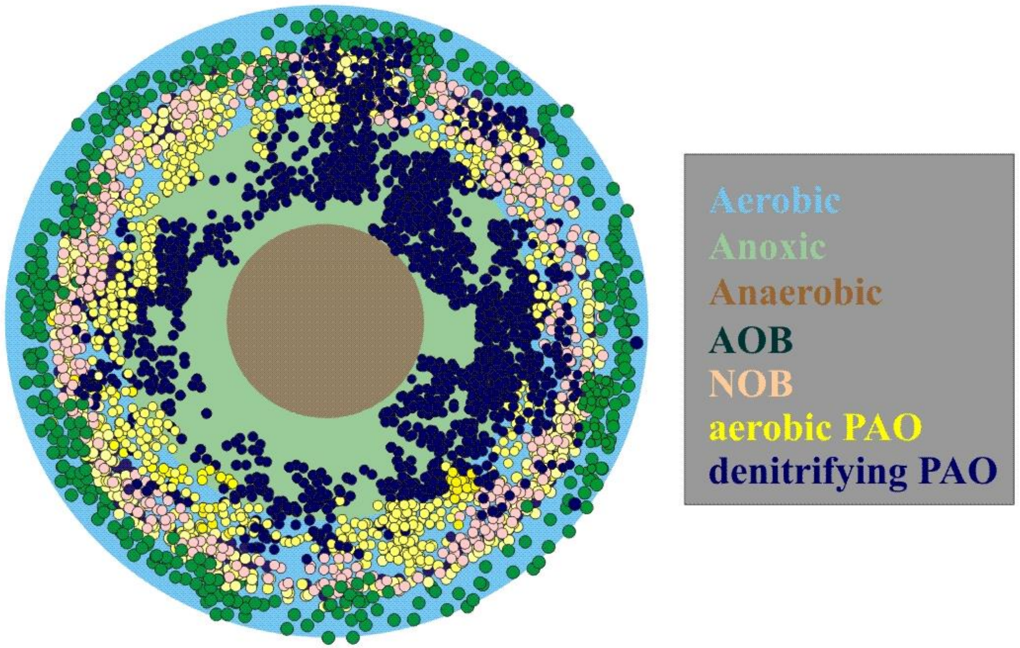
In the 1980s James Barnard observed what would later be termed enhanced biological phosphorus removal (EBPR). A typical EBPR flow diagram is shown below.

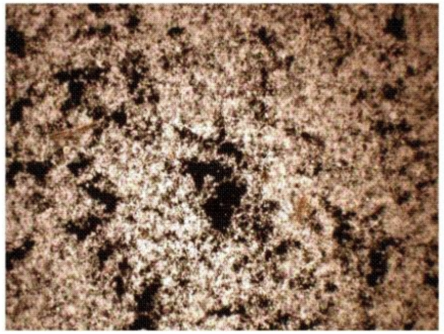


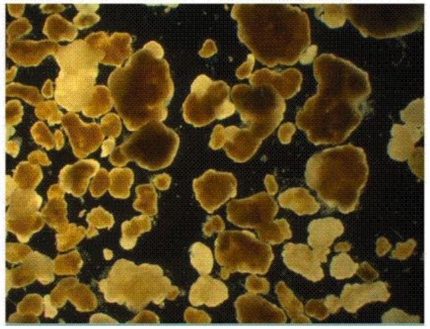
The PAOs are 'selected' for in the EBPR process which achieves both nitrogen removal and phosphorus removal. The PAOs are key to the development of microbial communities with extremely good settling properties which is important even where only nitrogen removal is required.

Aerobic Granular Sludge (AGS)

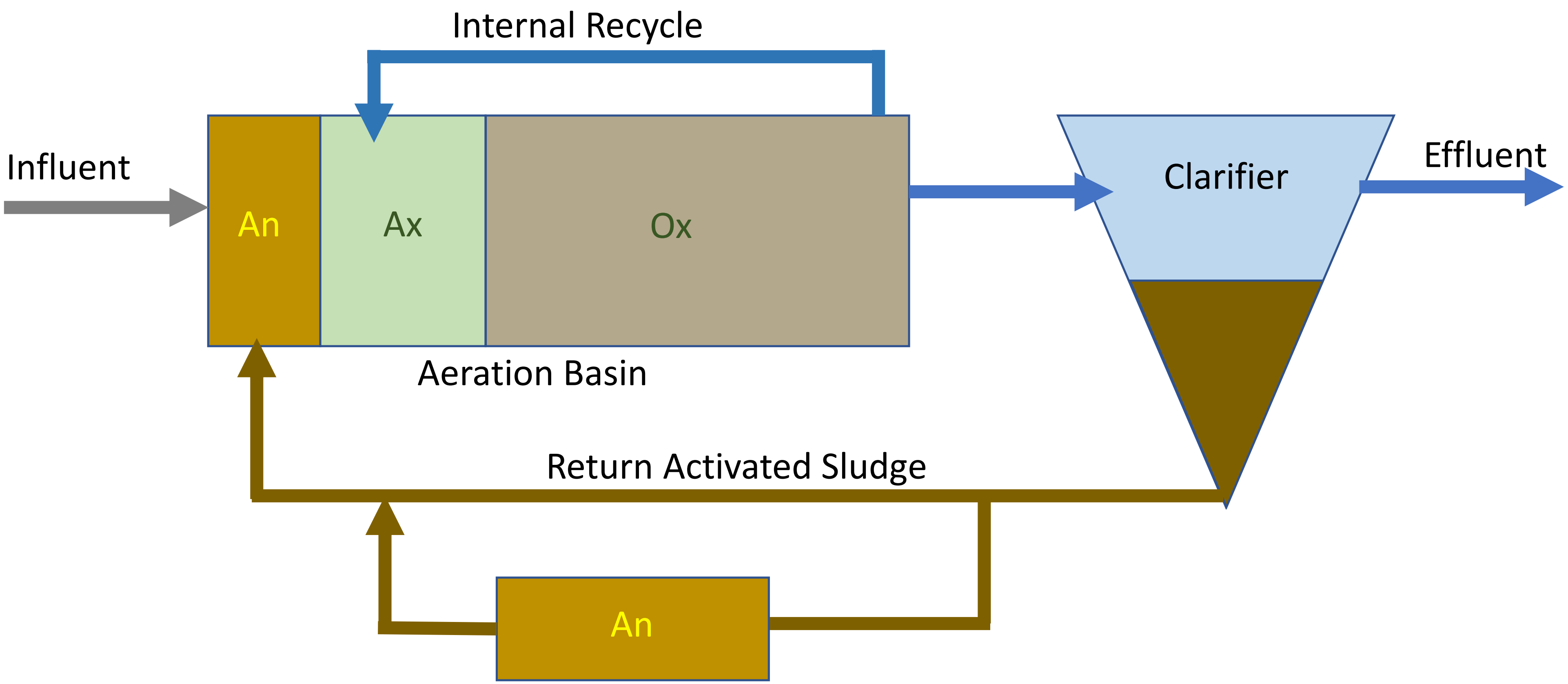








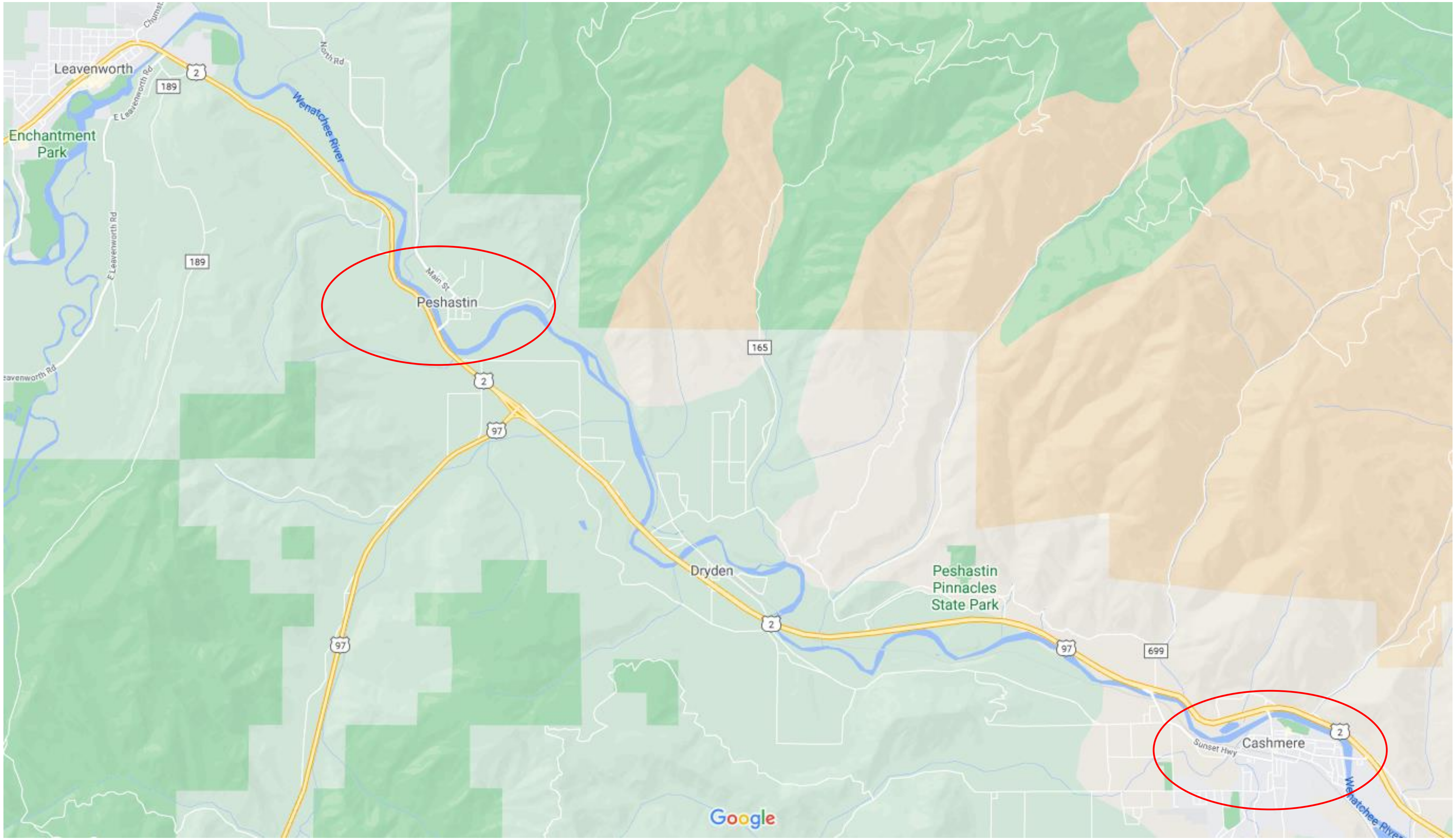
Sidestream Fermentation



Dave Stensel – Aerobic Granular Sludge

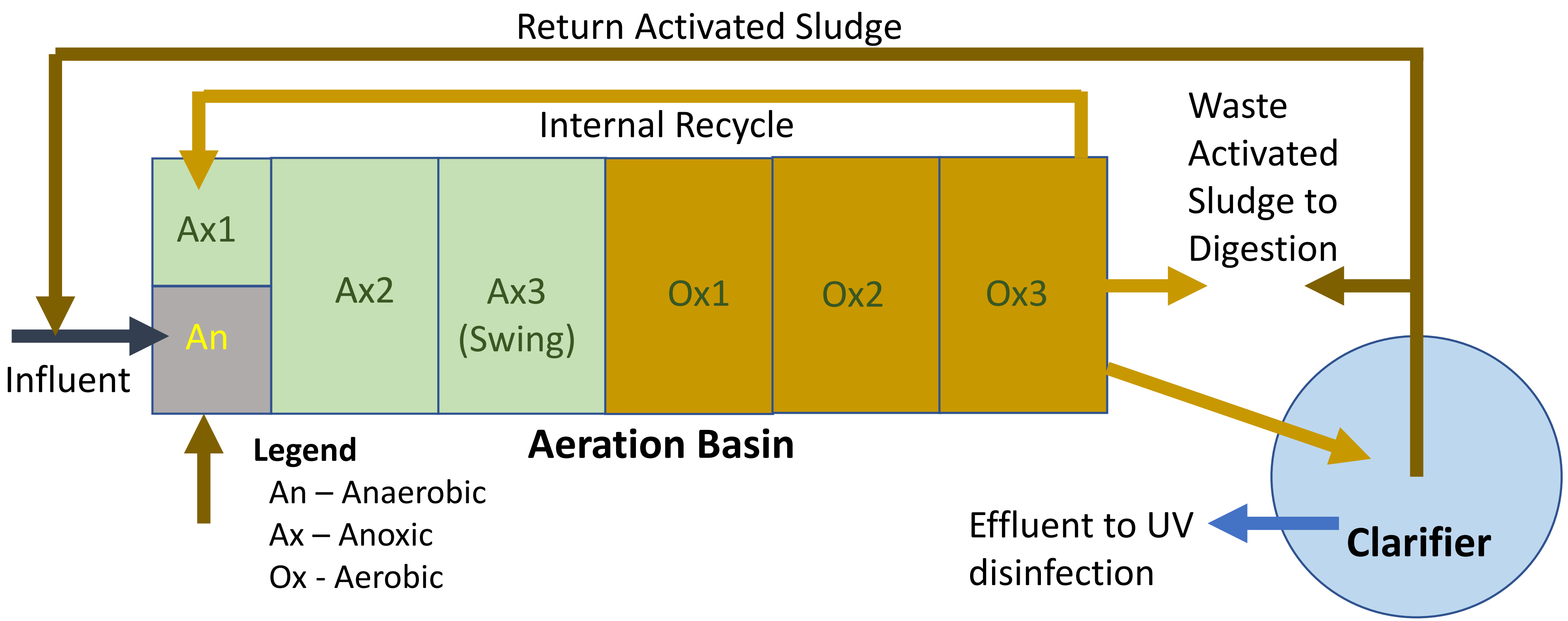
April Gu - Sidestream Fermentation

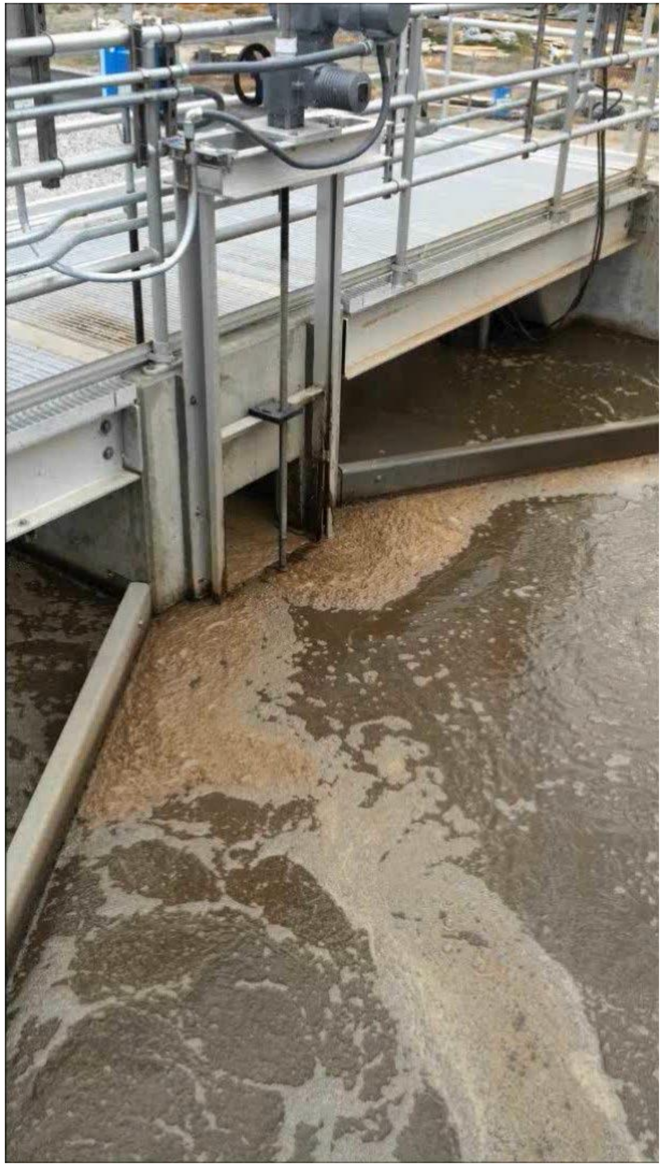
Case studies: Cashmere and Peshastin WWTPs



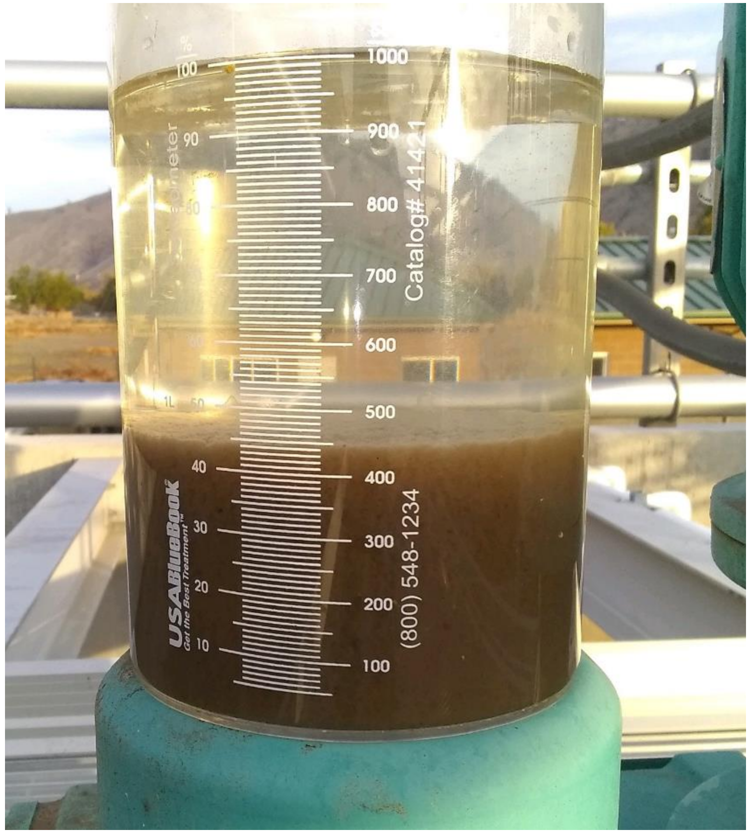
Cashmere WWTP – EBPR and Fermentation Case Study

Cashmere WWTP – Process Flow Schematic

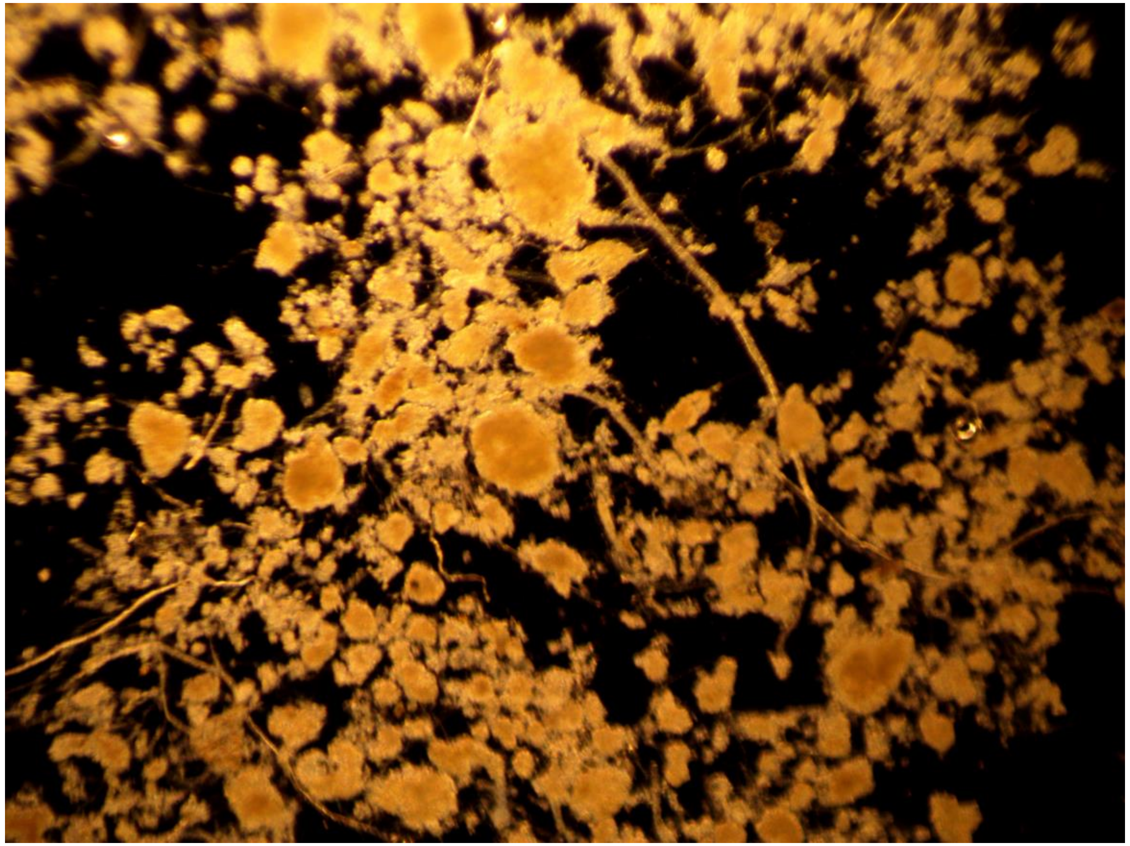




Cashmere WWTP – Settleability and Granule formation

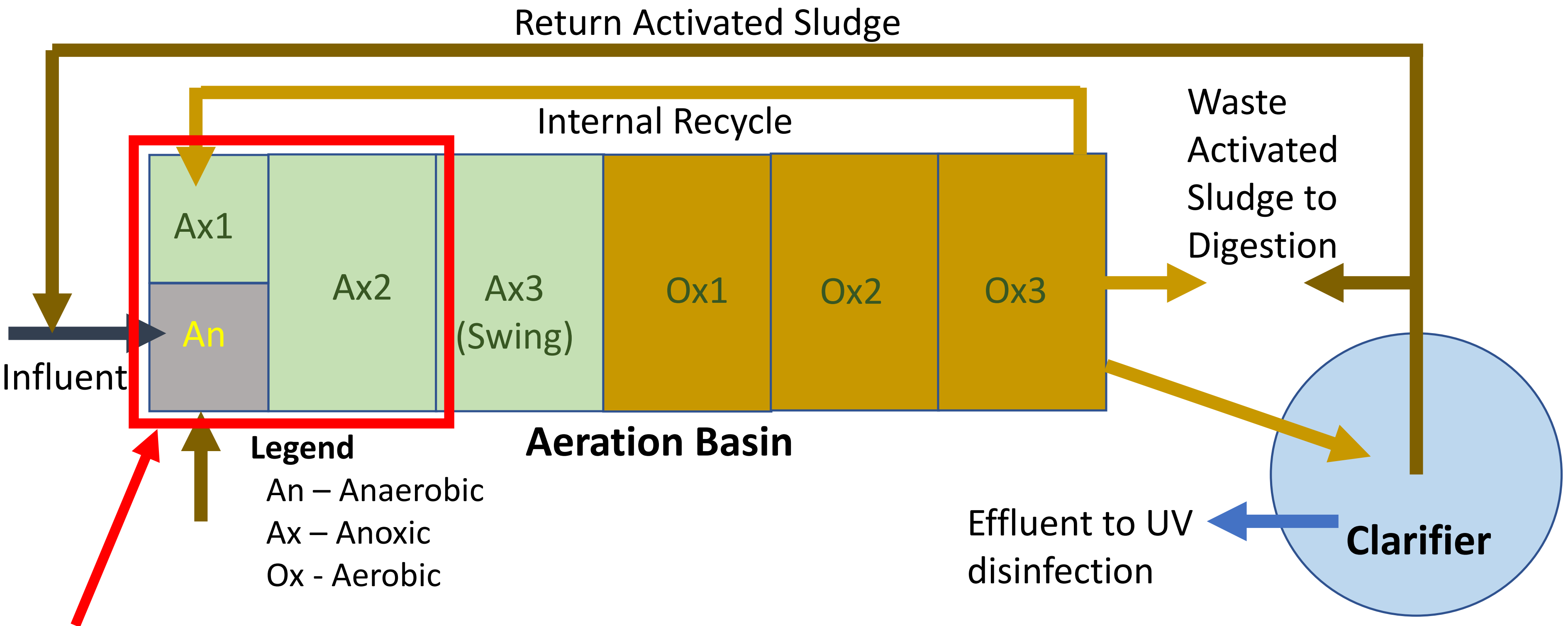


<u>*Photo from 10/15/19*</u>
30-MIN Settle: 440
MLSS: 7,400 MG/L
SVI: 59 mL/G



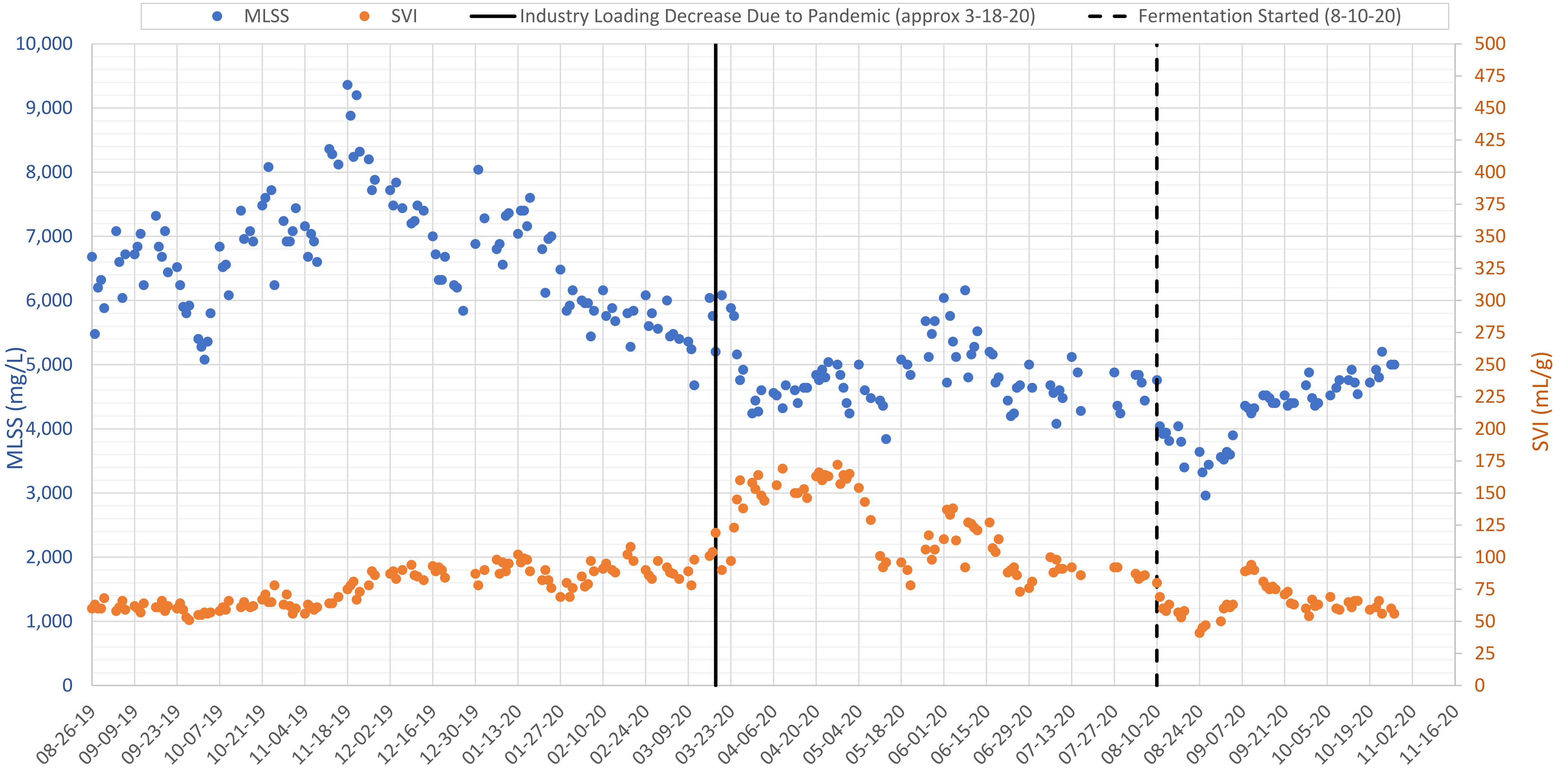
<u>*Stereo microphotograph from 11/15/19*</u>
Magnification approximately 35X.
Granules ranging in size from 200 to 600 microns

Cashmere WWTP – Mixed Liquor Fermentation Pilot Test

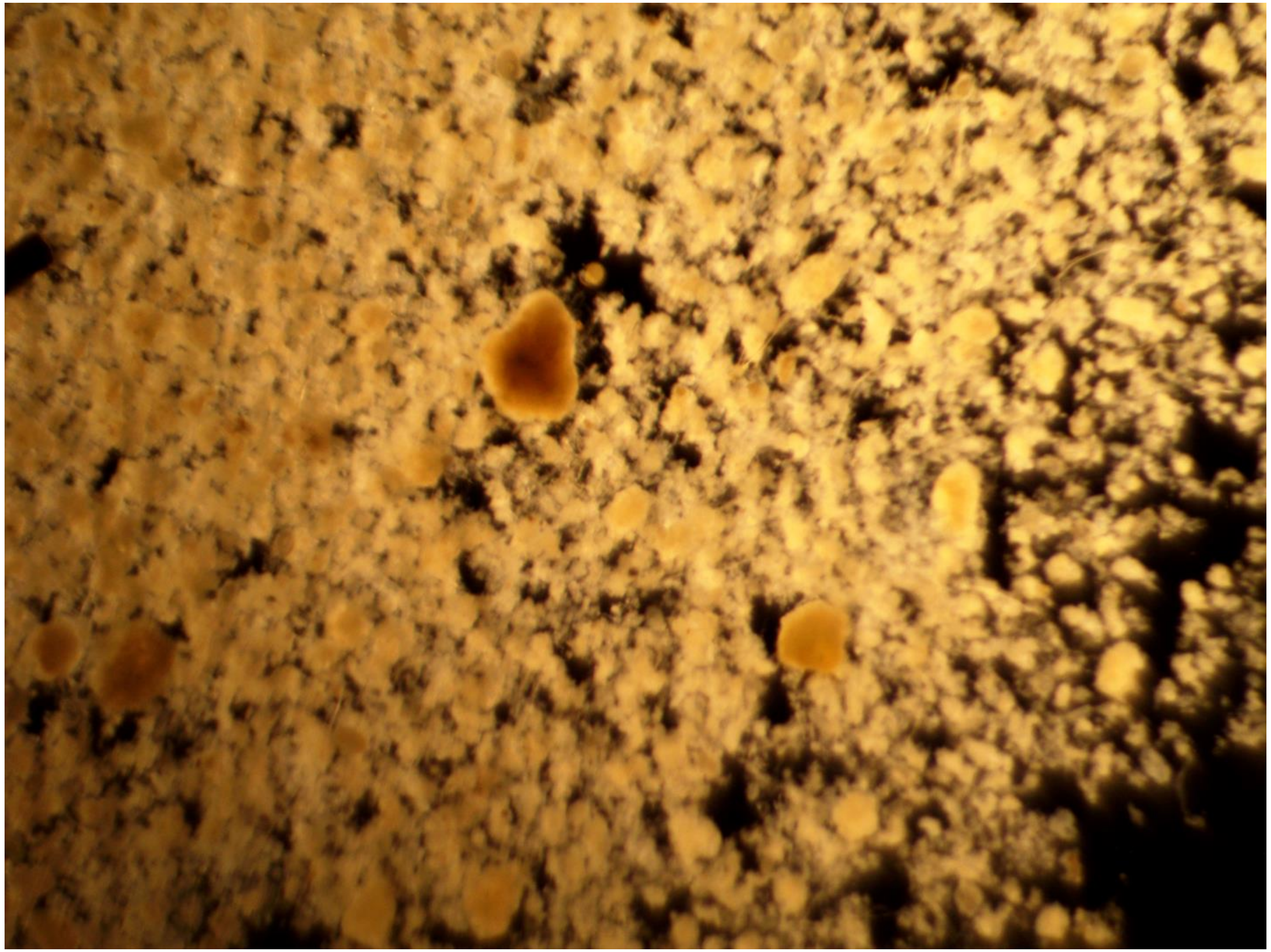


Fermentation pilot test – turn off mixers in An, Ax1 and Ax2 during the low flow period of the early morning hours (initially 4 AM to 7 AM).

Cashmere WWTP – Fermentation Pilot Test SVI data



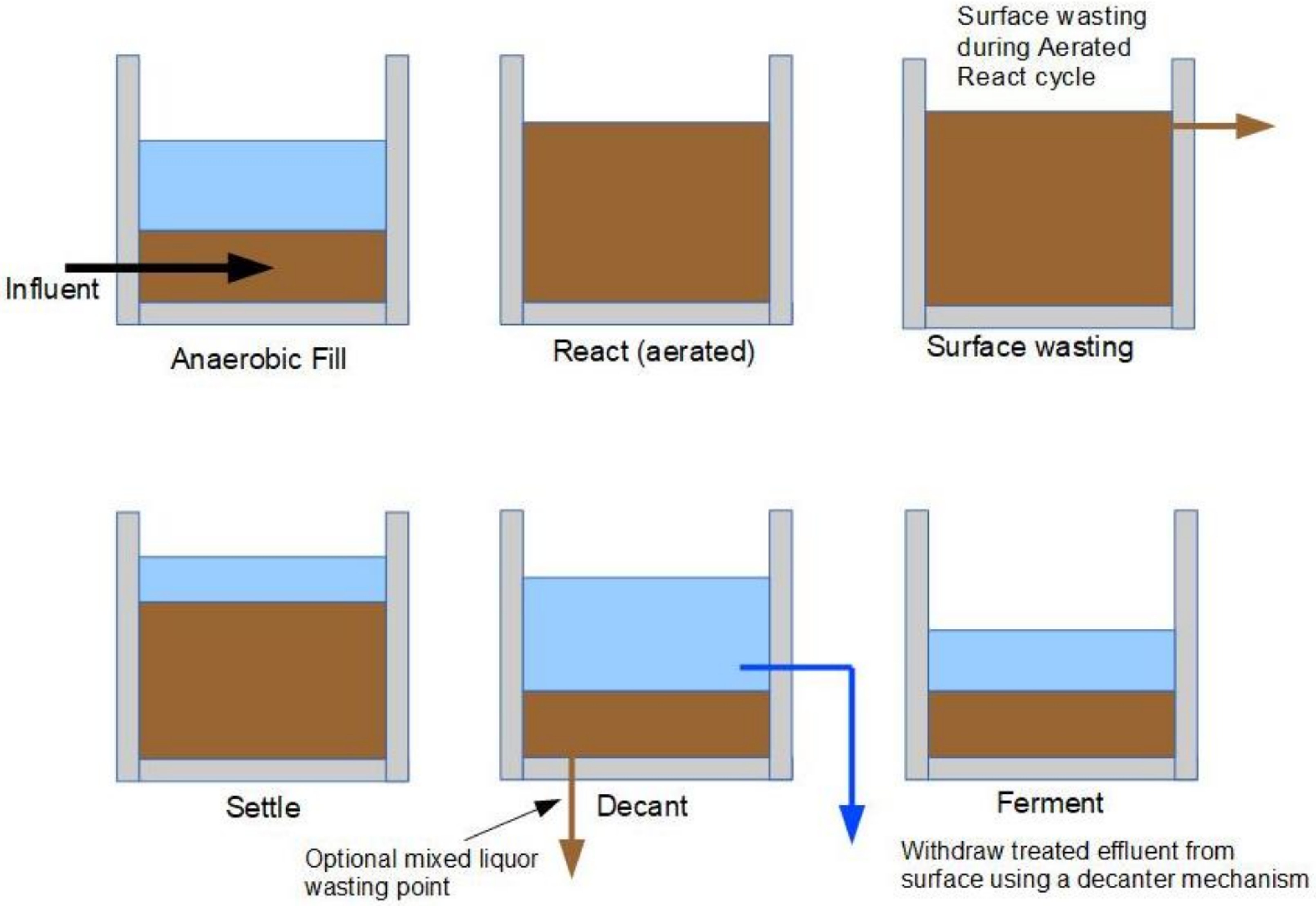
Cashmere WWTP – Fermentation Pilot Test observations

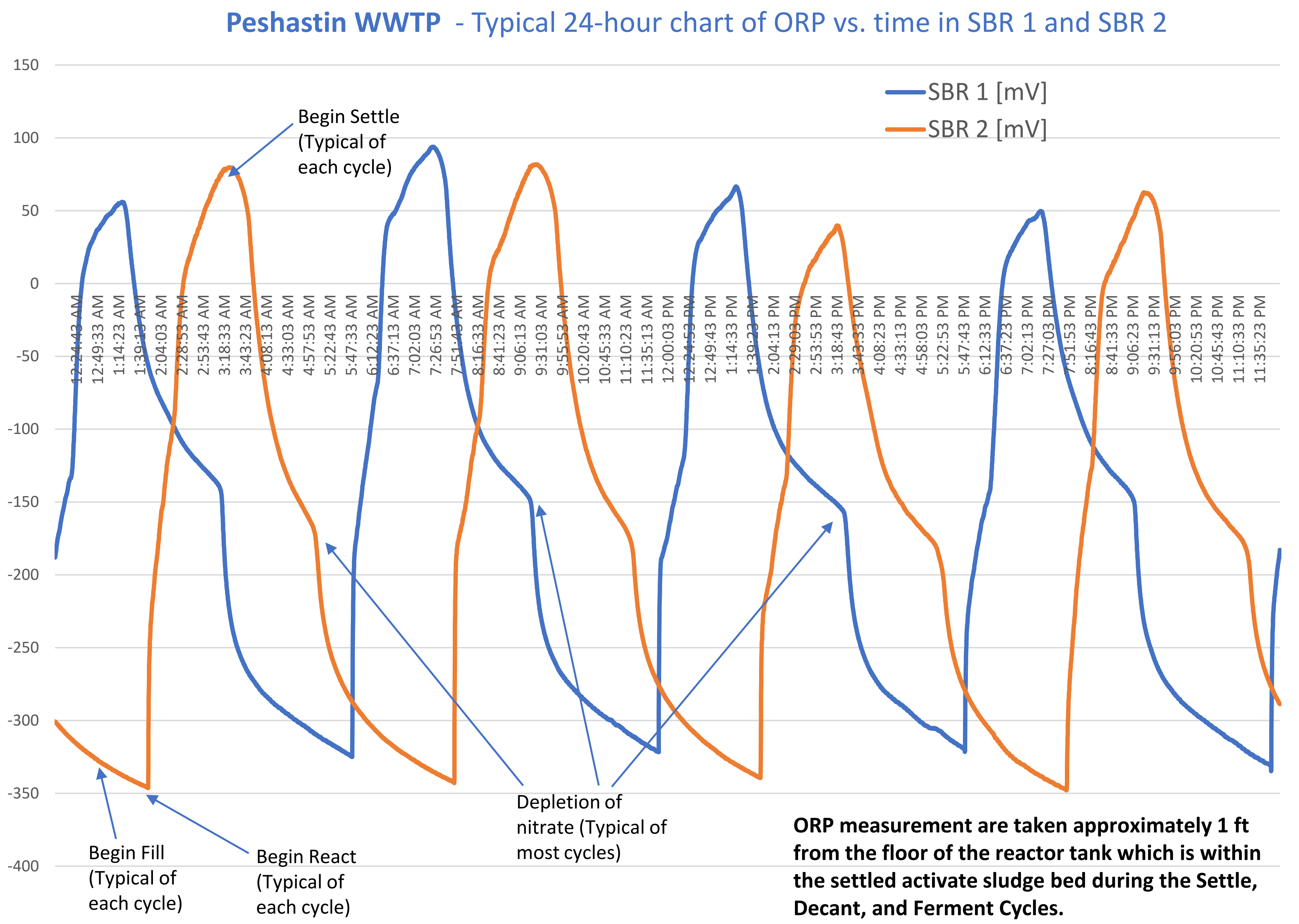


<u>Stereo microphotograph from 10/15/20</u>
Magnification approximately 15X.
Granules ranging in size from about 200 to 700 microns

Peshastin WWTP – Sequencing Batch Reactor Upgrade

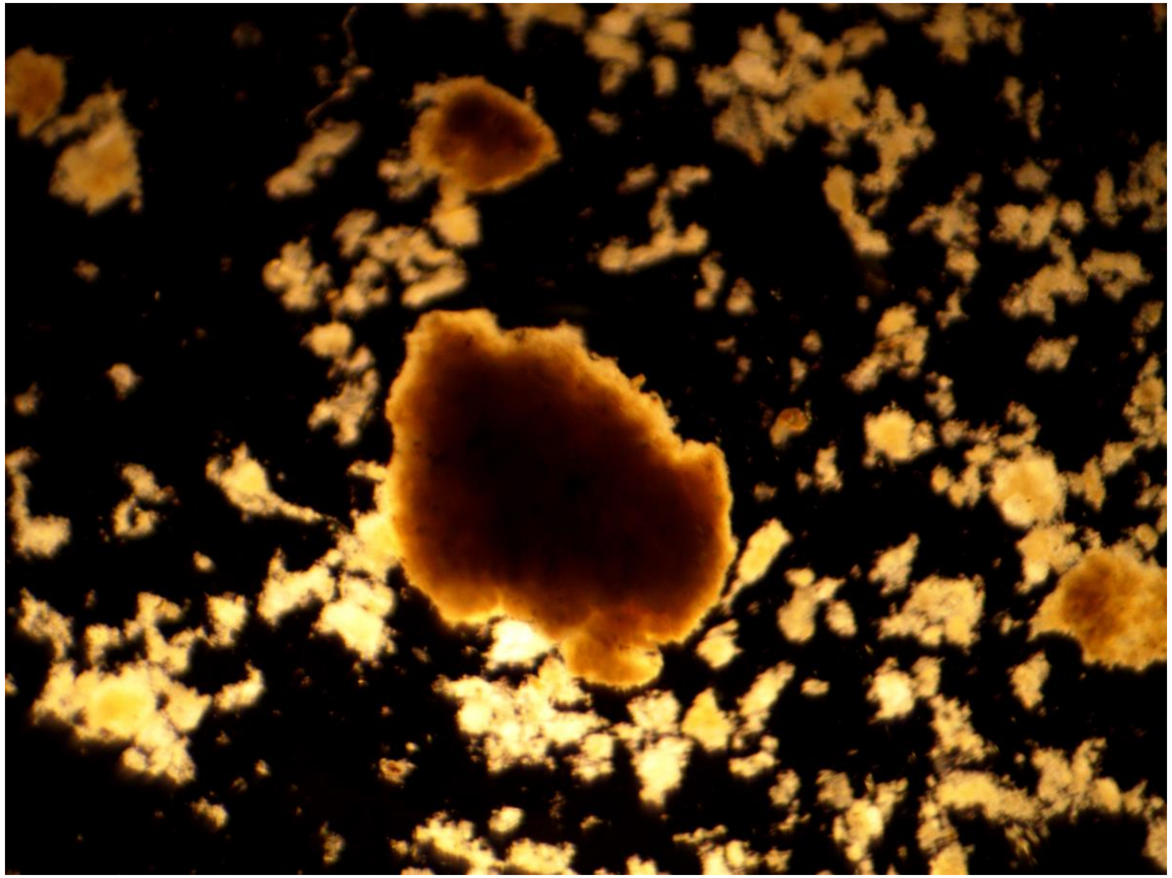
Peshastin WWTP – Sequencing Batch Reactor Cycles



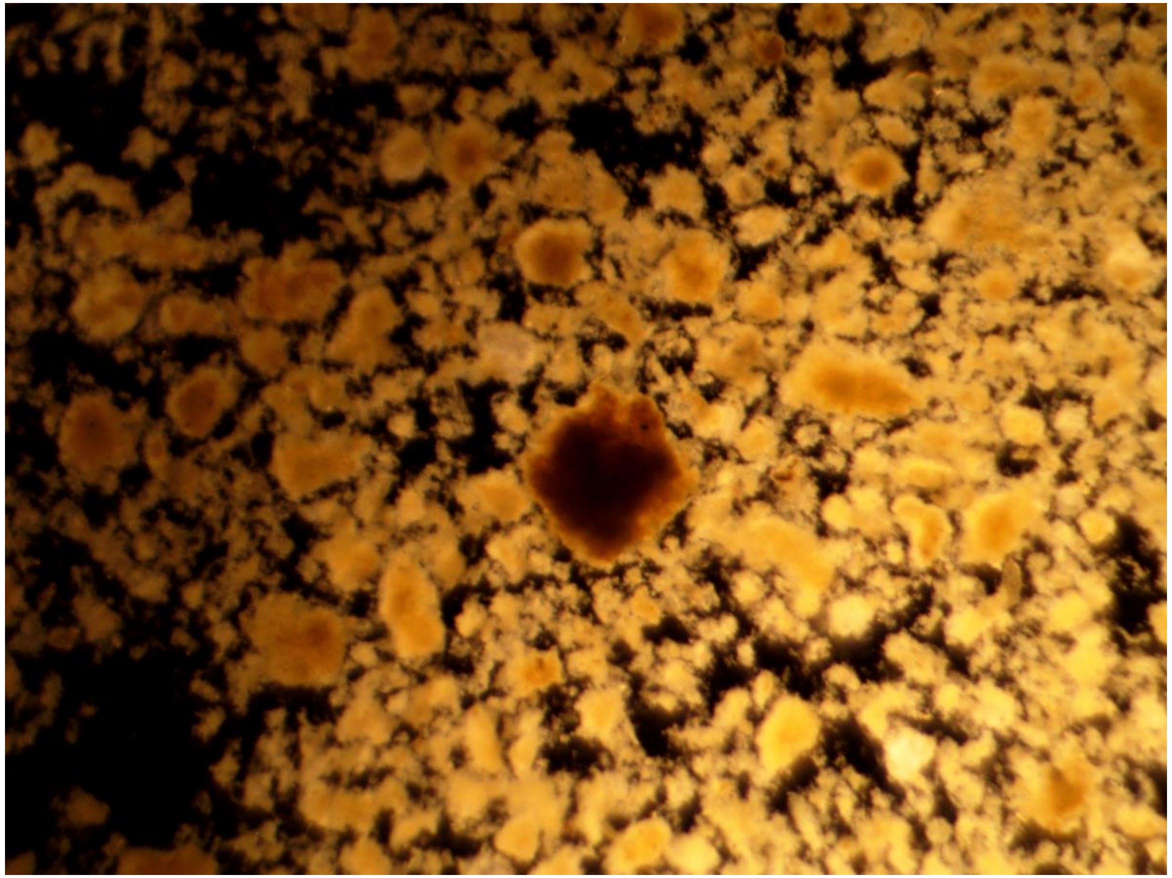

Peshastin WWTP - Typical 24-hour chart of ORP vs. time in SBR 1 and SBR 2
SBR 1 [mV]
SBR 2 [mV]
150
100
50
0
-50
-100
-150
-200
-250
-300
-350
-400
Begin Settle (Typical of each cycle)
Begin Fill (Typical of each cycle)
Begin React (Typical of each cycle)
Depletion of nitrate (Typical of most cycles)
ORP measurement are taken approximately 1 ft from the floor of the reactor tank which is within the settled activate sludge bed during the Settle, Decant, and Ferment Cycles.

Peshastin WWTP – Surface Wasting System

Peshastin WWTP – stereo photomicrographs of granules

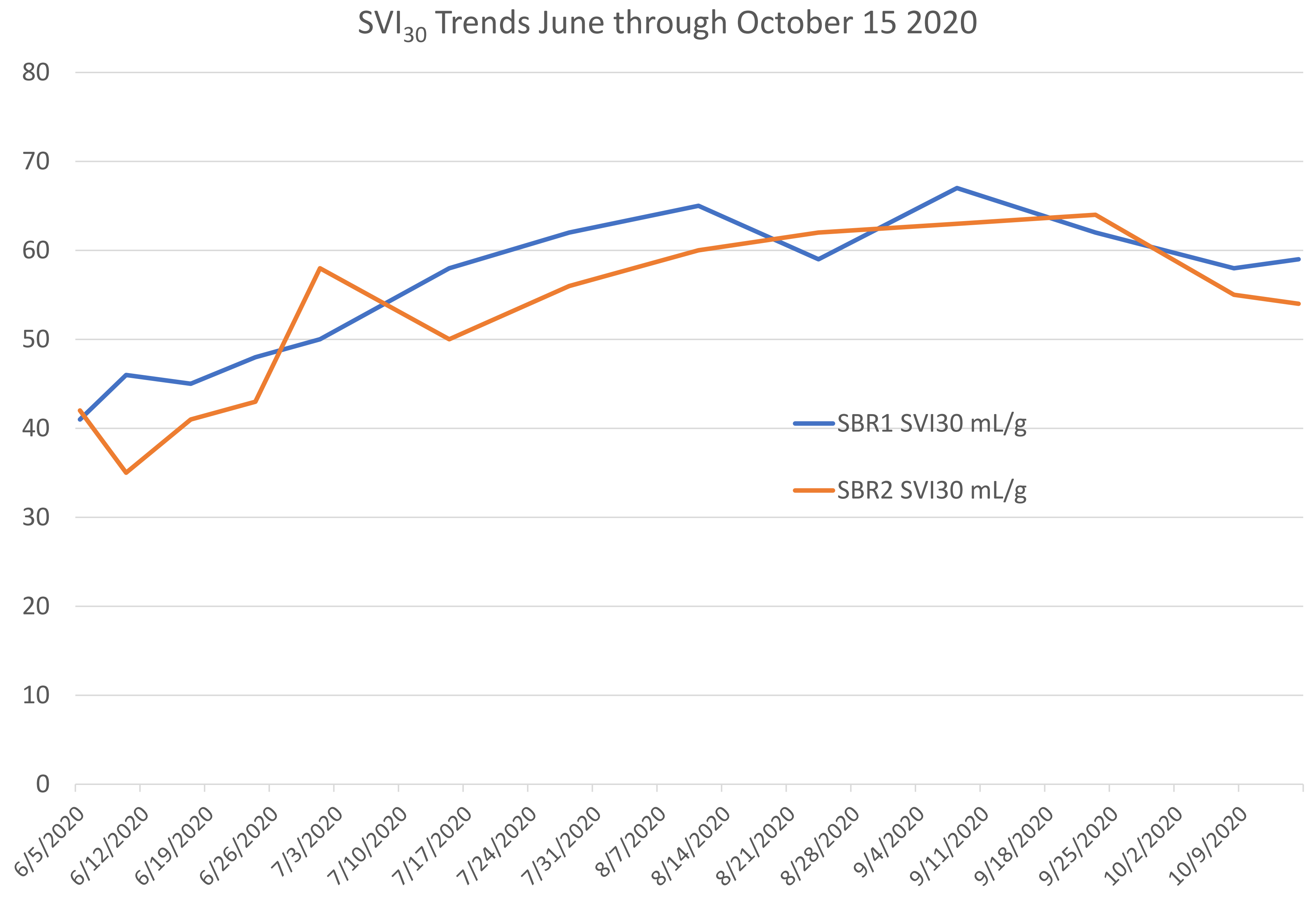


<u>Stereo microphotograph from 7/15/20</u>
Magnification approximately 15X.
Granule in the center is approximately 2 mm



<u>Stereo microphotograph from 7/15/20</u>
Magnification approximately 15X.
Granule in the center is approximately 1 mm

Peshastin WWTP   SVI trends June – October 2020



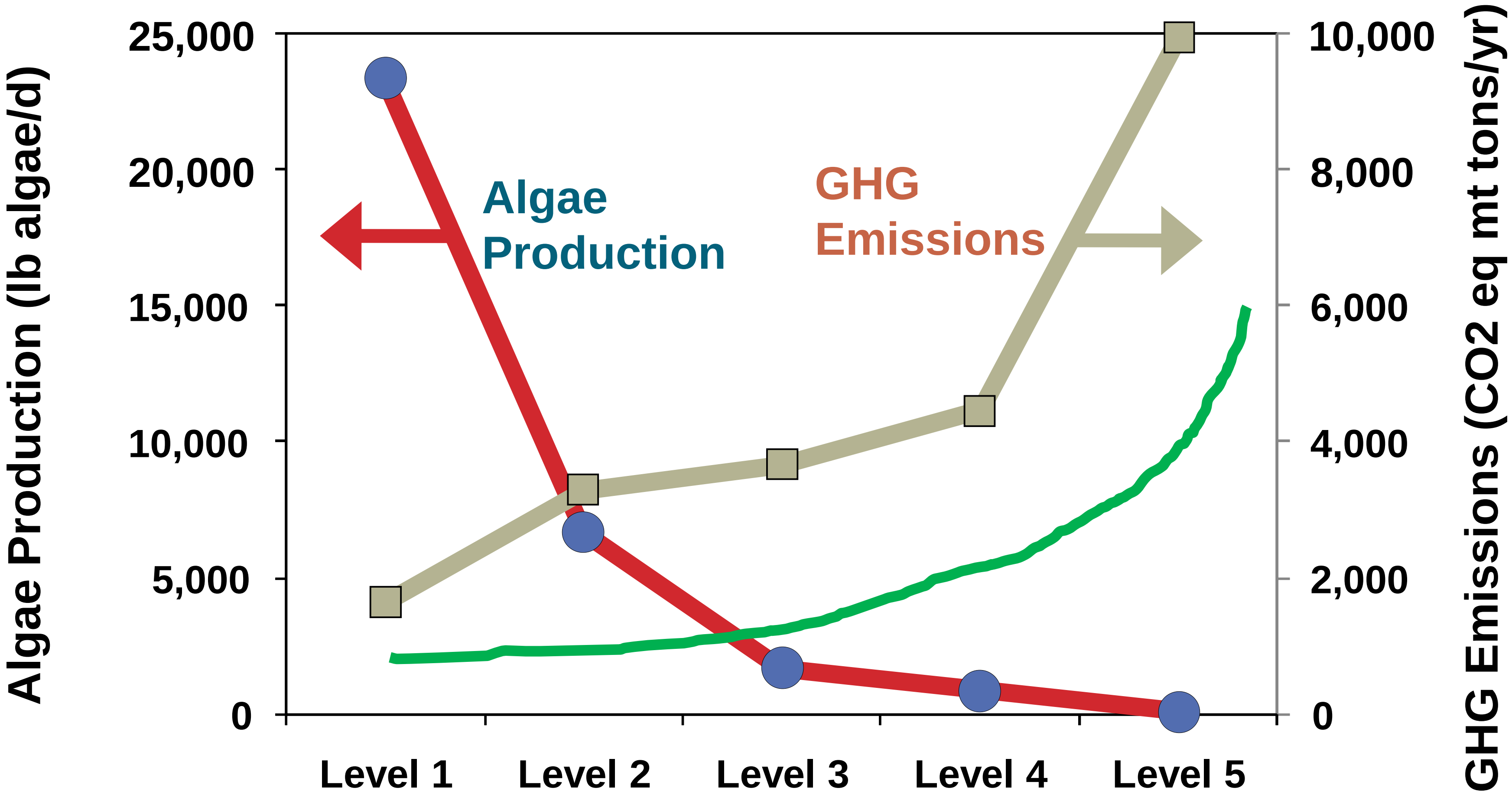
Striking a Balance Between Nutrient Removal in Point Sources and Sustainability

Environmental Stewardship

Greenhouse Gas

Adapted from Water Environment Research Foundation Report (December 2010)

Algae Production Potential vs GHG



Level	TN (mg/L)	TP (mg/L)
1	-	-
2	8	1
3	4-8	0.1-0.3
4	3	<0.1
5	1	<0.01

Note: Assumes Algae Comprised of 10% N and 1% P

Adapted from Water Environment Research Foundation Report (December 2010)

Questions

Discussion

Next Steps?