West Boise WWTF Use of Struvite Crystallization Technology as Part of the Phosphorus Removal Plan

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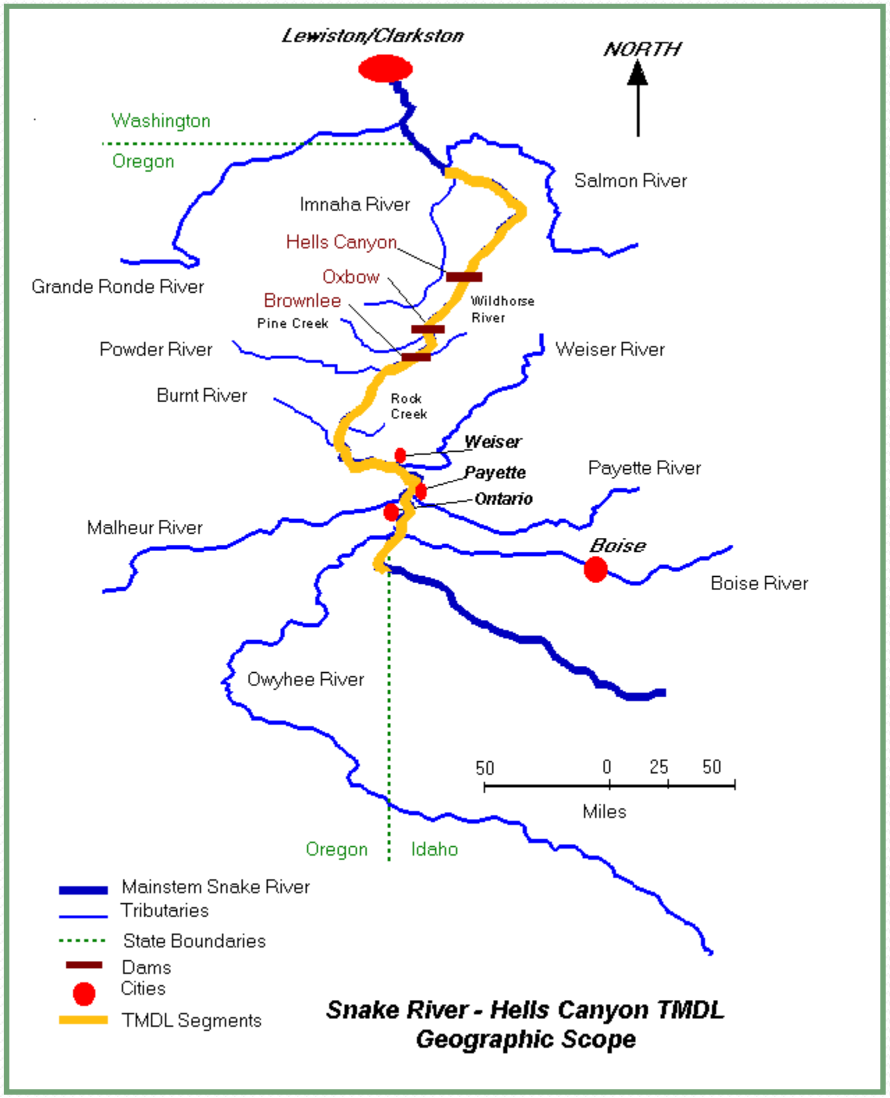
- Keith Bowers, PhD, Multiform Harvest Inc.

BOISE CITY OF TREES

Multiform Harvest Inc

PE PHARMER ENGINEERING LLC

Snake River / Hells Canyon TMDL

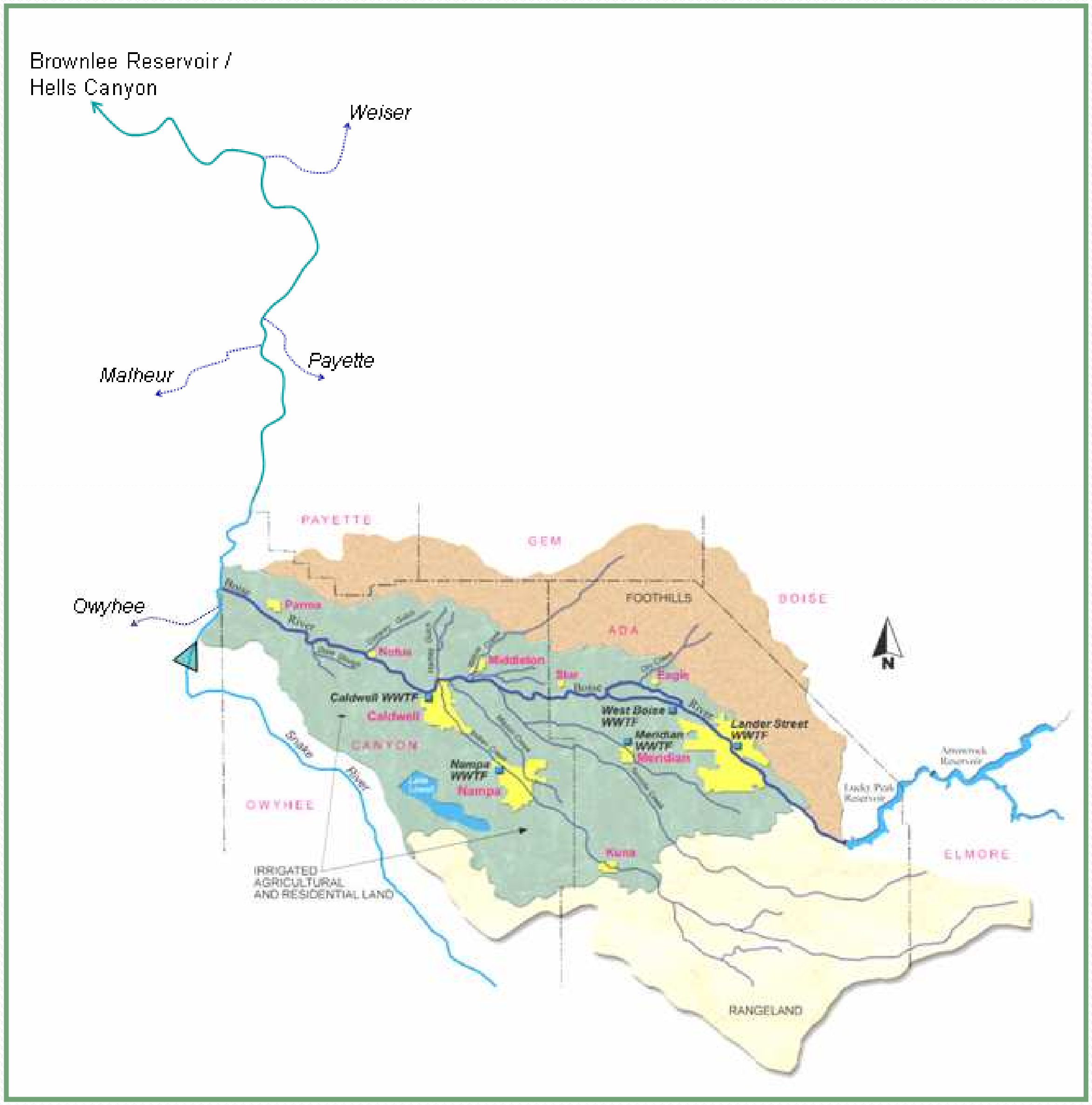


- >220 River Miles
- Extremely complex and highly modified
- Phase approach (50 to 70 years implementation)
- 8 Pollutants (bacteria, nutrients, mercury, pesticides, sediment, temperature, TDG, pH)
- Approved for 4 Pollutants (nutrients, pesticides, sediment, TDG)
- Nutrient Target 0.07 mg/L for five tributaries (Boise, Payette, Weiser, Owyhee, Malhuer)

Per Robbin Finch
City of Boise

Lower Boise WWTF Target

- Total phosphorus at mouth, 0.07 mg/L
- IDEQ 2008 Point Source Targets at 0.200 mg/L TP for May through September
- EPA prefers point source allocations at 0.07 mg/L TP, monthly basis



Per Robbin Finch
City of Boise

City of Boise WWTFs

- **Lander Street WWTF.** Activated sludge and Class B digestion. Digested sludge pumped to West Boise
- **West Boise WWTF**. Activated sludge in two plants, Class B digestion, and dewatering of both plant's biosolids
- **Twenty Mile South Farm.** City owned land application site for WWTF biosolids. Soil phosphorus load is an future challenge.

City of Boise WWTF Phosphorus Removal Work Partial List

- Mid 1990s Facility Planning
- Studies at Lander Street WWTF and West Boise WWTF around 2000-2001
- Other work 2002 and
- Pilot work in 2003
- West Boise hands on work 2006 and 2008
- West Boise Phosphorus, 2007 to present

  (Target was 1.0 mg/L Total Phosphorus)

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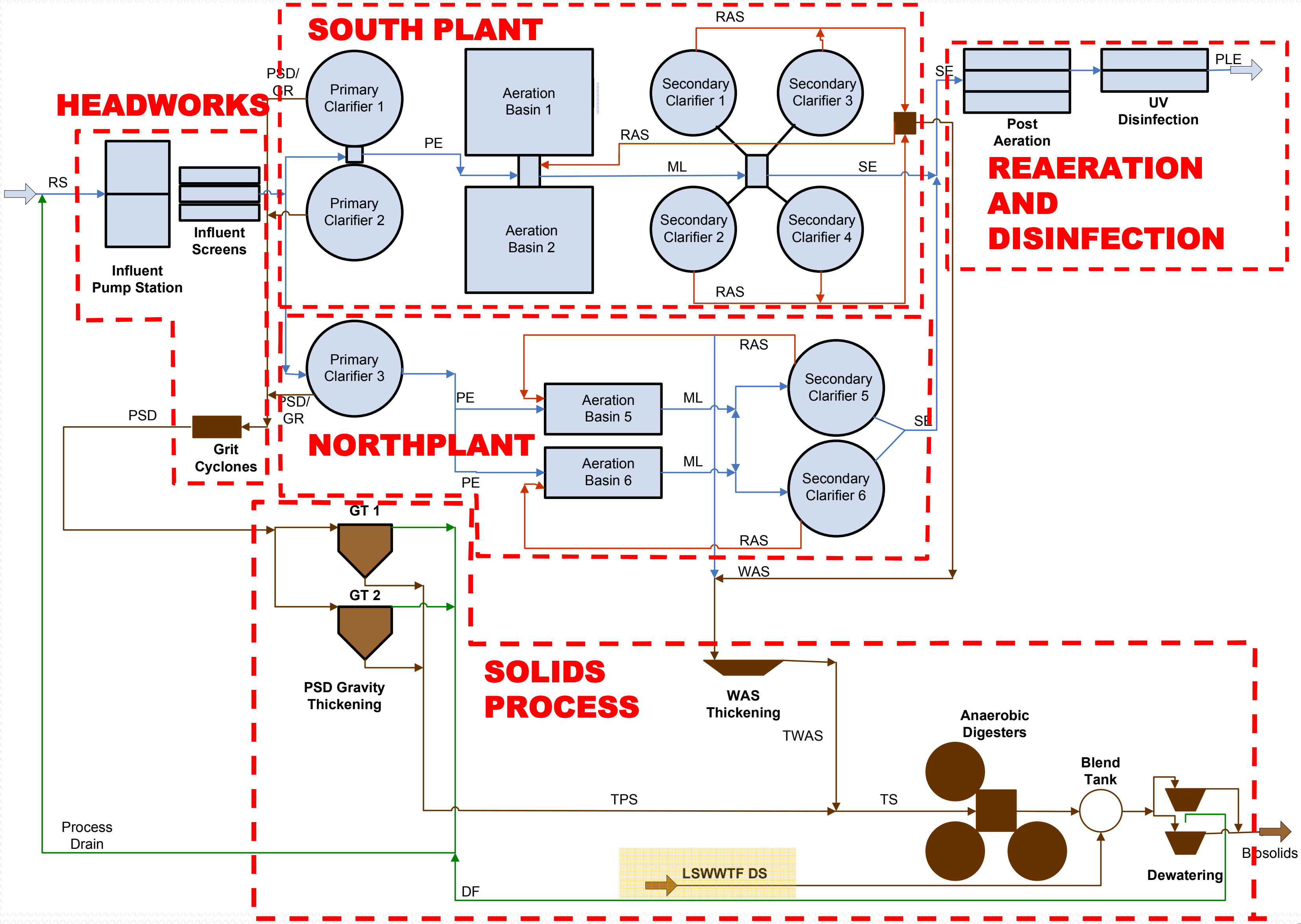
City of Boise WWTF Phosphorus Removal Project Objectives

Find solutions for the following potential permit limits:

- 1.0 mg/L Total P
- 0.2 mg/L Total P
- 0.07 mg/L Total P

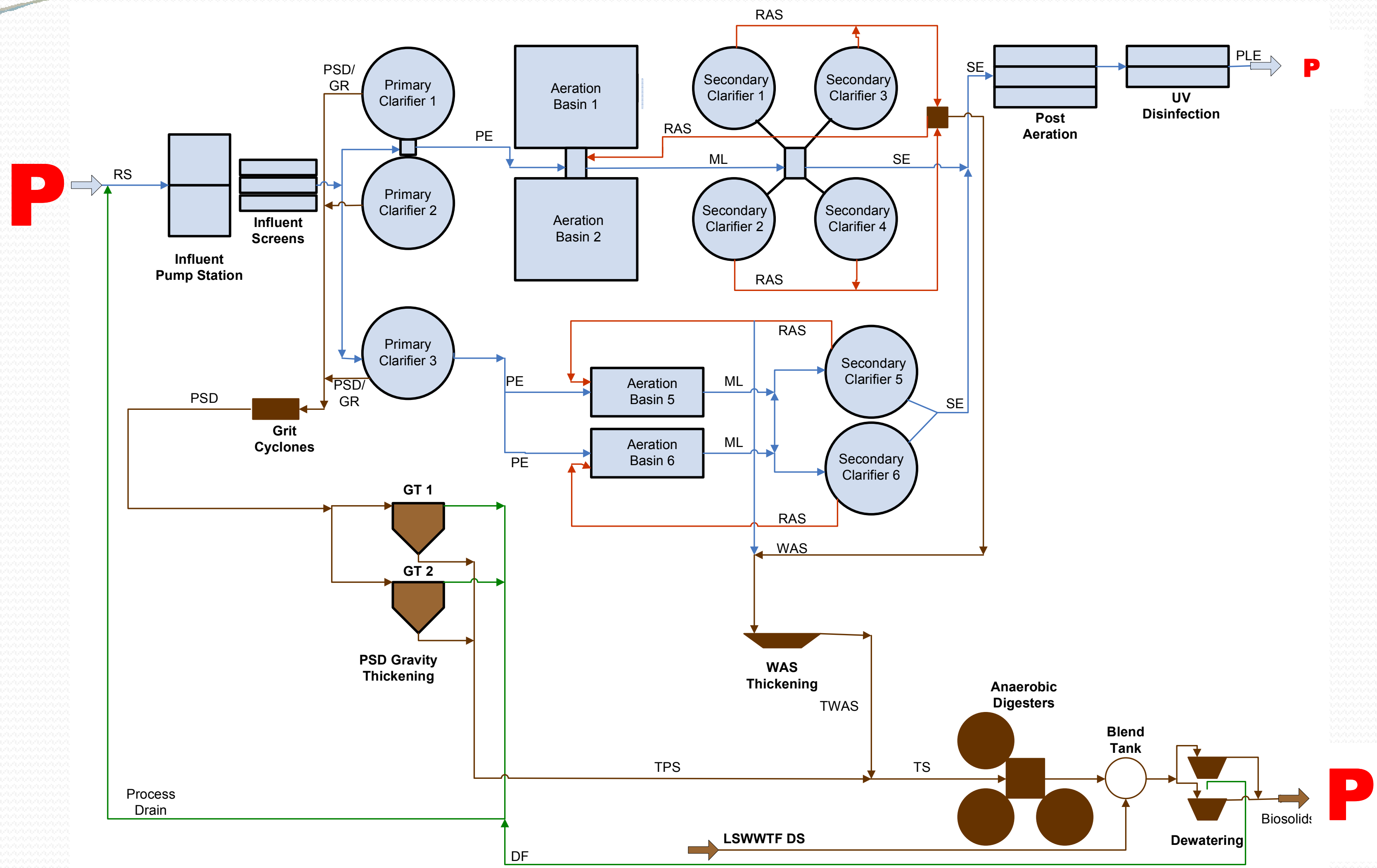
West Boise WWTF



PFD BY

CH2MHILL

Phosphorus Removal



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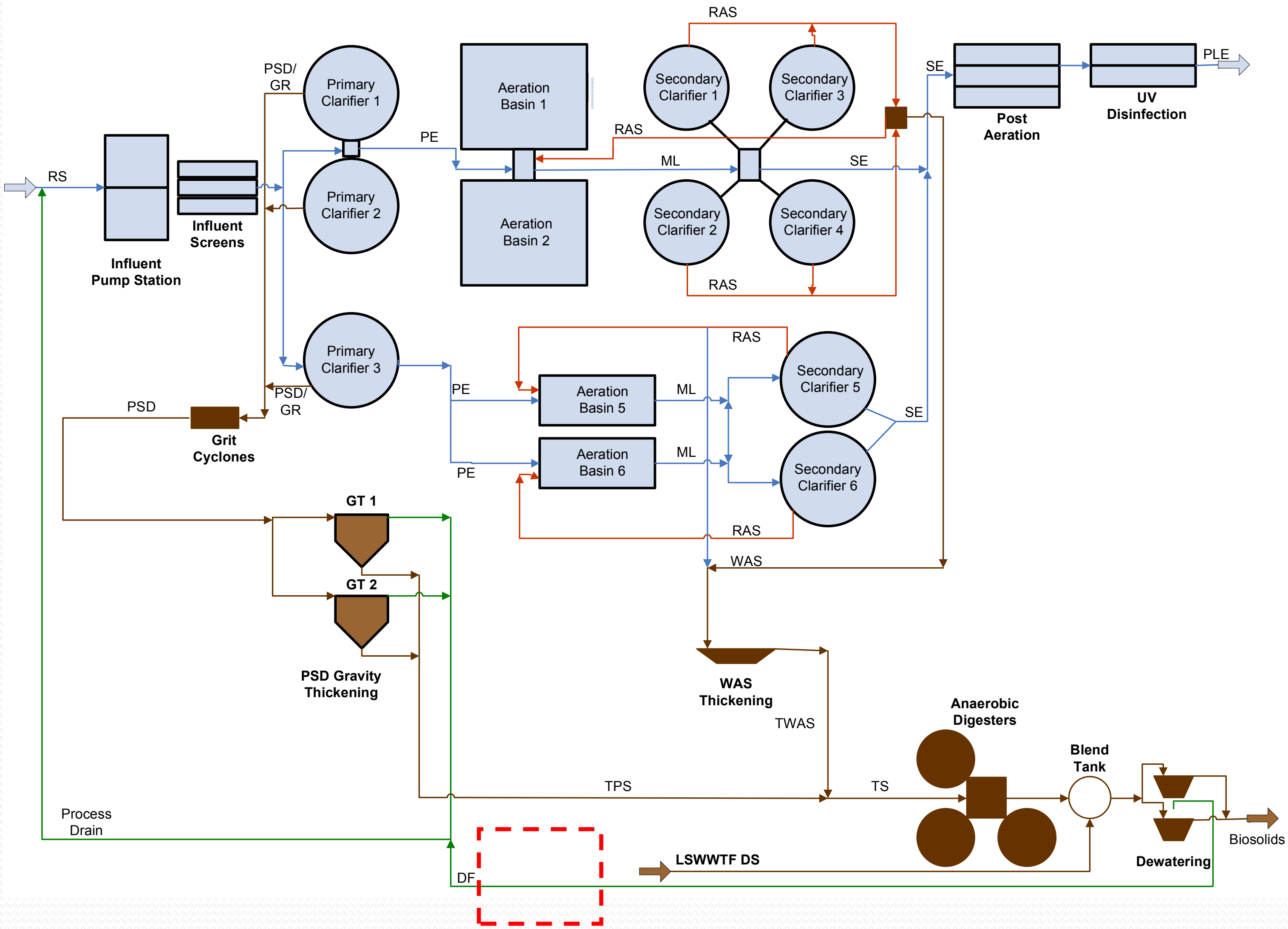
Phosphorus Removal at Filtrate



FILTRATE TREATMENT HERE

PFD BY CH2MHILL

Choices for Filtrate/Sidestream Treatment for Phosphorus for West Boise WWTF Project

- Metal Salts, Aluminum or Iron
- Intentional Struvite Crystallization

What is Struvite

- Magnesium Ammonium Phosphate Hexahydrate

  ($MgNH_4PO_4$-$6H_2O$)
- Sparingly soluble crystalline compound
- Good slow release fertilizer

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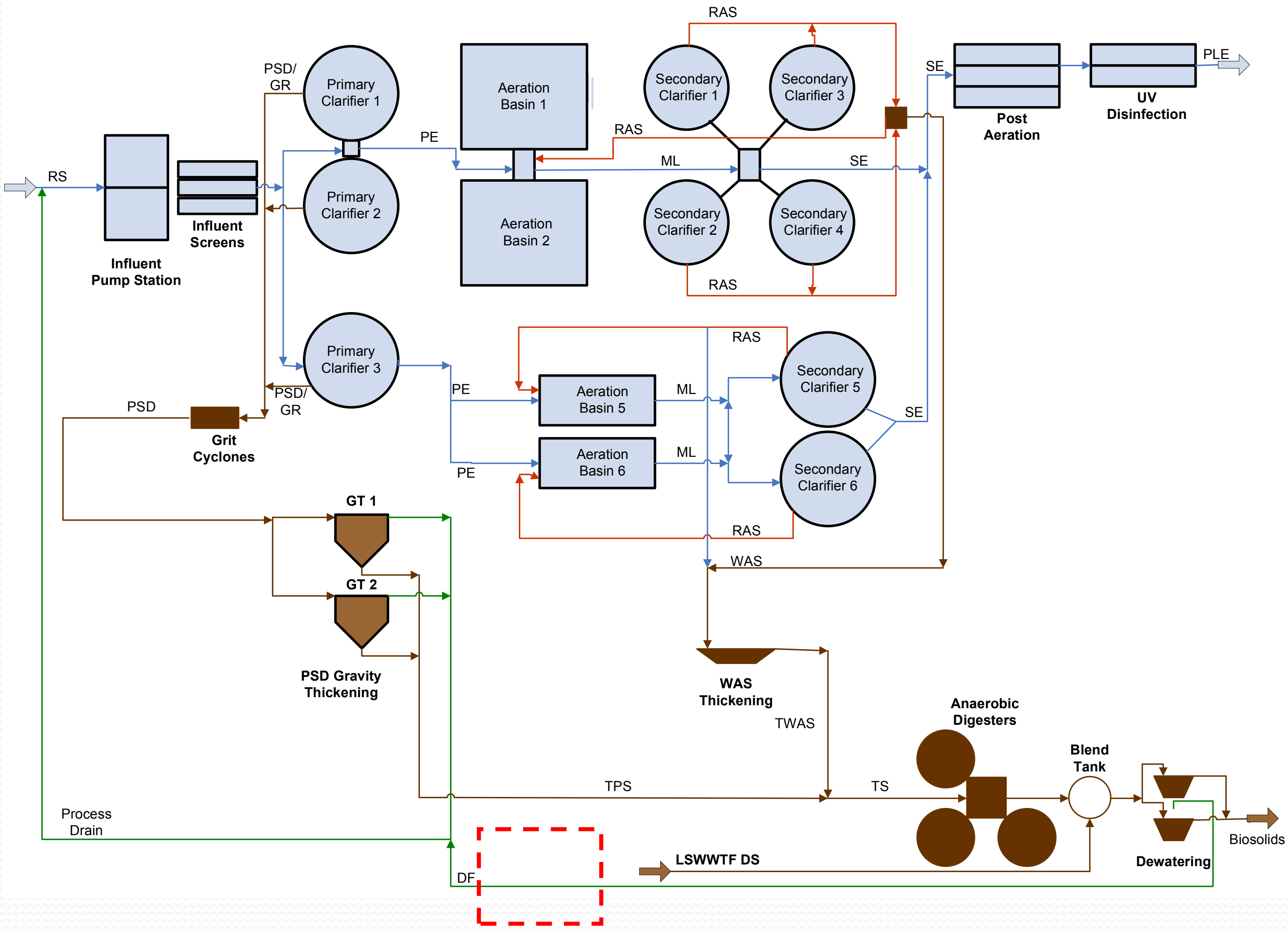
Phosphorus Removal at Filtrate



FILTRATE TREATMENT HERE

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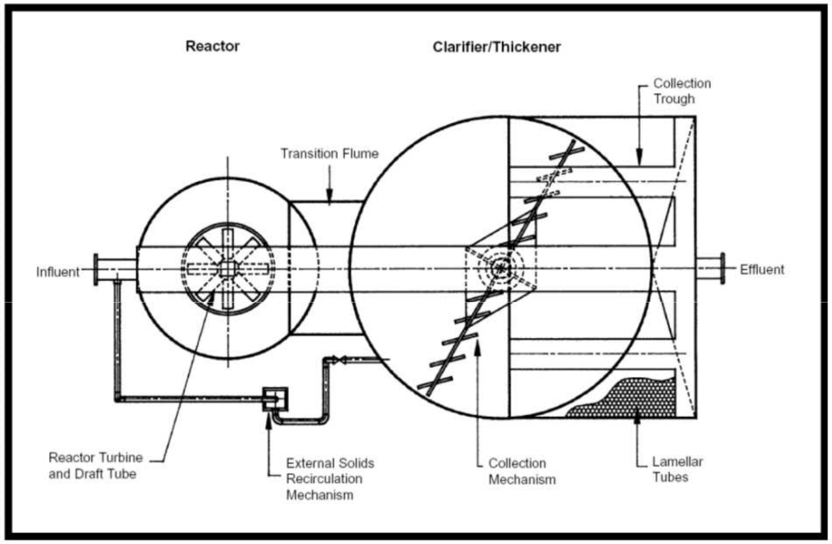
West Boise WWTF Filtrate Treatment Evaluation 2002

Considered

- Evaluated various approaches to high strength filtrate treatment
- Metal Salts (Ferric, Alum, Sodium Aluminate)
- Intentional struvite precipitation
- Ammonia recovery



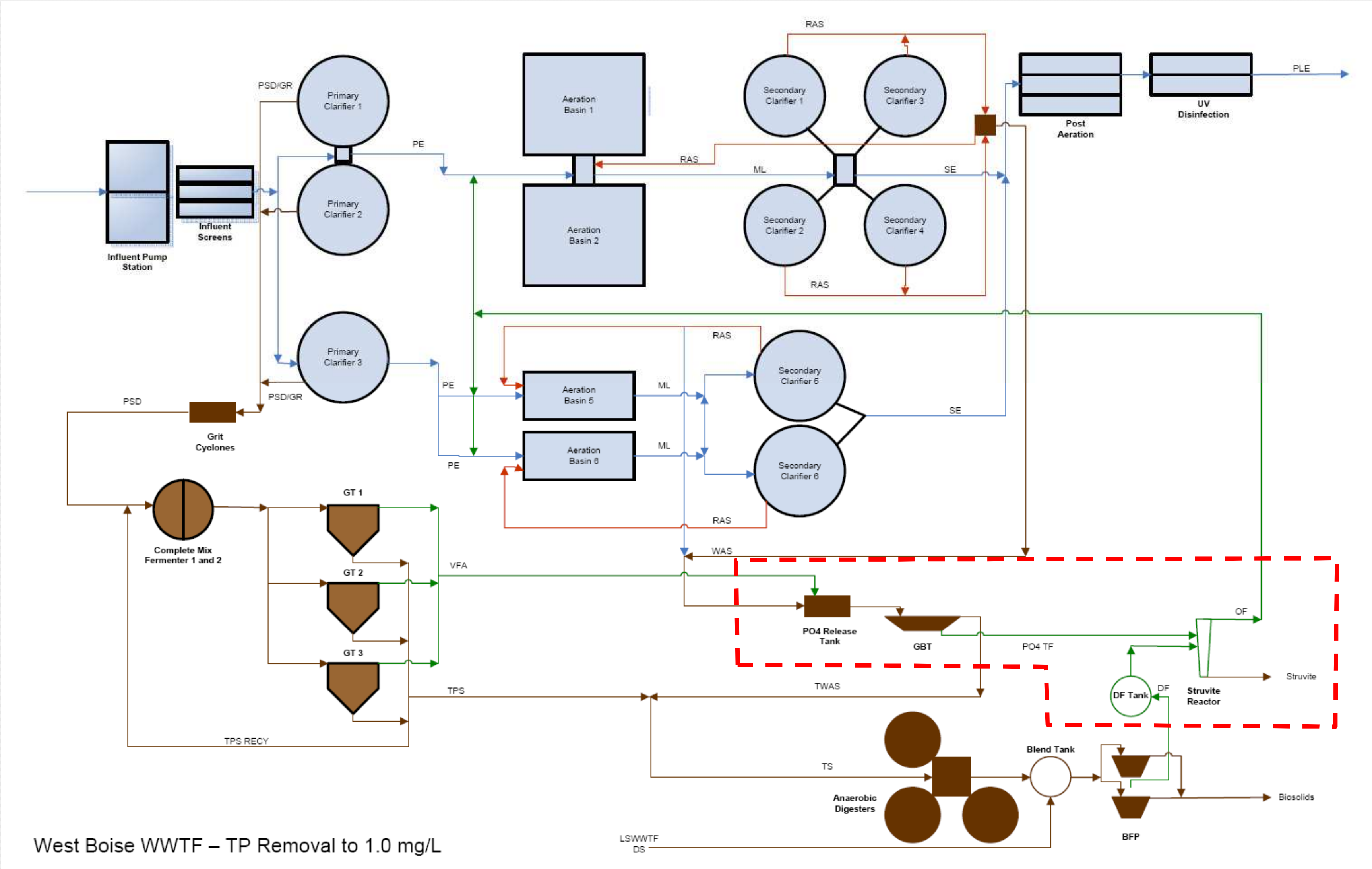
Struvite w/ a solids contact softening reactor?

Findings

- Ferric was less expensive at the time
- Struvite appeared competitive, within 10% of chemical only option

Integrated Sidestream Alt. BK2f

(Presented to group January 2008)



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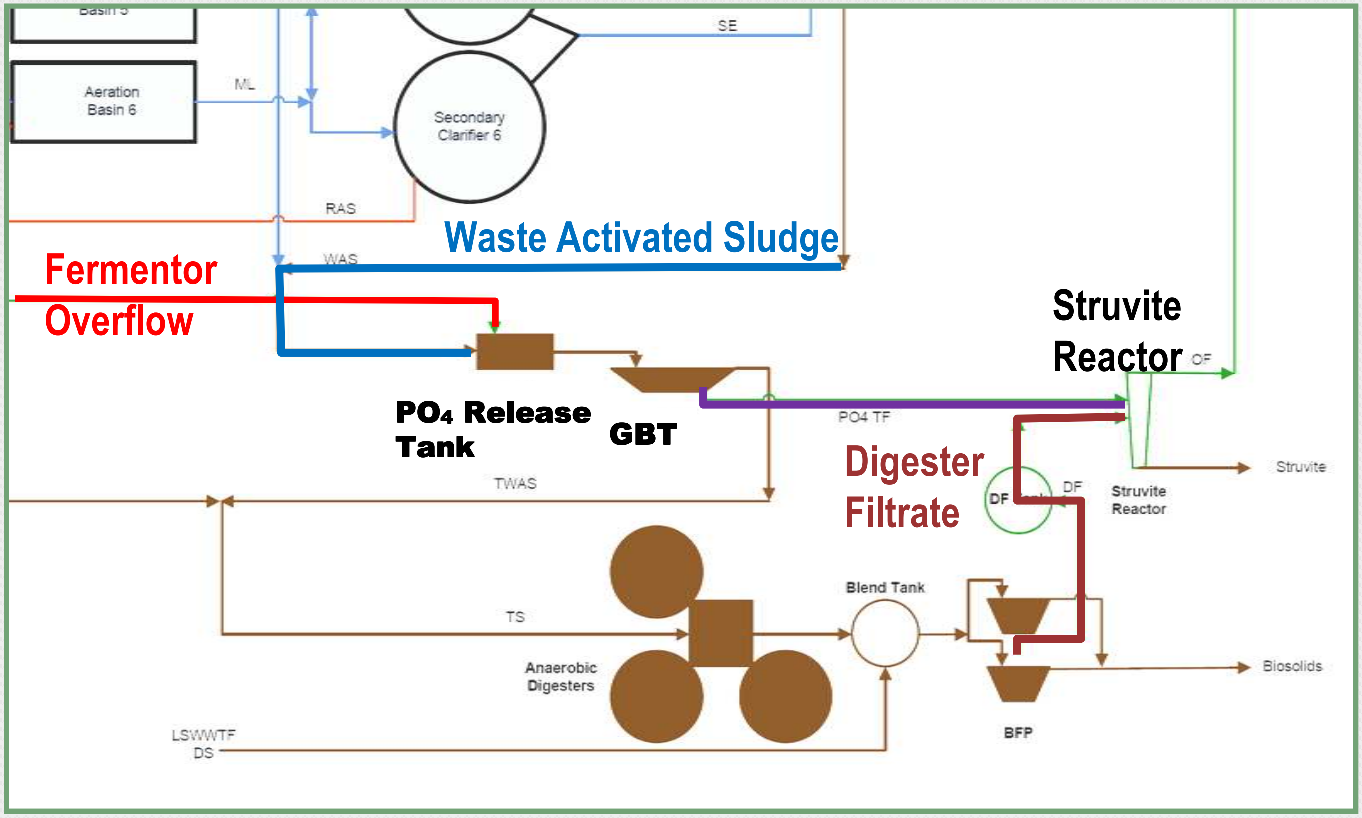
Integrated Sidestream – Alt. BK2f

Phosphorus Release Tank

- WAS + High VFA stream, anaerobic release (contains high ortho-P and some magnesium)
- Remove phosphorus before digestion

Digester Filtrate

- Contains high ammonia



Combine two streams at struvite reactor

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2008 Struvite Pilot

2008 Struvite Pilot

- Reactor and Pilot Work by <u>Dr. Keith Bowers Multiform Harvest Inc</u>
- Upflow fluidized bed reactor
- ~7 Minute HRT
- Dose influent and reagents at bottom
- Harvest from bottom

2008 Struvite Pilot

Ortho-Phosphate in Testing Periods

Period 1: Existing Belt Press Filtrate, Approx 65 mg/L Ortho-P, Small pH boost ~0.5 units,

Period 2: Simulated higher concentration with 150 mg/L Ortho-P augmented with phosphoric acid

Period 3: Simulated higher concentration with >1,000 mg/L Ortho-P augmented with phosphoric acid

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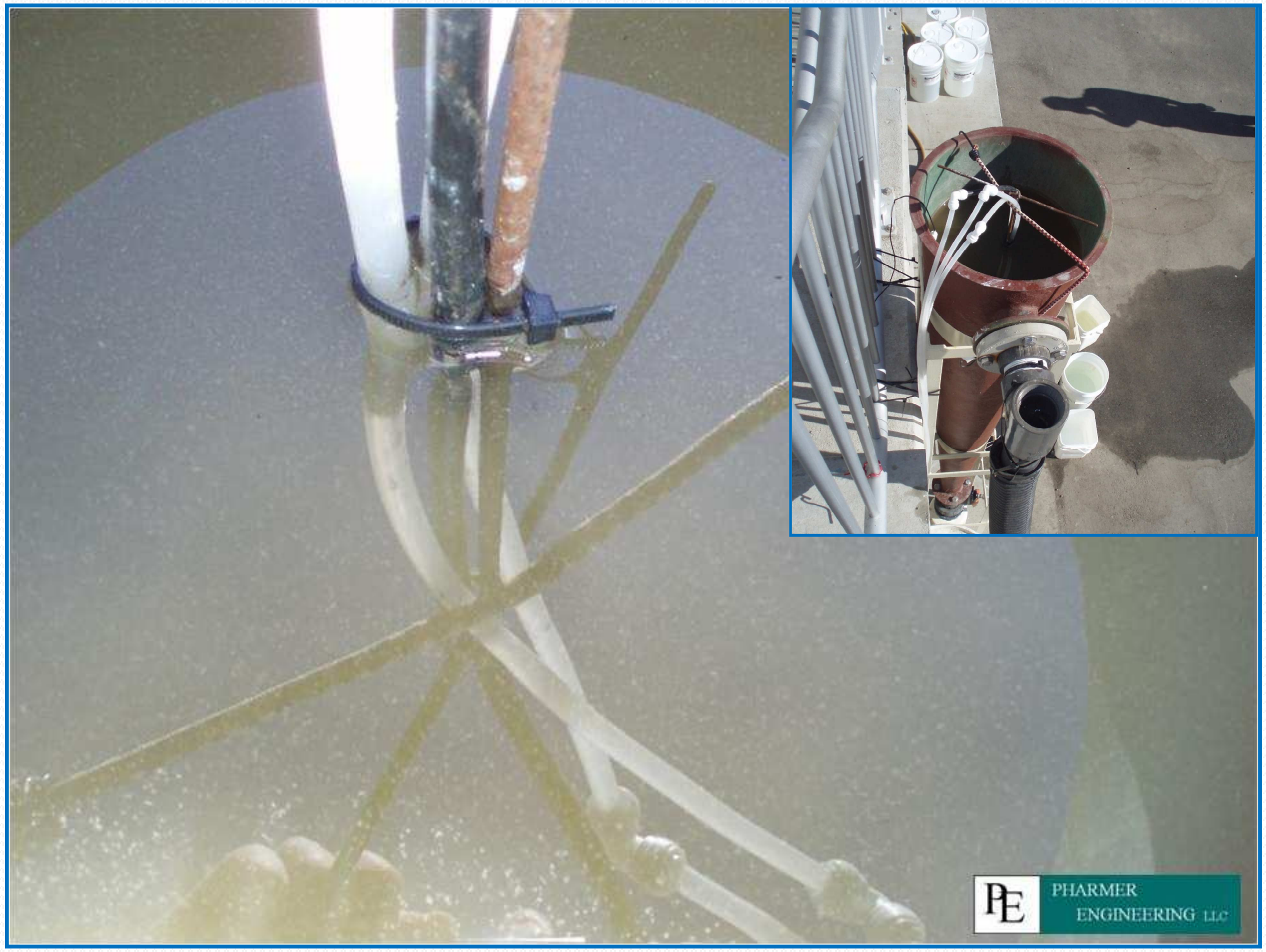
2008 Struvite Pilot

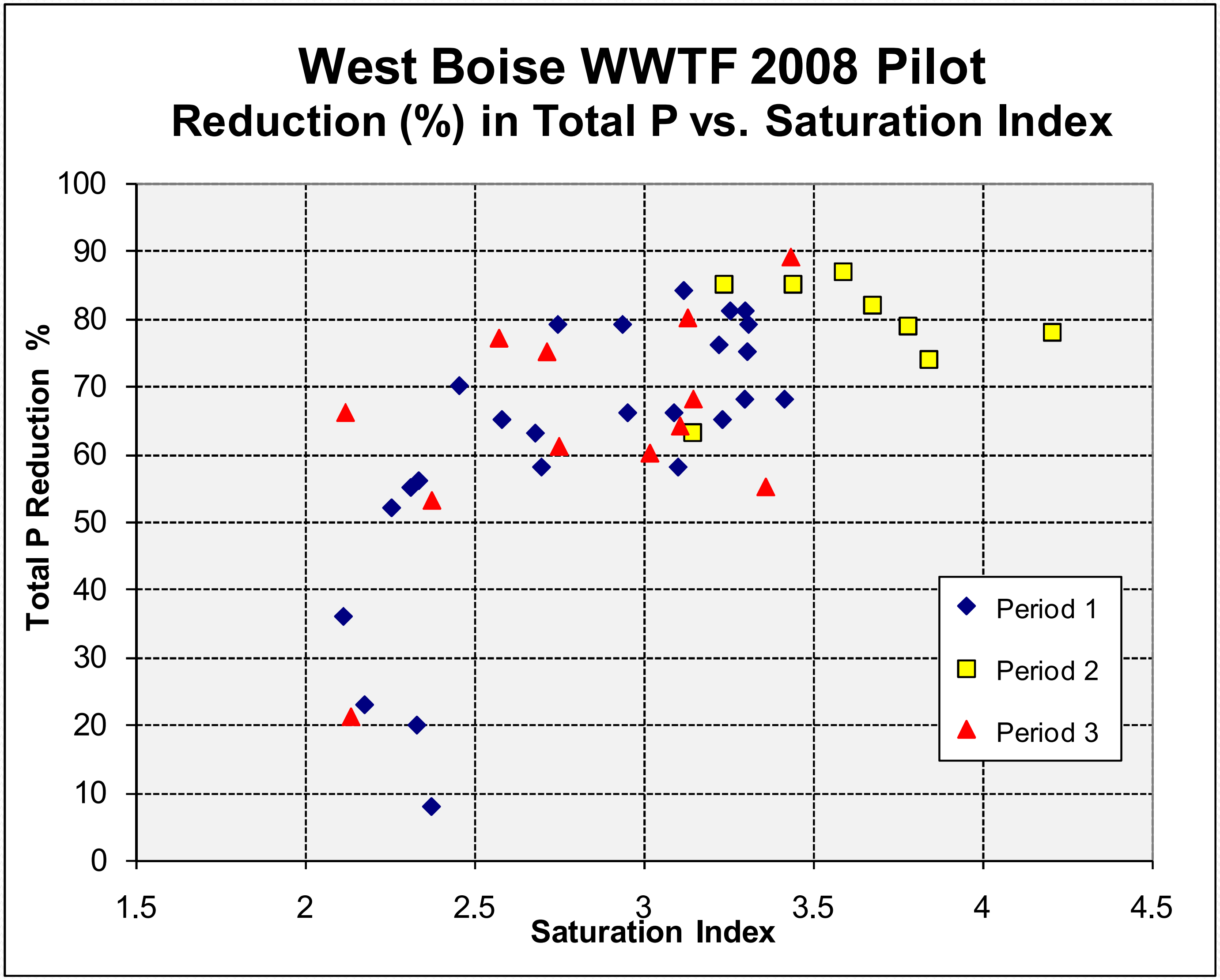
- High Concentration System (1,200 mg/L P)
- Overdose of reagents can lead to nucleation / dusting
- System Requires Thoughtful Operation



Struvite Process Effluent

- Reactor effluent is cleaner
- Lower ammonia and phosphorus

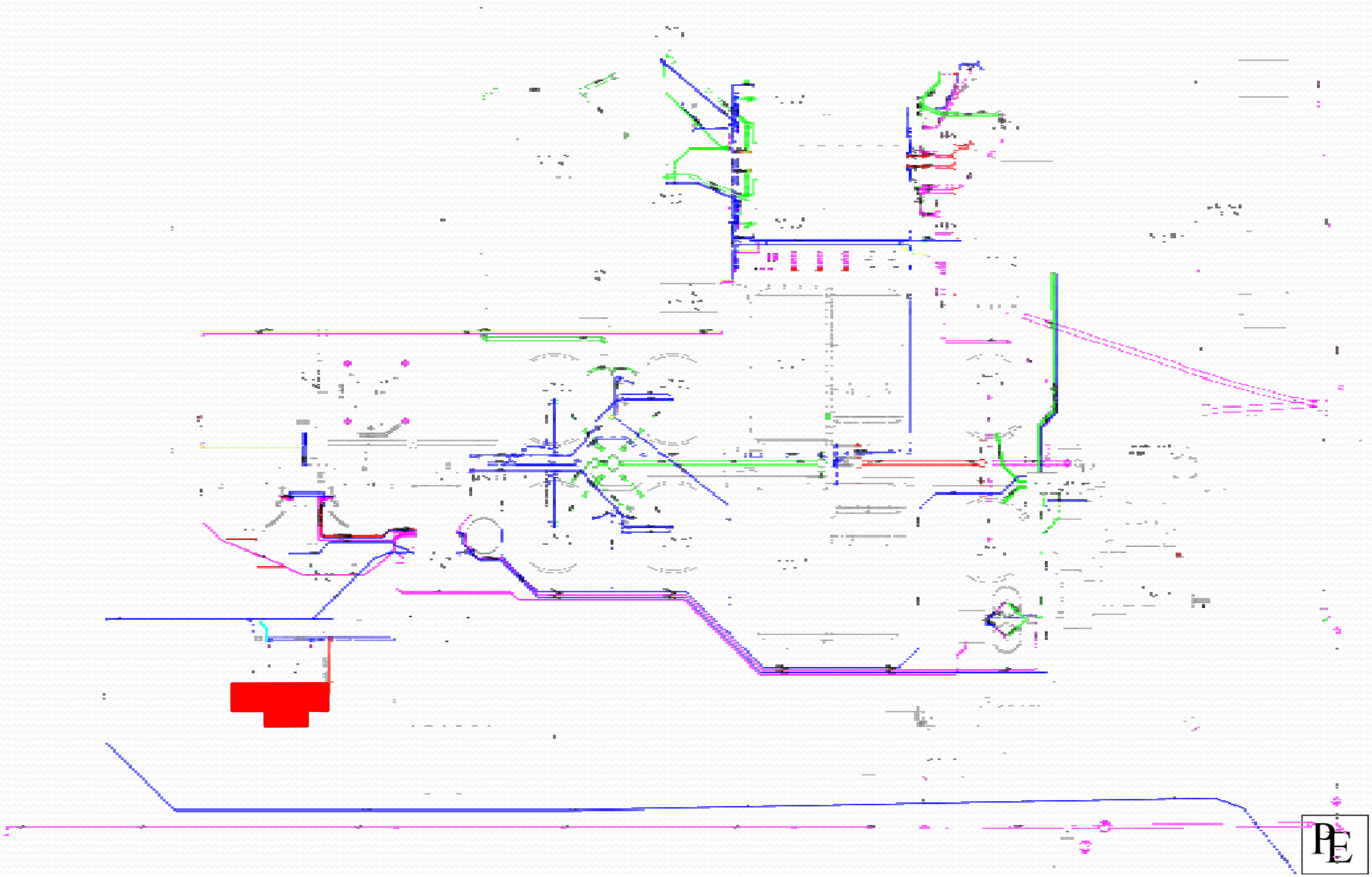
Relative Pilot Results



Struvite Process Product

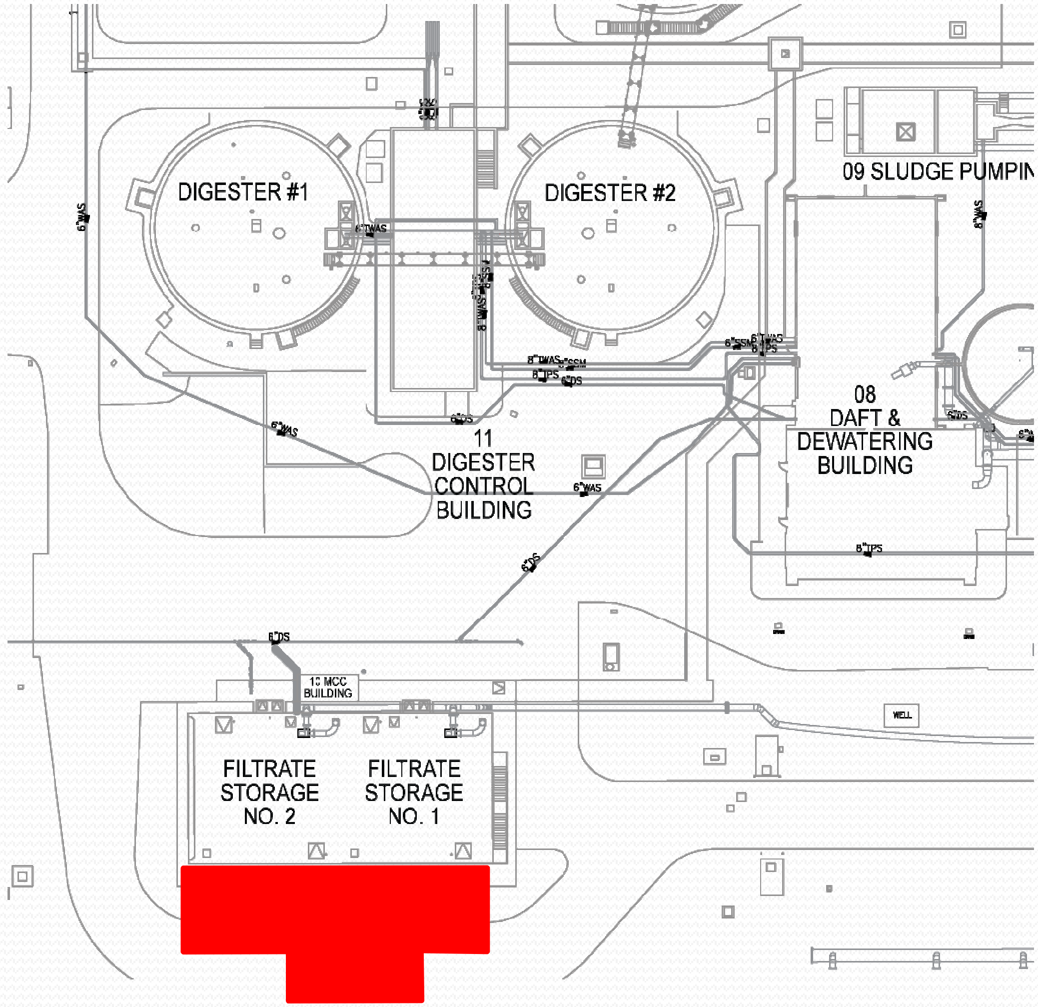
- Product material is a 5-28-0 + 10% Mg fertilizer
- Mesh varies
- Sometimes dusty
- Market minimally developed to date

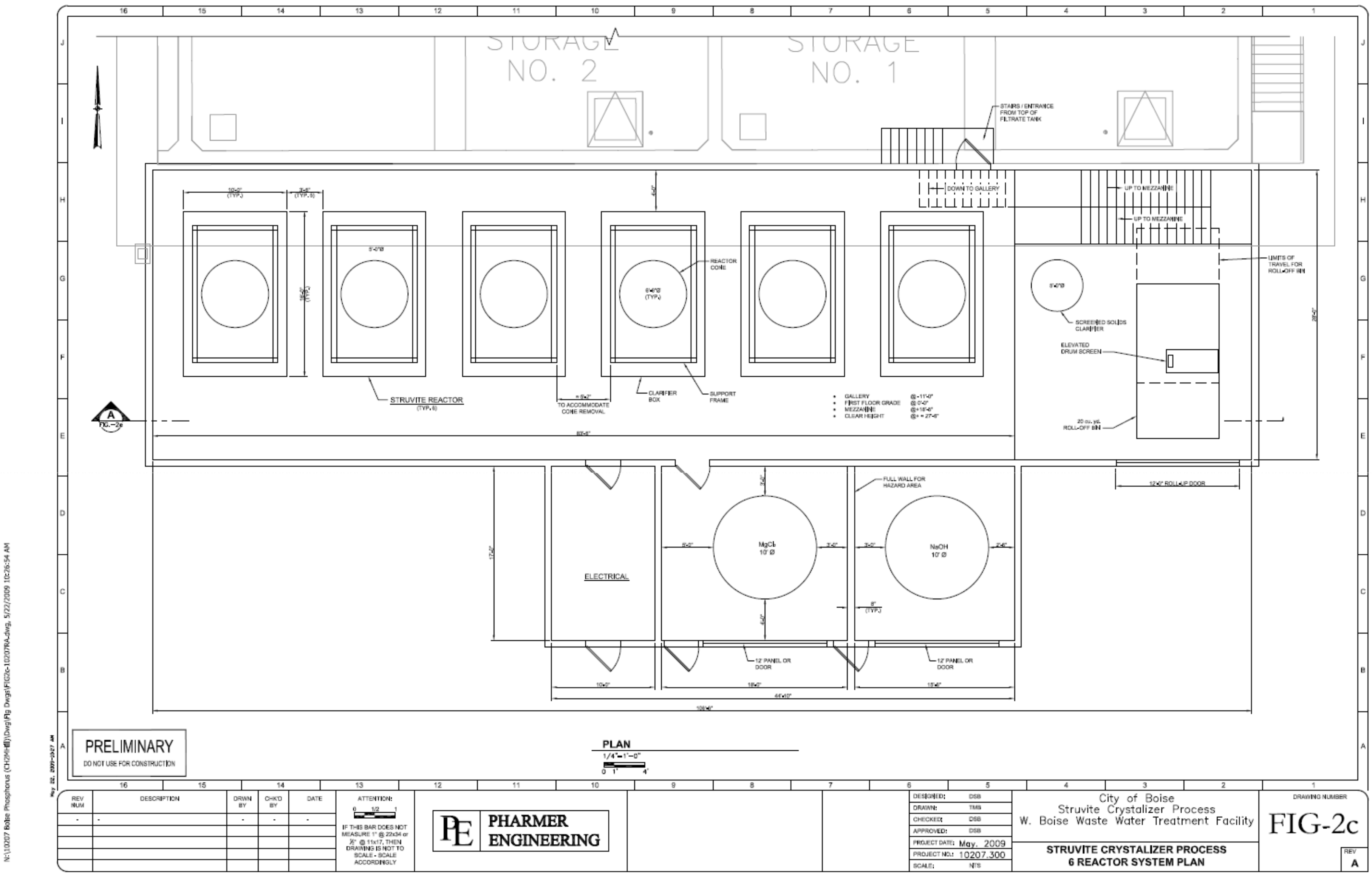
Implementation



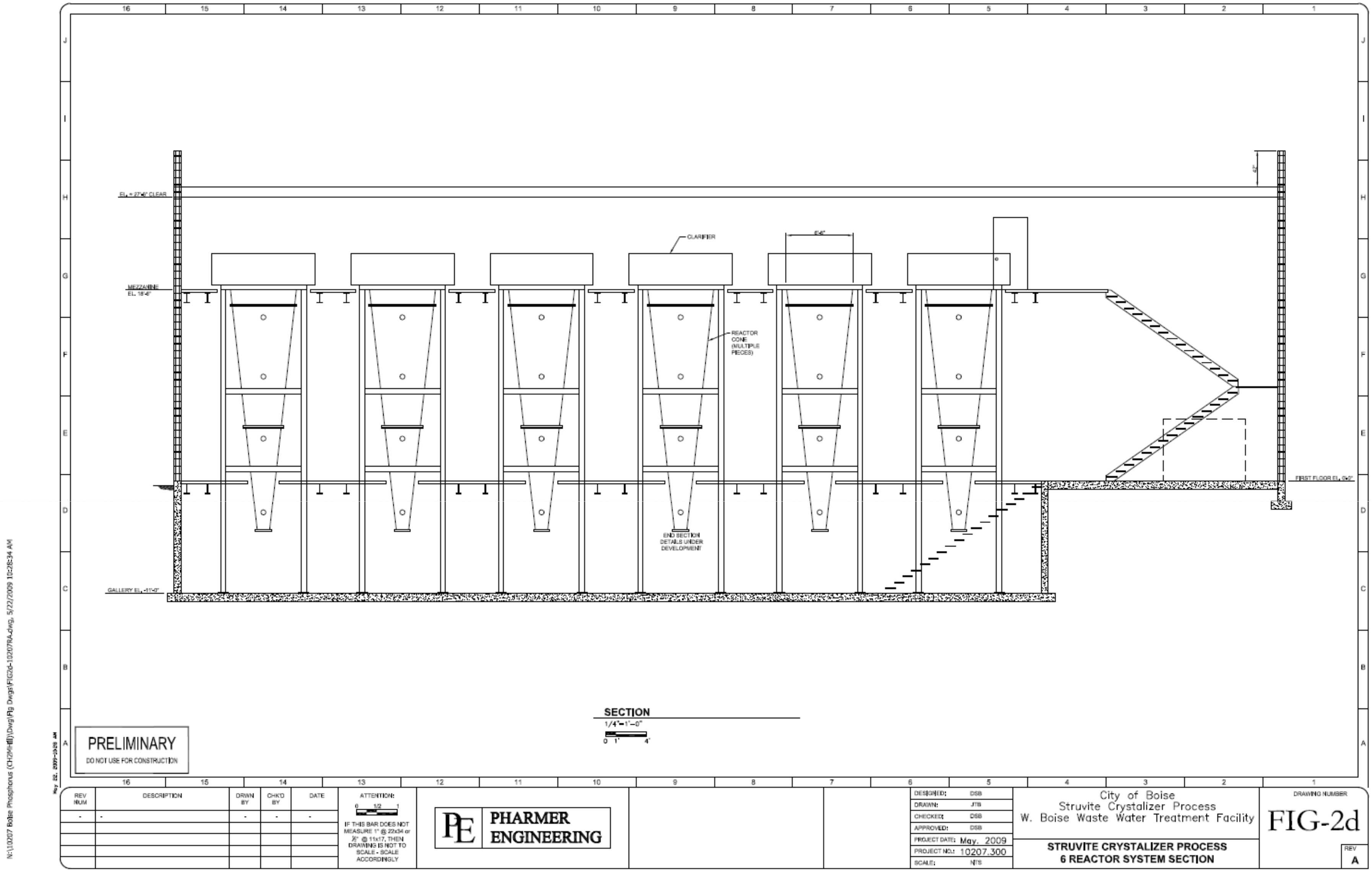
Implementation

- New struvite facility adjacent to existing filtrate basins





Layout – Six Reactor System



Section – Six Reactor System

What is Struvite Worth

MAP (10:52), commodity level	~ $400 (in 2008 3+x)
Struvite (5:28), commodity level (theoretical)	~ $200/DT
As a slow release Mg/combined, retail	~ $800/DT - ~ $1,200/DT
MagAMP was selling for, retail	~ $3,500/DT
Best guess, raw product (As a niche market fertilizer)	~ $300/DT to ~ $600/DT
Guess as unprocessed commodity	~ <$100/DT

Higher value of struvite requires there be a developed niche market

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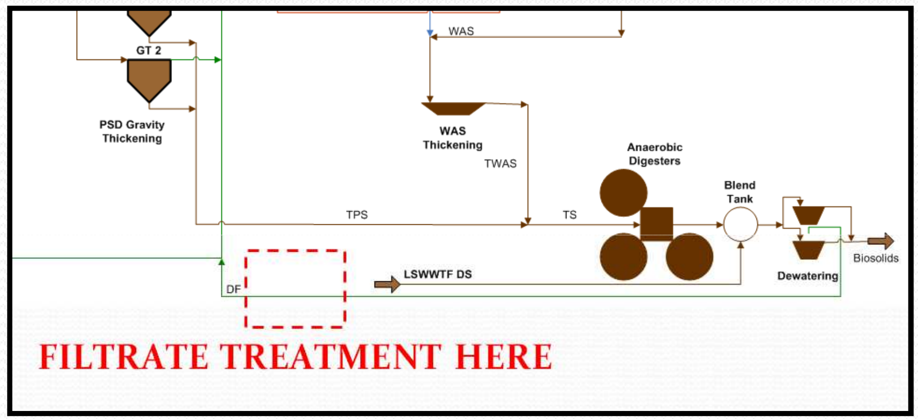
In Conventional Filtrate Treatment

- Capital Cost Opinion \$3.3 million (w/ >25% Contingency)
- Annual Related Costs
  - Power
  - Heat
  - Labor
  - Magnesium Chloride
  - Caustic
  - Hauling
  - Operational Cost Contingency at ~50%
  - (Product Revenue)



Struvite Economics
In Conventional Filtrate Treatment

West Boise WWTF
Phosphorus Removal Evaluation
Traditional Filtrate Treatment
Struvite Payback Analysis - Range of Raw Product Values

Raw Struvite Product Value ($/DT)	**Total Annual Cost** ($/Yr)	**Total Net Present Value**[A,B,C] ($)
$0	$576,777	$9,910,000
$100	$438,137	$8,320,000
$200	$299,497	$6,730,000
$300	$160,858	$5,140,000
$400	$22,218	$3,550,000
$600	($255,061)	$370,000
$800	($532,341)	($2,820,000)
$1,000	($809,620)	($6,000,000)

A. 0.12 MGD struvite facility at 1,200 lbs/d P feed
B. Capital cost opinion at $3.3 million for the struvite facility
C. Payback calc includes only struvite facility capital and operating costs
D. 20 year return period with 6% discount rate

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Metal Salt Economics

In Conventional Filtrate Treatment

- 80% Removal of filtrate phosphate = 960 lb/d
- At 1:1 (Fe:P) dose, need 12,500 lb/d ferric solution (40% by weight)
- Costs:
  - At $0.26 / lb solution, $3,250 /day
  - Sludge, labor, maint costs; ~ half of chemical $1,600 / day
    (does not include capital and associated facility derating)
  - Total ~$4,875 / day
  - 6 months per year: $ 890,000 / year
    - (20 yr PW= ~ $ 10 million)
  - 12 months per year: $1,780,000 / year
    - (20 yr PW= ~ $ 20 million)

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In Conventional Filtrate Treatment
Conclusions

- Metal Salt Filtrate Treatment vs Struvite System on Filtrate
  - Zero product value of struvite = break even costs for 6-month permit limit
  - Zero product value on struvite for 12-month permit, struvite present worth is half of the metal salt
- At $600/DT raw product value (for this situation), facility pays for itself (mining break even)

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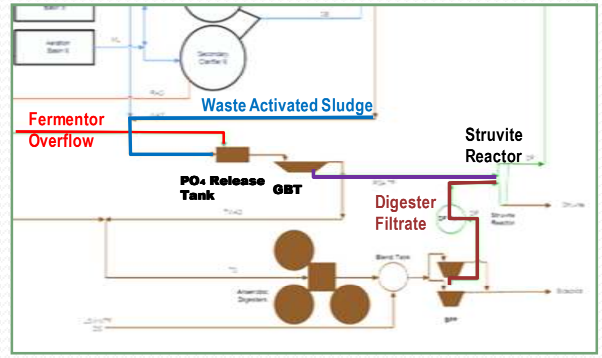
Struvite Economics

Integrated Sidestream BK2f

- Tradeoff economics less straight forward
- For 1.0 mg/L TP effluent target, process model suggests sucess without sidestream or filtrate treatment
- More cost effective with lower limits, avoided chemical costs



Discharge Goal / Alternative	Capital Cost
TP 1.0	
Bio-P Converstion w/ Fermentor	$ 8 million
Bio-P, Fermentor, Bk2f	$ 19 million
TP 0.2	
Bio-P, Fermentor, Filters	$ 34 million
Bio-P, Fermentor, Bk2f, Filters	$ 44 million
TP 0.07	
Bio-P, Fermentor, Chem Clarifiers, Filters,	$ 43 million
Bio-P, Fermentor, Bk2f, Filters	$ 45 million

Integrated Sidestream BK2f
Conclusions

- Economics show BK2f more expensive for 1.0 mg/L total phosphorus, requires more product revenue, but it is close
- Non-economic factors are significant
  - Over two times phosphorus removed, that does not go to farm
  - Digester unintentional struvite formation avoided

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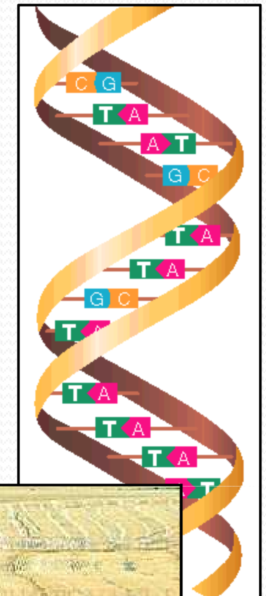
Phosphorus: The Enemy

- Too much P and N can cause algae blooms (algae is 16N:1P)
- In 12 of 16 EPA Regions, 90% of rives contain excess nutrients (most is from non-point)
- Over 1000 water bodies in the Pacific Northwest are nutrient limited
- For the West Boise WWTF, estimated effort is between $34 and $45 million, depending on where the final limit is.

Phosphorus: Uses

- Food Production / Fertilizers
- Synthetic detergents
- Industrial (cleaning)
- Corrosion control



World Production of Phosphorus Depends on Phosphate Rock Reserves

Phosphorus:
The Declining World Resource

World phosphate reserves will be consumed in 50 to 100 years

an Article from

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Phosphorus: A Looming Crisis

This underappreciated resource—a key part of fertilizers—is still decades from running out. But we must act now to conserve it, or future agriculture will collapse • By David A. Vaccari

Our planet is also a spaceship: it has an essentially fixed total amount of each element. In the natural cycle, weathering releases phosphorus from rocks into soil. Taken up by plants, it enters the food chain and makes its way through every living being. Phosphorus—usually in the form of the phosphate ion PO_4^{3-}—is an irreplaceable ingredient of life. It forms the backbone of DNA and of cellular membranes, and it is the crucial component in the molecule adenosine triphosphate, or ATP—the cell's main form of energy storage. An average human body contains about 650 grams of phosphorus, most of it in our bones.

Land ecosystems use and reuse phosphorus in local cycles an average of 46 times. The mineral then, through weathering and runoff,

West Boise WWTF
Use of Struvite Crystallization Technology as Part of the Phosphorus Removal Plan