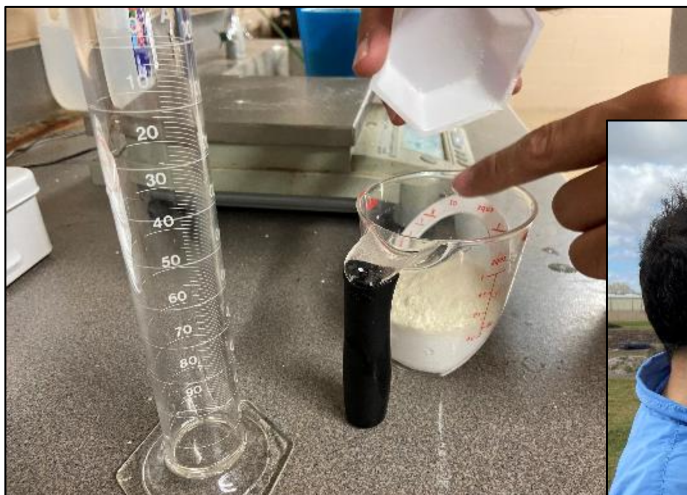
Development and application of a synthetic high strength waste formulation for evaluating aerobic treatment unit performance

Texas A&M OSSF Research Team

June Wolfe III
Anish Jantrania
Gabriele Bonaiti
Ryan Gerlich



TEXAS A&M AGRILIFE RESEARCH | EXTENSION

DISCLAIMER

The materials being presented represent the speaker's own opinions and do NOT reflect the opinions of NOWRA.

OSSF Research Funding in Texas

- Texas Commission on Environmental Quality (TCEQ)
- Texas On Site Sewage Facility Grant Program (TOGP)
- 4 Feb 2019 - TCEQ issues *RFGA Solicitation No:* *582-19-93772.*
- 29 Mar 2019 - TAMU submits 3 proposals: ATU, LPD, and Reuse
- 2 May 2019 - TCEQ notifies TAMU all 3 proposals selected for funding!

TCEQ - RFGA Research Topics

Eligible Projects (4)

1) Adequacy of Current ATU Designs with Higher Strength Wastewater

2) ATU Demand vs. Time Dosing

3) Low-Pressure Dose Systems with Various Configurations

4) Black Water Non-Potable Reuse

ATU Research Approach

Topic 2 - Dosing Method

Topic 1 – Increasing organic strength

	Demand	Time
Design	ATU **Baseline** (adequate)	Does ATU performance **improve**?
Higher	Is ATU design **adequate*** for use?	Does ATU performance **improve**?

*Adequate = meets NSF/ANSI Standard 40 effluent requirements

Flow reductions described in current Texas OSSF Rules

- Chapter 285.91(3) Wastewater Usage Rate; effects of water-saving devices

TYPE OF FACILITY	USAGE RATE GALLONS/DAY (Without Water Saving Devices)	USAGE RATE GALLONS /DAY (With Water Saving Devices)
Single family dwelling (one or two bedrooms) - less than 1,500 square feet.	225	180

- Chapter 285.81(b) Adjusted Hydraulic Flow; effect of graywater reuse on % hydraulic flow reductions

Table I. Potential Percent Reduction

Sewage sources entering the graywater reuse system or combined reuse system	Potential percent reduction to the effluent disposal system required in §285.33 of this title
Clothes-washing machine only	20
Showers, bathtubs, hand-washing lavatories, and sinks that are not used for the disposal of hazardous or toxic ingredients	30
Clothes-washing machines, showers, bathtubs, hand-washing lavatories, and sinks that are not used for the disposal of hazardous or toxic ingredients	50

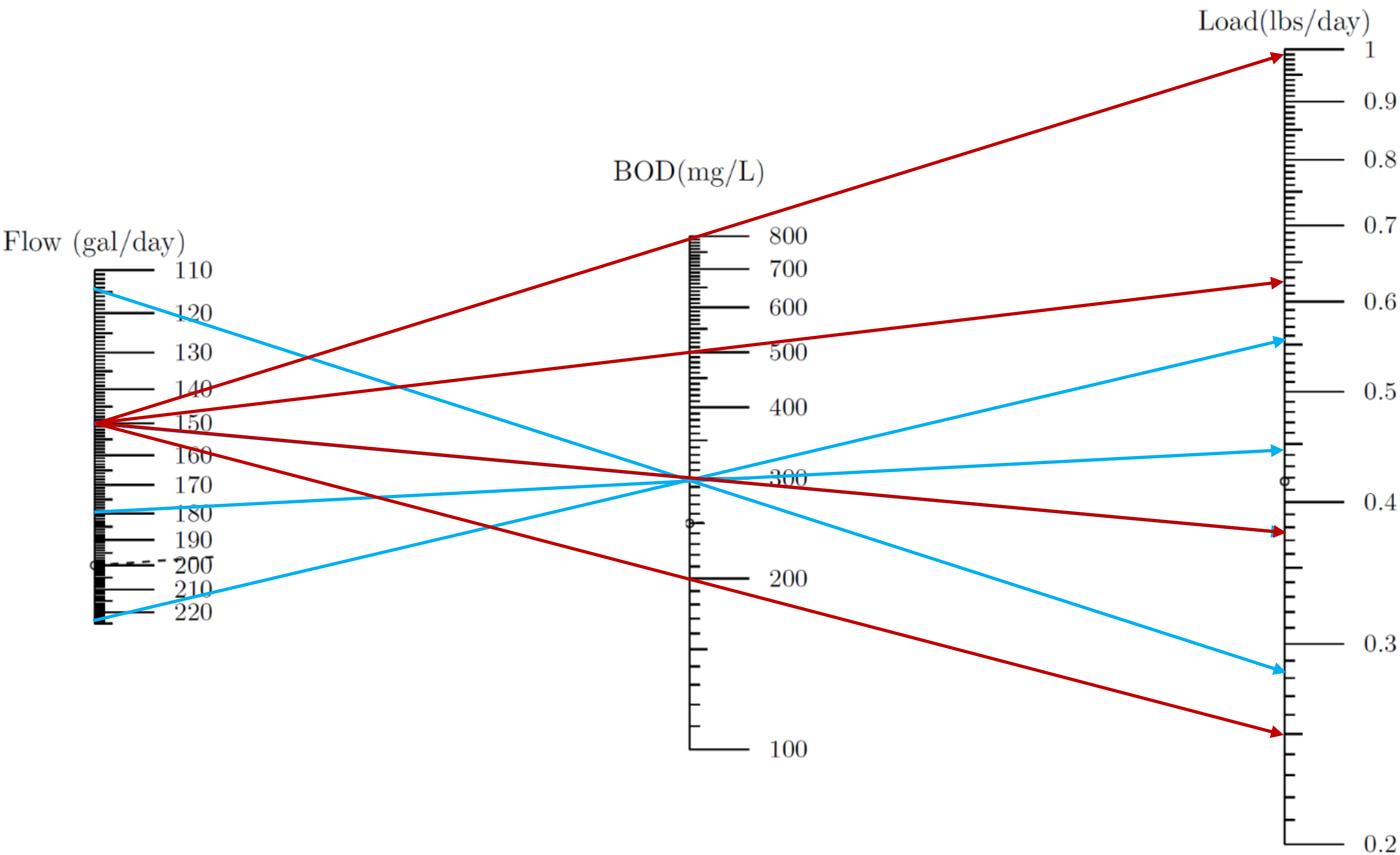
Organic strength described in current Texas OSSF Rules

- Chapter 285.81(d) Adjusted Organic Strength; effect of graywater reuse

Table II. Adjusted Organic Strength

Sewage sources entering a graywater reuse system or a combined reuse system	**Five-day Biochemical Oxygen Demand (BOD_5) design strength for sewage entering on-site sewage facilities milligrams per liter (mg/l)**
Clothes-washing machine only	375
Showers, bathtubs, hand-washing lavatories, and sinks that are not used for the disposal of hazardous or toxic ingredients	430
Clothes-washing machines, showers, bathtubs, hand-washing lavatories, and sinks that are not used for the disposal of hazardous or toxic ingredients	600

Flow (gal/day) x Concentration (mg/L) x 0.00000834 = Load (lbs/day)



Research plan

Aerobic Treatment Unit Evaluation Plan – Parallel ATU's – Demand vs Time Dose

Experiment*	Flow	Concentration	Load
	[gal/day]	[mg/L]	[lb/day]
1	225	300	0.56
2	180	375	0.56
3	157	430	0.56
4	112	600	0.56
5	112	800	0.75
6	157	900	1.18
7	180	1000	1.50
8	225	1000	1.88

***Six weeks per experiment:**
2-week equilibration, 2-week sampling, 2-week data review and prep for next

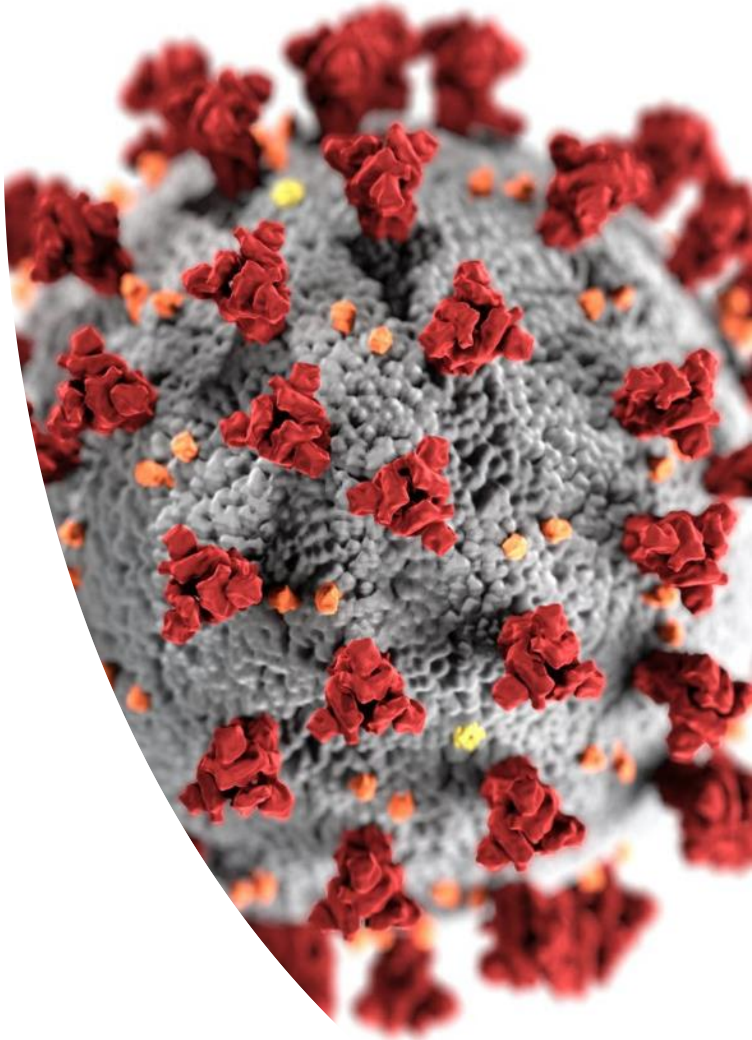
COVID-19 Effect upon OSSF research Timeline and progress

Timeline

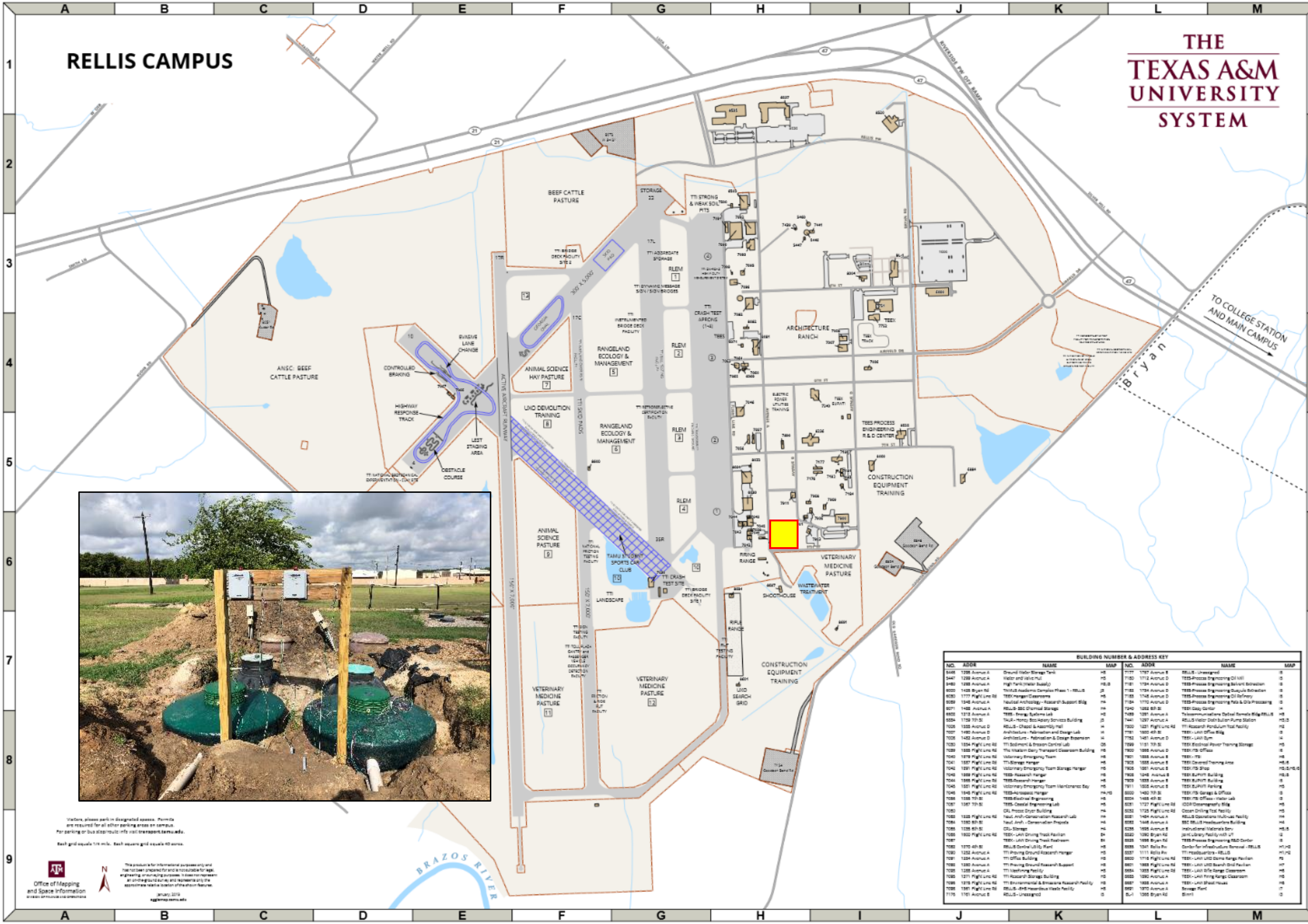
- 16 March 2020 – AgriLife suspends all field and lab activity
- 15 May 2020 – AgriLife resumes 25% activity
- 1 Jun 2020 – AgriLife resumes 50% activity
- 1 Sep 2020 – AgriLife resumes 75% activity
- 1 Dec 2020 – AgriLife resumes 100% activity

OSSF Research Progress under COVID conditions

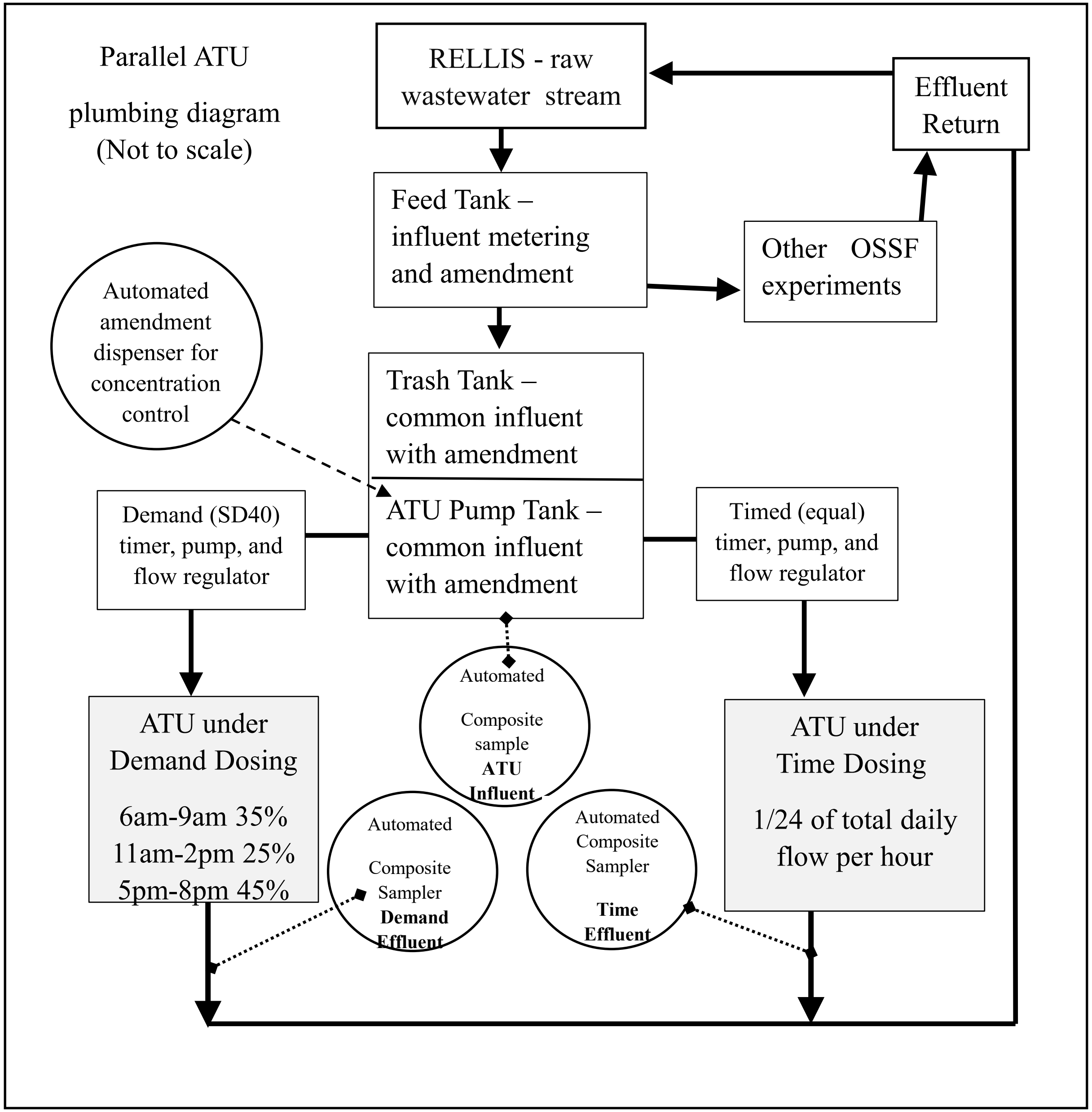
- Upgraded infrastructure at RELLIS OSS Research Facility
- Developed synthetic high strength waste formulation
- Procured equipment, instrumentation, and supplies
- Completed ATU installation



Virtual Tour

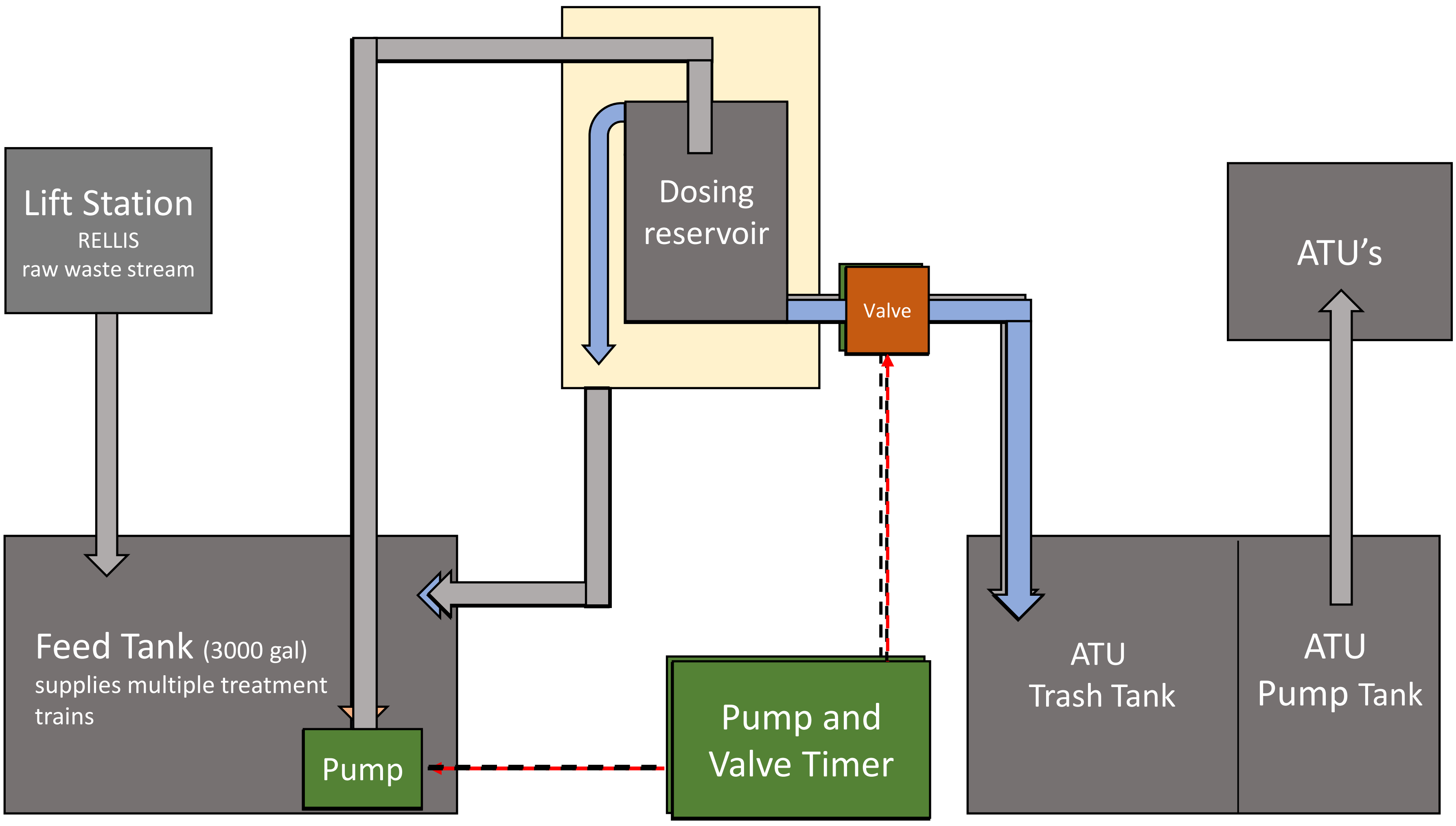

RELLIS CAMPUS
THE TEXAS A&M UNIVERSITY SYSTEM
BEEF CATTLE PASTURE
ANSC: BEEF CATTLE PASTURE
ANIMAL SCIENCE HAY PASTURE
ANIMAL SCIENCE PASTURE
RANGELAND ECOLOGY & MANAGEMENT
UXO DEMOLITION TRAINING
TTI SKID PADS
ACTIVE AIRCRAFT RUNWAY
RLEM
ARCHITECTURE RANCH
TEES PROCESS ENGINEERING R & D CENTER
CONSTRUCTION EQUIPMENT TRAINING
VETERINARY MEDICINE PASTURE
WASTEWATER TREATMENT
SHOOTHOUSE
FIRING RANGE
RIFLE RANGE
TTI CRASH TEST SITE
TAMU STUDENT SPORTS CAR CLUB
TTI LANDSCAPE
STORAGE
EVASIVE LANE CHANGE
CONTROLLED BRAKING
HIGHWAY RESPONSE TRACK
LEFT STAGING AREA
OBSTACLE COURSE
TTI STRONG & WEAK SOIL PITS
TO COLLEGE STATION AND MAIN CAMPUS
Bryan
BRAZOS RIVER
BUILDING NUMBER & ADDRESS KEY
Office of Mapping and Space Information
A B C D E F G H I J K L M
1 2 3 4 5 6 7 8 9

A. Wastewater Treatment Plant
B. Cleanout
C. Feed Tank
D. ATU Trash Tank and Pump Tank
E. ATU-A, STD40 Dosing
F. ATU-B, Equalized Dosing
G. Low Pressure Drip - Septic Tank
H. Low Pressure Drip - Drainfield
I. ATU
J. Membrane Bio Reactor (MBR)
J
I
29
154
H1
H2
H
H3
H4
C
D
38
E&F
25
28
F
102
185
G
B
420
A

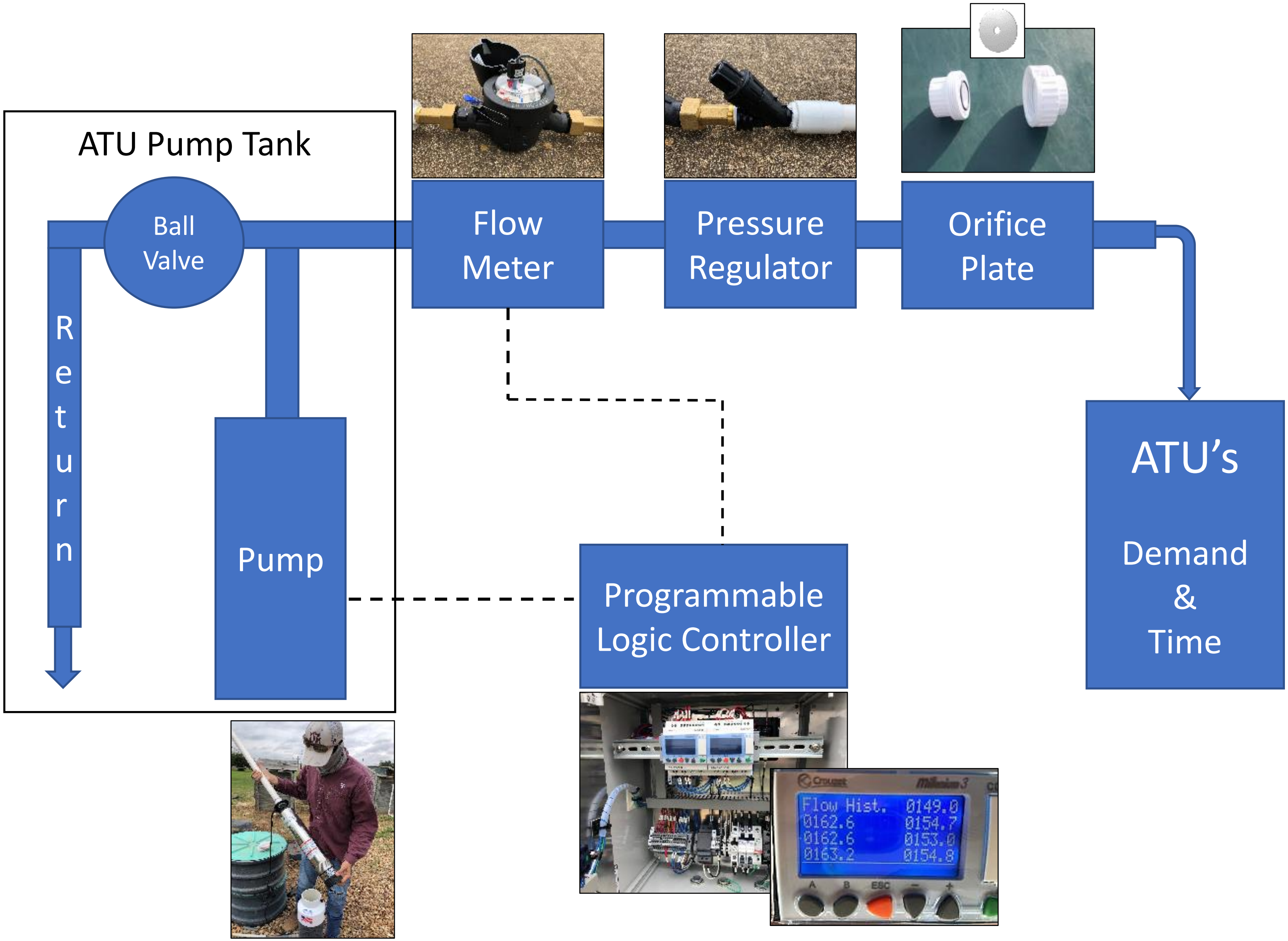

Parallel ATU
plumbing diagram
(Not to scale)
RELLIS - raw wastewater stream
Effluent Return
Feed Tank – influent metering and amendment
Other OSSF experiments
Automated amendment dispenser for concentration control
Trash Tank – common influent with amendment
ATU Pump Tank – common influent with amendment
Demand (SD40) timer, pump, and flow regulator
Timed (equal) timer, pump, and flow regulator
ATU under Demand Dosing
6am-9am 35%
11am-2pm 25%
5pm-8pm 45%
Automated Composite sample ATU Influent
ATU under Time Dosing
1/24 of total daily flow per hour
Automated Composite Sampler Demand Effluent
Automated Composite Sampler Time Effluent

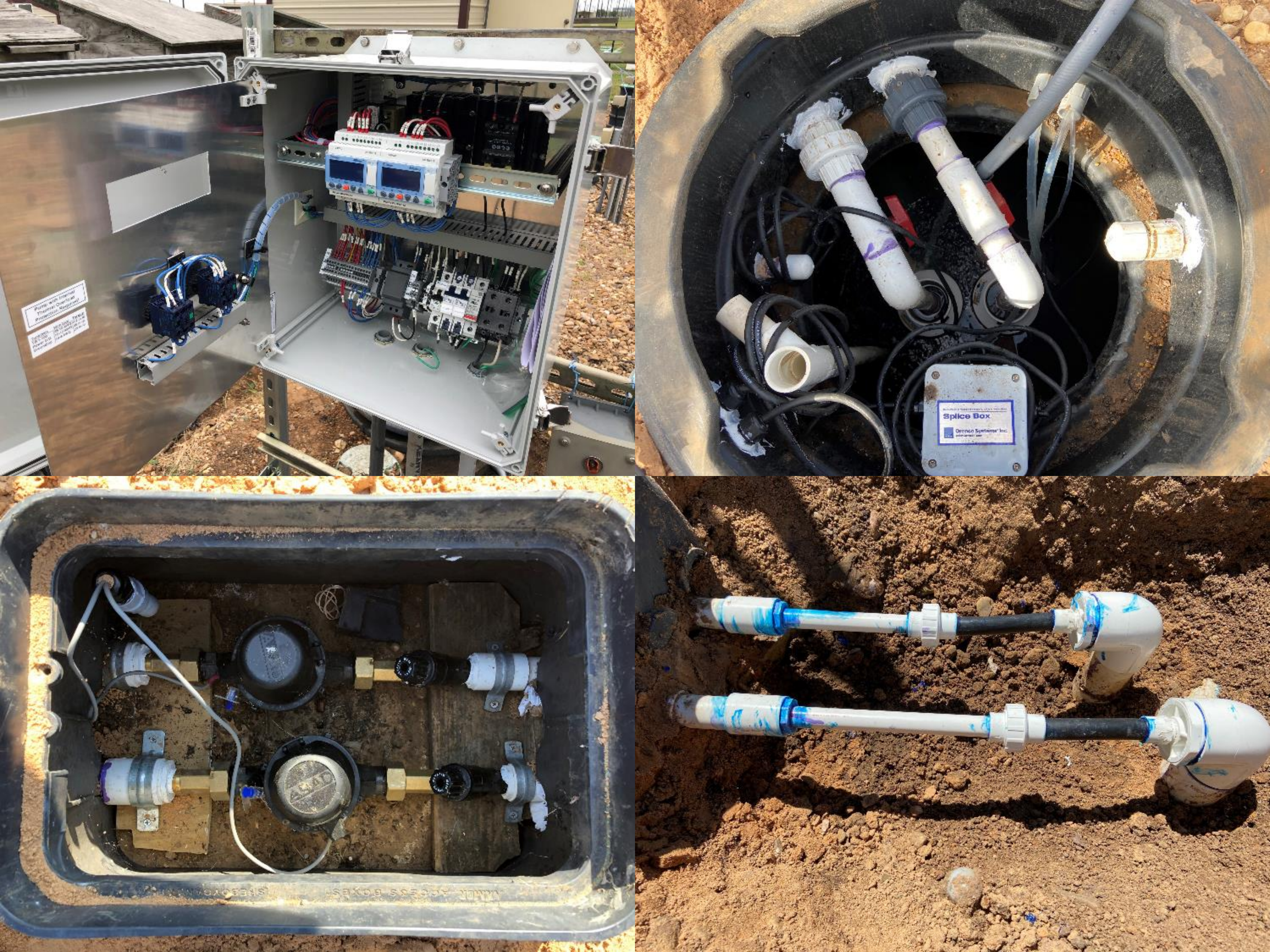

TAEX


Influent volume/dose regulation

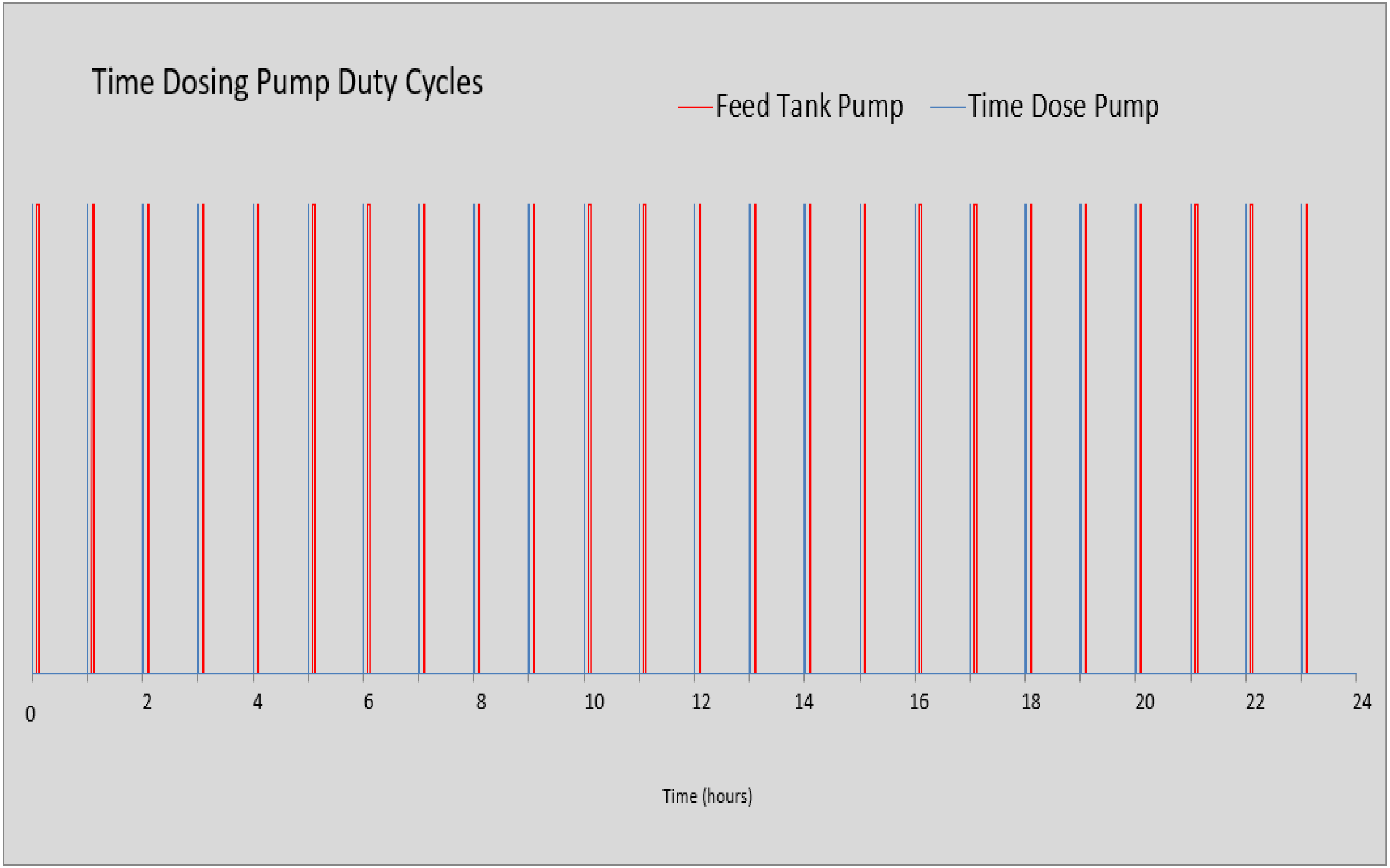


Flow control – Pump timer with orifice plate




Splice Box

Pump schedules and coordination



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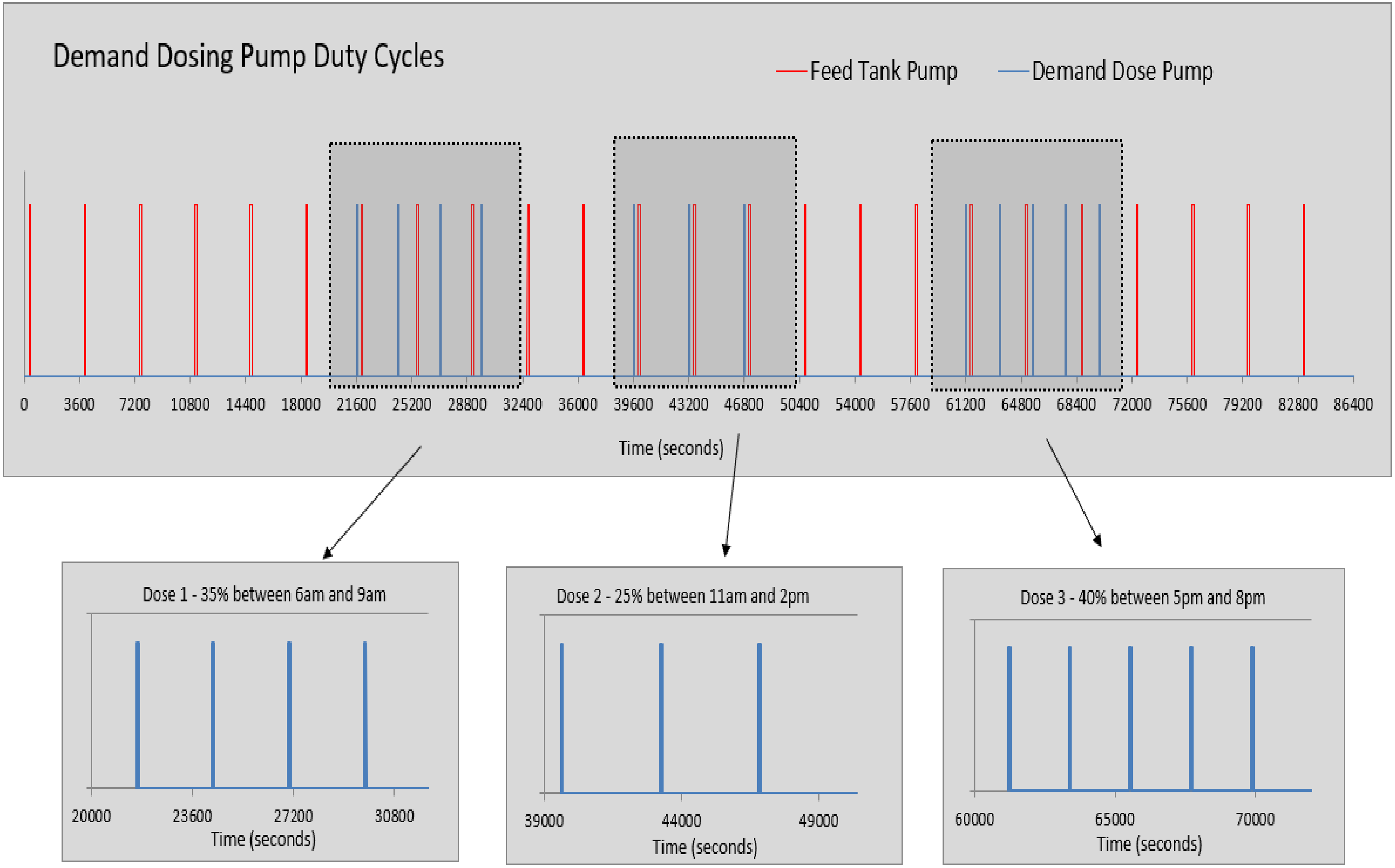

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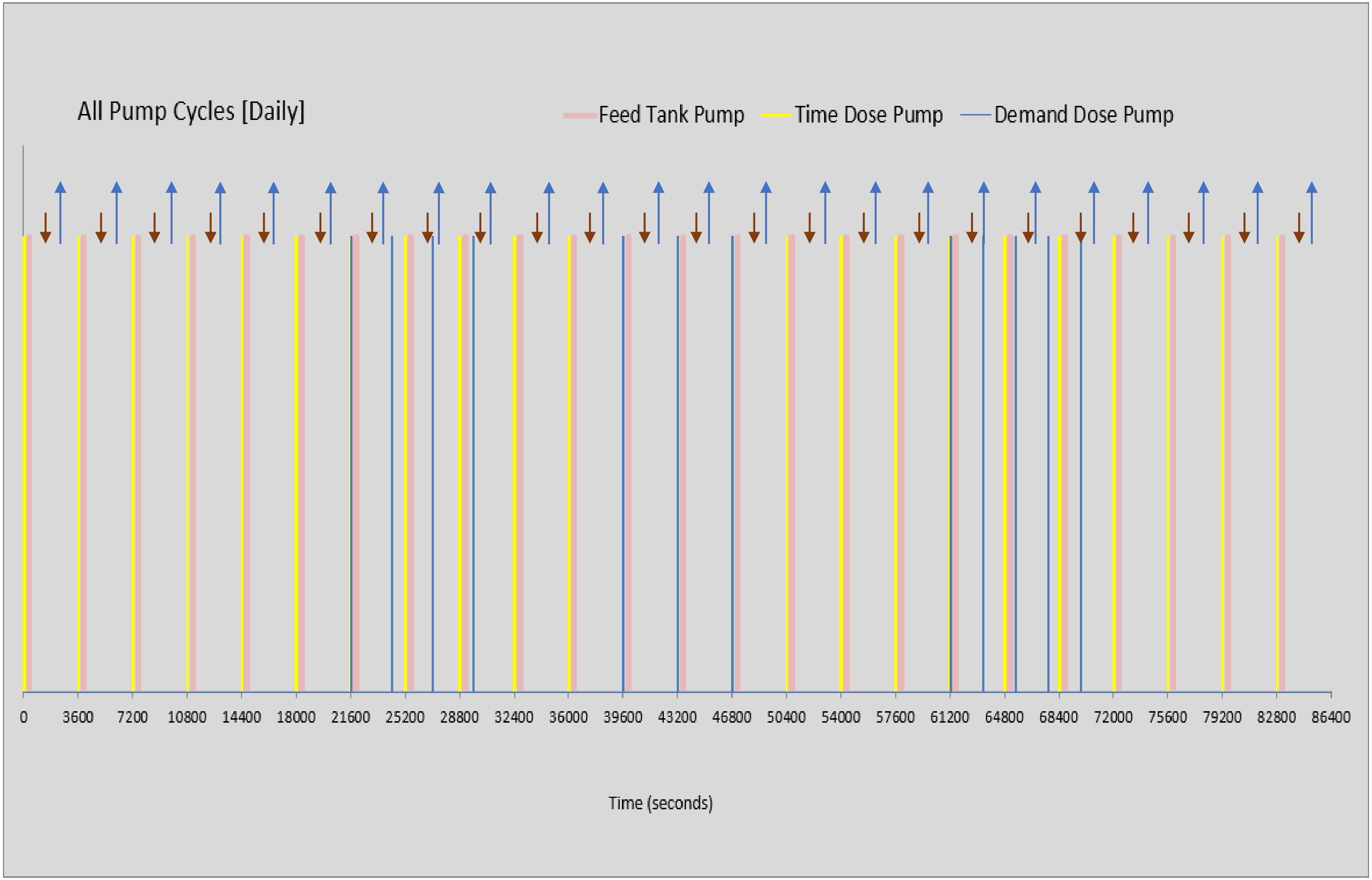
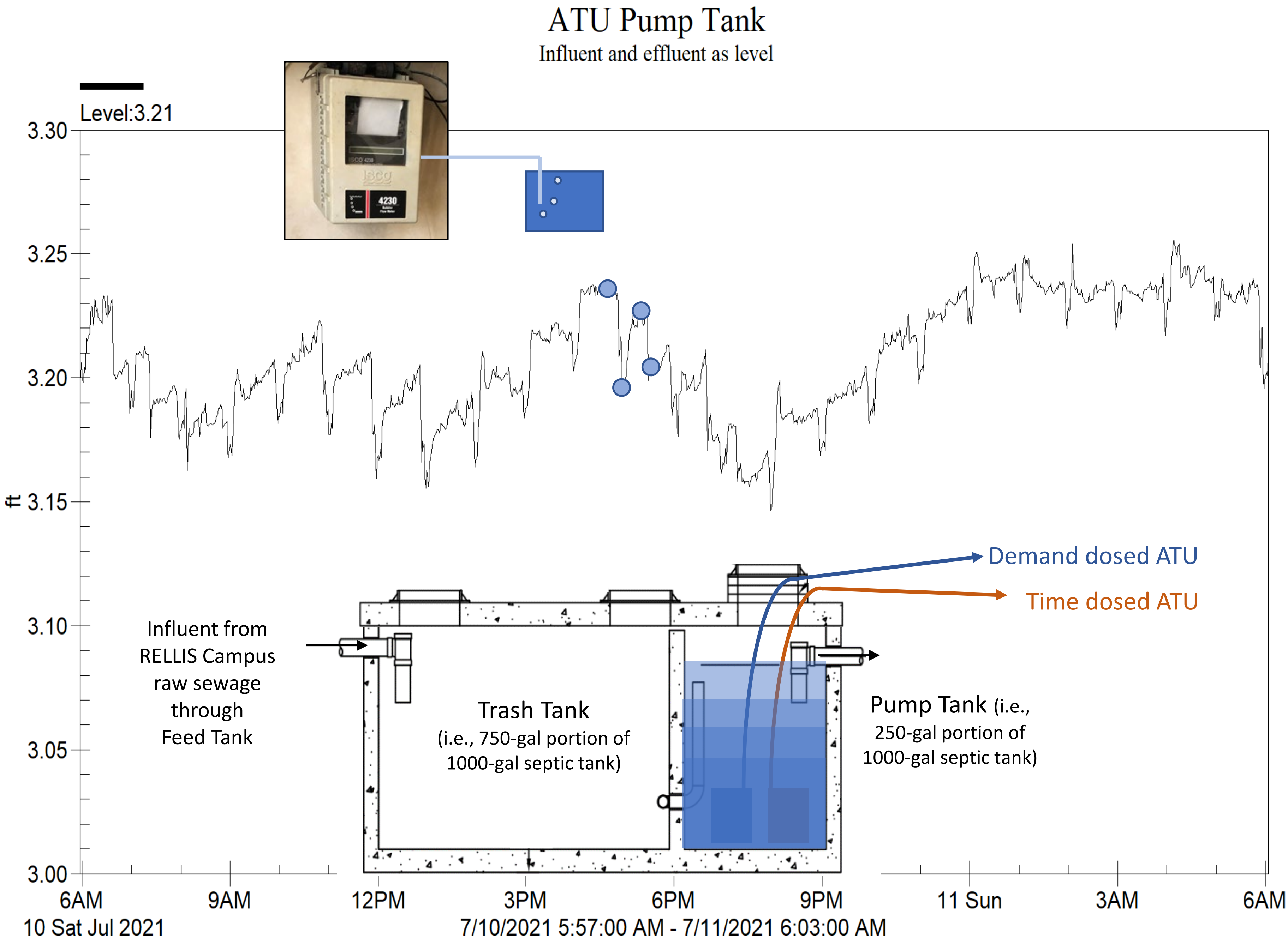
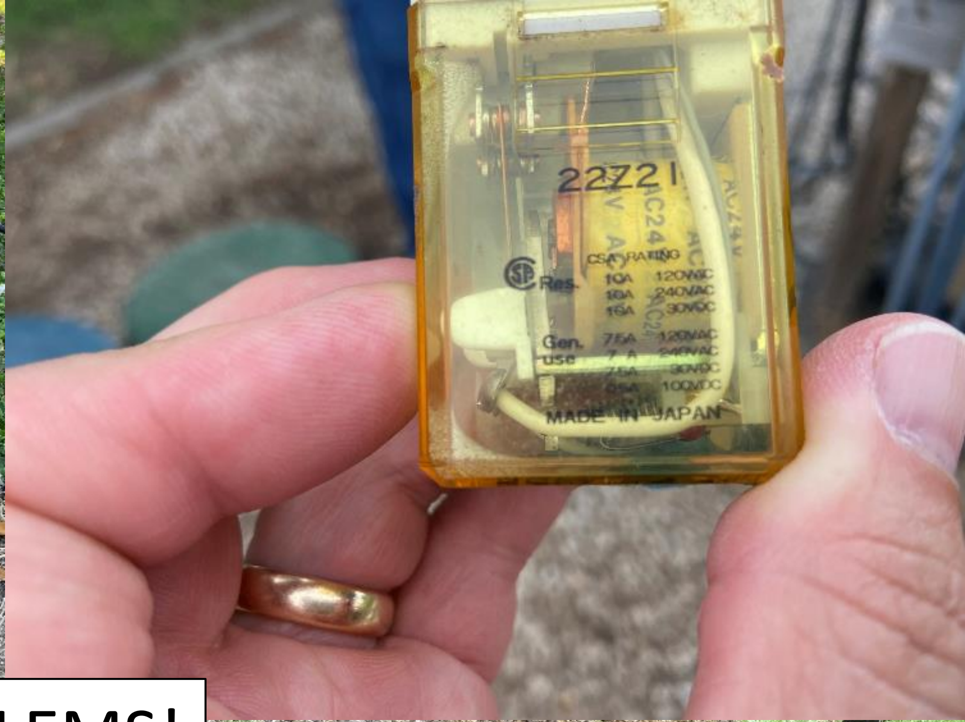




ATU Pump Tank
Influent and effluent as level
Level:3.21
ISCO 4230
4230
3.30
3.25
3.20
ft
3.15
3.10
3.05
3.00
6AM
10 Sat Jul 2021
9AM
12PM
3PM
6PM
9PM
11 Sun
3AM
6AM
7/10/2021 5:57:00 AM - 7/11/2021 6:03:00 AM
Demand dosed ATU
Time dosed ATU
Influent from RELLIS Campus raw sewage through Feed Tank
Trash Tank
(i.e., 750-gal portion of 1000-gal septic tank)
Pump Tank (i.e., 250-gal portion of 1000-gal septic tank)

SAMPLING



PROBLEMS!

Synthetic High-Strength Waste

- Constituent characterization
- Measured mass/volume
- BOD_5 determination
- Standard curve

Modified, grain-based animal feed

- Carbohydrate source (starches)
- Protein source (veg)
- Vitamin, mineral source
- Trace element source

- Increases BOD_5 and TSS

- Low cost
- Local availability
- Storage and handling
- Consistent composition
- Moderately high BOD_5

Issues
- Settling
- Slow breakdown

Modified, grain-based animal feed

- Carbohydrate source (starches)
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Issues
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PP LAY CRUMBLE	
Ingredient	% by wt.
Corn	55.00
Soybean meal - 48%	22.00
Calcium carbonate	8.00
Rice bran	7.50
Liquid molasses binder	2.50
Dehydrated alfalfa, 17%	2.00
Corn gluten meal	1.60
Monocalcium phosphate, 21%	0.70
Salt Mix	0.45
Poultry Vitamin Mix	0.15
D-L-Methionine 98%	0.05
Choline chloride	0.05
Total	100.00

Modified, grain-based animal feed

- Carbohydrate source (starches)
- Protein source (veg)
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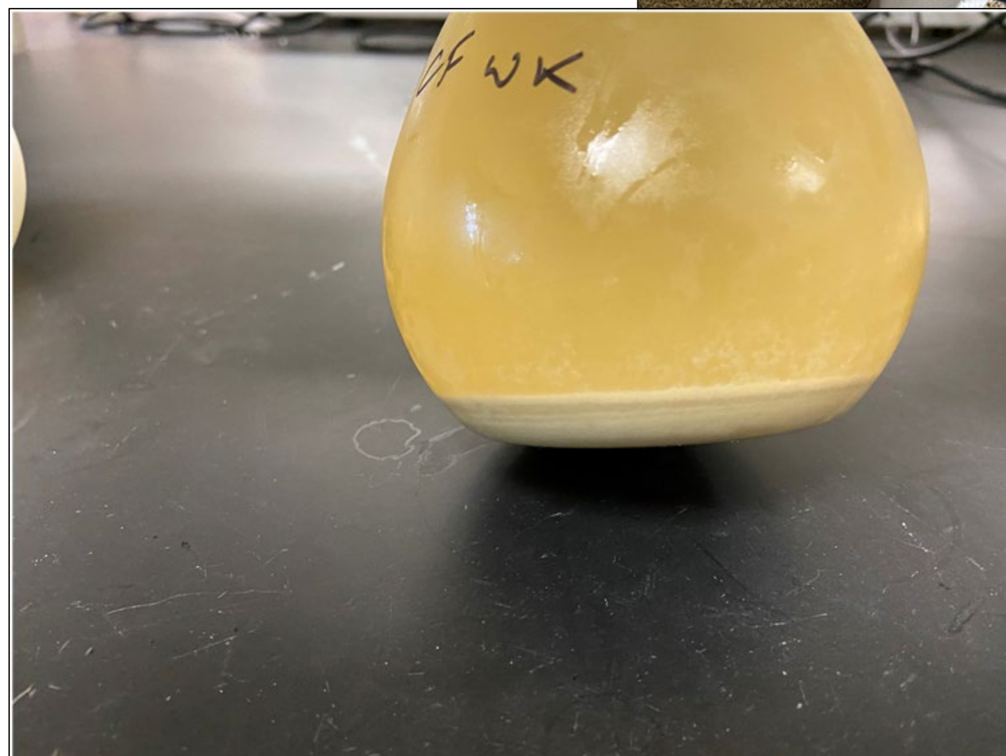


Grade A, Low Heat Skim Milk Powder

- Carbohydrate source (lactose)
- Protein source
- Mineral source

- Increases BOD_5 and TSS

- Cost
- Availability
- Storage and handling
- Consistent composition/quality
- Relatively high BOD_5
- Liquid delivery (measurement)

Problems

- High viscosity (i.e., foaming)
- Volume determination at high concentrations

Grade A, Low Heat Skim Milk Powder

- Carbohydrate source (lactose)
- Protein source
- Mineral source

- Increases BOD_5 and TSS

TABLE I.—Average Composition of Milk and Dried Skim Milk

Constituent	Whole Milk (%)	Dried Skim Milk (%)	Solution Containing	
			1% Milk (p.p.m.)	0.1% Dried Skim Milk (p.p.m.)
Fat	3.9	0.9	390	9
Protein	3.2	36.9	320	369
Lactose	5.1	50.5	510	505
Ash	0.7	8.1	70	81
Total Solids	12.9	96.4	1,290	964
Organic Solids	12.2	88.3	1,220	883

TABLE II.—Comparison of Oxygen Demands of Solutions Determined Chemically and Biologically

Type of Solution	C.O.D. (p.p.m.)		B.O.D. (p.p.m.)	
	Total	68%	20-day	5-day
Skim Milk	1,052	715	1,056	636
Lactose	516	351	519	431
Casein	604	412	639	327

From Porges et al. (1950)

Grade A, Low Heat Skim Milk Powder

- Carbohydrate source (lactose)
- Protein source
- Mineral source

- Increases BOD_5 and TSS

- Cost
- Availability
- Storage and handling
- Consistent composition/quality
- Relatively high BOD_5
- Liquid delivery (measurement)

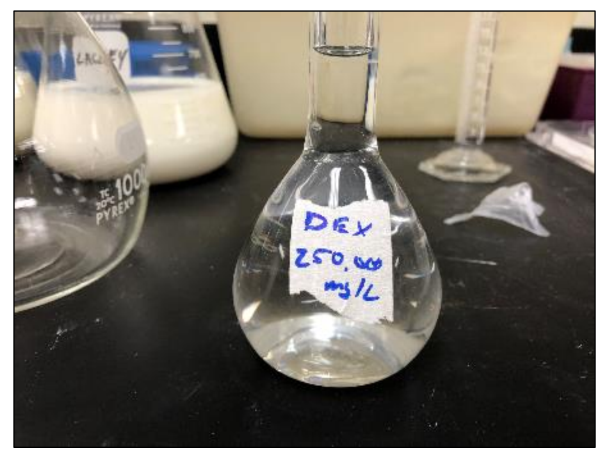
Problems
- High viscosity (i.e., foaming)
- Volume determination at high concentrations

Dextrose (derived from corn starch)

- Carbohydrate source (simple sugar)

- Low cost
- Availability
- Storage and handling
- Consistent composition/quality
- Relatively high BOD_5
- Liquid delivery (measurement)

Problems
- Volume determination at high concentration

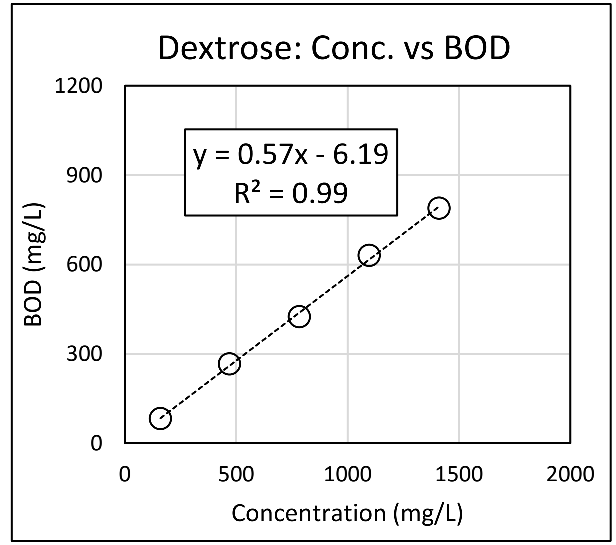


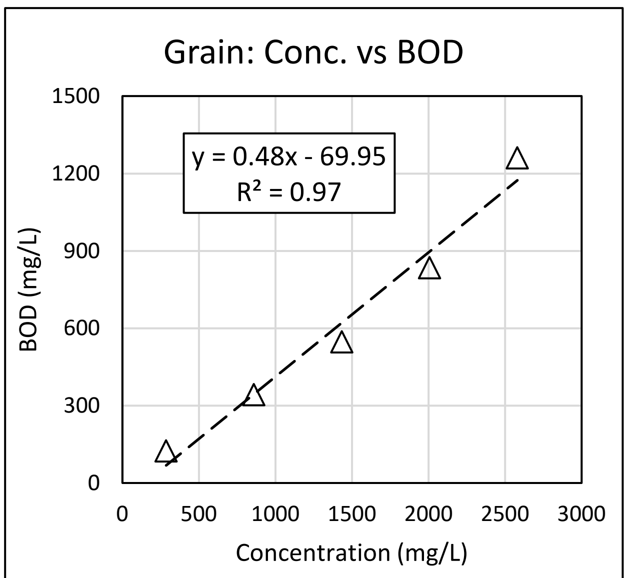

KIMTECH
KIMTECH
10000 ml
KIMAX
KIMBLE
PRODUCERS
COOPERATIVE
Avalanche

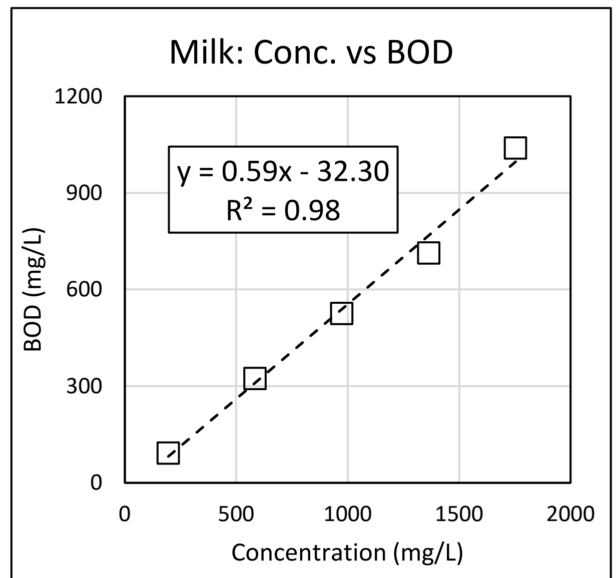
Amendments – standard curve development

Material	Conc.	BOD_5
Dextrose 100	160	83
Dextrose 300	470	267
Dextrose 500	783	425
Dextrose 700	1097	631
Dextrose 900	1410	789
Milk 100	195	92
Milk 300	585	324
Milk 500	974	526
Milk 700	1364	714
Milk 900	1754	1040
Grain Mix 100	287	124
Grain Mix 300	860	342
Grain Mix 500	1433	547
Grain Mix 700	2007	834
Grain Mix 900	2580	1260

Amendments – standard curve development



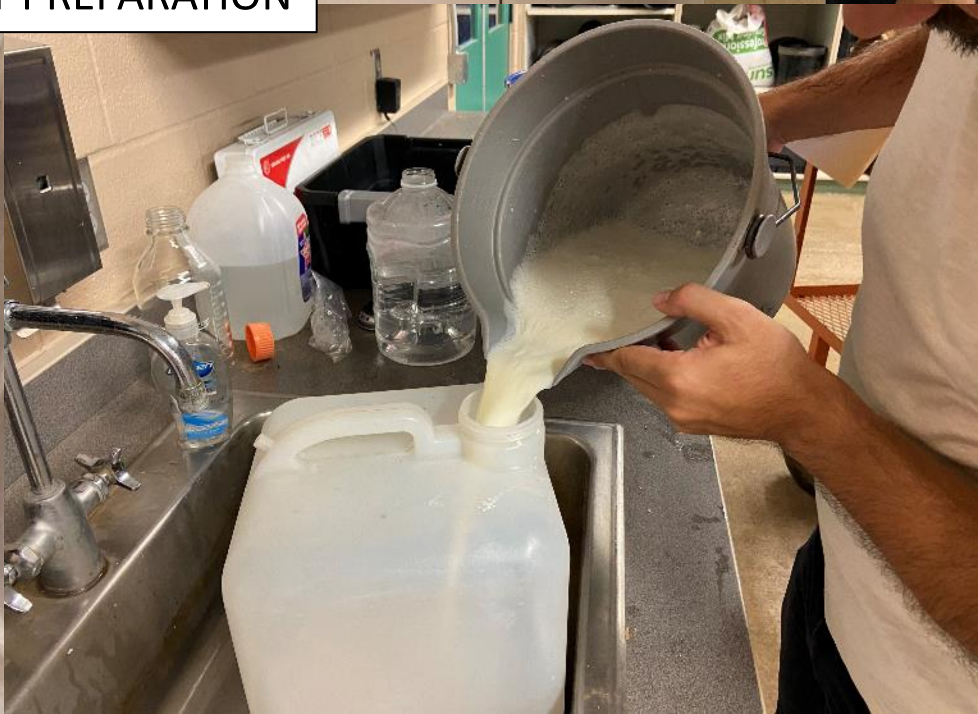




Amendments in wastewater

Sample Description	BOD_5 (mg/L)	Mean	St. Dev.	Less WW	Mean
Wastewater (ATU Pump Tank) – Rep 1	109				
Wastewater (ATU Pump Tank) – Rep 2	121				
Wastewater (ATU Pump Tank) – Rep 3	105				
Wastewater (ATU Pump Tank) – Rep 4	100				
Wastewater (ATU Pump Tank) – Rep 5	100	107	9		
Wastewater + Dextrose 300 – Rep 1	438			331	
Wastewater + Dextrose 300 – Rep 2	437			330	
Wastewater + Dextrose 300 – Rep 3	438			331	
Wastewater + Dextrose 300 – Rep 4	434			327	
Wastewater + Dextrose 300 – Rep 5	436	437	2	329	330
Wastewater + Milk 300 – Rep 1	561			454	
Wastewater + Milk 300 – Rep 2	572			465	
Wastewater + Milk 300 – Rep 3	566			459	
Wastewater + Milk 300 – Rep 4	543			436	
Wastewater + Milk 300 – Rep 5	555	560	11	448	452
Wastewater + Dextrose:Milk (70:30) 300 – Rep 1	450			343	
Wastewater + Dextrose:Milk (70:30) 300 – Rep 2	460			353	
Wastewater + Dextrose:Milk (70:30) 300 – Rep 3	476			369	
Wastewater + Dextrose:Milk (70:30) 300 – Rep 4	478			371	
Wastewater + Dextrose:Milk (70:30) 300 – Rep 5	484	470	14	377	363
Feed Tank Wastewater – Rep 1	287				
Feed Tank Wastewater – Rep 2	293				
Feed Tank Wastewater – Rep 3	308				
Feed Tank Wastewater – Rep 4	284				
Feed Tank Wastewater – Rep 5	295	293	9		
Feed Tank Wastewater + Grain Mix 300 – Rep 1	805			512	
Feed Tank Wastewater + Grain Mix 300 – Rep 2	773			480	
Feed Tank Wastewater + Grain Mix 300 – Rep 3	756			463	
Feed Tank Wastewater + Grain Mix 300 – Rep 4	737			444	
Feed Tank Wastewater + Grain Mix 300 – Rep 5	748	764	27	455	470

AMENDMENT PREPARATION



AMENDMENT DELIVERY

Results (preliminary) – influent BOD_5 increase from SHSW amendments

Exp	Average* Raw Sewage Influent BOD_5 [mg/L]	Average SHSW Amended Influent BOD_5 [mg/L]	SHSW Amended Influent Percentage increase from Raw Sewage Influent
1	56	230	311%
2	82	163	99%
3	123	403	228%
4	120	201	68%
5	122	190	56%
6	261	461	77%
7	210	548	161%
8	136	650	378%
9	60	956	1493%
10	344	2943	756%

* Average of 8 samples over 2-week experimental period (6 for Experiment 3)

Results (preliminary) – BOD_5

	Common Influent (Demand and Time Dose)				Demand Dose Effluent		Time Dose Effluent	
EXP	Flow Reduction [% of normal]	Average* Influent Flow [gal/day]	Average Influent BOD_5 [mg/L]	Average Influent BOD_5 Load [lb/day]	Average Effluent BOD_5 [mg/L]	Average Effluent BOD_5 Reduction	Average Effluent BOD_5 [mg/L]	Average Effluent BOD_5 Reduction
1	100% -	225	230	0.43	**42**	**82%**	**42**	**82%**
2	100% -	225	163	0.31	21	87%	18	89%
3	80% ↓	180	403	0.60	21	95%	21	95%
4	70% ↓	158	201	0.26	20	90%	22	89%
5	70% -	157	190	0.25	29	85%	26	86%
6	50% ↓	111	461	0.43	23	95%	12	97%
7	50% -	112	548	0.51	25	95%	31	94%
8	50% -	114	650	0.62	25	96%	19	97%
9	50% -	113	956	0.90	15	98%	12	99%
10	50% -	114	2943	2.80	34	>99%	31	>99%

* Average of 8 samples over 2-week experimental period (6 for Experiment 3)

Results (preliminary) – TSS

	Common Influent (Demand and Time Dose)			Demand Dose Effluent		Time Dose Effluent	
EXP	Flow Reduction [% of normal]	Average Influent Flow [gal/day]	Average Influent TSS [mg/L]	Average Effluent TSS [mg/L]	Average Effluent TSS Reduction	Average Effluent TSS [mg/L]	Average Effluent TSS Reduction
1	100% -	225	53	**40**	**25%**	**52**	**2%**
2	100% -	225	74	21	72%	12	84%
3	80% ↓	180	138	18	87%	18	87%
4	70% ↓	158	131	9	93%	20	85%
5	70% -	157	347	26	93%	24	93%
6	50% ↓	111	506	12	98%	11	98%
7	50% -	112	1886	18	>99%	19	>99%
8	50% -	114	4468	9	>99%	15	>99%
9	50% -	113	4115	8	>99%	26	>99%
10	50% -	114	17530	22	>99%	28	>99%

* Average of 8 samples over 2-week experimental period (6 for Experiment 3)

Summary

- Installed parallel ATU treatment trains at TAMU RELLIS OSSF
- Developed synthetic high-strength waste formulation
- Developed precision flow and dosing procedures
- Implemented 10, 2-week experiments, 8 sample measurements
- Lowered flow to 50% of normal; simulating conservation/reuse
- Raised BOD_5 concentration >300 mg/L; simulating high strength
- Both Demand and Time ATUs met BOD_5/TSS 30:30 or >90% reduction
- Differences in Demand and Time dosed ATU response minimal
- Visual difference between Demand and Time dosed TSS
- Formal analysis pending

QUESTIONS? and Thank You!

AgriLife OSSF Research Team

June Wolfe III - ATU

jwolfe@brc.tamus.edu

(254) 774-6016

Anish Jantrania - REUSE

ajantrania@brc.tamus.edu

(254) 774-6014

Gabriele Bonaiti - LPD

g.bonaiti@tamu.edu

(979) 862-2593

Ryan Gerlich – OSSF Management

rgerlich@tamu.edu

(979) 458-4185

Mesut Ozdemir

Ryan Gerlich