Optimization Protocol for Nitrogen Removal from Domestic Wastewater

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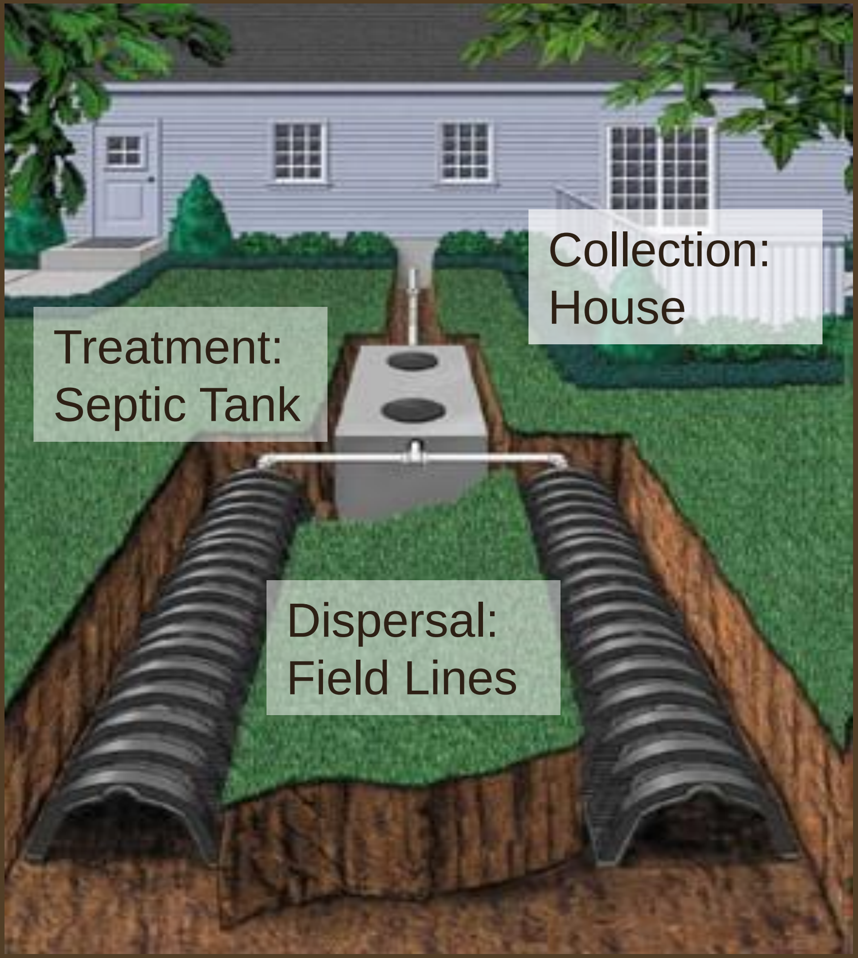
Onsite Wastewater Treatment Systems (OWTS)

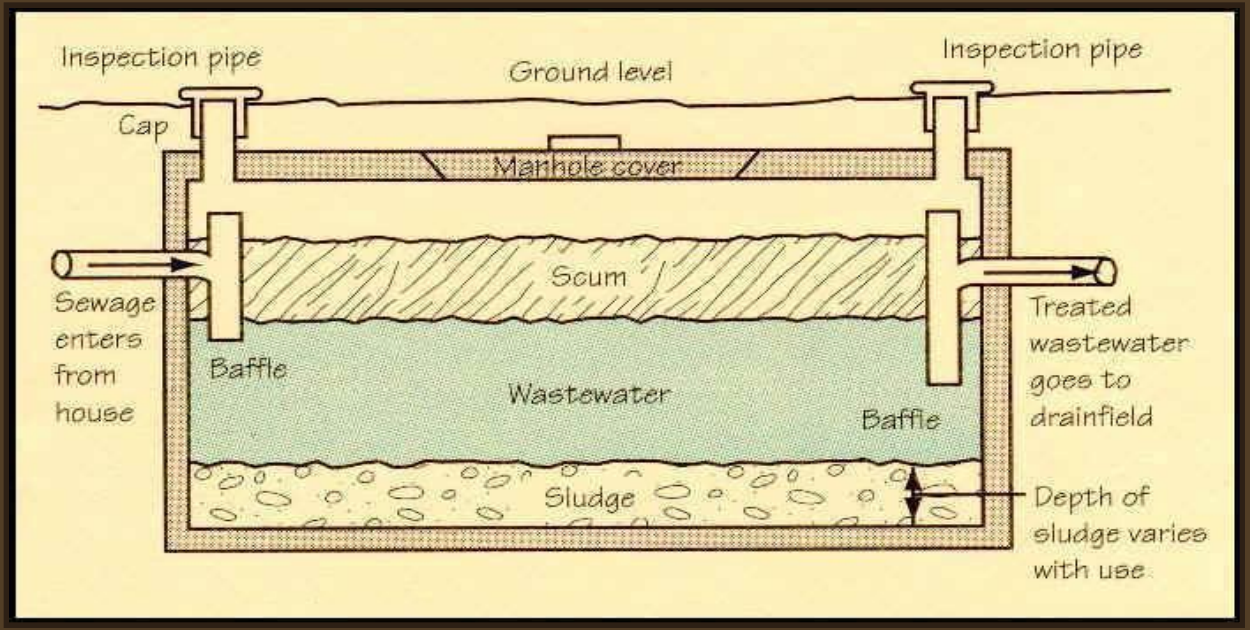
- Three parts to every OWTS
  - Collection
  - Treatment
  - Dispersal
- High failure rates in field lines



http://www.ainspect.com/CMContent/septic/septic_tank.html

Onsite Wastewater Treatment Systems (OWTS)

- Septic systems are the most common type of OWTS.
- Septic tanks gravity separate liquid and solid wastes into three layers



http://extension.umd.edu/environment/Water/files/septic.html

OWTS Failures

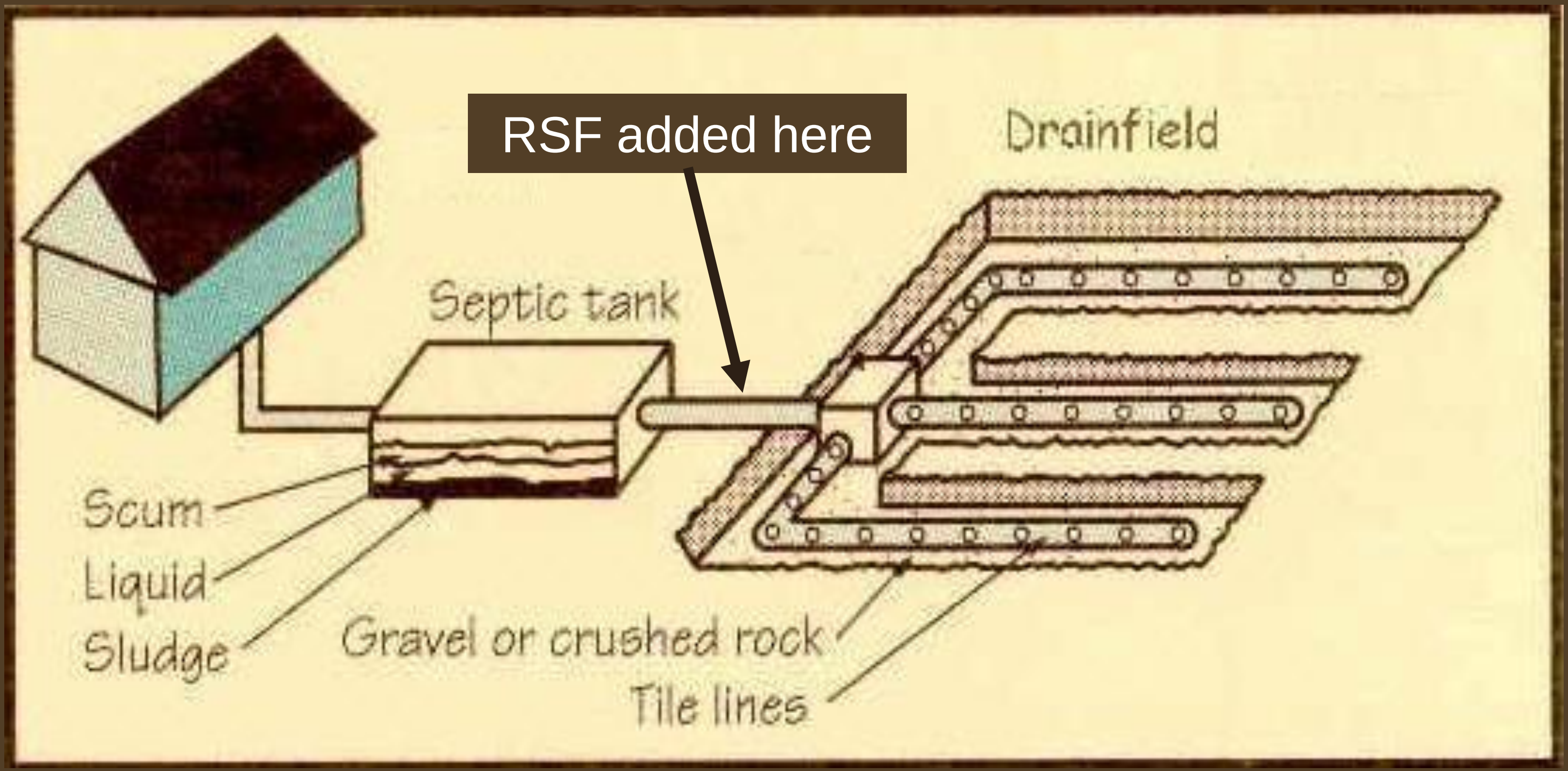
High Nitrogen Levels

- Eutrophication of waterways
- Harmful algal blooms
- Decreased dissolved oxygen
- Aquatic species decline
- Economic losses

Center for Decentralized Wastewater Management

Recirculating Sand Filter

- RSF added where soil is inadequate
- Treatment makes dispersal more predictable



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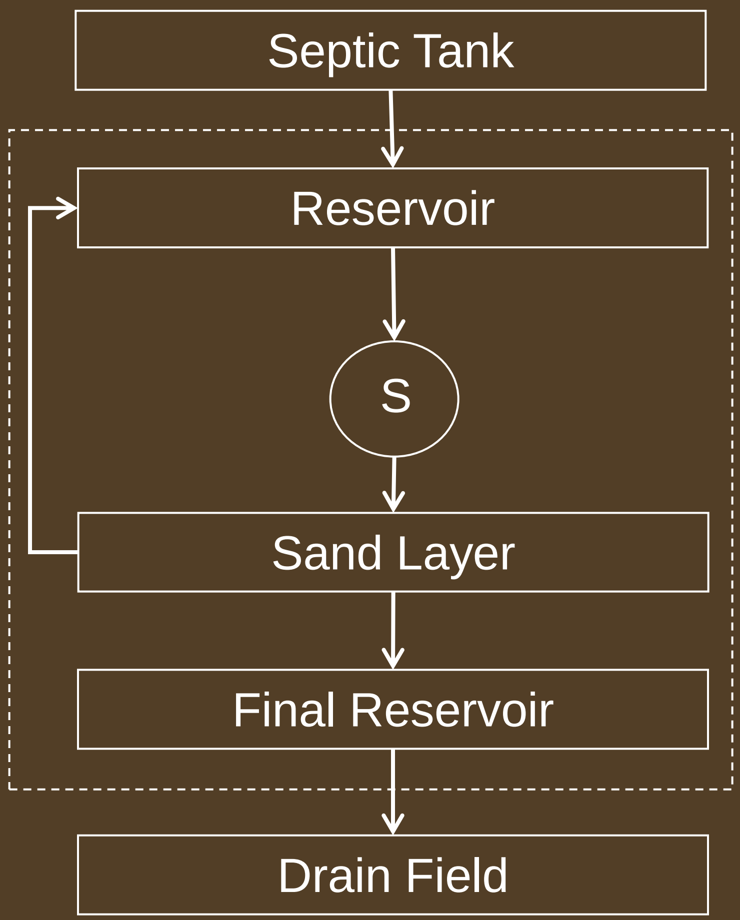
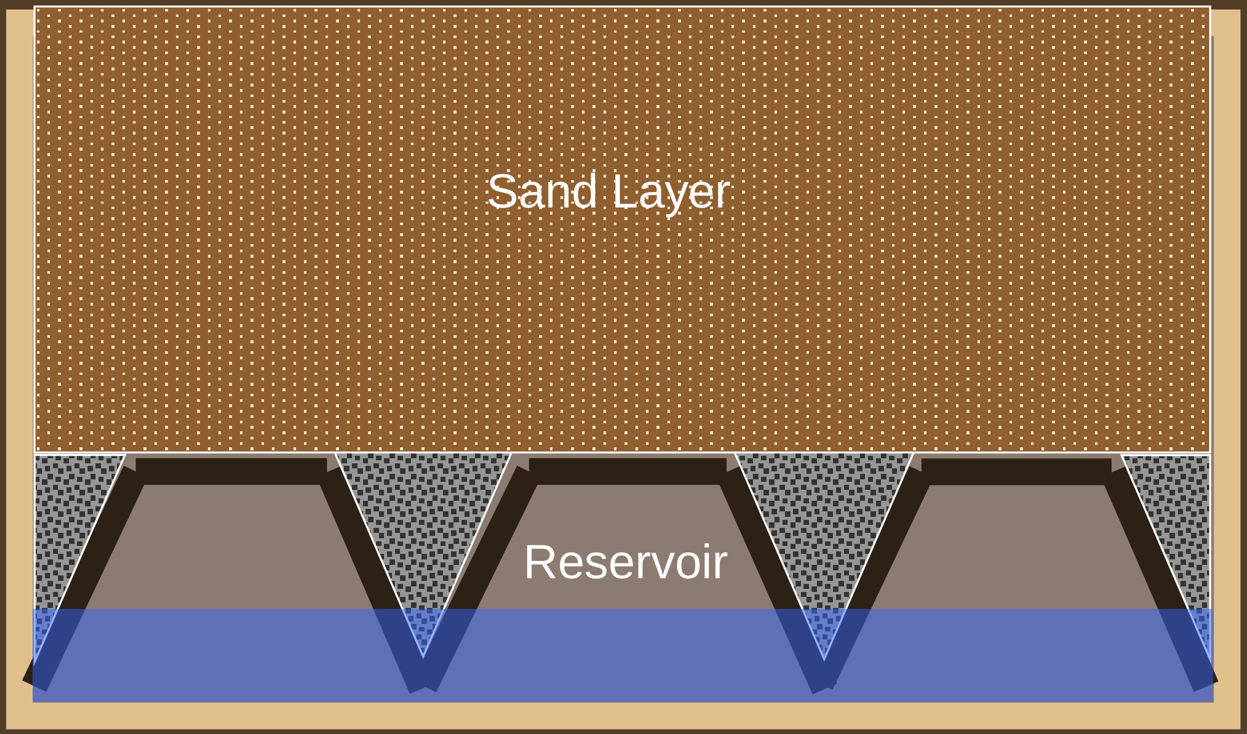
What is a Recirculating Sand Filter?



1. Human waste enters the reservoir from a septic tank
2. Wastewater is circulated through the sand layer
3. Wastewater is given a final filtration
4. Discharge cleaned effluent to drain field

Biological Treatment

- Wastewater is treated by bacteria in system
- Aeration and nitrification occur in sand layer
- Reservoir is anoxic and denitrification occurs



Problems with Conventional RSFs

- “Dumb” control system
  - Recirculation and discharge on fixed schedule
  - No information on reservoir conditions
- Poor nitrogen removal
  - Not optimized for nitrification/denitrification

Scope

- Design a control system for an RSF incorporating sensor feedback and variability
- Evaluate the effectiveness of adding sensor feedback into the control process

Project Requirements

- Process 100 gal/day
- Control system operates in humid, acidic environment
- Easy to maintain
- Cost less than $1000
  - Assume mass production
- Run on 120 VAC

Approach

- Build an RSF in the lab
- Develop and run control systems
  - Monitor system parameters
  - Integrate sensor feedback
  - Optimize microbial environment
- Evaluate effectiveness of sensor feedback
  - Collect water quality data
  - Compare control systems

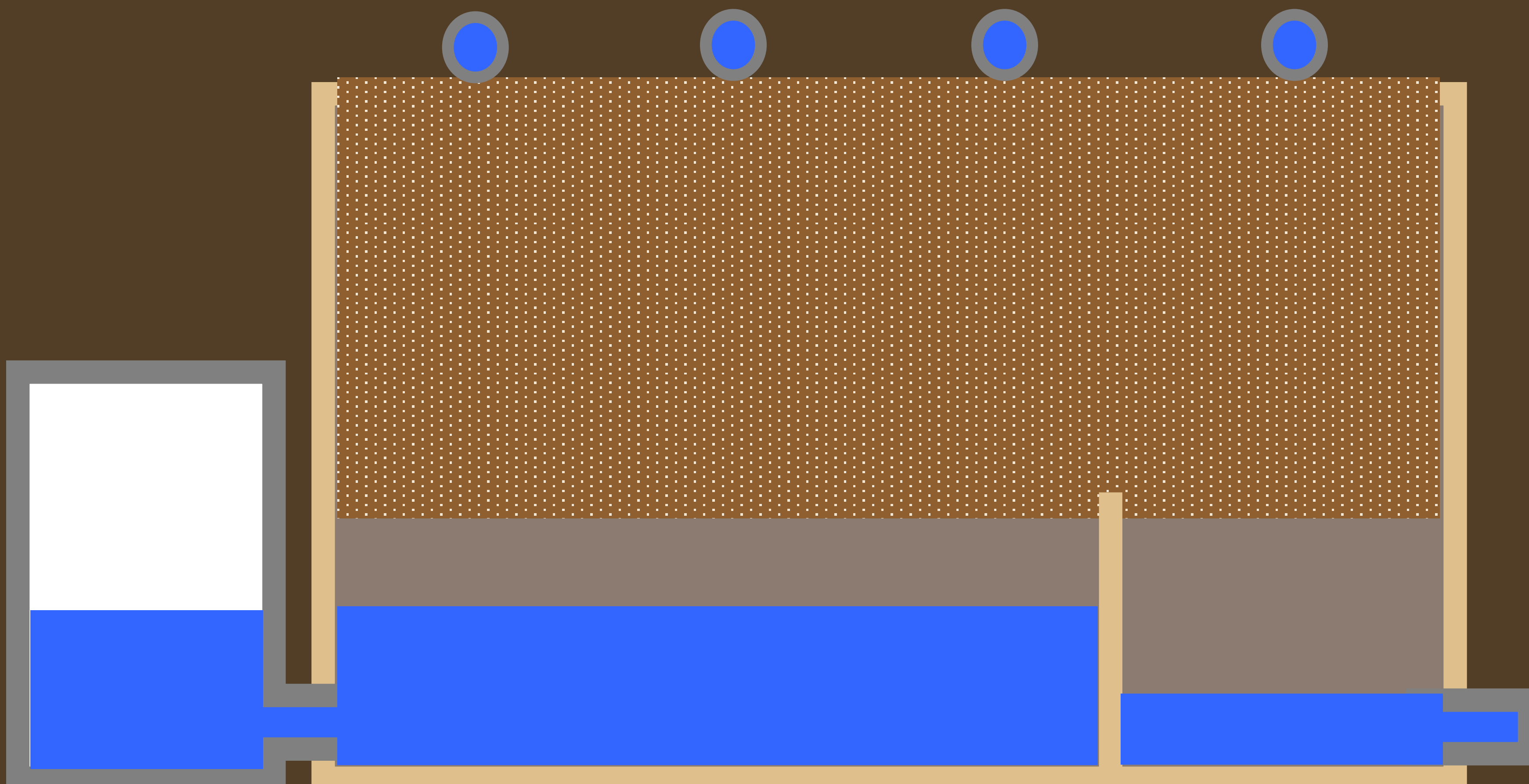
Lab RSF

- Designed and built 100 gal/day RSF
- Standard loading of 4 gal/ft^2/day of wastewater
- Sidewalls resist up to 840 lbf
  - Based analysis on American Wood Council's design stresses
  - 2001 NDS supplements for wood construction
- Weighs approximately 10,000 lbs

Lab RSF

- Depth profile: 1 ft of void space and 2 ft of media
- Chambers maintain void space
  - Divided for recycle and discharge
- Fine gravel media
- 6 in. standpipe installed during model construction

RSF Cross Section



Lab RSF Plumbing

- Pump housed in pump tank
  - Pump tank connected to the void space
- Four parallel distribution pipes - 1/2 in. PVC
  - 5/32 in. diameter orifices
  - Provide desired flow rate
- Pipes and orifices - 15 in. on-center spacing

Electronic Components

- Sensors
  - Dissolved Oxygen
  - pH
  - Water levels (high and low)
- Control Board
  - Datalogging and Dynamic control

Control Boards

- Campbell Scientific CR23X
  - Reliable datalogging
  - Cumbersome for control
- Parallax BASIC Stamp Development Board
  - Affordable
  - Easy to program and control

Control Programs

- All control programs
  - Compensated for high and low flow conditions
  - Saved sensor data every 15 minutes
  - Discharge for 30 seconds every 14 minutes
- Conventional Control
  - Recirculate and discharge on a fixed schedule

Control Programs

- **Nitrify:** run recirculation lines
- **Denitrify:** do not run recirculation lines
- **pH Driven w/DO:** pH primary driver
- **DO Driven w/pH:** DO primary driver
- **Independent DO:** DO only driver

System State	Dissolved Oxygen (mg L^{-1})	pH
Denitrify	Greater than 2.0	Less than 7.5
Nitrify	Less than 2.0	Less than 7.5
Denitrify	Less than 2.0	Less than 6.5
Nitrify	Less than 1.0	Greater than 7.5
Denitrify	Greater than 1.0	Greater than 7.5
Nitrify	Greater than 1.0	Greater than 9.0

System State	Dissolved Oxygen (mg L^{-1})
Denitrify	Greater than 2.0
Nitrify	Less than 0.2

Testing

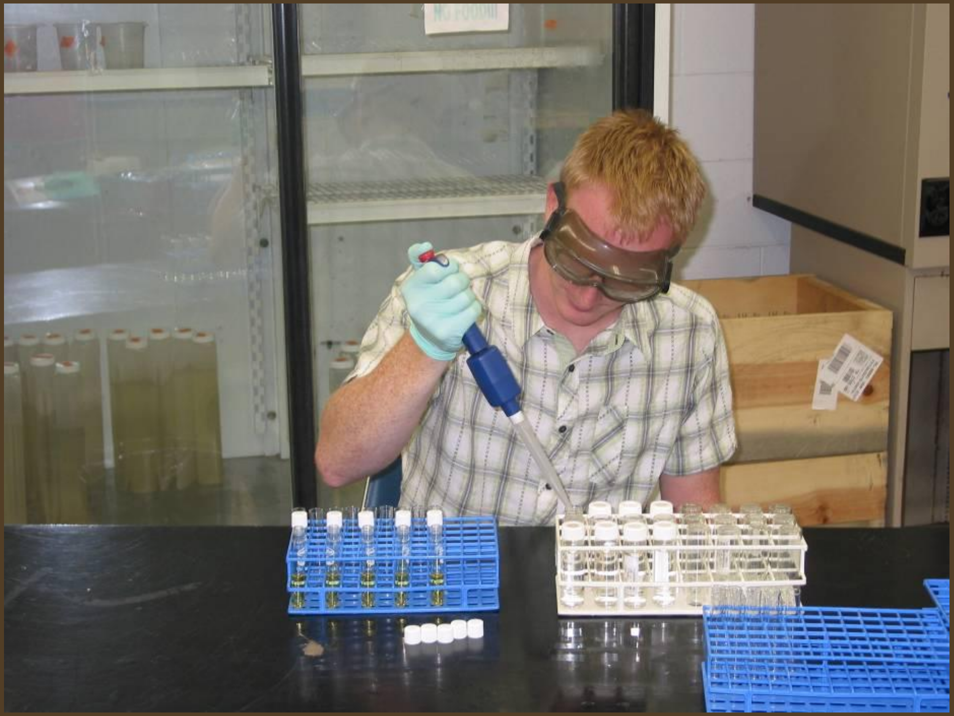
Program	Time
Inoculation	21 days
Conventional	21 days
pH Driven w/ DO	5 days
DO driven w/ pH	10 days
Independent DO	10 days

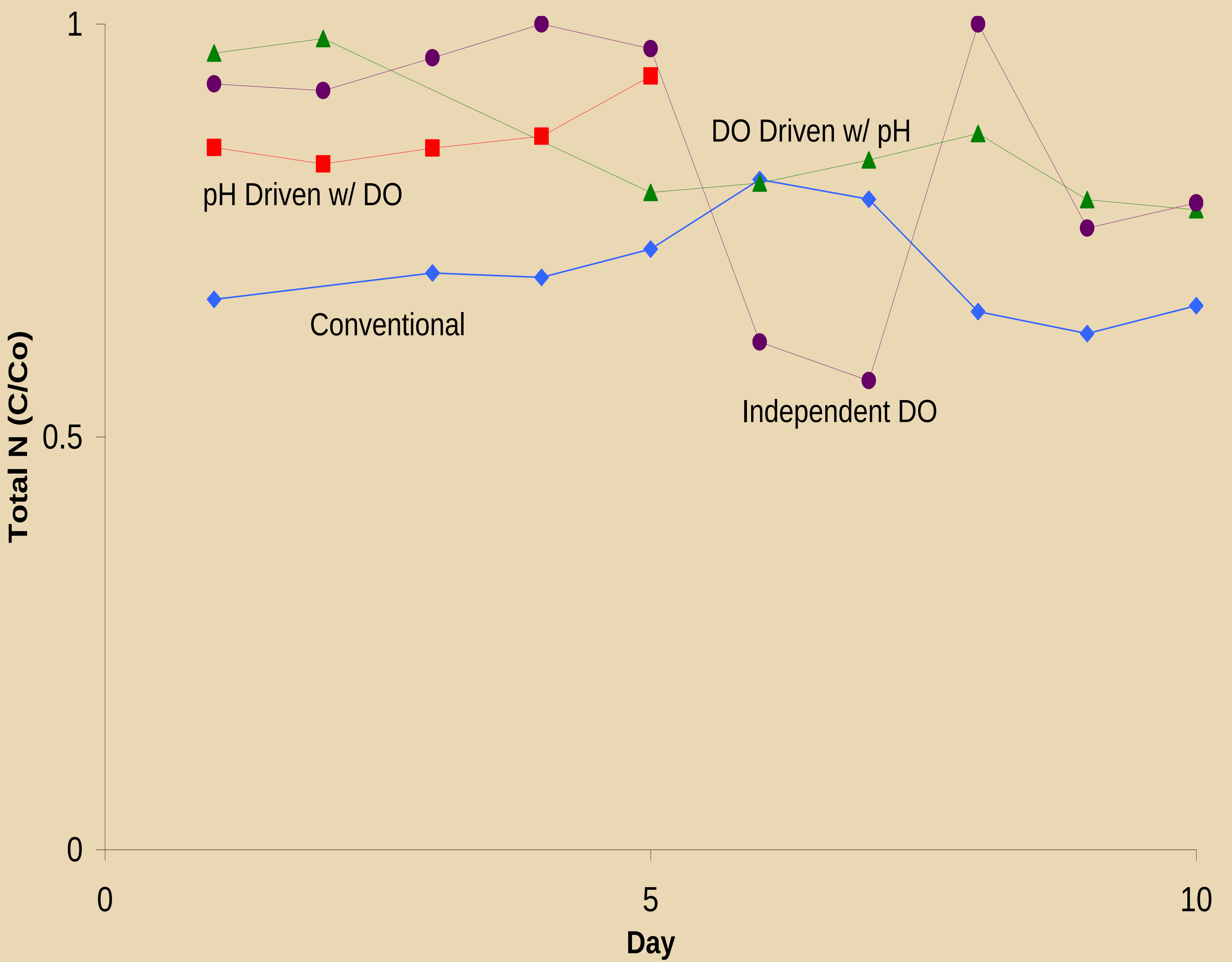
Teledyne ISCO Avalanche Sampler

- Hourly Influent and Effluent Samples
- 8-hour aggregates analyzed

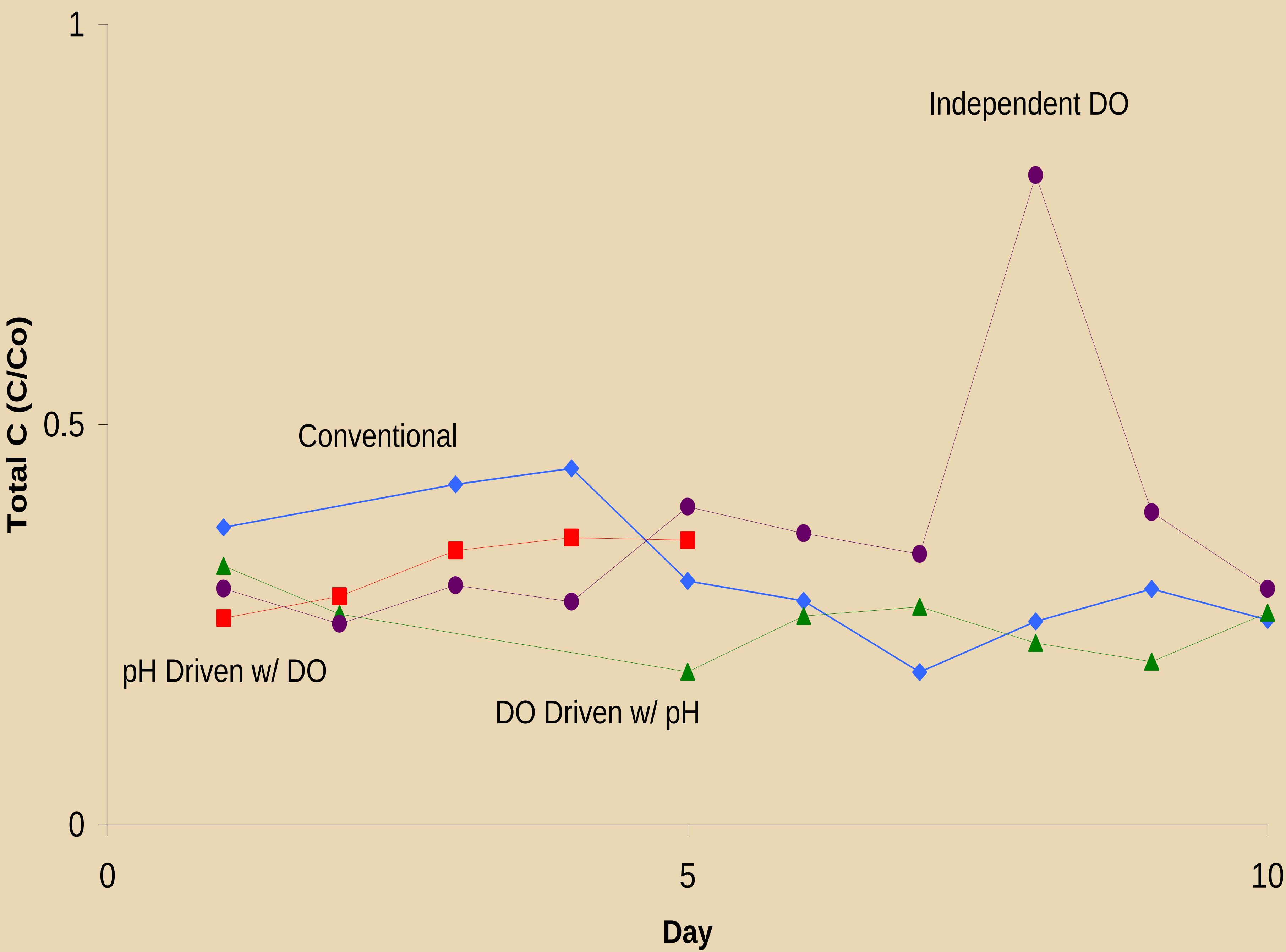
Water Quality Analysis

- Chemical Oxygen Demand
- Total Nitrogen
- Total Carbon
- Nitrate and Nitrite
- Ammonia

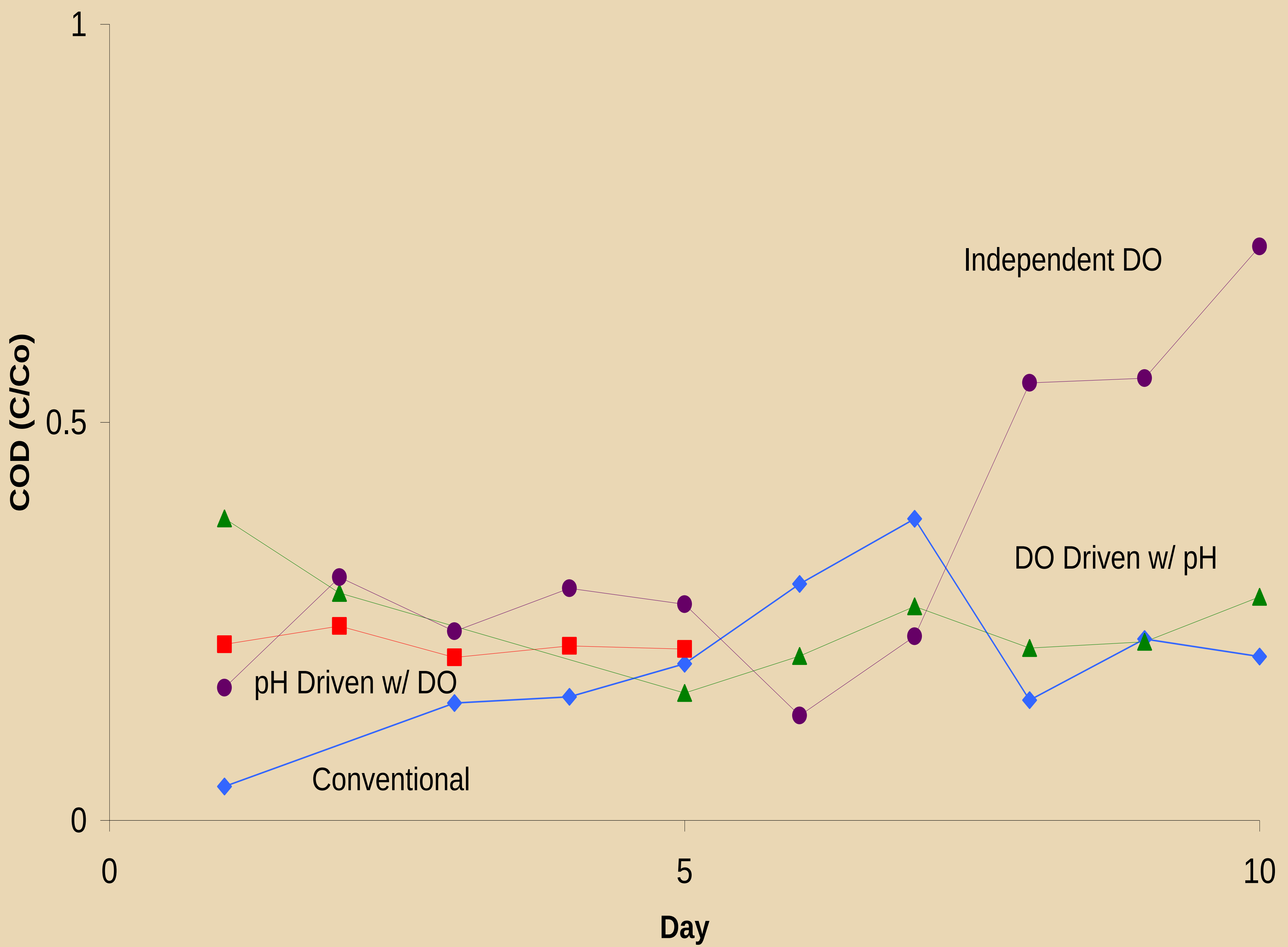




Total N (C/Co)
1
0.5
0
0
5
10
Day
DO Driven w/ pH
pH Driven w/ DO
Conventional
Independent DO



Independent DO
Conventional
pH Driven w/ DO
DO Driven w/ pH
Total C (C/Co)
1
0.5
0
0
5
10
Day



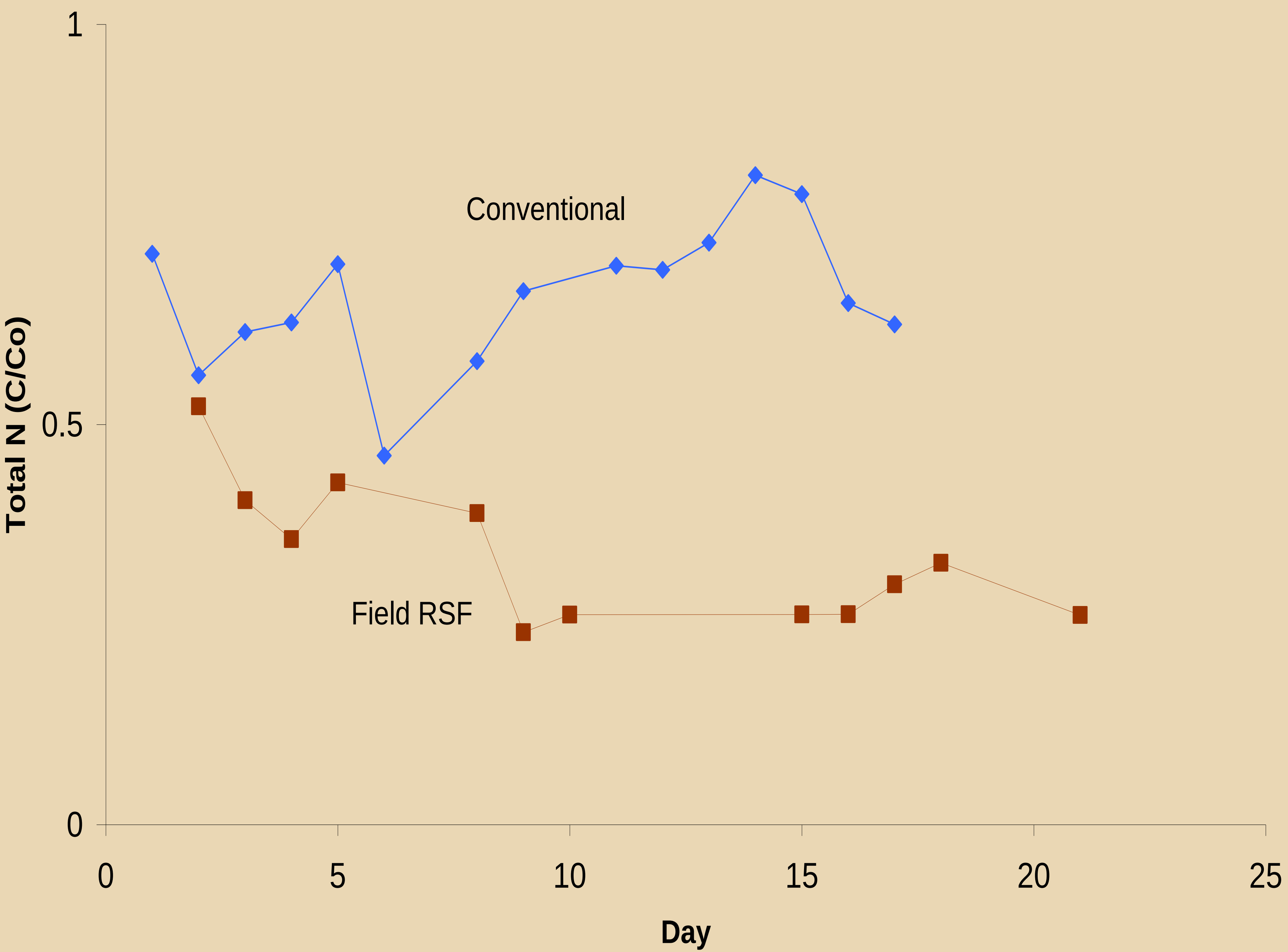
1
0.5
0
COD (C/Co)
Independent DO
DO Driven w/ pH
pH Driven w/ DO
Conventional
0
5
10
Day

Findings

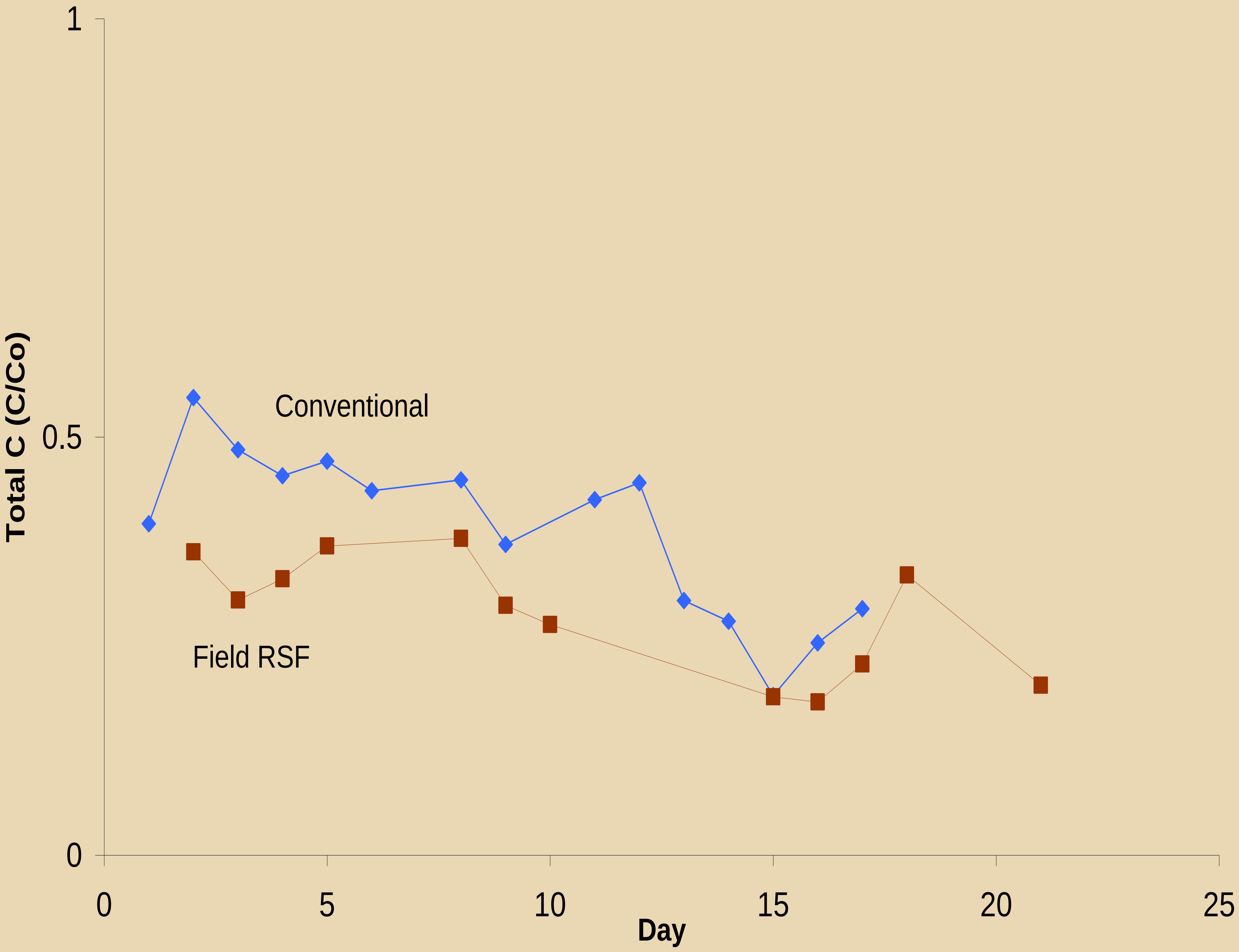
- Incorporating sensor feedback caused a change in the system
- pH not varied enough for feedback control
- DO with pH not significantly different from conventional control system
- Independent DO did not work as designed due to low water level problems
- Independent DO might perform better if flow sensor data is added to control

Validation of Model

- Compare conventional control on lab RSF to field RSF
- Verify lab RSF is functioning properly



Total N (C/Co)
1
0.5
0
Conventional
Field RSF
0
5
10
15
20
25
Day



1
0.5
0
Total C (C/Co)
Conventional
Field RSF
0
5
10
15
20
25
Day

Validation Results

- Total Carbon similar for both RSF's
- Total Nitrogen difference is result of loading
  - Field RSF operating at half capacity
- Larger buffering capacity in field RSF
- Better established bacterial colonies in field RSF
- Testing was not simultaneous
  - Different waste streams

Cost

Item	Cost ($)
BASIC Stamp Board	15
BS2p Microcontroller	40
Integrated Chips	5
LCD Display	20
Wiring	10
Sensors	800
Housing	50
Total	940

Meeting Requirements

Requirement	Complete?
Processes 100 gal/day	Y
Control system operates in humid, acidic environment	Y
Stamp controller is easily maintained	Y
Costs less than $1000	Y
Runs on 120 VAC	Y

Recommendations

- Integrate flow measurements into control
- Add more I/O capacity to Stamp controller
  - Flow and pH
- Longer testing periods

Conclusion

- Lab RSF operated as designed
- Control systems with sensor feedback produced a change in system performance
- pH buffering capacity of system was too high to alter through recirculation control
- BASIC Stamp controller allows quick and easy modification of control

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