Seminole Electric COOPERATIVE, INC.

IN PARTNERSHIP WITH THOSE WE SERVE

Testing to Meet Low Mercury Limits in FGD Purge Water at a Coal-Fired Plant

Presented by - Paul Pigeon, PE, Golder Associates Inc.

EUEC 2015

I.1 Wastewater Management

Golder Associates

Acknowledgements

Co-Authors

Seminole Generating Station Technical Lead – Troy Patton

Golder Process Engineer – Rachel Hanson

Golder Field Engineer – Kristen Sealey

And

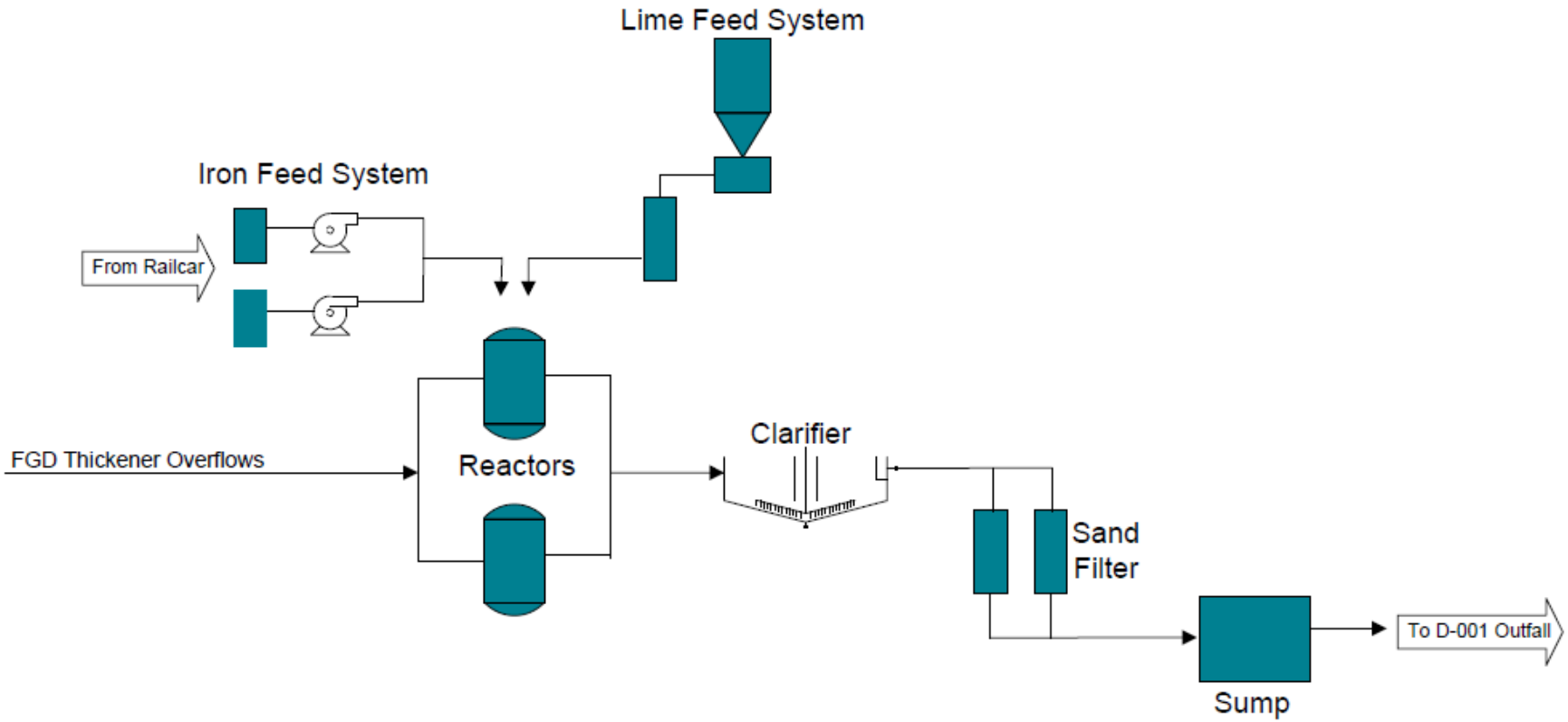
Seminole Generating Station Project Manager –Lance French

Golder Project Manager – Brian Huff

Seminole Generating Station Profile

- 1,500 MW Coal-Fired Plant near Palatka, Florida
- 2 – 750 MW Units with Wet Flue Gas Desulfurization (FGD) Systems
- FGD Produces Gypsum – Supplied to Co-Located Wallboard Plant
- FGD Purge Water Treatment System (PWTS)
  - Gypsum Desaturization
  - Iron Reduction for Selenium Removal
  - Coincident Mercury Removal
- Discharge to St.John's River with Other Low-Volume and Cooling Tower Blowdown Wastewaters at Outfall D-001
- Mercury Sometimes Exceeds Limit at D-001

Existing PWTS



Seminole Electric COOPERATIVE, INC.
IN PARTNERSHIP WITH THOSE WE SERVE

Golder Associates

Project Goals

- Study a PWTS Modification for Improved Mercury Removal to Meet NPDES Permit Limit at D-001
- Provide a Path Forward for Compliance with a Florida Department of Environmental Protection Order for Mercury
- Study PWTS Modification to Meet Draft EPA Effluent Limitation Guidelines (ELGs) for PWTS effluent –
  - Mercury – 119 nanograms per liter (ng/L)
  - Selenium – 10 micrograms per liter (ug/L)

Project Approach

- Bench-Scale Treatability Testing and Conceptual Analysis of Alternatives
  1. Single-Stage Organosulfide/Iron Precipitation and Filtration for Mercury Removal
  2. Two-Stage Iron and Organosulfide Precipitation and Filtration for Mercury and Selenium Removal

- Next Step – Pilot Testing of Either or Both Alternatives

Then…

- EPA delayed issuance of Steam Electric Effluent Guidelines

Seminole Pilot Test Decision

- Primary Focus on FDEP Order Compliance - Mercury
- Regulatory Uncertainty of EPA ELG Promulgation Date and Final Regulatory Option to be Selected
- Seminole Selected Alternative 1 and a 4-Week Pilot Test Period
  - Single-Stage Mercury Removal with Organosulfide/Ferric Iron Precipitation and Sand Filtration
- Pilot Testing Occurred in April and May 2014, immediately after an Outage on 1 Generating Unit

Pilot Testing Objectives

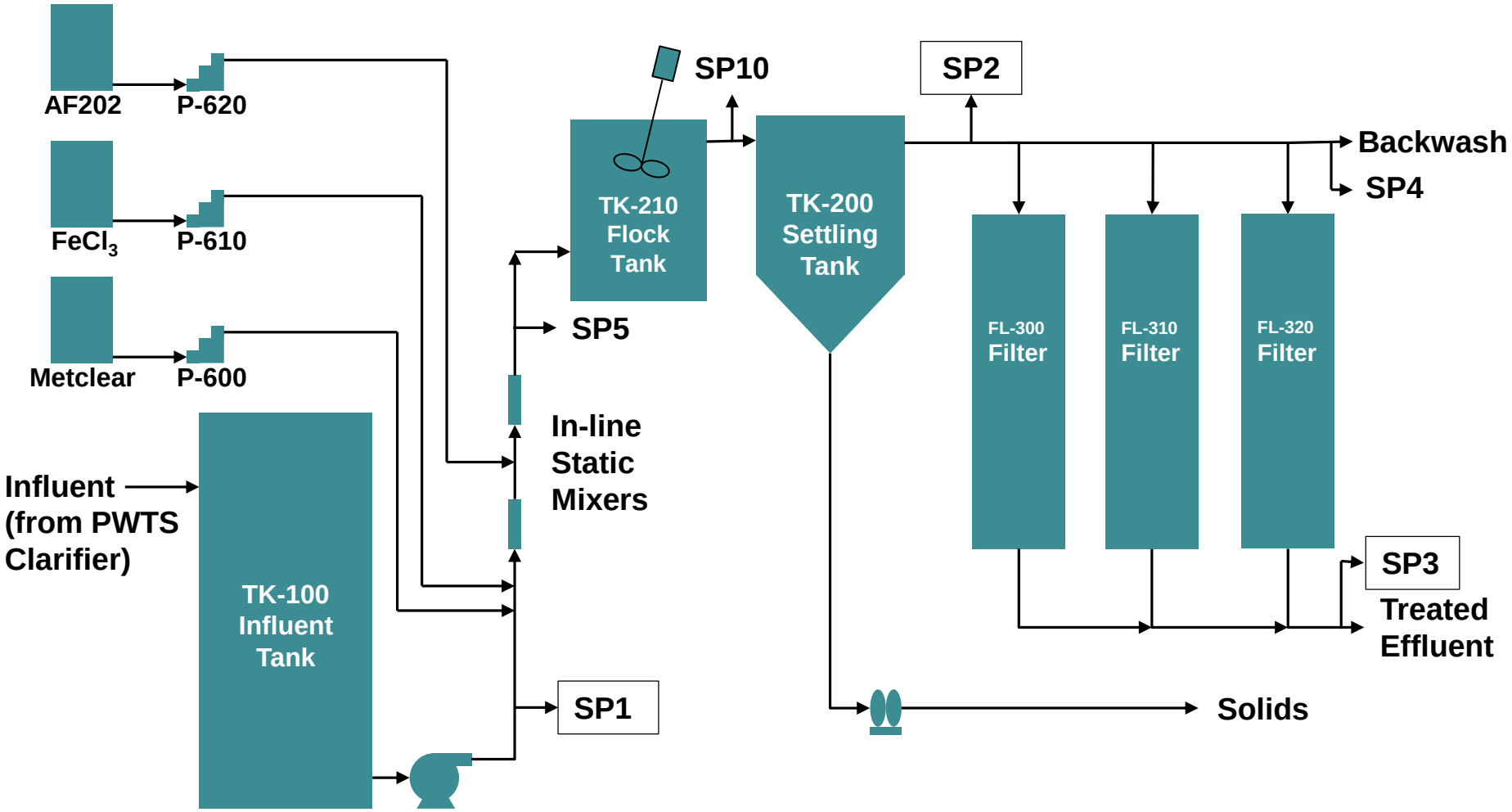
- Primary Objective: Pilot effluent Mercury concentration < 225 ng/l to assure compliance with NPDES effluent limit at D-001
- Secondary Objective: Pilot effluent Mercury concentration < 40 ng/l for ELG compliance (1/3 of Draft Guideline)
- Determine the dosages of organosulfide, ferric chloride, and polymer
- Demonstrate whether the TSS loading generated by chemical treatment can be handled by the existing sand filter units

Key Pilot System Design Criteria

- Design flow rate = 5.5 gpm (1% of PWTS flow rate)
- Chemical-physical treatment process for enhanced mercury removal
  - Metclear MR2405 (Organosulfide)
  - $FeCl_3$ (Ferric Chloride)
  - Hychem AF202 (Anionic Polymer)

Equipment Name	Design Criteria
Reaction Tank (plus Settling)	20 minute HRT 60° cone bottom
Reaction Tank Mixer	Low shear
Sand filters	2.33 gpm/ft^2 hydraulic loading rate 8-inch minimum diameter 3 filters operated in parallel

Simplified BFD with Added Flock Tank



Seminole Electric Cooperative, Inc.
In partnership with those we serve

Golder Associates

Sampling Locations

Sample Port	Sample Location
SP1	PWTS clarifier effluent/Pilot influent
SP2	Pilot sand filter influent
SP3	Sand filter effluent/Pilot effluent

Note: Additional sample IDs were assigned for tracking solids content and laboratory QA samples

Mercury Pilot Installation

Seminole Electric COOPERATIVE, INC.
IN PARTNERSHIP WITH THOSE WE SERVE

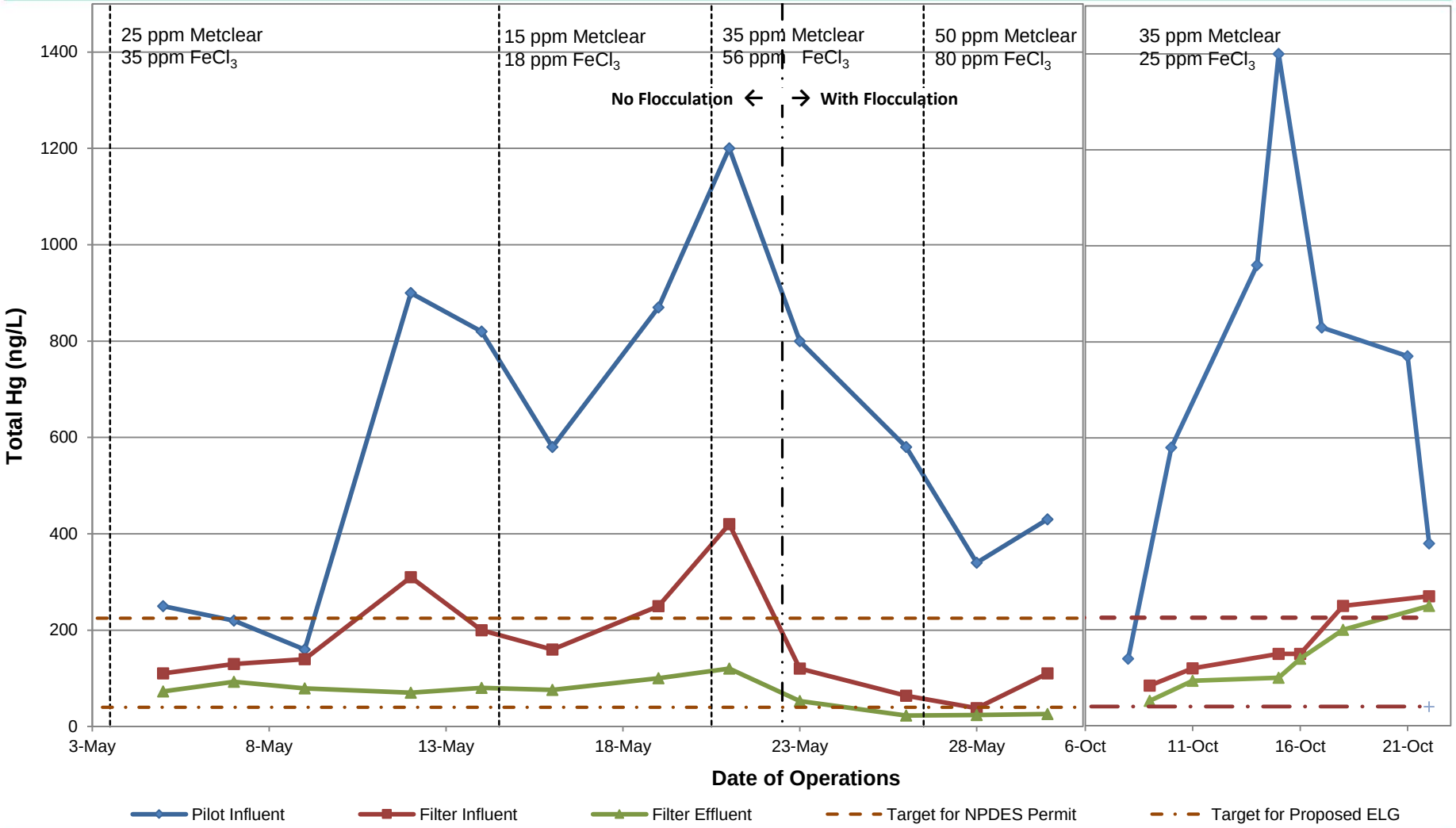
Golder Associates

Pilot Influent Water Quality (May)

Parameter	Unit	Average	Minimum	Maximum
Total Mercury	ng/l	586	160	1200
Dissolved Mercury	ng/l	247	96.0	500
Temperature	° C	31.2	24.0	39.3
Conductivity	µS	34,888	23,743	41,408
DO	mg/l	0.90	0.22	3.02
pH	s.u.	9.08	8.80	9.43
ORP	R. mV	0.4	-299.7	127.0
TSS	mg/l	38.4	ND	100.0

- Total Hg range: 160 ng/l to 1200 ng/l
- 50% of influent dissolved Hg samples < 225 ng/l target
- On average, 44% influent Hg was dissolved or colloidal (passed through 0.45 µm filter)

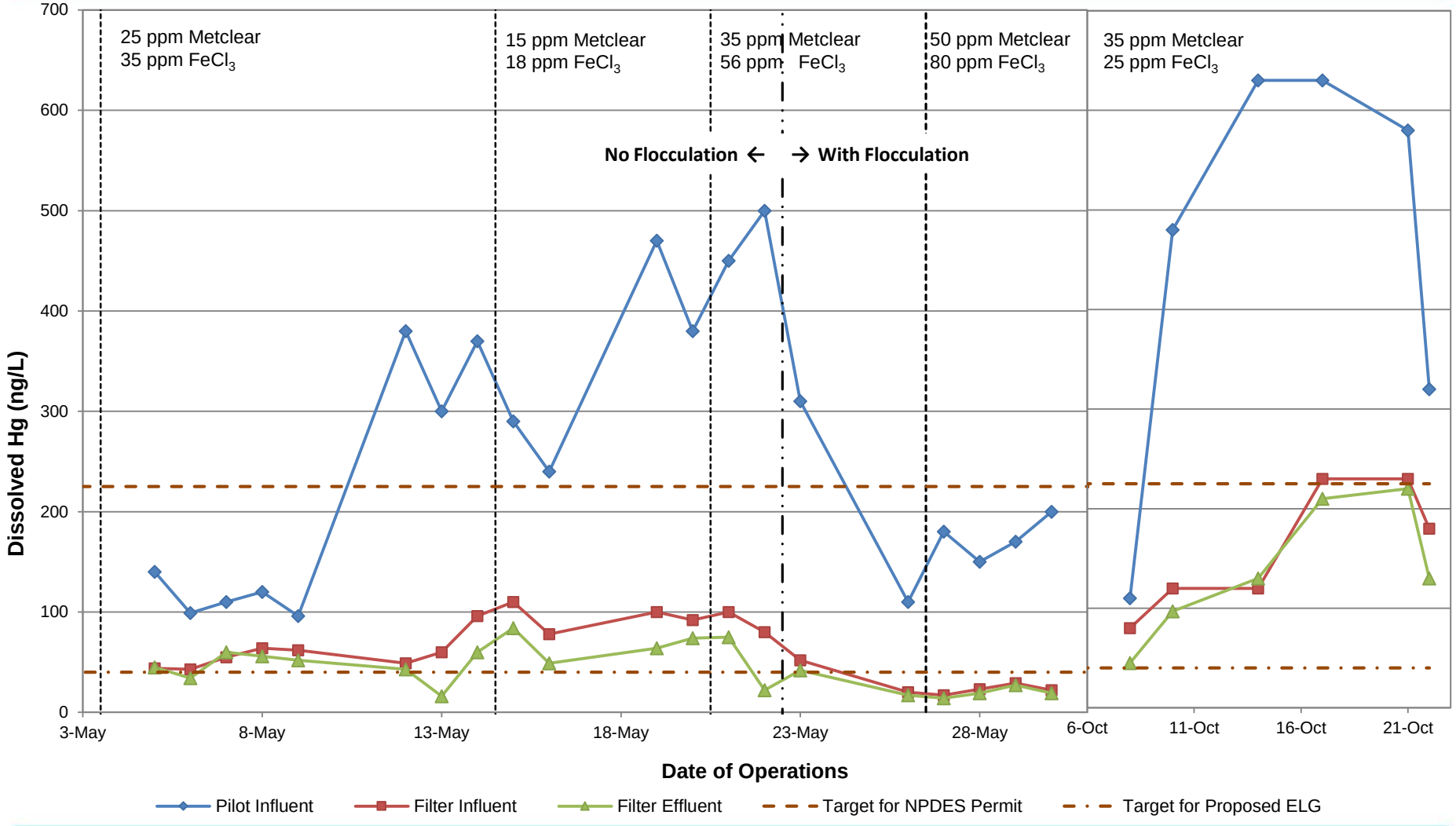
Total Mercury



Seminole Electric Cooperative, Inc.
In partnership with those we serve

Golder Associates

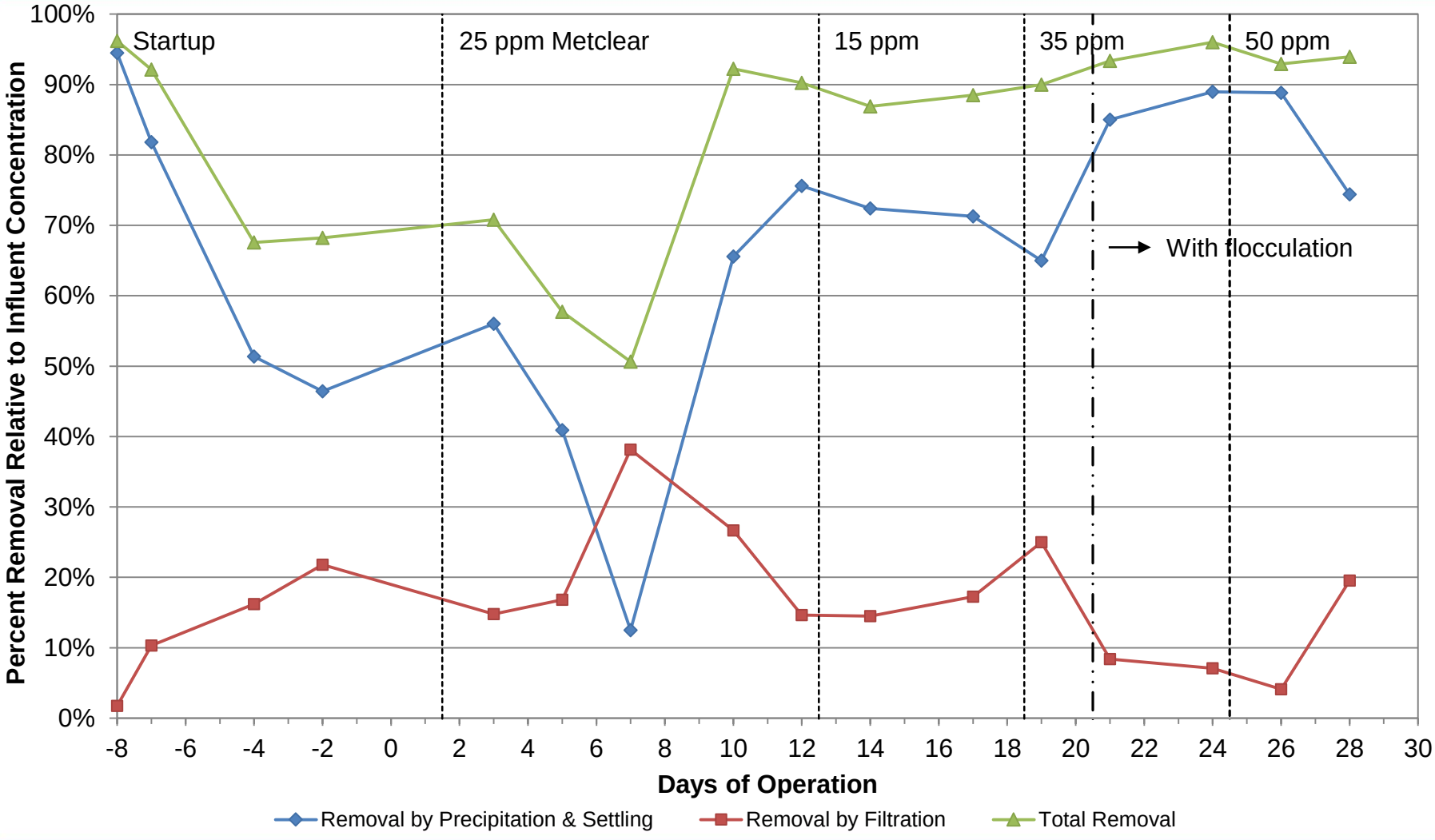
Dissolved Mercury



Seminole Electric COOPERATIVE, INC.
IN PARTNERSHIP WITH THOSE WE SERVE

Golder Associates

Mercury Removal



Seminole Electric COOPERATIVE, INC.
IN PARTNERSHIP WITH THOSE WE SERVE

Golder Associates

Effluent Water Quality (May)

Parameter	Unit	Average	Minimum	Maximum
Total Mercury	ng/l	70.4	22.0	120
Dissolved Mercury	ng/l	44.0	14.0	84.0
Temperature	° C	28.6	23.1	34.7
Conductivity	µS	31,394	9,998	39,711
DO	mg/L	1.11	0.36	2.92
pH	s.u.	8.74	8.37	9.04
ORP	R. mV	22.3	-225.6	156.4
TSS	mg/l	24.2	3.4	52.0

Effluent Mercury Concentrations

- Average effluent concentration (total Mercury)
  - Before Flock Tank Installation: 70.4 ng/l
  - After Flock Tank: 31.5 ng/l
- Effluent total and dissolved Mercury concentrations tended to be independent of the Metclear dose
  - Similar effluent concentrations over a range of doses prior to the addition of flocculation tank
- Effluent total and dissolved Mercury concentrations appeared to vary slightly with the influent concentration
  - If present, the effect of influent concentration on effluent concentration was weak
- 33% of effluent samples had **dissolved** Mercury < 40 ng/l
  - Ability to remove insoluble Mercury critical to achieve secondary treatment goal

Sequential Filtration

Mercury Fraction	Concentration (ng/l)	% of Total Mercury
Pilot Influent		
Total mercury (no filtration)	220	100%
After 0.45 µm filter ("dissolved")	110	50%
Pilot Sand Filter Effluent		
Total mercury (no filtration)	77.2	100%
After 0.45 µm filter ("dissolved")	64.9	84.1%
After 0.10 µm filter	42.9	55.6%
After 30 kDa MW filter	10.5	13.6%
After 10 kDa MW filter	8.21	10.6%

- 1 sample collected May 7, 2014
- At time of sample collection, pilot was more effective at removing particulate mercury than dissolved/colloidal mercury
- Average effluent dissolved mercury without flocculation was 64% of total mercury. After flocculation was installed, dissolved portion increased to 76% of total

Selenium Removal

Location	Units	5/7/14	5/16/14	5/21/14	5/28/14*
$FeCl_3$ dose	ppm	35 $FeCl_3$	18 $FeCl_3$	56 $FeCl_3$	80 $FeCl_3$
Pilot influent	µg/L	7.1	13.7	14.5	10.9
Pilot effluent	µg/L	6.8	12.9	12.1	7.2
Percent removal	%	4.2%	5.8%	16.6%	33.9%

* After Flocculation Tank Installation

- Remember: Draft Selenium ELG is 10 ug/L
- Some removal may have occurred during pilot treatment
  - Larger data set required to prove removal is statistically significant
  - Better removal observed during higher iron dosing periods
  - Better removal after flock tank was added.

Typical Solids Settling Tests During Pilot

Earlier – Lower Dosing

Later – Higher Dosing

Seminole Electric COOPERATIVE, INC.
IN PARTNERSHIP WITH THOSE WE SERVE

Golder Associates

Solids Characteristics

- Settled Solids Volume (SSV) in reaction/flocculation tank influent increased with increasing chemical dose
- Addition of separate flocculation tank reduced SSV in sand filter influent
- Filter backwash interval doubled after flock tank installation, even though chemical dosing was higher than prior to flock tank
- Solids passed TCLP for RCRA metals
  - Arsenic and barium were detected at less than RCRA limits
  - No other metals were detected

Conclusions – Mercury Removal

- Pilot testing successfully reduced effluent Mercury concentrations to < 225 ng/l.
  - Pilot influent concentrations were lower than historical maximums
- Pilot test process reduced effluent Mercury to < 40 ng/l after flocculation and settling unit operations were improved.
  - Results obtained in October 2014 (higher effluent Mercury) need further review (ratio of organosulfide:ferric iron may be a key)
- Substantial colloidal fraction of Mercury was present
  - Effective chemical addition, flocculation and settling are necessary so that sand filters (current Seminole polishing process) can be utilized.
  - Tighter membrane filtration might be needed

Conclusions – Solids Removal

- Visual observations indicated less turbid, higher quality water was produced after the flocculation step was added.
- Filter operation times increased after the addition of flocculation.
- Flocculation and settling appeared to play a larger role than chemical dosing in minimizing solids loading on the sand filters.
- Sand filters hydraulic loading rate of 2.33 gpm/ft^2 recommended for use during pilot operations should result in filter operations similar to current PWTS conditions.

Path Forward: Mercury Removal at Seminole

- After ELGs are issued for FGD wastewater, check ability of existing PWTS plus Organosulfide Mercury Polishing to provide reliable compliance for Mercury AND Selenium
- Conduct additional Mercury Polishing testing for:
  - Repeatable Mercury results
  - Check Selenium removal
  - Assess need for better filtration
- If another process would be needed for Selenium, consider optional technologies that may achieve both Mercury and Selenium removal in one process

Seminole Mercury Pilot Project

Questions?

Seminole Electric COOPERATIVE, INC.
IN PARTNERSHIP WITH THOSE WE SERVE

Golder Associates