Seasonality of Progressive Iron Removal within the Initial Oxidation Cell of a Passive Treatment System

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Importance of Iron Removal

- Accessibility via chemical activity (order of operations)
- Physical and chemical complications with other treatment cells staged later in the series.
- Side benefit of sorption of other trace metals (zeta potential dependent)

Understanding the System

- **Influent water quality and loading rates**
  - Metals species and concentrations
  - Flow rates (hydroperiod)

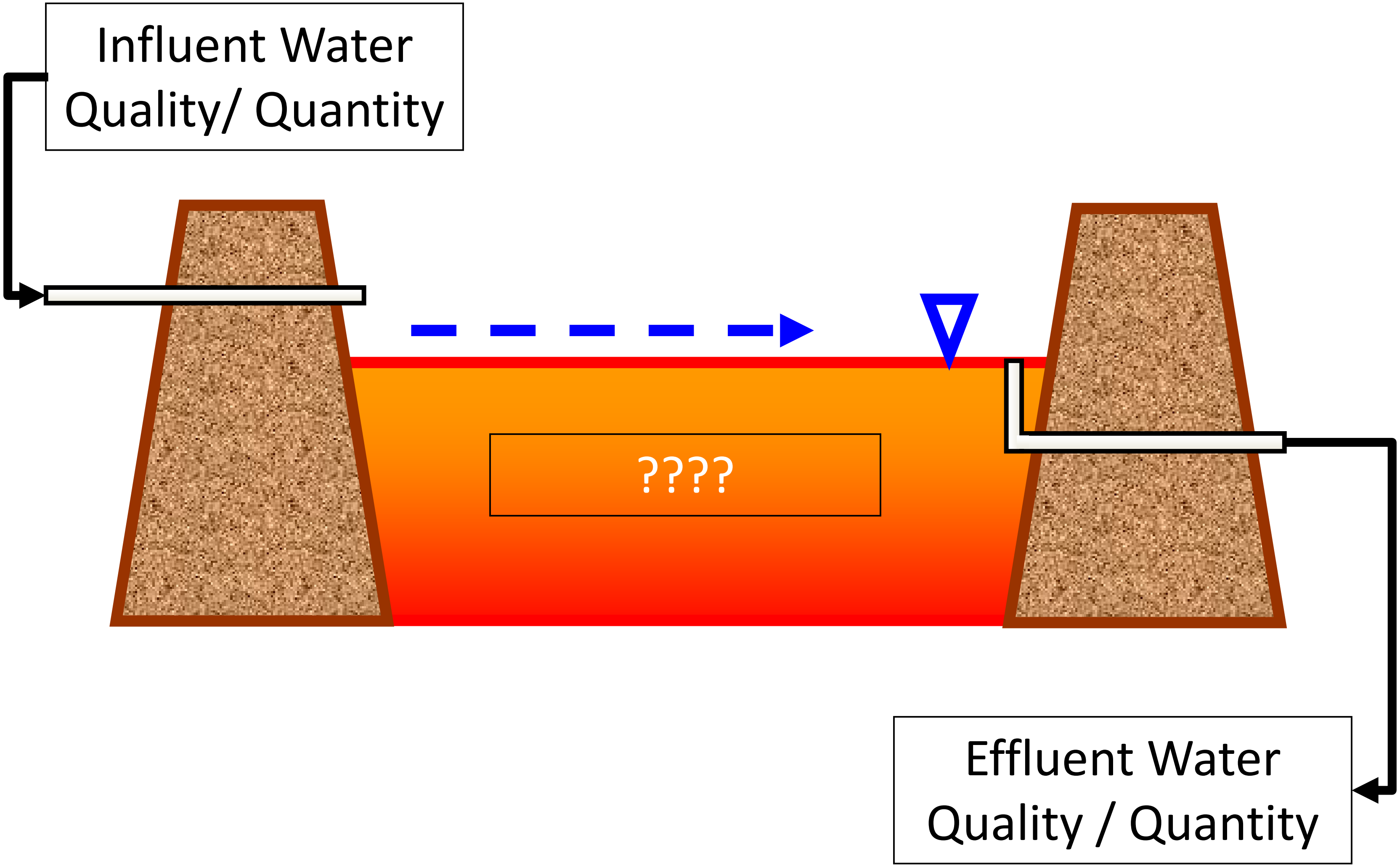
- **Removal efficiency (rate)**
  - Overall and per surface area unit (kg/m^2/year)
  - System sizing and transport state *(aqueous vs. solid)*

- **Settling and storage**
  - Short term performance (seasonal)
  - Long term performance (over design life)

Understanding Iron Chemistry

- Remediation of AMD impacted waters rely on a two step process for iron removal:
- Iron Oxidation – Fe^{2+} oxidized to Fe^{3+}
- $4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_20$
- Iron Hydrolysis: Iron Precipitation
- $Fe^{3+} + 3H_20 \rightarrow Fe(OH)_{3(s)} + 3H^+$

Cell Performance Monitoring



Influent Water Quality/ Quantity

????

Effluent Water Quality / Quantity

Why Profile a Treatment Cell?

- Additional mechanistic information to aid in troubleshooting or design enhancement within the current or future designs.

- Detailed performance comparison to design for proof of concept or validation.

Objective and Purpose

- To investigate the performance of the preliminary oxidation cells of a passive treatment system with respect to season.
- To determine if seasonal variability in total iron removal can be mitigated through system design features (secondary oxidation cells as surface flow wetlands)

Location (Tri State Mining District)

- The Mayer Ranch Passive Treatment System (MRPTS) was designed to treat AMD that is:
  - net-alkaline
  - ferruginous
  - lead-zinc drainage

- Tar Creek Superfund Site, Commerce OK.

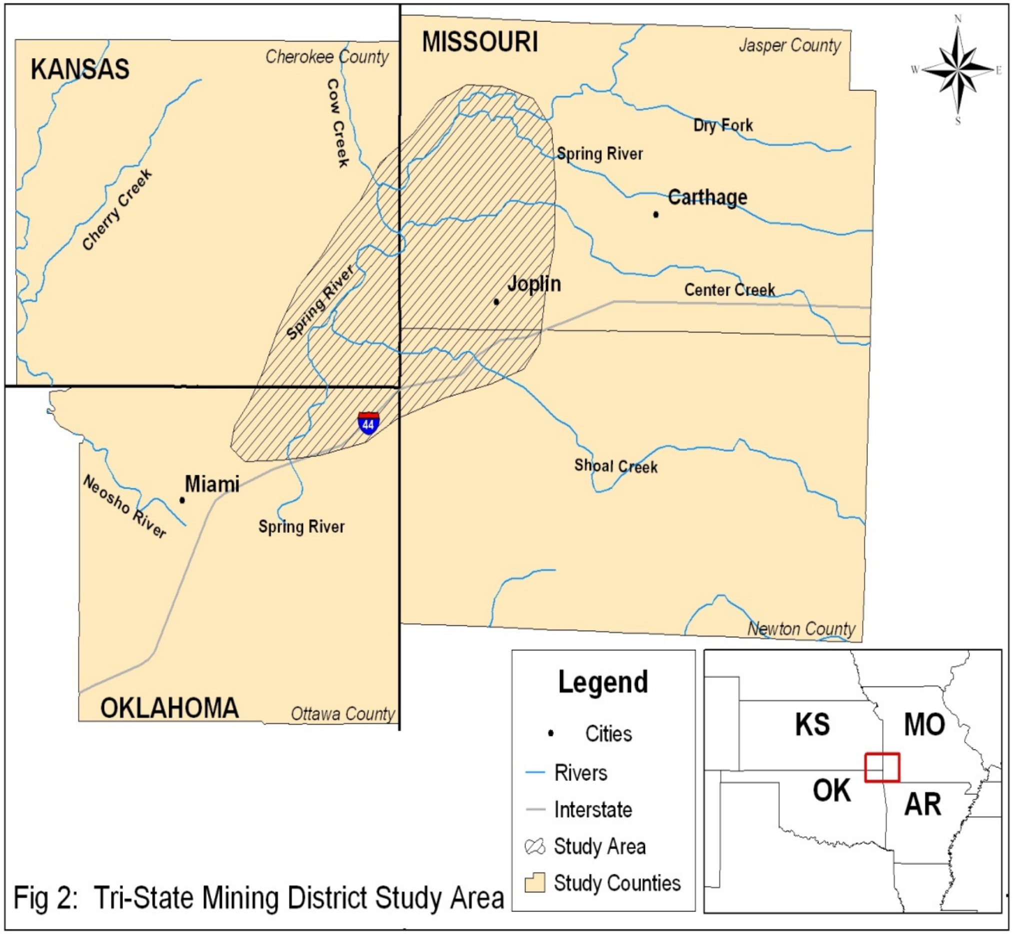


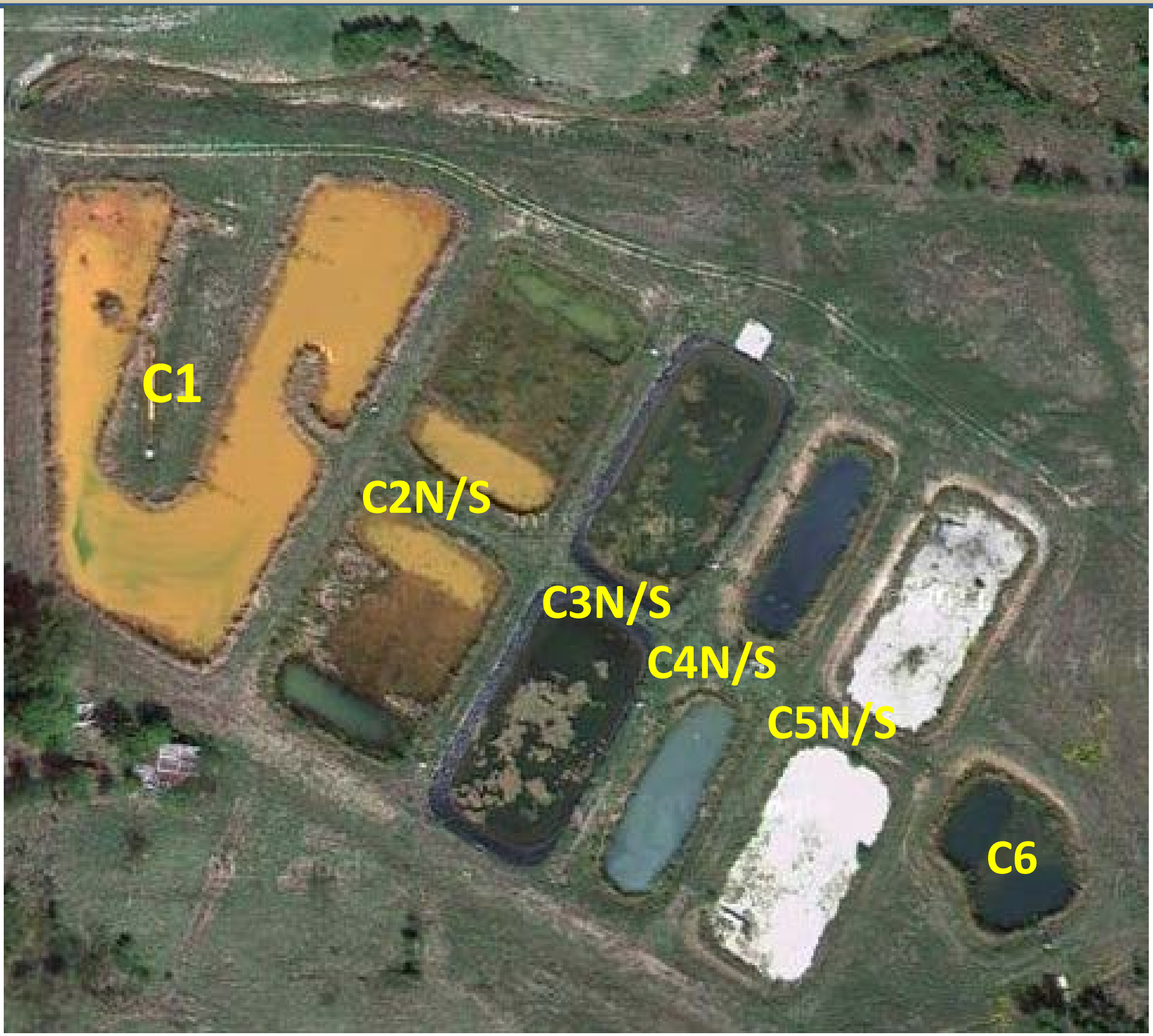
Fig 2: Tri-State Mining District Study Area

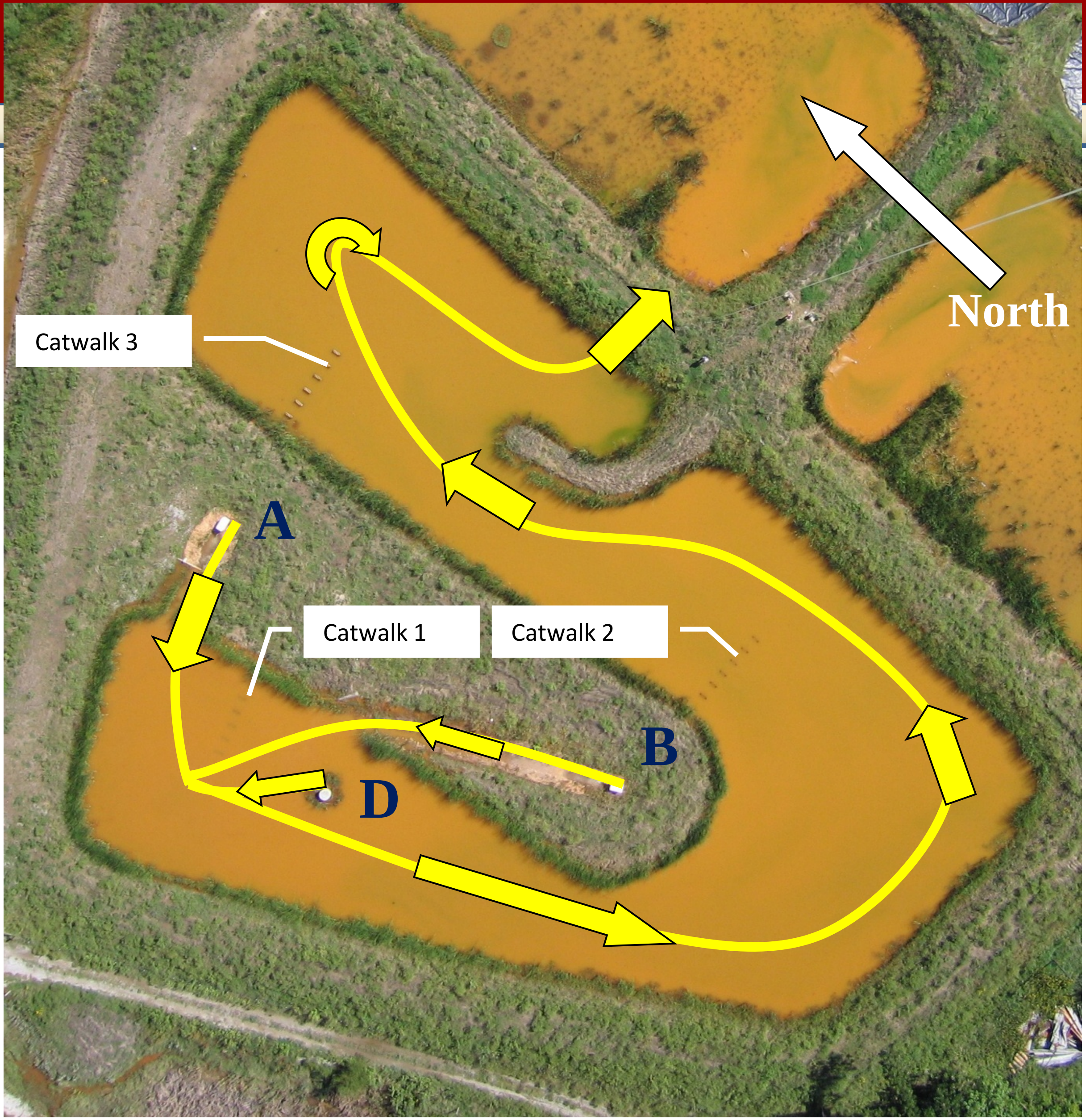
AMD and System Characteristics

- Q varies between 400-700 L\min annually
- Influent pH = 5.95 ±0.06
- Net Alkaline (Alkalinity 393 ± 13 mg\L $CaCO_3$)
- Mean mass loading = 106 kg Fe / Day (1st year)
- Average iron removal rate = 22 $g/m^2/day$ (1st year)

	Iron	Zinc	Lead	Cadmium
Average Influent	192±10 mg\L	11.0±0.7 mg/L	60±13 µg/L	17±4 µg/L

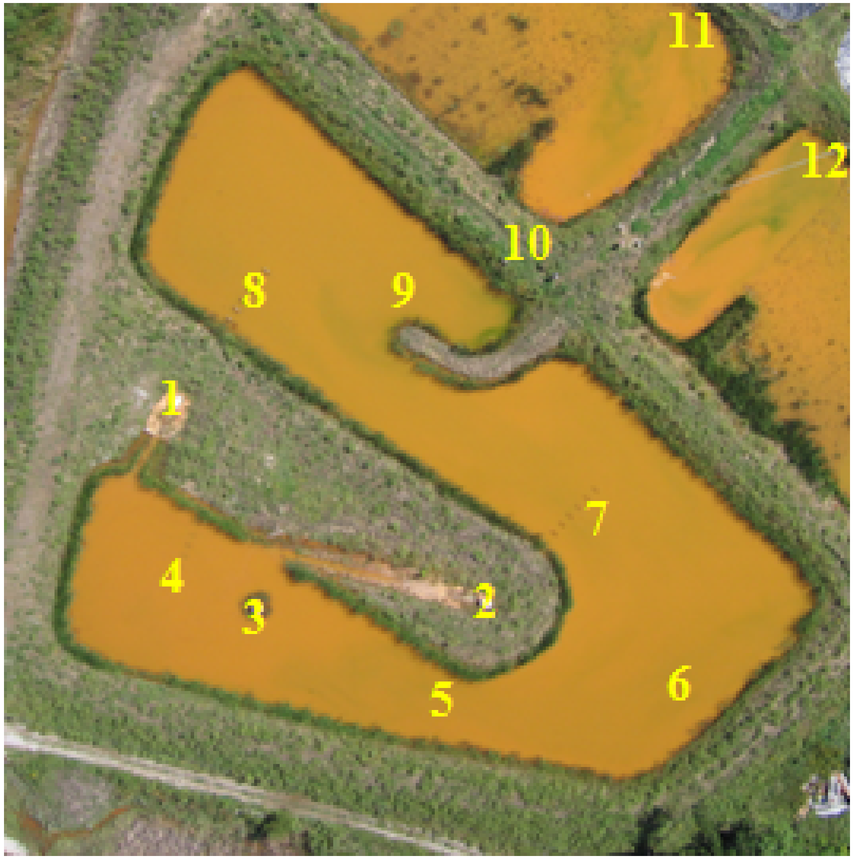
MRPTS Layout and Design




North
Catwalk 3
A
Catwalk 1
Catwalk 2
B
D

Sample Locations

Site #	Name
1, 2, 3	AMD Influent
4	Catwalk 1
5	S2 Bottleneck
6	S2 U-Bend
7	Catwalk 2
8	Catwalk 3
9	Cell 1 Effluent
10	C1 Out
11	C2Nout
12	C2Sout



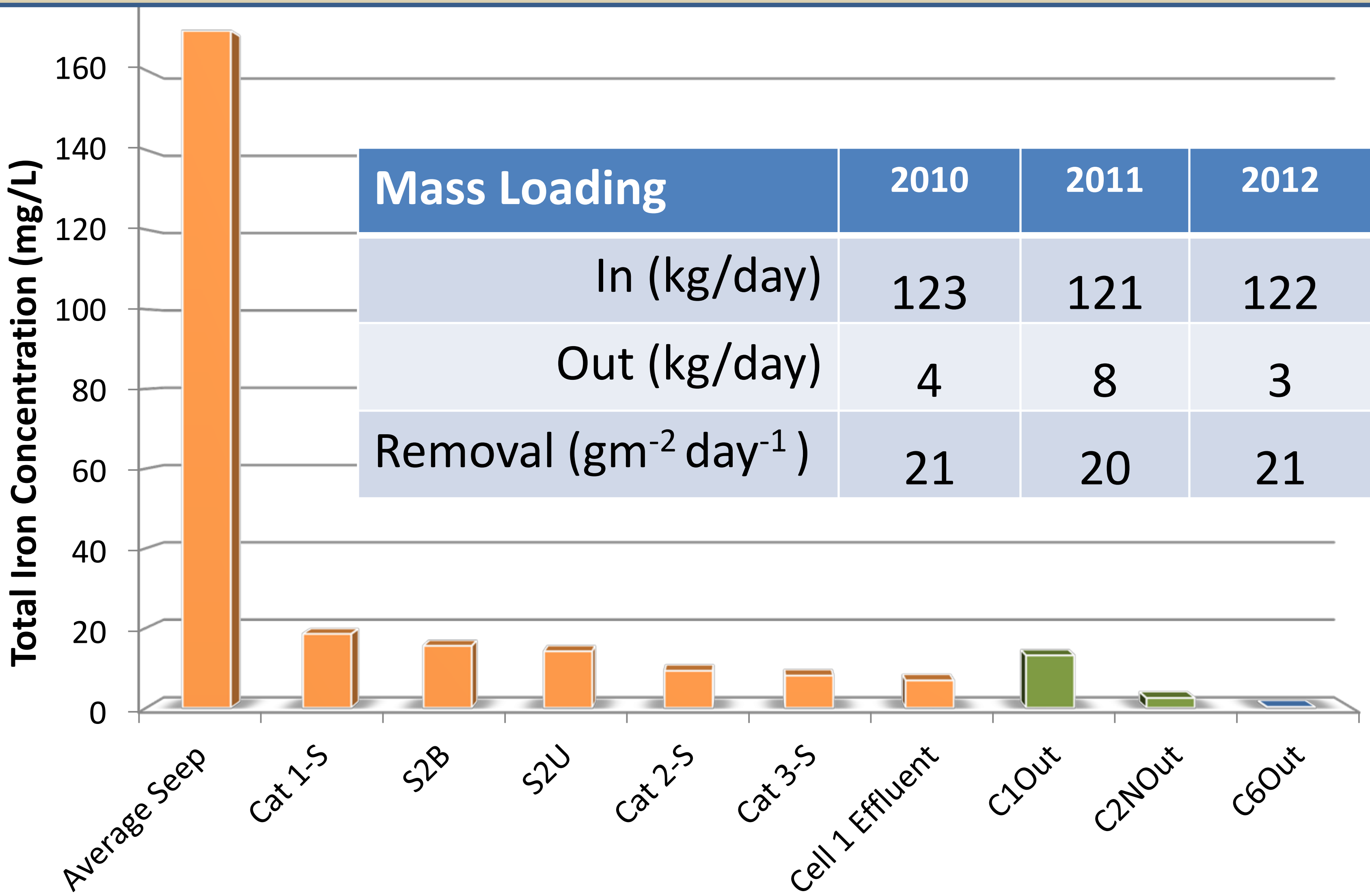
Sample Collection and Analysis

- Seasonal sampling was conducted four times a year for three years
  - (Jan, Apr, July, Oct 2009-2012)
- Iron concentrations (total and dissolved) with respect to:
  - Position
  - Depth
  - Time (season)

Grab Samples	Measurements
Total Metals	SONDE: pH, DO, SC, ORP, T, R, Sal, etc.
Dissolved Metals	Turbidity
Anions	Alkalinity

Spring (April 2010-2012):

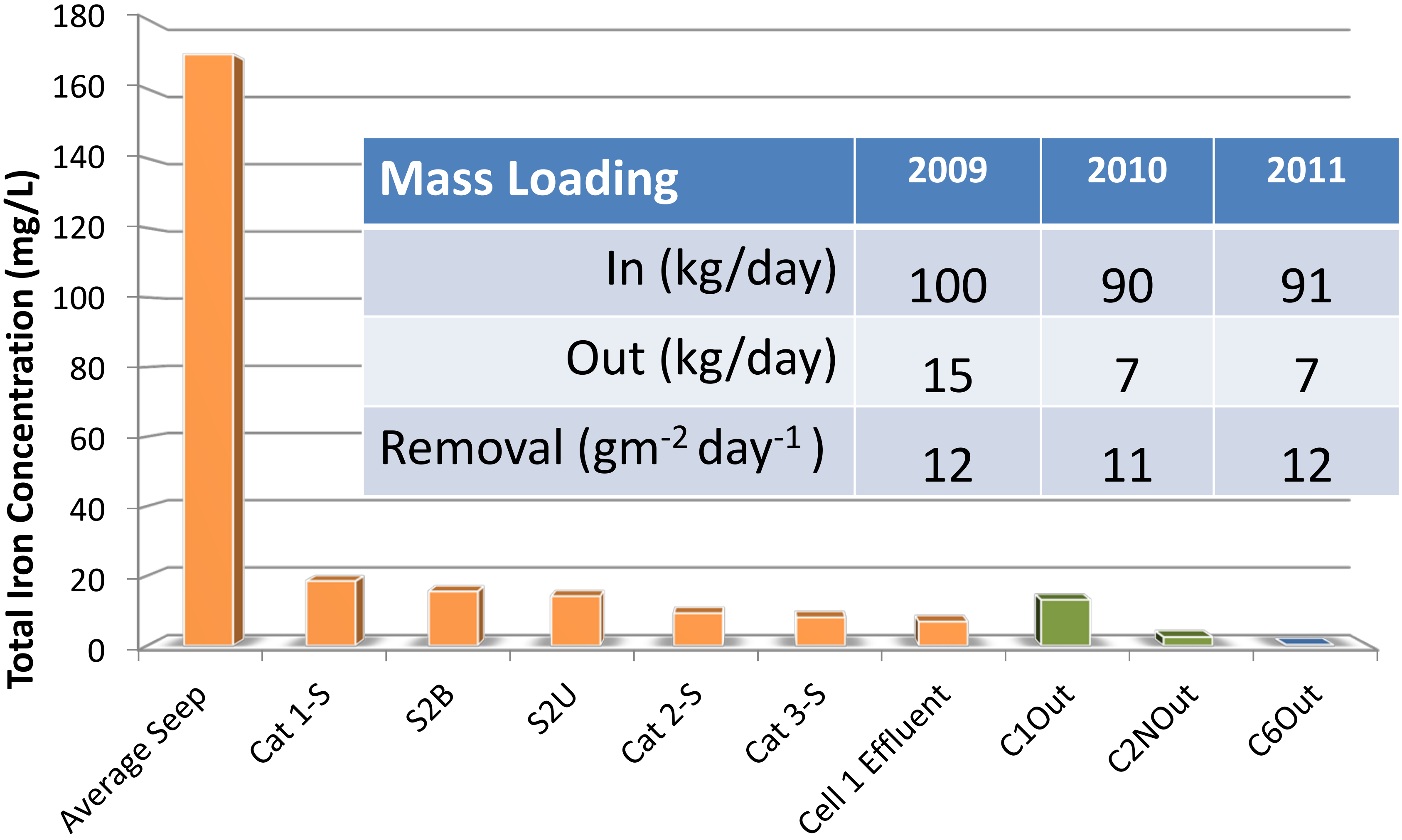
Total Iron Removal Profile (n=3 year average)



Mass Loading	2010	2011	2012
In (kg/day)	123	121	122
Out (kg/day)	4	8	3
Removal (gm^{-2} day^{-1})	21	20	21

Summer (July 2009-2011)

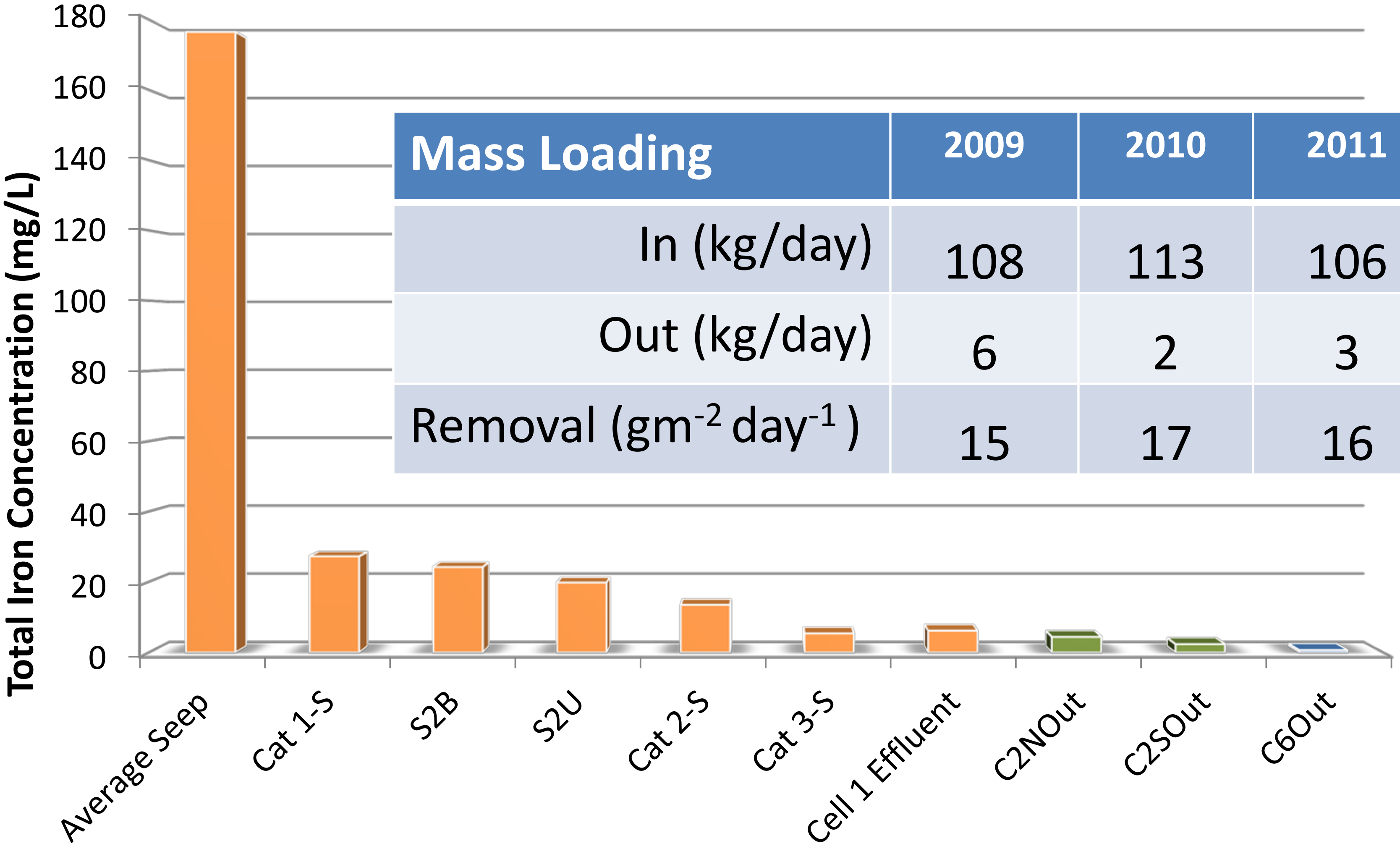
Total Iron Removal Profile (n= 3 year average)



Mass Loading	2009	2010	2011
In (kg/day)	100	90	91
Out (kg/day)	15	7	7
Removal (gm^{-2} day^{-1})	12	11	12

Fall (Oct 2009-2011)

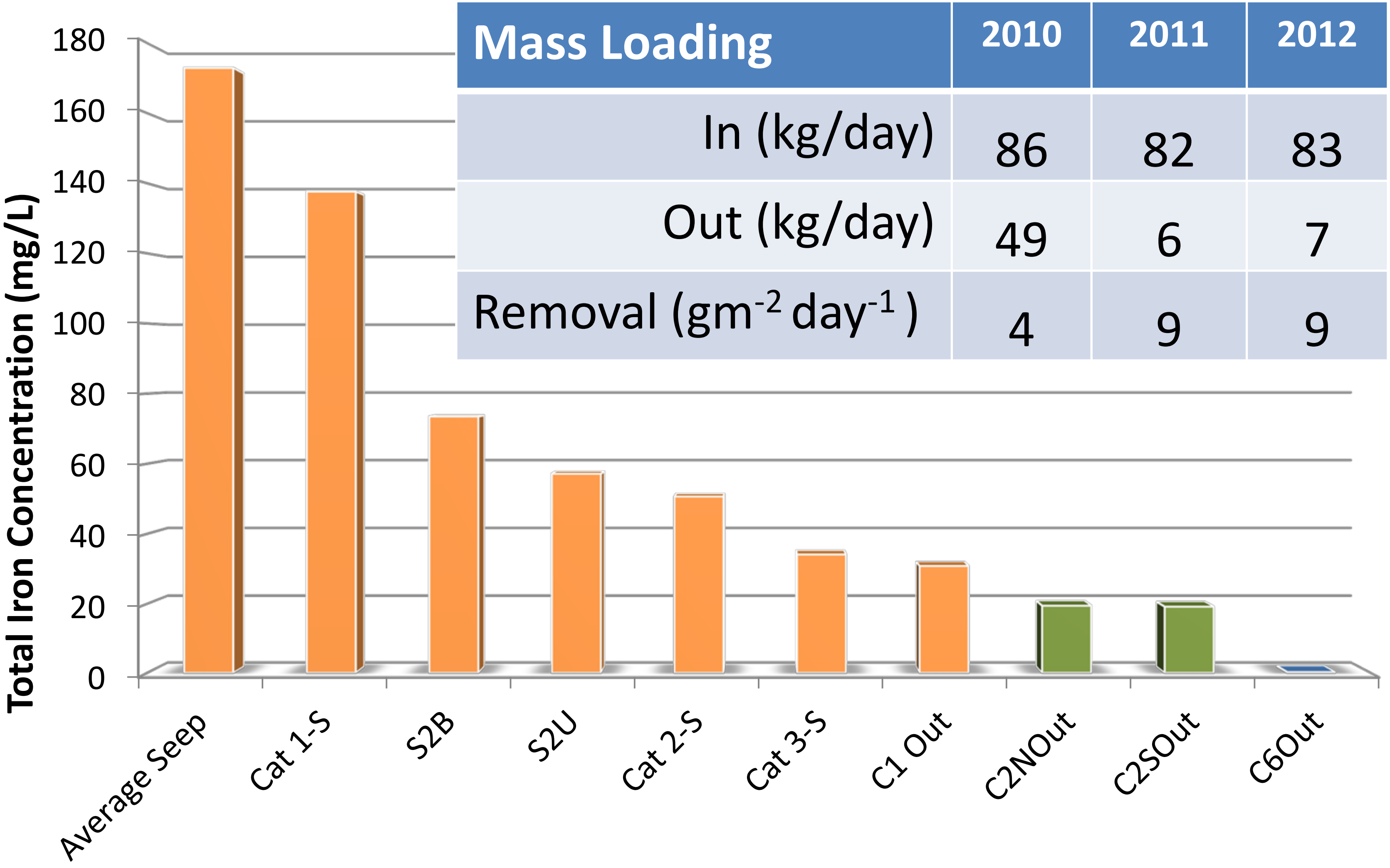
Total Iron Removal Profile (n= 3 year average)



Mass Loading	**2009**	**2010**	**2011**
In (kg/day)	108	113	106
Out (kg/day)	6	2	3
Removal (gm^{-2} day^{-1})	15	17	16

Winter (Jan 2010-2012)

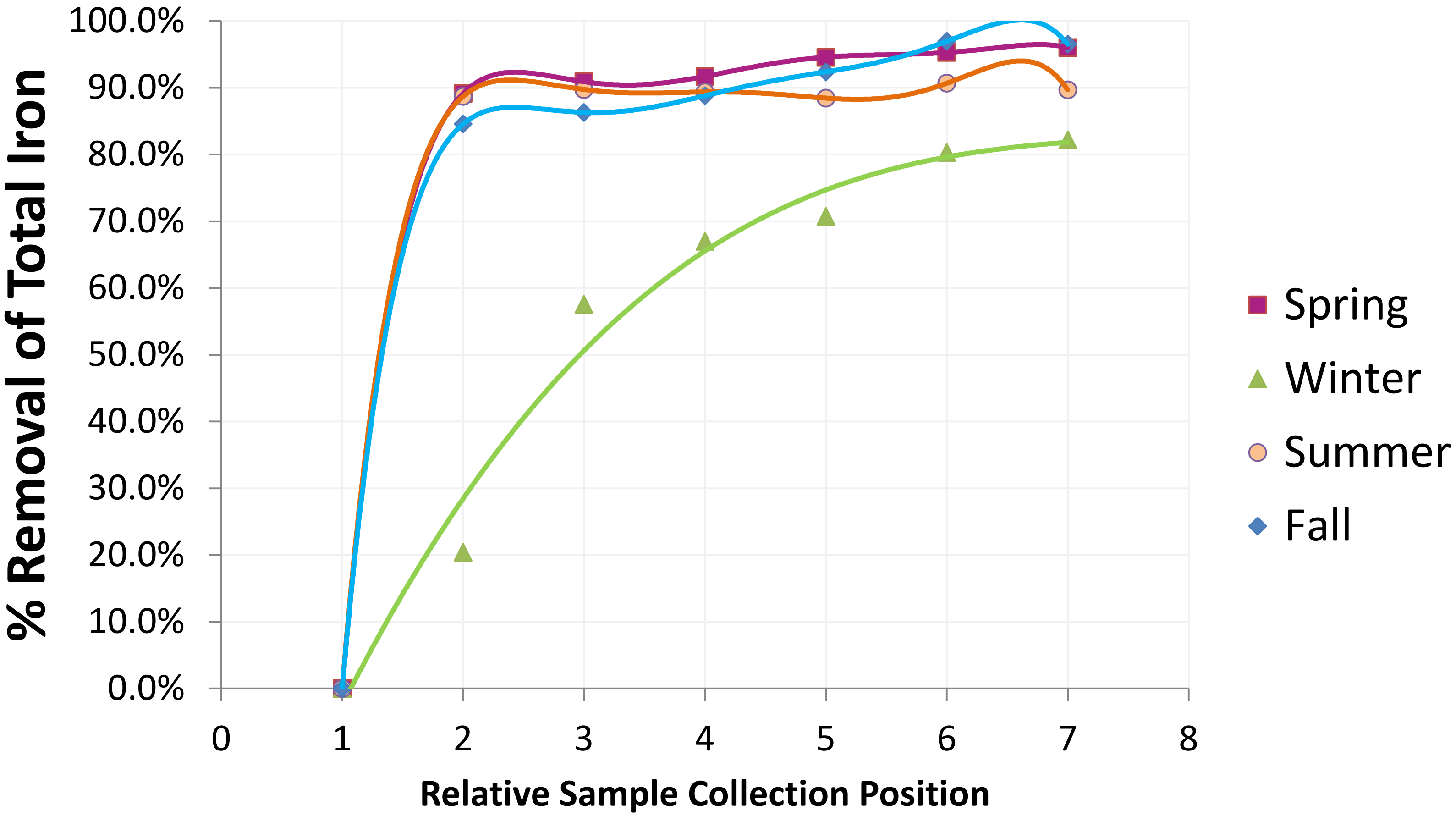
Total Iron Removal Profile (n= 3 year average)



Mass Loading	2010	2011	2012
In (kg/day)	86	82	83
Out (kg/day)	49	6	7
Removal (gm^{-2} day^{-1})	4	9	9

Total Iron Removal Comparison

Cell 1 Removal Profile (n= 3 year average)



Objective: To investigate performance with respect to season and design specification

- For most of the year (spring, summer, and fall), approximately 88% of loaded iron is removed in the first section of oxidation pond, and nearly all of it (~90%) is removed before reaching cells2N&S

- However, winter conditions reduce the removal of iron in the first section of the oxidation pond to a mere 20% with only 80% total removal within Cell 1.
  - Up to 90% removal observed at C2(N&S) effluent.

Purpose: To determine if seasonal variability can be mitigated through secondary oxidation wetlands

Comparison between the relative standard deviation (%) between area adjusted removal efficiencies (g $m^{-2}day^{-1}$)

Removal Conditions	Cell 1 Only (% RSD)	Cells 1 and 2 Together (%RSD)
All Seasons	40.5%	35.6%
No Winter	28.3%	28.5%

Small improvement in variability with oxidation cell series, but not as dramatic as expected.

Extracting the winter data from the set yields less variability overall.

Future Work

- Tracer study to determine actual hydraulic retention time of Cell 1.
- Interpretation of iron concentrations from depth samples as an indicator of solids accumulation.
  - core sampling for accumulation profiling and assessment

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Questions / Comments?

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