Iowa Department of Natural Resources

Leading Iowans in caring for our natural resources

Controlled Discharge Lagoons
2 Cell vs. 3 Cell Bacteria & Ammonia Performance

Some History - CDL Design in Iowa

- Pre-1979
  - 2 cells
  - Facultative lagoon sizing based on surface area loading
- Post 1979
  - 3 cells required by design standards for CDLs > 1 acre total surface area
  - 180 days of storage
- 1995 Pilot Program
  - 2 cells allowed by variance for a group of unsewered communities (pilot project) as a value engineering concept
- 1995 to recent
  - 2-cell variances granted on a regular basis for unsewered communities
  - Justification: Equivalent performance and cost savings

Some More History - CDL Effluent Limits

- No water quality based effluent limits in NPDES permits
  - "Properly operated CDLs with 180-days of storage pose no risk of violating applicable water quality criteria."
- 2006 - Revised water quality standards
  - Designation of all perennial streams
  - Removal of protected flow concept
- Mid 2000's – Present
  - Multiple TMDLs assigning waste load allocations to point sources (including CDLs)
- Spring 2009
  - Ammonia and bacteria <u>monitoring</u> required for all CDLs

Number of Cells vs. Performance

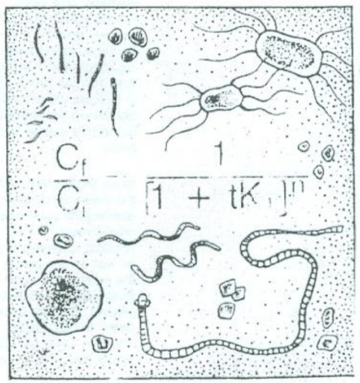
- Question: Are three cells better than two...
  ...for treatment of bacteria & ammonia by CDLs?
- Old concept ("Reactor Theory 101")
- Not considered in previous variances
- Applicable to CDLs?
  - Long holding times
  - Batch discharge
  - Not always operated in series

United States
Environmental Protection
Agency

August
1985

Wastewater Stabilization Ponds

An Update on Pathogen Removal



References

1. US Environmental Protection Agency, *Technology Transfer Process Design Manual, Municipal Wastewater Stabilization Ponds*, EPA-625/1-83-015, US EPA CERI, Cincinnati, OH 1983.

2. Marais, G.V.R., *Faecal Bacterial Kinetics in Stabilization Ponds*, J.EED, ASCE, 100.EE1, 1974, p. 119-139.

3. Bausum, H.T. et al., *Enteric Virus Removal in Wastewater Treatment Lagoon Systems*, PB83-234914, NTIS, Springfield, VA 1983.

4. Feachem, R.G., Bradley, J.T., Garelick, H., Mara, D.D. *Sanitation and Disease-Health Aspects of Excreta and Wastewater Management*, John Wiley & Sons, 1983.

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The equation can be rearranged to determine the optimum number of cells (typically 3) required for a particular level of pathogen removal. In general, a 3 or 4 cell system (in series) with a total actual detention time of about 20 days will remove fecal coliforms to desired levels and all parasites. It can also be shown with the design equation that the use of additional cells beyond 3 provides minimal benefits. The removal of

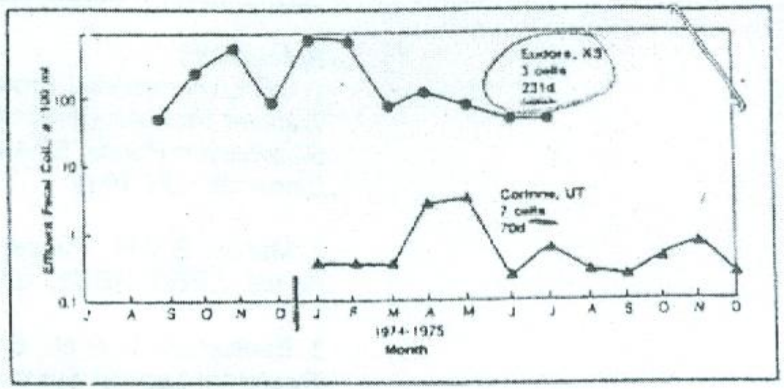
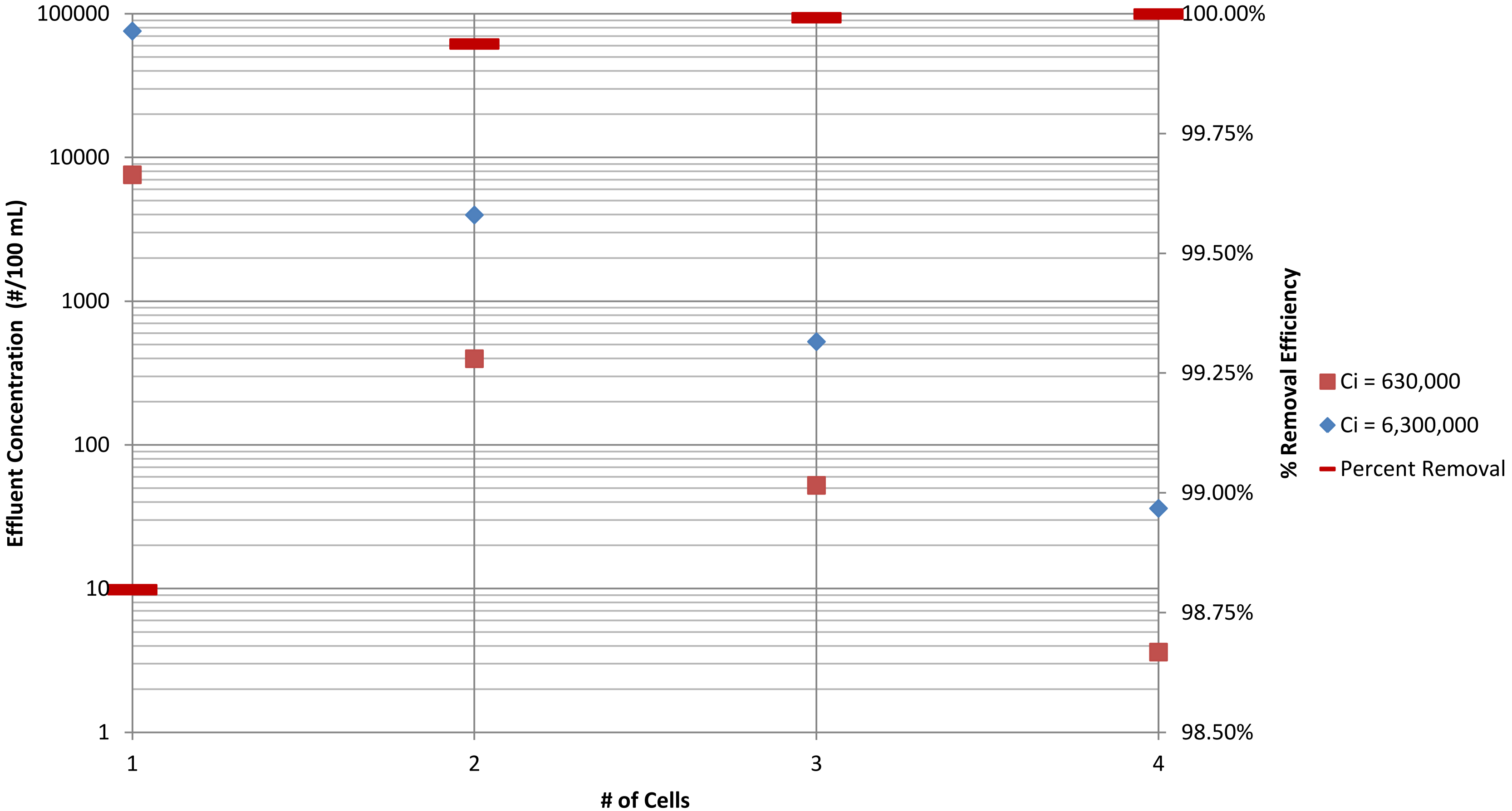


Figure 1. Fecal Coliform Numbers in Undisinfected Facultative Pond Effluent.

work elsewhere that the number of cells in the pond system is a critical factor in achieving high removal of pathogens and other contaminants. Multiple cells significantly reduce short circuiting; and as the number of cells increases, the hydraulic regime approaches the ideal plug flow conditions. A multiple cell system will consistently outperform a single large cell with an equivalent detention time.

Predicted Removal Efficiencies and Effluent Concentrations

- Series Operation
- k = 2.6
- 180 days total holding time
- HRT = 100% of storage time
- 2/3 of total volume in primary cells
- mean water temperature = 10 degrees C



Effluent Data (so far)

- 2006 - special sampling effort (DNR/UHL)
  - Support assumptions behind no water quality based effluent limits
  - 1, 2, 3 & 4 cell systems sampled
  - Majority 3 cells
  - No variance approved 2-cell systems
- 2009/2010 - special sampling effort (DNR/UHL)
  - Investigate variance-approved 2-cell performance
  - Samples from variance-approved 2-cell CDLs only
- NPDES Monitoring (2009 - present)
  - NPDES permits issued with new monitoring requirements
  - Larger data set than previous special sampling efforts
  - Will continue to grow

Effluent Data (so far)

	Sample Data Points (Post-1979)	
	2-Cell	3-Cell
Bacteria	159 (113)	229 (183)
Ammonia	146 (102)	214 (181)
# of Facilities	50 (41)	47 (36)

Example Data Set

- Five Sample Values:

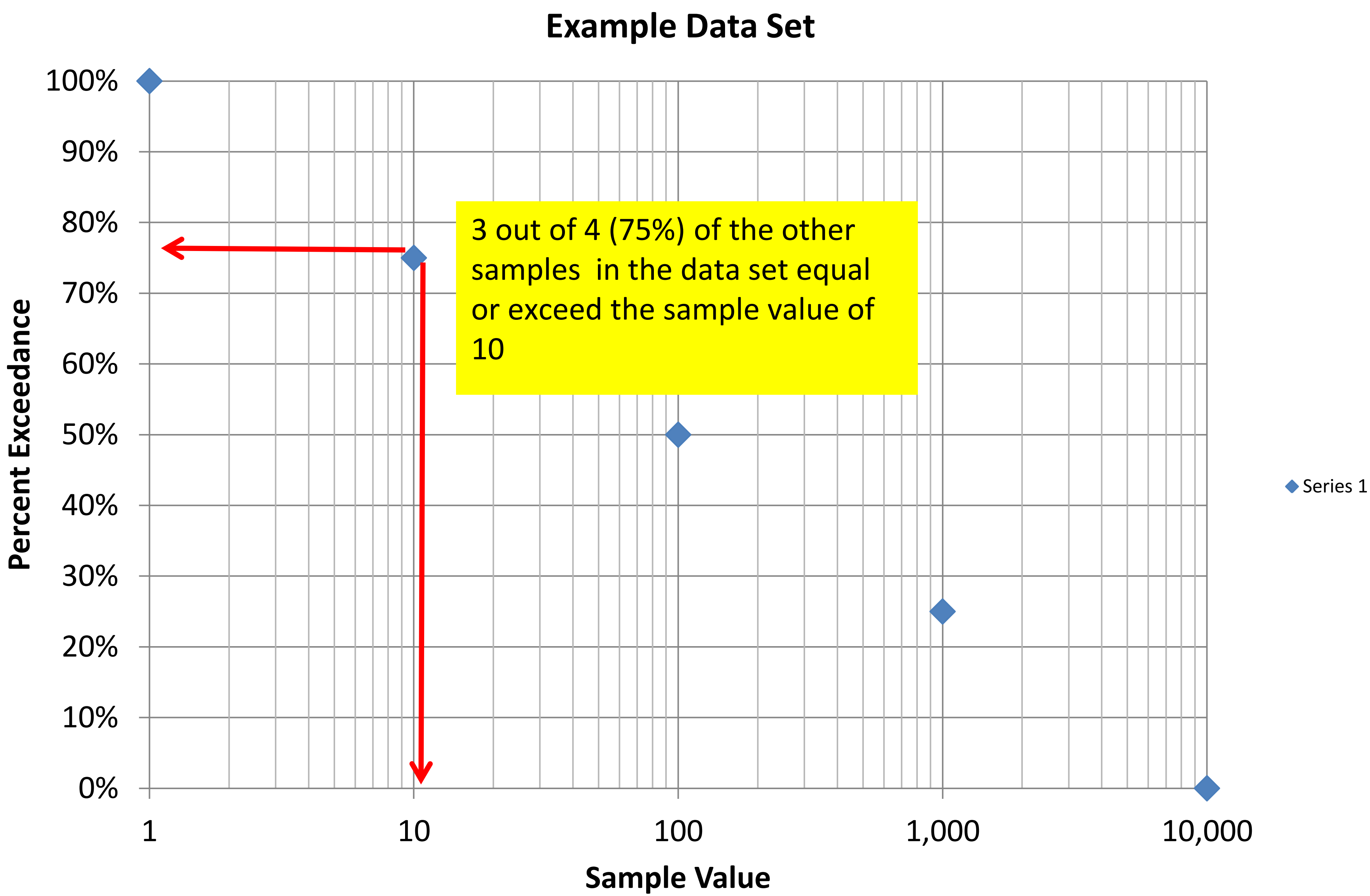
1	10	100	1,000	10,000

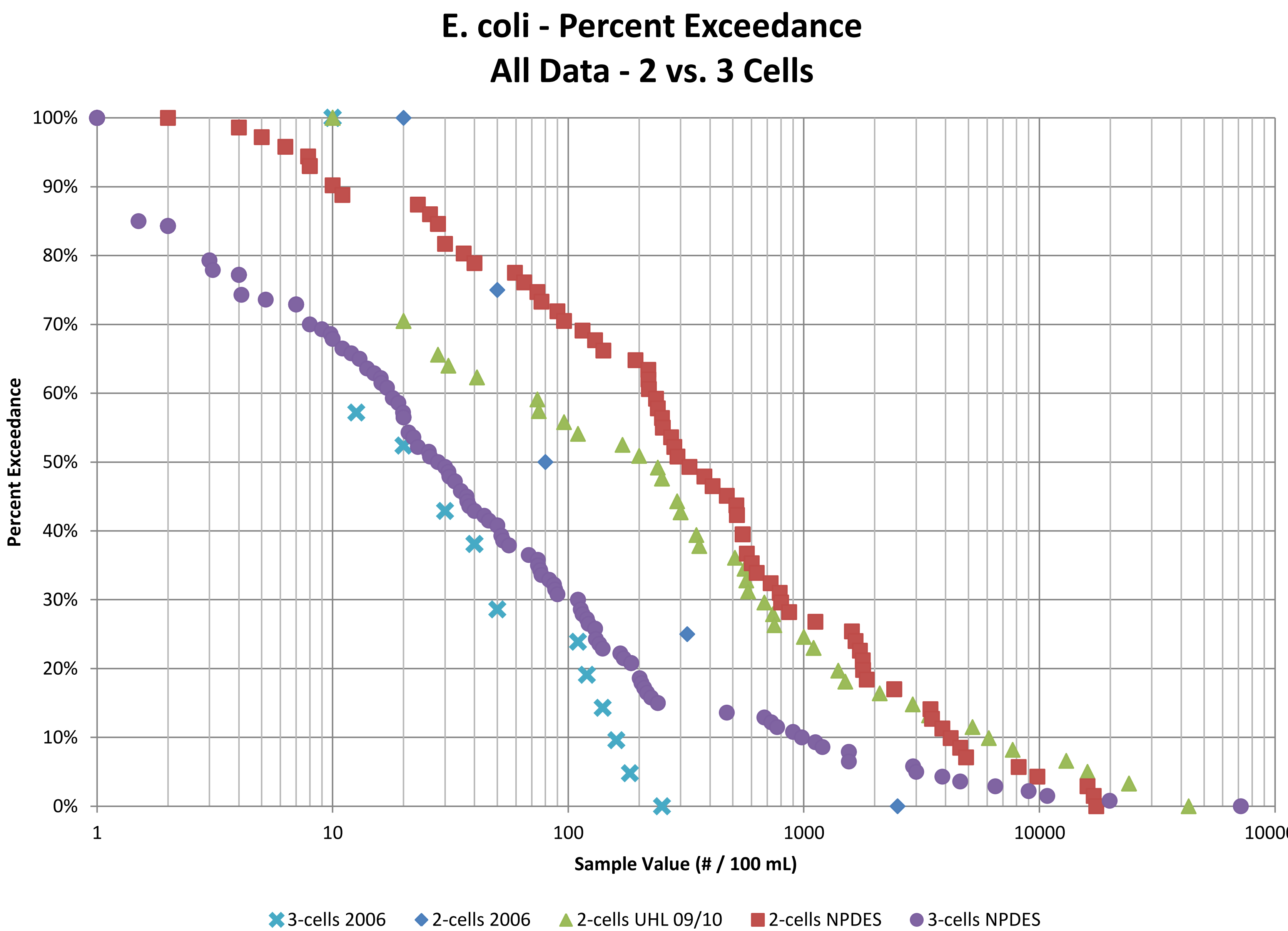
- Sample Value as Percent Rank (Percentile)
  - 1 sample smaller than 10, 3 values larger than 10, percent rank of 10 = 1/4 (25th percentile)

0	25	50	75	100

- Percent Exceedance (NOT exceedance probability)
  - 3 out of 4 (75%) of the remaining samples exceed (or equal) 10

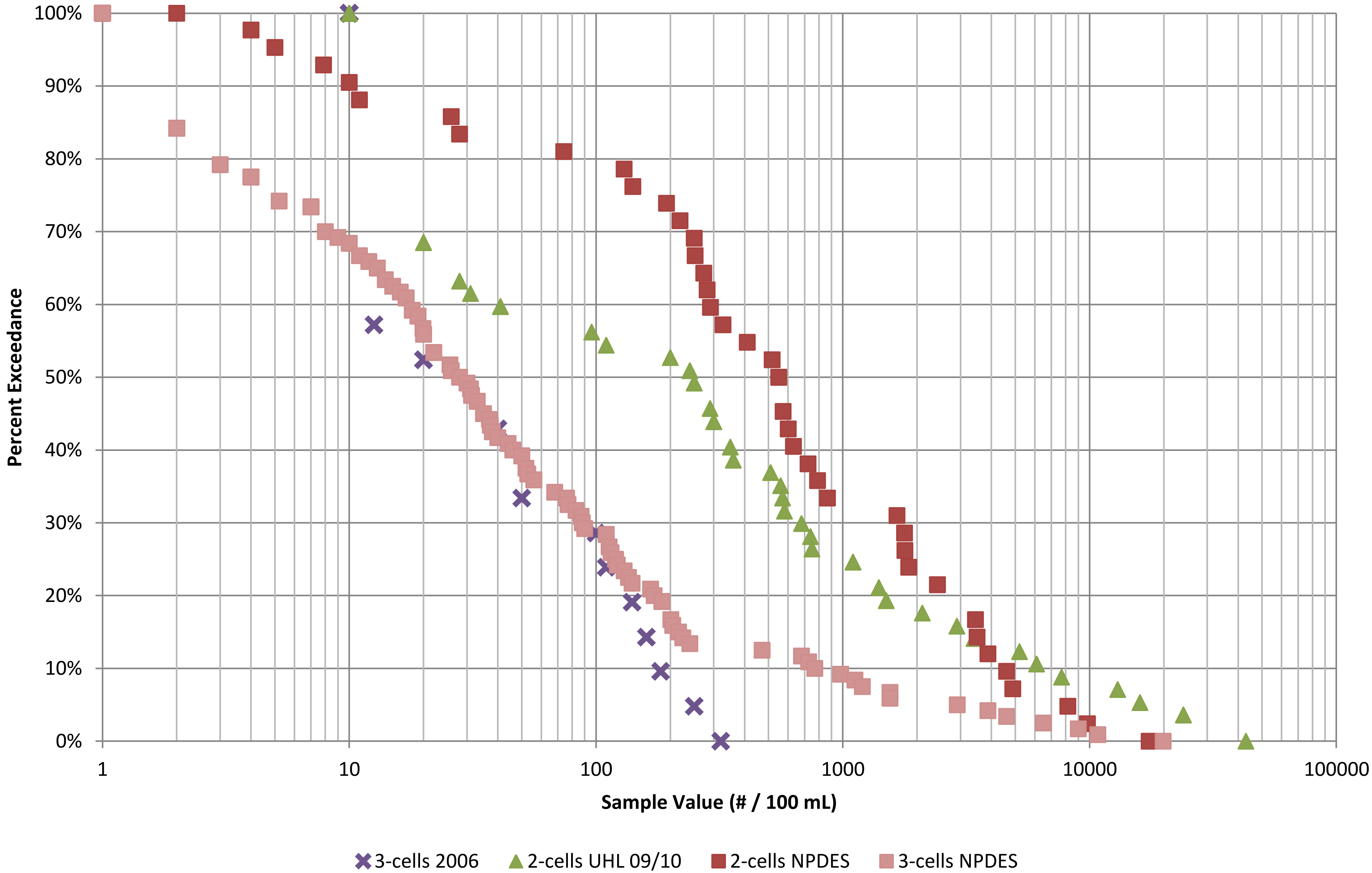
100	75	50	25	0


Example Data Set
Percent Exceedance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
3 out of 4 (75%) of the other samples in the data set equal or exceed the sample value of 10
Series 1
1
10
100
1,000
10,000
Sample Value

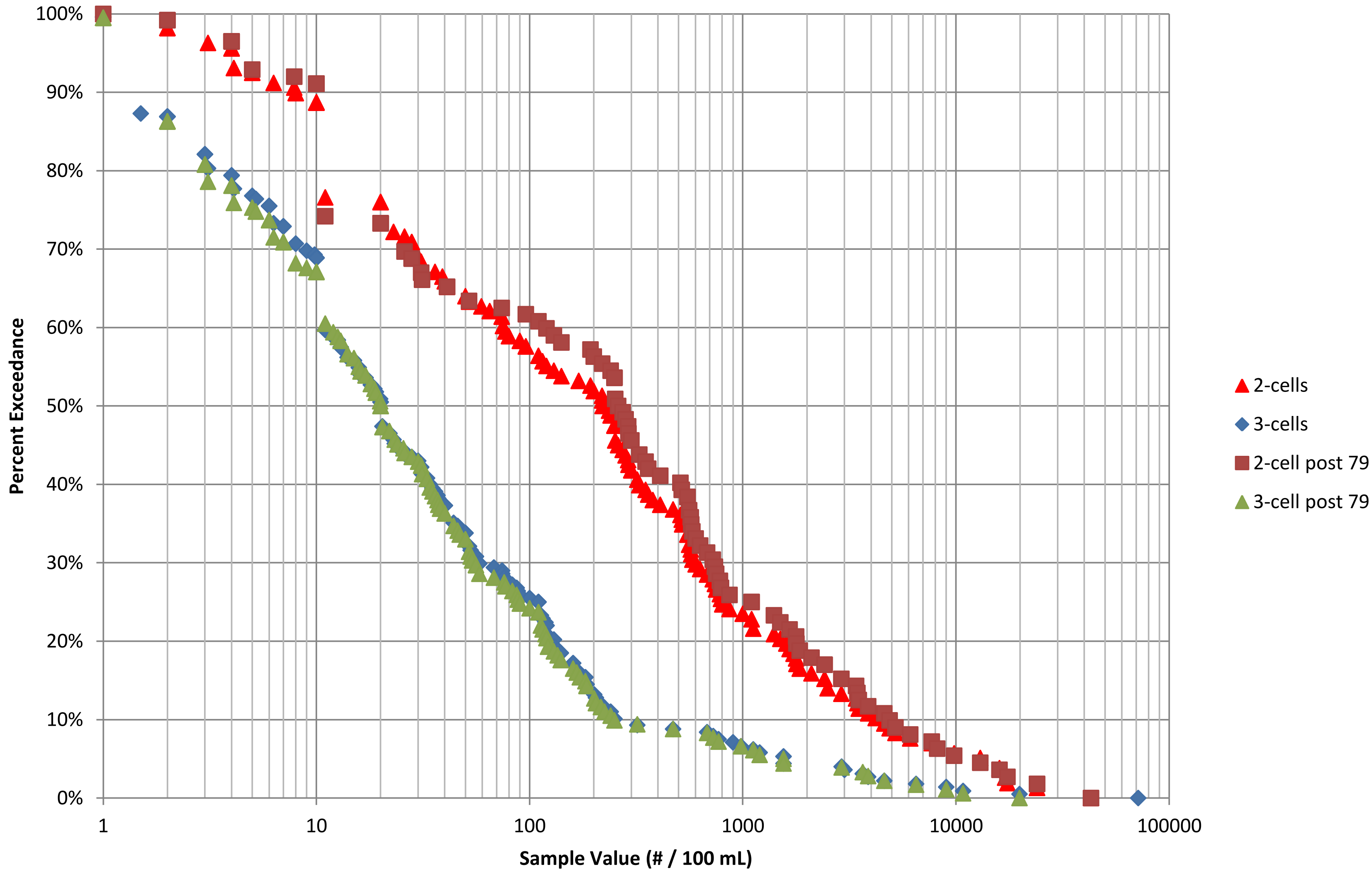


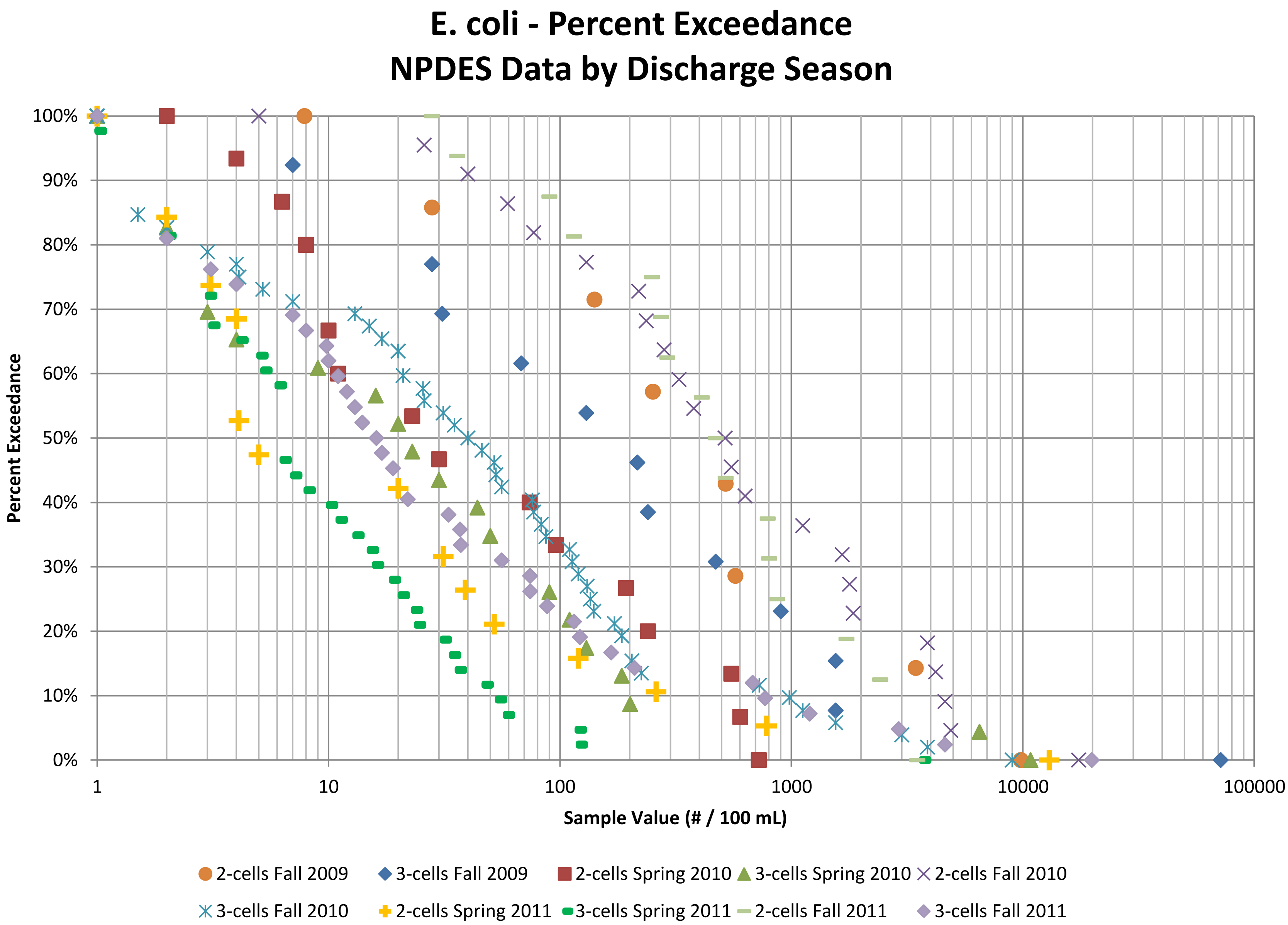
E. coli - Percent Exceedance
All Data - 2 vs. 3 Cells
Percent Exceedance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
100
1000
10000
100000
Sample Value (# / 100 mL)
3-cells 2006
2-cells 2006
2-cells UHL 09/10
2-cells NPDES
3-cells NPDES

E. coli - Percent Exceedance
Post 1979 - 2 vs. 3 Cells



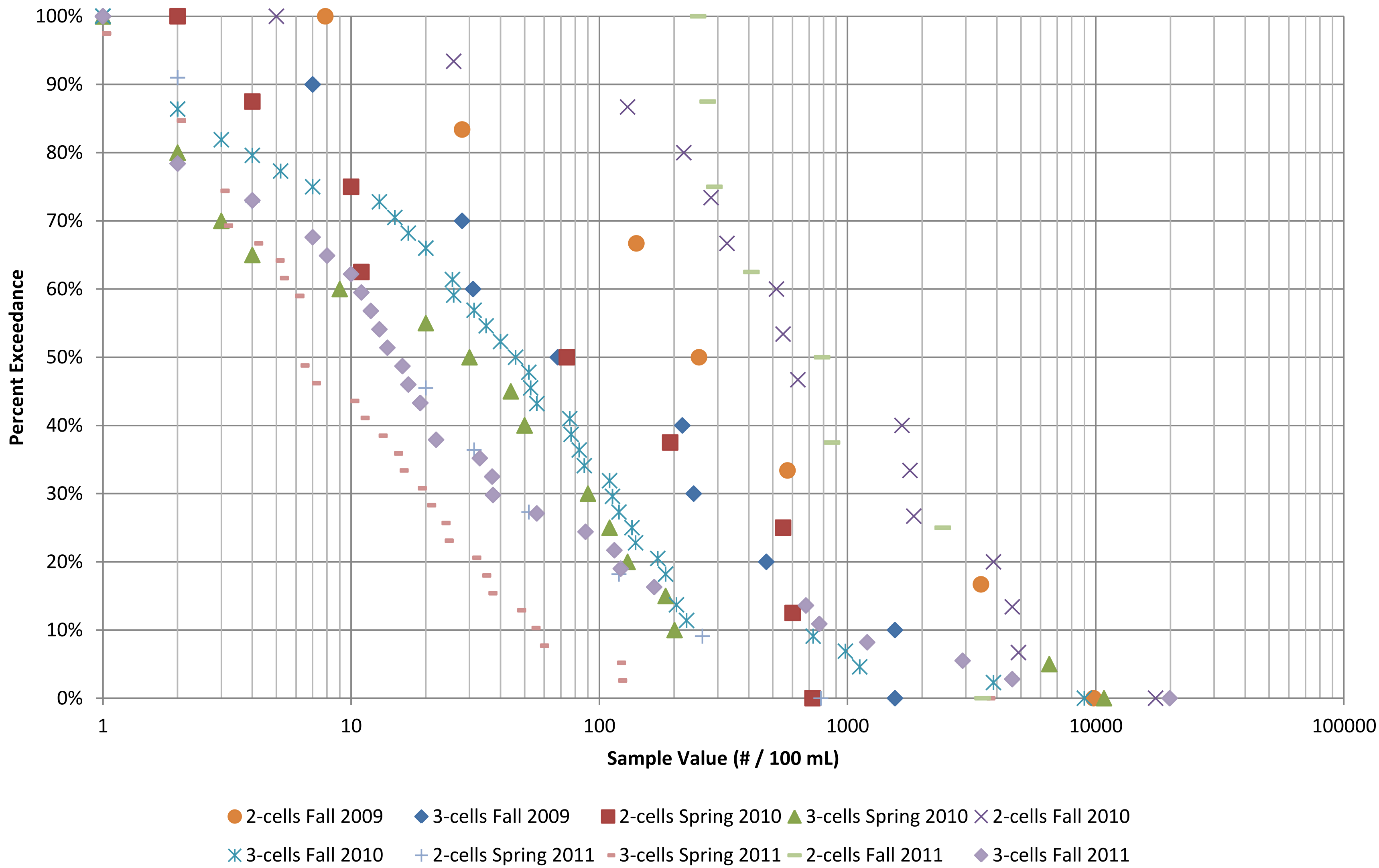
E. coli - Percent Exceedance
Combined Data Sets (2006 to 2011)



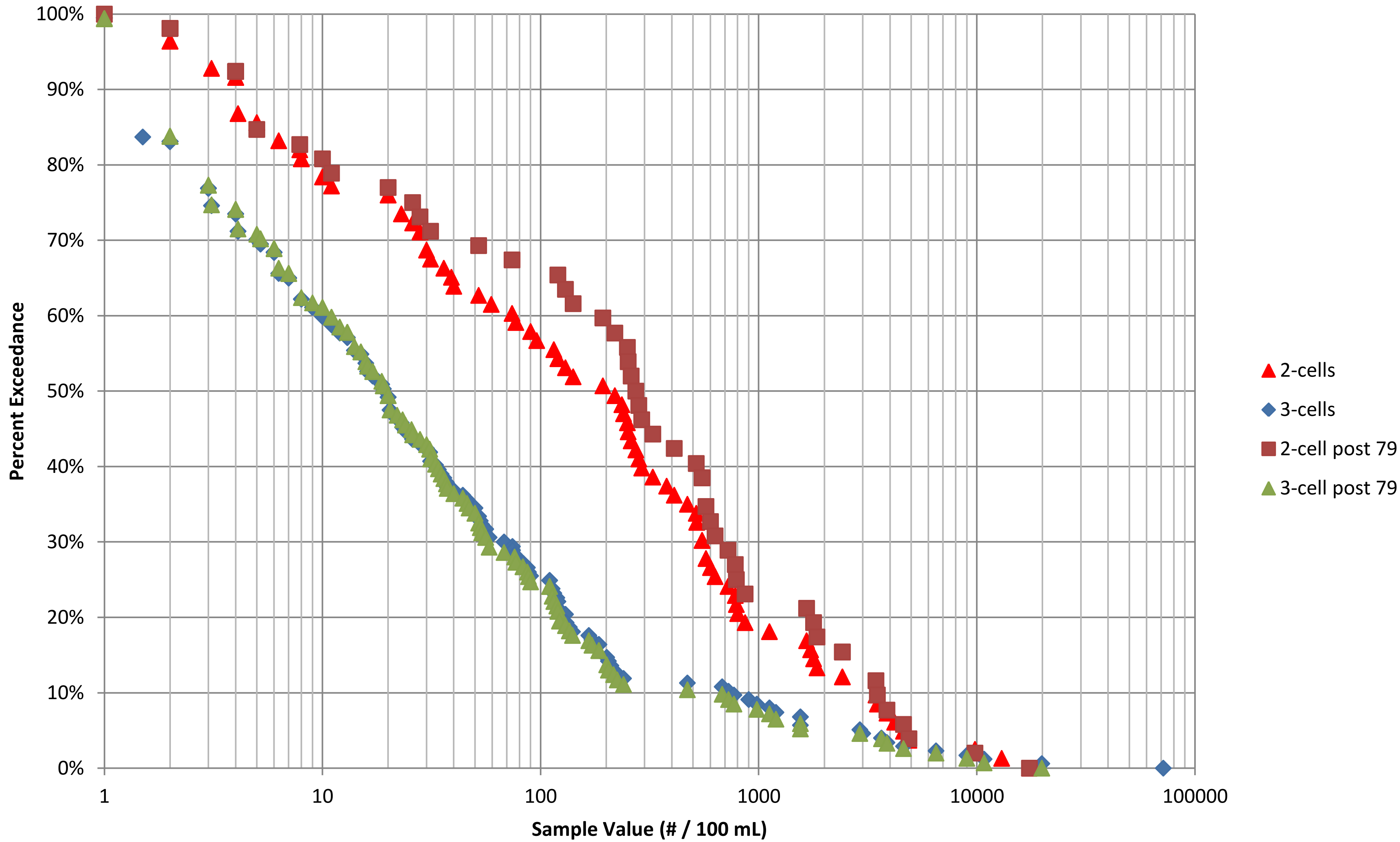


E. coli - Percent Exceedance
NPDES Data by Discharge Season
Percent Exceedance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
100
1000
10000
100000
Sample Value (# / 100 mL)
2-cells Fall 2009
3-cells Fall 2009
2-cells Spring 2010
3-cells Spring 2010
2-cells Fall 2010
3-cells Fall 2010
2-cells Spring 2011
3-cells Spring 2011
2-cells Fall 2011
3-cells Fall 2011

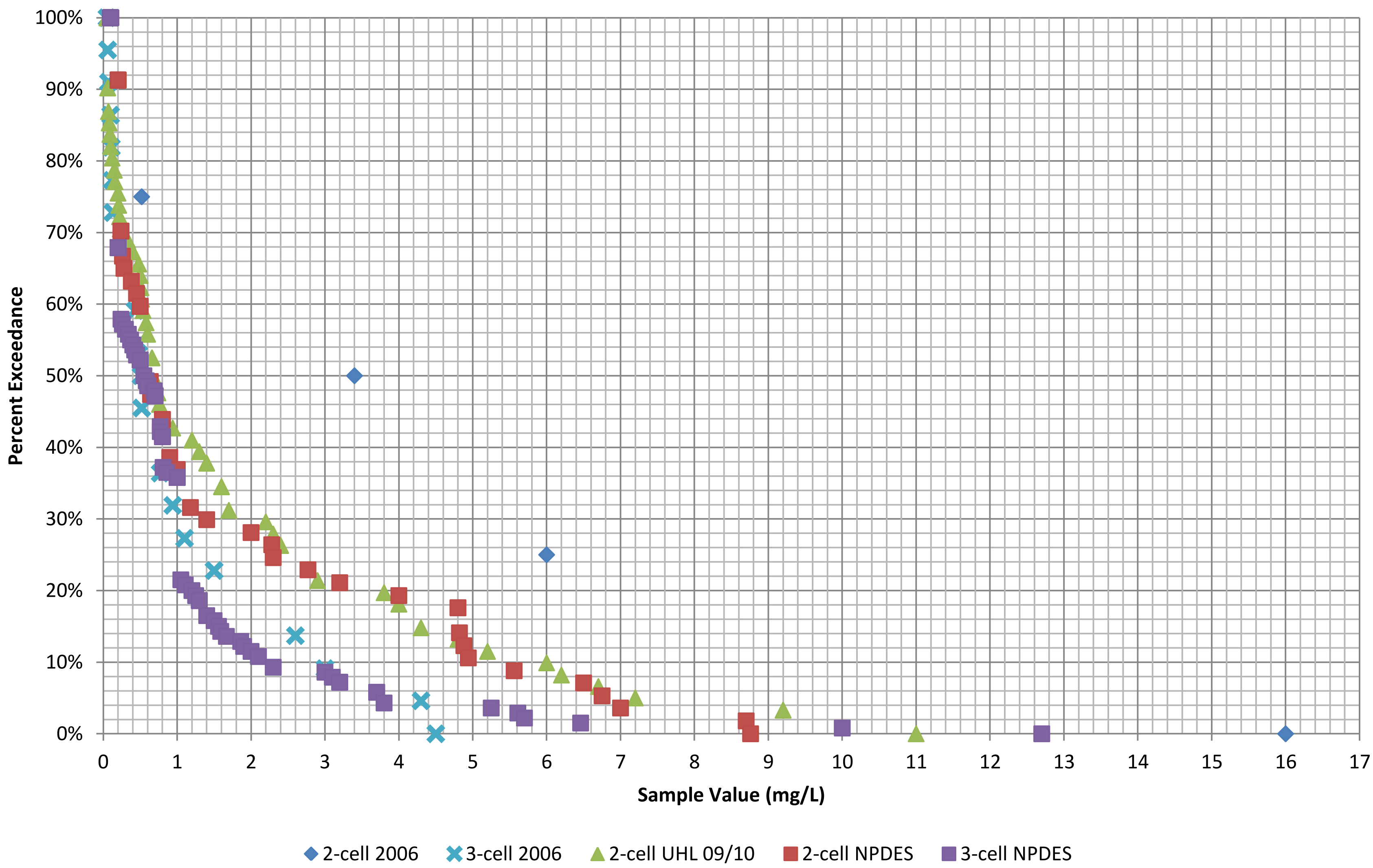
E. coli - Percent Exceedance
NPDES Data by Discharge Season (Post 79)



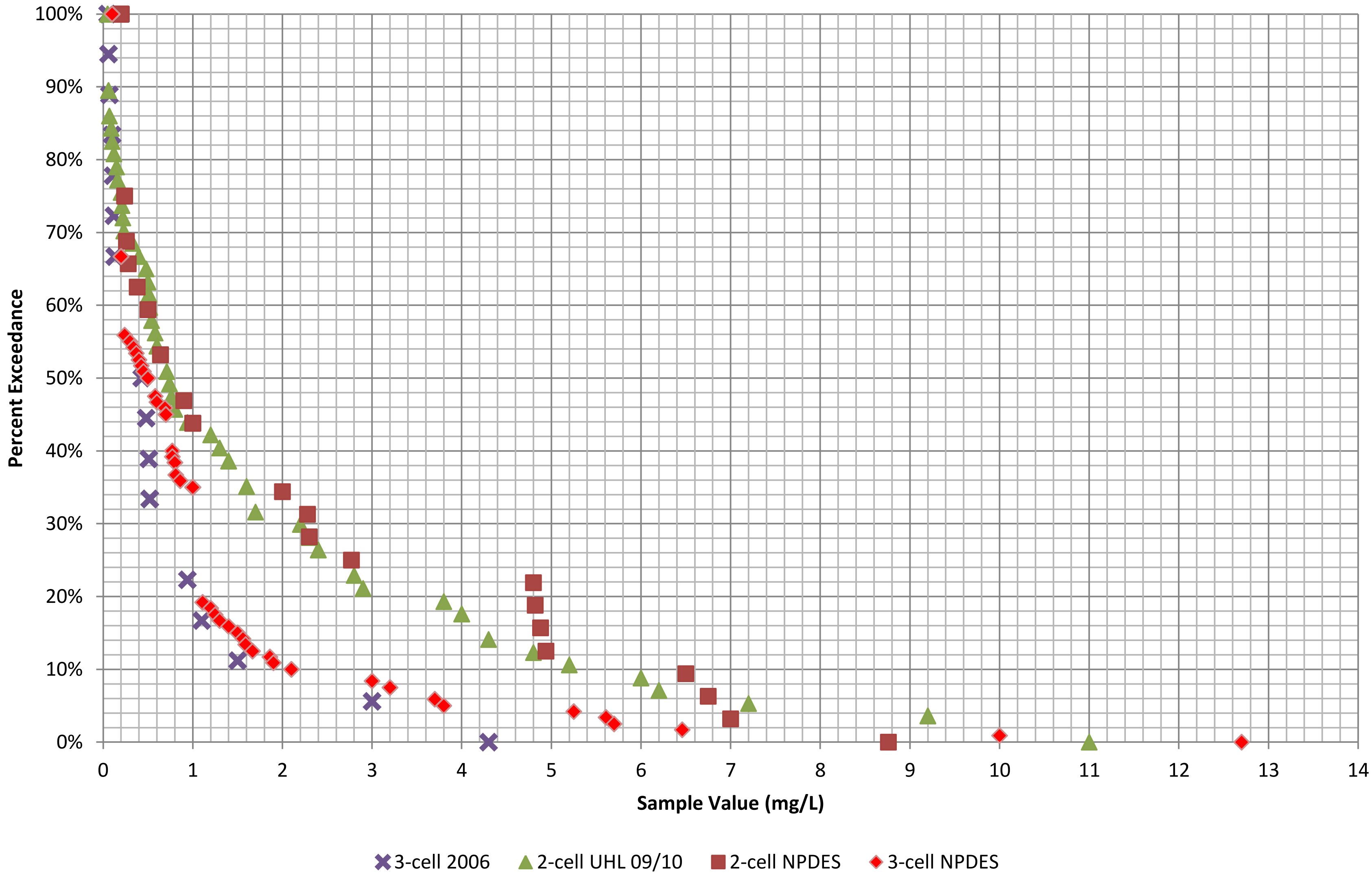
E. coli - Percent Exceedance
NPDES Data (Fall 2009 - Fall 2011)

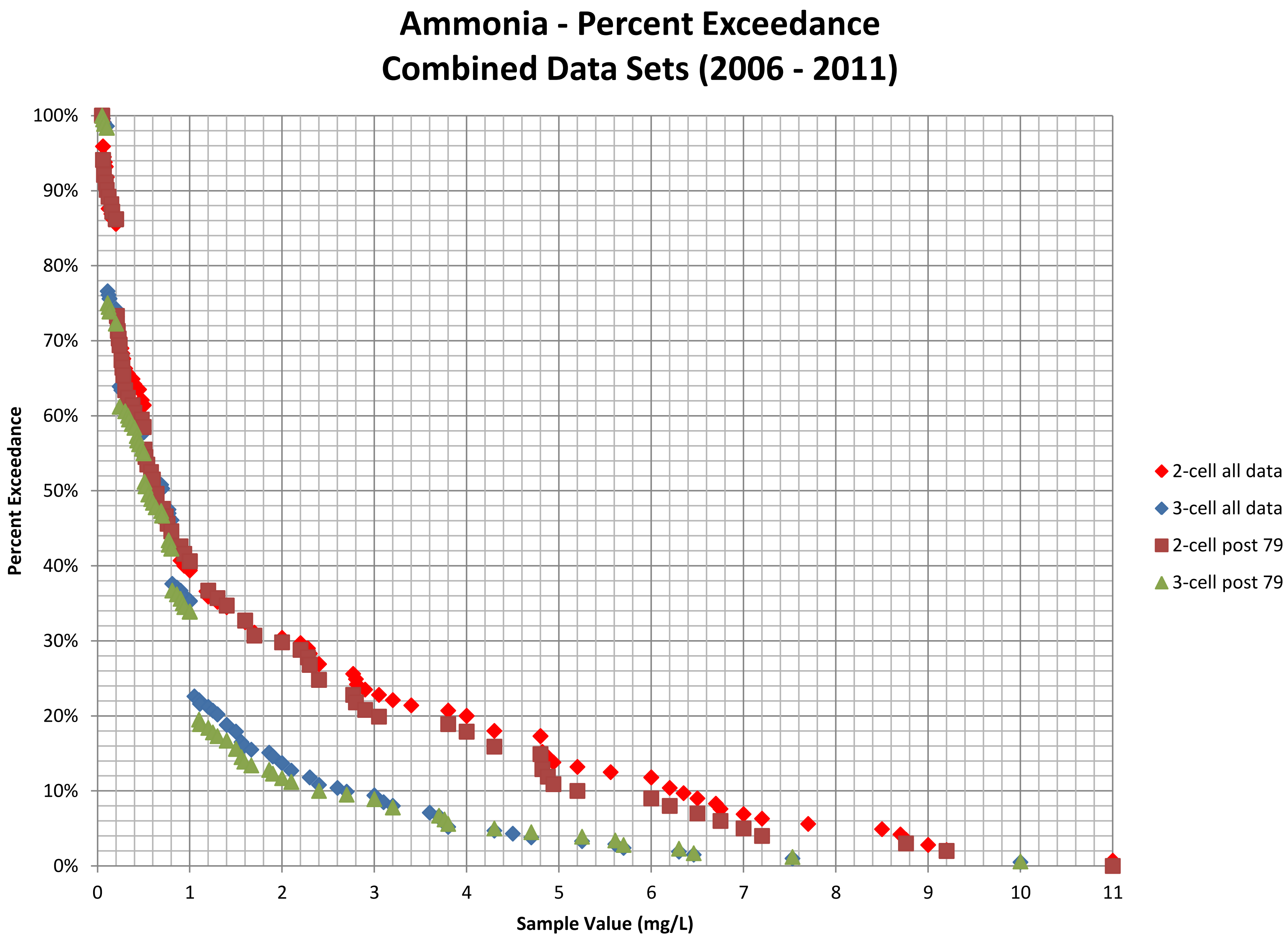


Ammonia - Percent Exceedance
All Data - 2 vs. 3 Cells



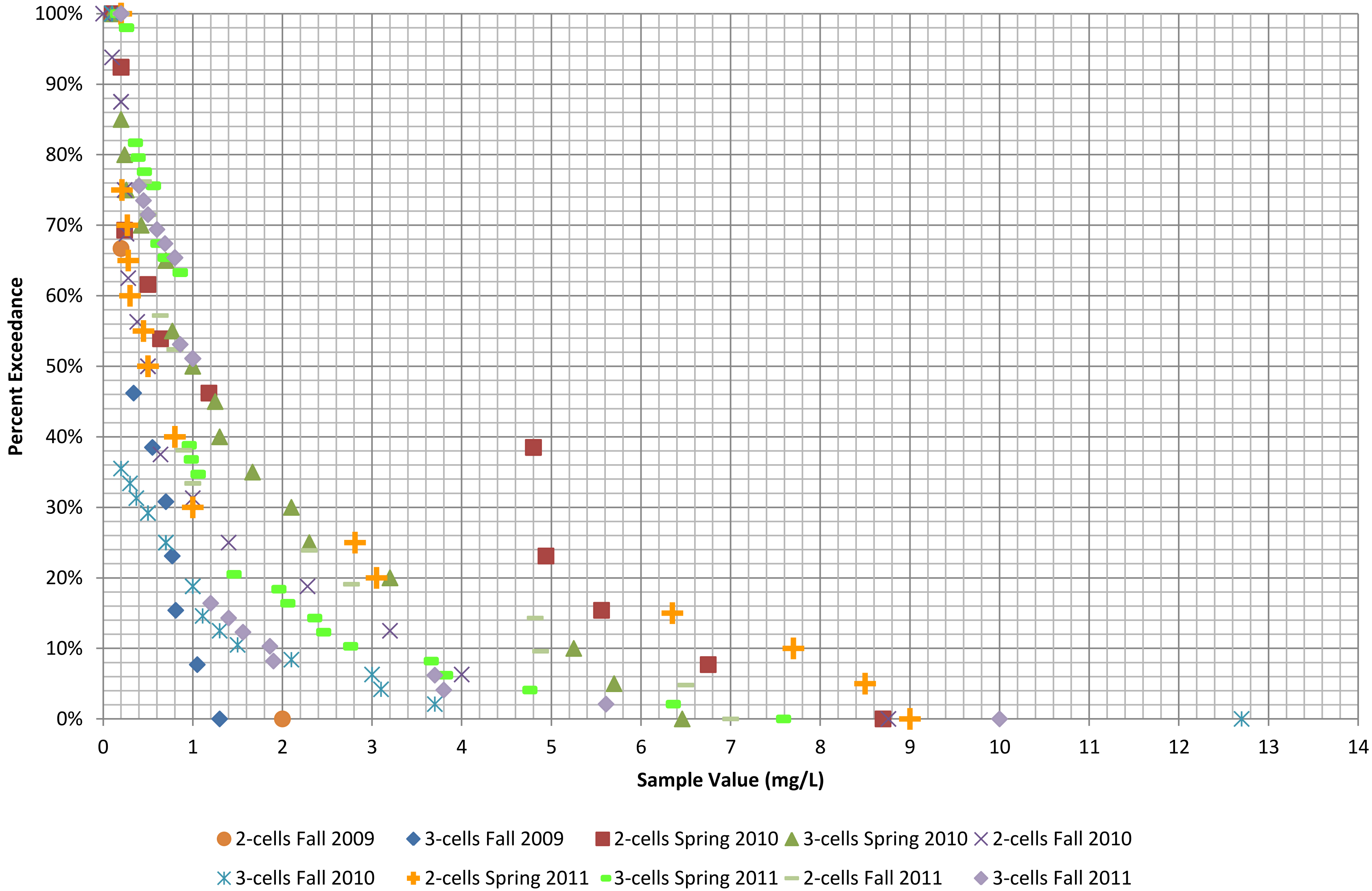
Ammonia - Percent Exceedance
Post 1979 - 2 vs. 3 Cells



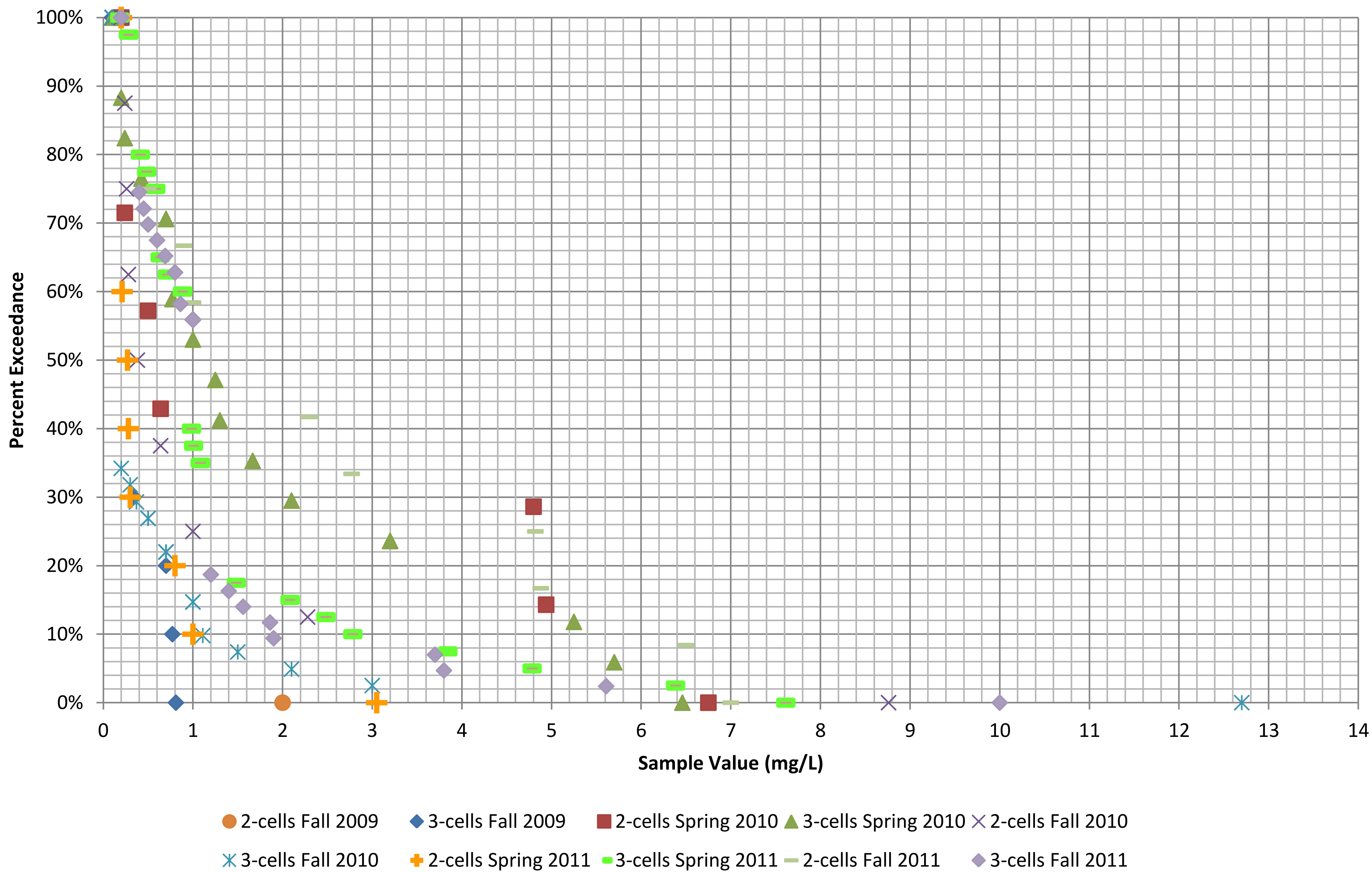


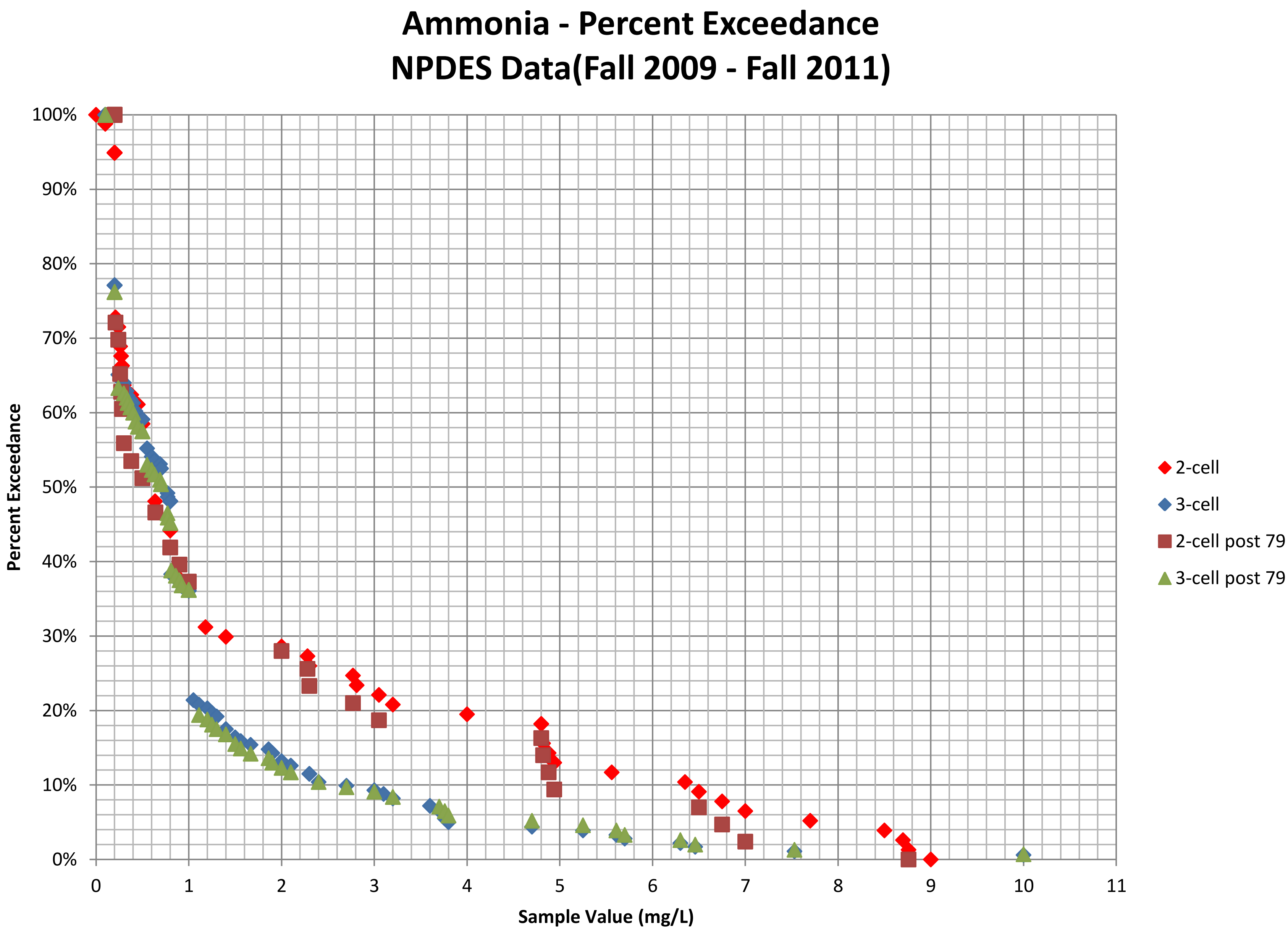
Ammonia - Percent Exceedance
Combined Data Sets (2006 - 2011)
Percent Exceedance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
11
Sample Value (mg/L)
2-cell all data
3-cell all data
2-cell post 79
3-cell post 79

Ammonia - Percent Exceedance
NPDES Data by Discharge Season



Ammonia - Percent Exceedance
NPDES Data by Discharge Season (Post 79)




Ammonia - Percent Exceedance
NPDES Data(Fall 2009 - Fall 2011)
Percent Exceedance
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
6
7
8
9
10
11
Sample Value (mg/L)
2-cell
3-cell
2-cell post 79
3-cell post 79

Observations

- Unknowns
  - Future bacteria limits for CDLs
  - Future ammonia limits for CDLs
  - Operational characteristics at the time of sampling (series, parallel, etc.)
  - Specific hydraulic/loading variability
- Knowns
  - Significant seasonal variability
  - In general, the data shows better bacteria & ammonia performance for 3-cell systems
    - Exception = ammonia data from Spring 2011
  - Better bacteria results from Spring discharges?
- Result
  - Variance approvals for new 2-cell systems based on "equivalent effectiveness" are no longer being recommended by DNR Engineering staff

Observations (cont.)

- Hypothetical Criteria vs. Observed NPDES Performance

	Comparison Criterion	Percent Exceedance (Post 1979)	
		2-Cell	3-Cell
Bacteria	1073 #/100 mL	18.3 (22.6)	8.1 (7.4)
Ammonia	1 mg/L	36.4 (37.3)	36.1 (36.2)
	2 mg/L	28.6 (28.0)	13.2 (12.3)
	3 mg/L	22.4 (19.1)	9.3 (9.1)
	4 mg/L	19.5 (17.4)	4.8 (5.7)
	5 mg/L	11.0 (7.8)	4.1 (4.9)

Questions?

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