Measuring the Impact of Nitrogen Management on Groundwater Quality in Sandy Soils

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WPVGA

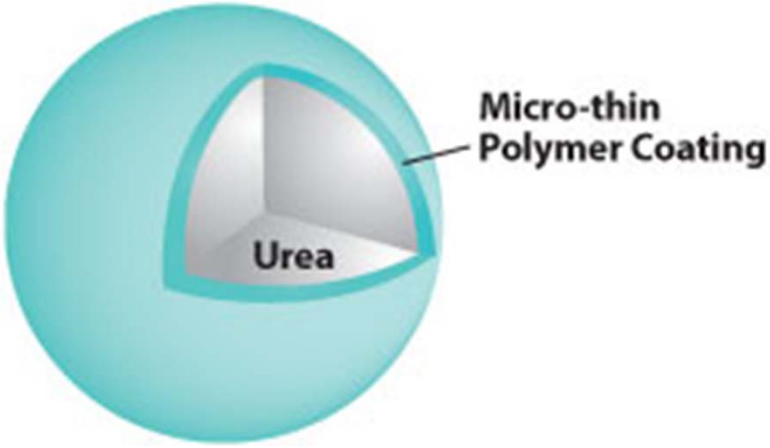
WISCONSIN
DEPT. OF NATURAL RESOURCES

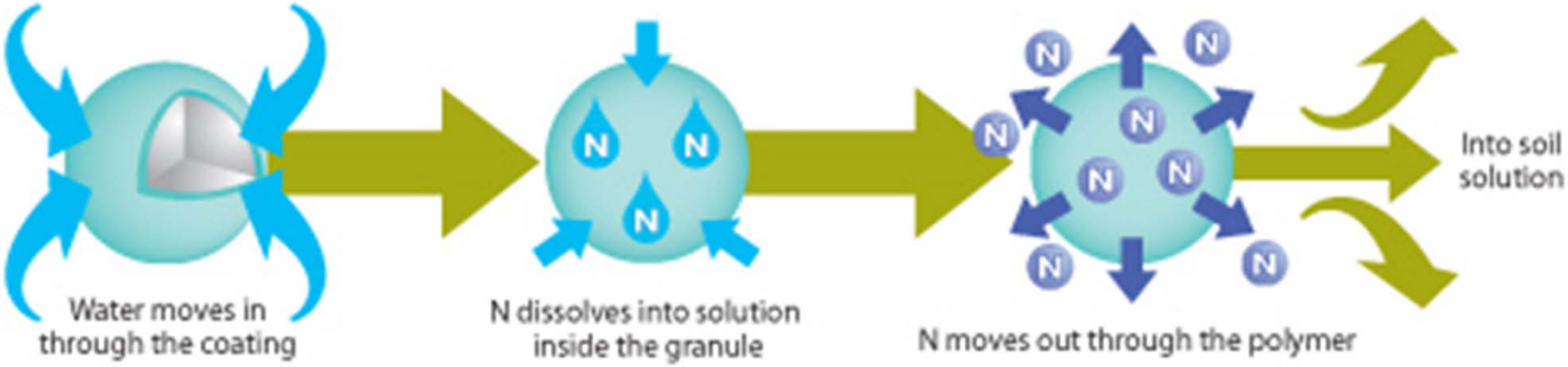
Wisconsin Groundwater Coordinating Council (GCC)

DEPARTMENT OF
SOIL SCIENCE
University of Wisconsin-Madison

- Alternative management methods
  - Controlled-Release Fertilizer as a polymer coated urea (PCU)

Environmentally Smart Nitrogen (ESN®)

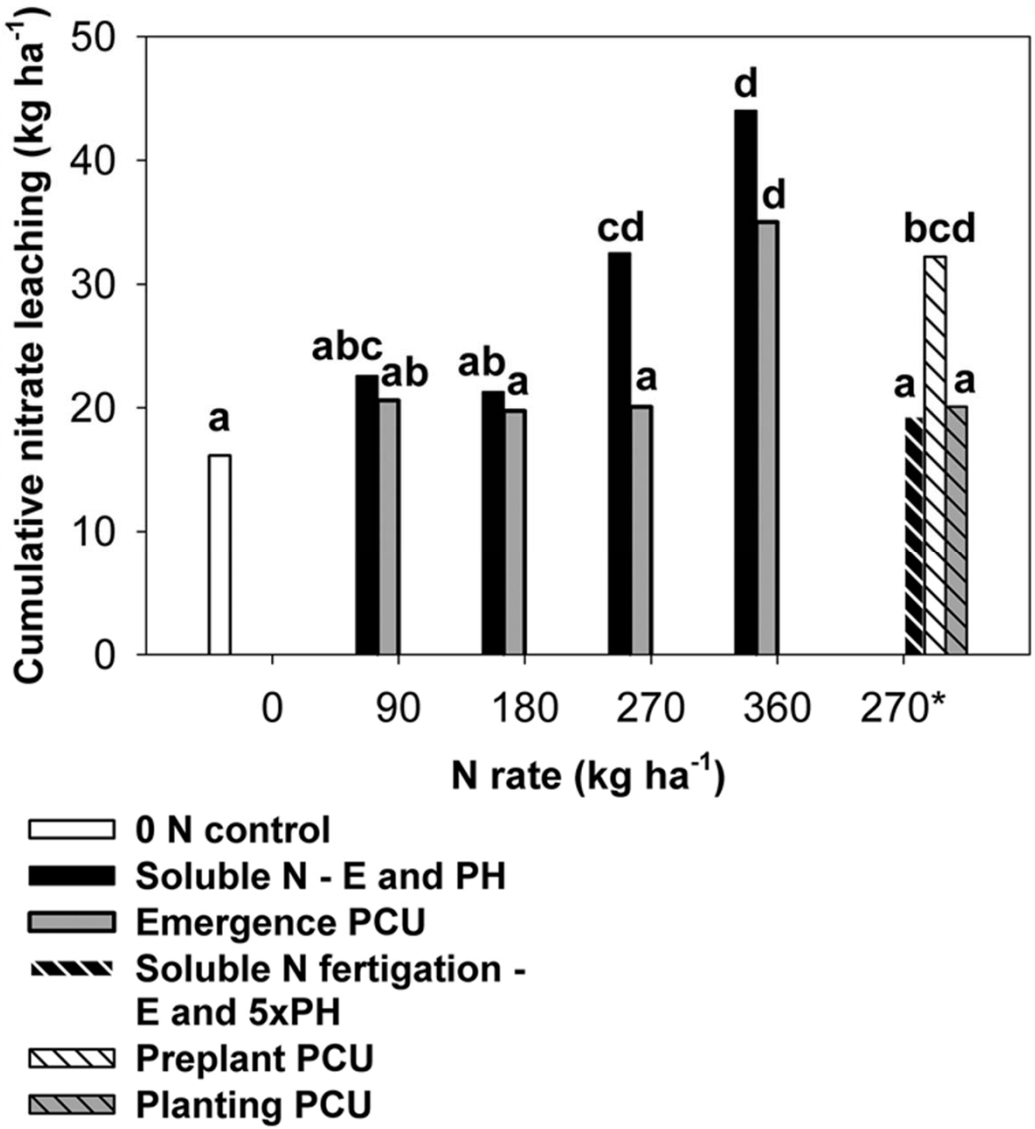




Mitigating N

- PCU has the potential to reduce the amount of N reaching the groundwater
  - Increase Nitrogen Use Efficiency
    - Increased yields with equivalent rate of application
    - Equal yields with reduced rates
  - Limit available N to leach from the root zone to groundwater
  - On sandy soil use of PCU has shown promise

Mitigating N



Graph from Wilson, Melissa L., Carl J. Rosen, and John F. Moncrief. "Effects of Polymer-coated Urea on Nitrate Leaching and Nitrogen Uptake by Potato." *Journal of Environmental Quality* 39.2 (2010): 492-99. Print.

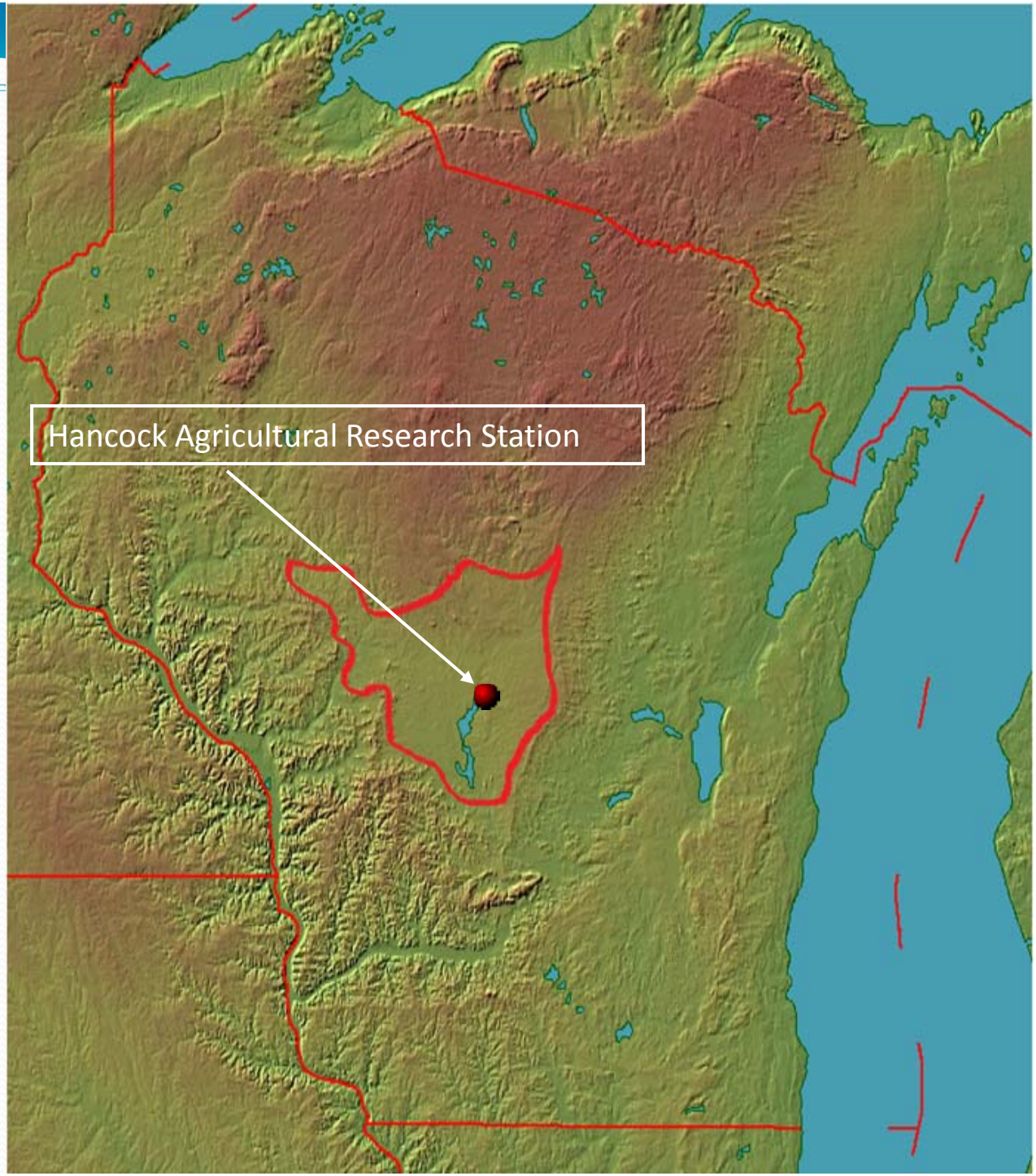
Mitigating N

- PCU studies have focused on N leaching directly below the root zone
  - Amount of N reaching the groundwater has only been inferred from root zone data
- Few, if any studies have been conducted directly measuring groundwater N concentrations under controlled-release fertilizer at large plot sizes in this area

Experimental Design

- Experimental design
- Bromide-chloride tracer study
- Water quality results
- Conclusions

- Hancock, WI
  - Central Sands
- Potato as a model crop
  - High N demand
  - Difficult to manage



Experimental Design

Treatment Code	Treatment	N applied at emergence (~20-25 DAP)	N applied at tuber inititaion (~35-45 DAP)
RCONV	280 kg N ha^{-1} AS-AN	93 kg N ha^{-1} as ammonium sulfate	187 kg N ha^{-1} as ammonium nitrate
RPCU	280 kg N ha^{-1} PCU	280 kg N ha^{-1} as ESN®	None
LPCU	224 kg N ha^{-1} PCU	224 kg N ha^{-1} as ESN®	None
0 N	0 N	None	None

- (All plots received 37 kg N ha^{-1} as starter fertilizer)
- DAP – Day after planting
- Plant Date was 29 April 2010 and 25 April 2011

Potato agronomic results

- Potato Yield

	2010		2011	
Treatment	**Marketable (Mg ha^{-1})**	**Total (Mg ha^{-1})**	**Marketable (Mg ha^{-1})**	**Total (Mg ha^{-1})**
RCONV	39.9 a	48.8 a	50.0 ab	54.5 a
RPCU	41.8 a	50.2 a	50.9 a	56.4 a
LPCU	39.2 a	47.8 a	52.1 a	56.4 a
0 N	21.6 b	30.9 b	41.2 b	48.6 a

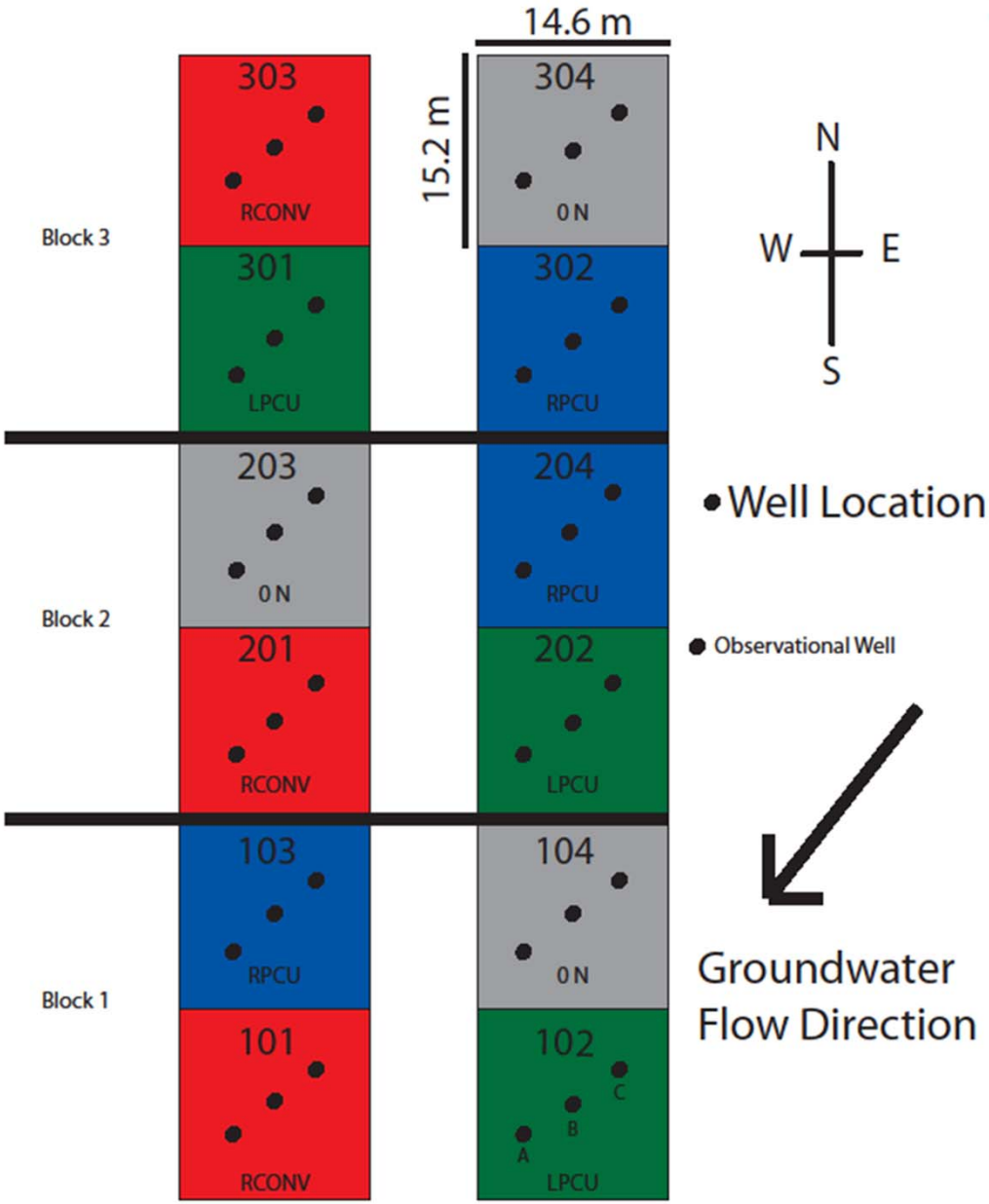
- Harvest date was 30 August 2010 and 12 September 2011
- (C.V.)

Potato agronomic results

Year	Treatment	N applied (kg ha^{-1})	Ave. N uptake (kg ha^{-1})	Ave. System N (0 N uptake) (kg ha^{-1})	Ave. N available to leach (kg ha^{-1})
2010	RCONV	280	162	63	181 a
	RPCU	280	144	63	199 a
	LPCU	224	150	63	137 b
2011	RCONV	280	281	155	154 a
	RPCU	280	273	155	162 a
	LPCU	224	272	155	107 b

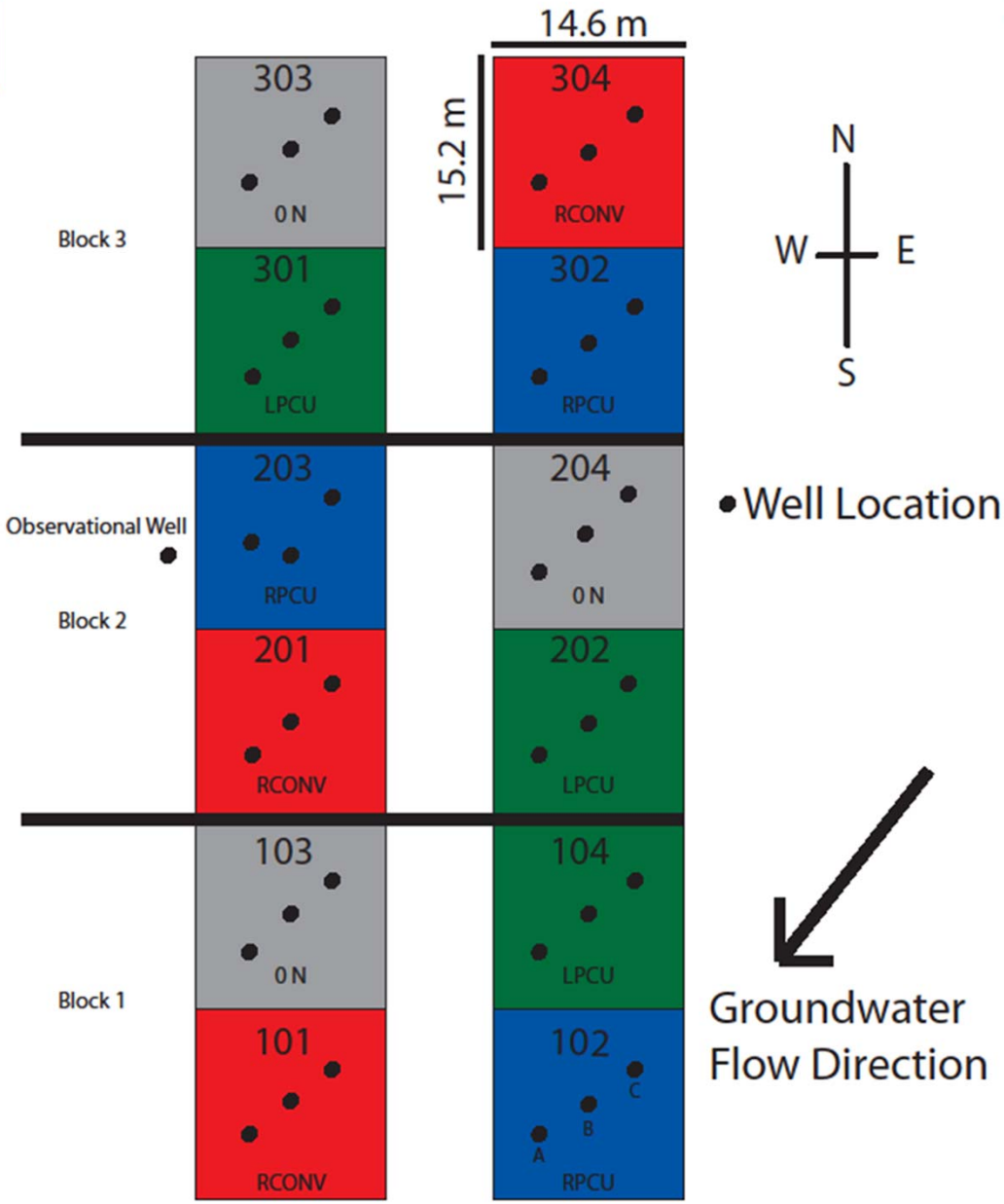
$\alpha = 0.1$; $P>F = 0.0070$ in 2010; $P>F = 0.0547$ in 2011

Experimental Design



- 4 fertilizer rates
  - RCONV (red)
  - RPCU (blue)
  - LPCU (green)
  - 0 N control (gray)
- Wells
  - Drilled to 9.75 m
  - 1.5 m screens (2010)
  - Water table at 6.75 m

Experimental Design



- 4 fertilizer rates
  - RCONV (red)
  - RPCU (blue)
  - LPCU (green)
  - 0 N control (gray)
- Wells
  - Drilled to 9.1 m
  - 2.3 m screens (2011)
  - Water table at 7.3 m

Experimental Design

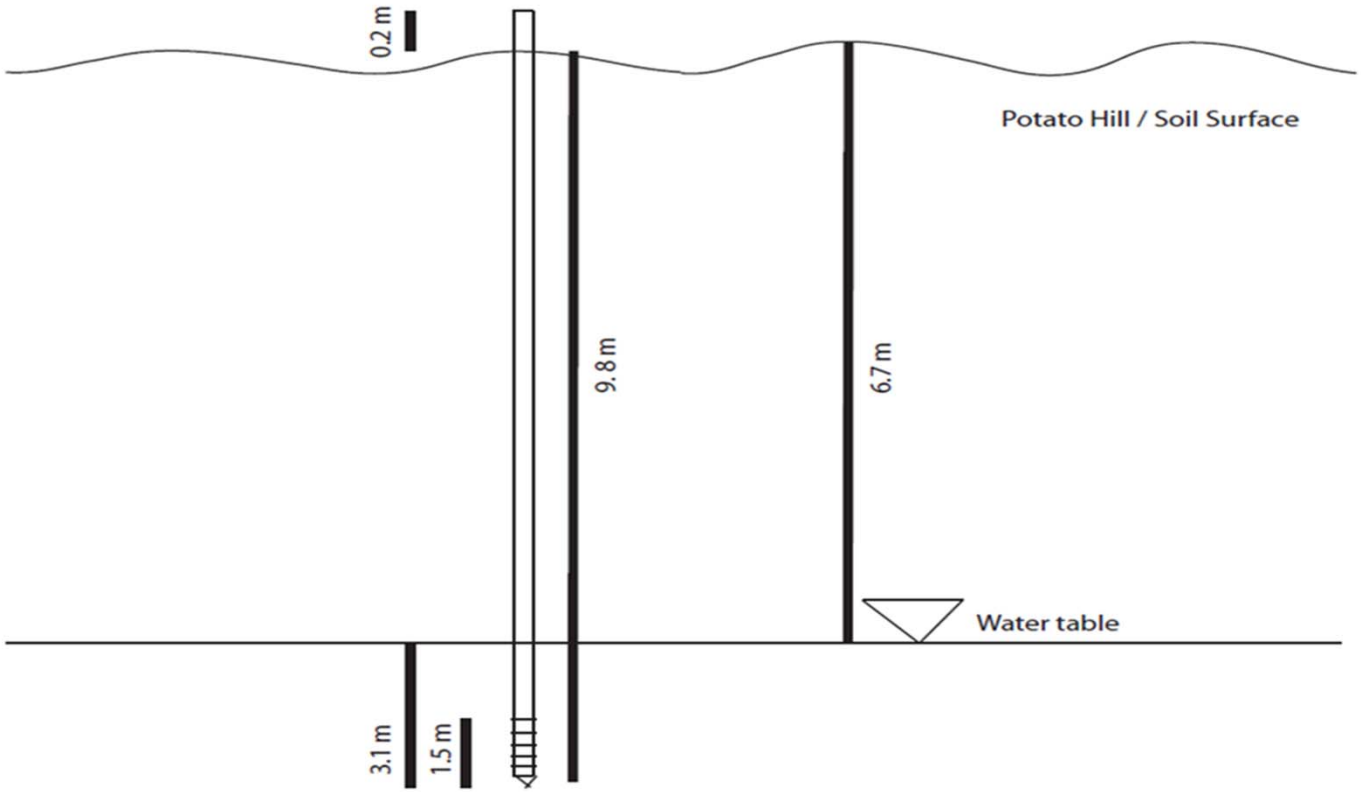
- 2010-2011 well side view diagram

Growing season
29 April – 30 August

- 540 mm precipitation
- 213 mm irrigation
- 19.4 °C

30 year averages

- 435 mm precipitation
- 17.5 °C



Experimental Design

- 2011-2012 well side view diagram

Growing season
25 April – 12 September

- 217 mm precipitation
- 283 mm irrigation
- 18.2 °C

30 year averages

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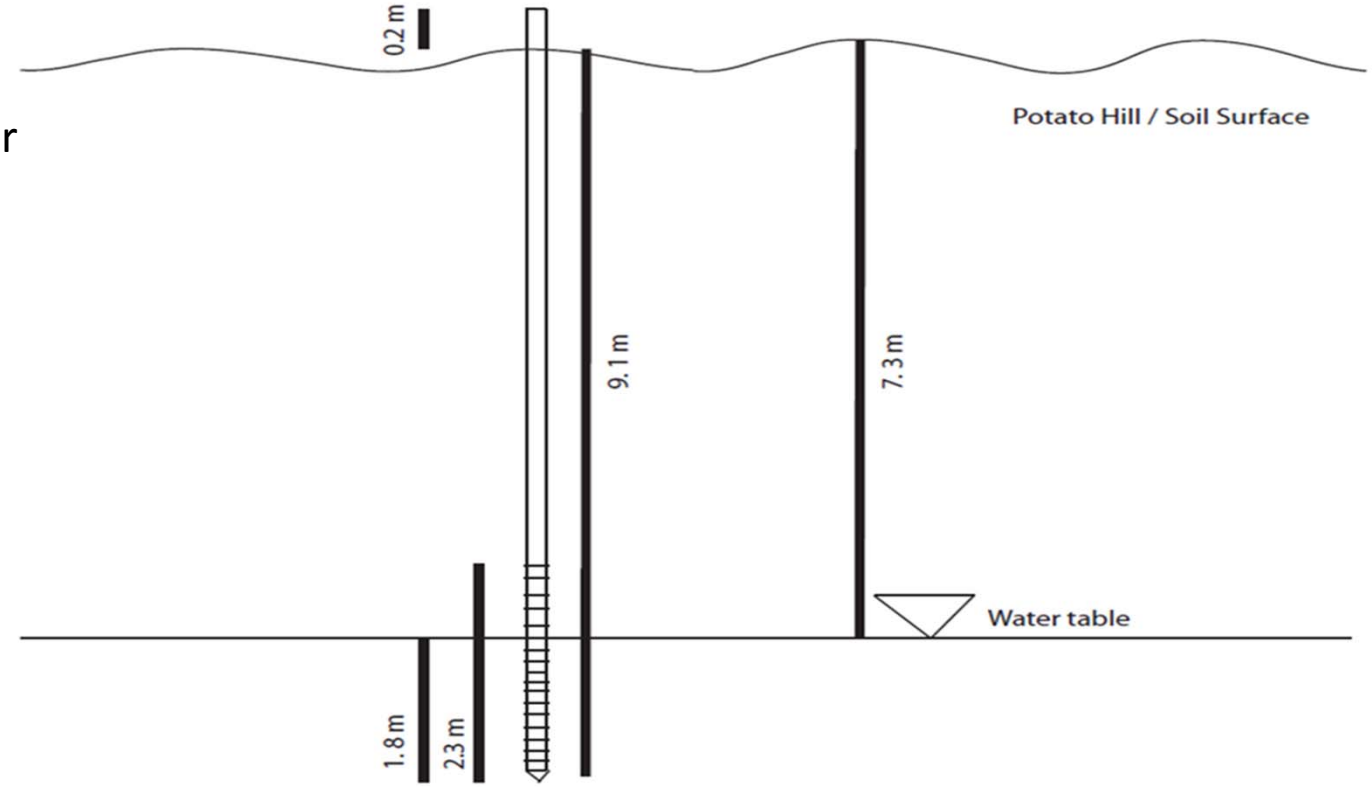
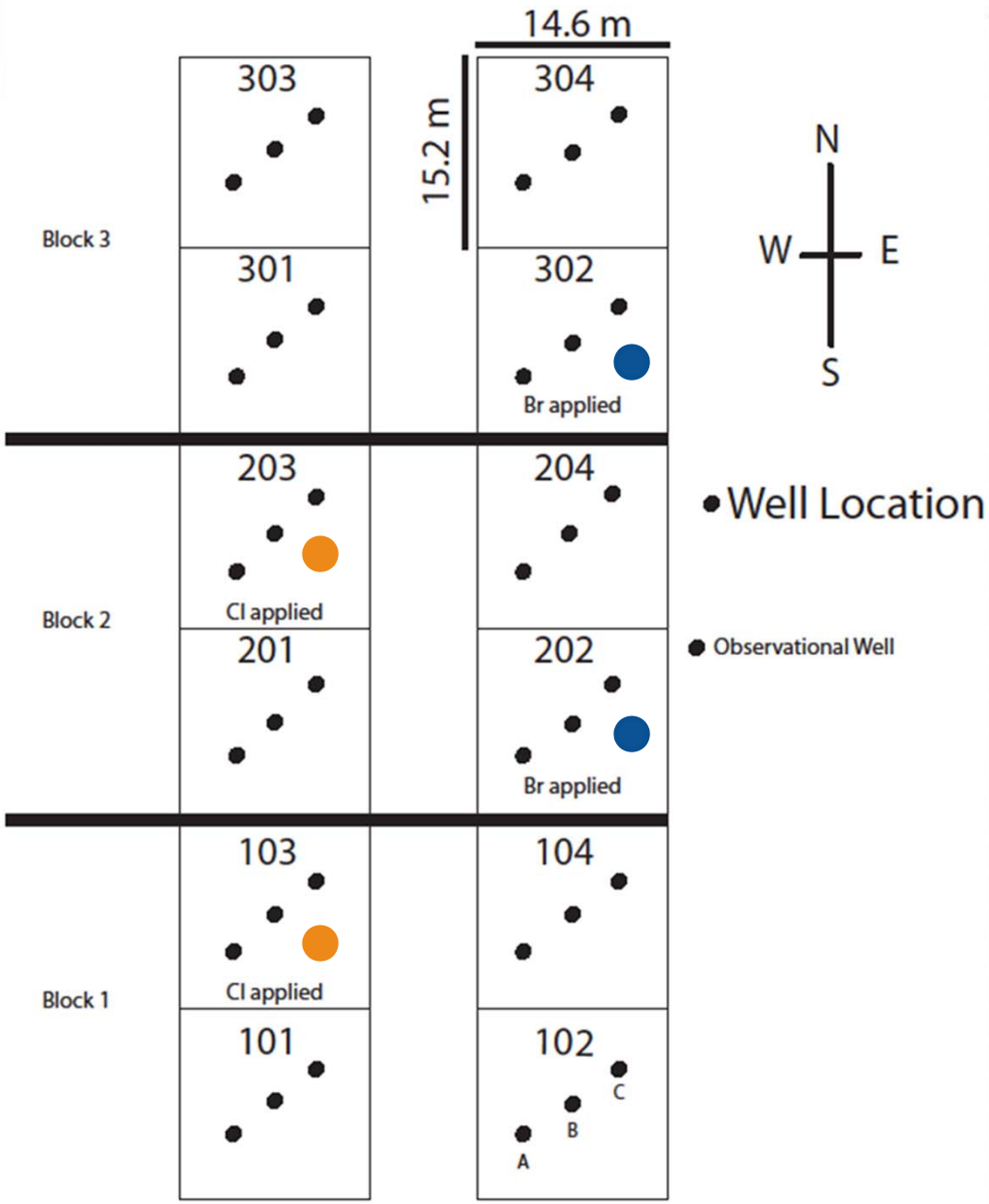


Bromide-Chloride tracer results

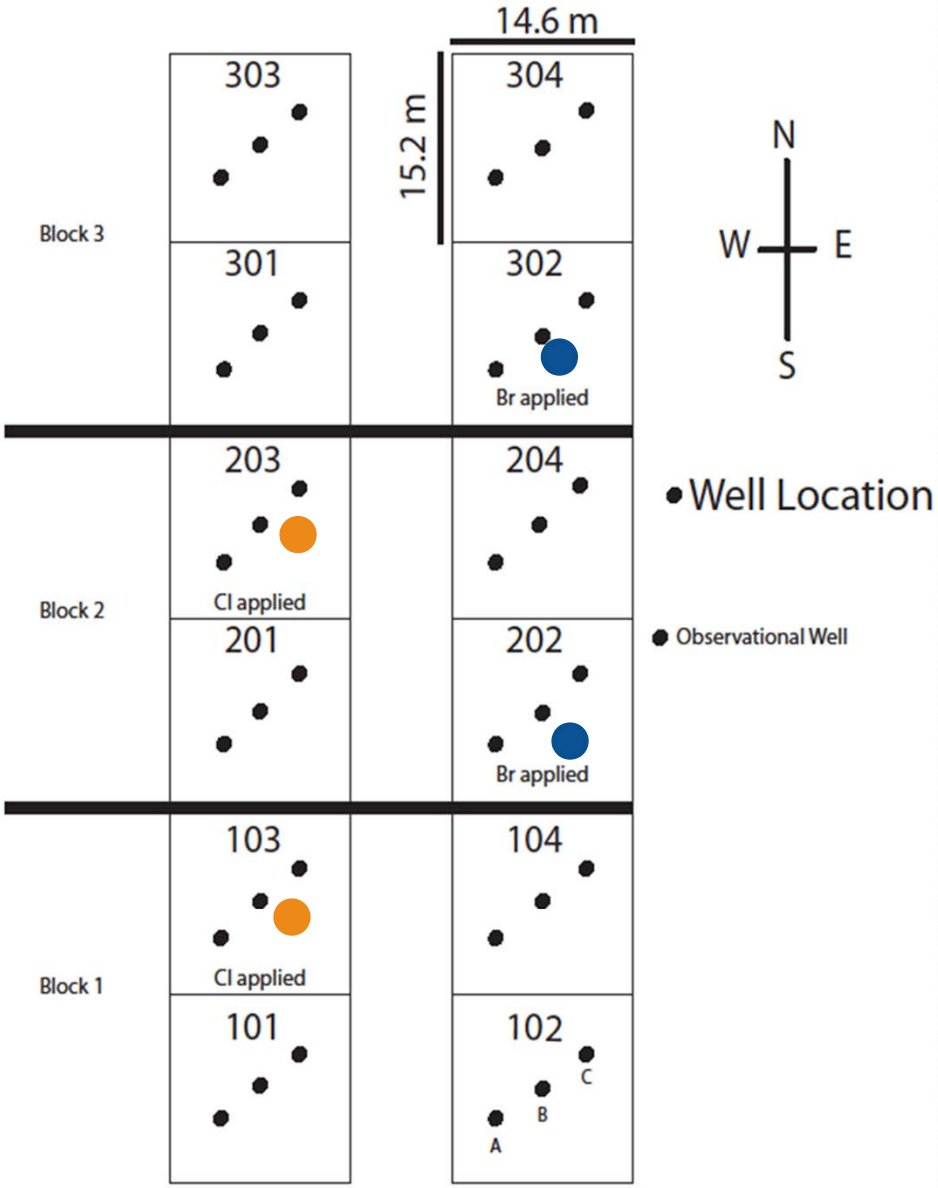
- Experimental design
- Bromide-chloride tracer study
- Water quality results
- Conclusions

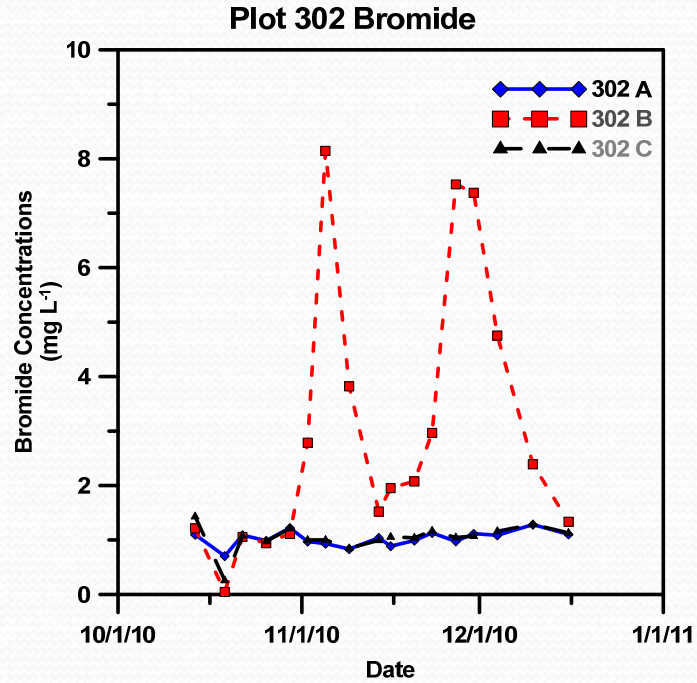
Bromide-Chloride tracer results

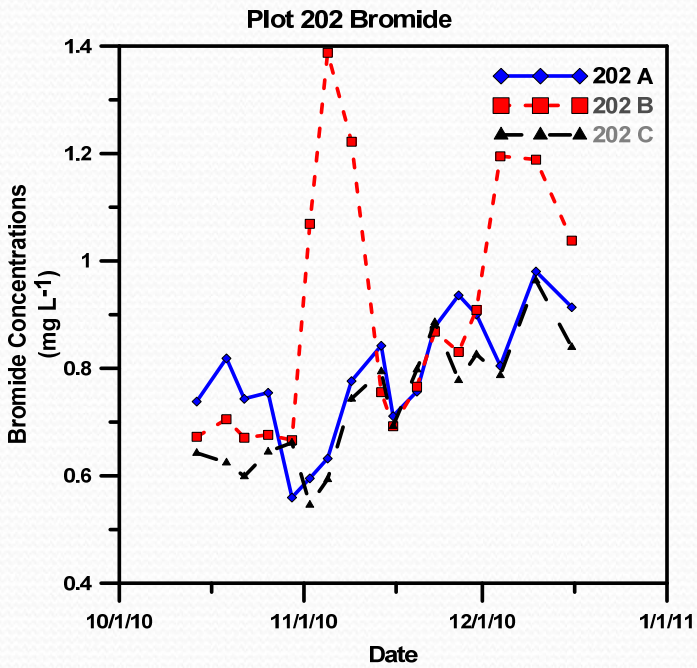


- Bromide and Chloride 2010
  - Moved center “B” well up to allow well screen to intersect water table
  - Tracers applied 14 Oct 2010
  - Irrigation provided water for leaching

Bromide-Chloride tracer results--Bromide







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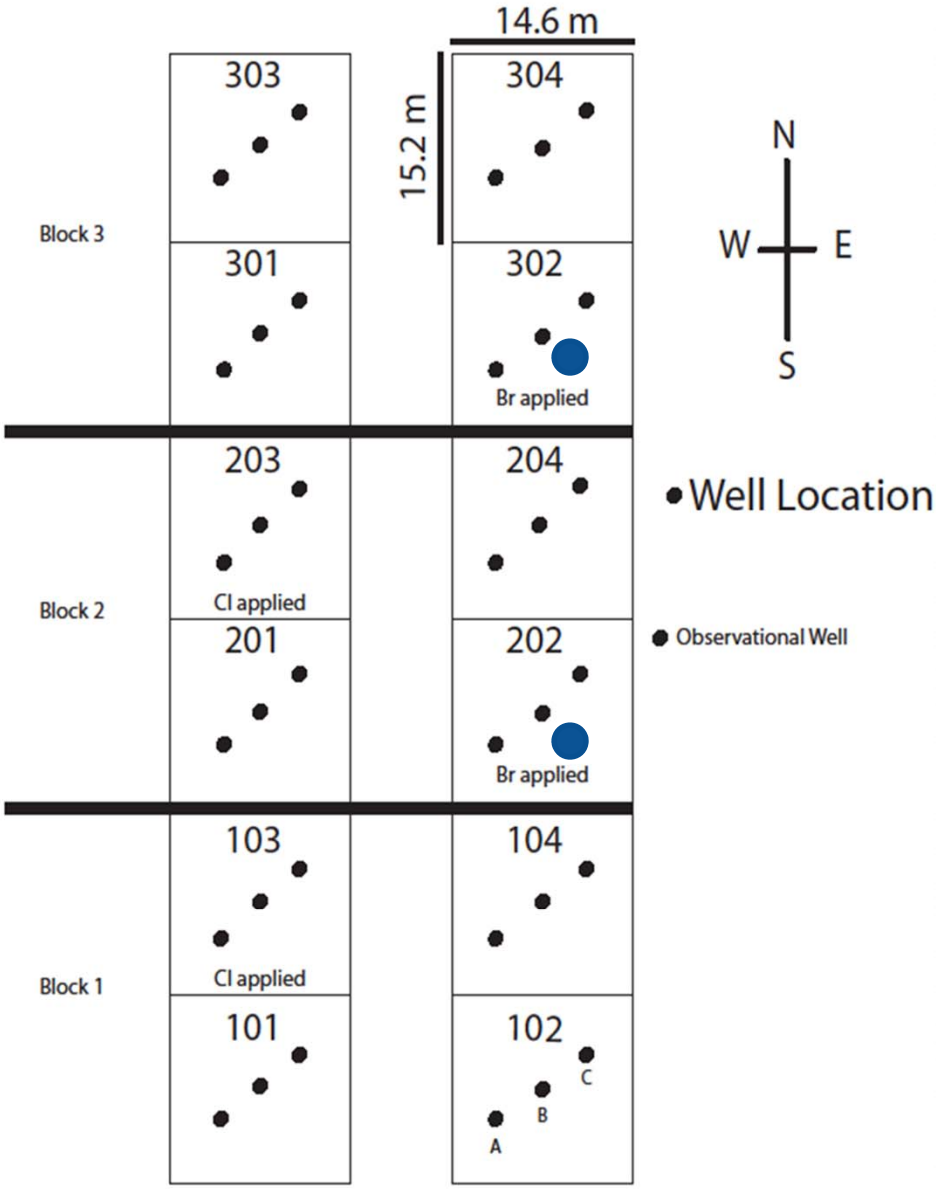
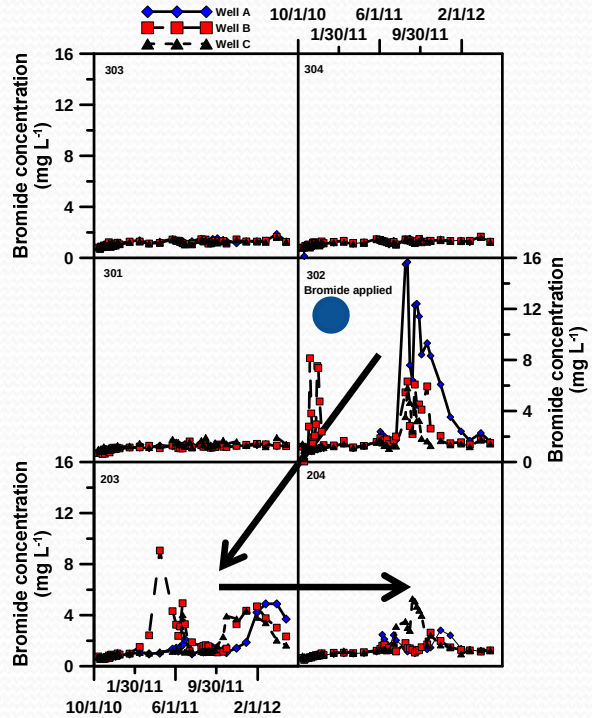
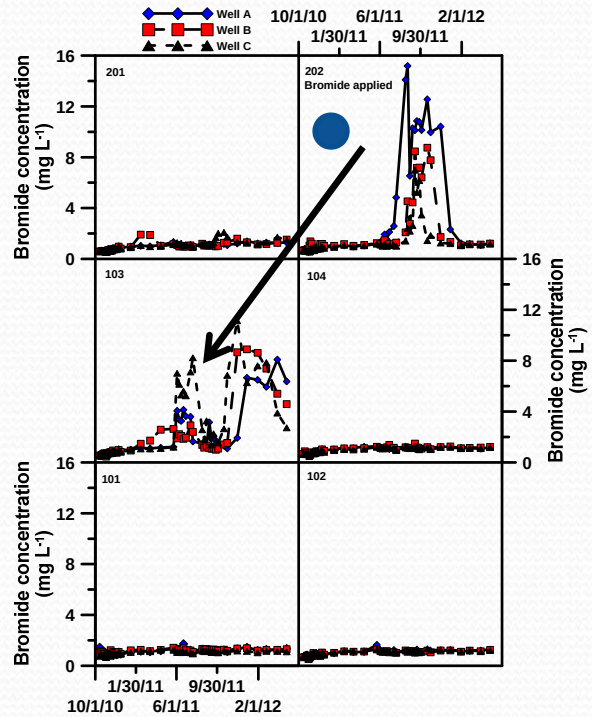
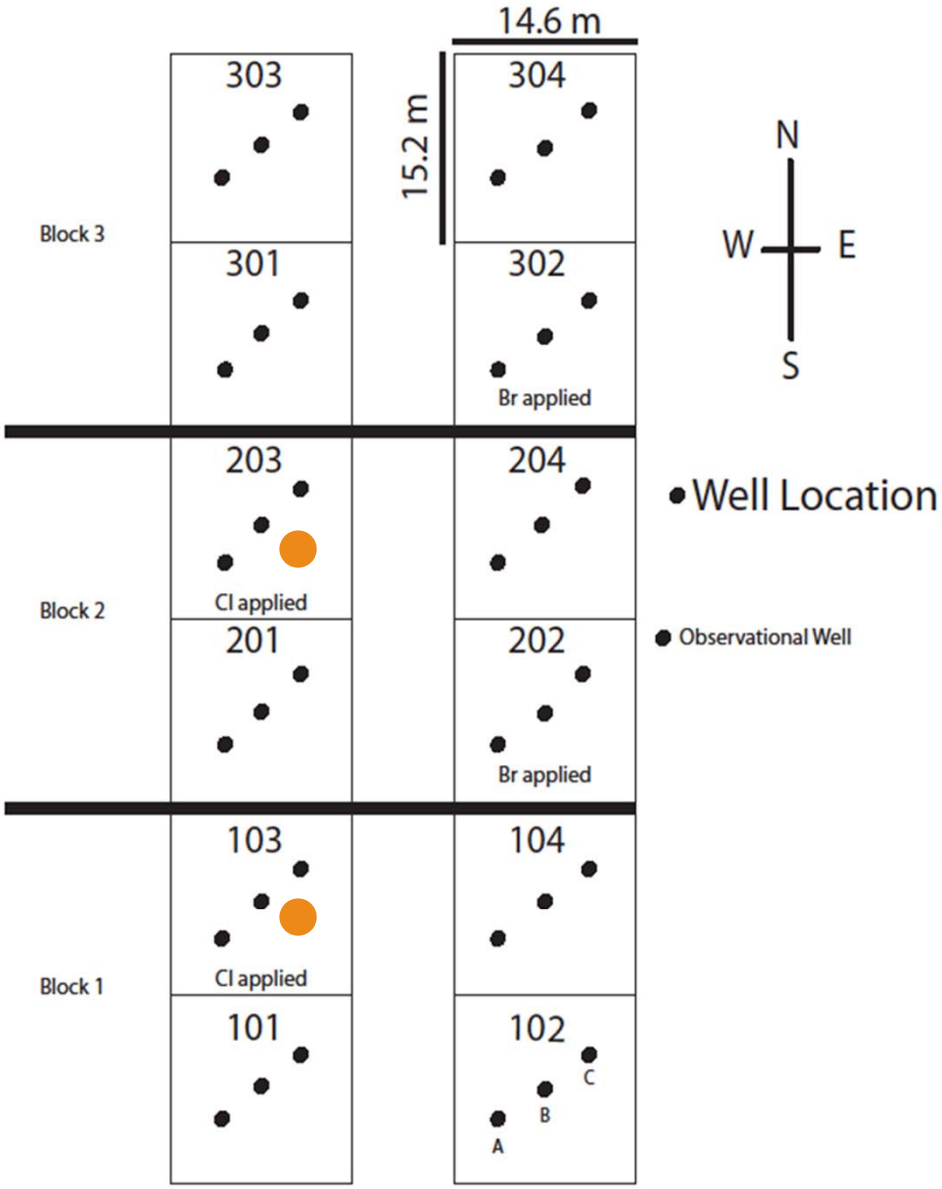


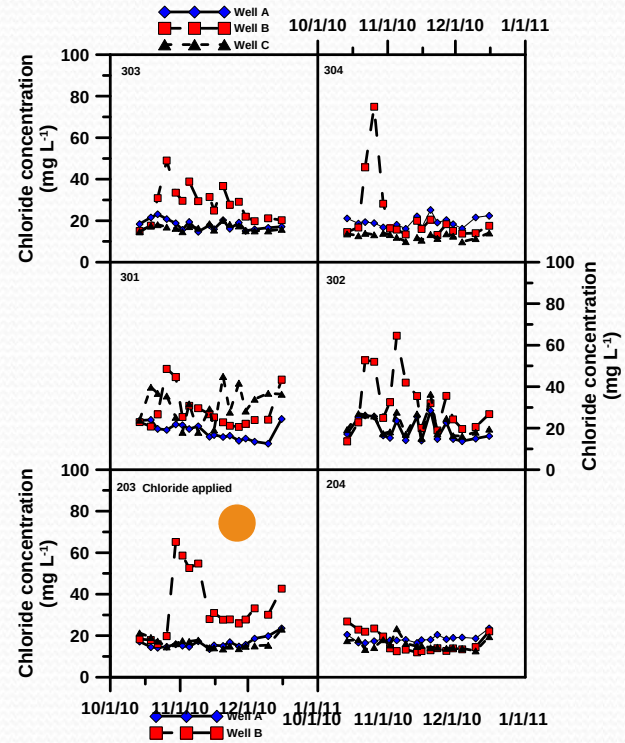


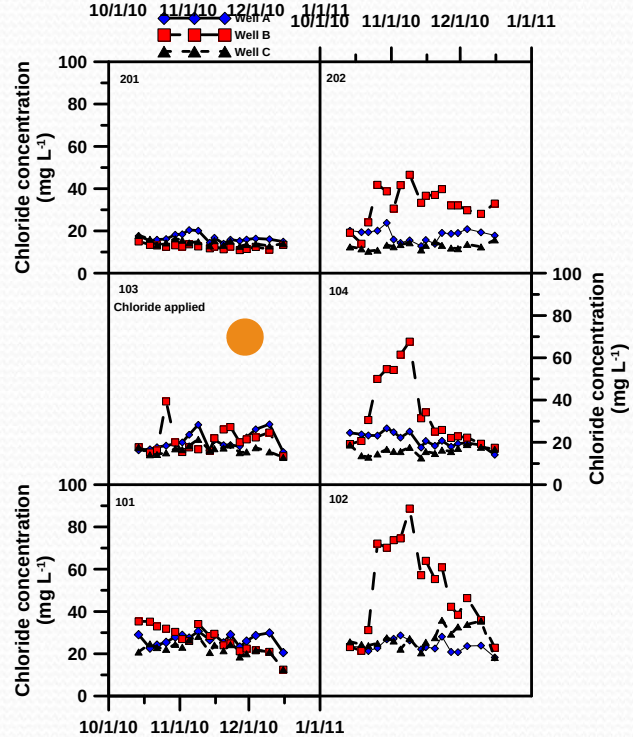


(All wells raised on 23 May 2011)

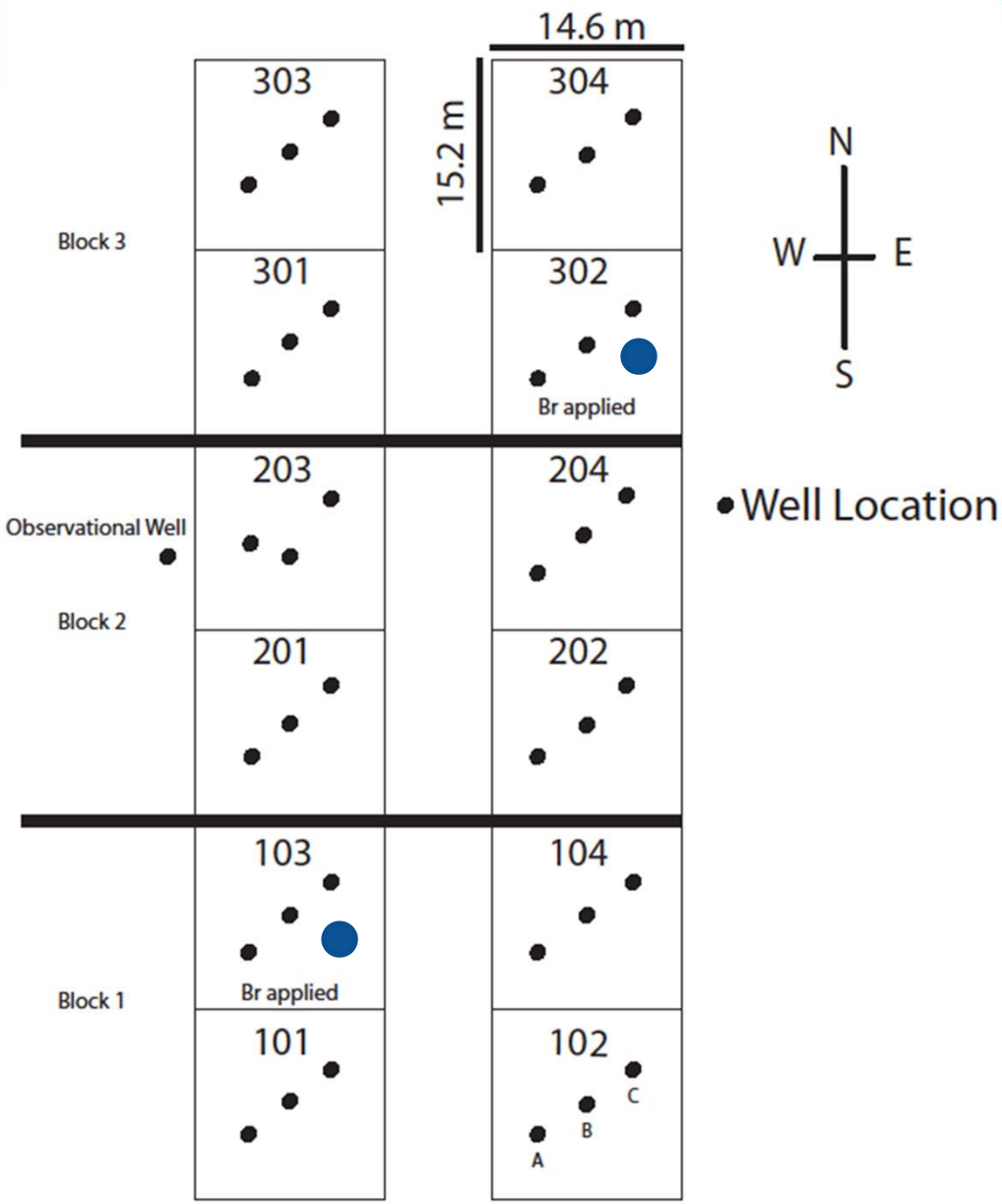
Bromide-Chloride tracer results--Chloride





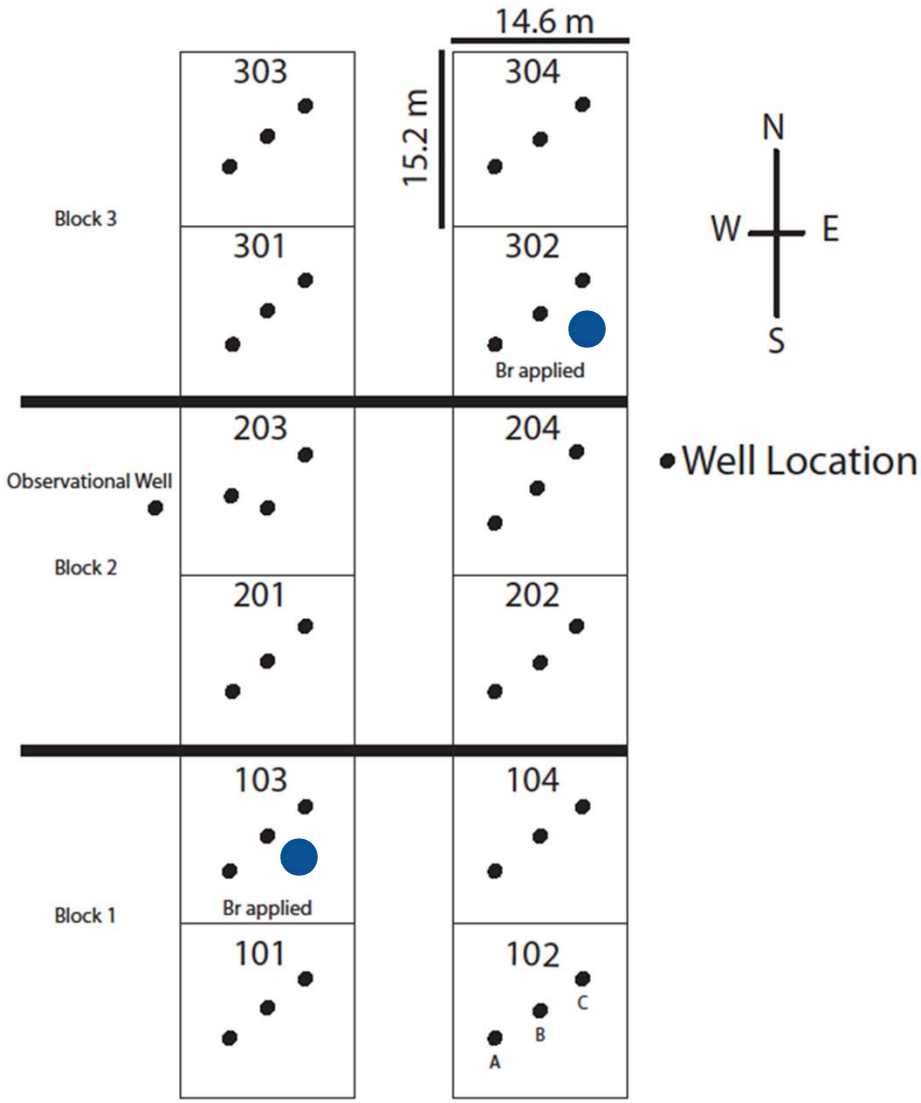


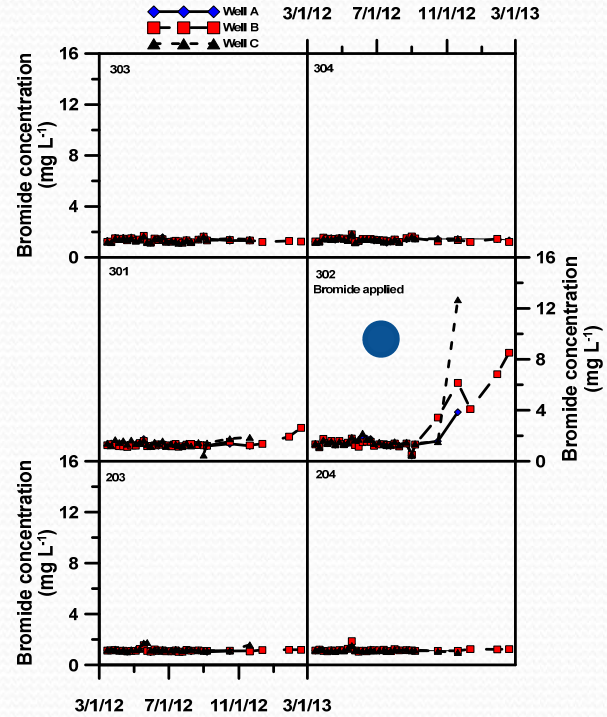
Bromide-Chloride tracer results

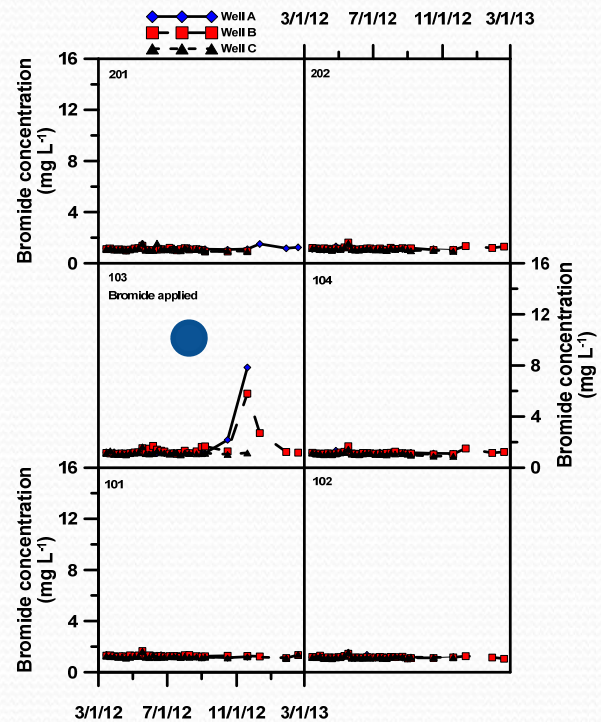


- Bromide 2012
  - All wells intersected the water table at all times during tracer study
  - Bromide applied 9 March 2012
  - Rainfall and crop irrigation as water source

Bromide-Chloride tracer results -- Bromide







Conclusions – Tracer study

- Bromide shows initial downward movement of solute in this area is within the 15 m × 15 m plot.
- While plot level monitoring wells are sufficient for initial N arrival, however plot to plot contamination will occur over time from groundwater flow
- Rainfall intensity has effect on lag time of solute leaching to the water table
- Chloride not an effective tracer in this area due to high and variable background concentrations

Water Quality Results

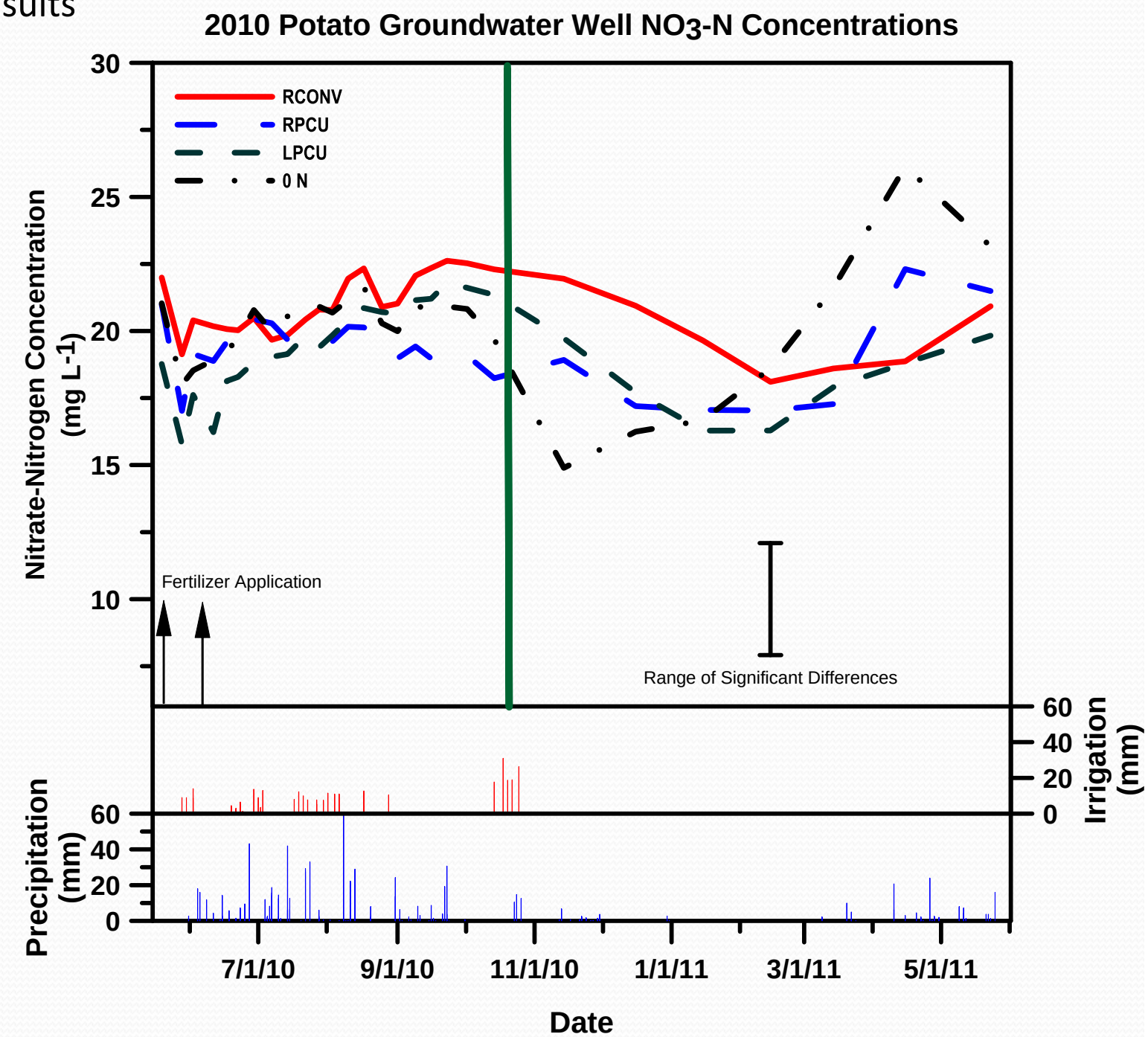
- Experimental design
- Bromide-chloride tracer study
- Water quality results
- Conclusions

Water Quality Results

Plot averages

- 13.5 – 26.5
- 13.1 – 29.9

NO_3-N (mg L^{-1})



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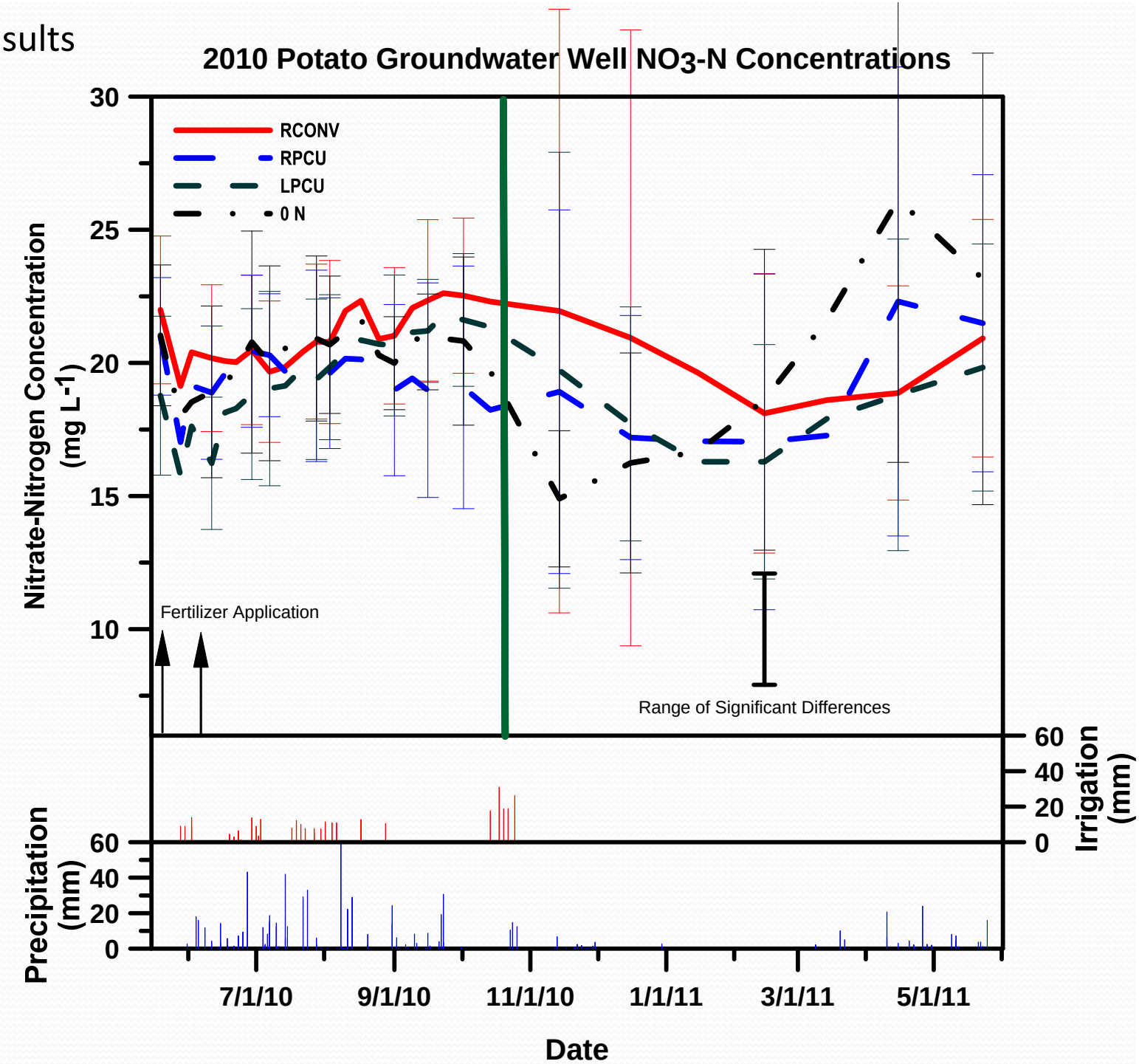
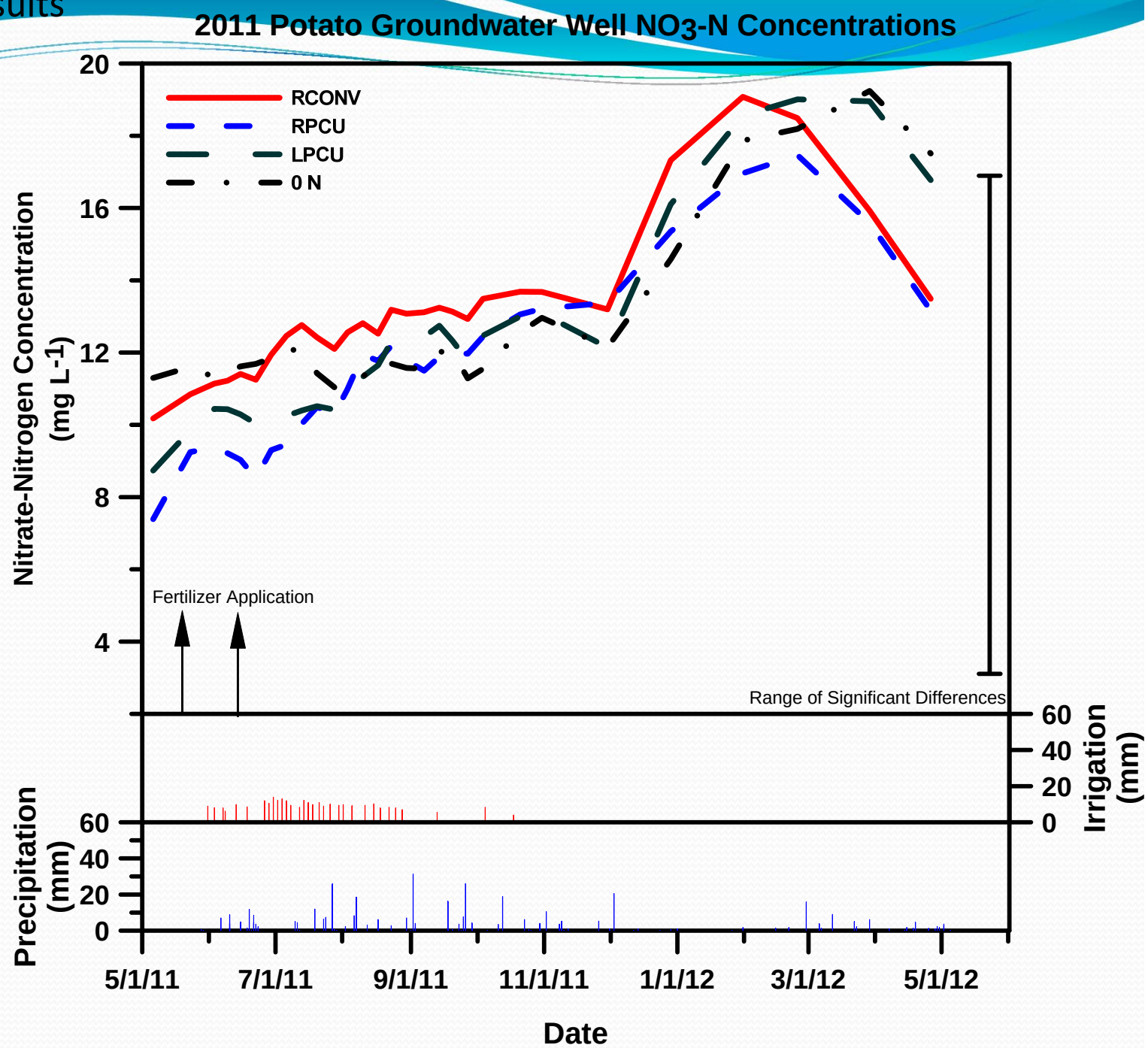


Water Quality Results

Plot averages

- 2.0 – 37.3 NO_3-N (mg L^{-1})



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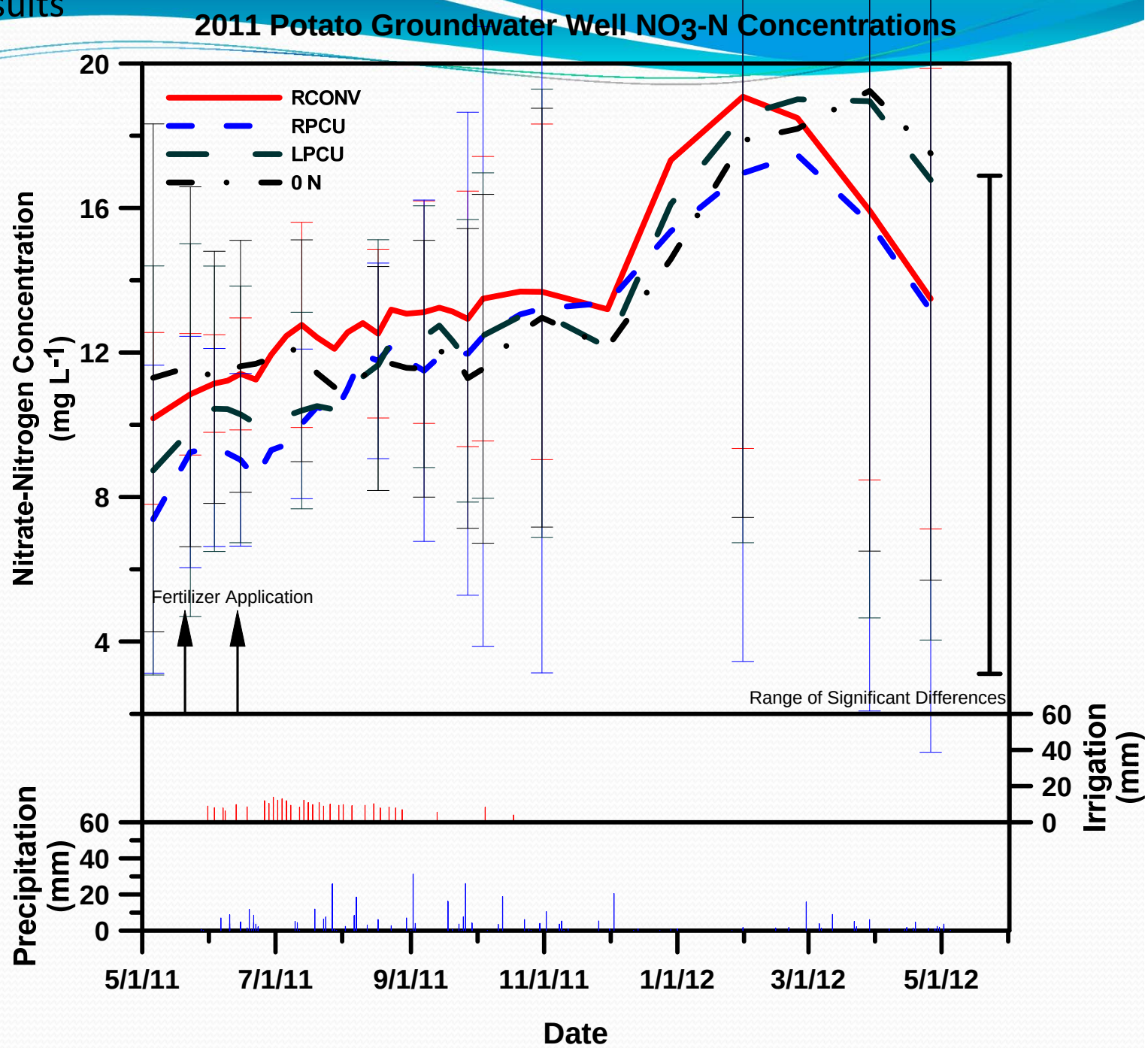


Conclusions – Water Quality

- Background and variability in groundwater N concentrations, both within and among plots resulted in no statistical difference between conventional and PCU fertilizer
- In the short term data collection should continue using root zone measurements, N balance and Nitrogen Use Efficiency
- Background and variation in groundwater N concentration addressed at field level over multiple years
  - Need field size large enough to account for movement of groundwater
  - May account for cumulative fertilizer effect on groundwater N concentrations
  - Evaluate water quality over time and agricultural systems

Questions?

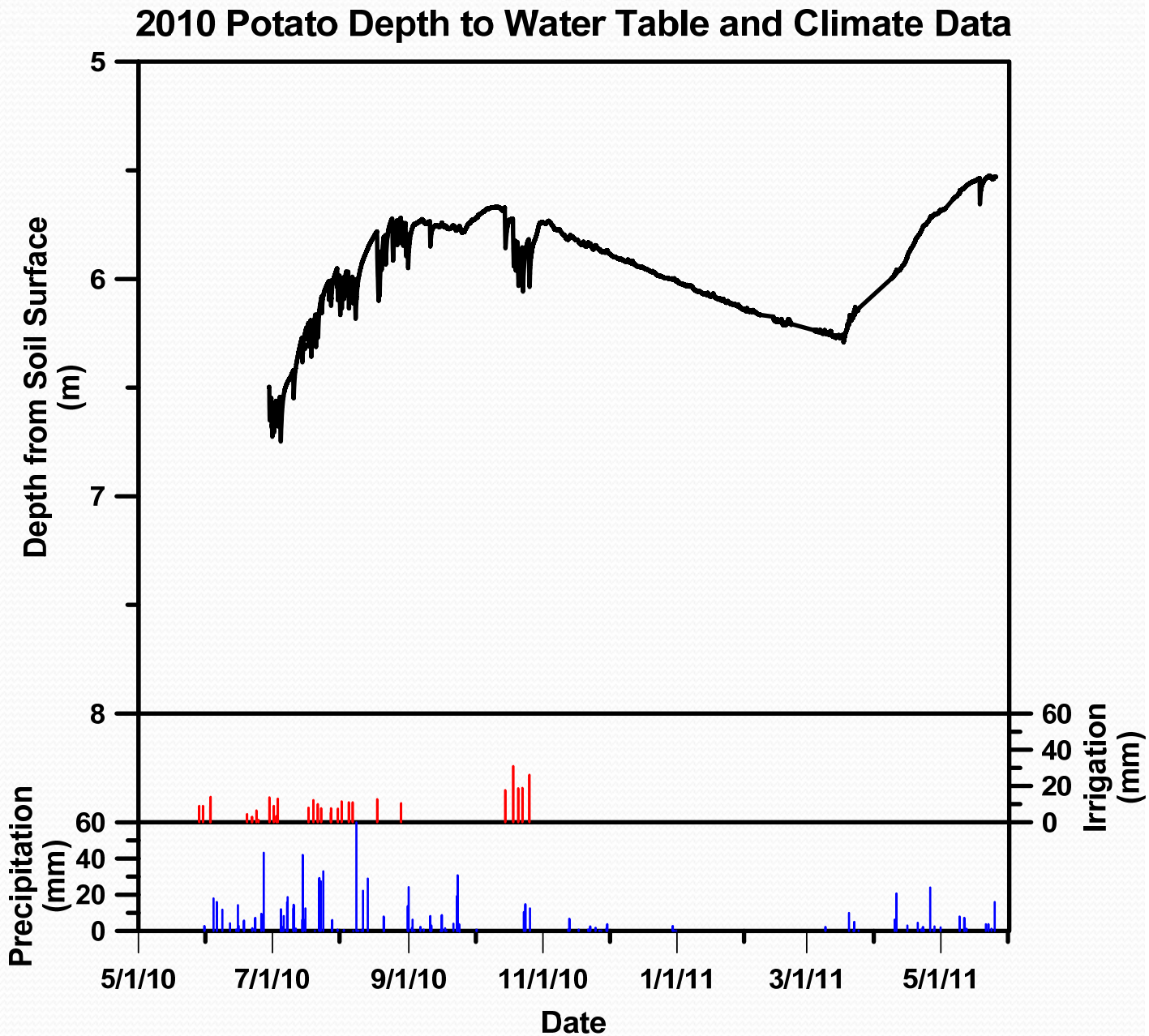
2010 Water table and climate

Growing season
29 April – 30 August

- 540 mm precipitation
- 213 mm irrigation
- 19.4 °C

30 year averages

- 435 mm precipitation
- 17.5 °C



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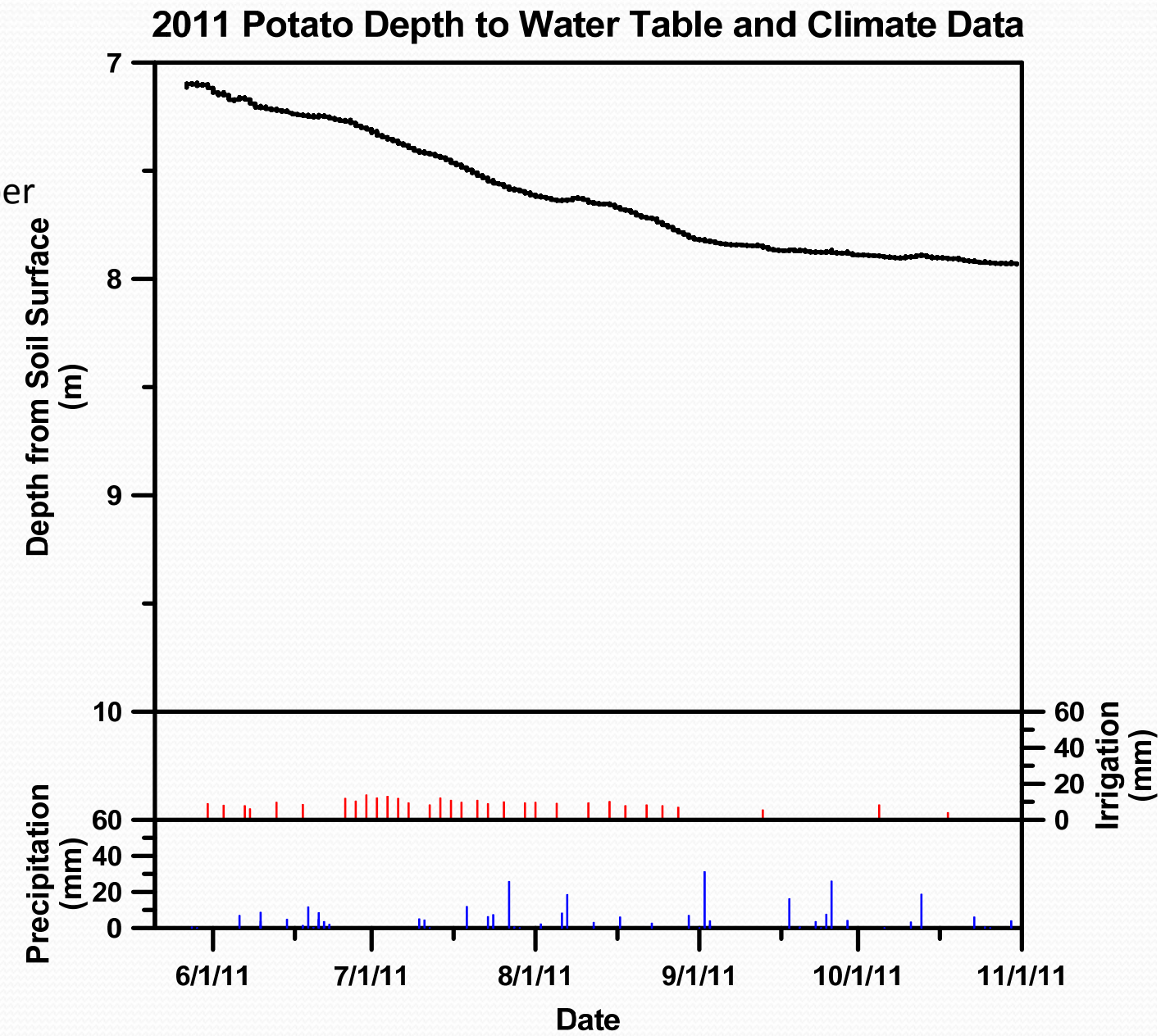

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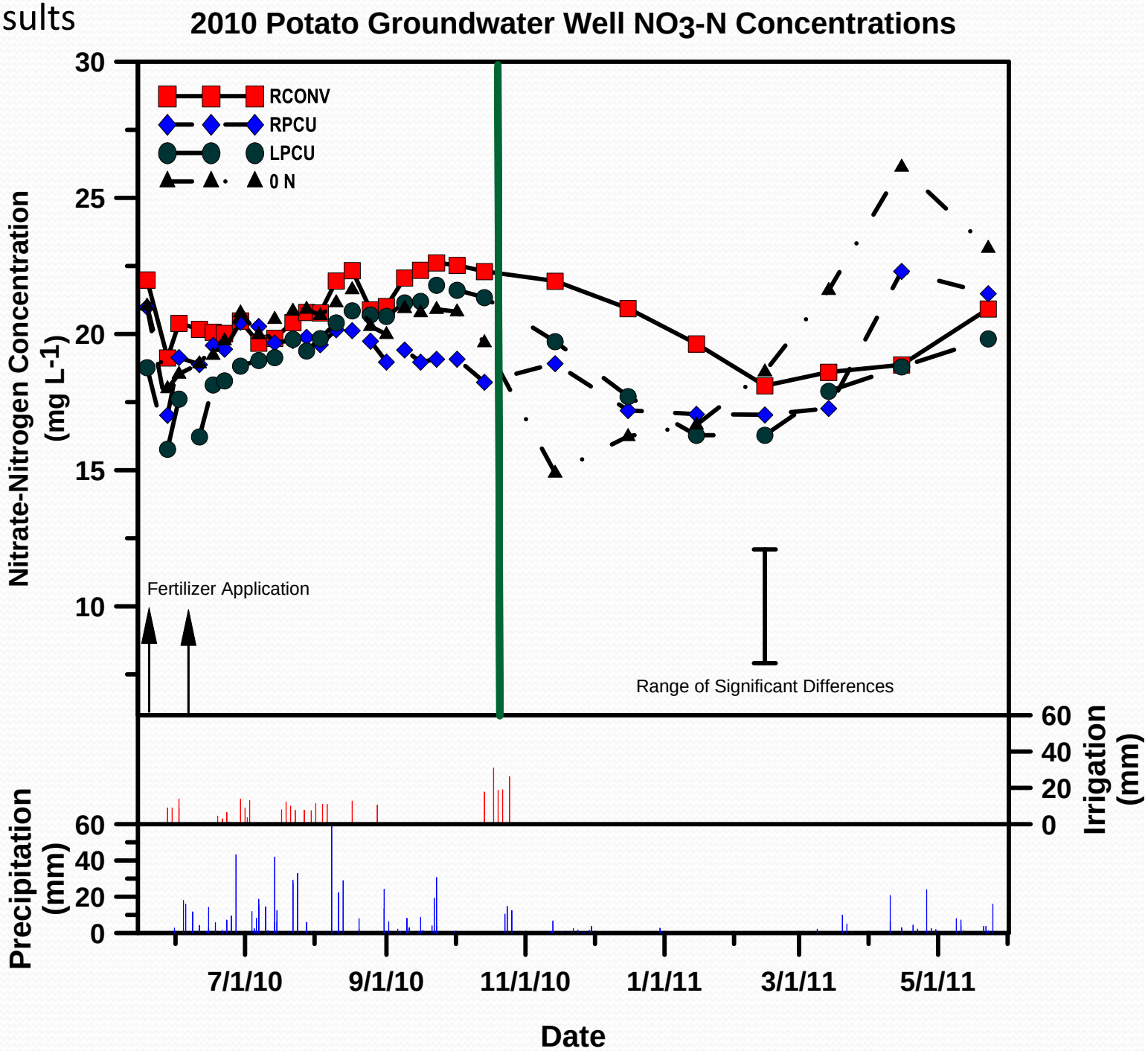

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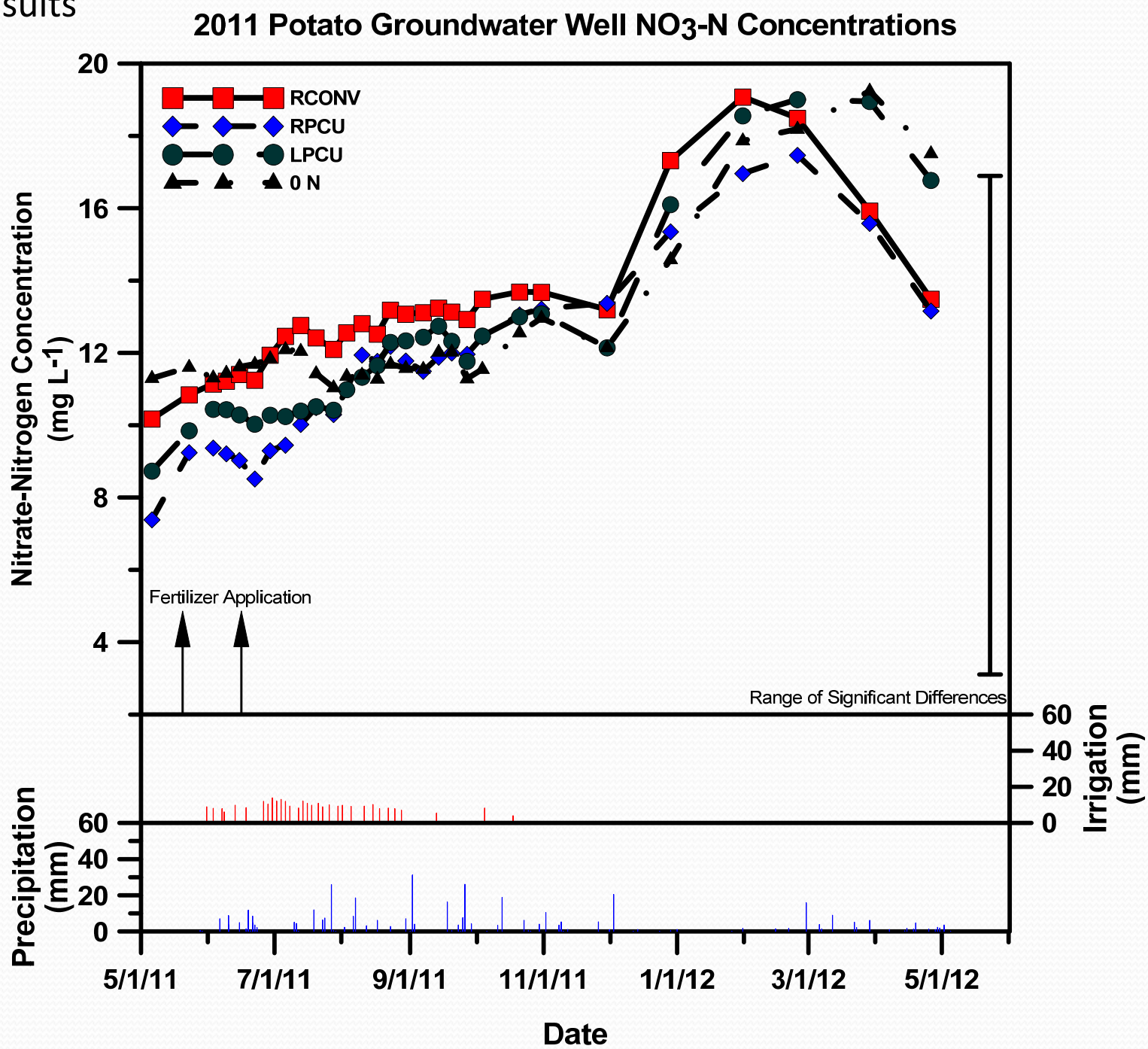

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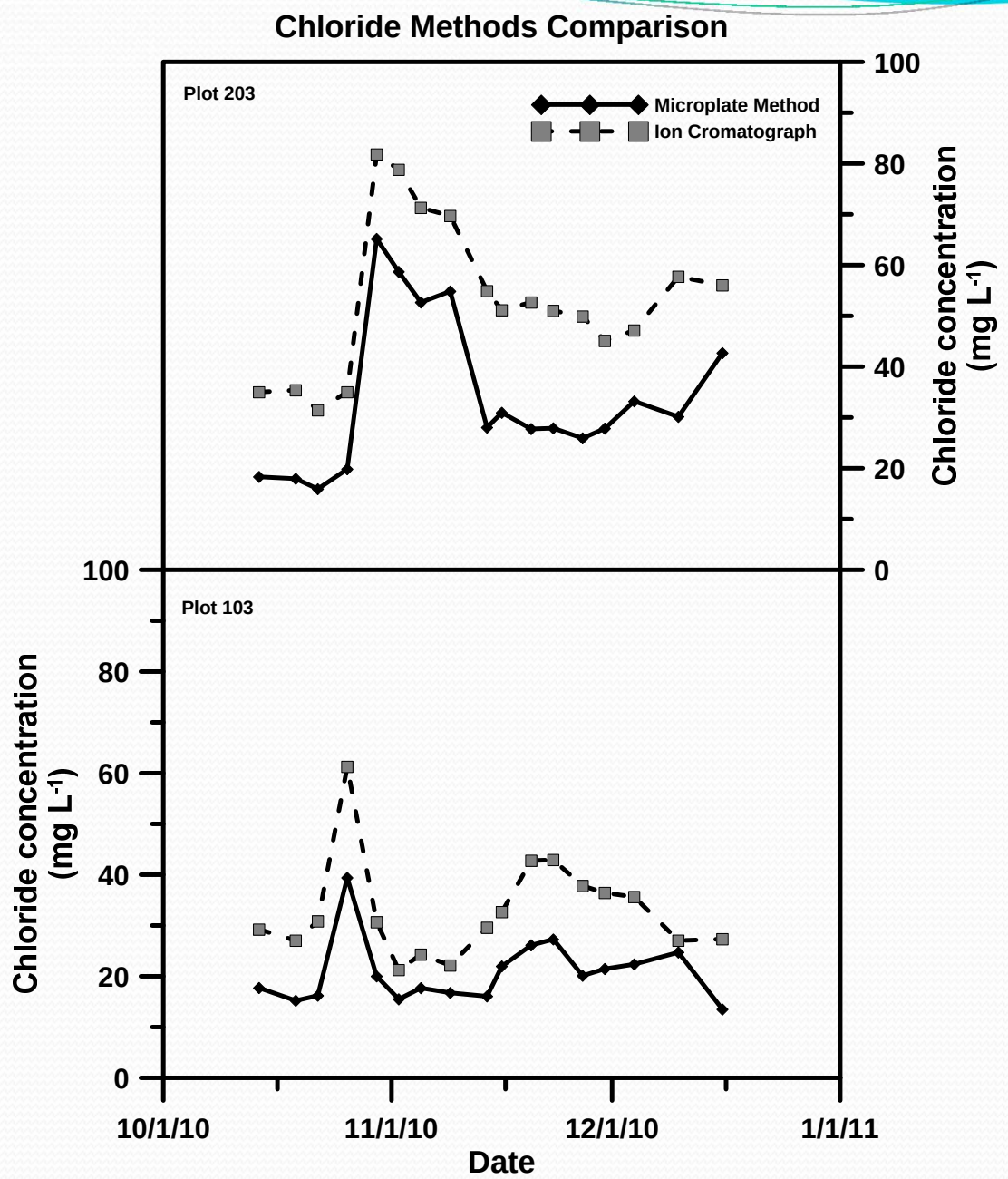

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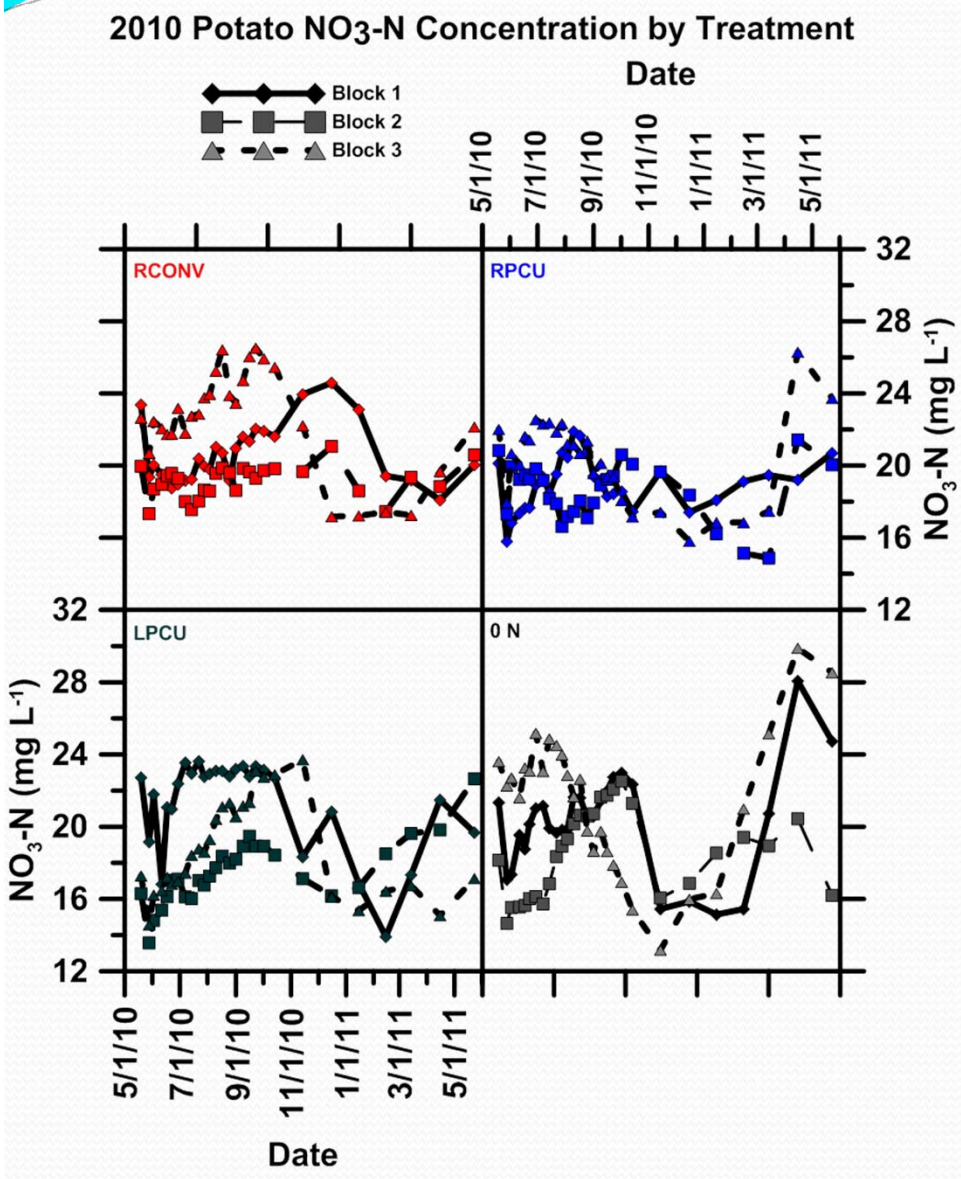
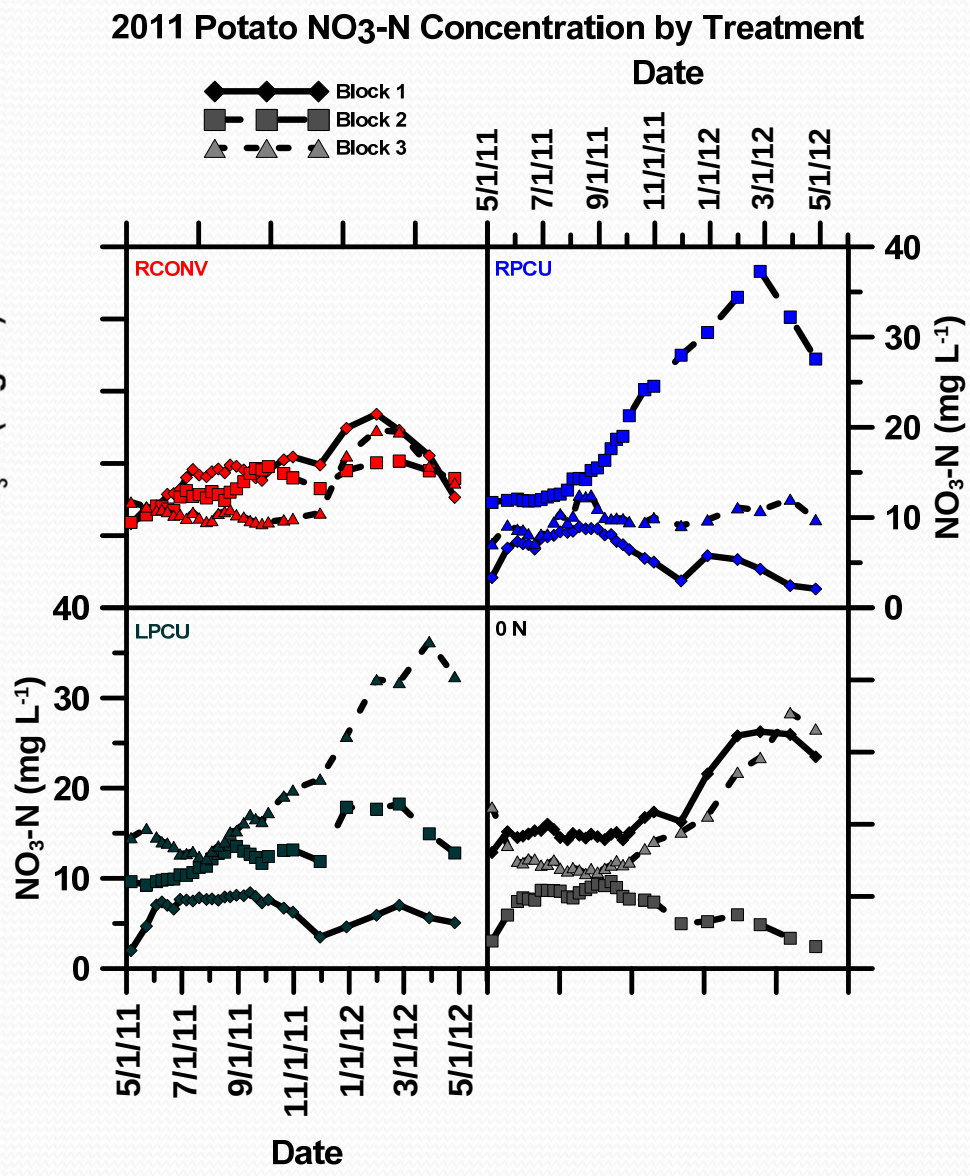




Potato plant N status and growth results

- Potato nitrogen use efficiencies

	Treatment	PNB (kg N ha^{-1}/kg N ha^{-1})	PFP (kg ha^{-1}/kg N ha^{-1})	NUE (whole) (kg N ha^{-1}/kg N ha^{-1})	NUE (tuber) (kg N ha^{-1}/kg N ha^{-1})
2010	**RCONV**	0.33 b	175 b	0.35 (15)	0.21
	RPCU	0.34 b	179 b	0.29 (13)	0.22
	LPCU	0.43 a	214 a	0.39 (8)	0.26
	P>F	*	**	ns	ns
2011	**RCONV**	0.68 b	195 b	0.45 (19)	0.20 b
	RPCU	0.71 b	202 b	0.42 (24)	0.23 b
	LPCU	0.92 a	252 a	0.52 (2)	0.32 a
	P>F	**	*	ns	*

PNB – Partial Nutrient Balance = N in harvested portion of crop/fertilizer applied
PFP – Partial Factor Productivity = Yield/fertilizer applied
NUE – Nitrogen Uptake Efficiency = N uptake (treatment) - N uptake (0 N)/fertilizer applied

- Potato Petiole Nitrate-Nitrogen

2010

Treatment	32 DAE	44 DAE	58 DAE	73 DAE
	----------Nitrogen concentration (%)----------			
RCONV	2.4 a	2.2 a	1.5 a	0.63 ab
RPCU	2.2 ab	1.6 b	1.1 ab	0.85 a
LPCU	1.7 b	0.89 c	0.67 bc	0.42 b
0 N	0.28 c	0.01 b	0.01 c	0.02 c
P>F	***	***	**	***

DAE – Days after emergence
Emergence on 17 May 2010

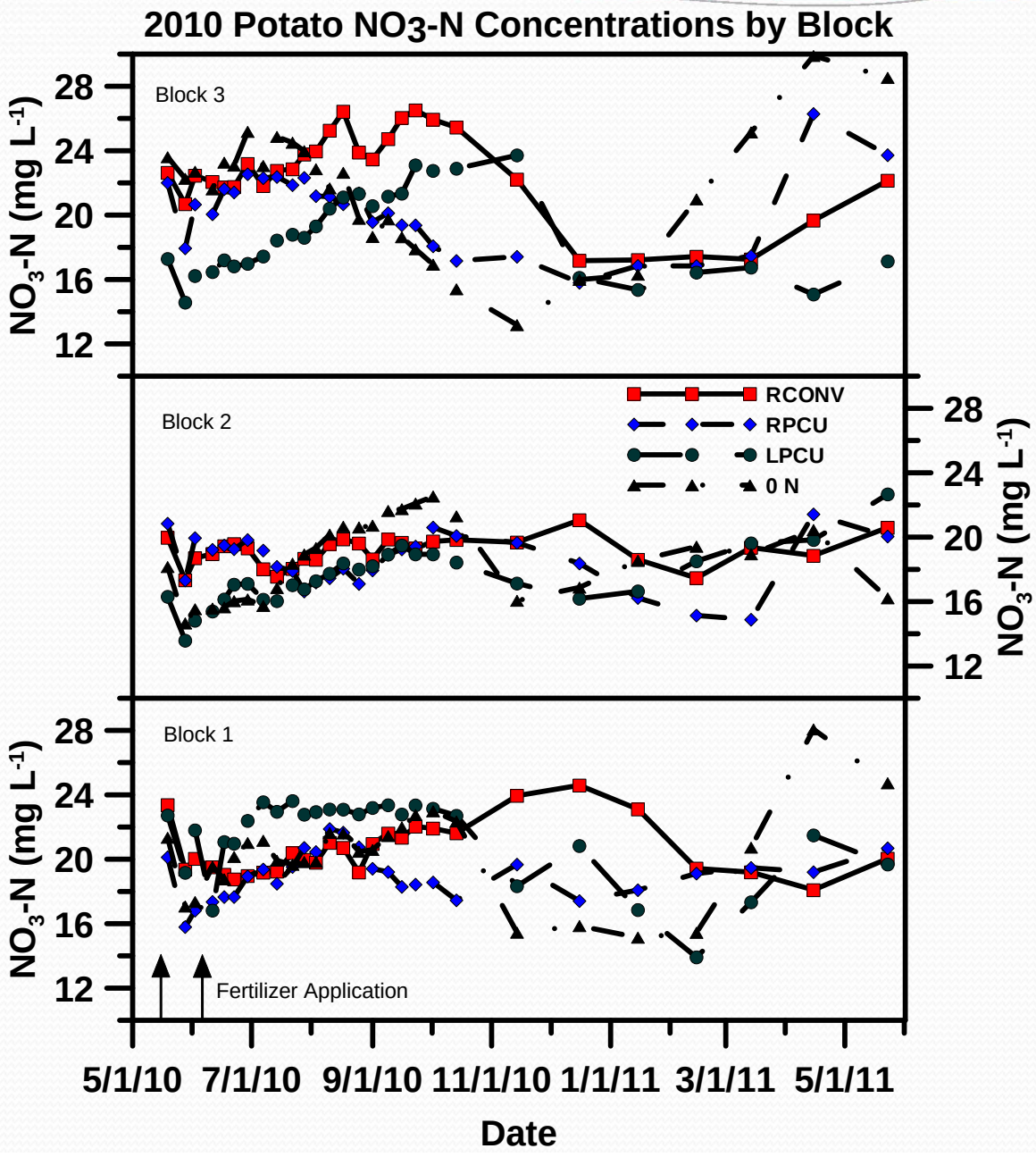
- Potato Petiole Nitrate-Nitrogen

2011

Treatment	27 DAE	40 DAE	54 DAE	67 DAE
	----------Nitrogen concentration (%)----------			
RCONV	3.5 a	1.9 a	1.7 ab	1.4 a
RPCU	3.2 a	1.8 a	1.8 a	1.4 a
LPCU	3.3 a	1.6 b	1.5 b	1.3 a
0 N	2.6 b	0.14 c	0.02 c	0.01 b
P>F	**	***	***	***

DAE – Days after emergence
Emergence on 20 May 2010

Water Quality Results



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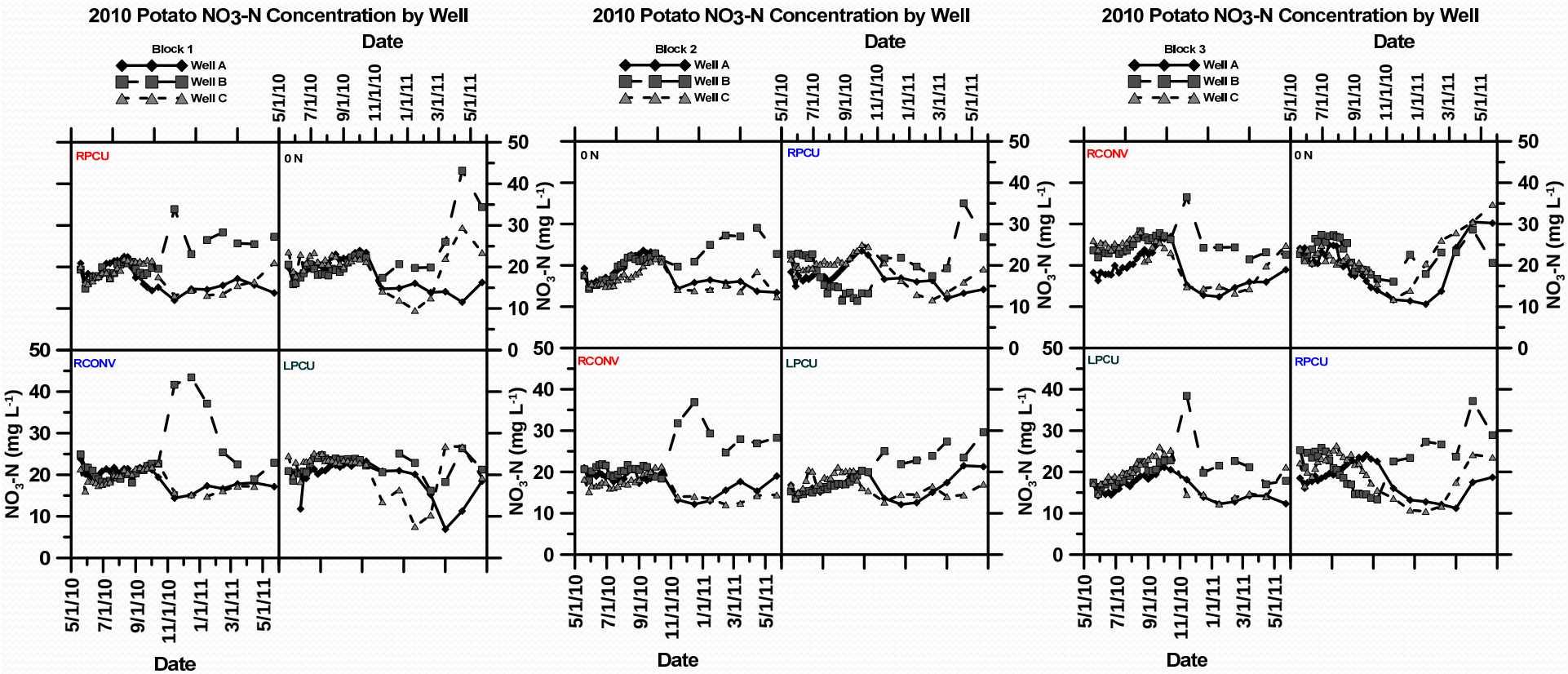

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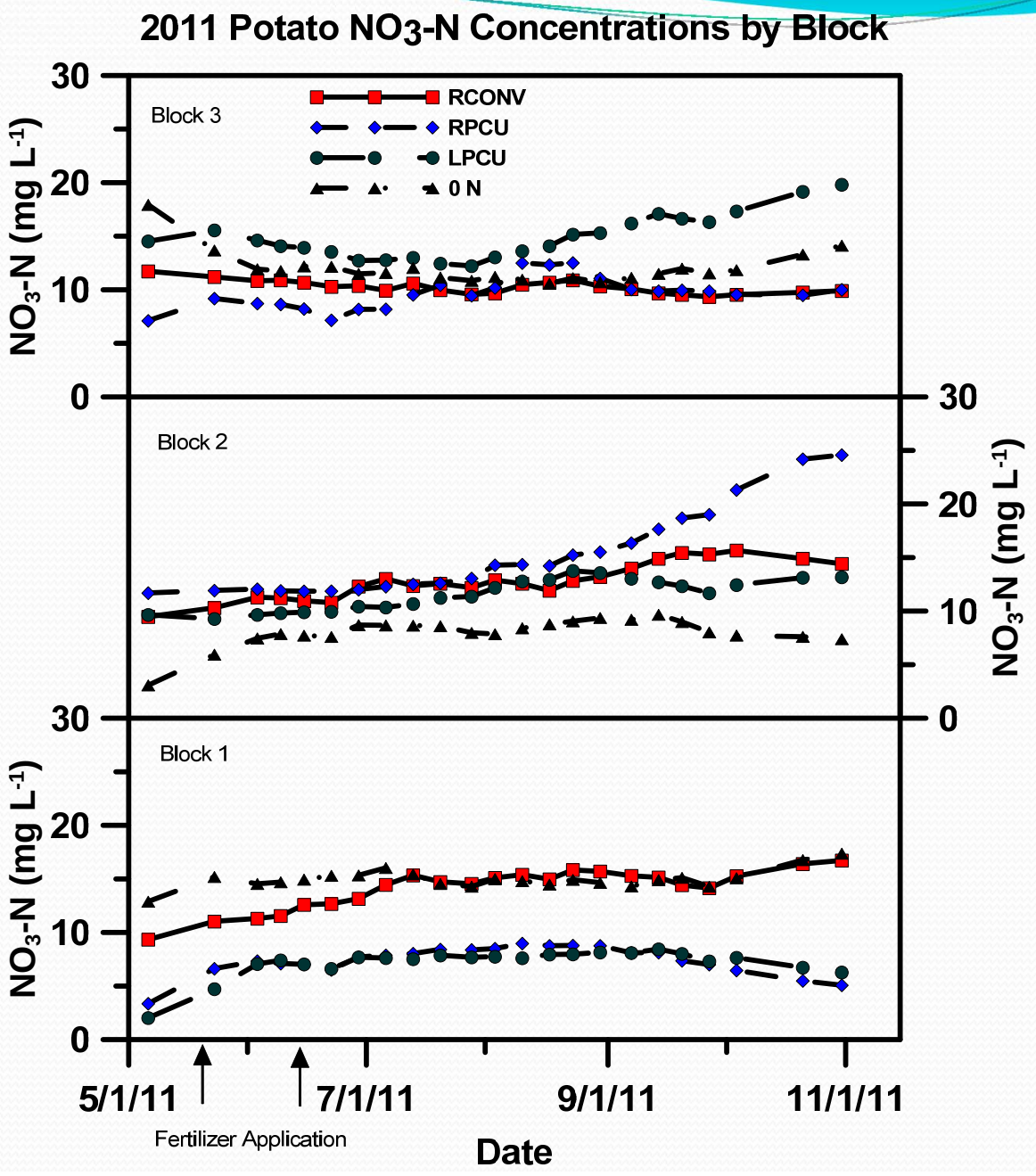

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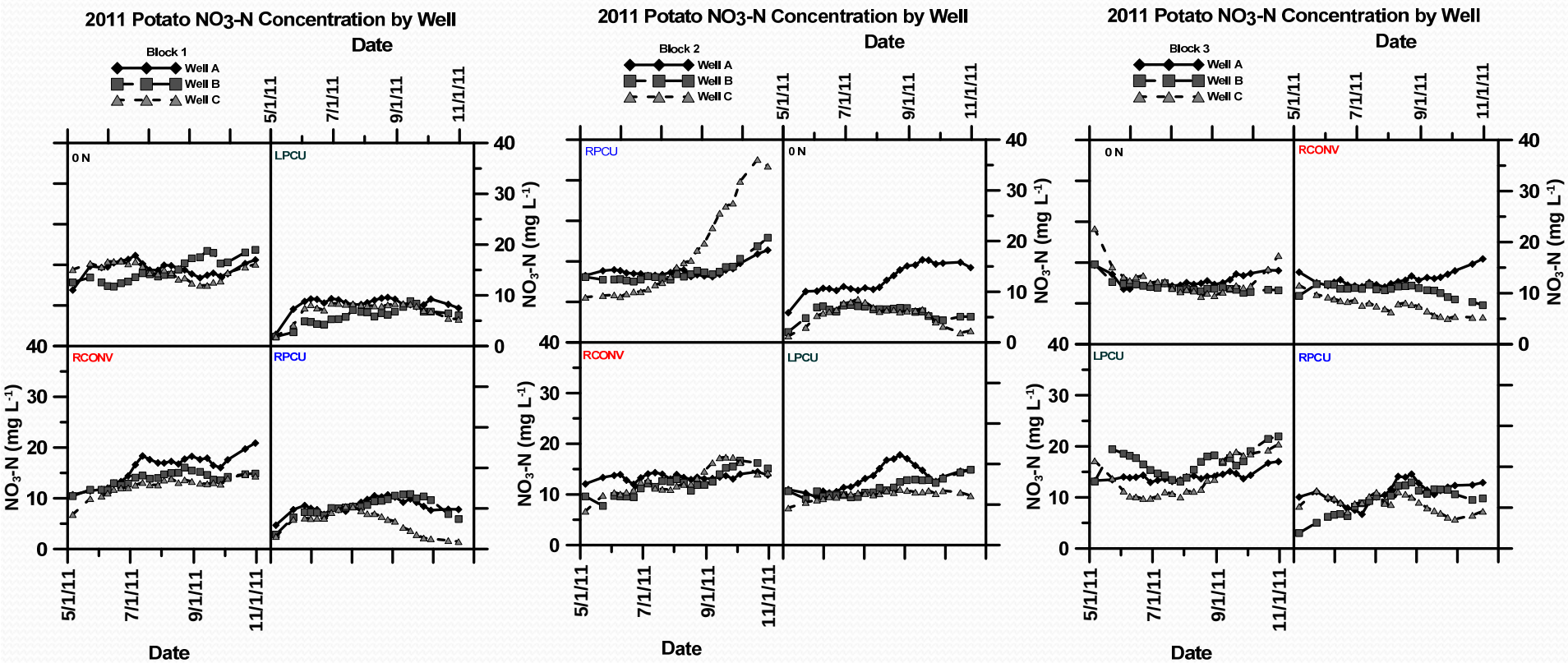
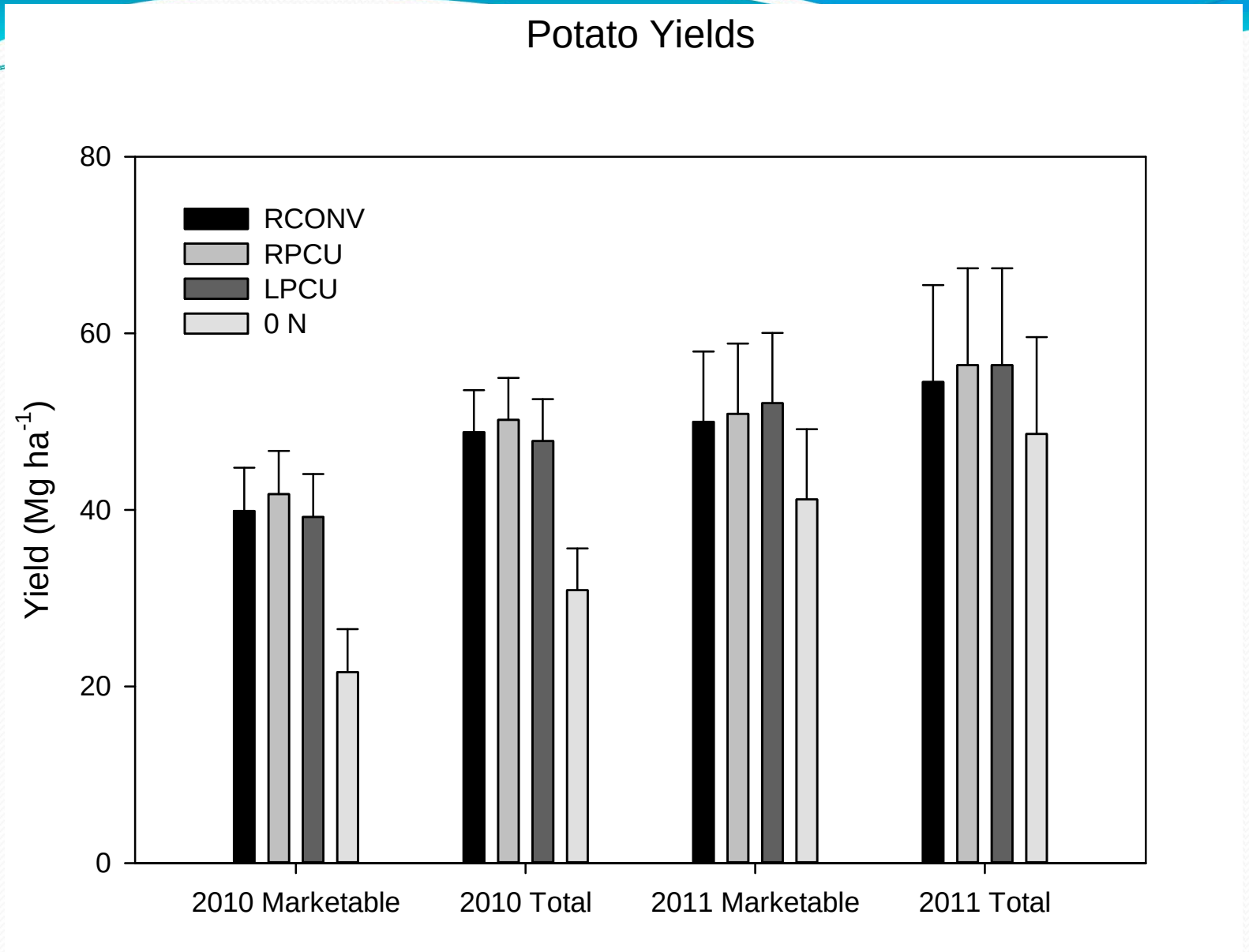


Potato plant N status and growth results



- Harvest date was 30 August 2010 and 12 September 2011
- (C.V.)

- Potato quality

Specific Gravity		
Treatment	**2010**	**2011**
RCONV	1.0757 a	1.0730
RPCU	1.0717 bc	1.0717
LPCU	1.0723 ab	1.0713
0 N	1.0683 c	1.0703
P>F	**	ns