Monitoring tile drainage and subirrigation water quality using electrical conductivity

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Xinhua Jia, Associate Professor, P.E.

Department of Agricultural and Biosystems Engineering

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In spring: Flooding in the field

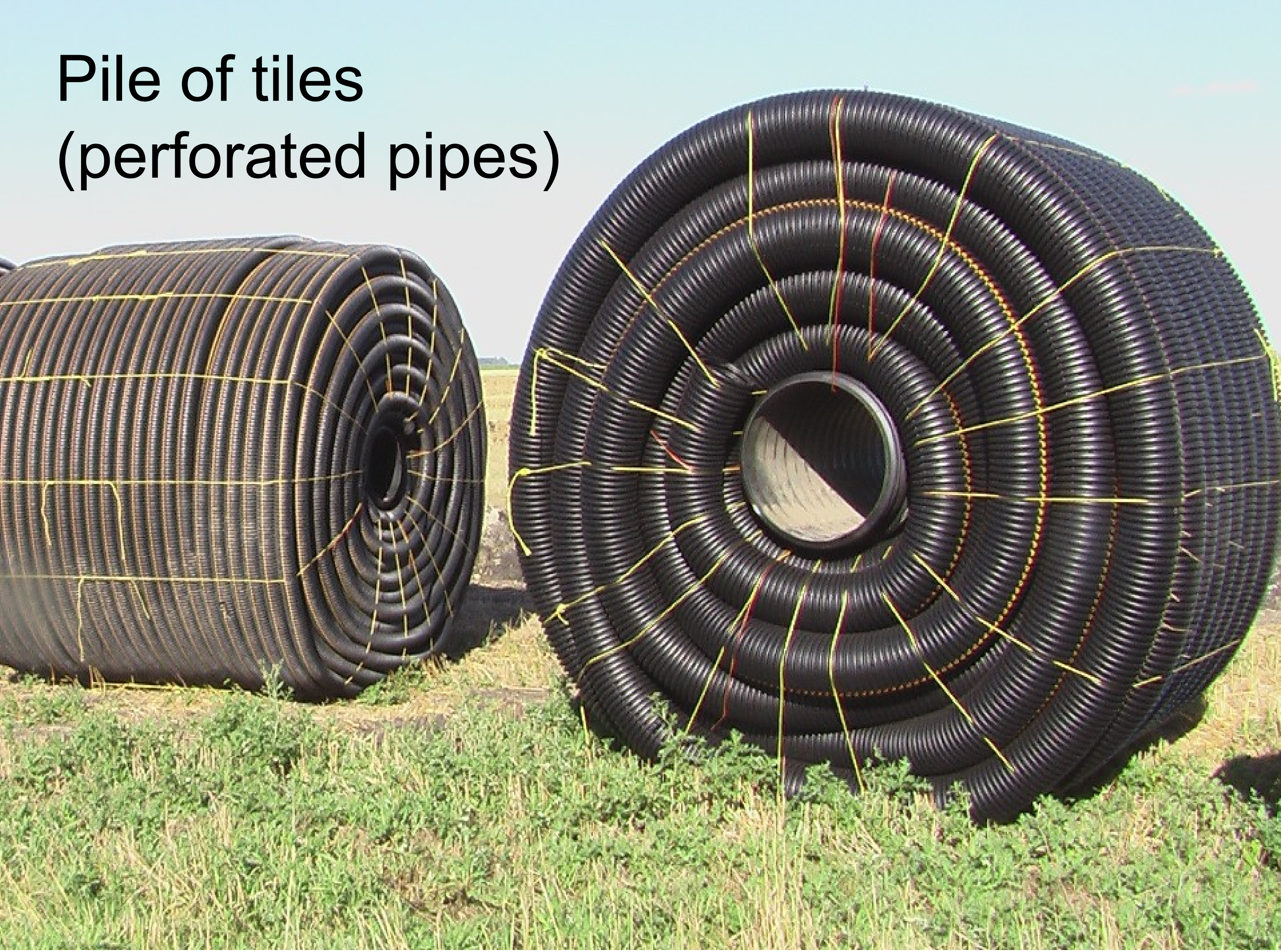

In spring: Flooding in the river

Draining in spring

Draining in winter

Tiling (Subsurface Drainage)

Pile of tiles
(perforated pipes)



Tile or Not?

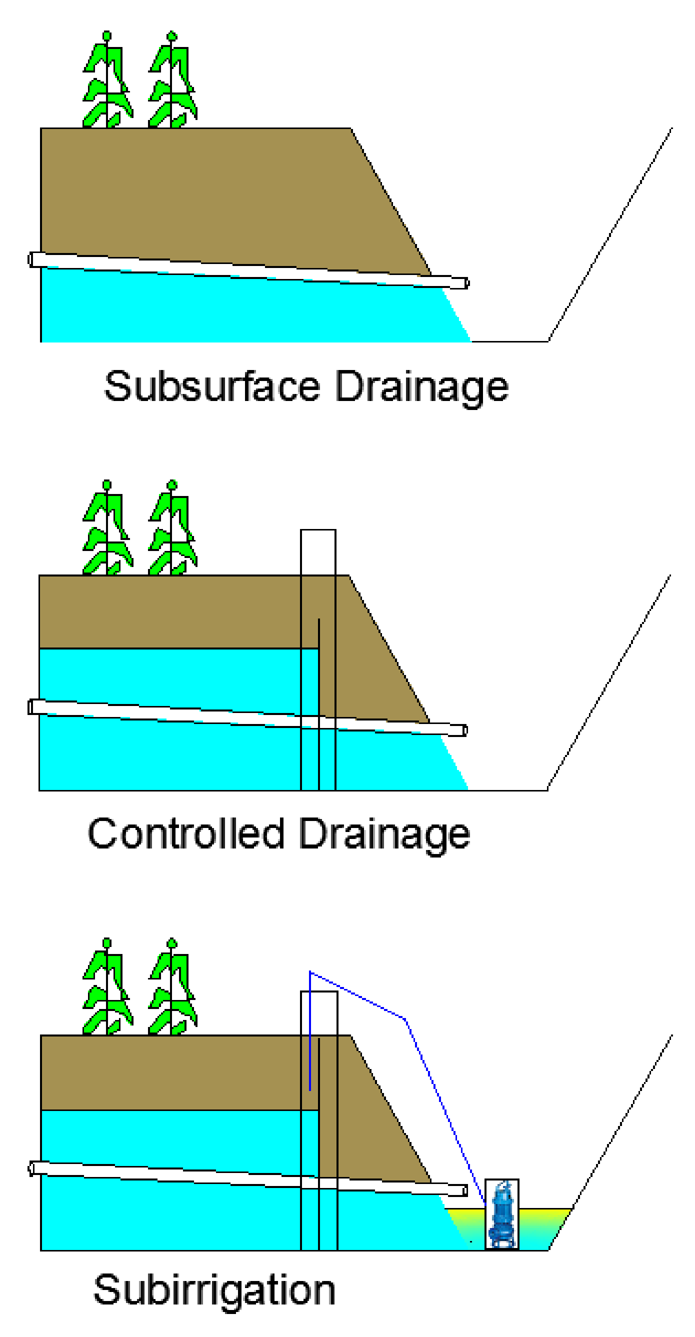
Field status in November 2009

Subsurface drainage (SD) uses subsurface conduits to remove water from a depth below soil surface.

Controlled drainage (CD) uses weirs or structures to manage the water level in the field so that it is drained only when it is necessary.

Subirrigation (SI) is application of irrigation water below the ground surface by raising the water table to within or near the root zone.

(ASABE, 2005)



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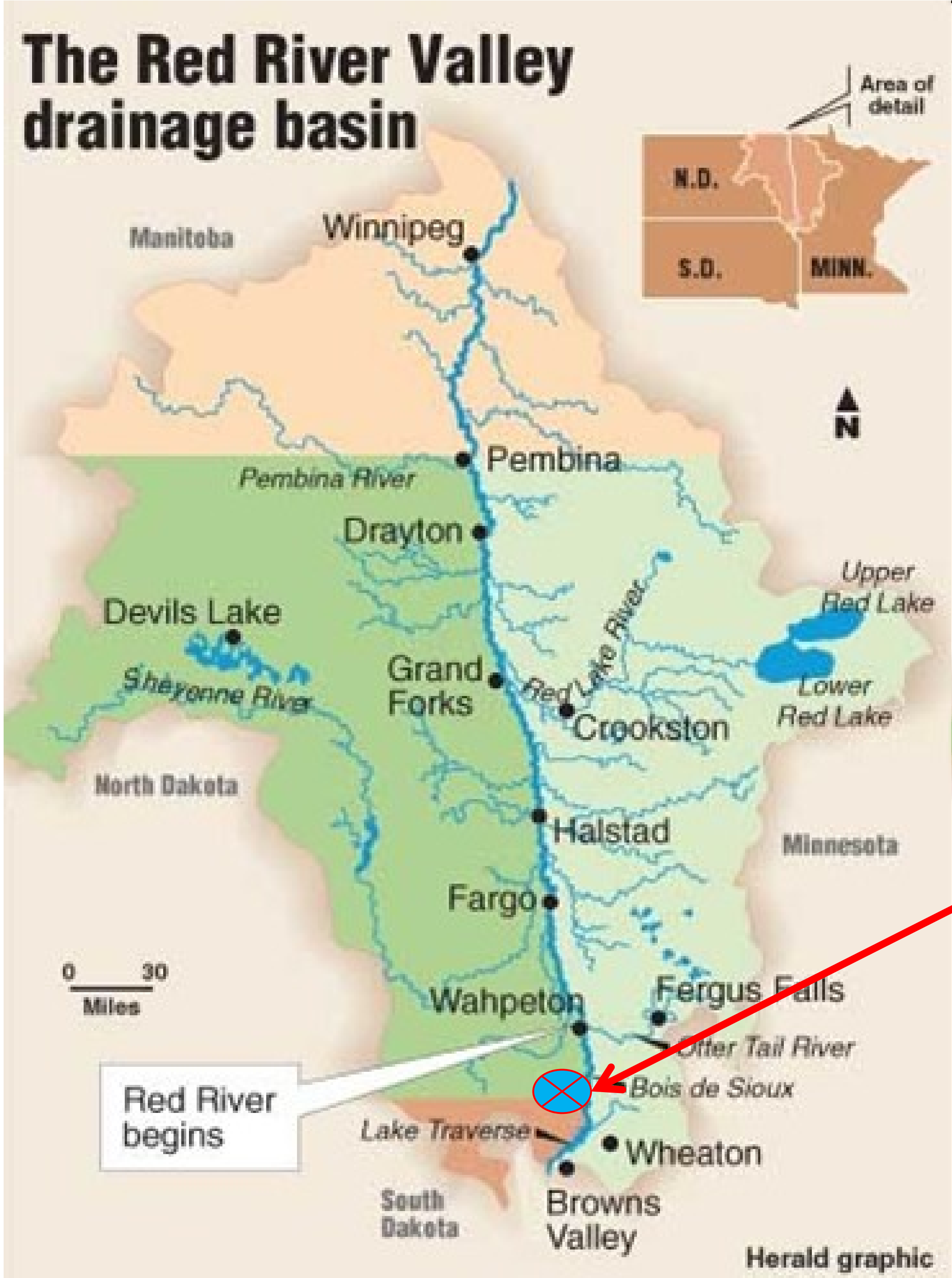


Experimental Site:
Fairmount
Richland County
North Dakota

http://www.rrbdin.org/red-river-basin-overview-2

Problems

Land owner:

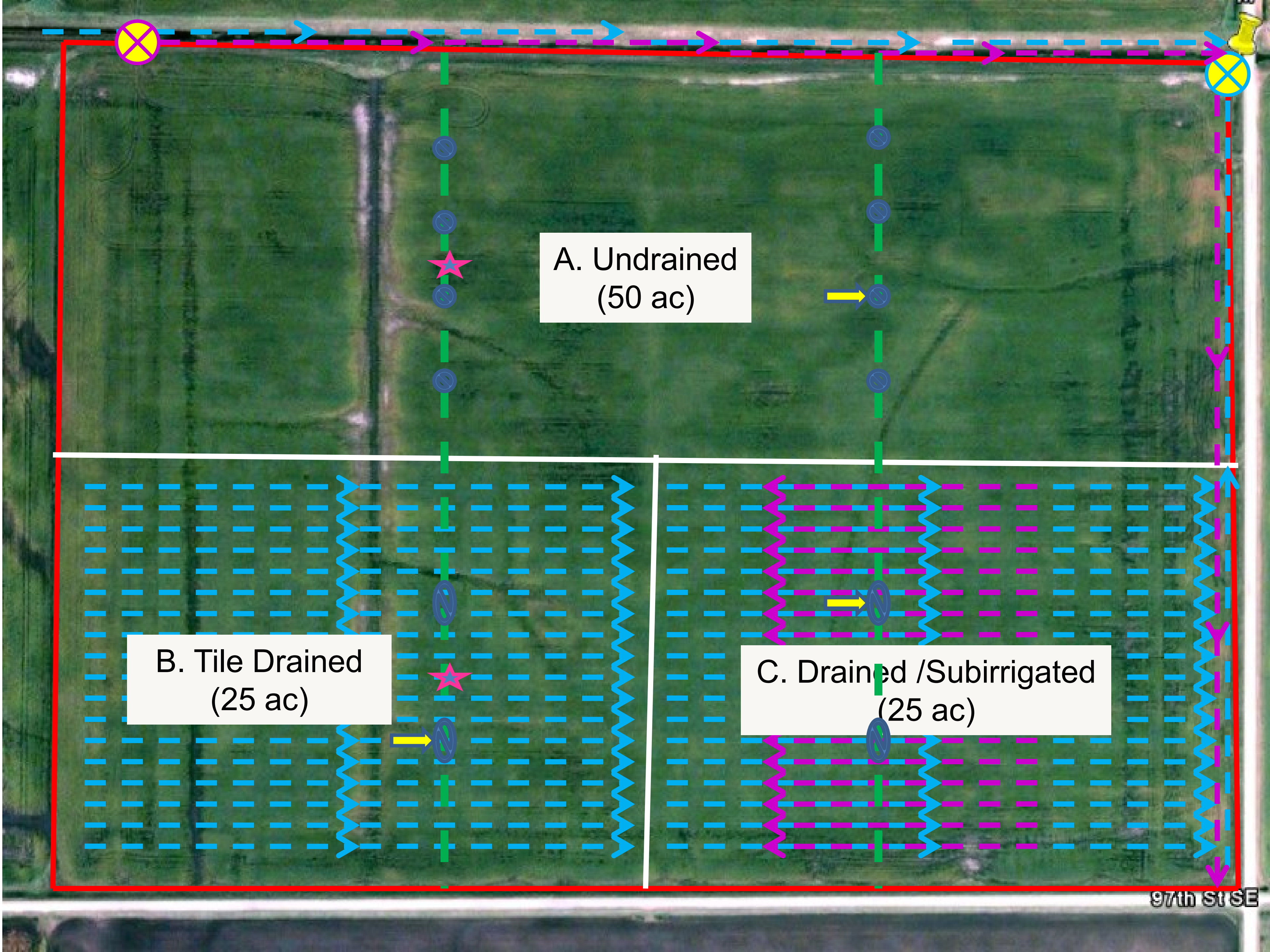
"will subsurface drainage and subirrigation increase crop yield?"

State agencies:

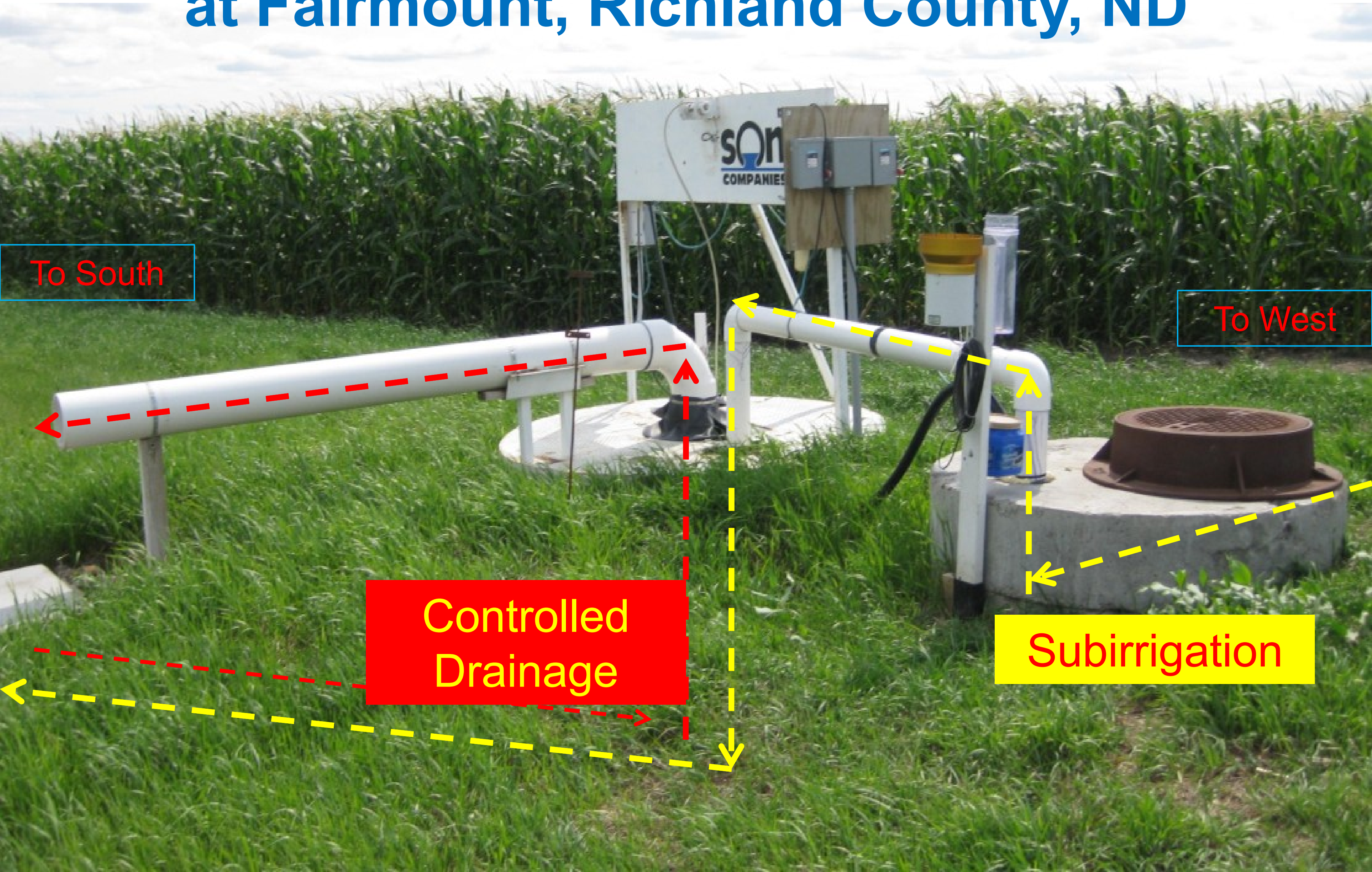
"what about the environmental impact, e.g. soil and water quality?"

Research engineers/scientists:

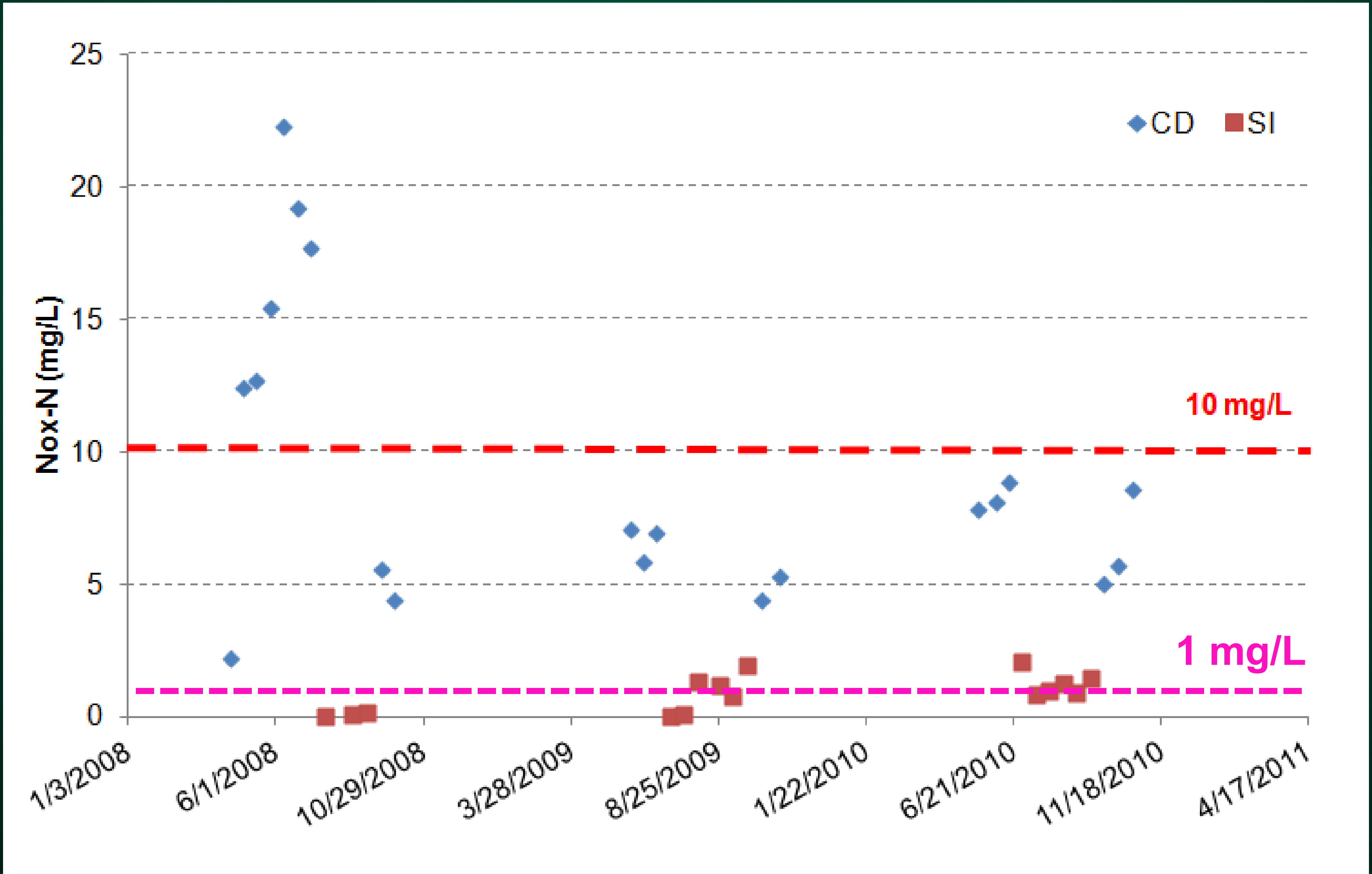
"where does the water/nutrients/salts go?"


A. Undrained
(50 ac)
B. Tile Drained
(25 ac)
C. Drained /Subirrigated
(25 ac)
97th St SE

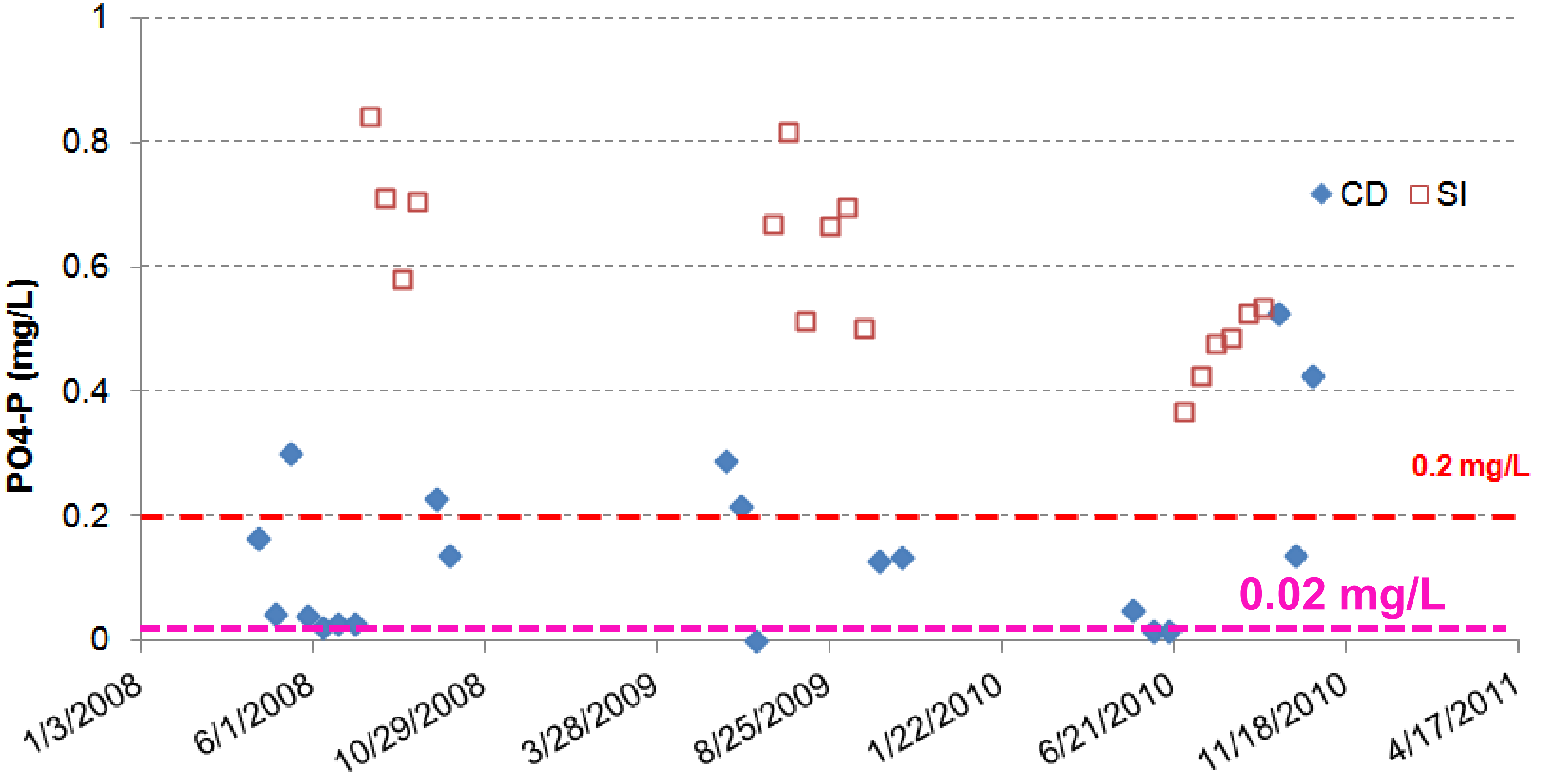
Controlled Drainage and Subirrigation at Fairmount, Richland County, ND



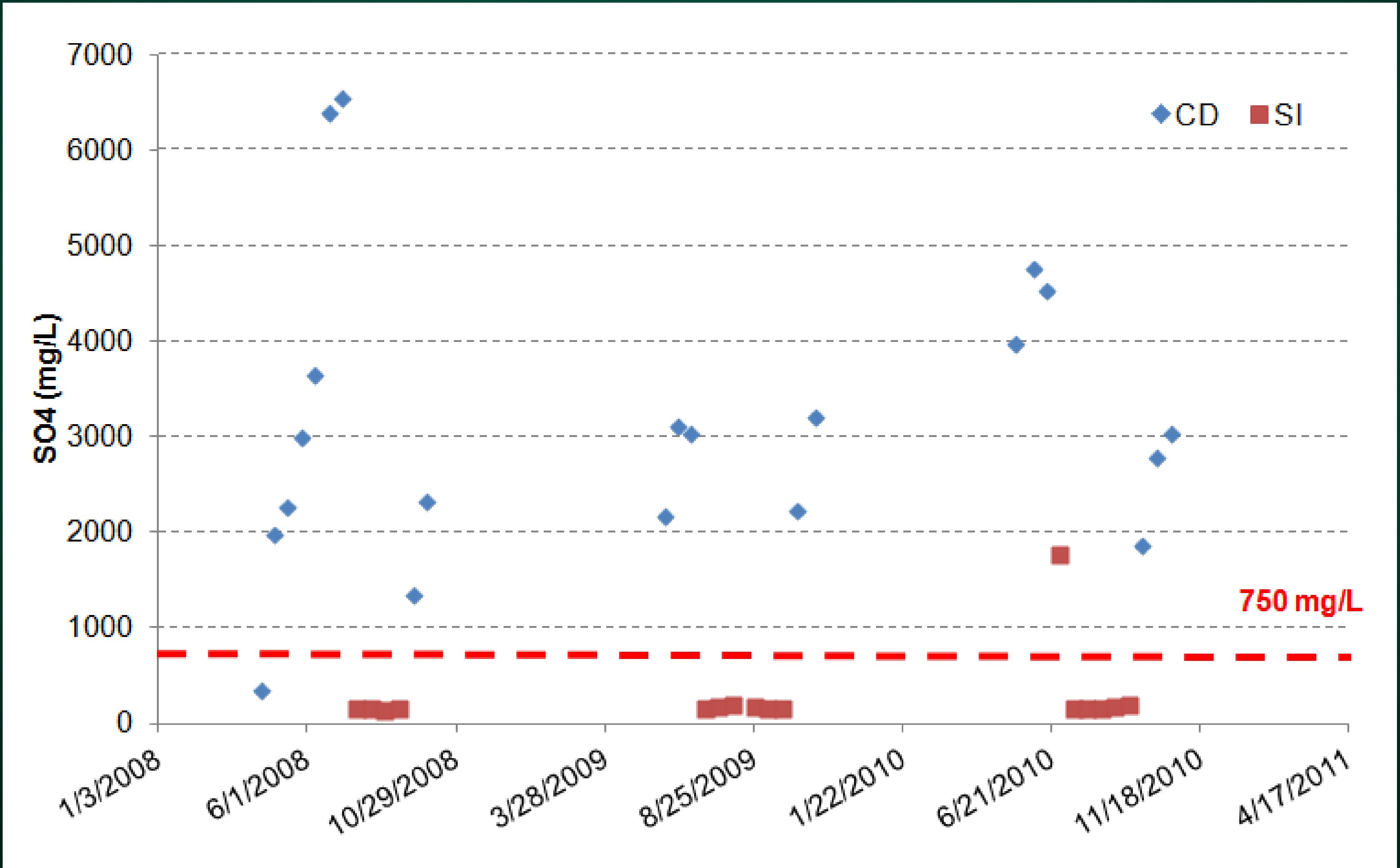
NO_x-N concentrations at the outlet



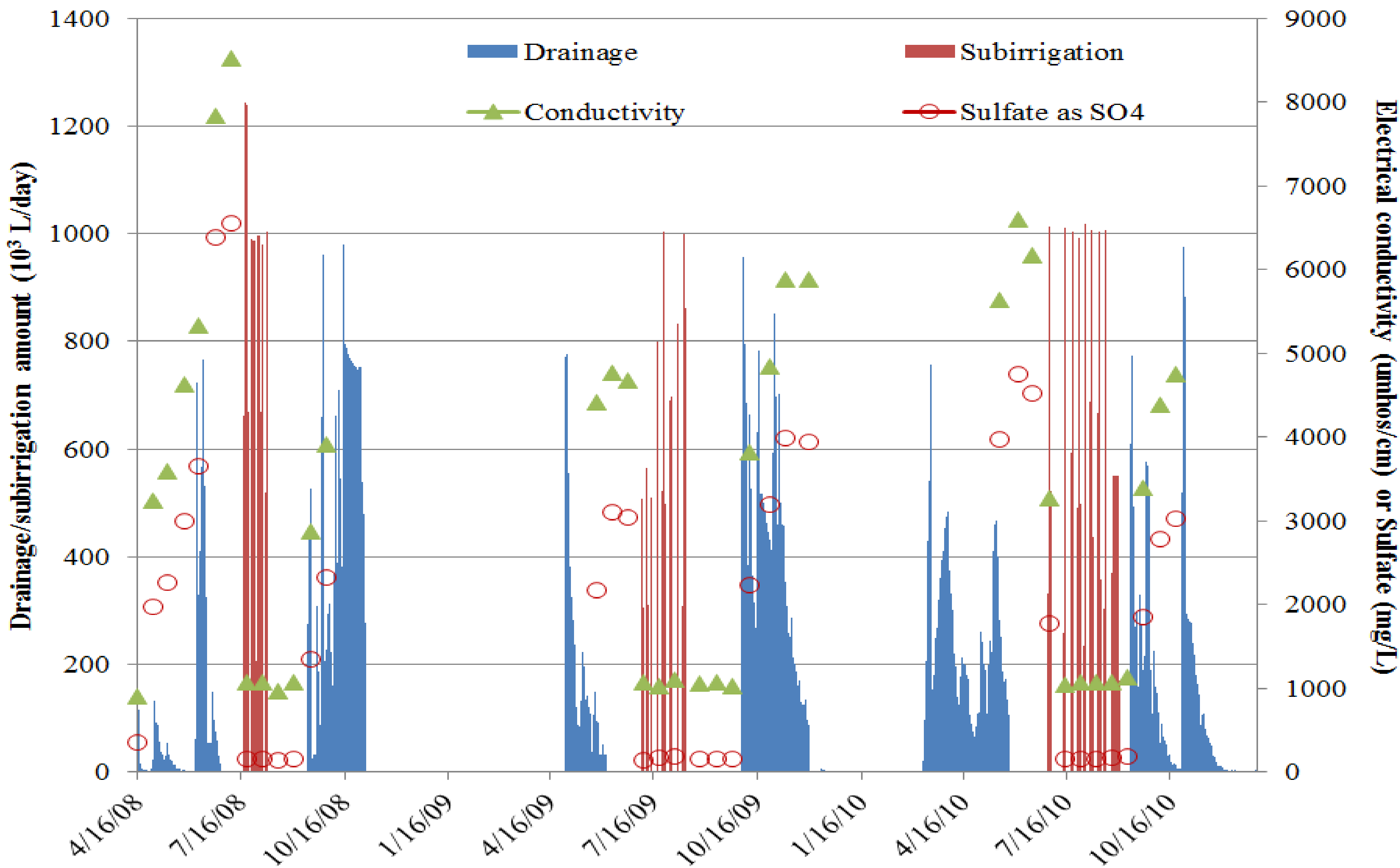
PO_4-P concentrations at the outlet



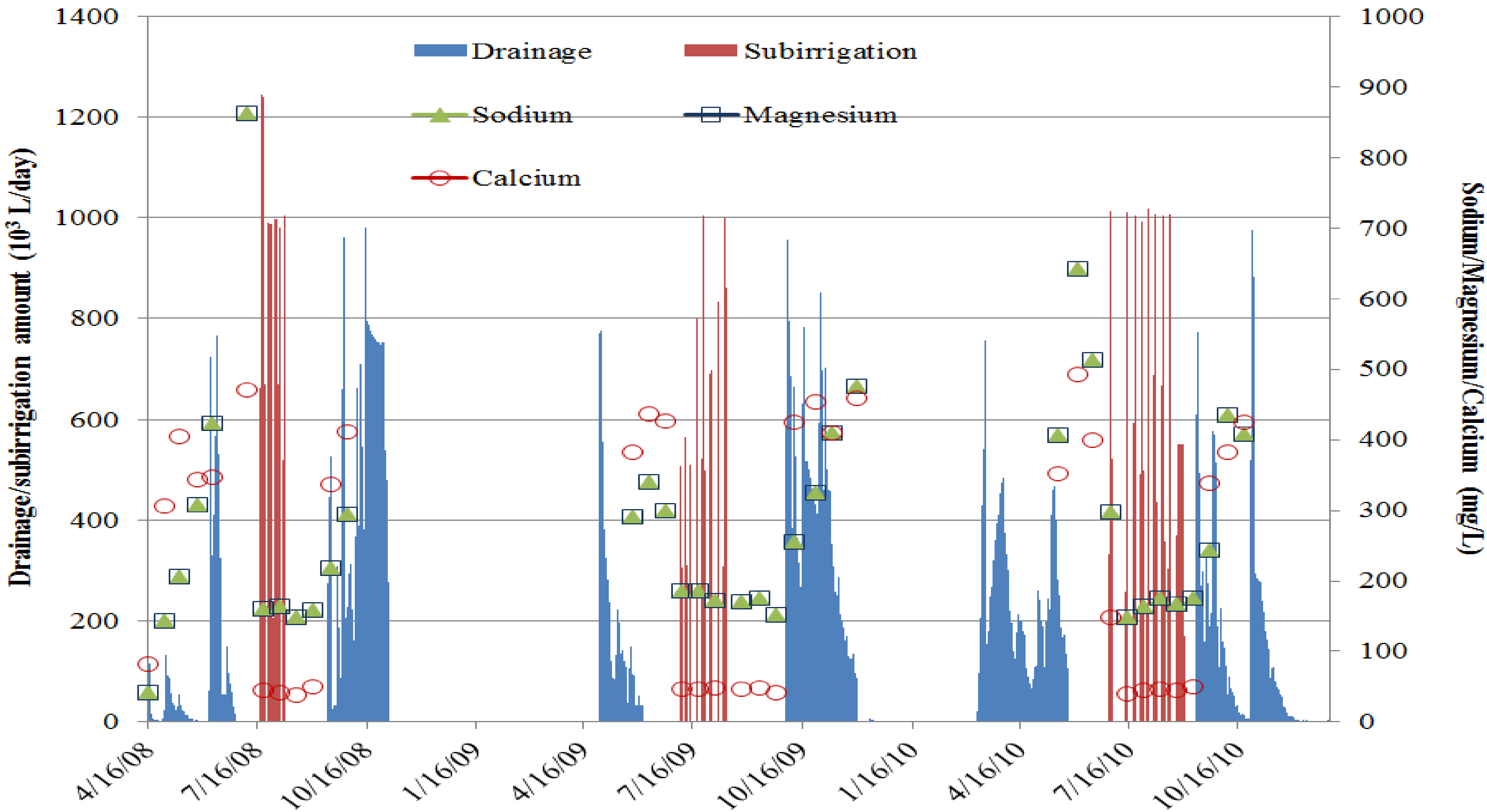
SO_4 concentrations at the outlet



Daily drainage and subirrigation volumes related to electrical conductivity and sulfate concentration



Sodium, magnesium, and calcium concentration compared with daily drainage and subirrigation volumes



Summary of water quality for tile drainage outflow and subirrigation inflow

	Unit	All Water			Drainage	Irrigation
		Average	Max	Min	Average	Average
Sodium	mg/L	279	862	42.2	356	167
Magnesium	mg/L	298	1210	6.10	485	22.7
Potassium	mg/L	3.54	16.4	0.00	3.81	3.17
Calcium	mg/L	241	493	38.8	371	45.4
Ammonia	mg/L	1.40	4.16	0.00	0.15	3.23
Nitrate + Nitrite	mg/L	5.74	22.3	0.00	8.77	0.77
Kjeldahl nitrogen	mg/L	2.07	4.74	0.00	0.95	3.80
Total nitrogen (total)	mg/L	7.65	22.1	2.67	9.69	4.53
Nickel	ug/L	6.57	17.7	0.00	10.2	0.96
Copper	ug/L	5.71	28.0	0.00	8.81	0.90
Zinc	ug/L	59.1	290	0.00	80.4	26.1
Arsenic	ug/L	1.85	26.6	0.00	2.91	0.00
Selenium	ug/L	16.7	84.4	0.00	26.3	0.00
Silver	ug/L	3.32	48.3	0.00	5.21	0.00
Lead	ug/L	0.35	5.67	0.00	0.55	0.00
pH		7.55	8.28	6.63	7.37	7.82
Carbonate	mg/L	0.00	0.00	0.00	0.00	0.00
Hardness total		1917	6150	143	3033	207
Phosphorus	mg/L	0.33	0.84	0.00	0.15	0.61
Sulfate as SO_4	mg/L	1966	6550	140	3143	162
Chloride	mg/L	25.5	37.4	8.64	19.6	34.6
% Sodium	%	37.8	73.2	13.8	20.5	63.2
SAR		3.70	6.74	0.90	2.76	5.08
Total dissolved solids	mg/L	2932	9330	572	4494	641
Electrical conductivity	umhos/cm	3298	8520	914	4755	1065

Electrical Conductivity (EC)

- EC is a measure of the ability of the water to transfer an electrical charge, and is affected by the amount of dissolved inorganic ions present in the water.

    - Its values depends on the geology of the area, the size of the watershed, and the source of water contributing to the watershed.

    - EC is a representation of the water quality of the specific area --- not universal for any area.

Objectives

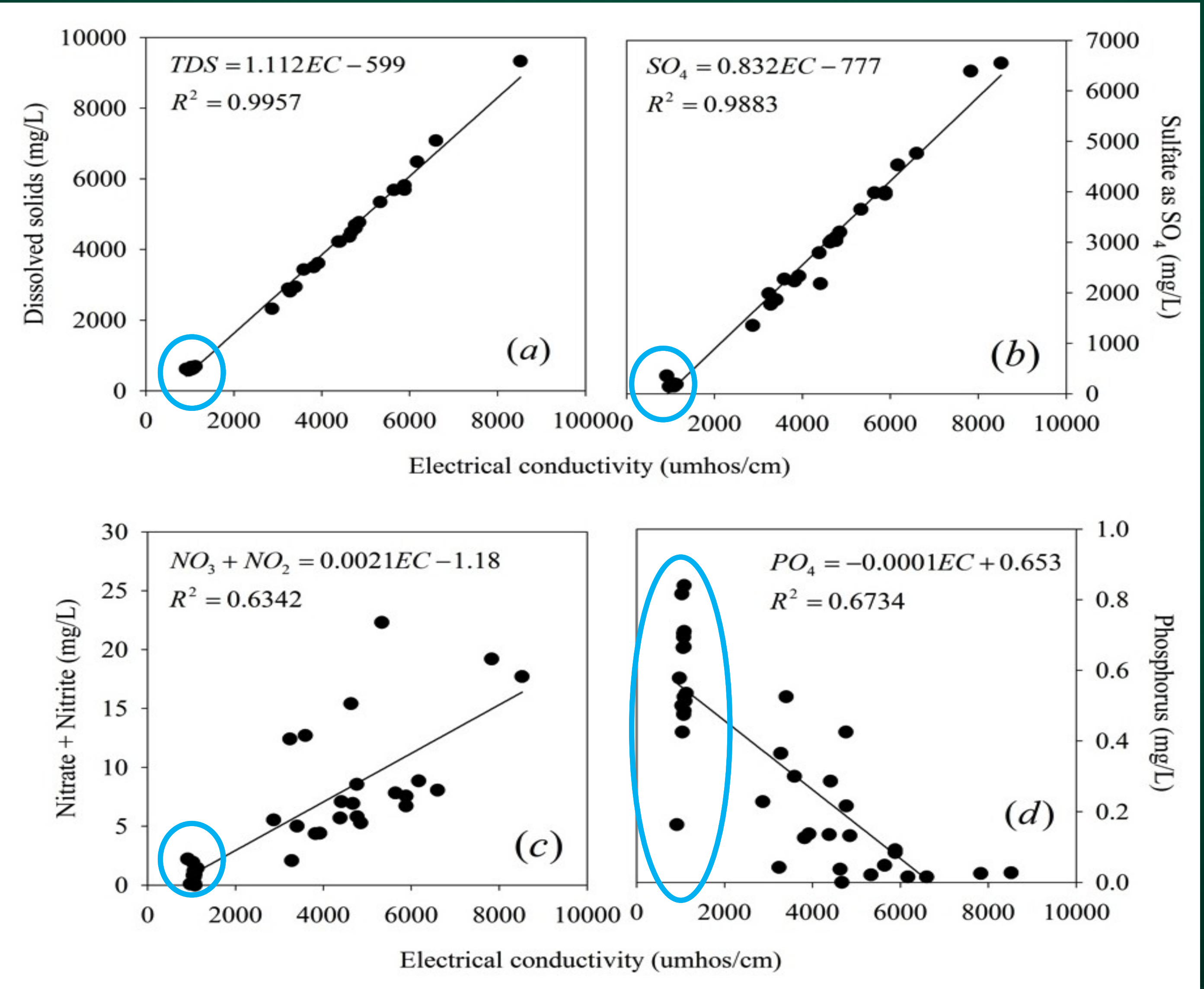
1. To determine whether EC can be used as a surrogate for major water quality parameters at this location

2. To develop a linear relationship based on EC and the key water quality parameters

3. To reduce the cost for chemical analysis

4. To calculate the chemical load continuously (from biweekly to daily/hourly)

Linear relationship between electrical conductivity and total dissolved solids (a), sulfate (b), nitrate + nitrite (c), and phosphorus (d) for all water samples. Blue circles indicate irrigation water source



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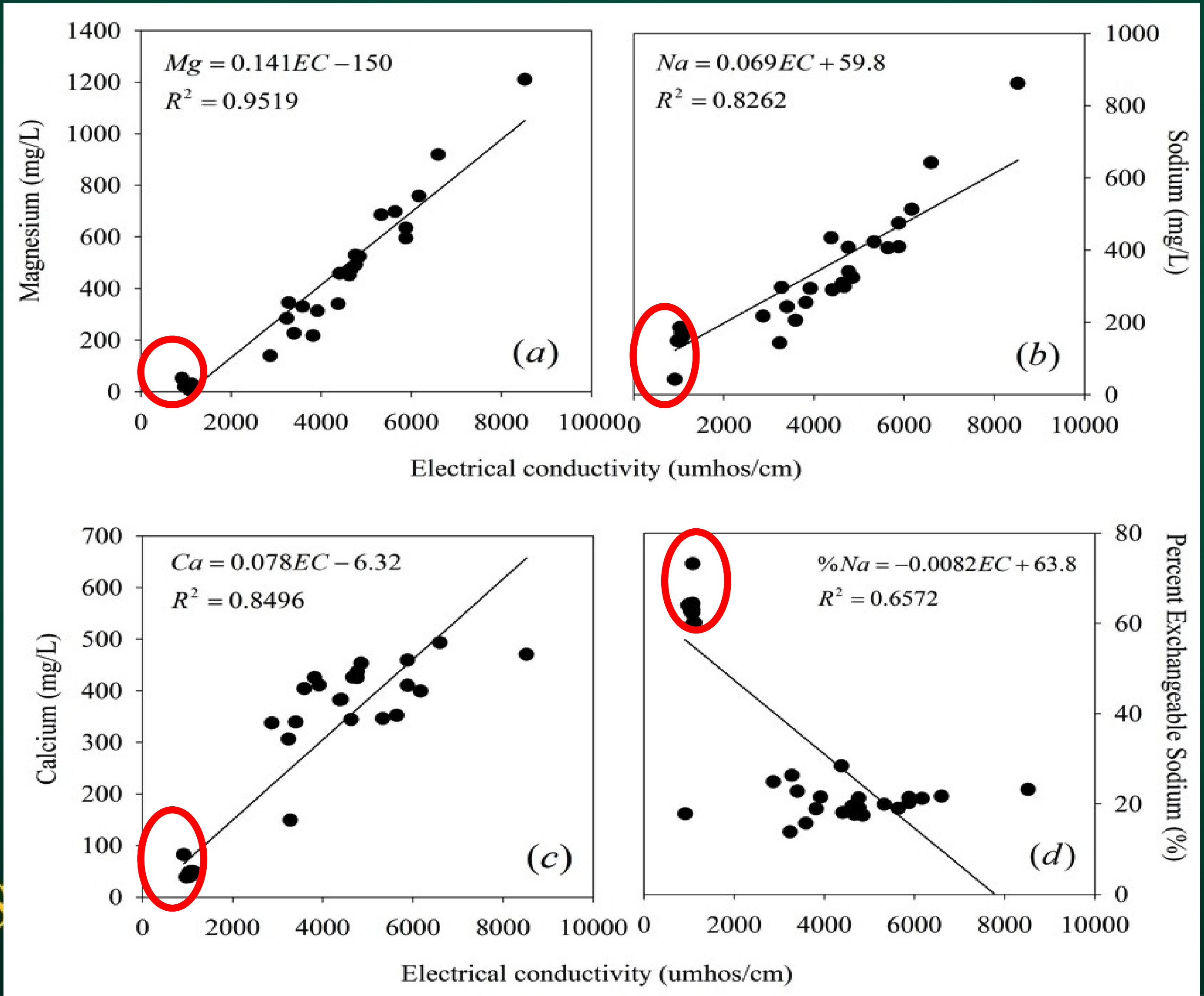
Linear relationship between electrical conductivity and magnesium (a), sodium (b), calcium (c), and percentage of exchangeable sodium (d) for all water samples. Red circles indicate irrigation water source.



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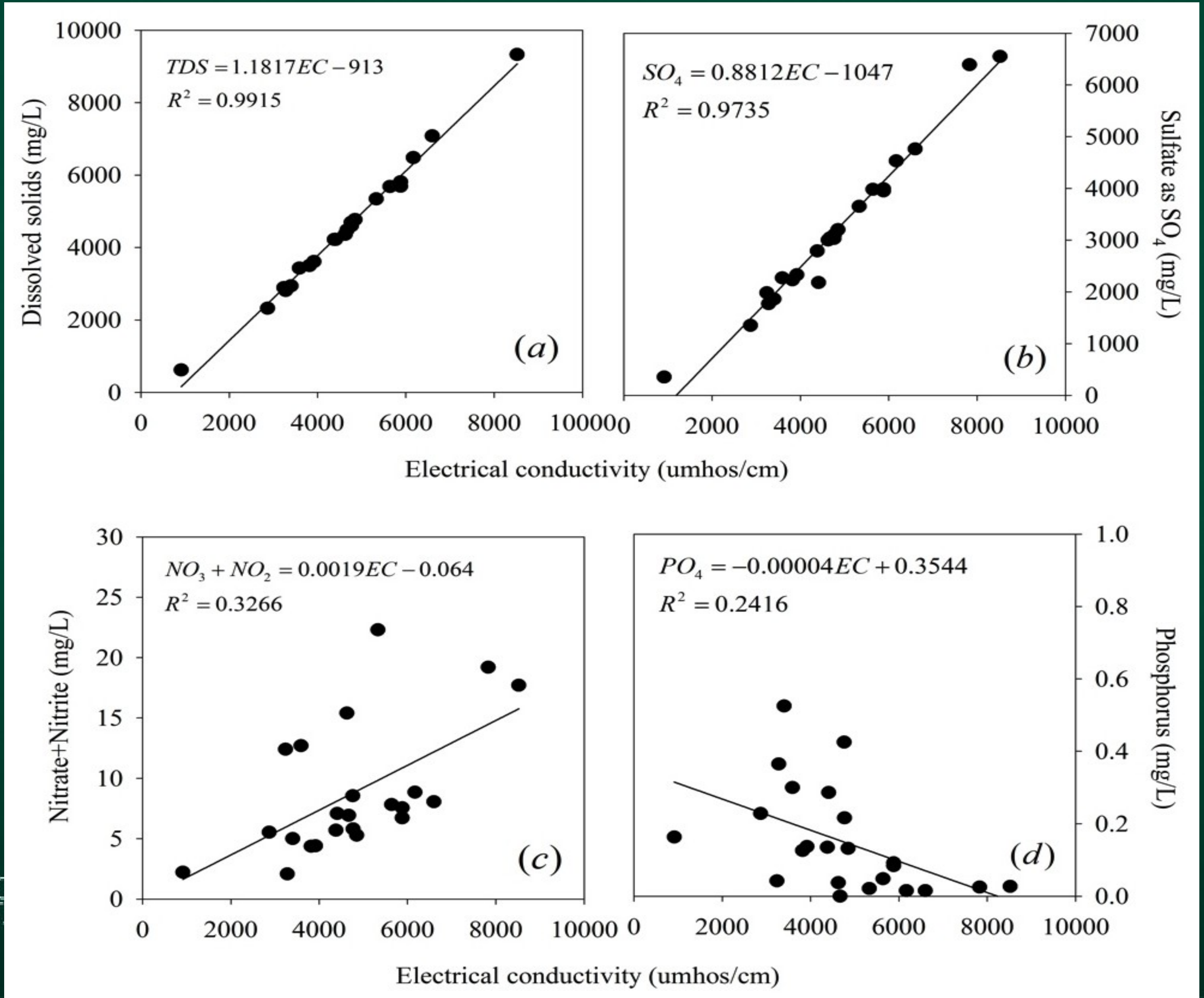
Linear relationship between electrical conductivity and total dissolved solids (a), sulfate (b), nitrate + nitrite (c), and phosphorus (d) for drainage outflow.



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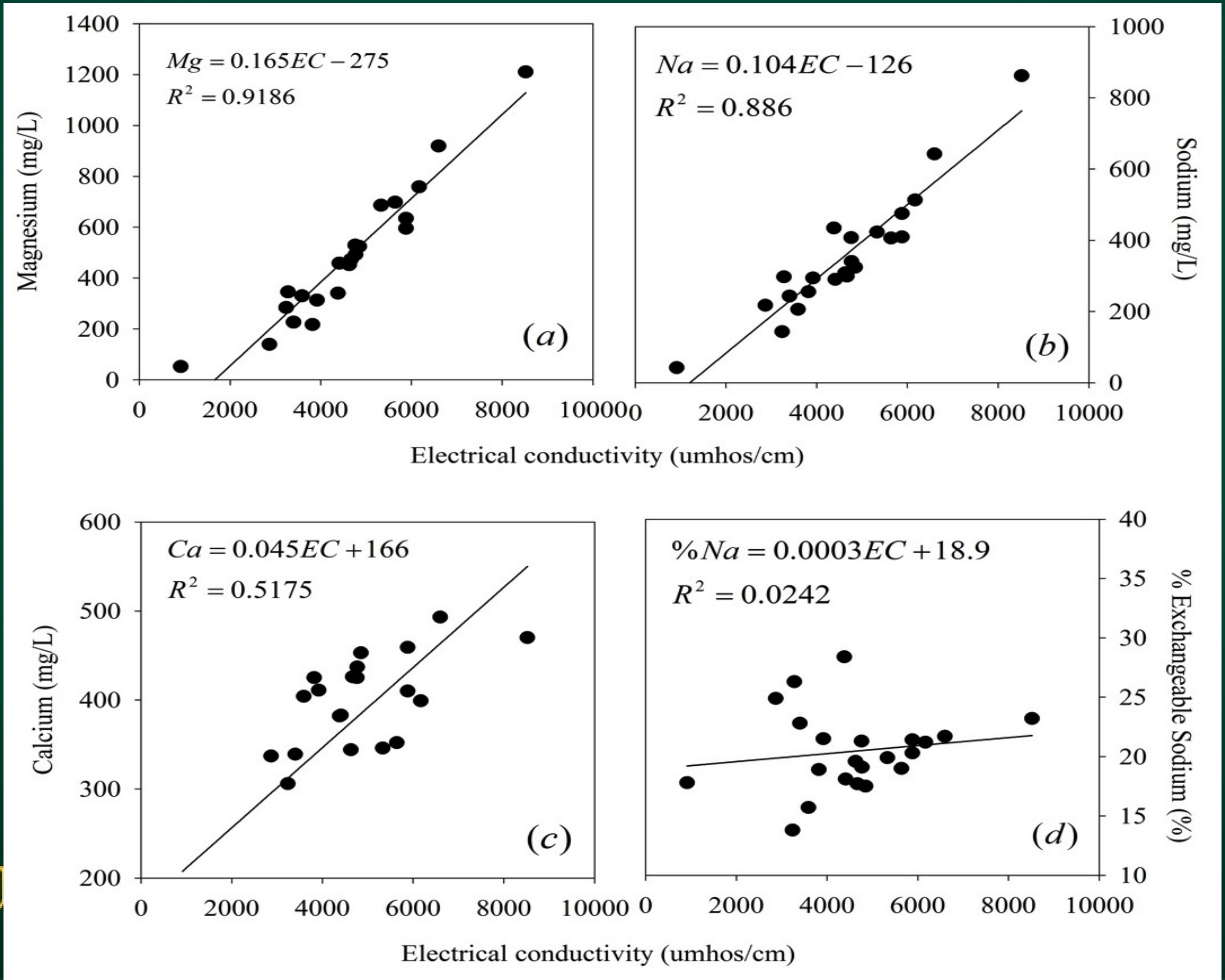
Linear relationship between electrical conductivity and magnesium (a), sodium (b), calcium (c), and percentage of exchangeable sodium (d) for drainage outflow.



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SUMMARY FOR 2008-2011 WATER QUALITY PARAMETERS

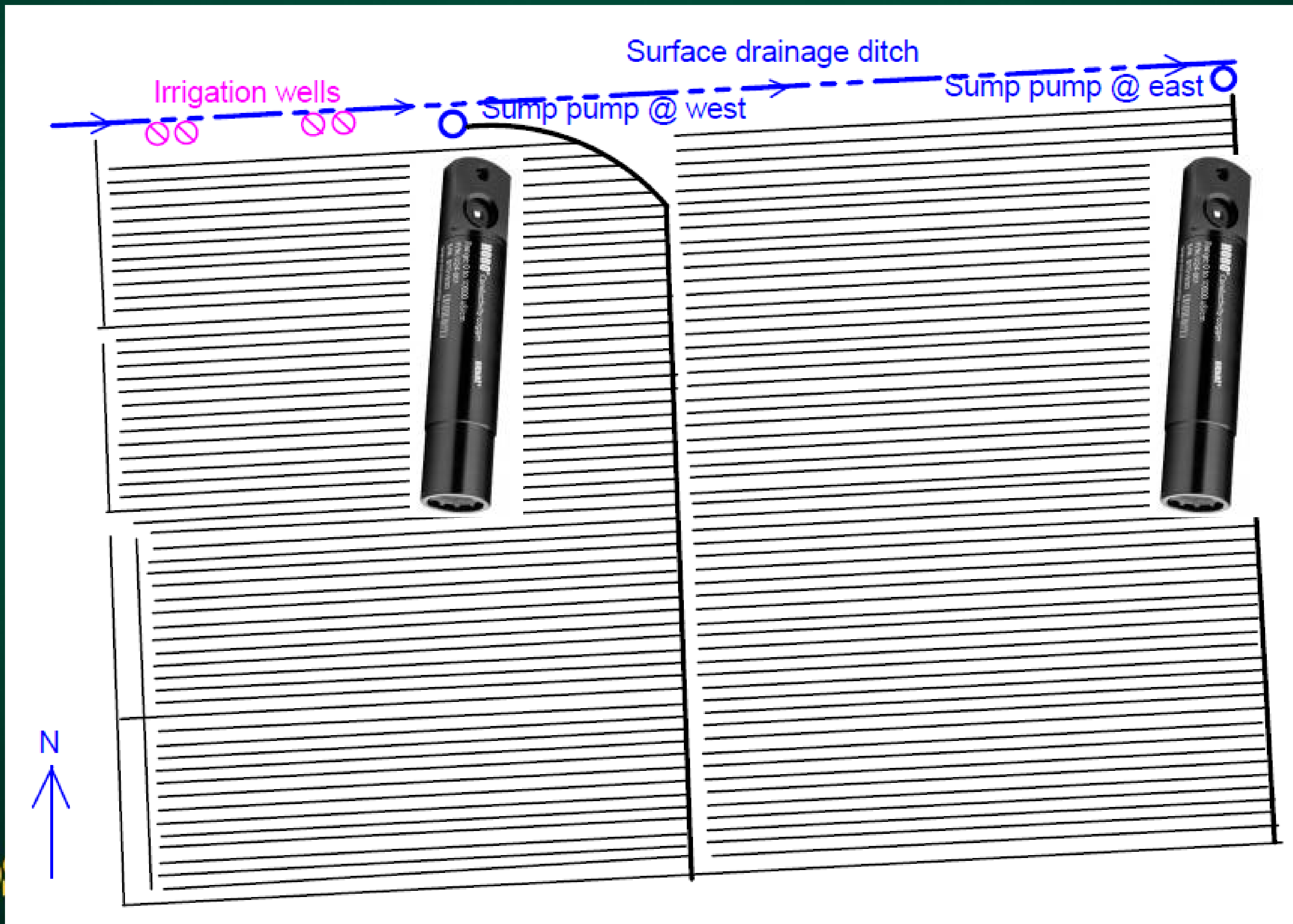
- ✓ Strong relationships were found between the EC and the dominant cations and anions (salts parameters) using linear regression analysis with $R^2 > 0.90$ for all water or drainage outflow.

- ✓ Weak relationships were found between the EC and nutrient parameters, with $R^2 = 0.63$ for nitrate + nitrite and $R^2 = 0.65$ for phosphorus for all water, but not for drainage outflow only.

- ✓ The EC in the drainage outflow was much higher than EC in subirrigation water, so it is easier to separate the water source using EC.

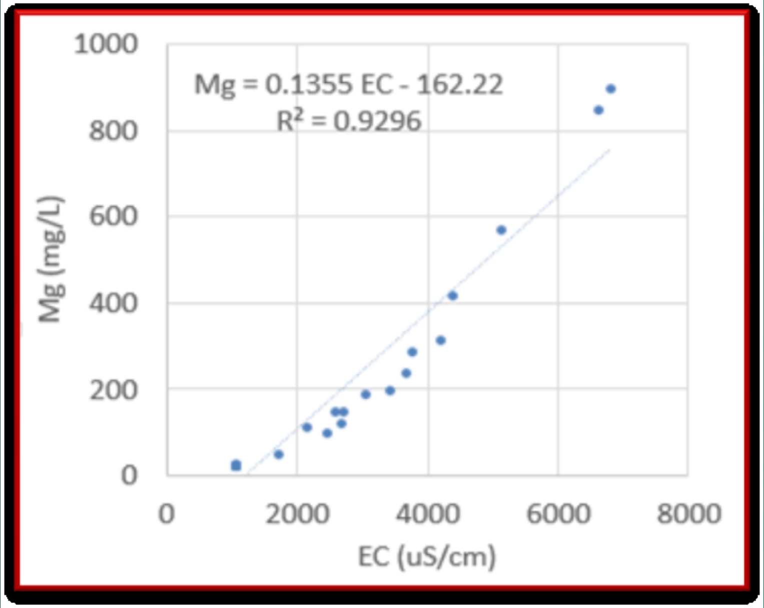
- ✓ Save cost: $300/sample x 26 samples = $7,800

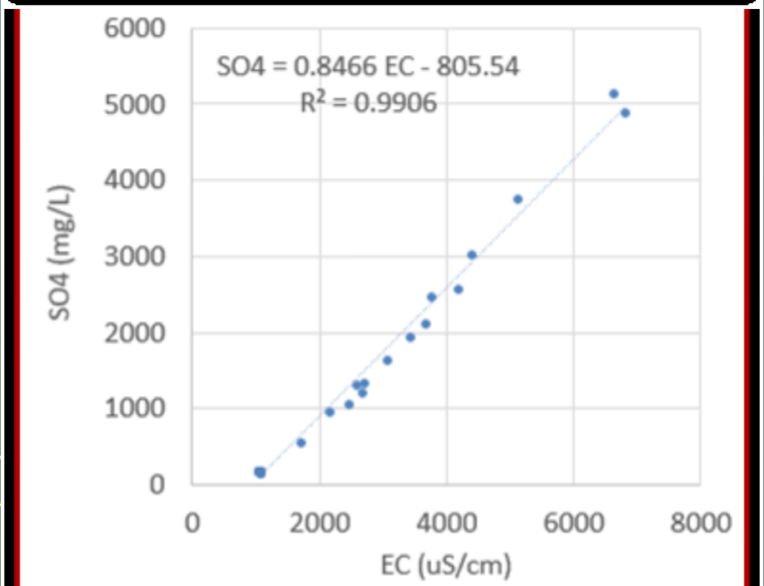
New tile drainage system layout since fall 2011:
30 ft spacing, 3.2-4 ft depth, and 1% grade. Subirrigate with groundwater from the down stream using the same mains.



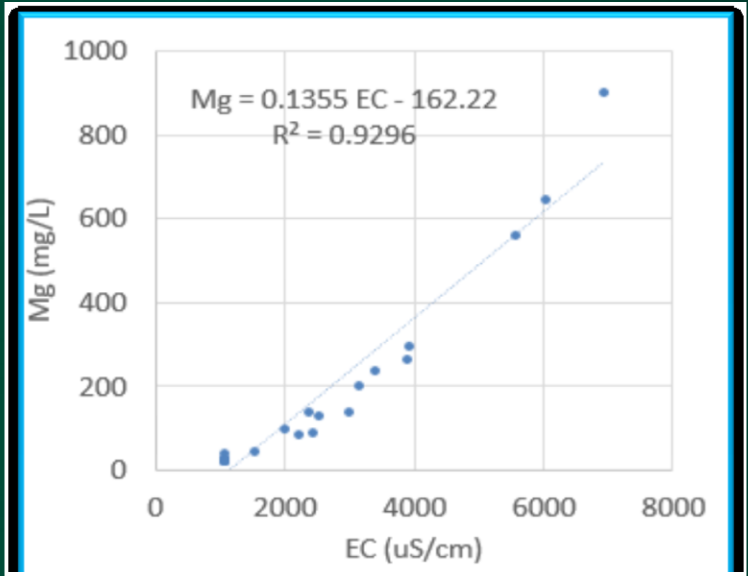
Water quality at the two sump pump structures in 2012-13

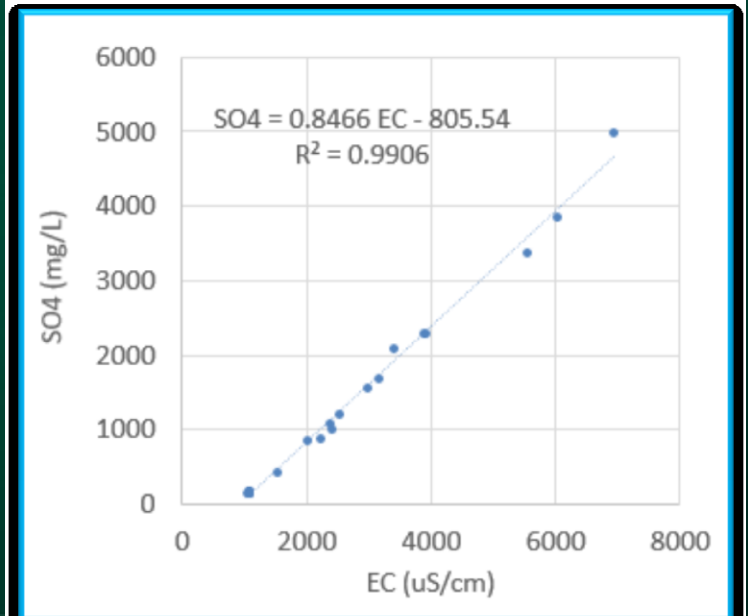
West sump

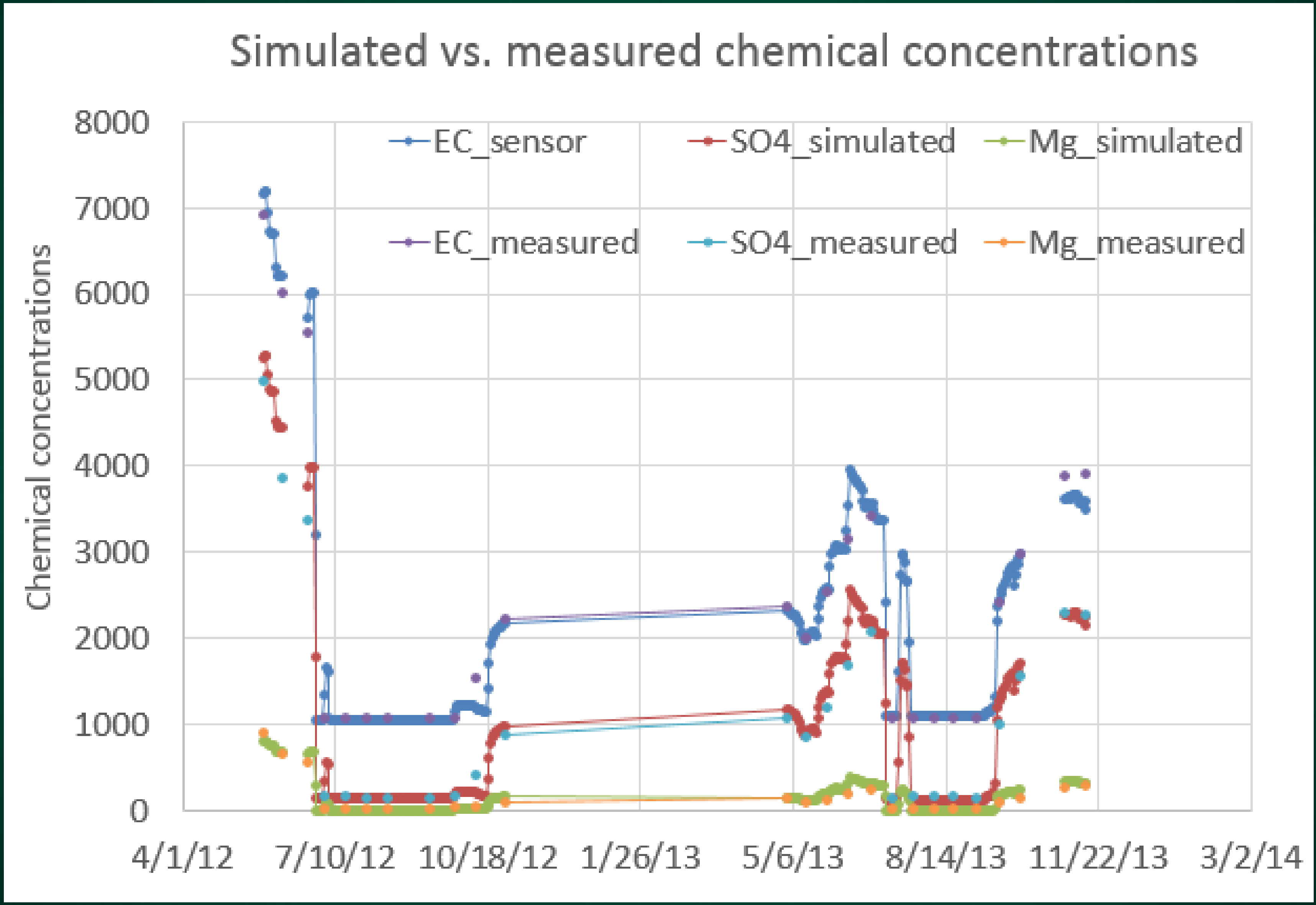




East sump







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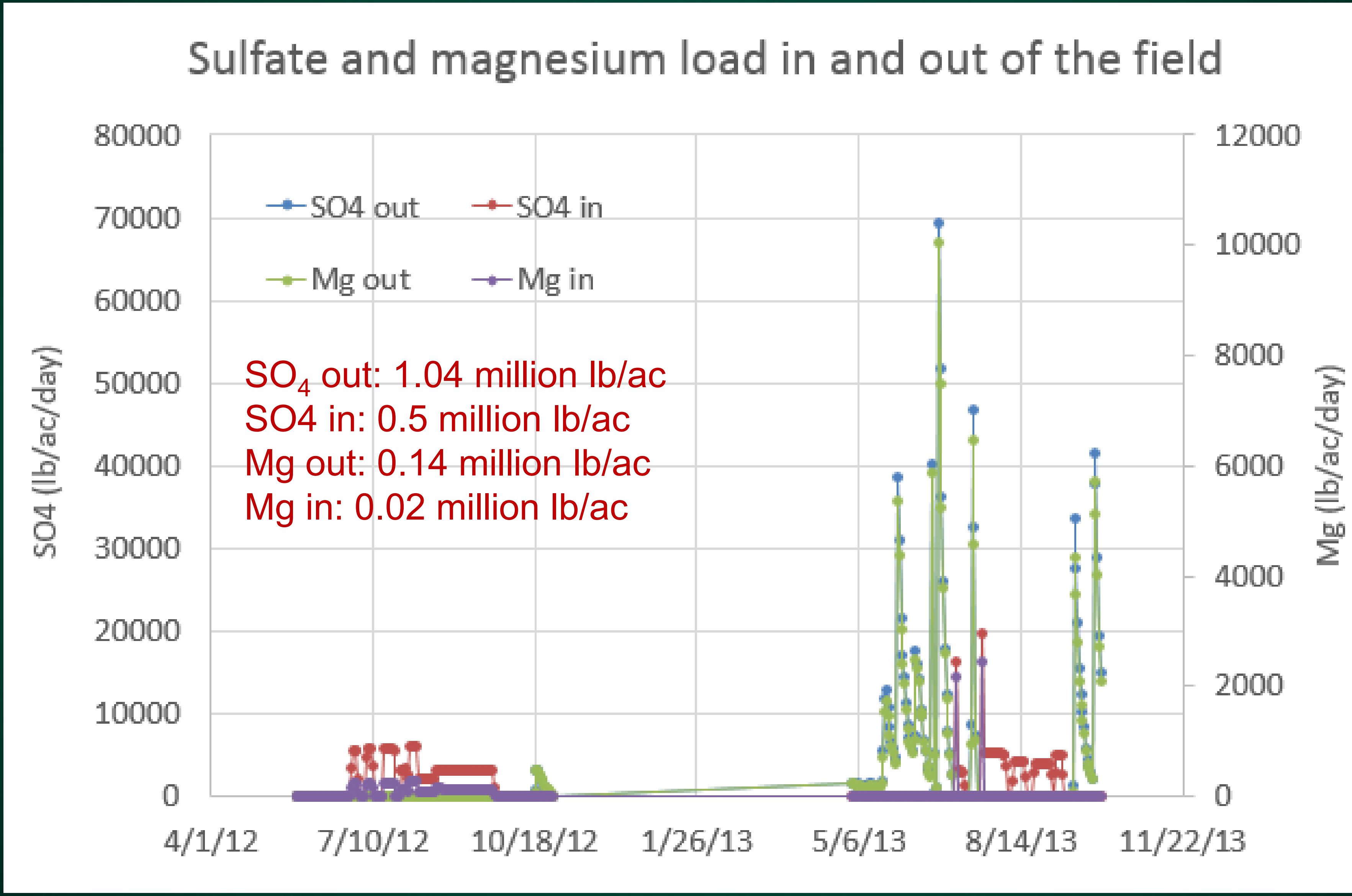
Sulfate and magnesium load in and out of the field
SO4 out
SO4 in
Mg out
Mg in
SO4 (lb/ac/day)
Mg (lb/ac/day)
80000
70000
60000
50000
40000
30000
20000
10000
0
12000
10000
8000
6000
4000
2000
0
4/1/12
7/10/12
10/18/12
1/26/13
5/6/13
8/14/13
11/22/13
SO4 out: 1.04 million lb/ac
SO4 in: 0.5 million lb/ac
Mg out: 0.14 million lb/ac
Mg in: 0.02 million lb/ac

Conclusion

1. EC can be used as a surrogate for major water quality parameters at this location;

2. Linear relationship based on EC and SO_4 and Mg were developed for 2012-13;

3. Daily chemical load as drainage outflow and subirrigation inflow were calculated; and

4. The daily loads as drainage outflow were much higher than the subirrigation inflow.

Acknowledgements

Our appreciation goes to the landowner at Fairmount, ND for providing his highly productive land for this research. The funding for the project was provided by USDA CSREES 2008-35102-19253, USDA NRCS 68-6633-8-0056, the North Dakota Agricultural Experiment Station, the North Dakota Water Resource Research Institute, the North Dakota State Water Commission, and the North Dakota Department of Health.

Mention of trade names is for information purpose only and does not imply endorsement by the authors.

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Thank you!