Project: TopCal for sodium management during leaching at Mission Viejo Country Club

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Summary

This study was designed to evaluate the ability of TopCal (12% Calcium derived from calcium chloride) to reduce soil salinity levels when it was applied to *Poa annua* greens prior to leaching. Key conclusions were:

- Leaching of either treated and non-treated greens resulted in significant reductions in soil salinity, chloride and nitrate, but leaching had no impact on soil sodium (parts per million or percentage) on either the treated or non-treated greens.

- Application of TopCal did not result in further reductions in soil salts or sodium, or in an increase in soil calcium in this study. It was simply leaching, whether on the treated or non-treated greens, that provided the only significant reductions in soil salts.

- It is likely that the recommended maximum rate of TopCal (20 gallons per acre) that was applied was not sufficient to provide the desired effects. With pre-treatment calcium levels in the soil at about 1,000 ppm, the additional 13 ppm* provided by the TopCal would not be expected to have an appreciable effect on increased calcium levels, or in displacement of sodium. For comparison's sake, the current standard practice for management of soil sodium relies on multiple applications of gypsum, at a rate of 10 lbs/1000 sq ft. With each gypsum application delivering 50 ppm** of calcium, and with monthly applications made (for a total of 600 ppm calcium added to the soil over the course of a year), this strategy has resulted in quantifiable and significant reductions in soil sodium levels under a wide range of conditions. For TopCal to approach this level of performance, the maximum rate would have to be increased almost four-fold, and applications would have be made on a monthly basis.

  *TopCal contains 12% calcium and has a bulk density of 11.11 lbs/gallon. Thus, the 20 gallon per acre rate would be expected to deliver 26 pounds of calcium per acre (11.11 * 20 * 0.12 = 26), which translates into an additional 13 ppm calcium per application.

  **Gypsum contains 23% calcium, and at a rate of 10 lbs/1000 sq ft, delivers 100 lbs of calcium per acre, which translates into 50 ppm calcium per application.

Bottom line: Leaching is an effective method for reducing soil salts. Liquid (calcium chloride solution), calcium-based products such as TopCal are much easier to handle than alternatives such as gypsum, but the current labeled rate of application for liquid products is too low to generate reductions in soil salts.

Materials and methods

Leaching was carried out using customized cycle-soak program with a 6 minute cycle and a 15 minute soak and a total of 150 minute run time. Rainbird 750 heads on a 60 ft spacing and 70 psi deliver 1.13 in/hour precipitation rate. The center of the greens that receive application from four heads received about 2.9 inches of irrigation during the leaching process.

Soil samples were collected before and after leaching using a ¾ inch diameter soil probe to a depth of three inches. Individual cores were collected throughout each green to a volume of about 500 cc. The thatch layer was left on the core samples. The soils were then analyzed using Mehlich III extraction for most nutrients with KCl extraction used for nitrogen and 1:2 soil:water electrical conductivity evaluation converted to a saturated paste extract equivalent. Soil analysis was conducted by Brookside Laboratories, New Knoxville, OH.

Samples are labeled as “01” to indicate before leaching results and “02” to indicate results after leaching was conducted. The letter “c” indicates the samples are from the non-treated check greens and the letter “t” indicates that the samples were collected from the TopCal treated greens. For example, “01c before” refers to the non-treated check greens before leaching and “02t after” represents samples from treated greens after leaching.

Water: Domestic water was the primary irrigation source but there was some recycled water mixing during the leaching process.

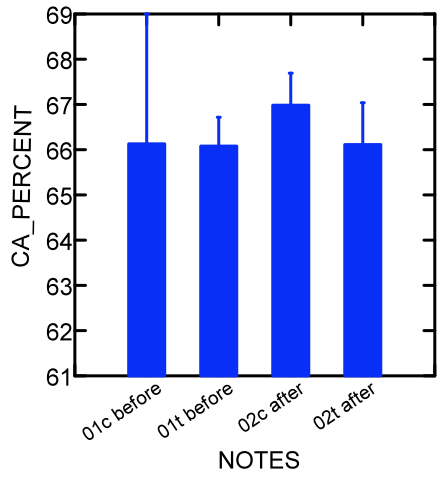
Key soil quality factors – Mehlich III extraction

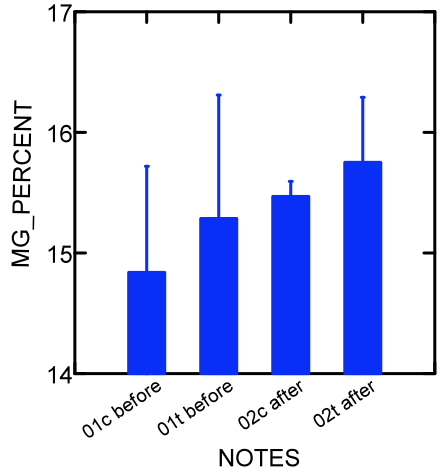
Values represent the average for three greens that were treated with TopCal (treated) or non-treated (check) before leaching (Before) and after leaching (After). Values are significantly different when there is less than a 5% ($P<0.05$) likelihood that the difference was due to chance. Means followed by the same letter are not significantly different using Fisher's LSD. Letters were only added to values that reported significant differences. Factors that reported significant differences before and after leaching are highlighted in green.

Parameter	Check Before	Check After	Treated Before	Treated After	P[1]
pH	7.3	7.5	7.3	7.5	0.101
Organic Matter (OM%)	1.9	1.8	1.8	1.8	0.861
Sulfur (SO4-S ppm)	102	65	101	68	0.103
Phosphorous (P ppm)	145	142	145	128	0.774
Calcium (Ca ppm)	1088	973	1078	972	0.469
Magnesium (Mg ppm)	150	136	150	141	0.744
Potassium (K ppm)	223	174	206	178	0.655
Sodium (Na ppm)	156	125	151	134	0.322
Calcium percentage	66	67	66	66	0.940
Magnesium percentage	15	15	15	16	0.704
Potassium percentage	6.8	6.2	6.4	6.2	0.917
Sodium percentage	8.2	7.5	8.1	8.0	0.375
Electrical Conductivity (EC dS/m)	1.7 a	1.2 b	1.7 a	1.3 b	0.002
Chloride (Cl ppm)	105 a	61 b	102 a	75 b	0.001
Boron (B ppm)	0.9	1.0	0.9	0.9	0.885
Iron (Fe ppm)	200	225	205	187	0.512
Manganese (Mn ppm)	66	64	69	75	0.751
Copper (Cu ppm)	2.3	2.3	2.4	2.2	0.849
Zinc (Zn ppm)	17	18	18	18	0.842
Ammonium nitrogen (NH4 ppm)	6.5	2.8	4.6	3.1	0.086
Nitrate nitrogen (NO3 ppm)	19 a	7.4 b	15 a	7.1 b	0.024
Total nitrogen (TOTN ppm)	25 a	10 b	20 a	10 b	0.033

[1]P = Fisher's Protected LSD probability that the values are the same

Figure 1. Soil cations reported in percentage of total extractable cations.
Desired values are: Calcium (Ca) 68%, Magnesium (Mg) 12 - 20%, sodium (Na) less than 3%. Samples are labeled as “01” to indicate before leaching and “02” to indicate after leaching. The letter “c” indicates the samples are from the non-treated check greens and the letter “t” indicates that the samples were collected from the TopCal treated greens.





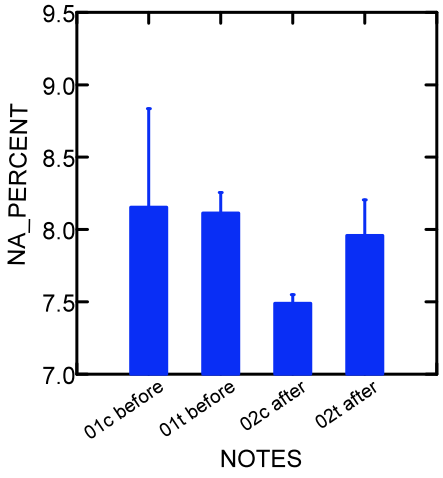
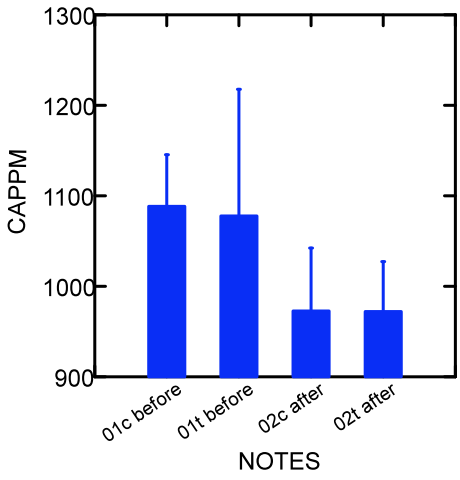
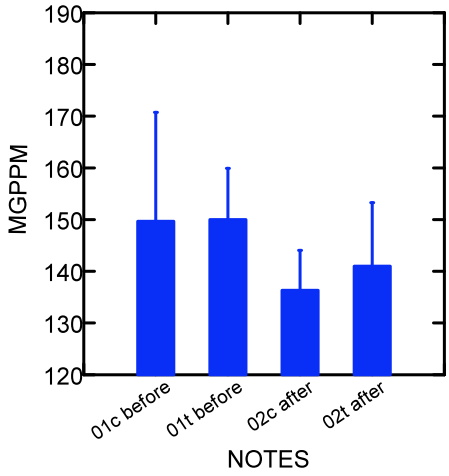


Figure 2. Soil cations reported in parts per million (ppm).
Desired values for calcium (Ca) is above 750 ppm, magnesium (Mg) above 140 ppm, and sodium (Na) below 110 ppm. Desired values are: Calcium (Ca) 68%, Magnesium (Mg) 12 - 20%, sodium (Na) less than 3%. Samples are labeled as “01” to indicate before leaching and “02” to indicate after leaching. The letter “c” indicates the samples are from the non-treated check greens and the letter “t” indicates that the samples were collected from the TopCal treated greens.





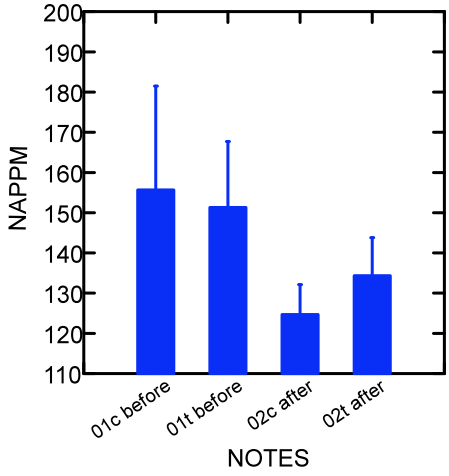


Figure 3. Soil plant available nitrogen values reported in parts per million (ppm), potassium (K ppm and K%) and phosphorus (P2O5).

Desired values are: Nitrate (NO_3) between 3 and 20 ppm, ammonium (NH_4) less than 7 ppm, nitrate:ammonium (NO_3NH_4) ratio greater than 3:1, and total plant available nitrogen less than 20 ppm. Potassium levels above 110 ppm are desired and phosphorus (BrayIIP) above 50 ppm is optimal. Desired values are: Calcium (Ca) 68%, Magnesium (Mg) 12 - 20%, sodium (Na) less than 3%. Samples are labeled as “01” to indicate before leaching and “02” to indicate after leaching. The letter “c” indicates the samples are from the non-treated check greens and the letter “t” indicates that the samples were collected from the TopCal treated greens.

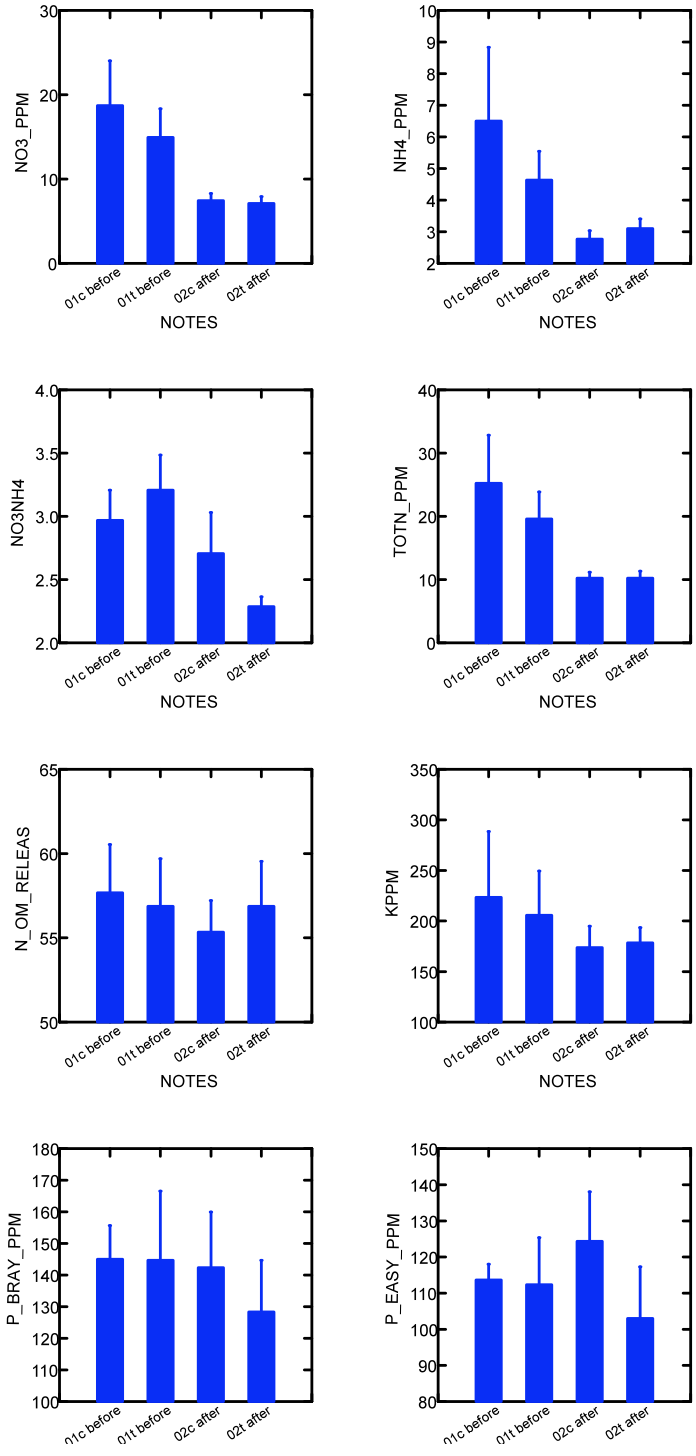


Figure 4. Soil pH, sulfate (ppm), organic matter (percentage) and electrical conductivity (EC dS/m).

Desired values are: pH between 6.2 and 7.4, sulfur between 15 and 130 ppm for poa. Organic matter less than 2% for greens. Soil salinity (EC) less than 2 dS/m for poa. Desired values are: Calcium (Ca) 68%, Magnesium (Mg) 12 - 20%, sodium (Na) less than 3%. Samples are labeled as “01” to indicate before leaching and “02” to indicate after leaching. The letter “c” indicates the samples are from the non-treated check greens and the letter “t” indicates that the samples were collected from the TopCal treated greens.

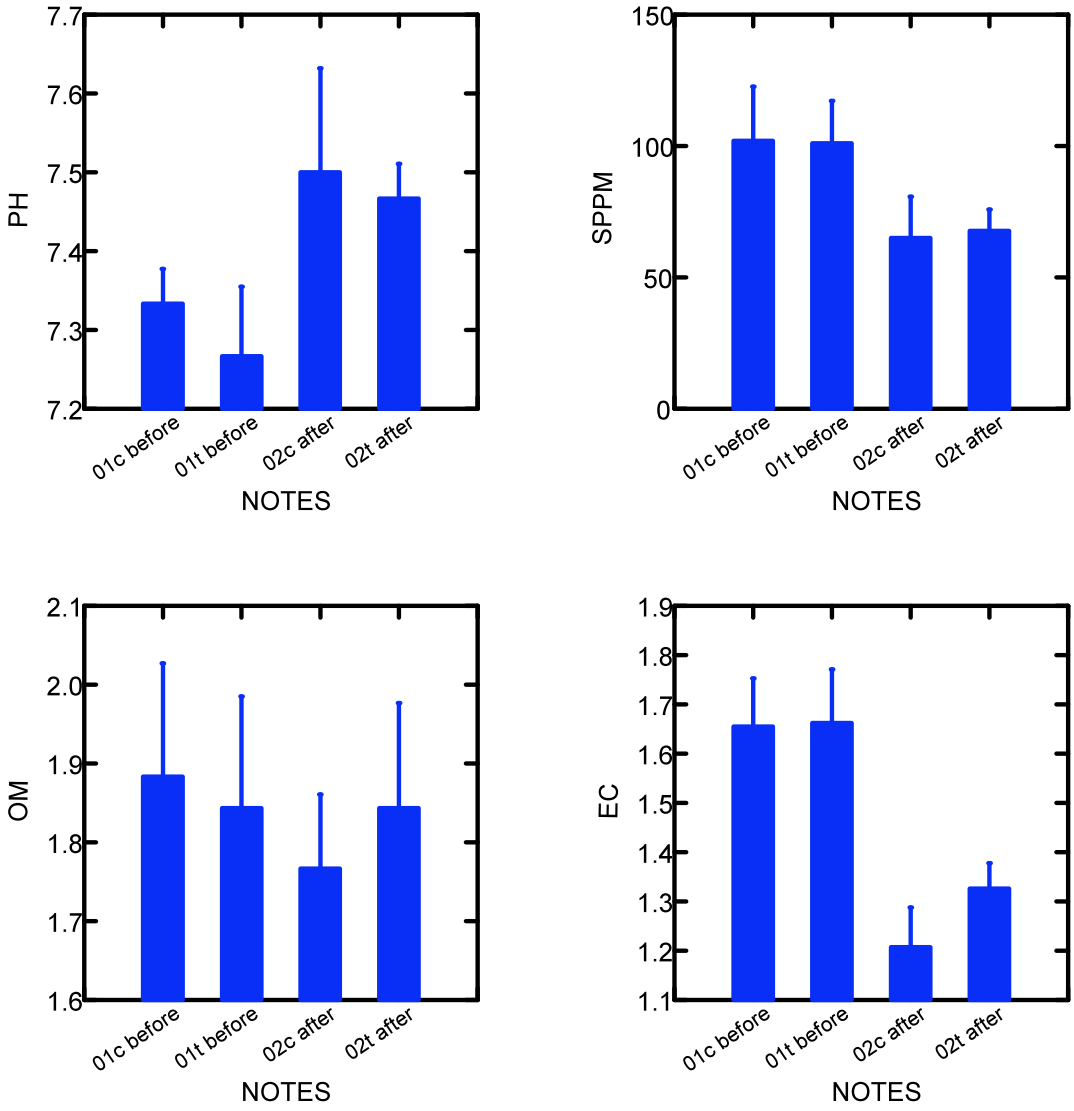
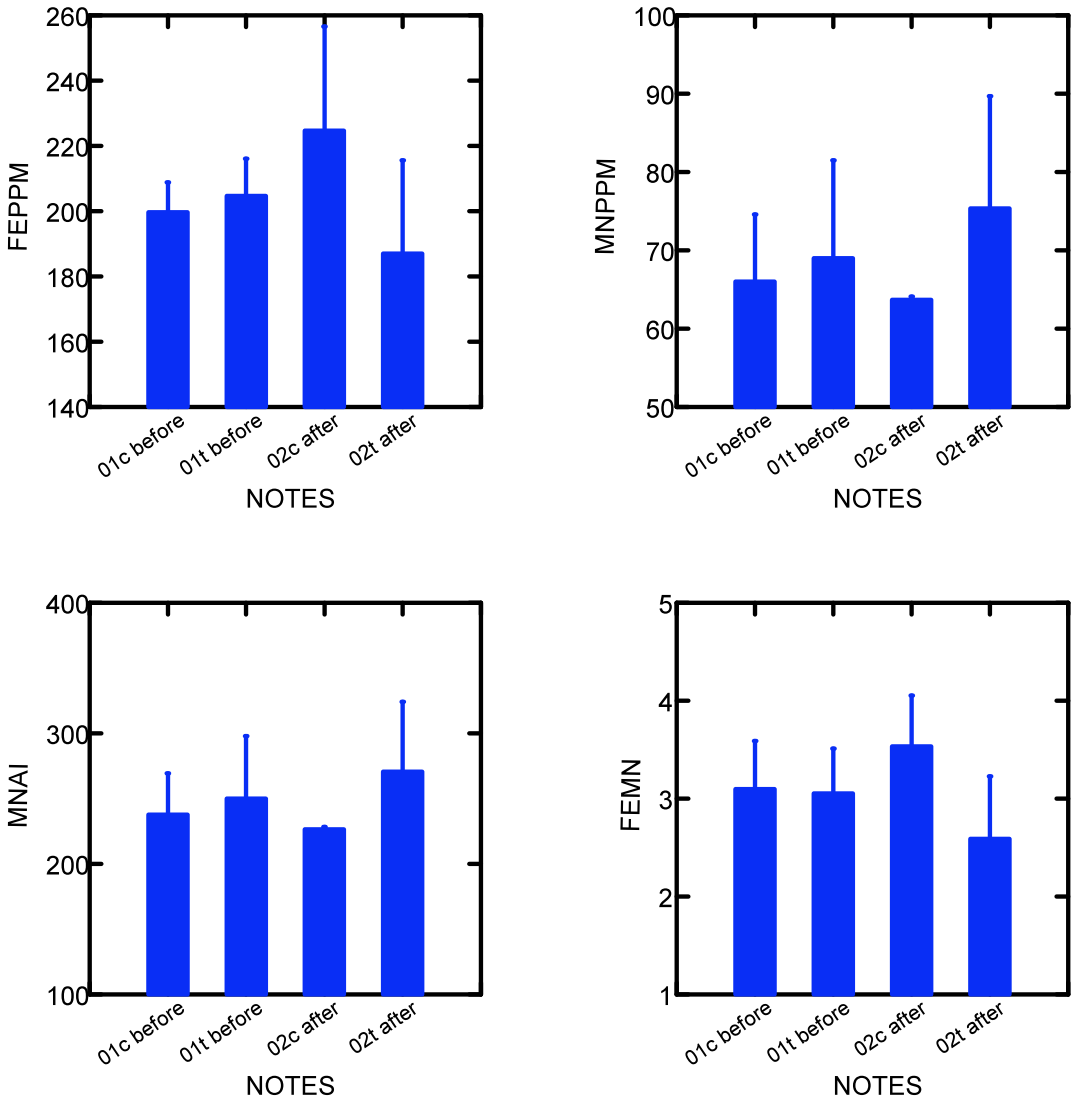


Figure 5. Iron and manganese relationships.
Desired values are currently based upon manganese availability and iron levels needed to balance the iron:manganese ratio. Manganese availability index (MnAI) should exceed 110. Iron should be present at three times the manganese level resulting in a iron:manganese ratio of 3:1. Desired values are: Calcium (Ca) 68%, Magnesium (Mg) 12 - 20%, sodium (Na) less than 3%. Samples are labeled as “01” to indicate before leaching and “02” to indicate after leaching. The letter “c” indicates the samples are from the non-treated check greens and the letter “t” indicates that the samples were collected from the TopCal treated greens.



Standard soil analysis (Mehlich III)

Mission Viejo Country Club **g 01**
09051201res Standard Extraction Methods 01c before
5/12/2009 Brookside 0014-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	151			
Phosphate P2O5 ppm:	346	119	0	0
Phosphorus (P) - Olsen (ppm):	31			
Phosphorus (P) - M3 (ppm)	112			
Phosphorus Saturation Index:	0.50	< 1.25		
Sulfur (S) ppm:	100	15-40		
Calcium (Ca) ppm:	1133	1127	0	0
Magnesium (Mg) ppm:	143	140	0	0
Potassium (K) ppm:	186			
Potash (K2O) ppm:	224	160	0	0
Sodium (Na) ppm:	147	< 67		
Aluminum (Al) ppm:	92			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.87	0.4 - 1.5		
Iron (Fe) ppm:	211.00	95		
Manganese (Mn) ppm:	59.00	32	Manganese Availability Index =	212.0
Copper (Cu) ppm:	1.98	0.6 - 2.0		
Zinc (Zn) ppm:	15.80	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	68.17	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.34	10 - 20 (12 optimum)
Percent Potassium (% K)	5.74	1.5 - 10
Percent Sodium (%Na)	7.69	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.3		
Percent Organic Matter (% OM):	1.8	Nitrate (NO3)	11.4
Soluble Salts (SS) 1:2 (ppm):	326.4	Ammonium (NH4)	3.6
Electrical Conductivity (EC) 1:2 (dS/m)	0.5	Total available	15.0
SS estimated saturated paste (ppm)	1005.4	NO3:NH4 ratio	3.2
EC estimated saturated paste (dS/m)	1.6	Organic N release	55.8
Total Extractable Cations (meq/100 g)	8.3		
Chloride Cl ppm	95.63		

Mission Viejo Country Club **g 01**
09051201res Standard Extraction Methods 02c after
5/12/2009 Brookside 0008-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	145			
Phosphate P2O5 ppm:	332	118	0	0
Phosphorus (P) - Olsen (ppm):	29			
Phosphorus (P) - M3 (ppm)	125			
Phosphorus Saturation Index:	0.50	< 1.25		
Sulfur (S) ppm:	88	15-40		
Calcium (Ca) ppm:	1078	1080	3	0
Magnesium (Mg) ppm:	148	140	0	0
Potassium (K) ppm:	170			
Potash (K2O) ppm:	205	157	0	0
Sodium (Na) ppm:	136	< 67		
Aluminum (Al) ppm:	103			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.98	0.4 - 1.5		
Iron (Fe) ppm:	237.00	97		
Manganese (Mn) ppm:	64.00	32	Manganese Availability Index =	229.2
Copper (Cu) ppm:	2.35	0.6 - 2.0		
Zinc (Zn) ppm:	17.86	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	67.63	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	15.47	10 - 20 (12 optimum)
Percent Potassium (% K)	5.47	1.5 - 10
Percent Sodium (%Na)	7.42	0.5 - 3

pH:	7.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.9	Nitrate (NO3)	6.6
Soluble Salts (SS) 1:2 (ppm):	249.6	Ammonium (NH4)	2.4
Electrical Conductivity (EC) 1:2 (dS/m)	0.4	Total available	9.0
SS estimated saturated paste (ppm)	844.2	NO3:NH4 ratio	2.8
EC estimated saturated paste (dS/m)	1.3	Organic N release	57.4
Total Extractable Cations (meq/100 g)	7.9		
Chloride Cl ppm	67.79		

Mission Viejo Country Club **g 03**
09051201res Standard Extraction Methods 01t before
5/12/2009 Brookside 0015-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	122			
Phosphate P2O5 ppm:	280	118	0	0
Phosphorus (P) - Olsen (ppm):	26			
Phosphorus (P) - M3 (ppm)	101			
Phosphorus Saturation Index:	0.46	< 1.25		
Sulfur (S) ppm:	82	15-40		
Calcium (Ca) ppm:	907	945	77	2
Magnesium (Mg) ppm:	142	140	0	0
Potassium (K) ppm:	157			
Potash (K2O) ppm:	189	149	0	0
Sodium (Na) ppm:	133	< 67		
Aluminum (Al) ppm:	92			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.84	0.4 - 1.5		
Iron (Fe) ppm:	204.00	97		
Manganese (Mn) ppm:	55.00	32	Manganese Availability Index =	195.5
Copper (Cu) ppm:	2.04	0.6 - 2.0		
Zinc (Zn) ppm:	15.52	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	64.97	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	16.95	10 - 20 (12 optimum)
Percent Potassium (% K)	5.77	1.5 - 10
Percent Sodium (%Na)	8.28	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.4		
Percent Organic Matter (% OM):	1.7	Nitrate (NO3)	10.7
Soluble Salts (SS) 1:2 (ppm):	320.0	Ammonium (NH4)	3.8
Electrical Conductivity (EC) 1:2 (dS/m)	0.5	Total available	14.5
SS estimated saturated paste (ppm)	992.0	NO3:NH4 ratio	2.8
EC estimated saturated paste (dS/m)	1.5	Organic N release	53.0
Total Extractable Cations (meq/100 g)	7.0		
Chloride Cl ppm	95.47		

Mission Viejo Country Club **g 03**
09051201res Standard Extraction Methods 02t after
5/12/2009 Brookside 0009-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	147			
Phosphate P2O5 ppm:	337	118	0	0
Phosphorus (P) - Olsen (ppm):	26			
Phosphorus (P) - M3 (ppm)	124			
Phosphorus Saturation Index:	0.51	< 1.25		
Sulfur (S) ppm:	70	15-40		
Calcium (Ca) ppm:	1049	1065	32	1
Magnesium (Mg) ppm:	154	140	0	0
Potassium (K) ppm:	161			
Potash (K2O) ppm:	194	156	0	0
Sodium (Na) ppm:	141	< 67		
Aluminum (Al) ppm:	101			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.24	0.4 - 1.5		
Iron (Fe) ppm:	229.00	98		
Manganese (Mn) ppm:	66.00	33	Manganese Availability Index =	235.2
Copper (Cu) ppm:	2.41	0.6 - 2.0		
Zinc (Zn) ppm:	19.08	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	66.73	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	16.33	10 - 20 (12 optimum)
Percent Potassium (% K)	5.25	1.5 - 10
Percent Sodium (%Na)	7.8	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.5		
Percent Organic Matter (% OM):	1.8	Nitrate (NO3)	5.9
Soluble Salts (SS) 1:2 (ppm):	236.8	Ammonium (NH4)	2.7
Electrical Conductivity (EC) 1:2 (dS/m)	0.4	Total available	8.6
SS estimated saturated paste (ppm)	817.3	NO3:NH4 ratio	2.2
EC estimated saturated paste (dS/m)	1.3	Organic N release	56.8
Total Extractable Cations (meq/100 g)	7.8		
Chloride Cl ppm	77.09		

Mission Viejo Country Club **g 08**
09051201res Standard Extraction Methods 02c after
5/12/2009 Brookside 0010-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	164			
Phosphate P2O5 ppm:	376	118	0	0
Phosphorus (P) - Olsen (ppm):	28			
Phosphorus (P) - M3 (ppm)	142			
Phosphorus Saturation Index:	0.53	< 1.25		
Sulfur (S) ppm:	59	15-40		
Calcium (Ca) ppm:	920	929	17	0
Magnesium (Mg) ppm:	130	140	20	0
Potassium (K) ppm:	148			
Potash (K2O) ppm:	178	148	0	0
Sodium (Na) ppm:	119	< 67		
Aluminum (Al) ppm:	108			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.24	0.4 - 1.5		
Iron (Fe) ppm:	259.00	97		
Manganese (Mn) ppm:	63.00	32	Manganese Availability Index =	225.5
Copper (Cu) ppm:	2.27	0.6 - 2.0		
Zinc (Zn) ppm:	17.62	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	67.15	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	15.82	10 - 20 (12 optimum)
Percent Potassium (% K)	5.54	1.5 - 10
Percent Sodium (%Na)	7.55	0.5 - 3

pH:	7.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.6	Nitrate (NO3)	8.7
Soluble Salts (SS) 1:2 (ppm):	211.2	Ammonium (NH4)	2.8
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	11.5
SS estimated saturated paste (ppm)	763.5	NO3:NH4 ratio	3.1
EC estimated saturated paste (dS/m)	1.2	Organic N release	52.6
Total Extractable Cations (meq/100 g)	6.8		
Chloride Cl ppm	63.59		

Mission Viejo Country Club **g 08**
09051201res Standard Extraction Methods 02c before
5/12/2009 Brookside 0016-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	129			
Phosphate P2O5 ppm:	296	118	0	0
Phosphorus (P) - Olsen (ppm):	28			
Phosphorus (P) - M3 (ppm)	109			
Phosphorus Saturation Index:	0.52	< 1.25		
Sulfur (S) ppm:	76	15-40		
Calcium (Ca) ppm:	1002	993	0	0
Magnesium (Mg) ppm:	126	140	28	1
Potassium (K) ppm:	163			
Potash (K2O) ppm:	196	152	0	0
Sodium (Na) ppm:	127	< 67		
Aluminum (Al) ppm:	86			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.71	0.4 - 1.5		
Iron (Fe) ppm:	201.00	95		
Manganese (Mn) ppm:	60.00	32	Manganese Availability Index =	215.7
Copper (Cu) ppm:	2.04	0.6 - 2.0		
Zinc (Zn) ppm:	15.27	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	68.35	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.32	10 - 20 (12 optimum)
Percent Potassium (% K)	5.7	1.5 - 10
Percent Sodium (%Na)	7.53	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.3		
Percent Organic Matter (% OM):	1.8	Nitrate (NO3)	25.3
Soluble Salts (SS) 1:2 (ppm):	332.8	Ammonium (NH4)	9.7
Electrical Conductivity (EC) 1:2 (dS/m)	0.5	Total available	35.0
SS estimated saturated paste (ppm)	1018.9	NO3:NH4 ratio	2.6
EC estimated saturated paste (dS/m)	1.6	Organic N release	55.2
Total Extractable Cations (meq/100 g)	7.3		
Chloride Cl ppm	96.94		

Mission Viejo Country Club **g 10**
09051201res Standard Extraction Methods 01t before
5/12/2009 Brookside 0017-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	177			
Phosphate P2O5 ppm:	406	118	0	0
Phosphorus (P) - Olsen (ppm):	28			
Phosphorus (P) - M3 (ppm)	104			
Phosphorus Saturation Index:	0.48	< 1.25		
Sulfur (S) ppm:	97	15-40		
Calcium (Ca) ppm:	1054	1073	38	1
Magnesium (Mg) ppm:	143	140	0	0
Potassium (K) ppm:	191			
Potash (K2O) ppm:	230	157	0	0
Sodium (Na) ppm:	146	< 67		
Aluminum (Al) ppm:	95			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.83	0.4 - 1.5		
Iron (Fe) ppm:	190.00	94		
Manganese (Mn) ppm:	65.00	31	Manganese Availability Index =	236.0
Copper (Cu) ppm:	2.26	0.6 - 2.0		
Zinc (Zn) ppm:	17.15	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	66.54	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	15.05	10 - 20 (12 optimum)
Percent Potassium (% K)	6.18	1.5 - 10
Percent Sodium (%Na)	8.01	0.5 - 3

		Plant available soil nitrogen ppm	
pH:	7.2		
Percent Organic Matter (% OM):	2.0	Nitrate (NO3)	14.5
Soluble Salts (SS) 1:2 (ppm):	339.2	Ammonium (NH4)	4.1
Electrical Conductivity (EC) 1:2 (dS/m)	0.5	Total available	18.6
SS estimated saturated paste (ppm)	1032.3	NO3:NH4 ratio	3.5
EC estimated saturated paste (dS/m)	1.6	Organic N release	60.4
Total Extractable Cations (meq/100 g)	7.9		
Chloride Cl ppm	104.1		

Mission Viejo Country Club **g 10**
09051201res Standard Extraction Methods 02t after
5/12/2009 Brookside 0011-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	133			
Phosphate P2O5 ppm:	305	118	0	0
Phosphorus (P) - Olsen (ppm):	23			
Phosphorus (P) - M3 (ppm)	88			
Phosphorus Saturation Index:	0.47	< 1.25		
Sulfur (S) ppm:	56	15-40		
Calcium (Ca) ppm:	905	920	30	1
Magnesium (Mg) ppm:	123	140	34	1
Potassium (K) ppm:	174			
Potash (K2O) ppm:	210	147	0	0
Sodium (Na) ppm:	120	< 67		
Aluminum (Al) ppm:	86			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.78	0.4 - 1.5		
Iron (Fe) ppm:	157.00	97		
Manganese (Mn) ppm:	63.00	32	Manganese Availability Index =	225.5
Copper (Cu) ppm:	1.81	0.6 - 2.0		
Zinc (Zn) ppm:	16.42	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	66.64	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	15.1	10 - 20 (12 optimum)
Percent Potassium (% K)	6.57	1.5 - 10
Percent Sodium (%Na)	7.68	0.5 - 3

pH:	7.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	2.0	Nitrate (NO3)	8.0
Soluble Salts (SS) 1:2 (ppm):	243.2	Ammonium (NH4)	3.5
Electrical Conductivity (EC) 1:2 (dS/m)	0.4	Total available	11.5
SS estimated saturated paste (ppm)	830.7	NO3:NH4 ratio	2.3
EC estimated saturated paste (dS/m)	1.3	Organic N release	60.4
Total Extractable Cations (meq/100 g)	6.8		
Chloride Cl ppm	71.25		

Mission Viejo Country Club **g 11**
09051201res Standard Extraction Methods 01t before
5/12/2009 Brookside 0018-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	135			
Phosphate P2O5 ppm:	309	119	0	0
Phosphorus (P) - Olsen (ppm):	34			
Phosphorus (P) - M3 (ppm)	132			
Phosphorus Saturation Index:	0.56	< 1.25		
Sulfur (S) ppm:	124	15-40		
Calcium (Ca) ppm:	1272	1299	55	1
Magnesium (Mg) ppm:	165	140	0	0
Potassium (K) ppm:	269			
Potash (K2O) ppm:	324	171	0	0
Sodium (Na) ppm:	175	< 67		
Aluminum (Al) ppm:	99			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.01	0.4 - 1.5		
Iron (Fe) ppm:	220.00	94		
Manganese (Mn) ppm:	87.00	31	Manganese Availability Index =	318.5
Copper (Cu) ppm:	2.99	0.6 - 2.0		
Zinc (Zn) ppm:	21.63	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	66.32	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.34	10 - 20 (12 optimum)
Percent Potassium (% K)	7.19	1.5 - 10
Percent Sodium (%Na)	7.93	0.5 - 3

pH:	7.2	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.9	Nitrate (NO3)	19.6
Soluble Salts (SS) 1:2 (ppm):	403.2	Ammonium (NH4)	6.0
Electrical Conductivity (EC) 1:2 (dS/m)	0.6	Total available	25.6
SS estimated saturated paste (ppm)	1166.7	NO3:NH4 ratio	3.3
EC estimated saturated paste (dS/m)	1.8	Organic N release	57.2
Total Extractable Cations (meq/100 g)	9.6		
Chloride Cl ppm	107.03		

Mission Viejo Country Club **g 11**
09051201res Standard Extraction Methods 02t after
5/12/2009 Brookside 0012-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	105			
Phosphate P2O5 ppm:	241	118	0	0
Phosphorus (P) - Olsen (ppm):	28			
Phosphorus (P) - M3 (ppm)	97			
Phosphorus Saturation Index:	0.48	< 1.25		
Sulfur (S) ppm:	77	15-40		
Calcium (Ca) ppm:	962	1009	94	2
Magnesium (Mg) ppm:	146	140	0	0
Potassium (K) ppm:	200			
Potash (K2O) ppm:	241	153	0	0
Sodium (Na) ppm:	142	< 67		
Aluminum (Al) ppm:	93			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.76	0.4 - 1.5		
Iron (Fe) ppm:	175.00	98		
Manganese (Mn) ppm:	97.00	33	Manganese Availability Index =	351.5
Copper (Cu) ppm:	2.23	0.6 - 2.0		
Zinc (Zn) ppm:	17.76	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	64.56	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	16.33	10 - 20 (12 optimum)
Percent Potassium (% K)	6.88	1.5 - 10
Percent Sodium (%Na)	8.29	0.5 - 3

pH:	7.5	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.7	Nitrate (NO3)	7.4
Soluble Salts (SS) 1:2 (ppm):	275.2	Ammonium (NH4)	3.1
Electrical Conductivity (EC) 1:2 (dS/m)	0.4	Total available	10.5
SS estimated saturated paste (ppm)	897.9	NO3:NH4 ratio	2.4
EC estimated saturated paste (dS/m)	1.4	Organic N release	53.4
Total Extractable Cations (meq/100 g)	7.4		
Chloride Cl ppm	77.48		

Mission Viejo Country Club **g 13**
09051201res Standard Extraction Methods 01c before
5/12/2009 Brookside 0019-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	155			
Phosphate P2O5 ppm:	355	119	0	0
Phosphorus (P) - Olsen (ppm):	37			
Phosphorus (P) - M3 (ppm)	120			
Phosphorus Saturation Index:	0.56	< 1.25		
Sulfur (S) ppm:	130	15-40		
Calcium (Ca) ppm:	1130	1244	227	5
Magnesium (Mg) ppm:	180	140	0	0
Potassium (K) ppm:	321			
Potash (K2O) ppm:	387	167	0	0
Sodium (Na) ppm:	193	< 67		
Aluminum (Al) ppm:	97			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.21	0.4 - 1.5		
Iron (Fe) ppm:	187.00	97		
Manganese (Mn) ppm:	79.00	32	Manganese Availability Index =	285.5
Copper (Cu) ppm:	2.90	0.6 - 2.0		
Zinc (Zn) ppm:	18.99	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	61.55	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	16.34	10 - 20 (12 optimum)
Percent Potassium (% K)	8.97	1.5 - 10
Percent Sodium (%Na)	9.14	0.5 - 3

pH:	7.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	2.1	Nitrate (NO3)	19.4
Soluble Salts (SS) 1:2 (ppm):	396.8	Ammonium (NH4)	6.2
Electrical Conductivity (EC) 1:2 (dS/m)	0.6	Total available	25.6
SS estimated saturated paste (ppm)	1153.3	NO3:NH4 ratio	3.1
EC estimated saturated paste (dS/m)	1.8	Organic N release	62.0
Total Extractable Cations (meq/100 g)	9.1		
Chloride Cl ppm	120.96		

Mission Viejo Country Club **g 13**
09051201res Standard Extraction Methods 02c after
5/12/2009 Brookside 0013-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	118			
Phosphate P2O5 ppm:	270	118	0	0
Phosphorus (P) - Olsen (ppm):	30			
Phosphorus (P) - M3 (ppm)	106			
Phosphorus Saturation Index:	0.52	< 1.25		
Sulfur (S) ppm:	48	15-40		
Calcium (Ca) ppm:	920	947	54	1
Magnesium (Mg) ppm:	131	140	18	0
Potassium (K) ppm:	203			
Potash (K2O) ppm:	245	149	0	0
Sodium (Na) ppm:	119	< 67		
Aluminum (Al) ppm:	93			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.86	0.4 - 1.5		
Iron (Fe) ppm:	178.00	100		
Manganese (Mn) ppm:	64.00	33	Manganese Availability Index =	224.7
Copper (Cu) ppm:	2.37	0.6 - 2.0		
Zinc (Zn) ppm:	17.32	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	65.81	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	15.62	10 - 20 (12 optimum)
Percent Potassium (% K)	7.45	1.5 - 10
Percent Sodium (%Na)	7.4	0.5 - 3

pH:	7.7	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.8	Nitrate (NO3)	7.0
Soluble Salts (SS) 1:2 (ppm):	185.6	Ammonium (NH4)	3.1
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	10.1
SS estimated saturated paste (ppm)	709.8	NO3:NH4 ratio	2.3
EC estimated saturated paste (dS/m)	1.1	Organic N release	56.0
Total Extractable Cations (meq/100 g)	7.0		
Chloride Cl ppm	52.91		

Irrigation water analysis

Mission Viejo Country Club

09051201res

d #8 domestic Lab No: 990 5/7/2009 Brookside

pH	7.53		
Hardness ppm	305.92		
Electrical Conductivity (dS/m, mmhos/cm)	1.17	TDS (ppm)	750.1
Sodium Adsorption Ratio (SAR)	2.30		
Adjusted SAR (Adj.SAR)	4.08		
pHc	7.63		
Residual Sodium Carbonate (RSC)	0.00		

Cations	**ppm**	**meq/l**	**lbs/acre ft**
Calcium Ca	74.03	3.69	201.50
Magnesium Mg	28.96	2.38	78.82
Potassium K	5.33	0.14	14.51
Sodium Na	92.33	4.02	251.31
Iron Fe	1.04		2.83
Anions	**ppm**	**meq/l**	**lbs/acre ft**
Total Alkalinity	118.08		
Carbonate CO3	0.00	0.00	0.00
Bicarbonate HCO3	144.09	2.36	392.19
Hydroxide OH	0.00		
Chloride Cl	108.93	3.07	296.49
Sulfur as SO4	259.56	5.40	706.48
Minors	**ppm**		**lbs/acre ft**
Boron B	0.16		0.44
Manganese Mn	0.03		0.07
Copper Cu	0.00		
Zinc Zn	0.00		
Aluminum Al	0.86		
Nutrients	**ppm**		**lbs/acre ft**
NO2-N			
NO3-N	1.8		4.90
NH3-N	0		0.00
Total P	0.21		0.57

Acid injection is frequently used to amend waters that are high in carbonates and bicarbonates. However, acid amendment is only recommended when carbonates and bicarbonates together comprise more than 50% of the total anions, the RSC is greater than 1.25, and ideally when the water EC is less than 0.5 dS/m.

Reported Carbonates and bicarbonates as a percent of the total anions	28
Estimated pounds of H2SO4 needed per acre ft of water to neutralize CO3 and HCO3	315
Estimated Gallons of H2SO4 needed per acre ft of water to neutralize CO3 and HCO3	21

Gypsum injection is an alternative method of amending water to deliver additional calcium to soils when water EC is less than 1.2 dS/m. In this case, the target is two times more calcium than sodium or magnesium (a 2:1 ratio) measured in milliequivalents per liter (meq/l).

Reported Calcium:sodium ratio in meq/l	0.92
Pounds of gypsum per acre ft of water to deliver 2:1 Ca:Na ratio	1015
Reported Calcium:magnesium ratio in meq/l	1.55
Pounds of gypsum per acre ft of water to deliver 2:1 Ca:Mg ratio	251

In addition to waters that require modification to balance the cations or for removal of carbonates, some waters have a low EC and moderate SAR that requires amendment to increase the EC of the water to improve water infiltration. Gypsum injection has been the product of choice for this amendment because it increases the EC and drops the SAR at the same time.

Pounds of gypsum needed per acre foot of water to balance the EC/SAR relationship. If the value is zero, no gypsum is needed.	0

Note: Values reported as 0 (zero) indicate that the element is present below minimum levels of detection. Minimum detection levels for selected elements and compounds are listed below in parts per million (ppm):
NO2 < 0.01; NO3 < 0.10; NH4 < 0.10; Al <0.20; Cu <0.02; Fe <0.10; Zn <0.04, K<0.60

Guidelines for iron and manganese, for soils at a range of different pHs.

Note that the desired levels of micronutrients increases as soil pH increases. Maintaining higher levels of manganese and iron helps to overcome their tendency to become bound, and therefore unavailable, to the plant in more basic soils. We have paid special attention to these two micronutrients because plants are more likely to be deficient in iron than any other micronutrient. And higher levels of manganese appear to play a role in suppressing turf diseases caused by *Gaeumannomyces* such as bermudagrass decline, kikuyugrass decline, and take-all patch.

	Desired soil concentrations (ppm) for pH 6 - 8.5 soils						Average range for greens, tees & fairways (across all pHs)
	6	6.5	7	7.5	8	8.5	
Iron (Fe)	**80**	**86**	**92**	**98**	**104**	**110**	**157-185**
Manganese (Mn)	**27**	**29**	**31**	**33**	**35**	**37**	**30-43**

Table 2. Soil nutritional guidelines. Iron and manganese values are reported in Table 1 above.

	Greens		Tees		Fairways	
Nutrient concentration (ppm)	Average	Desired	Average	Desired	Average	Desired
Nitrate (NO_3)	6.7	3-20	17.1	3-20	24.2	3-20
Ammonium (NH_4)	2.5	<7	4.2	<7	4.4	<7
NO_3 + NH_4	9.4	<20	21.3	<20	28.6	<20
Phosphorous (P)	99	51	92	40	101	44
Potassium (K)	156	144	135	174	235	229
Calcium (Ca)	1346	1327	1857	1916	2640	3043
Magnesium (Mg)	174	140	332	203	611	322
Sodium (Na)	174	<67	260	<67	584	<67
Sulfate (SO_4)	139	15 - 40	135	15 - 40	490	15 - 40
Boron (B)	1.0	0.4 - 1.5	1.2	0.4 - 1.5	1.7	0.4 - 1.5
Copper (Cu)	4.7	0.6 - 2.0	3.1	0.6 - 2.0	2.4	0.6 - 2.0
Iron (Fe)	185	See Table 1	175	See Table 1	157	See Table 1
Manganese (Mn)	30	See Table 1	30	See Table 1	43	See Table 1
Zinc (Zn)	18.9	1.3 - 3.5	13.9	1.3 - 3.5	8.4	1.3 - 3.5

	Greens		Tees		Fairways	
Other soil measurements	Average	Desired	Average	Desired	Average	Desired
pH	7.1	6.5 - 7.5	7.4	6.5 - 7.5	7.2	6.5 - 7.5
EC (dS/m)	3.2	<3.0	3.0	<3.0	6.4	<3.0
TEC (meq/100 g)	9.9	NA	14.5	NA	24	NA
OM%	2.0	NA	3.0	NA	4.4	NA
% Ca	69	68	66	68	59	68
% Mg	15	12-20	20	12-20	23	12-20
% K	4	4	3	4	3	4
%Na	8	<3	8	<3	11	<3
% H	0	10 - 15	0	10 - 15	0	10 - 15

These guidelines are based upon PACE data collected from golf course greens, tees and fairways. Soil analysis using Melich III extraction by Brookside Laboratories, New Knoxville, OH. This data can be used as an aid in developing turf fertility programs, but should always be used in conjunction with specific soil test results from your golf course.

Regional variation in soil nutrients on greens

A comparison based on 120 samples from the Florida Panhandle, Coastal Louisiana and Mississippi, Minnesota, Southern California, Minnesota and Chicago, IL. Data based on a 2001 collaborative project among R. Carrow (University of Georgia); S. Davis (Bayer) and L. Stowell (PACE Turfgrass Research Institute). Additional support was provided by Arthur Clesen Inc., Turf Supply, Lesco and ProSource One. *Desired values provided by Dr. R. Carrow, University of Georgia

Parameter	Desired*	MN	IL	CA	FL	LA/MS
pH	6.0-7.5	7.0	7.0	7.1	6.5	6.9
Phosphorous (ppm)	>50	240	105	99	85	28
Potassium (ppm)	>110	146	170	156	88	37
Calcium (ppm)	>750	1660	2726	1346	544	225
Magnesium (ppm)	>140	160	343	174	91	53
Sulphur (ppm)	15 - 40	12.5	63	139	20	4
Boron (ppm)	0.5 – 1.5	---	<1	1	1.2	3
Copper (ppm)	0.1 – 2.5	1.35	4	5	3.3	0.6
Iron (ppm)	>90	108	248	185	42	59
Manganese (ppm)	>30	24	34	30	2.9	6.7
Zinc (ppm)	1 - 4	16	20	19	6.9	5.1
Sodium (ppm)	<67	10	40	174	48	---
% Base Saturation						
% calcium	65 – 80%	69%	76%	69%	71%	69%
% potassium	2 - 7%	4%	3%	4%	4%	6%
% magnesium	10 - 20%	15%	17%	15%	20%	26%
% sodium	<3%	<1%	1%	8%	6%	---
Other Values						
EC (dS/m)	<1.5	0.25	0.48	3.2	0.05	0.14
TEC (meq/100g)	>4	7.8	17.8	9.9	2.1	1.6
% Organic matter	<4%	<3%	3%	2%	0.15%	0.15%

Irrigation water guidelines

Guidelines are based on the published literature and on PACE's database of water quality samples from around the U.S. Water that meets the "no restriction" guidelines can be used almost anywhere with good results.

Parameter	No restriction	Domestic	Rain	Recycled	Poor Well	Good Well	Urban Runoff
EC (dS/m)	<0.8	0.7	0.1	1.1	4.02	0.6	16.1
TDS (ppm)	<525	499	46	723	2573	378	10323
pH	6.5-7.8	7.8	6.3	7.2	7.5	8.1	7.7
SAR	<3.0	2.7	0.5	4.0	5.2	0.9	11.7
HCO_3 (ppm)	<50	134	26	201	364	266	847
Na (ppm)	<100	85	5.6	147	407	30.5	1820
RSC (meq/l)	<1.0	0.04	0	0.12	0	0	0
B (ppm)	<0.5	0.22	0.03	0.42	0.41	0.06	2.05
Cl (ppm)	<90	74	0.7	149	1004	45	3886
NO_3 (ppm)	<8.0	3.2	—	7.3	—	3.6	0.4

Using water analysis data to calculate nutrients delivered in irrigation water.

In addition to keeping turf alive during dry periods, irrigation water is also the (frequently unknown) source of hundreds of pounds of nutrients to your turf. Depending on the water, different nutrients -- from calcium to sodium to boron to nitrogen -- are prevalent.

To keep track of both the beneficial and injurious nutrients that are delivered through your irrigation water, it should be tested at least annually by an analytical laboratory. You can then compare it against PACE's water quality guidelines so that you can identify any potential problems.

Using the data from your report, it is also relatively easy to calculate how many pounds of each nutrient are being delivered each year to your golf course. The procedure is the same for any nutrient, but we will use total dissolved salts (TDS) below as an example.

1. On your water report, locate the total dissolved salts analysis. It will probably be reported either in ppm (parts per million) or milligrams per liter (mg/liter). These two measurements are equivalent.
2. Multiply the ppm or mg/l value by 2.72. The value you obtain is the pounds of total dissolved salts per acre foot of water. A value of 500 ppm TDS on a water report (this is a fairly low number that results in very few problems with soil salinity) will therefore translate into 1,360 pounds (2.72 X 500) total dissolved salts per acre foot of water.
3. To determine how many pounds of total dissolved salts are delivered per year to the golf course, multiply the 1,360 pounds value by the number of acre feet of water that you use on the golf course per year per acre. In this example, suppose that the course used 3 acre feet of water per acre last year. This would translate into 4,080 lbs of salts (3 X 1,360) per acre delivered to the golf course per year. This is equivalent to 94 lbs/1000 sq ft of salts. Obviously, as the volume of water used for irrigation increases, the pounds of salts dumped onto the golf course will also escalate.