Project: Evaluation of leaching using closed drains at the start of the leaching event compared to open drain lines throughout the leaching event on USGA specification greens

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Summary

Leaching to remove salts and to draw air into the root zone as water drains is a common practice in the arid Southwest. The practice is not standardized and many methods have been used to drop soil salts and to help relieve black layer. This study compares leaching with the irrigation heads for a prolonged irrigation cycle using the two techniques below. There was no significant difference in salt leaching when these two techniques were compared to one another.

1) Closing the green drain valve and running the irrigation system until water fills the green cavity and runoff is clearly visible. Once the cavity is full, open the drain valve so that suction will aid in pulling water from the soil profile.

2) Leaving the green drain valve open and running the irrigation system.

Leaching irrigation in this study delivered between 3 and 10 inches of water to the greens over the course of 3.75 hours depending upon location where samples were collected. A significant portion of the water did not pass through the soil due to low infiltration rate at the soil surface compared to the very high precipitation rate delivered by the irrigation system (0.8 – 2.7 inches per hour). However, maximum water flow through the green soil profile should have taken place in the leaching event for much of the 3.75 hours of run time.

The PACE leaching guideline suggest that 6 inches of water must pass through the root zone to drop soil salts by about 50%. Soil salts measured by the standard extraction method (2:1 water:soil) revealed that there was a significant reduction is soil salts following leaching but there was no significant difference in salt reduction when the two techniques were compared (18% reduction for closed drain and 22% for open drain). Similar results were observed for other ions that are easily leached (e.g. potassium and chloride). Saturated paste extract results were inconsistent possibly due to the low salinity level of the green prior to leaching (there may not have been sufficient salts to detect the reduction using the saturated paste methodology).

These results suggest that heavy irrigation can reduce soil salts by about 20% when precipitation rates average 1.8 inches per hour and the run time is almost four hours. The limiting factor in this type of leaching system is probably the soil surface infiltration rate and saturated hydraulic conductivity between the surface and the drain. Recent soil physical analysis indicates that saturated conductivity of a disturbed sample is about 6 inches per hour. The observed runoff was due to slow infiltration or a barrier to drainage. Lower precipitation rate strategies are needed to improve leaching efficiency.

Using the current irrigation system, a 3 minute run cycle followed by a 3 minute soak cycle would be a good starting place for future leaching events to allow time for water to infiltrate into the green and for water to make its way to drain. The 3 minute cycle would apply about 0.09 inches of water (at a precipitation rate of 1.8 in/hr average) for each cycle-soak (0.9 in/hr). A total of 6.7 hours would be needed to apply 6 inches of water at a rate that more closely matches soil hydraulic conductivity. The alternative is to place a lower precipitation sprinkler on the green and run for sufficient time to deliver 6 inches of water. Even a slower precipitation rate would be more desirable.

Materials and Methods

Two greens were selected to compare leaching methods. The drain outlet at the low end of the green was closed on one green until water filled the green cavity and water freely ran off the front of the green (Green 5). The second green was leached without closing the drain and the drain was allowed to flow freely during the leaching event (green 15). Three cup cutter samples to a depth of 4 inches were collected from each green before leaching as illustrated in Figure 1. A catch can was placed adjacent to the location where each soil sample was located and the irrigation system was allowed to run for 3 minutes to estimate precipitation rate. For leaching, the irrigation system was allowed to run for continuously for 3.75 hours. Following leaching, three after-leaching samples were collected adjacent to the before-leaching samples. Standard Mehlich III soil extraction and saturated paste extract analyses of the soils were conducted.

Soil samples were coded to indicate the location where each soil sample was collected. For example, “g 05a” was collected from green 5 location A. Time of sample collection was designated with the number “1” for before leaching and the number “2” to indicate the sample was collected after leaching. For example, sample “g 05a1” was collected from green 5 position A before leaching.

Statistical analysis was conducted using Systat 10.2,Systat Software Inc., Richmond, CA.

Illustration 1. Illustration of approximate locations where greens samples were collected. One cup cutter sample to a depth of 4 inches was collected at each location before and after leaching. A catch can was placed on the green during at each location and the irrigation system was turned on for 3 minutes to determine precipitation rate at each location.

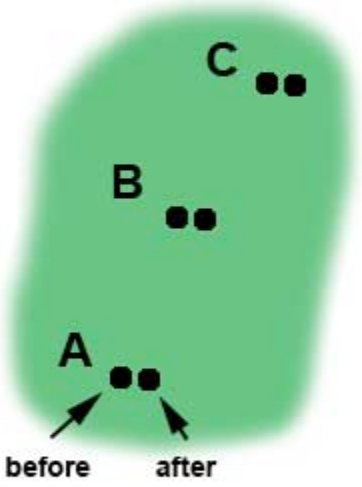
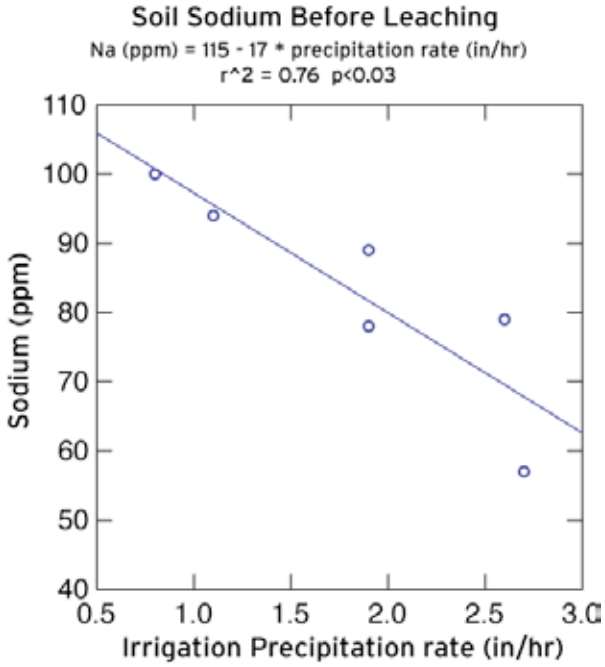


Table 1. Total inches of precipitation delivered at each sample location.
Run time 3.75 hours, 180 degree arc. Precipitation rate was estimated by running the irrigation system for 3 minutes with catch cans at each of the A, B, and C sample locations and computation of precipitation rate in inches per hour (in/hr).

Location	Inches Precipitation and Precipitation rate Green 5	Inches Precipitation and Precipitation rate Green 15
A	7.2 in (1.9 in/hr)	4.1 in (1.1 in/hr)
B	9.8 in (2.6 in/hr)	10.1 in (2.7 in/hr)
C	3.0 in (0.8 in/hr)	7.1 in (1.9 in/hr)

Illustration 2. Sodium levels as a function of precipitation rate compared before and after leaching.



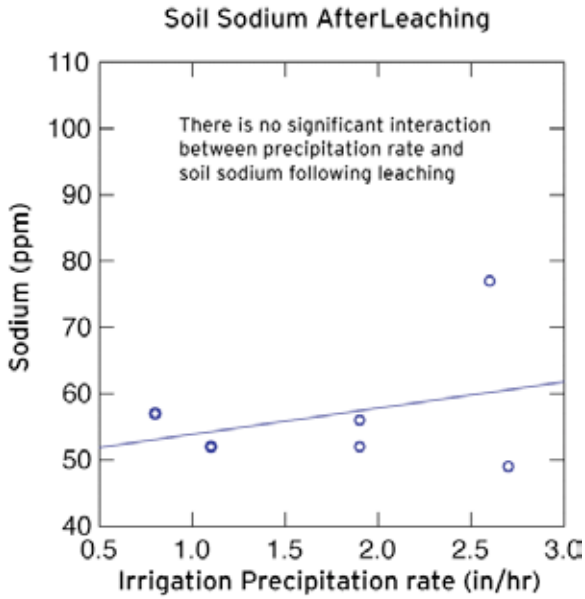


Table 2. Nutritional deficits, pH and EC.

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		Ca	Mg	K2O lb/M	P2O5	Mn lb/M	Fe lb/M	pH	EC dS/m
g 05	c after	0	0	4	0	0.0	0.0	8.70	0.88
g 05	c before	0	0	2	0	0.0	0.7	8.70	1.30
g 05	b after	0	0	6	0	0.0	0.0	8.10	0.92
g 05	b before	0	0	4	0	0.0	0.0	8.50	1.05
g 05	a after	0	0	4	0	0.0	0.0	8.40	0.90
g 05	a before	0	0	3	0	0.0	0.0	8.70	0.96
g 15	a before	0	0	1	0	0.0	0.0	8.60	1.09
g 15	c after	0	0	4	0	0.0	0.0	8.30	0.79
g 15	a after	0	0	4	0	0.0	0.0	8.30	0.86
g 15	c before	0	0	2	0	0.0	0.0	8.60	1.17
g 15	b after	0	0	5	0	0.0	0.0	8.30	0.84
g 15	b before	0	0	2	0	0.0	0.0	8.50	0.94

Table 3. Key soil quality factors Standard extraction full data summary.

Values in the same row that are followed by the same letter are not significantly different based upon a Fisher's Protected LSD with P < 0.10. Electrical conductivity values have been converted to saturated paste equivalents.

	Green 5 Closed		Green 15 Open	
Parameter	**Before Flush**	**After Flush**	**Before Flush**	**After Flush**
pH	8.63 a	8.40 ab	8.57 a	8.30 b
Organic Matter (OM%)	1.1 b	1.4 a	1.1 a	1.2 a
Sulfur (SO4-S ppm)	51 a	31 ab	50 a	24 b
Phosphorous (P Bray ppm)	149 a	162 a	123 a	142 a
Calcium (Ca ppm)	1698 a	1668 a	1300 a	1262 a
Magnesium (Mg ppm)	209 a	213 a	191 a	171 b
Potassium (K ppm)	100 a	62 b	105 a	53 b
Sodium (Na ppm)	86 a	62 b	80 a	52 b
Calcium percentage	76 a	76 a	73 b	76 a
Magnesium percentage	15 b	17ab	18 a	17 ab
Potassium percentage	2.3 b	1.5 c	3.0a	1.6 c
Sodium percentage	3.4 a	2.5 b	3.9 a	2.7 b
Electrical Conductivity (EC dS/m)	1.10 a	0.90 b	1.07 a	0.83 b
Chloride (Cl ppm)	39 a	17 b	35 a	17 b
Boron (B ppm)	1.10 a	1.18 a	0.97 ab	0.83 b
Iron (Fe ppm)	112 c	162 a	136 bc	149 abc
Manganese (Mn ppm)	98 a	99 a	96 a	106 a
Copper (Cu ppm)	5.2 b	6.4 a	4.7 b	4.7 b
Zinc (Zn ppm)	22 ab	27 a	20 b	19 b
Ammonium nitrogen (NH4 ppm)	1.6 ab	1.6 ab	1.9 a	1.4 b
Nitrate nitrogen (NO3 ppm)	10 a	8.3 a	9.5 a	7.0 a
Total nitrogen (TOTN ppm)	12 a	9.9 ab	11 ab	8.4 b

Table 4. Key soil quality factors saturated paste extraction. Significant differences in pre-flush treated vs. non-treated evaluated after flushing and after fertilization.

Values in the same row that are followed by the same letter are not significantly different based upon a Fisher's Protected LSD with $P < 0.05$.

	Green 5 Closed		Green 15 Open	
Parameter	**Before Flush**	**After Flush**	**Before Flush**	**After Flush**
pH	8.6 a	8.5 a	8.4 a	8.4 a
Salts (ppm)	525 a	518 a	245 b	284 b
Chloride (Cl ppm)	45 a	45 a	13 b	15 b
Nitrate (NO3 ppm)	8.8 ab	11 a	5.37 b	7.43 b
Ammonium (NH4 ppm)	0 a	0.067 a	0 a	0.067 a
Bicarbonate (HCO3 ppm)	135 a	135 a	105 a	132 a
Sulfur (S ppm)	55 a	52 a	19 a	18 a
Phosphorus (P ppm)	1.19 b	1.19 b	1.41 a	1.36 a
Calcium (Ca ppm)	54 a	52 a	29 b	36 ab
Calcium (Ca meq)	2.71 a	2.63 a	1.44 b	1.79 ab
Calcium (Ca %)	32 c	32 c	35 b	38 a
Magnesium (Mg ppm)	21 a	21 a	11 b	14 ab
Magnesium (Mg meq)	1.8 a	1.73 a	0.93 b	1.13 ab
Magnesium (Mg %)	21 b	20 b	23 ab	24 a
Potassium (K ppm)	40 a	45 a	15 b	14 b
Potassium (K meq)	1.0 a	1.14 a	0.39 b	0.363 b
Potassium (%)	12 ab	14 a	9.80 b	7.54 b
Sodium (Na ppm)	70 a	64 a	30 b	32 b
Sodium (Na meq)	3.1 a	2.80 a	1.30 a	1.39 a
Sodium (Na %)	36 a	34 a	32 b	30 b
Boron (B ppm)	0.22 a	0.24 a	0.24 a	0.24 a
Iron (Fe ppm)	0.68 ab	0.54 b	0.57 b	1.24 a
Manganese (Mn ppm)	0.077 a	0.090 a	0.070 a	0.147 a
Copper (Cu ppm)	0.057 a	0.060 a	0.043 a	0.057 a
Zinc (Zn ppm)	0.023 ab	0.023 ab	0.017 b	0.040 a
Aluminum (Al ppm)	0.79b	0.66b	0.58b	1.25 a
ESP (estimated)	1.73 a	1.51 a	0.500 b	0.450 b
SAR (estimated)	2.05 a	1.89 a	1.197 b	1.163 b

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%.

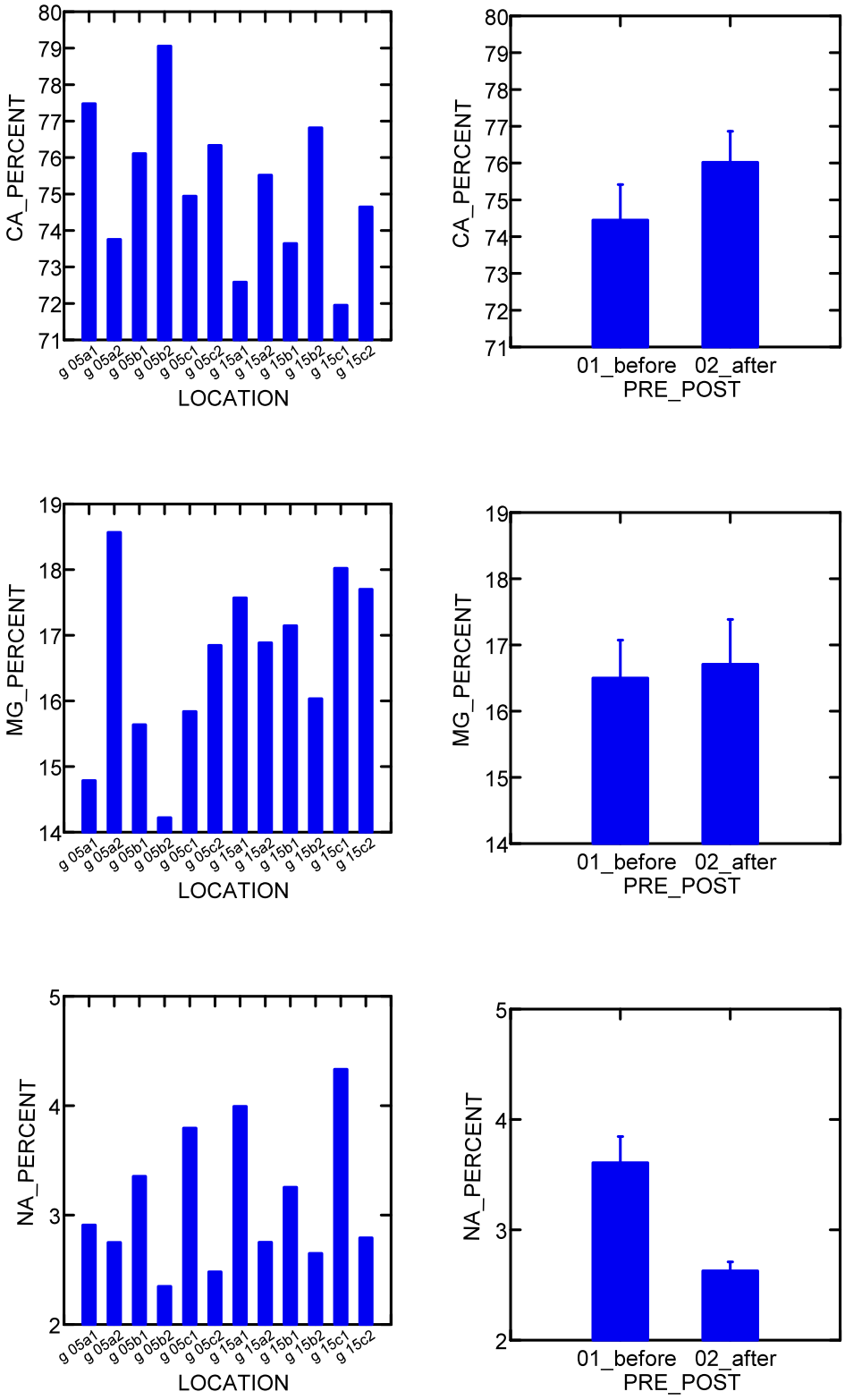


Figure 2. Soil cations reported in parts per million (ppm).
Desired values are calcium (Ca) greater than 750 ppm, magnesium (Mg) greater than 140 ppm, and sodium (Na) less than 110 ppm.

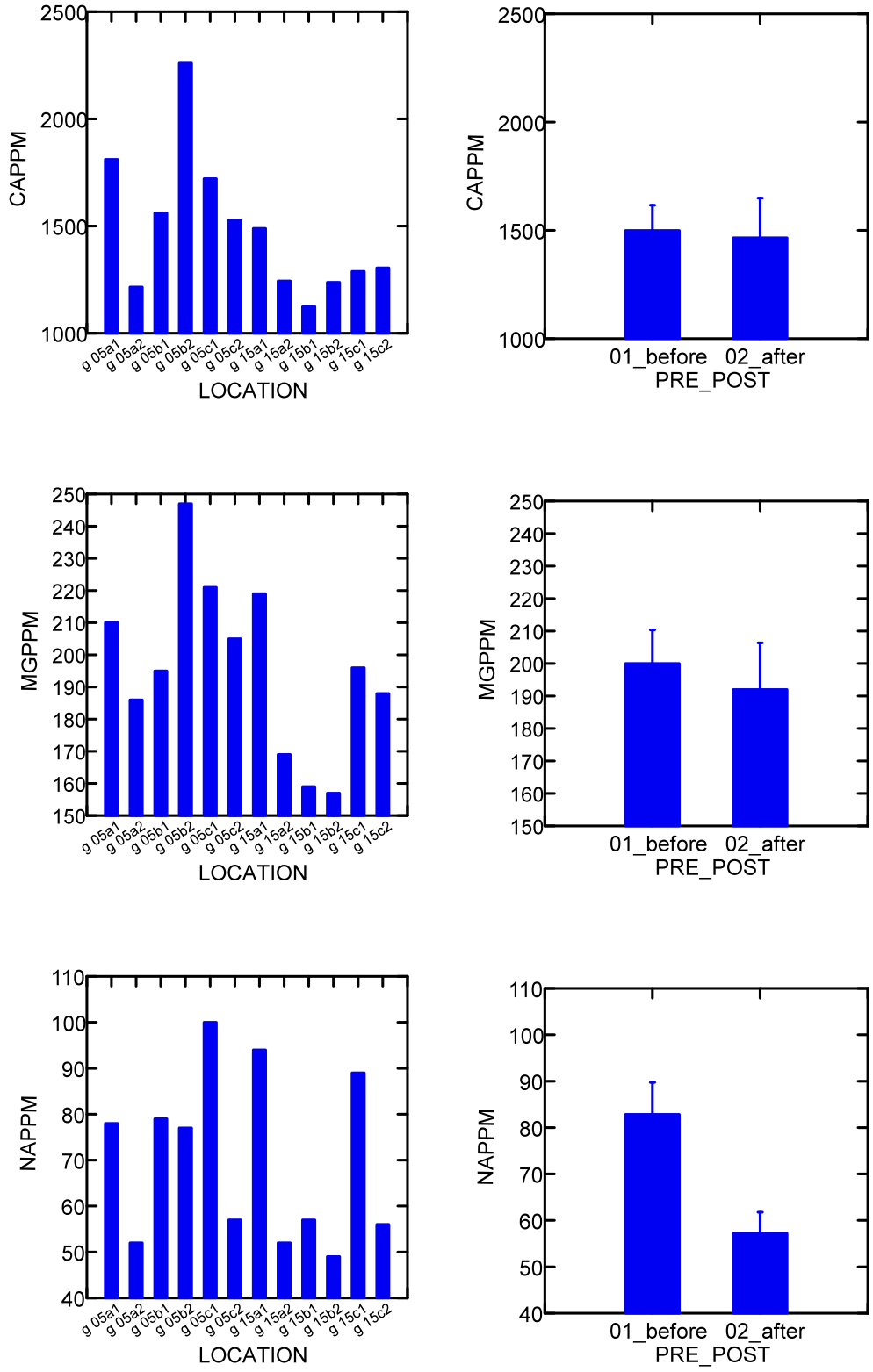


Figure 3. Soil plant available nitrogen values reported in parts per million (ppm), potassium and phosphorus.

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.

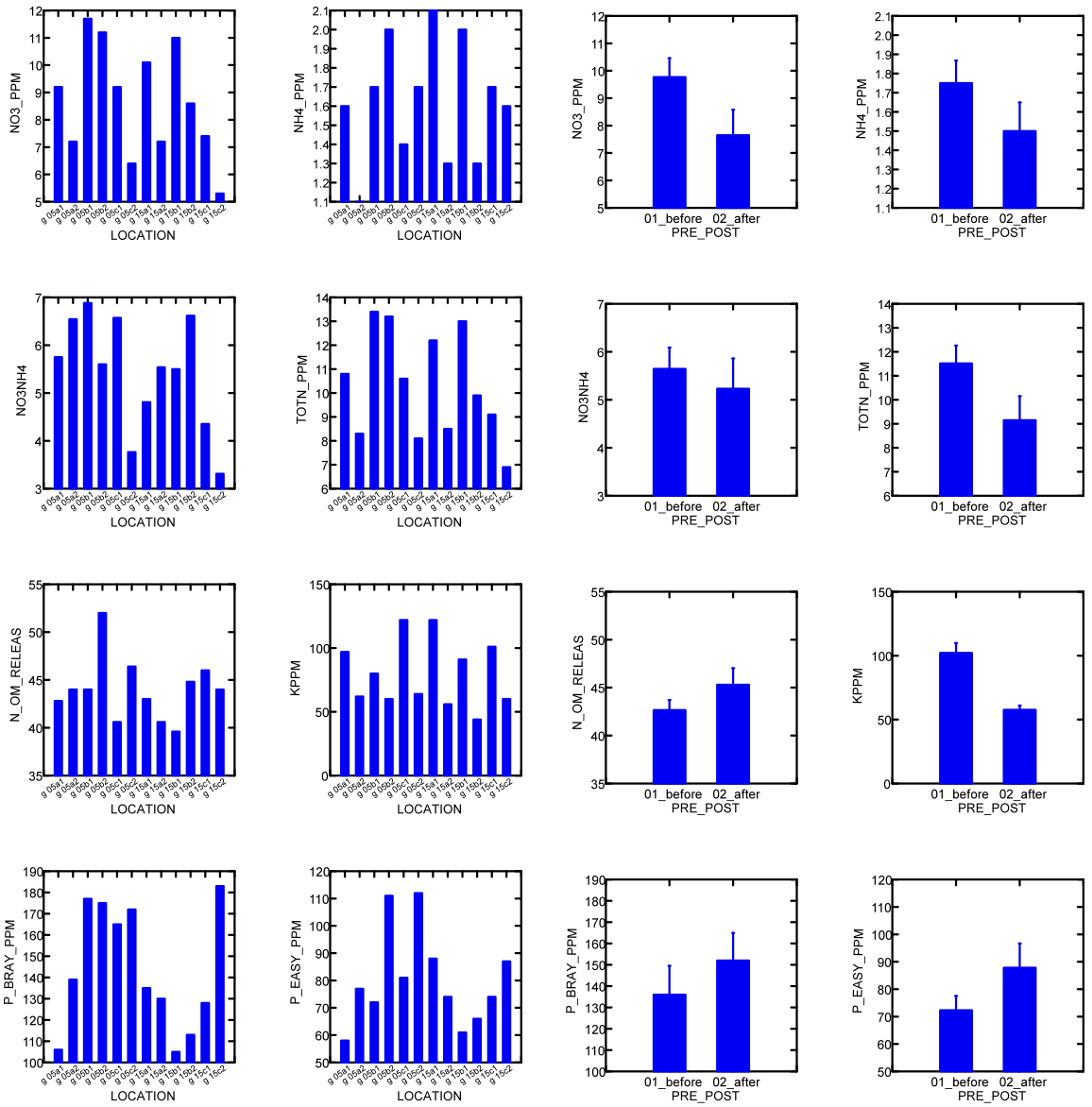


Figure 4. Soil pH, sulfate (ppm), organic matter (percentage) and electrical conductivity (EC dS/m).

Desired values are: pH between 6.2 and 7.4, sulfate between 15 and 200 ppm, organic matter less than 2% for greens and less than 4% for fairways, electrical conductivity less than 3 dS/m for poa greens, less than 4 dS/m for bentgrass greens, less than 6 dS/m for ryegrass and tall fescue, less than 8 dS/m for bermuda and less than 12 dS/m for paspalum.

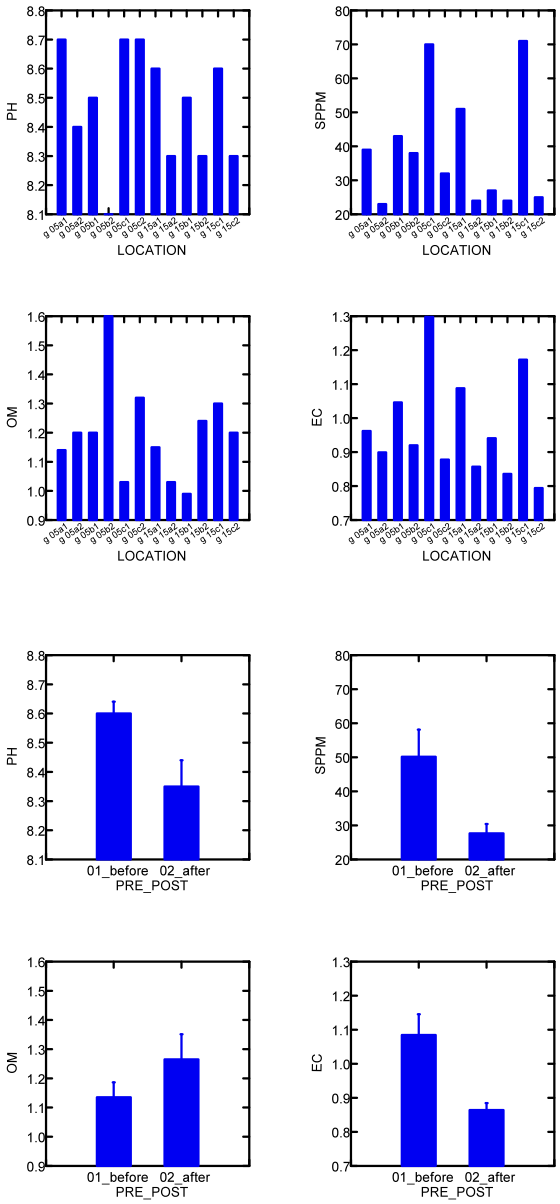
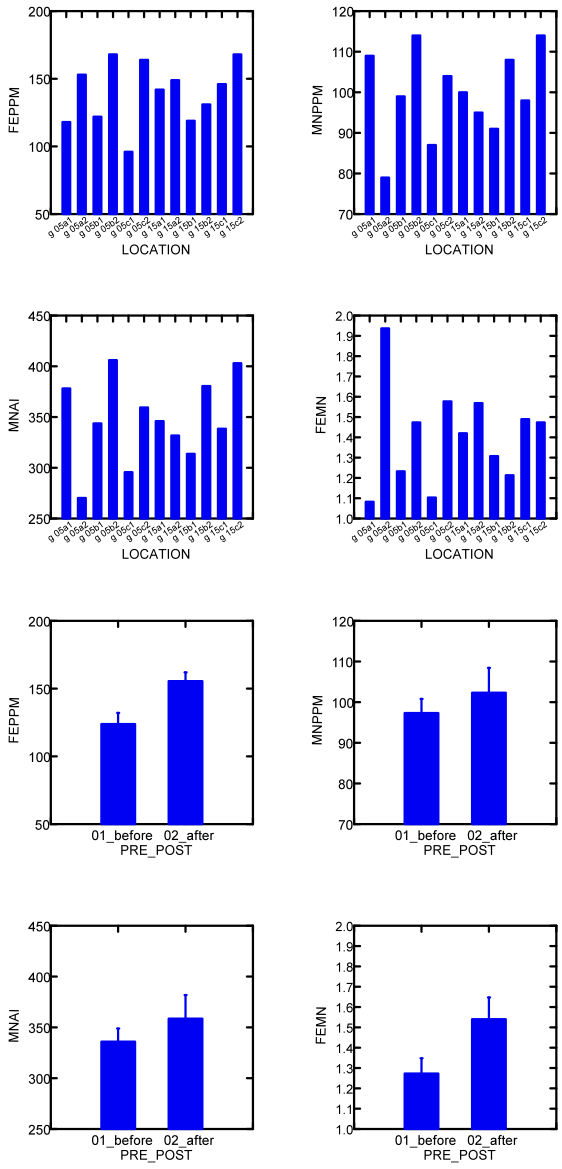


Figure 5. Iron and manganese relationships.

Desired values are currently based upon manganese availability and iron levels needed to balance the iron:manganese ratio. Manganese availability index should exceed 110. Iron should be present at three times the manganese level resulting in a iron:manganese ratio of 3:1.



Standard Soil appraisals

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Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	172			
Phosphate P2O5 ppm:	394	119	0	0
Phosphorus (P) - Olsen (ppm):	44			
Phosphorus (P) - M3 (ppm)	112			
Phosphorus Saturation Index:	0.72	< 1.25		
Sulfur (S) ppm:	32	15-40		
Calcium (Ca) ppm:	1529	1359	0	0
Magnesium (Mg) ppm:	205	144	0	0
Potassium (K) ppm:	64			
Potash (K2O) ppm:	77	175	195	4
Sodium (Na) ppm:	57	< 67		
Aluminum (Al) ppm:	57			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.19	0.4 - 1.5		
Iron (Fe) ppm:	164.00	112		
Manganese (Mn) ppm:	104.00	37	Manganese Availability Index =	359.5
Copper (Cu) ppm:	5.81	0.6 - 2.0		
Zinc (Zn) ppm:	24.96	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	76.15	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	17.02	10 - 20 (12 optimum)
Percent Potassium (% K)	1.63	1.5 - 10
Percent Sodium (%Na)	2.47	0.5 - 3

pH:	8.7	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.3	Nitrate (NO3)	6.4
Soluble Salts (SS) 1:2 (ppm):	115.2	Ammonium (NH4)	1.7
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	8.1
SS estimated saturated paste (ppm)	561.9	NO3:NH4 ratio	3.8
EC estimated saturated paste (dS/m)	0.9	Organic N release	46.4
Total Extractable Cations (meq/100 g)	10.0		
Chloride Cl ppm	15.38		

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Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	165			
Phosphate P2O5 ppm:	378	120	0	0
Phosphorus (P) - Olsen (ppm):	35			
Phosphorus (P) - M3 (ppm)	81			
Phosphorus Saturation Index:	0.74	< 1.25		
Sulfur (S) ppm:	70	15-40		
Calcium (Ca) ppm:	1721	1559	0	0
Magnesium (Mg) ppm:	221	165	0	0
Potassium (K) ppm:	122			
Potash (K2O) ppm:	147	187	80	2
Sodium (Na) ppm:	100	< 67		
Aluminum (Al) ppm:	49			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.09	0.4 - 1.5		
Iron (Fe) ppm:	96.00	112		
Manganese (Mn) ppm:	87.00	37	Manganese Availability Index =	295.7
Copper (Cu) ppm:	4.34	0.6 - 2.0		
Zinc (Zn) ppm:	19.70	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	74.83	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	16.01	10 - 20 (12 optimum)
Percent Potassium (% K)	2.72	1.5 - 10
Percent Sodium (%Na)	3.78	0.5 - 3

pH:	8.7	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.0	Nitrate (NO3)	9.2
Soluble Salts (SS) 1:2 (ppm):	243.2	Ammonium (NH4)	1.4
Electrical Conductivity (EC) 1:2 (dS/m)	0.4	Total available	10.6
SS estimated saturated paste (ppm)	830.7	NO3:NH4 ratio	6.6
EC estimated saturated paste (dS/m)	1.3	Organic N release	40.6
Total Extractable Cations (meq/100 g)	11.5		
Chloride Cl ppm	56.54		

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Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	175			
Phosphate P2O5 ppm:	401	122	0	0
Phosphorus (P) - Olsen (ppm):	32			
Phosphorus (P) - M3 (ppm)	111			
Phosphorus Saturation Index:	0.68	< 1.25		
Sulfur (S) ppm:	38	15-40		
Calcium (Ca) ppm:	2260	1940	0	0
Magnesium (Mg) ppm:	247	205	0	0
Potassium (K) ppm:	60			
Potash (K2O) ppm:	72	211	277	6
Sodium (Na) ppm:	77	< 67		
Aluminum (Al) ppm:	61			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.17	0.4 - 1.5		
Iron (Fe) ppm:	168.00	105		
Manganese (Mn) ppm:	114.00	35	Manganese Availability Index =	406.1
Copper (Cu) ppm:	7.57	0.6 - 2.0		
Zinc (Zn) ppm:	33.39	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	78.91	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.37	10 - 20 (12 optimum)
Percent Potassium (% K)	1.07	1.5 - 10
Percent Sodium (%Na)	2.34	0.5 - 3

pH:	8.1	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.6	Nitrate (NO3)	11.2
Soluble Salts (SS) 1:2 (ppm):	128.0	Ammonium (NH4)	2.0
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	13.2
SS estimated saturated paste (ppm)	588.8	NO3:NH4 ratio	5.6
EC estimated saturated paste (dS/m)	0.9	Organic N release	52.0
Total Extractable Cations (meq/100 g)	14.3		
Chloride Cl ppm	19.78		

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Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	177			
Phosphate P2O5 ppm:	406	120	0	0
Phosphorus (P) - Olsen (ppm):	28			
Phosphorus (P) - M3 (ppm)	72			
Phosphorus Saturation Index:	0.55	< 1.25		
Sulfur (S) ppm:	43	15-40		
Calcium (Ca) ppm:	1562	1393	0	0
Magnesium (Mg) ppm:	195	147	0	0
Potassium (K) ppm:	80			
Potash (K2O) ppm:	96	177	161	4
Sodium (Na) ppm:	79	< 67		
Aluminum (Al) ppm:	56			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.08	0.4 - 1.5		
Iron (Fe) ppm:	122.00	110		
Manganese (Mn) ppm:	99.00	37	Manganese Availability Index =	343.8
Copper (Cu) ppm:	5.21	0.6 - 2.0		
Zinc (Zn) ppm:	21.79	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	75.97	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	15.81	10 - 20 (12 optimum)
Percent Potassium (% K)	2	1.5 - 10
Percent Sodium (%Na)	3.34	0.5 - 3

pH:	8.5	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	11.7
Soluble Salts (SS) 1:2 (ppm):	166.4	Ammonium (NH4)	1.7
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	13.4
SS estimated saturated paste (ppm)	669.4	NO3:NH4 ratio	6.9
EC estimated saturated paste (dS/m)	1.0	Organic N release	44.0
Total Extractable Cations (meq/100 g)	10.2		
Chloride Cl ppm	36.73		

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Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	139			
Phosphate P2O5 ppm:	319	119	0	0
Phosphorus (P) - Olsen (ppm):	23			
Phosphorus (P) - M3 (ppm)	77			
Phosphorus Saturation Index:	0.47	< 1.25		
Sulfur (S) ppm:	23	15-40		
Calcium (Ca) ppm:	1216	1119	0	0
Magnesium (Mg) ppm:	186	140	0	0
Potassium (K) ppm:	62			
Potash (K2O) ppm:	75	160	170	4
Sodium (Na) ppm:	52	< 67		
Aluminum (Al) ppm:	70			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.18	0.4 - 1.5		
Iron (Fe) ppm:	153.00	109		
Manganese (Mn) ppm:	79.00	36	Manganese Availability Index =	270.3
Copper (Cu) ppm:	5.84	0.6 - 2.0		
Zinc (Zn) ppm:	22.62	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	73.61	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	18.77	10 - 20 (12 optimum)
Percent Potassium (% K)	1.92	1.5 - 10
Percent Sodium (%Na)	2.74	0.5 - 3

pH:	8.4	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	7.2
Soluble Salts (SS) 1:2 (ppm):	121.6	Ammonium (NH4)	1.1
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	8.3
SS estimated saturated paste (ppm)	575.4	NO3:NH4 ratio	6.5
EC estimated saturated paste (dS/m)	0.9	Organic N release	44.0
Total Extractable Cations (meq/100 g)	8.2		
Chloride Cl ppm	14.62		

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Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	106			
Phosphate P2O5 ppm:	243	120	0	0
Phosphorus (P) - Olsen (ppm):	18			
Phosphorus (P) - M3 (ppm)	58			
Phosphorus Saturation Index:	0.45	< 1.25		
Sulfur (S) ppm:	39	15-40		
Calcium (Ca) ppm:	1811	1586	0	0
Magnesium (Mg) ppm:	210	168	0	0
Potassium (K) ppm:	97			
Potash (K2O) ppm:	117	189	144	3
Sodium (Na) ppm:	78	< 67		
Aluminum (Al) ppm:	56			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.00	0.4 - 1.5		
Iron (Fe) ppm:	118.00	112		
Manganese (Mn) ppm:	109.00	37	Manganese Availability Index =	378.2
Copper (Cu) ppm:	6.04	0.6 - 2.0		
Zinc (Zn) ppm:	24.21	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	77.33	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	14.94	10 - 20 (12 optimum)
Percent Potassium (% K)	2.12	1.5 - 10
Percent Sodium (%Na)	2.9	0.5 - 3

pH:	8.7	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.1	Nitrate (NO3)	9.2
Soluble Salts (SS) 1:2 (ppm):	140.8	Ammonium (NH4)	1.6
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	10.8
SS estimated saturated paste (ppm)	615.7	NO3:NH4 ratio	5.8
EC estimated saturated paste (dS/m)	1.0	Organic N release	42.8
Total Extractable Cations (meq/100 g)	11.7		
Chloride Cl ppm	23.08		

Los Angeles Country Club **g 15**
08102001res Standard Extraction Methods a before
10/20/2008 Brookside 0070-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	135			
Phosphate P2O5 ppm:	309	120	0	0
Phosphorus (P) - Olsen (ppm):	31			
Phosphorus (P) - M3 (ppm)	88			
Phosphorus Saturation Index:	0.57	< 1.25		
Sulfur (S) ppm:	51	15-40		
Calcium (Ca) ppm:	1489	1392	0	0
Magnesium (Mg) ppm:	219	147	0	0
Potassium (K) ppm:	122			
Potash (K2O) ppm:	147	177	59	1
Sodium (Na) ppm:	94	< 67		
Aluminum (Al) ppm:	66			

Minor Elements	Observed	Desired		
Boron (B) ppm:	1.12	0.4 - 1.5		
Iron (Fe) ppm:	142.00	111		
Manganese (Mn) ppm:	100.00	37	Manganese Availability Index =	346.0
Copper (Cu) ppm:	5.15	0.6 - 2.0		
Zinc (Zn) ppm:	25.17	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	72.42	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	17.75	10 - 20 (12 optimum)
Percent Potassium (% K)	3.04	1.5 - 10
Percent Sodium (%Na)	3.98	0.5 - 3

pH:	8.6	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	10.1
Soluble Salts (SS) 1:2 (ppm):	179.2	Ammonium (NH4)	2.1
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	12.2
SS estimated saturated paste (ppm)	696.3	NO3:NH4 ratio	4.8
EC estimated saturated paste (dS/m)	1.1	Organic N release	43.0
Total Extractable Cations (meq/100 g)	10.2		
Chloride Cl ppm	35.33		

Los Angeles Country Club **g 15**
08102001res Standard Extraction Methods c after
10/20/2008 Brookside 0066-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	183			
Phosphate P2O5 ppm:	419	119	0	0
Phosphorus (P) - Olsen (ppm):	26			
Phosphorus (P) - M3 (ppm)	87			
Phosphorus Saturation Index:	0.50	< 1.25		
Sulfur (S) ppm:	25	15-40		
Calcium (Ca) ppm:	1305	1186	0	0
Magnesium (Mg) ppm:	188	140	0	0
Potassium (K) ppm:	60			
Potash (K2O) ppm:	72	164	183	4
Sodium (Na) ppm:	56	< 67		
Aluminum (Al) ppm:	70			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.91	0.4 - 1.5		
Iron (Fe) ppm:	168.00	107		
Manganese (Mn) ppm:	114.00	36	Manganese Availability Index =	403.0
Copper (Cu) ppm:	5.26	0.6 - 2.0		
Zinc (Zn) ppm:	21.01	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	74.49	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	17.88	10 - 20 (12 optimum)
Percent Potassium (% K)	1.76	1.5 - 10
Percent Sodium (%Na)	2.78	0.5 - 3

pH:	8.3	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	5.3
Soluble Salts (SS) 1:2 (ppm):	89.6	Ammonium (NH4)	1.6
Electrical Conductivity (EC) 1:2 (dS/m)	0.1	Total available	6.9
SS estimated saturated paste (ppm)	508.2	NO3:NH4 ratio	3.3
EC estimated saturated paste (dS/m)	0.8	Organic N release	44.0
Total Extractable Cations (meq/100 g)	8.7		
Chloride Cl ppm	17.33		

Los Angeles Country Club **g 15**
08102001res Standard Extraction Methods a after
10/20/2008 Brookside 0064-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	130			
Phosphate P2O5 ppm:	298	119	0	0
Phosphorus (P) - Olsen (ppm):	24			
Phosphorus (P) - M3 (ppm)	74			
Phosphorus Saturation Index:	0.48	< 1.25		
Sulfur (S) ppm:	24	15-40		
Calcium (Ca) ppm:	1244	1118	0	0
Magnesium (Mg) ppm:	169	140	0	0
Potassium (K) ppm:	56			
Potash (K2O) ppm:	67	160	184	4
Sodium (Na) ppm:	52	< 67		
Aluminum (Al) ppm:	62			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.88	0.4 - 1.5		
Iron (Fe) ppm:	149.00	107		
Manganese (Mn) ppm:	95.00	36	Manganese Availability Index =	331.8
Copper (Cu) ppm:	4.67	0.6 - 2.0		
Zinc (Zn) ppm:	17.64	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	75.39	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	17.07	10 - 20 (12 optimum)
Percent Potassium (% K)	1.74	1.5 - 10
Percent Sodium (%Na)	2.74	0.5 - 3

pH:	8.3	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.0	Nitrate (NO3)	7.2
Soluble Salts (SS) 1:2 (ppm):	108.8	Ammonium (NH4)	1.3
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	8.5
SS estimated saturated paste (ppm)	548.5	NO3:NH4 ratio	5.5
EC estimated saturated paste (dS/m)	0.9	Organic N release	40.6
Total Extractable Cations (meq/100 g)	8.2		
Chloride Cl ppm	13.75		

Los Angeles Country Club **g 15**
08102001res Standard Extraction Methods c before
10/20/2008 Brookside 0072-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	128			
Phosphate P2O5 ppm:	293	119	0	0
Phosphorus (P) - Olsen (ppm):	21			
Phosphorus (P) - M3 (ppm)	74			
Phosphorus Saturation Index:	0.48	< 1.25		
Sulfur (S) ppm:	71	15-40		
Calcium (Ca) ppm:	1288	1215	0	0
Magnesium (Mg) ppm:	196	140	0	0
Potassium (K) ppm:	101			
Potash (K2O) ppm:	122	166	88	2
Sodium (Na) ppm:	89	< 67		
Aluminum (Al) ppm:	63			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.99	0.4 - 1.5		
Iron (Fe) ppm:	146.00	111		
Manganese (Mn) ppm:	98.00	37	Manganese Availability Index =	338.5
Copper (Cu) ppm:	4.98	0.6 - 2.0		
Zinc (Zn) ppm:	19.50	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	71.79	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	18.21	10 - 20 (12 optimum)
Percent Potassium (% K)	2.89	1.5 - 10
Percent Sodium (%Na)	4.31	0.5 - 3

pH:	8.6	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.3	Nitrate (NO3)	7.4
Soluble Salts (SS) 1:2 (ppm):	204.8	Ammonium (NH4)	1.7
Electrical Conductivity (EC) 1:2 (dS/m)	0.3	Total available	9.1
SS estimated saturated paste (ppm)	750.1	NO3:NH4 ratio	4.4
EC estimated saturated paste (dS/m)	1.2	Organic N release	46.0
Total Extractable Cations (meq/100 g)	8.9		
Chloride Cl ppm	42.49		

Los Angeles Country Club **g 15**
08102001res Standard Extraction Methods b after
10/20/2008 Brookside 0065-1

Major Elements and Sodium	Observed	Desired	Deficit Lb/Acre	Deficit Lb/1000 Sq Ft
Phosphorus (P) - Bray II (ppm):	113			
Phosphate P2O5 ppm:	259	119	0	0
Phosphorus (P) - Olsen (ppm):	19			
Phosphorus (P) - M3 (ppm)	66			
Phosphorus Saturation Index:	0.47	< 1.25		
Sulfur (S) ppm:	24	15-40		
Calcium (Ca) ppm:	1238	1094	0	0
Magnesium (Mg) ppm:	157	140	0	0
Potassium (K) ppm:	44			
Potash (K2O) ppm:	53	158	210	5
Sodium (Na) ppm:	49	< 67		
Aluminum (Al) ppm:	58			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.69	0.4 - 1.5		
Iron (Fe) ppm:	131.00	107		
Manganese (Mn) ppm:	108.00	36	Manganese Availability Index =	380.5
Copper (Cu) ppm:	4.13	0.6 - 2.0		
Zinc (Zn) ppm:	16.92	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	76.7	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	16.21	10 - 20 (12 optimum)
Percent Potassium (% K)	1.4	1.5 - 10
Percent Sodium (%Na)	2.64	0.5 - 3

pH:	8.3	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.2	Nitrate (NO3)	8.6
Soluble Salts (SS) 1:2 (ppm):	102.4	Ammonium (NH4)	1.3
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	9.9
SS estimated saturated paste (ppm)	535.0	NO3:NH4 ratio	6.6
EC estimated saturated paste (dS/m)	0.8	Organic N release	44.8
Total Extractable Cations (meq/100 g)	8.0		
Chloride Cl ppm	18.71		

Los Angeles Country Club **g 15**
08102001res Standard Extraction Methods b before
10/20/2008 Brookside 0071-1

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):	17			
Phosphorus (P) - M3 (ppm)	61			
Phosphorus Saturation Index:	0.46	< 1.25		
Sulfur (S) ppm:	27	15-40		
Calcium (Ca) ppm:	1124	1036	0	0
Magnesium (Mg) ppm:	159	140	0	0
Potassium (K) ppm:	91			
Potash (K2O) ppm:	110	155	90	2
Sodium (Na) ppm:	57	< 67		
Aluminum (Al) ppm:	57			

Minor Elements	Observed	Desired		
Boron (B) ppm:	0.79	0.4 - 1.5		
Iron (Fe) ppm:	119.00	110		
Manganese (Mn) ppm:	91.00	37	Manganese Availability Index =	313.8
Copper (Cu) ppm:	3.92	0.6 - 2.0		
Zinc (Zn) ppm:	15.59	1.3 - 3.5		

Cations Expressed as Percent of Total Extractable Cations	Observed	Desired
Precent Calcium (% Ca)	73.46	60 - 70 (68 optimum)
Percent Magnesium (% Mg)	17.32	10 - 20 (12 optimum)
Percent Potassium (% K)	3.05	1.5 - 10
Percent Sodium (%Na)	3.24	0.5 - 3

pH:	8.5	Plant available soil nitrogen ppm	
Percent Organic Matter (% OM):	1.0	Nitrate (NO3)	11.0
Soluble Salts (SS) 1:2 (ppm):	134.4	Ammonium (NH4)	2.0
Electrical Conductivity (EC) 1:2 (dS/m)	0.2	Total available	13.0
SS estimated saturated paste (ppm)	602.2	NO3:NH4 ratio	5.5
EC estimated saturated paste (dS/m)	0.9	Organic N release	39.6
Total Extractable Cations (meq/100 g)	7.6		
Chloride Cl ppm	26.37		

Saturated Paste Soil Appraisals

Los Angeles Country Club **g 05**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10078 c after

		Desired
pH	8.6	6.2 - 6.9
Electrical Conductivity dS/m	0.54	<2.0
Chloride (Cl) ppm:	17	
Nitrate (NO3) ppm:	7.5	5 - 20
Bicarbonate (HCO3)	181.49	< 60
ESP (exchangeable sodium percentage)	0.32	< 5
SAR (Sodium Adsorption Ratio)	1.07	< 4

	ppm	Desired	Percent	Desired
Sulfur:	20.93			
Phosphorous:	1.49	2 - 10		
Calcium:	44.93	60 - 200	38.52	> 20
Magnesium:	18.69	20 - 70	26.41	
Potassium (ppm):	22.19	40-100	9.75	
Sodium	33.9	0 - 30	25.33	< 35

Los Angeles Country Club **g 05**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10077 b after

		Desired
pH	8.5	6.2 - 6.9
Electrical Conductivity dS/m	0.36	<2.0
Chloride (Cl) ppm:	13	
Nitrate (NO3) ppm:	6.5	5 - 20
Bicarbonate (HCO3)	113.77	< 60
ESP (exchangeable sodium percentage)	0.47	< 5
SAR (Sodium Adsorption Ratio)	1.18	< 4

	ppm	Desired	Percent	Desired
Sulfur:	14.09			
Phosphorous:	1.34	2 - 10		
Calcium:	28.85	60 - 200	37.48	> 20
Magnesium:	10.52	20 - 70	22.52	
Potassium (ppm):	10.74	40-100	7.15	
Sodium	29.01	0 - 30	32.84	< 35

Los Angeles Country Club **g 05**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10076 a after

		Desired
pH	8.6	6.2 - 6.9
Electrical Conductivity dS/m	0.36	<2.0
Chloride (Cl) ppm:	13	
Nitrate (NO3) ppm:	5.9	5 - 20
Bicarbonate (HCO3)	111.06	< 60
ESP (exchangeable sodium percentage)	0.4	< 5
SAR (Sodium Adsorption Ratio)	1.13	< 4

	ppm	Desired	Percent	Desired
Sulfur:	16.83			
Phosphorous:	1.2	2 - 10		
Calcium:	29.05	60 - 200	36.27	> 20
Magnesium:	11.53	20 - 70	23.73	
Potassium (ppm):	14.17	40-100	9.07	
Sodium	28.44	0 - 30	30.94	< 35

Los Angeles Country Club **g 05**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10072 c before

		Desired
pH	8.6	6.2 - 6.9
Electrical Conductivity dS/m	1.12	<2.0
Chloride (Cl) ppm:	76	
Nitrate (NO3) ppm:	9.7	5 - 20
Bicarbonate (HCO3)	146.28	< 60
ESP (exchangeable sodium percentage)	1.91	< 5
SAR (Sodium Adsorption Ratio)	2.17	< 4

	ppm	Desired	Percent	Desired
Sulfur:	87.42			
Phosphorous:	1.08	2 - 10		
Calcium:	76.05	60 - 200	32.04	> 20
Magnesium:	32.3	20 - 70	22.43	
Potassium (ppm):	58.32	40-100	12.59	
Sodium	89.71	0 - 30	32.93	< 35

Los Angeles Country Club **g 05**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10071 b before

		Desired
pH	8.6	6.2 - 6.9
Electrical Conductivity dS/m	0.63	<2.0
Chloride (Cl) ppm:	37	
Nitrate (NO3) ppm:	8	5 - 20
Bicarbonate (HCO3)	119.19	< 60
ESP (exchangeable sodium percentage)	1.66	< 5
SAR (Sodium Adsorption Ratio)	2	< 4

	ppm	Desired	Percent	Desired
Sulfur:	42.29			
Phosphorous:	1.17	2 - 10		
Calcium:	44.22	60 - 200	31.63	> 20
Magnesium:	17.58	20 - 70	20.72	
Potassium (ppm):	24.45	40-100	8.96	
Sodium	62.08	0 - 30	38.69	< 35

Los Angeles Country Club **g 05**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10070 a before

		Desired
pH	8.7	6.2 - 6.9
Electrical Conductivity dS/m	0.63	<2.0
Chloride (Cl) ppm:	29	
Nitrate (NO3) ppm:	9.4	5 - 20
Bicarbonate (HCO3)	125.96	< 60
ESP (exchangeable sodium percentage)	1.31	< 5
SAR (Sodium Adsorption Ratio)	1.75	< 4

	ppm	Desired	Percent	Desired
Sulfur:	35.45			
Phosphorous:	1.15	2 - 10		
Calcium:	41.69	60 - 200	32.38	> 20
Magnesium:	15.53	20 - 70	19.88	
Potassium (ppm):	31.04	40-100	12.36	
Sodium	52.28	0 - 30	35.38	< 35

Los Angeles Country Club **g 15**

08102001res Saturated Paste Extraction

10/16/2008 Brookside 10081 c after

		Desired
pH	8.3	6.2 - 6.9
Electrical Conductivity dS/m	0.33	<2.0
Chloride (Cl) ppm:	12	
Nitrate (NO3) ppm:	4.1	5 - 20
Bicarbonate (HCO3)	93.46	< 60
ESP (exchangeable sodium percentage)	0.6	< 5
SAR (Sodium Adsorption Ratio)	1.26	< 4

	ppm	Desired	Percent	Desired
Sulfur:	15.31			
Phosphorous:	1.5	2 - 10		
Calcium:	22.51	60 - 200	32.46	> 20
Magnesium:	8.92	20 - 70	21.2	
Potassium (ppm):	15.18	40-100	11.22	
Sodium	27.96	0 - 30	35.12	< 35

Los Angeles Country Club **g 15**

08102001res Saturated Paste Extraction

10/16/2008 Brookside 10080 b after

		Desired
pH	8.2	6.2 - 6.9
Electrical Conductivity dS/m	0.43	<2.0
Chloride (Cl) ppm:	16	
Nitrate (NO3) ppm:	8.3	5 - 20
Bicarbonate (HCO3)	100.23	< 60
ESP (exchangeable sodium percentage)	0.56	< 5
SAR (Sodium Adsorption Ratio)	1.24	< 4

	ppm	Desired	Percent	Desired
Sulfur:	19.58			
Phosphorous:	1.25	2 - 10		
Calcium:	34.16	60 - 200	39.01	> 20
Magnesium:	11.95	20 - 70	22.48	
Potassium (ppm):	9.79	40-100	5.73	
Sodium	32.94	0 - 30	32.78	< 35

Los Angeles Country Club **g 15**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10079 a after

		Desired
pH	8.4	6.2 - 6.9
Electrical Conductivity dS/m	0.46	<2.0
Chloride (Cl) ppm:	15	
Nitrate (NO3) ppm:	6.1	5 - 20
Bicarbonate (HCO3)	109.71	< 60
ESP (exchangeable sodium percentage)	0.5	< 5
SAR (Sodium Adsorption Ratio)	1.2	< 4

	ppm	Desired	Percent	Desired
Sulfur:	23.39			
Phosphorous:	1.52	2 - 10		
Calcium:	34.94	60 - 200	37.06	> 20
Magnesium:	13.42	20 - 70	23.46	
Potassium (ppm):	16.74	40-100	9.1	
Sodium	32.86	0 - 30	30.37	< 35

Los Angeles Country Club **g 15**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10075 c before

		Desired
pH	8.7	6.2 - 6.9
Electrical Conductivity dS/m	0.85	<2.0
Chloride (Cl) ppm:	45	
Nitrate (NO3) ppm:	5.1	5 - 20
Bicarbonate (HCO3)	117.83	< 60
ESP (exchangeable sodium percentage)	1.72	< 5
SAR (Sodium Adsorption Ratio)	2.04	< 4

	ppm	Desired	Percent	Desired
Sulfur:	60.53			
Phosphorous:	1.01	2 - 10		
Calcium:	52.08	60 - 200	31.07	> 20
Magnesium:	21.15	20 - 70	20.8	
Potassium (ppm):	39.94	40-100	12.21	
Sodium	69.11	0 - 30	35.92	< 35

Los Angeles Country Club **g 15**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10074 b before

		Desired
pH	8.3	6.2 - 6.9
Electrical Conductivity dS/m	0.68	<2.0
Chloride (Cl) ppm:	30	
Nitrate (NO3) ppm:	13.6	5 - 20
Bicarbonate (HCO3)	131.38	< 60
ESP (exchangeable sodium percentage)	1.3	< 5
SAR (Sodium Adsorption Ratio)	1.75	< 4

	ppm	Desired	Percent	Desired
Sulfur:	33.09			
Phosphorous:	1.35	2 - 10		
Calcium:	40.39	60 - 200	30.28	> 20
Magnesium:	15.25	20 - 70	18.84	
Potassium (ppm):	44.93	40-100	17.26	
Sodium	51.48	0 - 30	33.62	< 35

Los Angeles Country Club **g 15**

08102001res Saturated Paste Extraction
10/16/2008 Brookside 10073 a before

		Desired
pH	8.6	6.2 - 6.9
Electrical Conductivity dS/m	0.98	<2.0
Chloride (Cl) ppm:	54	
Nitrate (NO3) ppm:	13.4	5 - 20
Bicarbonate (HCO3)	169.3	< 60
ESP (exchangeable sodium percentage)	1.82	< 5
SAR (Sodium Adsorption Ratio)	2.11	< 4

	ppm	Desired	Percent	Desired
Sulfur:	62.26			
Phosphorous:	1.39	2 - 10		
Calcium:	66.72	60 - 200	32.17	> 20
Magnesium:	25.48	20 - 70	20.25	
Potassium (ppm):	56.62	40-100	13.99	
Sodium	79.96	0 - 30	33.59	< 35

Soil chemical guidelines - Melich III extraction

Table 1. 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
Phosphorus (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.

Soil chemical guidelines - Saturated Paste Extraction

Soil Saturated Paste Analysis desired values for soils that are calcareous or for soils that otherwise can not be effectively analyzed using Melich III extraction methods.

	Desired
PH	6.2 – 6.9
Salt (ppm)	< 1280
Chloride (ppm)	<3,000
Nitrate (ppm)	5 - 20
ammonium	<7
Bicarb HCO3 (ppm)	<60
Phosphorous (ppm)	2 – 10
Calcium	60 – 200 ppm or >20%
Magnesium	20 – 70 ppm
Potassium	40 – 100 ppm
Sodium	0 – 30 ppm or <35%
ESP	<5.0%
SAR	< 4.0