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STUDIES OF THE USE OF NON-POTABLE IRRIGATION ON THE AIR FORCE A--ETC(U)
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FRANK J. SEILER RESEARCH LABORATORY

STUDIES OF THE USE OF NON-POTABLE IRRIGATION ON THE AIR FORCE ACADEMY GOLF COURSE

OCTOBER 1977

AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE

59

FJSRL-TR-77-0008

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Randal A. Gaseor
RANDAL A. GASEOR, Capt, USAF
Project Scientist

Orwyn Sampson
ORWYN SAMPSON, Lt Col, USAF
Director of Research
Dept of Chemistry and Biological Sciences

FOR THE COMMANDER

Charles E. Simon
CHARLES E. SIMON, Lt Col, USAF
Chief Scientist

Ben A. Loving
BEN A. LOVING, Lt Col, USAF
Director, Chemical Sciences

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The use of non-potable water for turf irrigation was investigated at the USAF Academy. From the time of its construction in 1960, the Eisenhower Golf Course has been irrigated with non-potable water. Soil sampling began in 1964. Elevated levels of copper, iron and zinc occurred in soils from the irrigated portions of the golf course. Analysis of selected sites sampled in 3 inch increments to a depth of 18 inches or in 6 inch increments to a depth of 36 inches, indicates a buildup in metal concentration which is inversely proportional to depth. A change in the species composition of the turf has occurred;

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20. Abstract (continued)

the perennial grasses originally established on the greens and tees (seaside bentgrass, Agrostis palustris) and on the fairways (common bluegrass, Poa pratensis; redtop, Agrostis alba; and colonial bentgrass, Agrostis tenuis) have been replaced by shallow rooted annuals, primarily annual bluegrass (Poa annua). Some adverse effects (e.g., yellowing and premature needle drop) have also been observed in Ponderosa Pine (Pinus ponderosa) on and adjacent to irrigated areas. This report reflects the data collected over a 12 year soil sampling period, and includes related water and irrigation pond sediment analysis.

FJSRL-TR-77-0008

STUDIES OF THE USE OF NON-POTABLE IRRIGATION ON THE AIR FORCE ACADEMY GOLF COURSE

by

Capt Randal A. Gaseor
Capt Lawrence J. Biever

October 1977

Department of Chemistry and Biological Sciences
US Air Force Academy, Colorado 80840

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INTRODUCTION

Land application as a method for recycling liquid effluent from municipal and industrial sewage treatment plants is of current interest. This method has been proposed as the final step in waste water treatment because (a) water is reclaimed into the natural water cycle, (b) where irrigation is necessary or desirable sewage effluent can be used as irrigation water, thereby reducing the demand on primary water supplies and water treatment facilities, and (c) land application has potential for reducing commercial fertilizer costs by taking advantage of the nutrients in sewage effluent.

The major use of municipal sewage effluent irrigation has been in turf grass areas, such as municipal parks, golf courses, cemetaries, and highway medians. Many U.S. municipalities and 17 Air Force bases use sewage effluent irrigation (13). However, many of the projects that have been initiated, evaluate the use of sewage effluent in agricultural and forest irrigation (8,9,11). Other studies have been conducted using sewage effluent for reclamation of disturbed land areas such as strip mines and mine spoils. Some of these studies have been designed to determine the effects of overland flow sewage treatment (3,7).

Numerous examples have been reported where effluent irrigation caused changes in soil composition and in soil build up of water inclusions (5,10). Some of these soil changes are acceptable or even desirable; however, in some cases the build up has resulted in the formation of nonproductive soils (4).

Even where well or river water has been used for agricultural irrigation soil build up of water inclusions is a problem. In arid

regions high evaporation rates may accelerate surface accumulation of salts, thus requiring a soil flushing procedure to remove the accumulations. However, management practices for turf grass irrigation do not include a flushing procedure. Sewage effluents generally contain a diversity of inclusions at concentrations not found in normal irrigation water. Some of these inclusions are toxic at low concentrations. Some of them have been demonstrated to be biologically concentrated or even magnified in food chains (6).

The present study was initiated to determine the extent of salt and mineral accumulation and to evaluate the effects that have occurred during 16 years of sewage effluent irrigation on turf grass at the U.S. Air Force Academy.

SITE DESCRIPTION

Location and Climate[1]

The Air Force Academy is located 11 miles north of Colorado Springs in El Paso County, Colorado. It includes 17,900 acres of foothills and plains at an altitude ranging from 6,340 to 8,000 feet on the eastern slope of the Rocky Mountains (Figure 1).

The Air Force Academy lies in an area where a continental-type climate prevails; the summers are long and warm, and the winters are short and occasionally quite cold. The atmospheric pressure is about 76% of that at sea level and the humidity averages about 53.5%. The prevailing climate is characterized by limited and erratic rainfall, high winds in the late fall and early spring, and high evaporation (Table 1). Because of the rain-shadow effect of the Continental Divide, weather is changeable. The high mountains to the west of the Academy block the atmospheric moisture originating from the Pacific Ocean so that the primary source of moisture is the Gulf of Mexico. The transport of atmospheric water from the Gulf into central Colorado is not consistent. Consequently, most of the area has relative low humidity and low precipitation.

Average annual precipitation is 17.5 inches which is slightly more than a semiarid climate. There is a distinct maximum average in the spring and summer of 1.9 and 2.4 inches per month, respectively, and a minimum average of 0.53 inches per month in the winter. The winter minimum is due to the infrequent occurrence of northerly moving storms

[1] A complete description of the location and climate of the Air Force Academy has been reported by Varnes *et al.* (12).

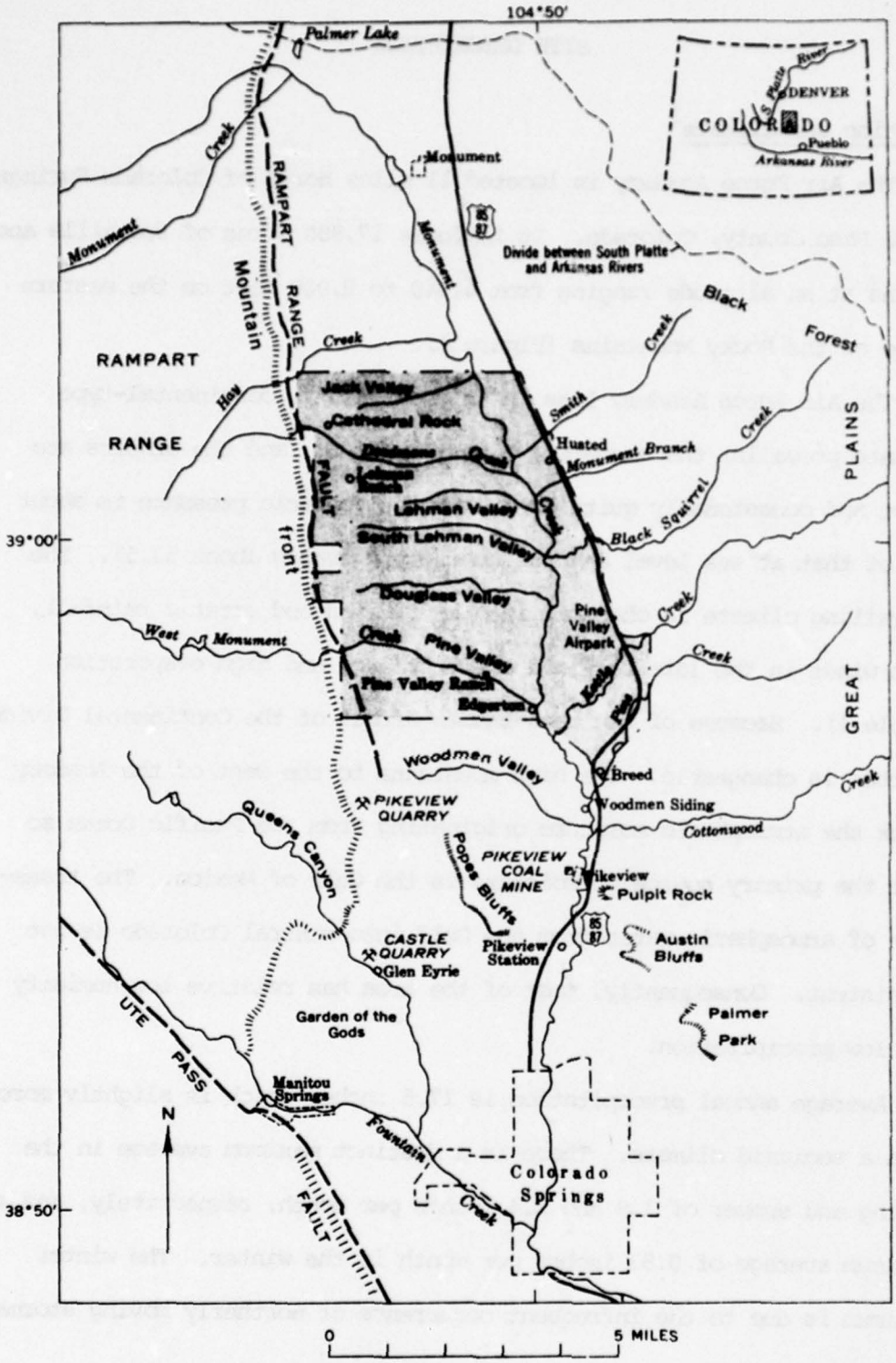

FIGURE 1.—Map showing location of U.S. Air Force Academy, El Paso County, Colo., and vicinity.

Table 1. Weather Data[a]

(From Third Weather Group, US Air Force, Ent Air Force Base, Colorado Springs, Colo., calculated for Air Force Academy site from data gathered at Colorado Springs, Glen Eyrie, Husted, Monument, Auldhurst, and Peterson Field. Data for Glen Eyrie, Husted, and Auldhurst are for years prior to 1931. Data for Colorado Springs and Monument are for periods both before and after 1931. Peterson Field data are for years after 1942.)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation averages:													
Inches	0.40	0.60	1.10	2.20	2.50	1.80	2.90	2.70	1.10	1.00	0.60	0.60	17.50
Number of days	4	3	5	9	10	9	13	12	3	4	3	2	77
Snow (inches)	4	8	13	17	4	0	0	0	1	5	6	8	66
Temperatures, °F:													
Extreme maximum	68	70	74	78	87	97	97	95	91	86	75	71	—
Mean daily maximum	42	43	47	56	65	75	80	79	73	62	51	43	—
Mean daily	27	29	34	42	51	59	65	64	57	46	36	28	—
Mean daily minimum	12	15	20	28	37	44	50	49	41	30	20	13	—
Extreme minimum	-26	-27	-13	-8	16	24	33	36	17	-9	-16	-25	—
Humidity averages (percent):													
Local time:													
0600	60	65	65	70	70	60	70	70	65	65	60	60	—
1200	40	40	40	45	45	35	40	40	35	35	40	40	—
1800	55	50	45	50	50	40	50	45	40	45	55	50	—
2400	55	60	65	65	70	60	65	70	60	55	60	60	—

[a]Taken from: Varnes, D.J., Scott, G.R., Cardwell, W.D.E, and Jenkins, E.D. 1967. General and Engineering Geology of the United States Air Force Academy Site, Colorado. Geological Survey Professional Paper 551. United States Government Printing Office, Washington (reference 12).

which bring Gulf moisture to the region. The average annual snowfall measures 66 inches per year. The winter snows are preserved on the north facing slopes until the warmer spring days when the water soaks into the ground before plant growth begins.

Spring and summer bring much more frequent movement of air from the south and more solar radiation to produce convective showers. In 13 years of record, the largest precipitation was 2.9 inches in July, while 0.4 inches was recorded for the January average (Table 1).

A large portion of the precipitation occurs in short, often destructive, cloud bursts which are generally localized. This rainfall is so rapid that most of the moisture is lost to runoff. Average precipitation values are made up of many years slightly smaller than normal and a few years above normal. Most years will be below the average.

Extremes of temperature (Table 1) can take place within 24 hours, but extended periods of subzero weather or of temperatures above 100°F are not common. The average date of the last killing frost at Colorado Springs is April 27, and of the first, October 14. The ground becomes frozen about November 30, but the depth of frost penetration depends on the exposure and altitude. The frost goes deeper and stays longer on north facing slopes. The ground freezes to a depth of 2 feet in an average winter and rarely to 4 feet.

Freeze data are dependent upon minimum temperatures which can vary considerably over short distances since cold air tends to flow down to low elevations and become trapped. Intense cold air pools can form in canyons, river valleys and low spots in flat terrain.

Mean wind speed at the Academy is 9 knots, however, wind speeds can be highly variable (Table 2). The prevailing wind direction is

Table 2. Wind Speed Information for the US Air Force Academy[a]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	28	32	43	29	24	28	18	25	23	28	28	24
Mean	6.6	9.1	11.5	8.7	7.3	6.4	7	6.8	6.5	6.2	6.5	7.2
Minimum	0	0	0	0	0	0	0	0	0	0	0	0

[a]Wind speed given in knots: 1 knot = 1.14 statute miles

south-southeast. In the immediate lee of the Rockies a type of wind event, known as a Chinook, is frequently experienced. Measurements of the wind over both space and time are limited but they do indicate that speeds exceed 60 mph several times a year and it is possible that some locations occasionally exceed 100 mph.

Geology and Soils

Precambrian Pikes Peak Granite forms the mountains of the Rampart Range at the west edge of the Academy area. The predominant bedrock within the Academy area is Dawson Arkose of Cretaceous and Paleocene age. The Dawson Arkose consists about equally of coarse arkosic sandstone and of interbedded lenticular siltstone and clay.

The several stages of downcutting and alleviation have produced gravel-covered bedrock surfaces at three levels. Remnants of these pediments that trend eastward from the mountain front form narrow fingerlike mesas at two levels and broader valleys at the third and youngest level. These ridges and valleys terminate at the principal line of drainage, Monument Creek, which flows southward through the eastern part of the Academy grounds.

The soil type analyzed has been reported as sandy loam.

A complete description of the geology of the Air Force Academy site has been reported by Varnes et al. (12).

Golf Course and Irrigation System

The Eisenhower Golf Course is located in South Lehman Valley at the Academy (Figures 1 and 2). The first course was opened in 1960 with 18 holes and a driving range (Figure 3). In construction of the course,

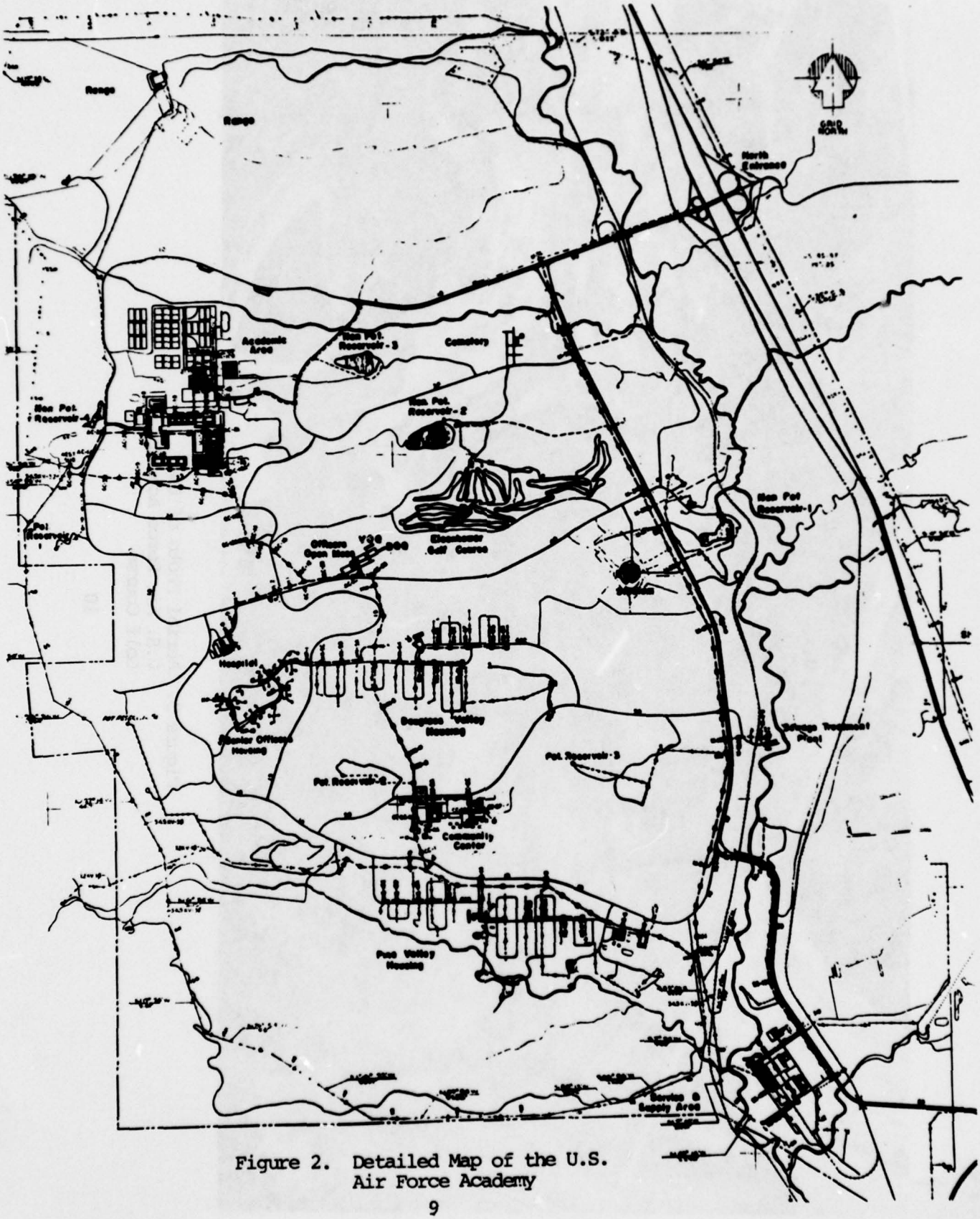

Figure 2. Detailed Map of the U.S. Air Force Academy

Figure 3. Aerial Photo of the U.S. Air Force Academy Golf Course

provision was made for sprinkler irrigation with non-potable water. Modification in 1975 relocated sprinkler heads in order to avoid irrigation of trees in a number of areas and to more efficiently distribute water in turf areas. Irrigation with non-potable water has been continuous on this course since the system was activated in 1960.

Irrigation Water Source

Irrigation water for the golf course originates from the Air Force Academy Sewage Treatment Plant. The plant includes both full primary and secondary treatment (1). Sewage effluent is pumped sequentially through a series of non-potable reservoirs. These have been identified as non-potable reservoirs 1, 2, 3, and 4, as defined by the pumping sequence (Figure 2). Reservoirs 1 and 2 are aeriated. Water for golf course irrigation is taken from non-potable reservoir 2.

Plant Species on the Eisenhower Golf Course

The dominant tree species on the golf course in Ponderosa Pine (Pinus ponderosa). Fairways have been seeded with common bluegrass (Poa pratensis), redtop (Agrostis alba) and colonial bentgrass (Agrostis tenuis). Greens and tees have been seeded with seaside bentgrass (Agrostis palustris).

Repeated botanical observations have been made by Air Force Academy personnel (unpublished data). These observations have indicated a gradual shift of species density on greens, tees, and fairways from the preferred seeded perennial grasses to the less desirable, shallow rooted annual bluegrass (e.g., Poa annua). In fact, it is estimated that some areas are now more than 90% annual bluegrass.

In addition, there has been a gradual increase in excessive needle yellowing and premature needle drop observed in the irrigated Ponderosa Pine.

SAMPLING PROTOCOL AND ANALYTICAL RESULTS

Water Composition

In 1975 a water sampling program was initiated for the Academy Golf Course. Samples were drawn from the irrigation system during a period of active irrigation. These samples were analyzed by the USAF Occupational and Environmental Health Laboratory, Kelly AFB, Texas, and the results are presented in Table 3.

Water Application Rates

Although quantitative application rates for irrigation water are not available, the following estimate has been provided by the Golf Course Superintendent:

a. Approximately 110 acres of the golf course are irrigated.

b. There are 753 sprinkler heads used to irrigate the golf course.

c. Each sprinkler head output is 28 gallons per minute.

d. Each sprinkler head runs approximately 15 minutes per night for approximately 180 days per year.

e. The annual irrigation rate is 1.58 acre feet per year[2].

Nutrient Application Rates

Estimated application rates for the nutrient content of the irrigation water are given in Table 4[3]. They are presented only to give an "order of magnitude" estimate for the rate of application.

---

[2]The calculation for water application rate is as follows:
(753 heads)(28 gal/min/head)(15 min/day)(180 days/yr) ÷ (110 acres) = 517,516 gal/acre/yr
517,516 gal/acre/yr ÷ 328,012 gal/acre ft = 1.577 acre ft/yr

[3]The calculation for water inclusions is in pounds per acre per year. Note that they are based on only three water samples and the estimated water application rate.

Table 3. Irrigation Water Analysis

Test Run	14 Aug 75[a]	20 Oct 75[a]	20 Oct 75[a]	Average[a]
Ammonia Nitrogen	19	<0.2	17.5	12.2
Cadmium	<0.01	<0.01	<0.01	<0.01
Chemical Oxygen Demand	28	11	33	24
Chlorides	28	28	24	27
Chromium (Hexavalent)	<0.01	<0.01	<0.01	<0.01
Chromium (Total)	<0.05	<0.05	<0.05	<0.05
Color	25 units	20 units	20 units	22 units
Copper	<0.02	<0.02	<0.02	<0.02
Cyanides	<0.01	<0.01	<0.01	<0.01
Dissolved Solids	189	242	318	250
Fluorides	0.5	0.6	1	0.7
Iron	0.33	0.12	0.2	0.22
Lead	<0.05	<0.05	<0.05	<0.05
Manganese	0.2	<0.05	<0.05	0.1
Mercury	<0.005	<0.005	<0.005	<0.005
Nitrates	<1	1	50	17
Nitrate Nitrogen	<0.02	0.07	0.07	0.05
Oils and Greases	0.4	0.6	0.6	.53
Phenols	0.205	0.03	<0.001	0.079
Phosphates	23.5	18.2	18.8	20.2
Silver	<0.01	<0.01	<0.01	<0.01
Sulfates	32	35	34	34
Surfactants	0.5	0.3	0.2	0.3
Total Organic Carbon	10	2	14	9
Turbidity	2 units	4 units	4 units	3 units
Zinc	0.05	0.1	0.05	0.07

[a]All results in mg/l unless otherwise noted.

Table 4. Nutrient Application Rate Estimates

Test Run	Nutrient[a] Application Rate lb/acre/yr
Ammonia Nitrogen	52.6
Cadmium	0.04
Chemical Oxygen Demand	--
Chlorides	116
Chromium (Hexavalent)	0.04
Chromium (Total)	0.22
Color	--
Copper	0.09
Cyanides	0.04
Dissolved Solids	1,077
Fluorides	3.0
Iron	0.95
Lead	0.22
Manganese	0.4
Mercury	0.022
Nitrates	73
Nitrite Nitrogen	0.22
Oils and Greases	22.8
Phenols	0.340
Phosphates	87.1
Silver	0.04
Sulfates	147
Surfactants	1.3
Total Organic Carbon	39
Turbidity	--
Zinc	0.30

[a]To determine the amount of chemical effluent deposited in lb/acre/year, the water concentrations obtained by analysis at the Environmental Health Laboratory at Kelly AFB are treated as follows:

(mg of chemical/l)(.001 g/mg)(.0022 lb/g)(1,959,012 l/acre/year) = lb of chemical/acre/year

Soil Analysis

Soil analysis data are available since 1964 for turf areas (greens, tees and fairways). All soil analyses except those conducted in 1971 and 1972 were performed by the Cooperative Extension Service and Experimental Station Soil Testing Laboratory, Colorado State University, Fort Collins, Colorado. The 1971 and 1972 sample analyses were performed by the Turf Service Bureau, Sewage Commission, City of Milwaukee, Wisconsin.

Two sampling techniques have been employed for the collection of soil samples. From 1964 through 1975, composite samples were taken to a 3 inch depth using a 1 inch diameter soil probe. The results are presented in Table 5. Soil samples taken on greens, tees, and fairways in late 1975 and 1976, were taken with a 3 inch diameter soil auger. In 1975 the samples were collected to a depth of 36 inches in 3 inch increments and to a depth of 12 inches in 1976. These results are shown in Table 6.

Soil samples were also taken from adjacent forested areas with the soil auger. In 1975, the samples were taken in 6 inch increments to a depth of 36 inches. In 1976, the samples were taken in 3 inch increments to a depth of 18 inches. The results of these samples are shown in Table 7. The results labeled control in Table 7a are from a non-irrigated natural forest site. The samples labeled fresh water control in Table 7b are from a fresh water irrigated site on the Academy grounds. All other samples (Table 7) are from sites which have been under irrigation since 1960 and which show stress.

Table 5a. Golf Course Irrigated Turf Areas as a Function of Location (Tees)

	T-1	T-2	T-3	T-4	T-5	T-6	T-7	T-8	T-9	T-10	T-10	T-11	T-11	T-12	T-12
Year	1975	1975	1975	1975	1975	1975	1975	1975	1975	1964	1975	1964	1975	1964	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	7.0	6.7	6.6	6.4	6.7	6.5	6.7	6.6	6.5	7.0	6.2	7.0	6.6	7.2	6.4
pH (paste)															
Salts, mmhos/cm	.7	.5	.6	.7	1.2	.6	.5	.4	.7	.9	1.3	.8	.9	.9	.4
Nitrates (ppm)	72	64	91	66	56	35	50	58	53		87		66		60
P_2O_5 (ppm)										95		96		100	
P (ppm)	80+	50	67	47	61	45	74	54	64		73		71		62
K_2O (ppm)										152		150		110	
K (ppm)	165	192	236	161	153	109	152	143	210		166		129		130
Zn (ppm)	9.99+	9.99+	9.99+	9.99+	9.99+	9.99+	9.99+	9.99+	7.30		9.99+		7.1		9.8
Fe (ppm)	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+		40.0+		40.0+		40.0+
Gypsum	.9	.9	.9	.9	.9	.9	.9	.9	.9		.9		.9		.9
Cu (ppm)	2.4	1.2	2.1	1.6	1.4	1.0	1.1	1.0	.8		1.5		1.1		1.8
Lime	Low	Low	Low	Low	Low	Low	Low	Low	Low	.1	Low	.2		.2	Low
Organic Matter (%)	6.6	4.7	6.3	6.2	3.7	2.6	5.8	3.8	2.9	1.8	4.3	2.0	3.1	2.3	4.8

Table 5a. Continued

	T-13	T-13	T-14	T-14	T-15	T-15	T-16	T-16	T-17	T-17	T-17	T-18	T-18
Year	1964	1975	1964	1975	1964	1975	1964	1975	1964	1970	1975	1964	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	7.3	6.7	7.3	6.5	7.0	6.4	7.0	6.5	6.8		6.3	6.7	6.4
pH (paste)										8.5			
Salts, mmhos/cm	.8	1.3	.6	.4	.5	.7	.6	1.5	.6	.5	1.7	.9	.4
Nitrates (ppm)		70		83		67		74		1.5	99+		48
P_2O_5 (ppm)	42		79		97		101		67			69	
P (ppm)		69		74		64		80		40.8	80+		58
K_2O (ppm)	125		150		165		130		115			175	
K (ppm)		123		116		138		206		78	199		102
Zn (ppm)		8.0		8.2		8.4		9.99+		5.26	9.99+		7.5
Fe (ppm)		40.0+		40.0+		40.0+		40.0+		40.0+	40.0+		40.0+
Gypsum		.9		.9		.9		.9		<1.0	.9		.9
Cu (ppm)		1.5		1.3		1.3		3.0			3.6		1.3
Lime	.1	Low	.1	Low	.1	Low	.2		.1	0.0	Low	0.0	Low
Organic Matter (%)	2.0	4.2	2.5	4.3	1.9	4.0	1.9	7.0	1.8	2.5	6.9	1.1	2.2

Table 5b. Golf Course Irrigated Turf Areas as a Function of Location (Fairways)

	F-1	F-2	F-2	F-3	F-4	F-5	F-6	F-7	F-8	F-8	F-9	F-10	F-10	F-11	F-11
Year	1975	1968	1975	1975	1975	1975	1975	1975	1968	1975	1975	1964	1975	1964	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	5.8	6.2	6.0	6.0	6.5	6.7	6.5	6.8		6.9	5.7	6.9	6.1	6.6	6.2
pH (paste)									6.1						
Salts, mmhos/cm	.9	1.1	1.8	.5	.7	.7	.8	.5	1.4	.6	.5	.5	.8	1.1	.5
Nitrates (ppm)	37		29	33	33	34	32	37		40	31		39		22
P_2O_5 (ppm)		101							150+			121		140	
P (ppm)	62		64	80+	74	42	71	55		65	69		80+		65
K_2O (ppm)		212							290			197		260	
K (ppm)	122		174	223	196	100	253	91		269	176		286		159
Zn (ppm)	9.99+	10.0+	2.7	9.99+	8.0	4.0	4.5	9.99+	10.0+	6.8	7.3		6.6		1.6
Fe (ppm)	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+	40.0+		40.0+		40.0+
Gypsum	.9		.9	N/A	.9	.9	.9	.9		.9	.9		.9		.9
Cu (ppm)	.9		.4	1.1	.8	.4	.8	.5		1.0	.8		.9		.9
Lime	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	.1	Low	0.0	Low
Organic Matter (%)	1.7	1.5	1.5	2.3	2.3	1.3	2.6	1.8	2.8	2.3	2.2	1.8	3.4	3.8	1.5

Table 5b. Continued

	F-12	F-12	F-12	F-13	F-13	F-14	F-14	F-15	F-15	F-16	F-16	F-17	F-17	F-18	F-18	F-18
Year	1964	1968	1975	1964	1975	1964	1975	1964	1975	1964	1975	1964	1975	1964	1968	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	7.0		6.0	7.0	6.7	6.8	5.8	7.0	6.0	7.1	6.5	6.8	6.2	6.6		6.3
pH (paste)		7.0													6.2	
Salts, mmhos/cm	.9	1.4	.6	.6	.5	.6	.7	.4	.8	.6	2.8	.6	.7	.6	.6	1.2
Nitrates (ppm)			29		51		35		46		99+		37			44
P_2O_5 (ppm)	97	55		86		115		106		115		100		113	150+	
P (ppm)			50		80+		80+		74		76		80+			80+
K_2O (ppm)	140	160		215		197		130		200		151		160	90	
K (ppm)			89		170		234		203		200		135			196
Zn (ppm)		10.0+	2.2		4.0		2.2		3.5		7.0		4.3		4.8	6.1
Fe (ppm)		40.0+	38.5		40.0+		40.0+		40.0+		40.0+		40.0+		40.0+	40.0+
Gypsum			.9		.9		.9		.9		.9		.9			.9
Cu (ppm)			.7		.7		.4		.7		2.1		.8			.8
Lime	.1	Low	Low	.1	Low	.1	Low	0.0	Low	0.0	Low	.2	Low	.2	Low	Low
Organic Matter (%)	2.6	2.2	1.4	2.4	2.0	1.5	1.6	2.1	1.7	2.1	5.8	1.1	1.5	1.6	2.6	2.5

Table 5c. Golf Course Irrigated Turf Areas as a Function of Location (Green #1)

Year	1965	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	7.8	6.3						6.8
pH (paste)			5.7	5.7	6.5	6.9	7.1	
Salts, mmhos/cm	.9	1.1	.8			1.0	2.9	1.0
Nitrates (ppm)						2	2	99+
P_2O_5 (ppm)	84	96	150+					
P (ppm)				465	305	65	80+	80+
K_2O (ppm)	90	225	258	380	1220			
K (ppm)						500+	500+	380
Zn (ppm)			10.0+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				970	1260			
Na (ppm)				330				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								4.6
Lime	0.0	0.0	Low			Low	Low	Low
Organic Matter(%)	5.8	4.1	11.0			5.0+	5.7	4.3
Ca (ppm)				3200	13200			

Table 5d. Golf Course Irrigated Turf Areas as a Function of Location (Green #2)

Year	1965	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	8.1	6.6						7.2
pH (paste)			5.8	5.8	6.5	7.1	6.9	
Salts, mmhos/cm	.7	1.3	1.4			1.0	2.6	1.2
Nitrates (ppm)						2	1	99+
P_2O_5 (ppm)	92	77	150+					
P (ppm)				435	315	69	80+	80+
K_2O (ppm)	85	148	270	380	1325			
K (ppm)						500+	500+	434
Zn (ppm)			10.0+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				950	1260			
Na (ppm)				330				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								6.5
Lime	0	0	Low			Low	Low	Low
Organic Matter(%)	4.7	4.5	10.6			5.0+	5.2	6.7
Ca (ppm)				3350	12600			

Table 5e. Golf Course Irrigated Turf Areas as a Function of Location (Green #3)

Year	1965	1966	1968	1971	1972	1973	1974	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.8	6.5							
pH (paste)			5.5	5.7	6.3	7.0		6.5	9.1
Salts, mmhos/cm	.9	1.4	1.0			1.1		2.9	.6
Nitrates (ppm)						16			90
P_2O_5 (ppm)	82	92	150+						
P (ppm)				575	315	67		80+	80+
K_2O (ppm)	75	198	253						
K (ppm)				480	1325	490		500+	368
Zn (ppm)			10+			9.99+		9.99+	9.99+
Fe (ppm)			40.0+			40.0+		40.0+	40.0+
Mg (ppm)				850	1260				
Na (ppm)				240					
Chlorides				250					
Sulfates				Trace					
Gypsum									.9
Cu (ppm)									8.9
Lime	0	0	Low			Low		Low	Low
Organic Matter(%)	5.9	5.1	10.4			5.0+		6.4	7.0
Ca (ppm)				2700	16200				

Table 5f. Golf Course Irrigated Turf Areas as a Function of Location (Green #4)

Year	1965	1966	1968	1971	1972	1973	1974	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.4	6.4						.	6.8
pH (paste)			5.4	5.45	6.3	6.7		6.9	
Salts, mmhos/cm	1.4	1.1	1.0			1.4		2.0	1.8
Nitrates (ppm)						30		3	98
P_2O_5 (ppm)	94	76	150						
P (ppm)				465	315	61		80+	76
K_2O (ppm)	95	163	500+	320	890				
K (ppm)						445		500+	343
Zn (ppm)			10+			9.99+		9.99+	9.99+
Fe (ppm)			40.0+			40.0+		40.0+	40.0+
Mg (ppm)				800	800				
Na (ppm)				210					
Chlorides				250					
Sulfates				Trace					
Gypsum									.9
Cu (ppm)									4.9
Lime	0	.1	Low			Low		Low	Low
Organic Matter(%)	5.6	4.4	9.2			3.7		7.0	4.5
Ca (ppm)				2400	4800				

Table 5g. Golf Course Irrigated Turf Areas as a Function of Location (Green #5)

Year	1965	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.8	6.5						6.9
pH (paste)			5.5	5.4	6.4	6.8	6.6	
Salts, mmhos/cm	1.3	1.5	1.0			1.3	3.0	.6
Nitrates (ppm)						6	3	77
P_2O_5 (ppm)	79	77	150+					
P (ppm)				445	445	69	80+	74
K_2O (ppm)	70	165	500+	285	1325			
K (ppm)						490	500+	317
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				900	1390			
Na (ppm)				250				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								3.6
Lime	0	0	Low			Low	Low	Low
Organic Matter(%)	4.9	4.9	8.0			5.0	7.0+	4.1
Ca (ppm)				2300	11700			

Table 5h. Golf Course Irrigated Turf Areas as a Function of Location (Green #6)

Year	1965	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.8	6.7						7.0
pH (paste)			5.5	5.8	6.6	7.0	6.4	
Salts, mmhos/cm	1.1	1.3	1.0			1.0	2.8	.9
Nitrates (ppm)						4	2	80
P_2O_5 (ppm)	73	72	150+					
P (ppm)				435	375	61	80+	76
K_2O (ppm)	75	143	500+	320	1010			
K (ppm)						403	500+	303
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				1000	1390			
Na (ppm)				300				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								3.6
Lime	.1	.1	Low			Low	Low	Low
Organic Matter(%)	4.9	4.9	8.0			5.0+	6.2	4.1
Ca (ppm)				3100	15400			

Table 5i. Golf Course Irrigated Turf Areas as a Function of Location (Green #7)

Year	1965	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.8	6.7						6.8
pH (paste)			5.6	5.1	6.5	6.9	7.3	
Salts, mmhos/cm	1.0	1.3	1.1			1.1	2.0	1.0
Nitrates (ppm)						10	2	93
P_2O_5 (ppm)	85	90	150					
P (ppm)				355	425	58	80+	69
K_2O (ppm)	75	225	500+	340	1615			
K (ppm)						500+	500+	417
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				625	1200			
Na (ppm)				150				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								4.8
Lime	.1	.1	Low			Low	Low	Low
Organic Matter(%)	5.1	.5	9.2			5.0+	6.4	4.2
Ca (ppm)				2200	13000			

Table 5j. Golf Course Irrigated Turf Areas as a Function of Location (Green #8)

Year	1965	1966	1968	1970	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.4	6.8							7.0
pH (paste)			5.4	7.1	5.55	6.7	6.9	7.5	
Salts, mmhos/cm	1.0	1.1	.9	.7			1.1	1.4	1.0
Nitrates (ppm)				4.8			5	30	90
P_2O_5 (ppm)	77	60	150+						
P (ppm)				57	450	415	64	80+	70
K_2O (ppm)	70	138	500+		400	1550			
K (ppm)				105			500+	500+	429
Zn (ppm)			10+	6.95			9.99+	9.99+	9.99+
Fe (ppm)			40.0+	40.0+			40.0+	40.0+	40.0+
Mg (ppm)					770	1320			
Na (ppm)					240				
Chlorides					250				
Sulfates					Trace				
Gypsum				<1.0					.9
Cu (ppm)									4.5
Lime	.2	0	Low				Low	Low	Low
Organic Matter(%)	6.0	.4	11.0				5.0+	5.5	5.8
Ca (ppm)					2600	14200			

Table 5k. Golf Course Irrigated Turf Areas as a Function of Location (Green #9)

Year	1965	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	7.8	6.5						7.0
pH (paste)			6.2	6.0	6.5	7.0	7.6	
Salts, mmhos/cm	1.2	1.3	1.2			.9	1.0	1.3
Nitrates (ppm)						1	9	99+
P_2O_5 (ppm)	105	70	150+					
P (ppm)				420	395	58	80+	79
K_2O (ppm)	113	203	463	660	1475			
K (ppm)						445	500+	457
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				880	1260			
Na (ppm)				340				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								6.4
Lime	.2	0	Low			Low	Low	Low
Organic Matter(%)	5.5	3.3	9.0			5.0	5.4	5.5
Ca (ppm)				3200	12800			

Table 51. Golf Course Irrigated Turf Areas as a Function of Location (Green #10)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.0	6.6						7.0
pH (paste)			5.5	6.1	6.3	6.6	7.3	
Salts, mmhos/cm	.6	1.3	1.1			1.2	1.7	.4
Nitrates (ppm)						16	10	96
P_2O_5 (ppm)	70	81	150+					
P (ppm)				390	395	64	80+	76
K_2O (ppm)	40	213	500+	325	1565			
K (ppm)						500+	500+	406
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				1000	1460			
Na (ppm)				270				
Chlorides				250				
Sulfates								
Gypsum								.9
Cu (ppm)								4.9
Lime	.4	.2	Low			Low	Low	Low
Organic Matter(%)	2.7	5.3	8.8			5.0+	4.3	5.3
Ca (ppm)				3100	13600			

Table 5m. Golf Course Irrigated Turf Areas as a Function of Location (Green #11)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.5	6.6						6.9
pH (paste)			5.6	5.8	6.4	6.9	7.4	
Salts, mmhos/cm	.4	1.4	1.4			1.0	1.4	.9
Nitrates (ppm)						2	94	99+
P_2O_5 (ppm)	110	86	150+					
P (ppm)				415	475	61	80+	71
K_2O (ppm)	35	175	220	335	1500			
K (ppm)						425	500+	420
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				1010	1260			
Na (ppm)				350				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								7.6
Lime	.1	.2	Low			Low	Low	Low
Organic Matter(%)	3.7	2.7	13.6			5.0+	6.5	6.2
Ca (ppm)				2800	12600			

Table 5n. Golf Course Irrigated Turf Areas as a Function of Location (Green #12)

Year	1964	1966	1968	1970	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.5	6.8							6.7
pH (paste)			5.1	7.5	5.5	6.6	6.8	7.5	
Salts, mmhos/cm	1.0	1.1	1.5	.5			1.1	1.1	1.2
Nitrates (ppm)				2.0			14	3	99+
P_2O_5 (ppm)	63	68	150+		665	425			
P (ppm)				47.5			63	80+	74
K_2O (ppm)	48	193	280		515	1810			
K (ppm)				73			500+	500+	266
Zn (ppm)			10+	3.34			9.99+	9.99+	9.99+
Fe (ppm)			40.0+	40.0+			40.0+	40.0+	40.0+
Mg (ppm)					950	1390			
Na (ppm)					275				
Chlorides									
Sulfates									
Gypsum				<1.0					.9
Cu (ppm)									5.8
Lime	.2	.2	Low	0			Low	Low	Low
Organic Matter(%)	4.4	5.4	8.9	1.6			5.0+	6.3	4.9
Ca (ppm)					2450	15800			

Table 5o. Golf Course Irrigated Turf Areas as a Function of Location (Green #13)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.3	6.6						6.7
pH (paste)			5.6	6.0	6.6	6.9	7.4	
Salts, mmhos/cm	1.0	1.2	1.7			.9	2.4	.9
Nitrates (ppm)						4	60	99+
P_2O_5 (ppm)	25	77	150+					
P (ppm)				435	335	62	80+	80+
K_2O (ppm)	40	198	153	345	635			
K (ppm)						500+	500+	471
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				1000	940			
Na (ppm)				350				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								7.6
Lime	.1	.2	Low			Low	Low	Low
Organic Matter(%)	4.9	5.1	5.6			5.0+	5.5	6.2
Ca (ppm)				3200	3200			

Table 5p. Golf Course Irrigated Turf Areas as a Function of Location (Green #14)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	5.8	6.4						6.5
pH (paste)			5.5	5.4	6.4	6.8	6.9	
Salts, mmhos/cm	.8	1.3	1.4			.8	2.1	1.4
Nitrates (ppm)						3	2	99+
P_2O_5 (ppm)	68	94	150+					
P (ppm)				420	415	66	80+	80+
K_2O (ppm)	45	203	500+	370	1475			
K (ppm)						500+	500+	497
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				800	1200			
Na (ppm)				240				
Chlorides				250				
Sulfates								
Gypsum								.9
Cu (ppm)								7.8
Lime	.1	.1	Low			Low	Low	Low
Organic Matter(%)	3.4	5.2	10.6			5.0+	5.5	7.0
Ca (ppm)				2550	13600			

Table 5q. Golf Course Irrigated Turf Areas as a Function of Location (Green #15)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.6	6.8						6.6
pH (paste)			5.5	4.8	6.8	6.6	7.2	
Salts, mmhos/cm	.5	1.5	.8			1.2	3.2	.7
Nitrates (ppm)						14	99+	99+
P_2O_5 (ppm)	58	92	150+					
P (ppm)				310	425	65	80+	80+
K_2O (ppm)	35	258	185	285	1220			
K (ppm)						415	500+	395
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				600	1320			
Na (ppm)				160				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								8.2
Lime	.2	.6	Low			Low	Low	Low
Organic Matter(%)	3.3	4.4	9.6			5.0+	5.3	7.0
Ca (ppm)				1650	12100			

Table 5r. Golf Course Irrigated Turf Areas as a Function of Location (Green #16)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.0	6.6						6.6
pH (paste)			5.5	5.7	6.3	6.8	6.9	
Salts, mmhos/cm	.6	1.4	.9			1.1	3.1	1.6
Nitrates (ppm)						4	1	99+
P_2O_5 (ppm)	22	93	150+					
P (ppm)				465	395	64	80+	80+
K_2O (ppm)	33	193	500+	245	1025			
K (ppm)						365	500+	446
Zn (ppm)			10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				800	1390			
Na (ppm)				260				
Chlorides				250				
Sulfates				Trace				
Gypsum								.9
Cu (ppm)								8.2
Lime	.1	.2	Low			Low	Low	Low
Organic Matter(%)	2.4	4.6	13.6			5.0+	5.0	7.0
Ca (ppm)				2450	12800			

Table 5s. Golf Course Irrigated Turf Areas as a Function of Location (Green #17)

Year	1964	1966	1968	1970	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.6	6.4							6.7
pH (paste)			5.2	7.2	5.4	6.6	6.4	7.1	
Salts, mmhos/cm	.4	1.1	.9	.5			1.4	2.5	.9
Nitrates (ppm)				7.0			25	68	99+
P_2O_5 (ppm)	24	77	150+						
P (ppm)				61.5	475	445	69	80+	80+
K_2O (ppm)	50	153	298		245	1025			
K (ppm)				95			483	500+	349
Zn (ppm)			10+	10+			9.99+	9.99+	9.99+
Fe (ppm)			40.0+	40.0+			40.0+	40.0+	40.0+
Mg (ppm)					800	1520			
Na (ppm)					240				
Chlorides					250				
Sulfates					Trace				
Gypsum				<1.0					.9
Cu (ppm)									4.9
Lime	.1	.1	Low	0			Low	Low	Low
Organic Matter(%)	1.8	4.4	11.9	4.3			5.0+	5.4	6.2
Ca (ppm)					1650	11500			

Table 5t. Golf Course Irrigated Turf Areas as a Function of Location (Green #18)

Year	1964	1966	1968	1971	1972	1973	1975	1975
Depth (inches)	0-3	0-3	0-3	0-3	0-3	0-3	0-3	0-3
pH 1:5	6.7	6.4						6.7
pH (paste)			5.9	5.4	6.6	6.6	7.4	
Salts, mmhos/cm	.5	1.1	1.0			.7	2.6	.8
Nitrates (ppm)						6	15	99+
P_2O_5 (ppm)	47	80	150+					
P (ppm)				385	415	58	80+	80+
K_2O (ppm)	45	208	360	385	1475			
K (ppm)						225	500+	413
Zn (ppm)			10+			8.35	9.99+	9.99+
Fe (ppm)			40.0+			40.0+	40.0+	40.0+
Mg (ppm)				775	1390			
Na (ppm)				220				
Chlorides				250				
Sulfates				Trace				
Gypsum								
Cu (ppm)								6.1
Lime	.2	.1	Low			Low	Low	Low
Organic Matter(%)	2.8	4.9	8.6			4.0	6.3	6.7
Ca (ppm)				2400	8400			

Table 6a. Golf Course Irrigated Turf Areas as a Function of Depth of Sample (Tee 17)

Year	1976	1976	1976	1976
Depth (inches)	0-3	3-6	6-9	9-12
pH 1:5	6.6	6.6	6.6	6.8
Salts, mmhos/cm	1.2	.5	.7	.6
Nitrates (ppm)	16	6	7	4
P (ppm)	130	41	39	16
K (ppm)	195	93	93	55
Zn (ppm)	26.7	1.8	1.3	.8
Fe (ppm)	183.2	38.2	37.7	16.3
Cu (ppm)	3.95	.57	.53	.26
Lime	Low	Low	Low	Low
Organic Matter (%)	6.5	1.6	1.1	.5
Mn (ppm)	10.0	3.4	5.7	3.5

Table 6b. Golf Course Irrigated Turf Areas as a Function of Depth of Sample (Fairway 17)

Year	1976	1976	1976	1976
Depth (inches)	0-3	3-6	6-9	9-12
pH 1:5	6.7	6.9	7.2	6.8
Salts, mmhos/cm	.9	.9	.8	1.9
Nitrates (ppm)	12	8	8	8
P (ppm)	N/A	64	19	25
K (ppm)	220	133	93	95
Zn (ppm)	14.4	2.3	1.0	1.7
Fe (ppm)	168.3	73.8	31.0	44.8
Cu (ppm)	2.6	.79	.46	.77
Lime	Low	Low	Low	Low
Organic Matter (%)	6.1	1.3	.9	1.3
Mn (ppm)	11.3	7.3	8.5	6.0

Table 6c. Golf Course Irrigated Turf Areas as a Function of Depth of Sample (Green 15)

Year	1975	1975	1975	1975
Depth (inches)	0-2.5	2.5-5	0-5	5-10
pH 1:5	6.5	6.8	6.6	6.3
Salts, mmhos/cm	.8	.9	.8	.4
Nitrates (ppm)	99+	91	77	24
P (ppm)	71	60	53	21
K (ppm)	373	282	246	117
Zn (ppm)	9.99+	9.99+	9.99+	1.1
Fe (ppm)	40.0+	40.0+	40.0+	34.4
Gypsum	.9	.9	.9	.9
Cu (ppm)	1.6	4.2	4.7	.42
Lime	Low	Low	Low	Low
Organic Matter (%)	6.7	4.3	3.5	1.2

Table 6d. Golf Course Irrigated Turf Areas as a Function of Depth of Sample (Green 16)

Year	1976	1976	1976	1976
Depth (inches)	0-3	3-6	6-9	9-12
pH 1:5	6.8	6.8	6.7	6.2
Salts, mmhos/cm	.7	.5	.6	1.1
Nitrates (ppm)	18	9	8	9
P (ppm)	73	64	34	26
K (ppm)	325	200	210	170
Zn (ppm)	35.5	3.5	2.2	3.4
Fe (ppm)	164.3	93.2	40.7	58.9
Cu (ppm)	7.84	1.04	.61	1.14
Lime	Low	Low	Low	Low
Organic Matter (%)	6.5	2.1	1.9	1.4
Mn (ppm)	4.5	1.9	9.4	11.7

Table 6e. Golf Course Irrigated Turf Areas as a Function of Depth of Sample (Turf Behind Green 16)

Year	1975	1975	1975	1975	1975	1975
Depth (inches)	0-6	6-12	12-18	18-24	24-30	30-36
pH 1:5	6.4	7.2	7.6	7.8	8.0	8.1
Salts, mmhos/cm	.7	1.5	1.6	.9	1.6	2.8
Nitrates (ppm)	40	12	9	10	12	13
P (ppm)	43	37	45	31	41	27
K (ppm)	140	171	196	171	174	132
Zn (ppm)	3.9	.3	.2	.2	.2	.2
Fe (ppm)	36.4	12.4	9.4	5.2	4.3	4.1
Gypsum	.9	.9	.9	.9	.9	.9
Cu (ppm)	.78	.36	.4	.3	.3	.24
Lime	Low	Low	Low	Low	Low	Low
Organic Matter (%)	2.2	1.2	.9	.4	.6	.4

Table 6f. Golf Course Irrigated Turf Areas as a Function of Depth of Sample (Turf Behind Green 16)

Year	1975	1975	1975	1975	1975	1975
Depth (inches)	0-6	6-12	12-18	18-24	24-30	30-36
pH 1:5	7.1	7.5	7.6	7.8	7.7	7.8
Salts, mmhos/cm	1.6	2.2	.8	.6	.5	1.2
Nitrates	50	25	14	15	16	13
P (ppm)	48	5	5	11	6	2
K (ppm)	201	91	66	53	56	54
Zn (ppm)	2.4	.4	.4	.2	.3	.2
Fe (ppm)	40.0+	8.7	13	15.4	10.8	5.5
Gypsum	.9	.9	.9	.9	.9	.9
Cu (ppm)	.95	.26	.21	.14	.22	.22
Lime	Low	Low	Low	Low	Low	Low
Organic Matter (%)	2.0	.8	.7	.6	.6	.4

Table 7a. Forested Area (Control)

Year	1975	1975	1975	1975	1975	1975
Depth (inches)	0-6	6-12	12-18	18-24	24-30	30-36
pH 1:5	6.9	6.9	6.5	6.4	6.6	7.3
Salts, mmhos/cm	.2	.4	.1	.1	1.0	.2
Nitrates (ppm)	15	11	5	1	1	4
P (ppm)	2	4	5	4	3	3
K (ppm)	46	25	20	23	21	17
Zn (ppm)	.6	.1	.1	.1	.1	.1
Fe (ppm)	36	18.4	14.8	11.4	7	6.1
Gypsum	.9	.9	.9	.9	.9	.9
Cu (ppm)	.18	.13	.13	.16	.16	.13
Lime	Low	Low	Low	Low	Low	Low
Organic Matter (%)	1.6	.6	.5	.6	.4	.2

Table 7b. Forested Area (Fresh Water Irrigated)

Year	1976	1976	1976	1976	1976	1976
Depth (inches)	0-3	3-6	6-9	9-12	12-15	15-18
pH 1:5	6.6	6.6	7	7.1	7.2	7.2
Salts, mmhos/cm	.5	.5	.7	.5	.5	.5
Nitrates (ppm)	20	13	7	6	6	8
P (ppm)	38	24	13	10	12	11
K (ppm)	215	105	73	35	55	50
Zn (ppm)	8.7	2.9	1.6	1.1	1.3	.8
Fe (ppm)	40.0+	40.0+	18.6	16	14.1	10.3
Cu (ppm)	.7	.61	.51	.42	.36	.33
Lime	Low	Low	Low	Low	Low	Low
Organic Matter (%)	4.6	1.5	.8	.4	.4	.4
Mn (ppm)	9.7	4.3	2.8	1.8	1.9	1.2

Table 7c. Forested Area (Behind Green 16)

Year	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976
Depth (inches)	0-3	3-6	6-9	9-12	12-15	15-18	0-3	3-6	6-9	9-12	12-15	15-18
pH 1:5	9.2	6.2	6.8	7.3	7.3	7.2	5.8	6.5	6.8	6.5	6.9	7.0
Salts, mmhos/cm	.5	1.7	1.7	1.4	1.3	1.1	1.1	.9	.6	.5	.7	.7
Nitrates (ppm)	9	4	6	7	9	11	25	5	3	3	3	3
P (ppm)	49	50	45	33	38	41	76	44	34	29	27	23
K (ppm)	175	145	125	128	125	133	320	193	145	148	120	125
Zn (ppm)	12.5	3.9	1.6	.7	.6	.4	9.99+	3.6	1.1	1.1	.5	.4
Fe (ppm)	85.4	40.5	21.5	14.2	13.7	8.6	40.0+	35.7	22.3	20.4	13.6	9.7
Cu (ppm)	2.58	1.14	.49	.32	.24	.18	5.32	1.18	.73	.61	.28	.22
Lime	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Organic Matter(%)	7.0	2.7	1.5	.8	.8	.5	6.3	1.6	1.0	1.3	.9	.8
Mn (ppm)	18.5	12.3	6.0	1.8	1.4	.6	9.99+	9.99+	6.3	5.0	3.8	3.4

Table 7d. Forested Area (Behind Green 16)

Year	1975	1975	1975	1975	1976	1976	1976	1976	1976	1976
Depth (inches)	0-6	6-12	12-18	18-24	0-3	3-6	6-9	9-12	12-15	15-18
pH 1:5	6.4	7.0	6.9	7.0	9.2	6.2	6.8	7.3	7.3	7.2
Salts, mmhos/cm	.7	.7	.7	.8	.5	1.7	1.7	1.4	1.3	1.1
Nitrates (ppm)	26	9	7	9	9	4	6	7	9	11
P (ppm)	49	37	39	27	49	50	45	33	38	41
K (ppm)	120	138	173	151	175	145	125	128	125	133
Zn (ppm)	1.8	.7	.9	.6	12.5	3.9	1.6	.7	.6	.4
Fe (ppm)	24.8	15	16.3	15	85.4	40.5	21.5	14.2	13.7	8.6
Gypsum	.9	.9	.9	.9	N/A	N/A	N/A	N/A	N/A	N/A
Cu (ppm)	.76	.32	.65	.35	2.58	1.14	.49	.32	.24	.18
Lime	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Organic Matter(%)	1.5	1.3	1.8	1.3	7.0	2.7	1.5	.8	.8	.5
Mn (ppm)					18.5	12.3	6.0	1.8	1.4	.6

Irrigation Reservoir Sediment Analysis

In order to determine the nature of previous inclusions of the irrigation water, sediment samples were collected from non-potable reservoir 4. Non-potable reservoir 4 was selected because non-potable reservoir 2 had an aeration system and was difficult to core. A 10 inch sediment core was obtained and divided into 2 inch increments. Analysis of the core was also done by the USAF Occupational and Environmental Health Laboratory. These data are given in Table 8.

Table 8. Sediment Analysis Non-Potable Reservoir #4[a]

Depth (inches)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Zn
0-2	0.82	<0.01	2.3	50.4	4784.6	0.52	50.3	11.1	33.2
2-4	3.89	<0.27	3.8	265.9	11248.7	0.70	108.5	38.3	128.7
4-6	5.72	<0.01	4.2	300.3	12833.6	0.83	116.4	44.9	142.9
6-8	5.35	<0.01	4.1	331.1	12082.0	0.76	99.3	41.1	143.9
8-10	10.04	<0.01	5.4	376.7	14465.6	1.14	116.9	17.4	159.1

[a]Metal concentration in micrograms per gram (dry weight)

Table 8. Sediment Analysis Non-Potable Reservoir #4[a]

Depth (inches)	Ag	Cd	Cr	Cu	Fe	Hg	Mn	Pb	Zn
0-2	0.82	<0.01	2.3	50.4	4784.6	0.52	50.3	11.1	33.2
2-4	3.89	<0.27	3.8	265.9	11248.7	0.70	108.5	38.3	128.7
4-6	5.72	<0.01	4.2	300.3	12833.6	0.83	116.4	44.9	142.9
6-8	5.35	<0.01	4.1	331.1	12082.0	0.76	99.3	41.1	143.9
8-10	10.04	<0.01	5.4	376.7	14465.6	1.14	116.9	17.4	159.1

[a]Metal concentration in micrograms per gram (dry weight)

DISCUSSION AND CONCLUSIONS

Observations of pine trees on fresh water irrigated sites have identified symptoms similar to those observed on pine trees irrigated with sewage effluent. These observations raised the question of whether tree stress was caused by inclusions in the water or from high water application rates which produced unfavorable conditions for the pine (i.e., high soil water content and low soil oxygen). Furthermore, both fresh and sewage effluent water irrigated soils had nutrient and metal concentrations well above those in non-irrigated forest sites (see Table 7).

The data in Tables 5, 6, and 7 demonstrated accumulations of nutrients (e.g., phosphorous and potassium) and of several micro nutrients and metals (e.g., copper, zinc, iron, manganese, calcium, magnesium, sodium, and sulfates). Note that zinc on Tee 17 increased from 5.26 ppm in 1970 (Table 5a) to 26.7 ppm in 1976 (Table 6a). Comparisons between non-irrigated areas (0.6 ppm zinc) in 1975 (Table 7a) and the data from Green 16 (35.5 ppm zinc) in 1976 (Table 6d) were even more dramatic. Reliable quantitative records for such management practices (as fertilization or physical modification) were not available. Therefore, at this time it is not possible to determine whether observed changes were due to effluent irrigation or to the employed management practices.

The water data (Table 3), calculated application rates (Table 4), and the sediment analysis (Table 8) all indicated large input of macro-nutrients, micronutrients, and metals. These data supported the hypothesis that the buildup in soil concentrations of these inclusions

since 1964 were due to irrigation with sewage effluents.

Increment bore samples in both grass sites (Table 6) and in the forested sites (Table 7) demonstrated selective retention of macro-nutrients and trace metals within the soil profile. For example, zinc in the irrigated forest area near Green 16, decreased from 12.5 ppm in the top 0-3 inch sample to 0.4 ppm in the 15-18 inch sample (Table 7c). In the irrigated turf areas the stratification was even more pronounced. For example, on Tee 17, zinc concentration decreased from 26.7 ppm in the top 0-3 inch increment to 0.8 ppm in the 9-12 inch increment (Table 6a).

The literature (2) on Poa annua indicated that this shallow rooted species preferred high phosphate, frequent watering and short mowing. Therefore, the management practices necessary to maintain an outstanding golf course and the high nutrient content of the irrigation water may have combined to cause the observed spread of Poa annua.

In conclusion, at the Eisenhower Golf Course, land application of sewage effluent resulted in the soil accumulation of numerous minerals. The concentration of these minerals was inversely related to soil depth. It was not determined, however, whether the increased mineral content was actually responsible for the observed changes in vegetative growth and development. Further investigations of the ecological impact of land application of sewage effluent is warranted.

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