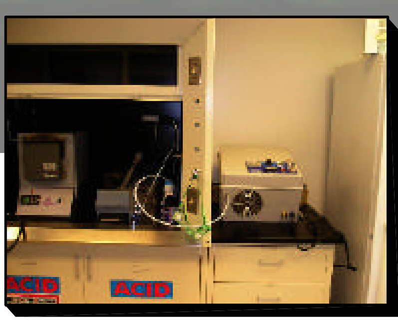
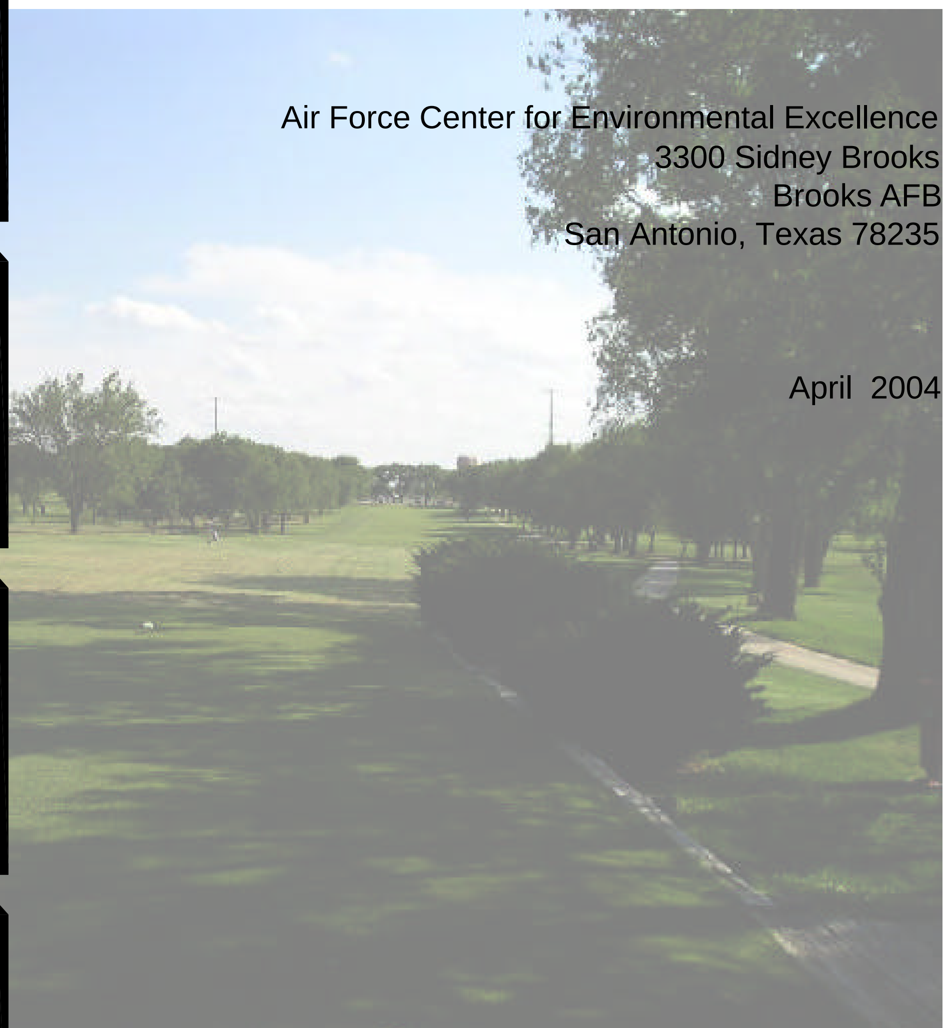
# Golf Course Water Quality Study at Cannon Air Force Base New Mexico







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April 2004

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## EXECUTIVE SUMMARY

A particularly difficult bio-fouling problem has plagued the Cannon Air Force Base (Cannon AFB). The problem manifests itself as filamentous growth and slime that clog the sprinklers in the whispering Winds Golf Course irrigation system and has been linked to re-use of wastewater. The Air Force Center for Environmental Excellence (AFCEE), supported by Science Applications International Corporation (SAIC), has determined the cause and options for solving this problem. The findings can be used throughout Cannon AFB to facilitate wastewater reuse.

The tasks included administrative support and project review meetings; a Quality Program Plan for investigation; a field investigation of the flow process, bench testing of various chemical treatments such as chlorine, bio-cides, and ozone; and an evaluation to identify the cause and potential remedies to the bio-fouling problem and a recommended course of action. Water sampling and field and laboratory analyses provided baseline water quality and documented changes in gross chemistry through re-use. In addition, the results of ongoing monitoring at Cannon AFB revealed information important to the study. Finally, bench testing served as an excellent screening technique to identify potentially useful cures to arrest biological fouling

The study concluded that the wastewater treatment plant produces a high quality effluent, but nevertheless feeds biological growth in the WWGC Main Pond. The pond and wetwell function as a biological reactor to host aerobic bacteria, slime-forming bacteria, iron-reducing bacteria, and green algae. In addition, a healthy macroinvertebrate population thrives in the Main Pond and Playa Lake. It was found that microbiological growth could most effectively be treated by oxidation with ozone and the biocide B-126, an “environmentally friendly” compound.

The most viable solution involves a combination of equipment and operations changes that can be implemented at a cost of less than $100,000. The location should be at the point of use, at the WWGC Main Pond irrigation pumping station and wetwell. Finer mesh inlet screening should remove biological macroparticulate from the irrigation stream. In addition, outlet filtration should be installed on the main pressure line to the sprinkler distribution system. Finally, the irrigation water should be disinfected using a combination of periodic chemical injection / dosing of B-126 for shock treatment and continuous ozonation for maintenance.

# 1.0 INTRODUCTION

The Air Force Center for Environmental Excellence (AFCEE) is responding to a request for assistance in solving a bio-fouling problem at Cannon Air Force Base (Cannon AFB). Science Applications International Corporation (SAIC) is assisting under Task Order No. 0012 for Contract F41624-03-D-8614. This report outlines the purpose and scope of the investigation, summarizes the results of the study, and presents the conclusions and recommended course of action.

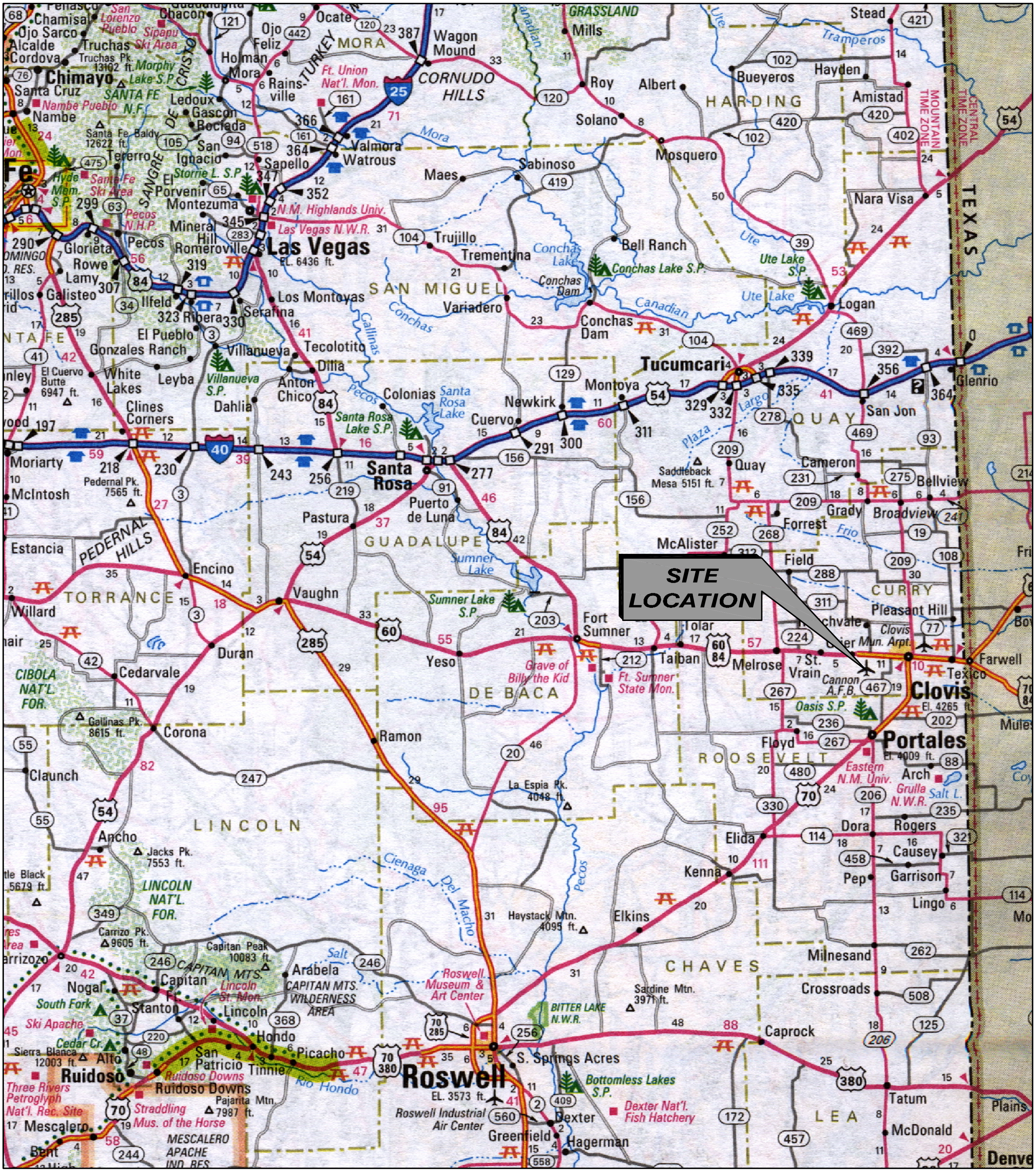
## Background

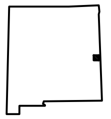
Bio-fouling has been linked indirectly to re-use of wastewater at Cannon AFB, Clovis, New Mexico (Figure 1). The problem is particularly evident in the irrigation system at the installation's Whispering Winds Golf Course (WWGC). Fouling is apparent, as filamentous growth and slime in the irrigation sprinkler system. During warm weather, from June through September, the material regularly clogs the sprinkler heads and requires an undue level of maintenance (an estimated 80 man hours per week). Although not the specific subject of this investigation, the wastewater overflow center-pivot irrigator is reported to be dysfunctional due to similar clogging.

Cannon AFB personnel acquired assistance from the University of New Mexico to identify the biological growth as fungal hyphae. Base personnel have compiled data from NPDES discharge monitoring, nitrate loading studies, soil analyses, and wastewater treatment operations. Various vendors have approached Golf Course personnel with potential solutions to the problem. However, there has been no comprehensive scientific study of the problem or potential causes.

## Purpose and Scope

The purpose of this study is to comprehensively examine the bio-fouling problem and determine a feasible action plan for mitigation. A solution to the golf course irrigation problem can likely be implemented throughout Cannon AFB to facilitate increasing the level of overall wastewater reuse in accordance with the long-term goals of the Base. In this view, the installation's wastewater becomes a recyclable resource and a significant pollution prevention measure. The four tasks identified in the AFCEE Statement of Work (SOW) complete the scope of the project, re-

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**CANNON AIR FORCE BASE REGIONAL LOCATION MAP**

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SAIC Science Applications International Corporation
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J:\CAD\Drafting\Air Force\Cannon AFB\1854-003.dwg, Layout1, 4/19/2004 10:02:02 AM, Adobe PDF.pc3 quiring an inter-disciplinary team approach with expertise in golf course irrigation and operations, wastewater treatment and chemical and process engineering.


**The Vision: To enhance support of the war fighting team and their families**

Task 1 included preparation of Contractor's Progress, Status and Management Reports (CPSMR); a project kick-off meeting to obtain additional information from Cannon AFB personnel regarding the irrigation system fouling problem, wastewater treatment plant performance, and unsuccessful mitigation measures employed to date, and a draft study review meeting to discuss comments from AFCEE and Cannon AFB personnel on the action plan / draft water quality study report.

Task 2 included a Quality Program Plan for investigation to address appropriate water sampling and bench testing, in accordance with guidance provided in the AFCEE Technical Services Quality Assurance Program. This information is summarized in Appendix A, and includes matrices summarizing the targeted tests and analyses. A simplified process flow diagram tracing the water flows through the re-use process served as the basis for the investigation.

Task 3 involved field investigation of appropriate segments of the water recycling process at Cannon AFB, including visual inspection of each stage in the flow process; water sampling at specific locations in the wastewater treatment, storage, distribution, and golf course irrigation systems; water sample packaging and shipment; and bench-testing of potential treatment methods. All analytical results received from the laboratory were verified and validated.

Task 4 summarized the results of the work into this report, which includes an irrigation system fouling evaluation to identify the cause and potential remedies to the bio-fouling problem and a recommended course of action.

## 2.0 STUDY FRAMEWORK

### Physical Setting

Cannon AFB is located adjacent to Clovis, New Mexico, on the High Plains (Llano Estacado) above the Ogallala aquifer. The region is characterized by terrain of relatively low relief with low slopes and occasional incised stream channels. Ground surface elevations range from 4250 to 4350 feet above mean sea level (msl). WWGC hosts three ponds, the largest of which (Main Pond) is used for irrigation. The ponds are located in a topographically low area in a former playa and receive limited runoff from adjacent areas (Figure 2).

An understanding of the overall water cycle at Cannon AFB is critical to targeting the investigation and identifying viable mitigation options. This cycle is illustrated as a simple process flow diagram in Figure 3. Key features in this process are shown on the map in Figure 4.

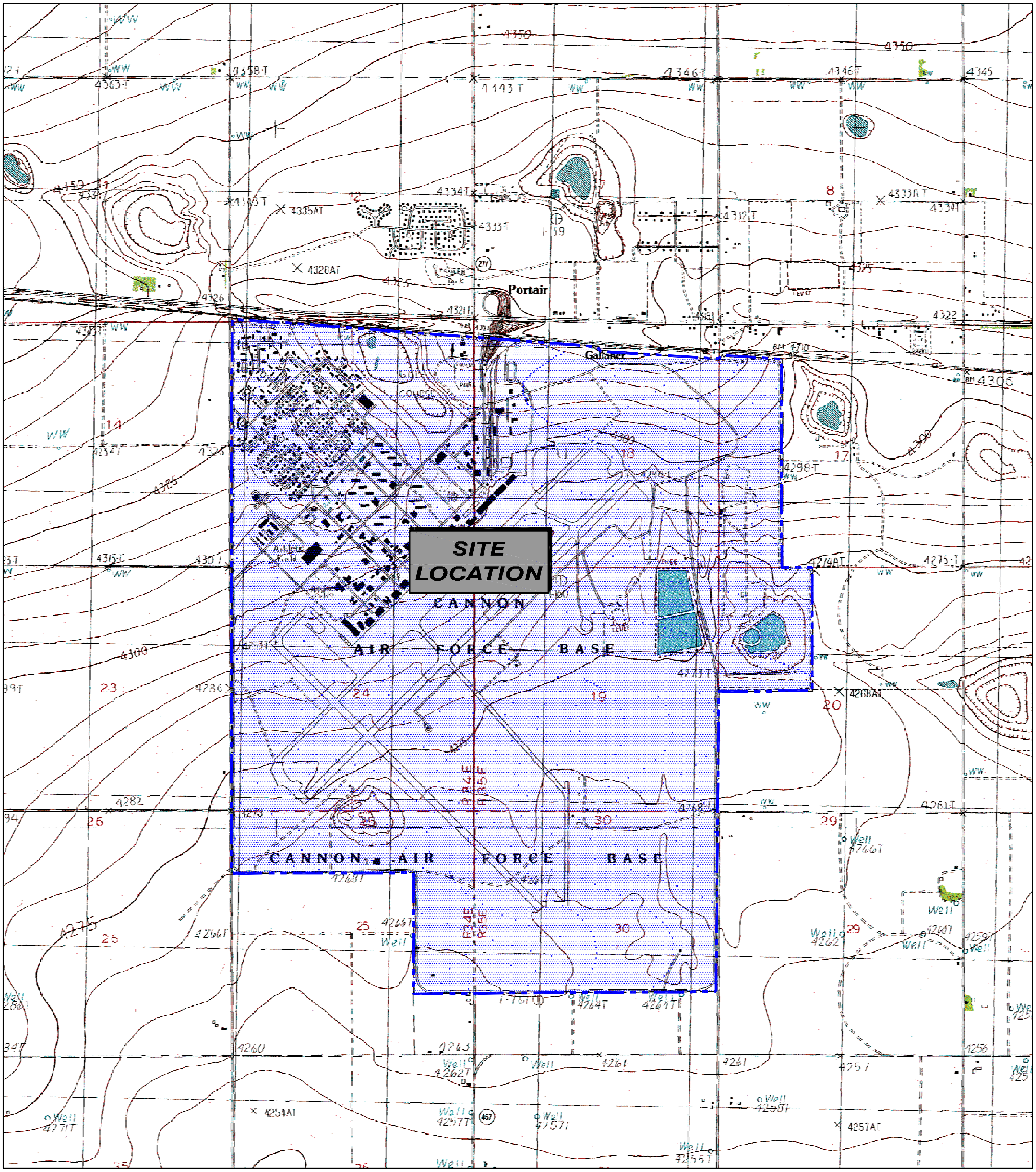
For the most part, water used at the installation originates as groundwater pumped from water wells tapping the Ogallala aquifer. Although this aquifer is one of the world's largest and most prolific, recharge to it is limited and it is therefore important to conserve this resource. Cannon AFB has recognized this and is moving toward using Ogallala water strictly for potable use and re-use of wastewater for irrigation purposes.

Once the water is used on the installation, it is collected and treated at the wastewater treatment plant. Once processed, it is discharged to Playa Lake or to WWGC for irrigation use.

### Cannon AFB Wastewater Treatment Plant

Both domestic and industrial wastewater produced by the installation is collected and treated at the base's Wastewater Treatment Plant (WWTP) (Figure 3). The WWTP uses a Sequencing Batch Reactor (SBR) process technology and began operations in June 1998. Effluent from the SBR process is disinfected with sodium hypochlorite in the chlorine retention basin. The initial chlorine target dosage is typically 1.5 to 2.0 mg/l, with a target chlorine residual at the over flow weir of 0.5 mg/l.

The disinfected effluent is directed to either the on-site 180,000-gallon effluent storage tank or flows by gravity via a 24-inch diameter pipe to Playa Lake. The residual chlorine is neutralized

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CANNON AIR FORCE BASE

NEW MEXICO

QUADRANGLE LOCATION

**NOTE:**

TOPOGRAPHIC CONTOUR INTERVAL = 5 FT.

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**CANNON AIR FORCE BASE**
**AREA TOPOGRAPHIC MAP**

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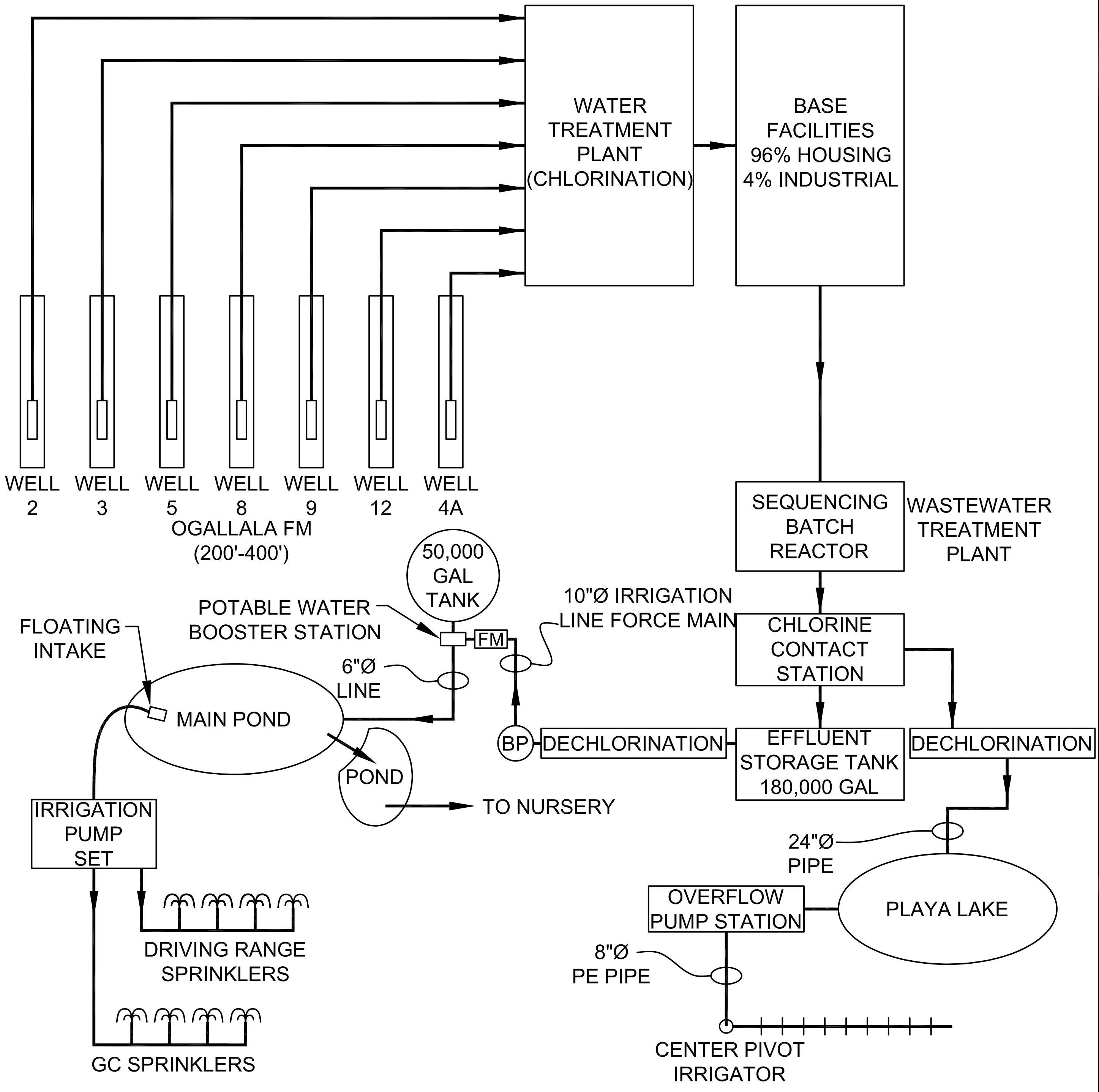


**LEGEND**

FM FLOW METER

BP BOOSTER PUMP

**NOT TO SCALE**

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**CANNON AIR FORCE BASE**
**PROCESS FLOW DIAGRAM**

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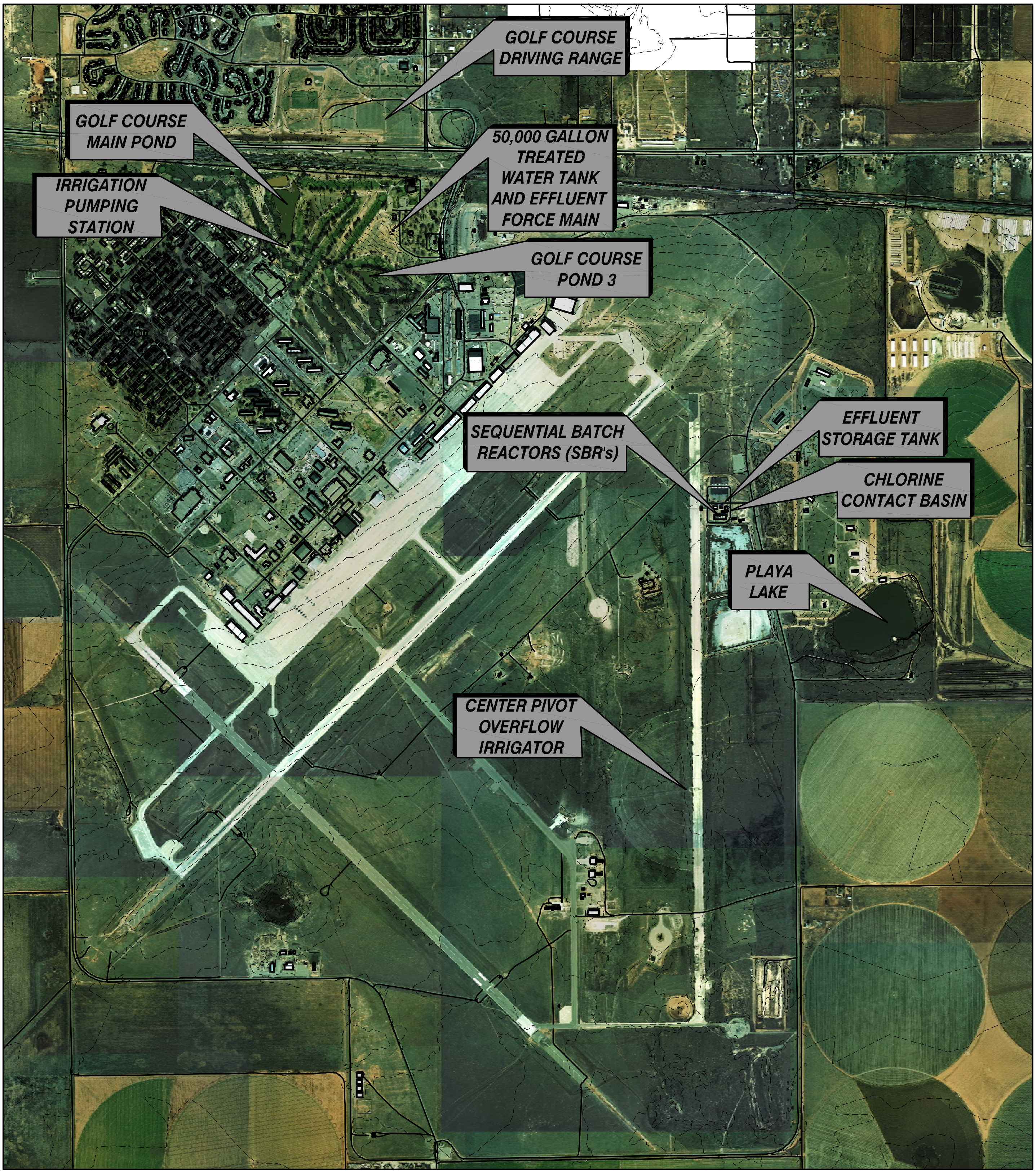


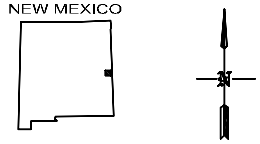


**NOTE:**

TOPOGRAPHIC CONTOUR
INTERVAL = 2 FT.

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**CANNON AIR FORCE BASE**
**KEY FEATURES & SAMPLING LOCATIONS**

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J:\CAD\Drafting\Air Force\Cannon AFB\1854-001.dwg, A-Size Base Map, 4/19/2004 9:53:30 AM, Adobe PDF.pc3 with sodium bisulfite to less than 0.011 mg/l. There are two pumps that transfer treated effluent from the storage tank via a 10-inch diameter force main to a point just south of the golf course maintenance shop area 150,000-gallon potable water storage tank. The water is conveyed from this point to the WWGC Main Pond via a 6-inch diameter line, which can also serve to convey well water to the Main Pond. Each pump delivers an average of 500 gallons per minute (gpm), although flows of over 700 gpm are possible upon pump start up, before the 6-inch diameter line fills and backpressure is low.

The Cannon AFB WWTP treats a significant volume of water that can serve as a resource for non-potable use. For example, approximately 147,517,000 gallons were treated in calendar year (CY) 2002, an average of over 400,000 gallons per day. Approximately 55,630,000 gallons were routed to WWGC Main Pond, or 37.7 % of the flows, with peak-month uses of over 7,800,000 gallons. Unfortunately, bio-fouling has occasionally reduced the volume of wastewater re-use and required supplemental groundwater pumping.

Wastewater Treatment Plant components—chlorine content basin (foreground) and sequencing batch reactors (left)

## Playa Lake

The majority of the WWTP discharge is currently routed to Playa Lake. Located on the east side of the base within approximately 2,100 feet of the WWTP (Figure 2 and 4), the lake is the site of a natural playa that has been improved with elevated embankments. As a playa, there is no discharge point from the lake; all water is infiltrated or evaporated from its approximate 18.3-acre surface. A spray irrigation pumping station can draw from Playa Lake whenever the lake is too full. Unfortunately, this system experiences clogging problems similar to WWGC, which reduce its effectiveness.

**Spray Irrigator for Playa Lake**

## Whispering Winds Golf Course Main Pond

The WWGC main pond is located approximately 7,200 feet from the WWTP and covers approximately 4.15 acres (Figure 4). It has a relatively flat bottom approximately seven feet deep covered by a relatively thin synthetic liner. Based on its area and depth, the total volume of the pond is estimated to be approximately nine million gallons. Pond water levels are maintained by flow from the WWTP and nearby well water, which can be routed through the common line to feed the pond. This line enters the pond on its east side through a submerged discharge pipe approximately six feet from the pond's edge. These flows are augmented by limited, occasional stormflows. Although the WWTP flows now constitute the primary source of water, golf course operators have had to temporarily dilute these flows with groundwater from the nearby well to combat bio-fouling. Two floating aerators have been added to the pond and are reportedly to have reduced algae growth.

**Golf Course Main Pond**

## Whispering Winds Golf Course Irrigation System

Water from the Main Pond is collected through a floating intake pipe into a wetwell and pumped by a "package" lift station manufactured by Pumping Systems Inc. (Model 10M50) to the irrigation distribution piping system. The irrigation duplex pump motors are 50 HP, 480 VAC, 3 phase and the six stage pumps are capable of delivering approximately 600 gpm individually and 1,100 gpm collectively. During a typical day in the primary irrigation season (April through September), 500,000 to 800,000 gallons of water may be pumped from the Main Pond for irrigation use. The system is used and maintained year-round, although the volume irrigated is significantly reduced between October and March.

**Golf Course Main Pond with floating intake (foreground) and floating aerators as fake rocks**

## 3.0 FIELD INVESTIGATIONS

### Water Sampling

Based on a comprehensive review of the wastewater treatment and irrigation systems, water sample locations were selected to provide baseline water quality parameters and to document changes in gross chemistry through the re-use process (Figure 3). Most samples were tested with the field instrumentation and selected for subsequent laboratory analyses (see matrices in Appendix A). The primary sampling sites are as follows:

- Cannon AFB WWTP effluent after the chlorine contact basin (CCB) - Sampled at the WWTP via automatic sampler at the effluent storage tank.
- Cannon AFB WWTP effluent in the force main to WWGC Main Pond (IFM) – Collected from a sample tap on the Booster Pump Station's Transmission Pipe near the WWGC Maintenance Building.
- WWGC Irrigation system intake at the Main Pond (ISI) – Sampled from the WWGC irrigation pump-set wetwell chamber.
- WWGC Irrigation system intake at the Main Pond (ISIMPI) – Sampled from the WWGC Main Pond at the wet well chamber intake pipe.
- WWGC Driving Range sprinkler heads (DRSH) – Collected biological growth from various sprinkler system strainers.
- WWGC Sprinkler System – Collected biological growth from various sprinkler system strainers (no water sample).
- WWGC Pond 3 (P3) – Sampled water below the lake surface (approximately 0.5 meters) in the central pond as representative of water not derived from treated wastewater.
- Playa Lake (PLYA) – Sampled water below the lake surface (approximately 0.5 meters) adjacent to the spray irrigator intake.

In addition to the raw water samples, a sample of treated (ozonated) water was taken for comparison of the effects on overall water chemistry. As per AFCEE Quality Assurance Project Plan 3.1, appropriate duplicate samples were taken for laboratory analyses.

**Baseline Water Quality in the Re-Use Process**

The data used in this assessment includes the results of ongoing monitoring conducted at Cannon AFB. This includes:

- Water quality testing at the wells producing the water,
- Operations monitoring data from the WWTP (by Petrus Environmental Services, Inc.),
- NPDES discharge monitoring and reporting for the WWGC Main Pond (discharge number 002A) and Playa Lake (discharge number 001A),
- Monthly monitoring and laboratory analyses of the Main Pond.

In addition, soil laboratory results for samples taken from two fairways and two greens were examined.

Selected reports leading up to the field sampling conducted for this investigation are reproduced in Appendix B. The results of the field analyses are summarized in Table 1. The laboratory results are summarized in Table 2, with supporting detail in Appendix C.

On-going Monitoring

In general, the raw Ogallala aquifer waters do not appear to have any parameters in concentrations that could influence the bio-fouling problems. Nitrates, TOC, chlorides, and most other major cations and anions are relatively low, with a moderate hardness. Once in the WWTP process, BOD and total suspended solids (TSS) removal and total chlorine residual (TCR) are greater than 98% (in compliance). The NPDES discharge monitoring is as anticipated, with relatively low residual BOD and TSS, and no chorine residual at the Main Pond and Playa Lake. The independent Main Pond monitoring (Table B-1) indicates water quality as would be anticipated, with minor suspended solids, little to no chorine residual, and elevated chlorides. Fecal

**Table 1. Summary of Field Analyses**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| Sample Site | sample depth (meters) | Sample ID | pH | electrical conductivity (s/cm) | temperature '(C) | turbidity (NTU) | dissolved oxygen (mg/l) | oxidation - reduction potential (mu) |
|---|---|---|---|---|---|---|---|---|
| Chlorine contact basin | | CCB | 7.84 | 0.921 | 24.3 | 0.7 | 9.8 | 189 |
| Irrigation supply force main | | IFM | 8.10 | 0.980 | 24.3 | 10 | 9.4 | 159 |
| Golf Course Main Pond - near wastewater discharge outfall | 0.5 | GCMP | 9.83 | 0.933 | 21.1 | 45 | 13.5 | 22 |
| | 1.0 | GCMP | 9.85 | 0.934 | 20.9 | 45 | 13.3 | 29 |
| | 2.0 | GCMP | 9.84 | 0.935 | 20.7 | 45 | 12.7 | 37 |
| Golf Course Main Pond - central area | 0.5 | GCMP | 9.64 | 0.941 | 20.3 | 46 | 13.4 | 174 |
| | 1.0 | GCMP | 9.69 | 0.942 | 20.2 | 45 | 13.0 | 172 |
| | 2.0 | GCMP | 7.99 | 0.990 | 20.0 | 65 | 12.1 | 208 |
| Golf Course Main Pond - west central area | 0.5 | GCMP | 9.76 | 0.940 | 20.6 | 45 | 13.0 | -50 |
| | 1.0 | GCMP | 9.79 | 0.940 | 20.5 | 40 | 13.27 | -26 |
| | 2.0 | GCMP | 9.75 | 0.942 | 20.1 | 47 | 12.0 | -16 |
| Golf Course Main Pond - south central area | 0.5 | GCMP | 9.81 | 0.939 | 20.5 | 45 | 12.84 | -25 |
| | 1.0 | GCMP | 9.81 | 0.940 | 20.3 | 45 | 12.5 | -14 |
| | 2.0 | GCMP | 9.78 | 0.939 | 20.2 | 45 | 12.0 | -54 |
| Golf Course Main Pond - at irrigation system intake | 0.5 | ISI | 9.88 | 0.938 | 24.1 | 40 | 14.2 | 0 |
| | 1.0 | ISI | 9.89 | 0.937 | 21.1 | 40 | 13.9 | 4 |
| | 2.0 | ISI | 9.89 | 0.937 | 20.9 | 45 | 13.4 | 24 |
| Irrigation system influent - wetwell | 0.5 | ISI | 9.36 | 0.930 | 19.6 | 35 | 2.0 | 91 |
| Irrigation system influent - wetwell (duplicate) | 0.5 | ISI DUP | 8.4+ | 0.956 | 20.1 | 17 | 5.9 | 186 |
| Irrigation system influent - wetwell ozonated sample | 0.5 | ISIOZ | 9.10 | 0.959 | 20.6 | 8 | 20.0 | 372 |
| Driving range spray head | | DRSH | 9.26 | 0.960 | 22.4 | 72 | 10.6 | 102 |
| Golf Course Pond 3 | 0.5 | P3 | 10.45 | 0.445 | 26.2 | 95 | 15.4 | 77 |
| Playa Lake at spray irrigation intake | 0.5 | PLYA | 9.95 | 1.24 | 20.0 | 75 | 13.8 | 181 |

Notes
Samples taken 23-Sept-03 and 24-Sept-03
mg/l = milligrams per liter

**Table 2. Summary of Analytical Laboratory Testing**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| Sample Site | Sample ID | alkalinity | biochemical oxygen demand | chloride | nitrate - nitrogen | orthophosphate | total dissolved solids | total organic carbon |
|---|---|---|---|---|---|---|---|---|
| Chlorine contact basin | CCB | 180 | 4.96 | 105 | 5.5 | 4.04 | 605 | 4.34 |
| Chlorine contact basin (duplicate sample) | CCBDUP | 183 | 4.96 | | 5.55 | 3.88 | | |
| Irrigation supply force main | IFM | 178 | ND | 112 | 4.91 | 3.72 | 645 | 4.35 |
| Irrigation system influent - wetwell | ISI | 180 | 21.7 | 105 | ND | 0.976 | 635 | 3.64 |
| Irrigation system influent - wetwell (duplicate) | ISI DUP | 178 | 12.6 | 105 | ND | 0.895 | 620 | 4.05 |
| Irrigation system influent - near irrigation intake | ISIMPI | 178 | 16.3 | 108 | ND | 0.747 | 630 | 3.04 |
| Irrigation system influent - wetwell ozonated sample | ISIOZ | 178 | 5.98 | 123 | 0.127 | 0.696 | 660 | 5.74 |
| Irrigation system influent - ozonated sample (duplicate) | ISIOZDUP | | 6.15 | | | | | |
| Driving range spray head | DRSH | 183 | 21.5 | 104 | ND | 0.934 | 650 | 7.65 |
| Golf Course Pond 3 | P3 | 71.2 | 51.1 | 53.2 | ND | ND | 276 | 20.3 |
| Golf Course Pond 3 (duplicate) | P3DUP | | | | | | 272 | |
| Playa Lake at spray irrigation intake | PLYA | 234 | 39.1 | 173 | ND | 1.71 | 850 | 9.64 |
| Playa Lake at spray irrigation intake (duplicate) | PLYADUP | | | 181 | | | | |

Notes: Samples taken 23-Sept-03 and 24-Sept-03
All results in milligrams per liter (mg/l)

coliform is generally non detectable, although there have been excursions. Nitrates are present but are not in high concentration, consistently less than 5 milligrams per liter (mg/l).

Field Analyses

Based on the field analyses (Table 1), the pH, electrical conductivity, and turbidity remain relatively constant through the re-use process from the WWTP to the sprinkler heads. Temperature of the WWTP discharge was slightly higher than in the Main Pond and wetwell, a relationship that would be expected to change depending on the time of year and time of day (the WWTP discharge would be expected to be relatively steady). Dissolved oxygen (DO) is affected by temperature, biological activity, and exposure to air, and was relatively high in the WWTP discharge. In general, DO concentrations increase further upon discharge to the Main Pond due to surface aeration and then decreas drastically in the wet well.

Oxidation-reduction potential (ORP) reflects biological activity from respiration of microbes that dissolve organic materials, was relatively consistent in the WWTP discharge but varied widely in the Main Pond. In a pond, the upper part of the water column is relatively oxygen-rich and this activity can generate inorganic substances that consume DO. In the lower water column, a reduction layer can contain microbes that dissolve organic materials through anaerobic respiration and fermentation. These microbes can also consume nitrates through a denitrification process and generate hydrogen sulfide through sulfuric acid reduction and methane from methane fermentation.

Laboratory Analyses

Based on the laboratory analyses (Table 2), alkalinity, chloride, and TDS remain relatively constant through the re-use process from the WWTP to the sprinkler heads. Significantly, BOD generally increases as nutrients (nitrate-nitrogen and orthophosphate) decrease through the process, reflecting biological growth after the WWTP process. TOC did not vary significantly in any of the analyses except for the Pond 3 sample (relatively high).

## Pond Stratification Testing

The WWGC Main Pond was thought to be relatively deep and as such could vary in water quality with depth. As such, pond stratification was investigated with the field instrumentation (pH, electrical conductivity, temperature, DO and ORP). This effort included measurement of pond depth and field parameters in locations as follows:

- Central portion of pond, approximately 50 feet from WWTP discharge point.
- West central portion of pond
- South central portion of pond
- Pond near the irrigation intake.

Samples were taken at depths of 0.5, 1.0, and 2.0 meters, which was generally the bottom of the pond.

The results are summarized in Table 1. As shown, pH, electrical conductivity, turbidity, and (importantly) temperature are relatively consistent through the water column and across the Main Pond. There is a slight decreasing trend in DO with depth, and ORP varies widely. Perhaps most significantly, the pond was found to have a relatively flat and shallow bottom, which is not conducive to stratification. The Main Pond water displays a lateral change in biological activity toward the irrigation intake; the biological activity in the wetwell appears to change further.

## Physical Observations

Observations of color and physical character were made during field sampling. Water samples from the Main Pond and Playa contained numerous skeletal remains of macroinvertebrates. Significantly, the same fragments were found in each slime sample taken and in every clogged sprinkler head examined. The particles observed were generally 3 to 20+ millimeters long. They have only a slightly greater specific gravity than water and are readily suspended with minor water turbulence.

**Sprinkler screen with dried bio-fouling materials, including macro invertebrate particulates**

During the Main Pond inspections and soundings, the condition of the liner for the pond was found to be poor. There are gaps in seaming and some apparent holes. Although the volume of loss was not quantifiable (irrigation metering had not yet been installed), the relatively sandy soils on site could transmit significant water from the pond. This loss could increase the volume of WWTP effluent required to maintain the pond level.

**The liner at the Main Pond is not totally effective**

## 4.0 BENCH TESTING TREATMENT ALTERNATIVES

Bench-top treatment and testing of chemical products was conducted in two phases. The first phase served to screen the treatment alternatives and included chemical treatment of irrigation system biological slime. The second phase focused on chemical treatment of the WWGC Main Pond water. Each bench-top testing phase is described below.

### Slime Treatment

The biological buildup from the irrigation system was suspected to be fungal growth or mycelium. The "slime" collected from the irrigation system strainers appeared to consist of mostly dark green biological growth and contained significant amounts of invertebrate exoskeletons. The slime samples from the WWGC Driving Range sprinkler heads were subjected to treatment with chlorine, hydrogen peroxide, ozone, and the propriety biocides B-126 and PS-200. A range of chemical concentrations were applied to evaluate the general effectiveness of each chemical.

This initial testing demonstrated that both chlorine and ozone were the most effective in breaking down the slime and reducing the water sample's turbidity. Both the chlorine and ozone appeared to oxidize and "bleach" the chlorophyll within the algae organisms. The B-126 killed the water's microorganisms, but also turned the water's greenish tint to a turbid grayish-white color. The biocide PS-200 did not visually impact the algae or slime material. Dosages of hydrogen peroxide did not visually impact the slime or algae organisms. Detailed sample information and actual observations are recorded in Table 3.

### Water Treatability Testing

Water treatability testing was conducted in two phases. The first was begun on site at the WWTP laboratory, followed by close monitoring for the following week. During the treatability testing, chlorine dioxide, ozone, hydrogen peroxide, and the propriety biocide B-126 were used to treat water samples from the WWGC Main Pond. Water collected from the WWGC Main Pond was obtained from the irrigation pump wet well to represent the Irrigation System Influent (ISI). These water samples were considered key since this water is used for irrigation and supports the biological growth within the piping system. Summaries of the biological analysis results are presented in Tables 4 and 5.

**Table 3 Preliminary Treatability Testing**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| Treatment Chemical | Dosage Applied | Dosage Residual | Contact time (min) | Sample size (liter) | Observations |
|---|---|---|---|---|---|
| Shock Chlorine | 50.0 | >3.5 | 10 | 2 | Sample of WWTP De-chlorinated effluent and bio-buildup from irrigation system. Water color was clear at 50 mg/l. |
| B126 | 10<br>20 | NA | | 2 | Sample of WWTP De-chlorinated effluent and bio-buildup from irrigation system. Water turned cloudy. |
| Ozone | 10 SCFH<br>50% Output | 1.5 mg/l | 5 | 2 | Sample of Irrigation System Influent Water with biological buildup, Oxygen Supplied, 0.9 psig Reactor Pressure, 4.8 Volts. Green tinted water cleared within 2 Minutes of aeration with oxygen. |
| Ozone | 10 SCFH<br>30% Output | 0.2<br>0.5 | 75<br>90 | 2 | Sample with biological buildup. Oxygen Supplied, 0.79 psig Reactor Pressure, 3 Volts. Green tinted water cleared within 60 Minutes of aeration with oxygen. |
| Hydrogen Peroxide | 100<br>200<br>300 | 0.25<br>0.30<br>0.25 | 20<br>+10<br>+20 | 2 | Sample with biological buildup. Water colored turned green to clear. Hydrogen Peroxide residual did not increase. |

**Table 4. Initial Treatability Testing and Observations**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| Water Sample Description | Test Method | 25-Sept 21:00 | 26-Sept 13:30 | 27-Sep | 28-Sep | 29-Sep | 30-Sep | 1-Oct |
|---|---|---|---|---|---|---|---|---|
| ISI Raw Water (Main Pond Wet Well) 9/24 @ 10:15 - 10:30 | TAB | 1 Red colony | 3 Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SLYM | Cloudy, yellow | Cloudy, dark yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow |
| | IRB | Clear, yellow | Clear, greenish yellow | Cloudy, dark greenish-yellow, foam on top | Black with foam | Black with foam | Black with bubbles | Black with bubbles |
| ISI Raw Treated with Chlorine Dioxide (125 mg/l) 9/24 @ 11:30 | TAB | 0 | 0 | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SLYM | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow |
| | IRB | Clear, yellow | Clear, yellow, bottom sediment | Cloudy, dark greenish-yellow, foam on top | Dark green with foam | Black with foam | Black with foam | Black with foam |
| ISI Raw Treated with B-126 (30 mg/l) 9/24 @ 13:45 | TAB | 0 | 0 | 0 | 1Red colony | 1 Red colony with red around 3 edges | 1 Red colony with red around 3 edges | 1 Red colony with red around 3 edges |
| | Y&M | 0 | 0 | 0 | 0 | 1 White fuzzy colony | 1 White fuzzy colony | 1 White fuzzy colony |
| ISI Raw Treated with Hydrogen Peroxide (100 mg/l) 9/24 @ 14:10 | TAB | 0 | 32 Red colonies | 5 Red colonies | 5 Red colonies with red around edge | 5 Red colonies with red around edge | 1 Red colony with red around 3 edges | 1 Red colony with red around 3 edges |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 1 White fuzzy colony | 1 White fuzzy colony |
| | SLYM | Clear, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow |
| | IRB | Clear, yellow | Clear, yellow | Clear, yellow | Clear, yellow | Clear, yellow | Clear, yellow | Clear, yellow |
| ISI Raw Treated with Ozone 9/24 @ 10:15 | TAB | 0 | 0 | 4 White fuzzy colonies | 4 White fuzzy colonies | 4 White fuzzy colonies | 4 White fuzzy colonies | 4 White fuzzy colonies |
| | Y&M | 0 | 0 | 1 White fuzzy colony with green center | 1 White fuzzy colony with green center | 1 White fuzzy colony with green center | 1 White fuzzy colony with green center | 1 White fuzzy colony with green center |
| | SLYM | Clear, yellow | Clear | yellow | Clear | Yellow, starting to cloud | Yellow, slight cloudiness | Yellow, slight cloudiness |

**Table 4. Initial Treatability Testing and Observations**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| Water Sample Description | Test Method | 25-Sept 21:00 | 26-Sept 13:30 | 27-Sep | 28-Sep | 29-Sep | 30-Sep | 1-Oct |
|---|---|---|---|---|---|---|---|---|
| WWTP Effluent 9/24 | TAB | 1 Red Colony | | 50 Red colonies | 50 Red colonies | 50 Red colonies | 50 Red colonies | 50 Red colonies |
| | Y&M | 0 | | 0 | 0 | 0 | 0 | 0 |
| | SLYM | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow | Cloudy, yellow |
| WWTP Effluent Treated with Ozone 9/24 @ 14:40 | TAB | 0 | 0 | 0 | 0 | 0 | 1 White fuzzy colony | 1 White fuzzy colony |
| | Y&M | 0 | 0 | White colony | White colony | Large white colony | Large white colony | Large white colony |
| WWTP Effluent Treated with Hydrogen Peroxide 9/24 @ 14:50 | TAB | 0 | TNTC | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies | TNTC Red colonies |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TAB - Total Aerobic Bacteria (Amber Media), Examine at 24 - 48 Hours
Y&M - Yeast and Mould (Red Media), Examine at 48 hours - 5 Days
SLYM - Slime-Forming Bacteria
IRB - Iron Reducing Bacteria
TNTC- Too Numerous To Count

**Table 5. Verification Treatability Testing and Observations**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| | Test Method | 9-Oct | 10-Oct | 11-Oct | 12-Oct | 13-Oct | 14-Oct | 15-Oct |
|---|---|---|---|---|---|---|---|---|
| ISI Raw Water | TAB | 4 Red colonies | 6 Red colonies & 1 side edge | 6 Red colonies & 3 side edges | TNTC | TNTC | TNTC | TNTC |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SLYM | Cloudy orange | Cloudy yellow | Cloudy yellow | Cloudy yellow | Cloudy yellow-orange | Cloudy yellow-orange | Cloudy yellow-orange; Glows under UV light |
| | IRB | Clear at top; Clear, yellow at bottom | Clear in top half, greenish yellow in bottom half | Greenish yellow | Greenish yellow | Yellow, slightly cloudy | Yellow, slightly cloudy | Yellow, slightly cloudy |
| ISI Raw Treated with B-126 (15 mg/l) | TAB | 2 Red colonies | 5 Large red colonies | 6 Merging red colonies | 2.5 Blocks covered with red colonies | 2.5 covered blocks & 1 large red circle | 2.5 covered blocks & 1 large red circle | 2.5 covered blocks & 1 large red circle |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SLYM | Clear at top; orange cloud at bottom | Clear at top; Orange cloud at bottom | Clear at top; Orange cloud at bottom | Clear at top; Orange cloud at bottom | Cloudy white at top, cloudy orange at bottom | Cloudy white at top, cloudy orange at bottom | Cloudy white at top, cloudy orange at bottom; Glows under UV light |
| | IRB | Clear at top; Clear, yellow at bottom | Clear in top half, greenish yellow in bottom half | Greenish yellow | Clear yellow | Clear yellow | Slightly cloudy, yellow color | Slightly cloudy, yellow color |
| ISI Raw Treated with B-126 (30 mg/l) | TAB | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SLYM | Clear at top; Orange cloud at bottom | Clear at top; Orange cloud at bottom | Clear at top; Orange cloud at bottom | Clear at top; Orange cloud at bottom | Cloudy white at top, cloudy orange at bottom | Slightly less cloudy than 15 mg/l sample | Cloudy white at top, cloudy orange at bottom; Glows under UV light |
| | IRB | Clear at top; Clear, yellow at bottom | Clear in top half, greenish yellow in bottom half | Greenish yellow | Clear yellow | Clear yellow | Slightly cloudy, yellow color | Slightly cloudy, yellow color |

**Table 5. Verification Treatability Testing and Observations**
**Wastewater Re-Use Water Quality Study**
**Cannon Air Force Base, New Mexico**

| | Test Method | 9-Oct | 10-Oct | 11-Oct | 12-Oct | 13-Oct | 14-Oct | 15-Oct |
|---|---|---|---|---|---|---|---|---|
| ISI Raw Treated with Ozone (40 mg/l, trace residual) | TAB | 0 | Colonies on 3.5 edges | Colonies on 4 edges | Spreading colonies on 4 edges | Red lines along edges | Red lines along edges | Red lines along edges |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | IRB | Clear at top with clear bubbles on sides under ball; Clear yellow at bottom | Clear in top half, greenish yellow in bottom half | Clear in top half, greenish yellow in bottom half | Cloudy yellow | Cloudy yellow-orange | Cloudy, orange color | Cloudy, orange color |
| ISI Raw Treated with Ozone (0.15 mg/l residual) | TAB | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Y&M | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ISI Raw Treated with Ozone (750 ml Test, 0.15 mg/l residual) | TAB | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Y&M | 0 | 0 | 0 | 0 | 0 | | |
| | SLYM | Clear at top; Orange color at bottom | Clear at top; Orange color at bottom | Clear at top; Orange color at bottom | Clear at top; Orange color at bottom | Clear at top; orange at bottom, slightly cloudy | Clear at top; orange at bottom, slightly cloudy | Clear at top; orange at bottom, slightly cloudy; slight glow under UV light |
| | IRB | Clear at top; Clear, yellow at bottom | Clear in top half, greenish yellow in bottom half | Greenish yellow | Clear yellow | Clear yellow | Clear yellow | Clear yellow |

Notes
Samples treated 10-Oct
TAB - Total Aerobic Bacteria (Amber Media), Examine at 24 - 48 Hours
Y&M - Yeast and Mould (Red Media), Examine at 48 hours - 5 Days
SLYM - Slime-Forming Bacteria
IRB - Iron Reducing Bacteria
TNTC- Too Numerous To Count

Verification testing of duplicate samples were begun at an SAIC facility approximately one week later, again followed by a week of close monitoring.

WWTP Effluent

The chlorine contact chamber was inspected and the chamber's effluent water contained algae organisms as evidenced by the green color. The wastewater treatment plant operators were interviewed and reported that the algae growth is persistent and survives despite the chamber's consistent chlorine residual. The operator's have temporarily and successfully treated algae in the chamber with a calcium hypochlorite dosage of 8 mg/l. However, the growth of algae returns when the chlorine dosage is reduced to normal disinfection concentrations.

A water sample of the WWTP's effluent was collected from the transmission pipe discharging to the WWGC Main Pond was microscopically examined. The sample was free of living flagellates and lacked the long strands of algae.

The SLYM's cloudy yellow color indicates the presence of Slime Forming Bacteria (SFB). The appearance of cloudy water within 24-hours indicates a SFB population greater than 500,000 cfu/ml.

ISI Raw Water

The golf course's main pond was visually inspected and found to contain a significant growth of algae. The algae appeared to be suspended in the water below the pond's surface and not growing or attached to the pond's sediment. Further microscopic examination of the pond water revealed the algae consisted of primarily long strands tapered at either end. The algae were suspended throughout the pond from end to end and surface to bottom.

The SLYM's cloudy yellow color indicates the presence of SFB. The appearance of cloudy water within 24-hours indicates a SFB population higher than 500,000 cfu/ml. The IRB's color change to green within 48-hours indicates the presence of Pseudomonad bacteria of approximately 100,000 cfu/ml.

ISI Raw Treated with Chlorine Dioxide

Various dosages of chlorine dioxide did not significantly change the intensity of the water's green color. In addition, microorganisms such as flagellates were not visually harmed.

The SLYM's cloudy yellow color indicates the presence of SFB. The appearance of cloudy water within 24-hours indicates the SFB population did not decrease significantly and as still higher than 500,000 cfu/ml. The IRB's color change to green within 3 days indicated treatment slightly reduced Pseudomonad bacteria to less than 100,000 cfu/ml. The subsequent color change of green to black confirms the presence of the Pseudomonad bacteria and also the presence of Enteric bacteria. The Enteric bacteria were reduced to an estimated level of 5,000 cfu/ml. Additionally, the presence of foam still indicates the presence of anaerobic bacteria.

ISI Raw Treated with Hydrogen Peroxide

Various dosages of hydrogen peroxide did not significantly change the intensity of the water's green color. In addition, microorganisms such as flagellates were not visually harmed.

The SLYM's cloudy yellow color indicates the presence of SFB. The appearance of cloudy water within 48-hours indicates the SFB bacteria population was slightly reduced to approximately 500,000 cfu/ml. The IRB slowly changed color from a pale yellow to a slightly darker yellow color over two days. However, the water remained clear and no slime or foam was observed. The changes above indicate this treatment significantly reduced the Pseudomonad, Enteric, and anaerobic bacteria and the left non-aggressive iron related bacteria.

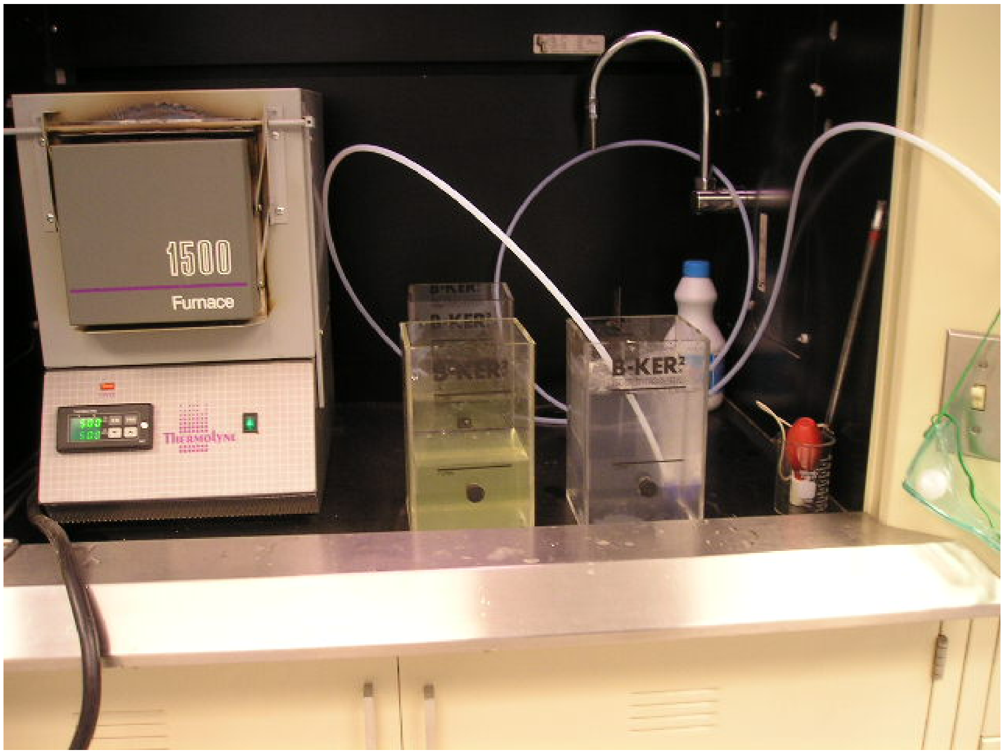
ISI Raw Treated with B-126

The biocide B-126 did kill flagellates in the water but did not have a significant impact on the algae's color or intensity.

ISI Raw Treated with Ozone

Ozone appeared to kill the water's microorganisms such as flagellates, bleached the algae's chlorophyll, and significantly improved the water's turbidity.

The SLYM's cloudy yellow color indicates the presence of SFB. The appearance of cloudy water within 60-hours indicates the SFB population was significantly reduced to less than 2,000 cfu/ml.




**Irrigation system influent before and after ozonation**

**<u>Summary of Results</u>**

The bench testing served as an excellent screening technique to identify potentially useful cures to arrest biological fouling of the irrigation distribution system. An overview of the methods and our assessment of the qualitative value of each are summarized in Table 5. As shown, the ozonation proved to be dramatically effective in eliminating most biological growth. The biocide B-126, an "environmentally friendly" compound, is an alternative to ozone, although is slightly less effective.

## Table 6. Summary of Treatability Testing
## Wastewater Re-Use Water Quality Study
## Cannon Air Force Base, New Mexico

| Aerobic Bacteria | Yeast - Mould | Slime-Forming Bacteria | Iron Reducing Bacteria | Microscopic Examination | Conclusions |
|---|---|---|---|---|---|
| **Wastewater Treatment Plant effluent - untreated** | | | | | |
| Present | Absent | Present | Absent | Green algae, no moving flagellates | Baseline water quality |
| **Irrigation system influent - wetwell - untreated** | | | | | |
| Abundant | Absent | Abundant | Present | Green algae, moving flagellates | Aerobically active |
| **Irrigation system influent - wetwell - chlorine dioxide treatment** | | | | | |
| Abundant | Absent | Abundant | Present | Green algae, moving flagellates | Ineffective control |
| **Irrigation system influent - wetwell - hydrogen peroxide treatment** | | | | | |
| Present | Absent | Present | Absent | Green algae, moving flagellates | Ineffective control |
| **Irrigation system influent - wetwell - B-126 treatment** | | | | | |
| Reduced or eliminated | Absent | Present | Present | Green algae, no moving flagellates | Partial control |
| **Irrigation system influent - wetwell - ozone treatment** | | | | | |
| Reduced or eliminated | Absent | Reduced | Present | Clear algae, no moving flagellates | Partial control |

**Notes**

Samples taken 23-Sept-03 and 24-Sept-03

## 5.0 CONCLUSIONS

Based on the results of this study, the following conclusions can be made:

- The bio-fouling problems at Cannon AFB are primarily evident as clogging of irrigation lines, pumps, and particularly spray heads on WWGC and the wastewater irrigator from Playa Lake.
- The WWGC Main Pond is functioning as a biological reactor (particularly in warmer months), using nutrients and TOC from the WWTP discharge to sustain abundant biological growth (bacteria, algae, fungi, and macroinvertebrates) in the pond and pumping station wetwell.
- The WWTP is functioning as designed and the effluent consistently meets applicable water quality criteria; although nutrient and TOC loads in the effluent are relatively low, they are adequate to sustain biological growth in the Main Pond.
- The Main Pond is relatively shallow (less than eight feet deep) and the water is well mixed; biological activity increases as water moves from the WWTP discharge point to the irrigation intake and into the wetwell.
- The bio-fouling in the wastewater re-use process is primarily from aerobic bacteria, slime-forming bacteria, iron-reducing bacteria, green algae, and a significant macroinvertebrate population thriving on the lower-order organisms.
- The microbiological growth in the wastewater re-use process at Cannon AFB is most effectively treated by oxidation with ozone, with various chemical treatments providing limited effectiveness.
- The problems with wastewater re-use at Cannon AFB, at the golf course, spray irrigator, and elsewhere, are readily solvable using a combination of treatments.

### General Options

Changes / treatment at the point of use are possible methods of control. This could involve using the WWTP discharge directly and bypassing the WWGC Main Pond or Playa Lake. Such a system would require significant changes in piping and balancing the WWTP flow with irrigation use.

Continued use of the Main Pond and Playa Lake might be maintained with changes to the existing WWTP, such as adding tertiary treatment. However, this relatively large expense cannot be justified by seasonal irrigation use. Similarly, treating the water once it is in the Main Pond or Playa Lake cannot be successful due the inability to totally control the pond environment without eradicating the entire biota and / or creating regulatory violations.

**Elimination of Direct Use Option**

The wastewater discharged from the WWTP could be directly piped into the WWGC wetwell. The existing ten-inch diameter line from the WWTP could be extended from the booster station at full diameter to eliminate the restriction created by the reduction to the six-inch diameter pipe to take advantage of the 700 gpm pumping capacity from the WWTP. Alternatively, six- or 8-inch diameter flexible line could be extended on the pond bottom from the existing discharge point into the wetwell. In either method, the lack of macrobiological particulates will reduce this mode of clogging and fouling and provide less of an opportunity for incubation of biological growth in the pond. This would also serve to backflush the wetwell intake whenever the irrigation system was not pumping.

Unfortunately, there are significant problems with implementing this option. An extension of the 10" diameter line would be difficult, expensive, and disruptive. It would necessarily cross various utilities, including a high-value fiber optic cable, irrigation lines, and two fairways. Extension of the existing line from its current location to the wetwell is more feasible but significantly less effective, since it could not carry the full flow required to meet the irrigation system demands. This would therefore require some water to be drawn from the Main Pond (with the attendant problems).

Perhaps most importantly, the operation of the WWTP cannot be coordinated with golf course irrigation. The primary irrigation cycles are programmed automatically during the evenings and early mornings to conserve water and not interfere with golf play. A contractor operates the WWTP during normal working hours. The discharge must be carefully monitored during operations to maintain compliance with the stringent discharge criteria. These different operations cycles are directly opposed and cannot be coordinated.

**Biological Treatment**

The most effective microbiological treatments, ozonation and B-126, do not release potentially environmentally harmful chemicals which can adversely affect local water quality and be detected in ongoing monitoring programs. These treatments must, however, be properly designed and operated to be safe. The off gassing of any unused ozone must be controlled and properly ventilated and the equipment must be compatible with the chemicals in use to prevent premature corrosion and failure. Other chemical treatments, such as chlorination or acid generation (like a "sulfa-burner") are less effective and could damage the environment and violate existing permit conditions.

**Particulate Treatment**

There are various filtration systems available for removal of the macrobiological particulates in the Main Pond and wet well. The larger particles can be filtered before they reach the pumping systems, which tend to break the larger particulates into a higher concentration particulate stream. The pumping system effluent can be further filtered with pressure screens or filters. All systems can be self-cleaning and matched to the capacity of the pumping system.

## 6.0 Recommended Course of Action

The most viable solution to the problems currently associated with wastewater reuse at Cannon AFB involves a combination of equipment and operations changes that can be implemented at a cost of less than $100,000.

### Location

The treatment should be at the point of use, specifically at the WWGC Main Pond irrigation pumping station and wetwell. This location has the advantage of being a regularly maintained part of golf course operations. In addition, there is both single and three-phase power available there. Most standard treatment equipment can be relatively compact and should fit into the existing structure for security. If necessary, the pump house can be readily modified with a small addition to accommodate additional treatment equipment or supplies.

### Inlet Filtration

Due to the volume of particulates evident in the Main Pond and wetwell, a two stage self cleaning screening and filtration system is recommended. The biological macroparticulate should be removed from the irrigation stream by screening inlet flows to the wetwell and filtering / screening the pumped water before it reached the irrigation distribution system. The system should effectively filter particulates down to less than a few millimeters at flow rates of up to 900 gpm. The first stage should be installed on the floating wetwell intake in the Main Pond to filter the coarser fraction of macrobiological particulates (>3 mm).

Inlet filtration components

| | | |
|---|---|---|
| ➢ Self-cleaning inlet strainer | 1 | rotating |
| ➢ High Pressure hose backflush hose | 100 | |
| ➢ Quick connect fittings | 2 | cam-lock |
| ➢ Electric solenoid valve | 1 | Ultraflow |
| ➢ Controller / timer | 1 | Rain Dial Plus |
| ➢ Labor | | |
| ➢ Expenses | | |

The rough order of magnitude cost for the system equipment and installation is $12,000.

**Outlet Filtration**

The second stage should be installed on the main pressure line to the sprinkler distribution system to filter the finer particulates (0.2 to 3 mm). The self-cleaning mechanisms should be automated to use the pressurized water available at the pumping station, with the removed particulates discharged to a settling area in the other end of the Main Pond.

Outlet filtration components

| | | |
|---|---|---|
| ➢ Full flow self cleaning filter | 1 | manual flush |
| ➢ Replacement screen | 1 | |
| ➢ Flanged elbow | 1 | |
| ➢ Flange adapter | 2 | |
| ➢ Electric solenoid valve | 1 | Ultraflow |
| ➢ Flush / drain line | 700 | bell end SDR 21 |
| ➢ Quick connect fittings | 2 | cam-lock |
| ➢ Drain line connector | 100 | flexible |
| ➢ Labor | | |
| ➢ Expenses | | |

The rough order of magnitude cost for the system equipment and installation is $24,000.

**Disinfection**

The treatment should include disinfection of the irrigation water before it reaches the irrigation distribution system using a combination of periodic chemical injection / dosing for shock treatment and continuous ozonation for maintenance. The treatment should be in the wetwell, using a one-way inlet valve and a circulation pump. This will prevent biological incubation in the wetwell and enable periodic flushing of the irrigation system with treated water.

Periodic chemical treatment should utilize the biocide B-126. This involves chemical injection and mixing into the wetwell at the irrigation pumping station. A simple adjustable chemical metering pump should be mounted on a 55 gallon mixing tank in the pump house. The B-126 mixture should be injected into the circulation pump outlet line into the wetwell.

Ozonation should likewise be controlled in the wetwell. A stainless steel distribution / diffuser manifold should be mounted on the bottom of the wetwell to take advantage of the approximate 7-foot water column there. The ozone generator should be sized based on the bench testing results, to enable oxidation treatment of the approximate 5000 gallons of water in the wetwell in and an injection rate appropriate to the irrigation cycles and rates. The unit should be mounted along on the south wall of the pump house and should include off-gas destruction.

Disinfection components

- Tideflex inlet / check valve 1
- Circulation jet pump 1
- Suction inlet 20
- Diffuser manifold outlet 1
- Mixing tank 1
- Metering pump 1
- Injection line and fittings 1
- Biocide (B-126) 470#
- Ozonator 1
- Venturi inductor 1
- Controller (metering pump, circulation pump, ozonation) 1
- Labor
- Expenses

The rough order of magnitude cost for the system equipment and installation is $65,000.

## 7.0 SELECTED REFERENCES

Larry Oehm, Superintendent
Whispering Winds Golf Course

Lynn Steinle, Contract Manager
Jesse Frogge, Assistant Contract Manager
Brenda Schiller, Plant Operator/Laboratory Technician
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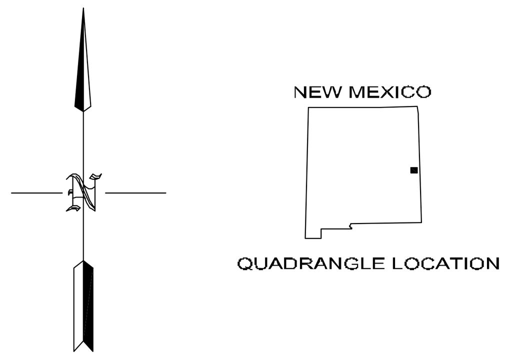


**NOTE:**

TOPOGRAPHIC CONTOUR INTERVAL = 2 FT.

150' 0 150'

SCALE IN FEET

U.S.AIR FORCE

**United States Air Force**

Air Force Center for Environmental Excellence

**CANNON AIR FORCE BASE**
**GOLF COURSE AREA**

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