ENTERED

**DEPARTMENT OF THE AIR FORCE**
**27TH SPECIAL OPERATIONS CIVIL ENGINEER SQUADRON (AFSOC)**
**CANNON AIR FORCE BASE NEW MEXICO**

Mr. Michael A. Poston
Deputy Base Civil Engineer
506 N DL Ingram Blvd.
Cannon AFB NM 88103-5003


01 AUG 2008

Mr. James Bearzi
Chief Hazardous Waste Bureau
New Mexico Environment Department
2905 Rodeo Park Drive East Building 1
Santa Fe NM 87505-5003

Dear Mr. Bearzi:

Cannon Air Force Base hereby submits the *Final No Further Action Report, SWMU 101 – Sewage Lagoons at Cannon AFB, New Mexico*. The report presents a comprehensive summary of the activities completed to date at SWMU 101 in an effort to grant Corrective Action Complete status to the site. Because the footprint of SWMU 101 was selected for redevelopment into raw and treated wastewater storage basins, your agency's expeditious and favorable consideration would be greatly appreciated.

If you have any questions regarding this information, please contact Mr. Jerry Pelfrey, Natural Resources Management, at (575) 784-6391 or email: gerald.pelfrey@cannon.af.mil.

Sincerely

MICHAEL A. POSTON

Attachment:
*Final No Further Action Report, SWMU 101*

cc:
NMED, HWB Bureau (C. Frischkorn)
NMED, HWB Bureau (D. Cobrain)
EPA Region VI (B. Sturdivant)

**DEPARTMENT OF THE ARMY**
CORPS OF ENGINEERS, OMAHA DISTRICT
1616 CAPITOL AVENUE
OMAHA NE 68102-4901

REPLY TO
ATTENTION OF

Environmental Remediation Branch

Mr. Gerald Pelfrey, P.G.
Environmental Restoration Program Manager
27th SOCES/CEVR
Cannon AFB, New Mexico 88103-5003

Dear Mr. Pelfrey:

Please refer to the enclosed three copies of the Sewage Lagoons, Solid Waste Management Unit (SWMU) 101 No Further Action (NFA) Final Report. This report presents a comprehensive summary of the work completed to date at this SWMU 101, at Cannon Air Force Base (AFB), New Mexico, to support a consideration of NFA by the New Mexico Environment Department (NMED).

The U.S. Army Corps of Engineers, Omaha District prepared this document in accordance with NMED, as authorized by the Environmental Protection Agency, to implement the federal Resource Conservation and Recovery Act (RCRA) hazardous waste program as part of the corrective action program activities. Corrective action activities have been conducted in accordance with Cannon AFB's Hazardous Waste Facility Permit.

A letter to accompany this submission of this report to the NMED is also enclosed. If you have any concerns, please contact Mr. Hector Santiago, Project Manager for this project at telephone number (402) 995-2738.

Sincerely,

Randal K. Petersen, P.E.
Chief, Environmental Remediation
Branch
Planning, Programs and Project
Management Division

Enclosures

# FINAL

# NO FURTHER ACTION REPORT

## SWMU 101—Sewage Lagoons

## CANNON AIR FORCE BASE, NEW MEXICO

**Prepared for:**
**27th SOCES/CEVR**
**Cannon Air Force Base**
**New Mexico**



**Prepared by:**

**U.S. Army Corps of Engineers**

**Omaha District**

**Omaha, Nebraska**

**July 2008**

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ACI | Arrowhead Contracting, Inc. |
| AFB | Air Force Base |
| Base | Cannon AFB |
| bgs | below ground surface |
| CAFB | Cannon Air Force Base |
| CAO | corrective action objective |
| CFR | Code of Federal Regulation |
| cm/sec | centimeters per second |
| CMS | Corrective Measures Study |
| COCs | chemicals of concern |
| COPC | chemicals of potential concern |
| COPEC | chemicals of potential ecological concern |
| cy | cubic yards |
| E & E | Ecology and Environment Inc. |
| ELCR | excess lifetime cancer risk |
| EPA | Environmental Protection Agency |
| ESQ | ecological screening quotient |
| ft | feet |
| FWEC | Foster Wheeler Environmental Corporation |
| gpf | gallons per feet |
| gpm | gallons per minute |
| HHRA | human health risk assessment |
| HHSLs | human health screening levels |
| HI | hazard index |
| HQ | hazard quotient |
| MCLs | maximum contaminant levels |
| mg/kg | milligrams per kilogram |
| mg/L | milligrams per liter |

# LIST OF ACRONYMS AND ABBREVIATIONS (continued)

| | |
|---|---|
| NFA | no further action |
| NMED | New Mexico Environment Department |
| PCB | Polychlorinated biphenyl |
| Permit | Hazardous Waste Facility Permit |
| PVC | Polyvinyl chloride |
| RCRA | Resource Conservation and Recovery Act |
| RI | Remedial Investigation |
| SBL | soil barrier layer |
| SESOIL | Seasonal Soil Compartment Model |
| SLERA | screening-level ecological risk assessment |
| SMCL | secondary maximum contaminant level |
| SVOC | semivolatile organic compound |
| SWMU | solid waste management unit |
| SWPPP | Stormwater Pollution Prevention Plan |
| TCLP | Toxicity Characteristic Leaching Procedure |
| TDS | Total Dissolved Solids |
| TtEC | Tetra Tech EC, Inc. |
| USACE | U.S. Army Corps of Engineers |
| USGS | United States Geological Survey |
| VCA | voluntary corrective action |
| VOC | volatile organic compound |

# EXECUTIVE SUMMARY

This No Further Action (NFA) Report presents a comprehensive summary of the work completed to date at the Sewage Lagoons, Solid Waste Management Unit (SWMU) 101, at Cannon Air Force Base (AFB), New Mexico, to support a consideration of NFA by the New Mexico Environment Department (NMED). A Voluntary Corrective Action (VCA) was completed as a Base-initiated risk-based management decision consisting of sludge and contaminated soil removal at the site. Previous investigations of the site and the Corrective Measures Study (CMS) indicated that the primary contamination at the site consisted of arsenic, dieldrin, polychlorinated biphenyl (PCB) -1260 and endrin aldehyde in the area of the former sewage lagoons. Closure efforts during the VCA included sludge removal from the former north lagoon, in-place consolidation in the former south lagoon, and closure using an engineered permanent cover with a biotic barrier. The cover design assumed that the contaminated media at the site consisted of approximately 2' of sludge overlying a 1' thick layer of soil. Prior to the VCA, work at the facility included a Remedial Investigation (RI), the CMS, and associated supplemental data collection activities to support characterization of the site prior to the VCA. The locations of Cannon AFB and the sewage lagoons are shown on Figures 1-1 and 1-2, respectively.

NMED is authorized by the U.S. Environmental Protection Agency (EPA) to implement the federal RCRA hazardous waste program and oversee the corrective action program activities conducted in accordance with Cannon AFB's Hazardous Waste Facility Permit (Permit). NMED issued a RCRA Permit to Cannon AFB on December 17, 1989. Cannon AFB's Draft RCRA Part B Permit Application, submitted in July 1999 (revised in November 2005), refers to the status of various assessment, investigation, and remediation projects for a number of SWMUs on the Base.

During the spring of 2000, Foster Wheeler Environmental Corporation (FWEC) conducted a field investigation as part of the CMS for SWMU 101. The focus of the CMS was to research, evaluate, and select corrective action alternatives to prevent future impact to human health and the environment. Additional data were required to support the CMS and preliminary remedial design work. Therefore, to characterize the sludge and underlying soil within the Sewage Lagoons, chemical and geotechnical analyses were performed on native soil and sludge samples.

The CMS identified and evaluated three potential correction action alternatives to prevent future impact to human health and the environment. The three alternatives evaluated were:

- Alternative 1 – No Action
- Alternative 2 – Sludge Dewatering In-Place, Consolidation, Compaction and Cover
- Alternative 3 – In-situ Bioremediation Through Composting

The preferred alternative chosen for further examination was Alternative 2. The alternative met the correction action objectives, conformed to the design criteria and provided the additional benefit of restoring the north lagoon for stormwater management.

The primary contaminants of concern at SWMU 101 were arsenic, dieldrin, PCB-1260 and endrin aldehyde, specifically in the area of the former sewage lagoons. The risk assessment, which was performed as part of the CMS, evaluated two of the three corrective action alternatives. The No Action alternative was evaluated quantitatively in both the Human Health

Risk Assessment (HHRA) and Screening Level Ecological Risk Assessment (SLERA). The second alternative, Sludge Dewatering In-Place, Consolidation, Compaction, and Cover, was evaluated qualitatively in the HHRA and SLERA. The third alternative, In-situ Bioremediation Through Composting, was deemed ineffective in reducing the levels of metals in sludge at the sewage lagoons and therefore, was not evaluated in the risk assessment.

Based on the results of the HHRA risk calculations, there is no risk to industrial workers due to exposure to sludge and soil at SWMU 101 under the second alternative. The SLERA showed that because this alternative required all of the affected soil and sludge in the north lagoon to be consolidated in the south lagoon, risk to ecological receptors in the north lagoon would be eliminated. However, a potentially complete exposure pathway for burrowing animals would still exist in the south lagoon. Therefore, it was recommended that a bio-barrier be used in the south lagoon to ensure that this exposure pathway is no longer complete for ecological receptors.

The Construction Completion Report (Tetra Tech EC Inc. (TtEC) 2005) documented the construction activities performed for remedial action at SWMU 101. TtEC conducted the remedial action and the objective was to design and implement a cover system for the Sewage Lagoons as part of a voluntary corrective measure to close the site. All field activities were performed according to USACE and Cannon AFB requirements and the approved Work Plan (FWEC, 2003). The USACE Albuquerque District personnel provided construction management oversight.

A summary of the VCA field activities and previous investigations is presented below to support the recommendation for the future of the Sewage Lagoons, SWMU 101.

- In 1985, a hydrogeologic investigation was conducted and four monitoring wells were installed, prior to the Sewage Lagoons being designated as a SWMU. One well was installed upgradient, and three wells were installed downgradient. The wells were sampled quarterly for only field parameters of pH, temperature and conductivity.

- Results of the 1991 RI showed that sludge samples from the lagoon areas contained low levels of pesticides and PCBs, but they were most likely as a result of base activities that transferred these contaminants through the sanitary sewer to the lagoons.

- The 1991 RI recommended to continue annual groundwater monitoring of the four wells for volatile organics, metals, pesticides, nitrate, sulfate and total dissolved solids (TDS). This recommendation was made to support site closure.

- Annual groundwater samples were taken from 1998 to 2001 from wells Well E, Well F, Well G, and Well H at SWMU 101. The groundwater was sampled and analyzed yearly by the United States Geological Survey (USGS) and analyzed by USACE's Southwestern Division Laboratory, located in Dallas, Texas. Iron was the only analyte detected above EPA's secondary maximum contaminant level (SMCL) of 0.30 milligrams per liter (mg/L).

- The results of the 1997 Supplemental Sludge Sampling effort showed that levels of analytes did not exceed RCRA limits for hazardous constituents. Additional sludge samples were recommended to adequately characterize the sludge prior to any corrective action.

- In 2000, a CMS was performed which included sludge and native soil sampling. Sludge results were less than Toxicity Characteristic Leaching Procedure (TCLP) levels;

therefore, it was considered non-hazardous, and it was determined that it would not require off-site disposal during removal.

- In 2000, the CMS reported that concentrations of pesticides decreased with depth. None of the soil was determined to be hazardous and it was determined that it would not require off-site disposal during removal.
- The CMS evaluated three alternatives; no action, sludge dewatering in-place, consolidation, compaction, and cover; and in-site bioremediation through composting. The recommended corrective action was sludge dewatering in-place, consolidation, compaction and cover. The alternative met the corrective action objectives (CAOs) conformed to the conceptual design criteria, and provided the additional benefit of restoring the north lagoon for stormwater management.
- Fate and transport modeling was performed during the CMS to support the risk assessment and the evaluation of the corrective alternatives. Results of the 50-year simulations predicted that vertical pollution migration does not reach groundwater.
- Risk characterization was evaluated during the CMS and showed negligible risk to industrial workers due to exposure to chemicals in the sludge or soil, but indicated there may be risk to ecological receptors that reside or visit the site.
- A VCA was performed during 2003-2004. Soils and sludge were removed from the former north lagoon and consolidated into the former south lagoon. The material was graded, compacted, and covered with a 20-acre, 42" thick soil barrier layer.
- Confirmation samples taken after excavation activities showed no contamination and no potential for leaching to groundwater.

The results of previous investigations, risk evaluations, and completion of the VCA at the Sewage Lagoons, SWMU 101, support a recommendation of NFA for this SWMU in accordance with NMED NFA Criterion #5:

> The site was characterized/remediated in accordance with applicable state and/or federal regulations, and the available data indicate that contaminants pose an acceptable level of risk under current and projected future land use.

# 1.0 REPORT PURPOSE AND SCOPE

This NFA Report presents a comprehensive summary of the work completed to date at the Sewage Lagoon, SWMU 101, at Cannon AFB, New Mexico, to support a consideration of NFA by the New Mexico Environment Department (NMED). A VCA was completed as a Base-initiated risk-based management decision consisting of in-place sludge dewatering, consolidation, compaction and a cover system. Previous investigations of the site and the CMS indicated that the primary contamination at the site consisted of arsenic, dieldrin, PCB-1254, and endrin aldehyde in soil and sludge in the area of the former sewage lagoons. Prior to the VCA, work at the facility included a RI, the CMS, and the associated supplemental data collection activities to support characterization of the site. The locations of Cannon AFB and the Sewage Lagoons are shown in Figures 1-1 and 1-2, respectively.

## 1.2 Regulatory Framework

NMED is authorized by the EPA to implement the federal RCRA hazardous waste program and oversee the corrective action program activities conducted in accordance with Cannon AFB's Hazardous Waste Facility Permit (Permit). NMED issued a RCRA Permit to Cannon AFB on December 17, 1989 (revised in 2005). Cannon AFB's Draft RCRA Part B Permit Application, submitted in July 1999, refers to the status of various assessment, investigation, and remediation projects for a number of SWMUs on the Base.

Based on the sites investigations and CMS conducted to date, the primary chemicals of concern (COCs) at SWMU 101 are volatile organic compounds, metals, pesticides, nitrate, sulfate and total dissolved solids in the groundwater. As a result, an interim monitoring program was implemented to support site closure and to comply with RCRA requirements.

An ecological survey showed that concentrations of inorganic chemicals produced elevated ecological screening values for potential ecological receptors. However, there was no risk identified to human health from exposure to surface or subsurface soil or sludge at the site. To prevent exposure to ecological receptors, sludge removal from the former north lagoon, in-place consolidation in the former south lagoon, and closure using an engineered cover with a biotic barrier was recommended as the corrective action for closing the lagoons from the corrective actions that were evaluated in the CMS: No Action; Sludge Dewatering In-Place, Consolidation, Compaction and Cover; and In-Situ Bioremediation Through Composting.

## 1.3 Site History

Cannon AFB is located in Curry County, New Mexico, approximately 7 miles west of the city of Clovis (Figure 1-1). Cannon AFB occupies 4,320 acres, primarily consisting of the airfield and associated operations, maintenance, and support facilities that are located northwest of the airfield. Housing facilities are located in the former northwest portion of the Base, west of U.S. Highway 277, and north of U.S. Highway 60. Additional Base support facilities, such as the munitions storage area, and current fire department training area, are located south and east of the airfield.

Cannon (CAFB), New Mexico, which has been in existence for 64 years, lies in the high plains of eastern New Mexico, near the Texas Panhandle. Its primary mission is to host the 27$^{th}$ Fighter Wing; an F-16 fighter wing capable of day and night operations.

SWMU 101, Sewage Lagoons, was constructed in 1966 and consisted of two unlined surface impoundments, operating in series, received combined sanitary and industrial wastewater from Base facilities. The lagoons had concrete-lined banks and unlined earthen bottoms and were located on the east-central part of the base between an abandoned north-south abandoned runway and perimeter road. The lagoons had a total surface area of 32 acres and were separated by a 12-foot-wide levee. In 1998, a new wastewater treatment plant was put into operation at Cannon AFB. Sewage discharge to the lagoons stopped in 1998, but the Base continued to discharge treated wastewater to the lagoons in order to prevent direct exposure to the underlying sludge. In early 1998, the Base stopped discharging treated wastewater to the lagoons and allowed them to dry. The lagoons are currently inactive and no longer support base operations. Efforts during the VCA included sludge removal from the former north lagoon, dewatering, in-place consolidation in the former south lagoon, and closure using an engineered cover with a biotic barrier. The cover design assumed that the contaminated media at the site consisted of approximately 2' of sludge overlying a 1' thick layer of soil.

## 1.4 Document Organization

This report is organized as follows:

- Section 1 contains the report purpose and organization.
- Section 2 summarizes the description and history for the sewage lagoons.
- Section 3 provides a background, previous investigations and site activities.
- Section 4 provides a description of the VCA.
- Section 5 provides a summary of the site conceptual model, contamination assessment, HHRA, ecological risk assessment, and a description of the current conditions of the site.
- Section 6 presents the conclusion and recommendations for the SWMU 101.
- Section 7 lists the references used to develop this report.

# 2. BACKGROUND INFORMATION

This section presents background information and a description of the sewage lagoons, in addition to the results of the CMS report. Previous investigations of the sewage lagoons are discussed in Section 3.

## 2.1 SWMU 101, Sewage Lagoons

The Sewage Lagoons were identified as SWMU 101 in the Cannon AFB Hazardous Waste Permit dated November 14, 1989. The Sewage Lagoons consisted of two unlined surface impoundments that were used from 1966 to 1998 and received combined sanitary and industrial waste from base facilities. The lagoons were located on the east-central part of the base between an abandoned north-south abandoned runway and perimeter road. The lagoons had a total surface area of 32 acres and were separated by a 12-foot-wide levee. In 1998, a new wastewater treatment plant was put into operation at Cannon AFB. Sewage discharge to the lagoons stopped in 1998, but the Base continued to discharge treated wastewater to the lagoons in order to prevent direct exposure to the underlying sludge. In early 1998, the Base stopped discharging treated wastewater to the lagoons and allowed them to dry.

The CMS identified and evaluated three potential correction action alternatives to prevent future impact to human health and the environment. The three alternatives evaluated were:

- Alternative 1 – No Action
- Alternative 2 – Sludge Dewatering In-Place, Consolidation, Compaction and Cover
- Alternative 3 – In-site Bioremediation Through Composting

The preferred alternative chosen for further examination was Alternative 2. The alternative met the correction action objectives, conformed to the design criteria and provided the additional benefit of restoring the north lagoon for stormwater management.

To characterize the sludge and underlying soil within the Sewage Lagoons before removal, chemical and geotechnical analyses were performed on native soil and sludge samples collected during the CMS.

Sludge and soil samples were analyzed for RCRA Metals, volatile organic compounds (VOCs), pesticides, PCBs, nitrate, TCLP Pesticides and Metals (sludge only) and Total Organic Carbon. TCLP results for sludge samples indicated that there was no potential for leachate to exceed regulatory levels. Low levels metals were detected in the soil at concentrations that tended to decrease with depth. Analytical results for soil indicated that the soil would be considered nonhazardous and would not require offsite disposal during removal action.

The preferred alternative was implemented as a voluntary corrective action by Cannon AFB. The cover system was designed to minimize any potential threat to human health and the environment by removing the sludge and underlying contaminated soil from the former north lagoon, referred to as the North Lagoon Area, consolidating the excavated material into the former south lagoon, referred to as the South Lagoon Area, grading and compacting the sludge and soil material to prepare the substrate, and constructing a 42-inch-thick engineered earthen cover system.

# 3.0 PREVIOUS INVESTIGATIONS AND SITE ACTIVITIES

This section presents an overview of the investigations prior to the VCA-related activities in 2005. Previous investigations covered in this section include the following:

- Hydrogeologic Investigation – 1985
- Remedial Investigation – 1991 to 1992
- Supplemental Sludge Sampling – 1998
- CMS – 2001
- Annual Groundwater Monitoring – 1998 to 2001

## 3.1 Hydrogeologic Investigation – 1985

From 1984 through 1985, William Matotan and Associates conducted a hydrogeological investigation at the Sewage Lagoons (William Matotan and Associates, 1985). At the time of the investigation, the Sewage Lagoons had not yet been designated a SWMU. This investigation included the installation of four monitoring wells: one upgradient and three downgradient of the Sewage Lagoons. These wells were sampled quarterly and analyzed for field parameters only, including pH, temperature, and conductivity.

## 3.2 Remedial Investigation – 1991 to 1992

The objective of the RI conducted by Woodward-Clyde (Woodward-Clyde, 1992) was to evaluate the nature and extent of the presence of potentially hazardous contaminants at 18 Cannon AFB sites, including the Sewage Lagoons. Field activities consisted of:

- Collecting eight sludge samples and three surface water samples for chemical analyses
- Measuring the static water level, purging completely and collecting groundwater samples from four monitoring wells for chemical analysis

The sampling objective at the Sewage Lagoons was to provide information regarding the nature and extent of contamination present in the wastewater sludge, the treated wastewater within the lagoons, and the groundwater downgradient of the SWMU. The data collected from the sludge, surface water, and groundwater samples were used to further evaluate the extent of potential contamination, if present, and to perform a baseline risk assessment to determine if the area poses a risk to human health or the environment.

Four sludge samples from the north lagoon and four sludge samples from the south lagoon were collected. Sludge samples were analyzed for TCLP parameters, VOCs, semivolatile organic compounds (SVOCs), metals, PCBs, and pesticides. The VOCs acetone and 2-butanone and the SVOC bis(2-ethylhexyl)phthalate were the only organic compounds identified as being present in the sludge samples collected during the RI. It is possible that the detections of these compounds are attributable to laboratory contamination since they were detected in up to 14 of the method blanks analyzed during the RI. Metals were detected above the site background levels for soil. The pesticides 4,4-DDD, 4,4'-DDE, and chlordane, and PCB-1254 were detected in the sludge samples from both the north and south lagoons. These pesticides and PCB-1254 were uniformly detected at low concentrations throughout the lagoons and are most likely the

result of an accumulation of materials from various base activities transferred to the lagoons through the sanitary sewer. Two sludge samples were also analyzed for TCLP parameters to evaluate the leachability of detected chemicals. None of the chemicals exceeded the TCLP criteria.

Four groundwater samples were collected from existing monitoring wells E, F, G, and H at the Sewage Lagoons during the RI. Wells F, G, and H are located downgradient from the Sewage Lagoons, and well E is located upgradient of the site. Groundwater samples were analyzed for Appendix IX constituents. Metals were the only analytes detected and results showed all concentrations were below respective maximum contaminant levels (MCLs).

Three surface water samples were collected and were analyzed for Appendix IX constituents. Various metals and sulfide were detected in all three surface water samples. Lead, copper, mercury, silver and zinc were detected or above either the acute or chronic EPA Ambient Water Quality Criteria for surface water. The sample located near the wastewater flow splitting pool reported the most detects of metals.

As a result of this investigation, the only recommendation made for ongoing work at the Sewage Lagoons was to continue annual groundwater monitoring for VOCs, metals, pesticides, nitrate, sulfate, and TDS. According to the RI report, the recommendation for an interim monitoring program was made to support site closure until the regulatory framework was resolved. Groundwater monitoring has been conducted on an annual basis to fulfill the requirements of RCRA.

### 3.3 Supplemental Sludge Sampling - 1998

The objective of the sampling conducted by (Ecology and Environment, Inc. (E & E) in 1997 was to support the preliminary evaluation of corrective action alternatives (E & E, 1998). Three sludge samples were collected and analyzed for total nitrogen, total solids, volatile solids, metals, and pathogens. Analytical results indicated that the levels of analytes detected did not exceed RCRA limits for hazardous constituents. E & E concluded that additional sludge samples were required to adequately characterize the sludge during the corrective action process of the Sewage Lagoons.

To propose the appropriate method of excavation and transferal, disposal area, and sludge hauling requirements, the sludge quantity was also investigated by E & E. The sludge volume in the lagoons during the 1997 investigation was estimated to be 165,000 cubic yards (cy).

### 3.4 RCRA Groundwater Monitoring – 1998 through 2001

As a result of the 1992 Woodward Clyde RI program, recommendations were made for annual groundwater sampling of the four monitoring wells (Well E, Well F, Well G, and Well H) at SWMU 101. The groundwater was sampled and analyzed yearly by the USGS, starting in 1998. Samples were analyzed for VOCs, metals, nitrate, sulfate and TDS and were analyzed by USACE's Southwestern Division Laboratory, located in Dallas, Texas. Analytical results are shown in Tables 3-2 through 3-5. Iron was the only analyte detected above EPA's SMCL. The SMCL for iron is 0.30 mg/L.

## 3.5 Corrective Measures Study - 2000

During the Spring of 2000, FWEC conducted a field investigation as part of the CMS for SWMU 101. The focus of the CMS was to research, evaluate, and select corrective action alternatives to prevent future impact to human health and the environment.

As part of the CMS, human health and ecological risk assessments were evaluated in order to determine the level at which contaminant and source control would be required. Additional data were required to support the CMS and preliminary remedial design work. Therefore, to characterize the sludge and underlying soil within the Sewage Lagoons, chemical and geotechnical analyses were performed on native soil and sludge samples. This additional data collection is further described in Section 4.2.

The CMS identified and evaluated three potential correction action alternatives to prevent future impact to human health and the environment. The three alternatives evaluated were:

- Alternative 1 – No Action
- Alternative 2 – Sludge Dewatering In-Place, Consolidation, Compaction and Cover
- Alternative 3 – In-site Bioremediation Through Composting

The preferred alternative chosen for further examination was Alternative 2. The alternative met the correction action objectives, conformed to the design criteria and provided the additional benefit of restoring the north lagoon for stormwater management.

## 4.0 VOLUNTARY CORRECTIVE ACTION

The CMS of SWMU101 at Cannon AFB was a voluntary program aimed at achieving closure of the Sewage Lagoons, which were active from 1966 through 1998. The CMS report for SWMU 101 was prepared in 2001 (FWEC, 2001) and its purpose was to identify and evaluate potential corrective action alternatives to prevent future impact to human health and the environment.

The Construction Completion Report (TtEC 2005) documents the construction activities conducted for remedial action at SWMU 101. TtEC conducted the remedial action and the objective was to design and implement a cover system for the Sewage Lagoons as part of a VCA to close the site. All field activities were performed according to USACE and Cannon AFB requirements and the approved Work Plan (FWEC, 2003). The USACE Albuquerque District personnel provided construction management oversight.

The cover system was designed to minimize any potential threat to human health and the environment by removing the sludge and underlying contaminated soil from the former north lagoon, referred to as the North Lagoon Area, consolidating the excavated material into the former south lagoon, referred to as the South Lagoon Area, grading and compacting the sludge and soil material to prepare the substrate, and constructing a 42-inch-thick engineered earthen cover system. The construction activities included:

- Grading and drainage
- Demolition and removal of concrete and piping
- Excavation and handling of contaminated material from the North Lagoon Area
- In-place consolidation of excavated material, random fill, and grading in the South Lagoon Area
- Construction of a 20-acre, 42-inch-thick engineered earthen cover (soil barrier layer)
- Installation of the biota barrier and erosion/vegetation layers
- Site revegetation and fencing

Complete removal of the concrete-lined banks of the former south lagoon and removal of the piping only from the former north lagoon was required in the Work Plan. However, instead, the concrete slabs covering the earthen banks of the southern half of the North Lagoon Area were also removed. Materials from the exposed earthen berms in the North Lagoon Area and the earthen berms surrounding the South Lagoon Area, approximately 20,000 cy, were used to construct the soil-barrier layer of the soil cover system. The berm material was tested and approved using the same requirements as offsite materials and resulted in cost savings to the project. During construction, permits were obtained and completed for construction activities. A National Pollutant Discharge Elimination System (NPDES) Stormwater Construction Permit was obtained since the construction area at SWMU 101 was greater than 5 acres. The permit included clearing, grading and excavation activities. A Stormwater Pollution Prevention Plan (SWPPP) was prepared for construction activities and the plan was followed during construction. The SWPPP was presented in the Final Work Plan (FW 2003).

According to the work plan, approximately 70,000 cy of contaminated material was to be excavated from the North Lagoon Area and placed in the South Lagoon Area. However, the thickness of the sludge and the layers of underlying contaminated soil were less than anticipated, resulting in approximately 60,200 cy. The variance in depth was attributed to evaporation of the

lagoons, beginning in 1999 through the initiation of construction. The sludge contained relatively little moisture and was consolidated without the need for dewatering.

During the excavation of the southern section of the North Lagoon Area, a subgrade "'trench" of sludge trending east-west was discovered below the established limits of the contaminated soil layer. This material, approximately 13,200 cy, was placed in the south Lagoon Area. The over-excavated area was backfilled with stockpiled material left over from former runway work at Cannon AFB. This stockpile is commonly referred to as the Keel material and was located adjacent and west of SWMU 101. TtEC conducted post excavation confirmation soil sampling. Hagar & Associates, P.C. Land Surveyors completed the post excavation topographical and sample location surveys. According to the sludge layer as-built survey, the total amount of fill materials placed in the South Lagoon Area, including concrete rubble, polyvinyl chloride (PVC) piping, sludge and soil, was 73,400 cy.

ACI (Arrowhead Contracting Inc,) excavated approximately 60,200 cy of sludge and contaminated soil materials from the North Lagoon Area and consolidated this with the South Lagoon Area material. The 13,200 cy of additional sludge material excavated from the North Lagoon Area was used as random fill in the South Lagoon Area in place of the Keel material, and the consolidated material and random fill was graded and surveyed.

A soil barrier layer (SBL) was constructed of an 18- to 21-inch-thick earthen cover system composed of clean, approved soil that was placed on top of the sludge and random fill layer. The purpose of the SBL was to reduce infiltration of moisture into the underlying layer of contaminated material. Both onsite and offsite sources were used for the SBL and was tested in accordance with the project specifications.

A biota barrier consisting of recycled, crushed concrete was placed on top of the SBL. The purpose of this layer is to prevent animals from burrowing into the SBL. A 6-inch erosion/vegetation layer was constructed on top of the SBL.

The South Lagoon Area, 23 acres, was revegetated with native species using an approved seed mix. A five-strand barbed-wire fence was installed on the northern boundary of the capped area to separate the North and South Lagoon Areas and to prohibit access to the site.

## 4.1 Evaluation of Site Conditions

Preliminary site work was completed in 1998 to support the use of sludge consolidation and covering the contaminant area with soil to achieve site closure. Human health and ecological risk assessments were conducted as part of the CMS in order to determine the level at which contaminant and source was required at the site. An ecological survey of the area was also conducted to support the risk assessment.

A field program was conducted during the CMS to characterize the Sewage Lagoon sludge and the native soil directly beneath the lagoons for the future design phase of the corrective action. Fate and transport modeling was performed to support the risk assessment and the evaluation of corrective action alternatives to simulate contaminant migration through the vadose zone. Results of the modeling under the site conditions at the time illustrated that degradation to groundwater, due to contaminants of concern in sludge, was unlikely to occur.

The CMS evaluated three alternatives; no action, sludge dewatering in-place, consolidation, compaction, and cover; and in-site bioremediation through composting. The recommended corrective action was sludge dewatering in-place, consolidation, compaction and cover. The alternative met the CAOs, conformed to the conceptual design criteria, and provided the additional benefit of restoring the north lagoon for stormwater management.

The Phase III Sludge Management, Compliance Evaluation, and Requirements Identification report (E&E, 1998) and the Sewage Lagoons Closure Final Specifications (USACE, 2002) concurred that dewatering, consolidation, and compaction of the contaminated material, followed by placement of a protective cover, was an economical solution to close the lagoons permanently. Construction activities at SWMU 101 were completed from 2003 to 2004 and documented in the Construction Completion Report (TtEC, 2005), and is presented in Section 4.3.

## 4.2 Pre-Voluntary Corrective Action Site Characterization

In order to characterize the Sewage Lagoon sludge and native soil directly beneath the lagoons before completion of corrective action activities, the CMS included a field investigation designed to collect additional analytical and geotechnical data.

The CMS field investigation was conducted during April 3-7, 2000 in order to characterize the sludge and native soil for the future design phase of the corrective action and included the following steps:

- Mobilization of personnel and equipment
- Construction of access ramps into the lagoons and to each sample location using road base materials
- Collection of sludge and native soil samples at five locations in each lagoon with a hollow-stem auger rid
- Restoration of the site to a state comparable to pre-CMS field activities
- Demobilization of personnel and equipment

Sludge and soil sampling was performed in April 3-7, 2000 in order to characterize the sludge and native soil for the future design phase of the corrective action.

Native soil sampling was conducted with a hollow-stem auger drilling rig. Prior to sampling, ten locations were identified. Five of the locations were located in the north lagoon (SB01 through SB05), and five were located in the south lagoon (SB06 through SB10). Soil samples were collected from each borehole at depth intervals of 0 to 2 ft, 4 to 6 ft, and 8 to 10 ft. One sludge sample was also collected at each sample location and the sludge thicknesses observed in the boreholes ranged from 2 to 10.5 inches. Coordinates and elevations were established for each borehole location using a portable global positioning system unit. Soil and sludge samples were analyzed for RCRA metals, VOCs, pesticides, PCBs, nitrate and total organic carbon (TOC). In addition, sludge samples were analyzed for TCLP Pesticides and Metals.

Very low TCLP concentrations of pesticides and metals were detected in the sludge samples from both the north and south Sewage Lagoons. All of the sludge TCLP concentrations were below the RCRA regulatory limits specified in 40 CFR 261. The sludge was considered to be

nonhazardous and does not require offsite disposal. TCLP results for sludge samples indicated that there was no potential for leachate to exceed regulatory levels.

Low levels of pesticides were detected in the soil in both the north and south lagoons. Various metals were also detected in the soil at concentrations that tend to decrease with depth. The soil was considered nonhazardous and did not require offsite disposal.

Geotechnical results for the soil samples indicated that the soil consisted mostly of clay and some silt with gravel. Fate and transport modeling using the Seasonal Soil Compartment Model (SESOL) simulated contaminant migration through the vadose zone. The modeling showed that degradation to groundwater from sludge migration was unlikely under normal conditions, where infiltration of water into the vadose zone is minimal.

## 4.3 Voluntary Corrective Action Activities

The Construction Completion Report (TtEC 2005) documents the construction activities conducted for remedial action at SWMU 101. All field activities were performed according to USACE and Cannon AFB requirements and the approved Work Plan (FWEC, 2003). The USACE Albuquerque District personnel provided construction management oversight. Construction activities occurred in 2003 and 2004.

The primary purpose of the Voluntary Corrective Action was to remove sludge from the sewage lagoons in order to close the site.

The Sewage Lagoons cover system was designed to minimize potential threat to human health and the environment by removing the sludge and underlying contaminated soil from the former north lagoon, (North Lagoon Area), consolidating the excavated material into the former south lagoon (South Lagoon Area), grading and compacting the sludge and soil material to prepare the substrate, and constructing a 42-inch-thick engineered earthen cover system.

Construction activities included:

- Grading and drainage
- Demolition and removal of concrete and piping
- Excavation and handling of contaminated material from the North Lagoon Area
- In-place consolidation of excavated material, random fill, and grading in the South Lagoon Area
- Construction of a 20-acre, 42-inch-thick engineered earthen cover (soil barrier layer)
- Installation of the biota barrier and erosion/vegetation layers
- Site revegetation and fencing

### 4.3.1 Grading and Drainage

Temporary soil erosion control measures were constructed along the southern and southeastern borders of SWMU 101 in order to prevent storm water runoff from leaving the site. Also, temporary soil erosion and sediment control measures were installed at two drop-inlets and one culvert on the east side of the entire unit during construction and post-construction activities.

### 4.3.2 Demolition and Removal

Roads were constructed into the lagoons and tree limbs were trimmed to prepare the site for demolition activities. Demolition at the site involved removing concrete structures, slabs, steel and polyvinyl chloride piping, and associated components from the North Lagoon Area. These materials were then used as fill in the South Lagoon Area.

Materials from the exposed earthen berms in the North Lagoon Area and earthen berms surrounding the South Lagoon Area, approximately 20,000 cy, were used to construct the SBL of the cover system.

### 4.3.3 Excavation and Handling of Contaminated Material

According to the work plan (FWEC, 2003), approximately 70,000 cy of contaminated material was to be excavated from the North Lagoon Area and placed in the South Lagoon Area. However, the thickness of the sludge and the layers of underlying contaminated soil were less than anticipated, resulting in approximately 60,200 cy of contaminated material. The variance in depth was attributed to evaporation of the lagoons, beginning in 1999 through the initiation of construction. The sludge contained relatively little moisture and was consolidated without the need for dewatering.

During the excavation of the southern section of the North Lagoon Area, a subgrade "'trench" of sludge trending east-west was discovered below the established limits of the contaminated soil layer. This material, approximately 13,200 cy, was placed in the south Lagoon Area. The over-excavated area was backfilled with stockpiled material left over from former runway work at Cannon AFB. This stockpile is commonly referred to as the Keel material and was located adjacent and west of SWMU 101. TtEC conducted post excavation confirmation soil sampling. Hagar & Associates, P.C. Land Surveyors completed the post excavation topographical and sample location surveys. According to the sludge layer as-built survey, the total amount of fill materials placed in the South Lagoon Area, including concrete rubble, piping, sludge and soil, was 73,400 cy**.**

### 4.3.4 Sludge Consolidation and Random Fill

Approximately 60,200 cy of sludge and contaminated soil materials from the North Lagoon Area were excavated and consolidated with the South Lagoon Area material. The 13,200 cy of additional sludge material excavated from the North Lagoon Area was used as random fill in the South Lagoon area in place of the Keel material specified in the Final Work Plan. This resulted in a cost savings to the project. The consolidated material and random fill was graded from 1 to 3 percent and surveyed to document as-built conditions.

### 4.3.5 Soil Barrier Layer Construction

The SBL/ is approximately 43,500 cy of an 18- to 21-inch-thick earthen cover system composed of clean, approved soil placed on top of the sludge and random fill layer. The purpose of the SBL was to reduce infiltration of moisture into the underlying layer of contaminated material. Both onsite and offsite sources were used for the SBL and were tested in accordance with the project specifications.

### 4.3.6 Biota Barrier Construction

The biota barrier consisted of 15 to 18 inches of recycled, crushed concrete placed on top of the SBL. The purpose of the layer was to prevent animals from burrowing into the SBL. Several sources were used to provide the material required to construct the biota barrier. Approximately 8,000 cy of material came from the crushed concrete stockpile at SWMU 97, Landfill 25; an additional 8,000 cy consisted of extra, unused Keel material. The biota barrier layer was placed in two lifts because the grain size of the two sources did not meet the requirements of the barrier specification. The first lift consisted of the SWMU 97 and Keel material and the second lift consisted of another 16,000 cy of 3- to 6- inch crushed concrete from an offsite borrow source.

### 4.3.7 Erosion/Vegetation layer Construction

The 6-inch erosion/vegetation layer was completed in mid-December 2003. Approximately 12,800 cy of material was imported from a borrow area located 8 miles north of the Village of Melrose, New Mexico to construct this layer. The area was re-seeded and the topsoil was crimp-mulched which was part of erosion control measures.

### 4.3.8 Site Revegetation and Fence Construction

In April 2004, the site was revegetated by seeding with native species using an approved seed mix. Also, a five-strand barbed-wire fence was installed on the northern boundary of the capped area to separate the North and South Lagoon Areas and to prohibit access. This fence was tied in with the existing fencing.

### 4.3.9 Confirmation Samples

Confirmation sampling was performed at SWMU 101 in the North Lagoon Area after excavation activities were completed. Also, offsite borrow sources were sampled prior to delivery.

Seventeen (17) composite samples plus three (3) field duplicate samples were collected to a depth of 1 ft within the North Lagoon. The last composite sample was collected in the southern portion of the lagoon area that was over-excavated to remove contamination extending deeper than anticipated.

All samples were analyzed for the parameters presented as chemicals of potential concern (COPCs) and included pesticides, PCBs, nitrate, and selected metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver).

Based on the data, the conditions at the North Lagoon do not impose a risk to human health and the environment and were considered free of contamination due to previous activities at the site. Complete results can be found in Appendix A of the Construction Completion Report.

## 5.0 SITE CONCEPTUAL MODEL

This section presents a summary of the elements of the site conceptual model SWMU 101. Information presented in this section originally was presented in the following reports generated for the different phases of work completed for SWMU 101:

- William Matotan and Associates – 1985
- Woodward Clyde, Remedial Investigation – 1992
- E & E - 1998
- CMS Report, FWEC – 2001

### 5.1 Soils and Geology

The near-surface stratigraphic units of interest at Cannon AFB are the Late Miocene-Late Pliocene age Ogallala Formation and the Early Triassic Dockum Group.

The Dockum Group consists of three formations. The stratigraphically lowest unit is the Santa Rosa Sandstone. Overlying the Santa Rosa Sandstone are the Chinle and Redonda Formations. The Chinle and Redonda Formations are composed mainly of red shales with lesser interbedded sands and are known locally as "redbeds." The top of the Dockum Group is marked by an erosional unconformity having relief of up to several hundred feet (ft).

Overlying the Dockum Group redbeds is the Ogallala Formation, which extends from eastern New Mexico and Colorado into Texas, Oklahoma, Kansas, Nebraska, and South Dakota. Drillers' logs from Cannon AFB indicate that the Ogallala Formation varies from 360 to 415 ft in thickness. The incised upper surface of Triassic redbeds strongly influences the Ogallala thickness. Stream valleys in the post-Triassic unconformity are deep and trend dominantly east-west. Ogallala thickness may, thus, vary significantly over short north-south distances.

The Ogallala is erosionally truncated to the south along the abandoned Portales Valley, to the west along the Pecos River Valley, and to the north in a series of ephemeral stream valleys. The Ogallala Formation extends more than 125 miles to the east before terminating as an escarpment in Briscoe County, Texas. Springs and seeps are common along the erosional margins of the Ogallala.

The Ogallala dips gently and monoclinally to the southeast in the vicinity of Cannon AFB. As reported in Lee Wan and Associates (1990), data suggest that some Quaternary warping may have occurred; however, most of the structures are well to the northwest and southwest of Cannon AFB. No faults or buried structural lineaments are known to exist in the vicinity of Cannon AFB.

The Ogallala Formation is composed of unconsolidated, poorly sorted gravel, sand, silt, and clay. The base of the Ogallala is generally marked by a gravel, cobble, and boulder deposit. This basal member contains sediment derived from igneous and sedimentary rock transported from the mountains to the west. The Ogallala Formation was laid down by stream and overbank deposits formed within coalescing alluvial fans. These fans form a broad pediment along the eastern flank of the Rocky Mountains. As is typical of alluvial deposits, Ogallala internal stratigraphy varies vertically and horizontally over short distances.

Except where strongly cemented by calcium carbonate (caliche), the sediment of the Ogallala is loose and friable. Authigenic and allogenic clays are found as a trace to abundant matrix mineral (Lee Wan and Associates, 1990). As reported by Lee Wan and Associates (1990), five zones have been distinguished within the Ogallala of east-central New Mexico on the basis of clay minerals. Smectites (montmorillonites) and attapulgite (with sepeotite) are the dominant clays throughout the Ogallala. Illite is a lesser but persistent clay, as is kaolinite. Smectite is a swelling clay, causing deep cracks to form in dry surface soil. Smectite in particular and, to a lesser extent, attapulgite and illite are clays with moderate to high cation exchange capacities (CEC). The formation as a whole should, therefore, have a relatively high CEC, which should inhibit the migration of charged contaminants, especially ionic forms of metals.

Caliche is a major feature of the Ogallala Formation, occurring as nearly continuous to discontinuous layers throughout. Caliche is hard, white to pale tan on fresh surfaces, weathering to gray, and has a chalky appearance. Caliche forms as calcium carbonate leached from overlying sediment, and precipitates in the pore space of the host sediment. Precipitation is caused by the evaporation of downward percolating water. The caliche may, thus, mark the position of ancient vadose zones. Lee Wan and Associates (1990) give radiocarbon dates for the upper climax caliche range from approximately 27,000 years before present (BP) to approximately 42,000 years BP.

Caliche is relatively soluble in acidic water (pH less then 7) or in water containing dissolved carbon dioxide. The top surface of the upper climax caliche in fresh outcrop shows solution etching.

## 5.2 Groundwater

The lower portion of the Ogallala Formation is the primary regional aquifer for both potable and irrigation water. No deeper aquifers are used in the vicinity of Cannon AFB. The Ogallala aquifer is part of the High Plains Aquifer, which extends continuously from Wyoming and South Dakota into New Mexico and Texas. In east-central New Mexico, the Ogallala aquifer rests on Dockum Group redbeds, which serve as the basal confining layer. The Ogallala is a water table, or unconfined aquifer. The Ogallala aquifer has a southeasterly regional gradient of about 10 to 15 ft per mile (mi) (Woodward-Clyde, 1992). Well yields vary from less than 1 gallon per minute (gpm) in thin silt and sand, and up to 1,600 gpm in thick sand and gravel (Lee Wan and Associates, 1990). Water quality is generally good with dissolved solids ranging from 250 to 500 mg/L (Gutentag et. al., 1984) and fluoride ranging from 2.2 to 2.7 mg/L (William Matotan and Associates, Inc., 1985).

Based on the mid-1960's data, the Ogallala aquifer at Cannon AFB has an average saturated thickness of 120 ft. The local groundwater gradient is southeasterly at 7 to 15 ft per mi (USAF, 1990). Cannon AFB water well tests have yields ranging from 205 gpm to 1,150 gpm. Specific capacities range from 11.4 gallons per ft (gpf) to 27.9 gpf (Lee Wan and Associates, 1990).

Estimates of hydraulic conductivity were made from well pump tests conducted by Cannon AFB using the Theis equation. The data used in these calculations were obtained to evaluate pump rates, efficiency, and well yield and were not intended for use in calculating aquifer properties, and should, therefore, be considered as estimates only.

Hydraulic conductivity values ranged from approximately $2.0 \times 10^{-3}$ centimeters per second (cm/sec) to $2.0 \times 10^{-2}$ cm/sec. These estimates appear to be low when compared to published

hydraulic conductivity data for sand and gravel (Freeze and Cherry, 1979). As reported in Kearney (1987), a groundwater flow velocity of about 150 ft per year has been estimated. Based on this calculation, the hydraulic conductivity is approximately $1.0 \times 10^{-1}$ cm/sec.

Recharge to the Ogallala is primarily through precipitation. Kearney (1987) indicated that the recharge rate may be as much as 1.0 in per year. Because of the evapotranspiration rate and low precipitation, recharge occurs only during heavy rainfall events in which the infiltration capacity of the soil is exceeded and runoff occurs, or during cool months when precipitation exceeds evapotranspiration. Excess runoff flows to playas, and the presence of water in playas allows deep percolation to the aquifer. The occurrence of this process is evidenced by the presence of clay deposits in playas and the possibility that caliche is thin or absent directly below playas. Caliche is soluble in acidic rain water and is leached over time to form percolation pathways.

Discharge from the Ogallala occurs through well pumping and springs along the eroded margins. Spring discharge does not occur on or near Cannon AFB. Domestic and irrigation water wells are common on and around the base. However, the rate of discharge exceeds local recharge. Water levels in the Ogallala have declined steadily from the 1930s to the present. From the 1930s to 1980, a decline of 50 to 100 ft has been observed in the area around Clovis, New Mexico.

The Ogallala will continue to be used as the primary source of potable and irrigation water for eastern New Mexico. In 1989, the New Mexico State Engineer designated Curry County as a Water Basin. This designation allows for regulation of water rights, usage, and well drilling.

## 5.3 Surface Water

Stream valleys in Curry County tend to be fairly broad and widely spaced. Streams are ephemeral and drainages are poorly developed. No permanent streams exist on or near Cannon AFB (Harza 1997).

Historically, runoff at Cannon AFB has drained into four natural ephemeral playas. The two northern playas were converted into plastic-lined golf course ponds. The southern playa is still intact; however, the surrounding drainage patterns have been altered. The eastern playa, known as the North Playa Lake, was bermed on the north, west, and south sides with topsoil and concrete debris. Drainage ditches at Cannon AFB are concentrated around the developed/landscaped areas of the Base and carry runoff to the playa lakes and golf course ponds. The playa lakes have no surface outlet, and any water they collect is eventually lost to evaporation or infiltration, or is used by plants and animals.

## 5.4 Nature and Extent of Contamination

Investigations began at the Sewage Lagoons in 1984 when four groundwater monitoring wells were installed (Motaton and Associates, 1985) The Sewage Lagoons were designated a SWMU in 1989, and since that time, many field investigations have been conducted in order to determine the nature and extent of contamination at this SWMU. In 1991, a RI was conducted by Woodward Clyde.

Sludge samples reported acetone, 2-butanone, and bis(2-ethylhexyl)phthalate. However, it is possible that the detections of these compounds are attributable to laboratory contamination since they were detected in many of the method blanks. Metals results of the sludge showed that barium, chromium, copper, selenium, silver, vanadium, and zinc all exceeded the site

background levels for soil. The pesticides 4,4'-DDD, 4,4'-DDE, chlordane, and PCB-1260 were detected in the sludge samples from both the north and south lagoons. However, these pesticides and PCB were uniformly detected at low concentrations throughout the lagoons and are most likely the result of an accumulation of materials from various base activities transferred to the lagoons through the sanitary sewer. Sludge samples were analyzed for TCLP parameters and none of the results exceeded the TCLP criteria.

Groundwater samples collected from the four existing wells reported metals above the reporting limits. Barium and vanadium were found in all four groundwater samples, but concentrations were less than MCLs.

Surface water samples were taken from the south lagoon, north lagoon, and wastewater flow splitting pool. The metals detected included barium, lead, copper, zinc, mercury, silver and vanadium.

In January 1997, E & E collected additional sludge samples to support the preliminary evaluation of corrective action alternatives. Three sludge samples were collected and analyzed for total nitrogen, total solids, volatile solids, metals, and pathogens. One sample each was collected from the north lagoon, the south lagoon, and the discharge point at the south lagoon that leads to the playa lake. Results indicate that the sludge samples did not exceed RCRA limits for hazardous constituents. E & E concluded that additional sludge samples were required to adequately characterize the sludge during the corrective action process of the Sewage Lagoons.

## 5.5 Contaminant Fate and Transport

Fate and transport modeling simulated contaminant migration through the vadose zone. The fate and transport of contaminants of concern (COCs) that exceeded appropriate screening criteria were modeled based on current, normal site conditions. The COCs modeled were heptachlor, gamma-BHC (lindane), nitrate, and total xylenes. Additional simulations were performed with excessive precipitation to evaluate the transport effects of the COCs with increased infiltration.

The Seasonal Soil Compartment Model (SESOIL) was used for the fate and transport modeling (General Sciences Corporation, 1998). The SESOIL model has been used by many local, state, and federal agencies at several sites across the country to evaluate the effectiveness of waste-contaminant cover systems.

SESOIL is a one-dimensional vertical transport model designed to simultaneously simulate water transport, sediment transport, and contaminant fate for the unsaturated zone. Input data include soil physical parameters, contaminant chemical parameters, and meteorological information. The specific input parameters are presented in Appendix D of the Revised Final CMS Report (FWEC, 2001).

The processes modeled by SESOIL are categorized into three cycles: hydrology, sediment washload, and pollutant transport; each cycle is a separate sub-model within the SESOIL code. SESOIL is a compartmental model that allows the user flexibility to divide the unsaturated zone into separate layers (if appropriate) and model contaminant release and migration within each layer down to the water table. The result is a calculated leachate concentration that will be introduced to groundwater. The model simulates leaching to groundwater and subsequent mixing that ultimately provides a groundwater concentration as a calculated result.

The simulations performed for the CMS applied conservative assumptions for the fate and transport modeling. The greatest concentrations of soil/sludge samples from field-testing were used to calculate loading rates for the COCs. The contaminant sources were modeled as instantaneous releases from the top 10 ft of the model. Groundwater was modeled as 290 ft below ground surface. The first simulation of each COC used climatic data specific for Clovis, New Mexico. Additional simulations were performed within one 24-hour, 100-year storm per year, and six 24-hour, 100-year storms per year, beyond normal precipitation events.

Results of the 50-year simulations for the current, normal conditions at Cannon predicted vertical contaminant migrations of 0.02 ft, 0.04 ft, 225.85 ft, and 53.02 ft for heptachlor, gamma-BHC (lindane), nitrate, and total xylenes, respectively. None of the COCs reached groundwater in the 50-year simulation under normal, current conditions. An extended duration simulation predicted nitrate reaching the groundwater after 65 years under current, normal conditions. The increased infiltration from the addition of one 24-hour, 100-year storm per year had a negligible effect on transport of the heptachlor and gamma-BHC (lindane). Nitrate and total xylenes showed vertical depth increases of approximately 12 to 13 percent. The precipitation equivalent of six 24-hour, 100-year storms per year were required to increase infiltration to the extent that nitrate reached groundwater within 45 years. Once nitrate reached groundwater, the model predicted concentrations above the EPA MCL.

Additional modeling was performed to observe the effects of standing water within the sewage lagoons. The unsaturated flow model VS2DTI was used to determine the infiltration rate of water from the sewage lagoons for a thirty-five year period. Based on predicted soil types and initial soil moisture contents, infiltrating water from the lagoons reached groundwater at 290 ft after approximately 2.7 years, yielding an infiltration rate of 107.4 ft per year.

A calibration was performed on the SESOIL model to imitate the predicted infiltration rate by increasing monthly precipitation. The contaminant surface loading rate for the model was manipulated to match observed groundwater concentrations of approximately 12 mg/L nitrate. Different simulations were performed using average contaminant concentrations from field data and calibrated surface loading to achieve measured groundwater concentrations. The results from the modeling indicated that extreme precipitation events were necessary to match the effects on infiltration of the standing surface water. Also, nitrate concentrations much greater than those measured in the field were necessary to achieve a groundwater concentration equivalent to that measured in the field.

The modeling illustrated that degradation to groundwater from sludge COCs migration is unlikely under current, normal conditions where infiltration of water into the vadose zone is minimal. In summary, the model predicted that under conservative conditions where extreme precipitation occurred or standing water is allowed to accumulate in the open lagoons, the only COC that would reach groundwater is nitrate. An extended discussion of the modeling effort, including output, is presented in Appendix D, Revised Final CMS (FWEC, 2001).

## 5.6 Human Health Risk Evaluation

As part of the CMS, a HHRA was performed. The HHRA was conducted in accordance with the New Mexico Environment Department (NMED) Position Paper, *Assessing Human Health Risks Posed by Chemicals: Screening-level Risk Assessment* (NMED 2000a), EPA's *Region 6 Human Health Medium-Specific Screening Levels* (EPA 1999), and standard EPA guidance, including *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation*

*Manual (Part A)* (EPA 1989) *and Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (EPA 1991). The entire HHRA and calculations are found in Appendix C, Revised Final CMS (FWEC, 2001).

### 5.6.1 Data Usability

The risk assessment was based on data that were collected in April 2000 in support of the CMS. SWMU 101 was divided into four media of concern for evaluation in the HHRA: north lagoon sludge, north lagoon soil, south lagoon sludge, and south lagoon soil. Each lagoon was evaluated separately; soil and sludge from the lagoons were also evaluated separately. The HHRA conservatively considered soil data from the 0 to10 ft interval and all the sludge data collected.

### 5.6.2 Selection of Chemicals of Potential Concern

Detected chemicals in soils and sludge were screened against site-specific background levels and EPA Region 6 residential human health screening levels (HHSLs).

For background comparisons, the maximum detected value in the site investigative data was compared to the maximum detected value in the site-specific background data presented in *Naturally Occurring Concentrations of Inorganics and Background Concentrations of Pesticides at Cannon Air Force Base, New Mexico* (Cannon, 1997). In accordance with EPA guidance (1989), those chemicals present on site at naturally occurring levels were eliminated from the quantitative risk assessment. The maximum detected concentrations of inorganics and 4,4'-DDT detected in sludge samples were compared to maximum concentrations detected in surface background soil samples collected from 0 to 1 ft bgs. The maximum detected concentrations of inorganics and 4,4'-DDT in soil samples collected from each lagoon from the 0 to 10 ft below the sludge-native soil interface were compared to maximum detected background soil samples collected from 0 to 40 ft bgs. Barium in north lagoon sludge and selenium in south lagoon soil were both detected below background concentrations and eliminated from further evaluation in the HHRA. No inorganics in the north lagoon soil or south lagoon sludge were detected below background concentrations.

A comparison with EPA Region 6 HHSLs for soil (EPA, 1999) was made as a conservative approach for selecting COPCs and is considered a conservative estimate of potential risk at SWMU 101. The residential HHSLs used in the screening incorporate oral, inhalation, and dermal exposure pathways. Based on NMED guidance (2000a), carcinogenic and non-carcinogenic compounds were compared to HHSLs differently. NMED requires if two or more non-carcinogenic chemicals are present at a site, each chemical must be compared to one-tenth of their respective HHSL to address the potential that two or more non-carcinogenic COPCs may affect the same target organs or systems. Once this initial COPC screening was performed, the critical effects and target organs of the non-carcinogenic compounds that exceeded the adjusted HHSLs were compared separately for soil and sludge in each lagoon and screened against readjusted HHSLs. The HHSLs were readjusted based on the number of chemicals with the same critical effects and/or target organs. The residential HHSL was divided by the number of chemicals with the same critical effects and maximum detected concentrations of the chemicals were all screened against the newly adjusted value.

Chemicals with maximum detections below the unadjusted and adjusted residential HHSLs were eliminated from the quantitative risk assessment. Arsenic was the only chemical detected above the HHSLs in both north and south lagoon soil; all other chemicals detected in soil were

eliminated from further evaluation in the HHRA. Polychlorinated biphenyl (PCB)-1260, dieldrin, heptachlor epoxide, and arsenic in north lagoon sludge were all detected above their respective HHSLs; all other chemicals detected in the north lagoon sludge were detected at concentrations below the HHSLs and were eliminated from further evaluation in the HHRA. Only dieldrin and arsenic were detected above their HHSLs in the south lagoon sludge; all other chemicals detected in south lagoon sludge were eliminated from further evaluation in the HHRA.

Based on the results of screening against background levels and the HHSLs, four COPCs were identified for further evaluation in the HHRA: arsenic, dieldrin, PCB-1260, and heptachlor epoxide. Arsenic is the only COPC found in both north and south lagoon soil. Arsenic and dieldrin are COPCs in sludge in both north and south lagoon; PCB-1260 and heptachlor epoxide are COPCs only in the north lagoon sludge.

### 5.6.3 Human Health Risk Assessment Results

The Management Action Plan for Cannon AFB indicated that the current land use at SWMU 101 is industrial and is expected to remain industrial in the future. Based on land use information, under both current and future conditions, industrial workers are the only potential receptors who have direct access to SWMU 101 and any related contamination. The pathways that represent potentially complete exposure routes for industrial workers include the following: ingestion and dermal contact with soils during work activities and inhalation of contaminated soil and soil particulates during wind or soil disturbance activities. The HHRA did not evaluate industrial worker exposure to chemicals detected in groundwater below the north and south lagoons because a complete exposure pathway does not exist.

For the industrial worker, the excess lifetime cancer risk (ELCR) or hazard quotient (HQ) value for each analyte and exposure pathway was summed to produce total cancer risk and hazard index (HI). As shown in Table 5-1, risks from COPCs in soil and sludge in the north and south lagoon were below the target HQ of 1.0 (NMED, 2000a). NMED has also established a target total ELCR of $1x10^{-5}$ for the sum of all carcinogens at a site or if only one carcinogen is present (NMED, 2000a). If multiple carcinogens are present the target ELCR for each carcinogen is $1x10^{-6}$ (NMED, 2000a). Arsenic was the only COPC that exceeded the target ELCR of $1x10^{-6}$ for a single chemical in sludge and soil in the north and south lagoons. Based on the results of the risk calculations, there is negligible risk to industrial workers from exposure to sludge and soil at SWMU 101.

## 5.7 Screening-Level Ecological Risk Assessment

As part of the CMS, a SLERA was performed. The procedures used were consistent with those presented in *Guidance for Assessing Ecological Risks Posed by Chemicals: Screening-Level Ecological Risk Assessment* (NMED 2000b), *Risk Assessment Handbook Volume II: Environmental Evaluation* (U.S. Army Corps of Engineers [USACE] 1996), *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1996), and *Guidelines for Ecological Risk Assessment* (EPA 1998). Chemical contamination that is determined to potentially cause ecological risk may require additional evaluation in a more detailed quantitative assessment. The entire Ecological Risk Assessment and calculations are found in Appendix C, Revised Final CMS (FWEC, 2001).

On April 6-7, 2000, a site survey of SWMU 101 was conducted to gather site-specific information to identify relevant and complete contaminant-pathway-receptor relationships.

### 5.7.1 Data Usability

The SLERA assessment was based on data that were collected in April 2000 in support of the CMS. SWMU 101 was divided into four media of concern for evaluation in the evaluation in the SLERA: north lagoon sludge, north lagoon soil, south lagoon sludge, south lagoon soil. Each lagoon was evaluated separately; soil and sludge from the lagoons were also evaluated separately. The SLERA considered soil data from the 0 to 6 ft interval and all the sludge data collected (0 to 1ft).

### 5.7.2 Screening-Level Risk Assessment Results

The pathways that represent potentially complete exposure routes for ecological receptors included the following: ingestion of soil and sludge, and ingestion of terrestrial invertebrates, plants, or vertebrate prey. Exposure to groundwater was not evaluated because groundwater does not discharge naturally through seeps and springs in the area; therefore a complete exposure pathway does not exist. The assessment endpoints indentified for the SLERA included decomposer/detritivore, habitat for wildlife, major food source for consumer species, seed disperser, and regulator of prey species. Measurement receptors for guilds were chosen for the following class-specific guilds: herbivorous mammal, herbivorous bird, omnivorous mammal, and carnivorous bird. Measurement receptors for guilds evaluated in the SLERA include deer mouse, mourning dove, least shrew, and red-tailed hawk.

The risk characterization for measurement receptors from potential exposure to chemicals of potential ecological concern (COPECs) in north lagoon sludge, south lagoon soil, and south lagoon sludge found that pesticides produced elevated ecological screening quotients (ESQs) for the deer mouse and least shrew. Results of the risk characterization are summarized in Table 5-2. Concentrations of VOCs did not produce elevated ESQs for any of the measurement receptors at the areas of concern. Concentrations of PCBs produced elevated ESQs for the deer mouse and least shrew in north lagoon sludge. This is the only area of concern in which PCBs were detected. Concentrations of inorganics produced ESQs for all measurement receptors in all four areas of concern. ESQs ranged from 1.1 for terrestrial invertebrates due to lead exposure to 5,300 for plants due to silver exposure. Many of the ESQs may be overestimated due to the presence of naturally high concentrations of inorganics, with most of the site inorganic concentrations only slightly higher than background; therefore risks to potential ecological receptors may exist even at background concentrations.

The SLERA was designed to evaluate potential risk to representative receptors from multiple trophic levels present at the site as well as wildlife temporarily visiting the site. The risk characterization indicated that there might be risk for multiple tropic-level species from COPECs (metals) present in all four areas of concern.

## 5.8 Post-Voluntary Correction Action Conditions and Associated Risk

A CMS for closure of SWMU 101 identified and evaluated potential corrective actions (FWEC, 2001). Human health and ecological risk assessments as described in the previous sections were conducted as part of the CMS to determine the requirements for contaminant containment and source control. Although no risk to human health was identified from exposure to surface or subsurface soil or sludge at the site, concentrations of inorganic chemicals produced elevated ESQs for potential ecological receptors.

At Cannon AFB the depth of groundwater is approximately 300 ft bgs, not currently used by industrial workers as a potable water source, nor does it discharge naturally through springs or seeps in the area. The groundwater exposure pathway was therefore considered to be incomplete for industrial workers and ecological receptors and was not evaluated in the risk assessments. As part of the CMS however, fate and transport modeling was performed to support the risk assessment and the evaluation of corrective action alternatives to simulate contaminant migration through the vadose zone. The fate and transport of COCs that exceeded risk-based screening criteria were modeled based on the current, normal site conditions. The simulations performed for the CMS applied conservative assumptions for the fate and transport modeling. Results of the 50-year simulations for the current, normal conditions at Cannon predicted vertical pollution migration does not reach groundwater. The modeling illustrated that degradation to groundwater, due to COCs in sludge, was unlikely under current, normal conditions. As a result of the 1992 RI program, recommendations were made for annual groundwater sampling of the four monitoring wells at SWMU 101. The groundwater was sampled yearly from 1998 through 2001 and analyzed for VOCs, metals, nitrate, sulfate and TDS. Iron was the only analyte detected above EPA's SMCL (0.30 mg/L), which indicate contaminants have not impacted the groundwater due to previous operations at the site.

Based on the SLERA, sludge removal from the former north lagoon, in-place consolidation in the former south lagoon, and closure using an engineered cover with a biotic barrier was selected as the corrective action for closing the lagoons. This alternative was considered a conservative design for closure of the lagoons and would prevent ecological receptors, including burrowing organisms, from coming in contact with the sludge. The evaluation and selection of the proposed corrective action alternatives was based on the ability to meet the following criteria: CAOs, conceptual design criteria; long-term reliability and effectiveness; reduction of waste toxicity, mobility, or volume; short-term effectiveness; implementability; safety; and cost.

The Phase III Sludge Management, Compliance Evaluation, and Requirements Identification report (E&E, 1998) and the Sewage Lagoons Closure Final Specifications (USACE, 2002) concurred that dewatering, consolidation, and compaction of the contaminated material, followed by placement of a protective cover, was an economical solution to close the lagoons permanently. The construction activities were documented in a Construction Completion Report (TtEC, 2005); excavation of sludge and soil, in-place consolidation of the material, and construction of an engineered cover were considered a voluntary corrective measure. The cover design assumed that the contaminated media at the site consisted of approximately 2 ft of sludge overlying a 1-ft-thick layer of soil.

## 5.9 Risk Characterization

Based on an industrial exposure scenario as demonstrated in Section 5.6, there is no risk due to exposure to chemicals in sludge and soils at SWMU 101. With the voluntary corrective measure in place, sludge and affected soil in the south lagoon are covered with debris, topsoil, and vegetation. The covering eliminates exposure to the COPCs; therefore, there is no risk to the industrial worker at the south lagoon. Because all of the sludge and affected soil was removed from the north lagoon, there is also no risk to an industrial worker working at the north lagoon.

Based on the SLERA, the risk characterization indicated that there might be risk for multiple tropic-level species from COPECs (metals) present in all four areas of concern. Because the voluntary corrective measure required all of the affected soil and sludge in the north lagoon to be

consolidated in the south lagoon, risk to ecological receptors in the north lagoon is also eliminated. In the south lagoon, sludge and affected soil were covered with a biotic barrier; which prevents ecological receptors, including burrowing organisms, from coming in contact with the sludge thus also eliminating potential risk.

There is also no potential risk to receptors from groundwater at SWMU 101. Groundwater beneath SWMU 101 is not used by industrial workers, nor does it discharge naturally through seeps or springs in the area to affect ecological receptors. Groundwater monitoring at the SWMU area indicated metals were the only analytes detected and results showed all concentrations were below respective MCLs. Fate and transport modeling was performed in the CMS to support the risk assessment and the evaluation of corrective action alternatives to simulate contaminant migration through the vadose zone. The fate and transport of COCs that exceeded risk-based screening criteria were modeled based on the current, normal site conditions. Results of the 50-year simulations for the current, normal conditions at Cannon predicted vertical pollution migration does not reach groundwater. The modeling illustrated that degradation to groundwater, due to COCs in sludge, was unlikely under current, normal conditions.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

A summary of the VCA field activities and previous investigations is presented below to support the recommendation for the future of the Sewage Lagoons, SWMU 101.

- In 1985, a hydrogeologic investigation was conducted and four monitoring wells were installed, prior to the Sewage Lagoons being designated as a SWMU. One well was installed upgradient, and three wells were installed downgradient. The wells were sampled quarterly for only field parameters of pH, temperature and conductivity.
- Results of the 1991 RI indicated that sludge samples from the lagoon areas contained low levels of pesticides and PCBs, but they were most likely as a result of base activities that transferred these contaminants from the lagoons through the sanitary sewer.
- The 1991 RI recommended to continue annual groundwater monitoring of the four wells for volatile organics, metals, pesticides, nitrate, sulfate and TDS. This recommendation was made to support site closure.
- Annual groundwater samples were taken from 1998 to 2001 from wells Well E, Well F, Well G, and Well H at SWMU 101. The groundwater was sampled and analyzed yearly by the USGS and analyzed by USACE's Southwestern Division Laboratory, located in Dallas, Texas. Iron was the only analyte detected above USEPA's SMCL of 0.30 mg/L.
- The results of the 1997 Supplemental Sludge Sampling effort showed that levels of analytes did not exceed RCRA limits for hazardous constituents. Additional sludge samples were recommended to adequately characterize the sludge prior to any corrective action.
- In 2000, a CMS was performed which included sludge and native soil sampling. Sludge results were less than TCLP levels; therefore, it was considered non-hazardous, and it was determined that it would not require off-site disposal during removal.
- In 2000, the CMS reported that concentrations of pesticides decreased with depth. None of the soil was determined to be hazardous and it was determined that it would not require off-site disposal during removal.
- The CMS evaluated three alternatives; no action, sludge dewatering in-place, consolidation, compaction, and cover; and in-site bioremediation through composting. The recommended corrective action was sludge dewatering in-place, consolidation, compaction and cover. The alternative met the CAOs, conformed to the conceptual design criteria, and provided the additional benefit of restoring the north lagoon for stormwater management.
- Fate and transport modeling was performed during the CMS to support the risk assessment and the evaluation of the corrective alternatives. Results of the 50-year simulations predicted that vertical pollution migration does not reach groundwater.
- Risk characterization was evaluated during the CMS and showed negligible risk to industrial workers due to exposure to chemicals in the sludge or soil, but indicated there may be risk to ecological receptors that reside or visit the site.

- A VCA was performed during 2003-2004. Soils and sludge were removed from the former north lagoon and consolidated into the former south lagoon. The material was graded, compacted, and covered with a 20-acre, 42" thick soil barrier layer.
- Confirmation samples taken after excavation activities showed no contamination and no potential for leaching to groundwater.

The results of previous investigations, risk evaluations, and completion of the VCA at the Sewage Lagoons, SWMU 101, support a recommendation of NFA for this SWMU in accordance with NMED NFA Criterion #5:

> The site was characterized/remediated in accordance with applicable state and/or federal regulations, and the available data indicate that contaminants pose an acceptable level of risk under current and projected future land use.

## 7.0 REFERENCES

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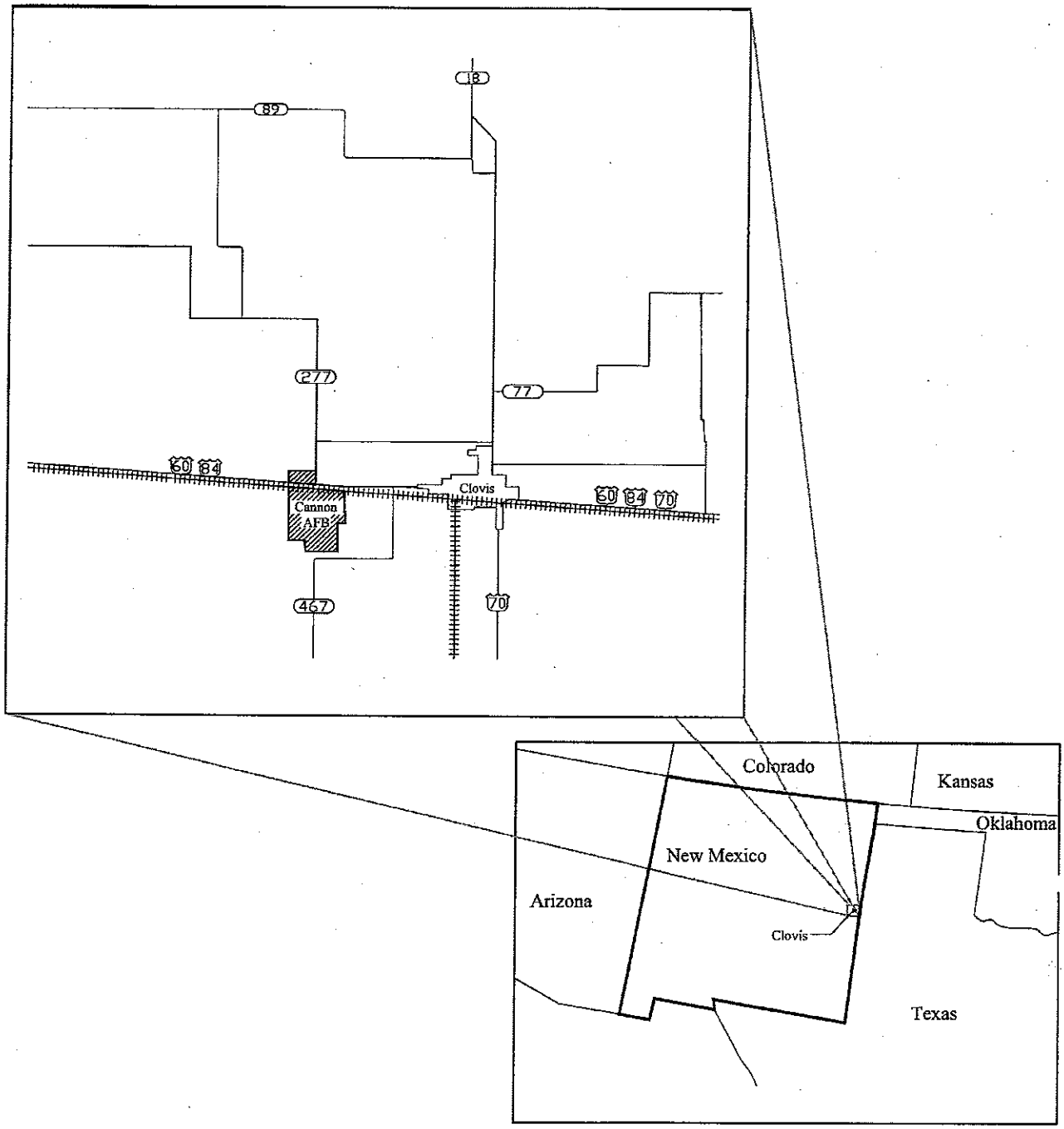
# FIGURES

# FIGURE 1-1

## Location of Cannon AFB



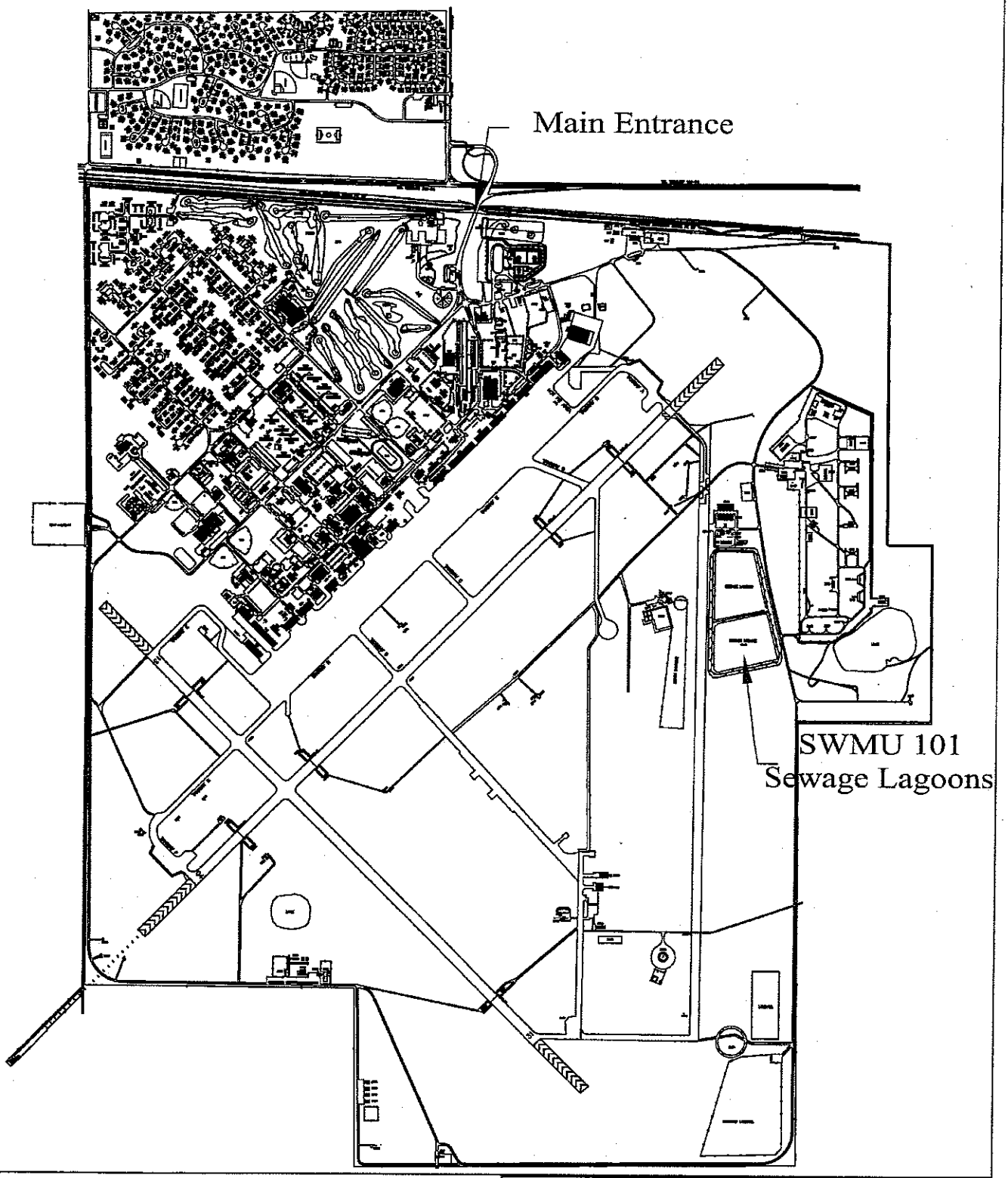

Closure of
SWMU 101 – Sewage Lagoon
Cannon Air Force Base, New Mexico
U.S. Army Corps of Engineers, Omaha District

Base Location Map

Figure 1-1

# FIGURE 1-2

## Location of SWMU 101, Sewage Lagoons




Closure of
SWMU 101 – Sewage Lagoons
Cannon Air Force Base, New Mexico
U.S. Army Corps of Engineers, Omaha District

Sewage Lagoons Site
Location Map

Figure 1-2

# TABLES

Table 3-1 Previous Investigation Sampling Programs at SWMU 101

| Year/Investigation | Number of Locations/Samples | VOCs | SVOCs | TCLP - Organics & Inorganics | Metals | Pesticides/ PCBs | General Chemistry | Field Parameters |
|---|---|---|---|---|---|---|---|---|
| 1985, Hydrogeologic Investigation[1] | 4 wells | | | | | | | pH, Temp, Conductivity |
| 1988, Supplemental Sludge Sampling[2] | 3 sludge | | | | x | | Total nitrogen, total solids, volatile solids, pathogens | |
| 1991, Remedial Investigation[3] | 8 sludge | | | x | | | | |
| | 3 surface water | x | x | | x | x | | |
| | 4 groundwater | x | x | | x | x | | |
| 1998 to 2001, Groundwater Sampling | 4 wells | x | | | x | | nitrate+nitrite, nitrate, sulfate, TDS | |
| 2000, Corrective Measures Study[4] | 10 sludge | | | | | | | |
| | 10 locations, 30 soil samples | | | | | | | |
| 2005, Final Construction Completion Report[5] | confirmation samples, borrow source samples | | | | x | x | nitrate | |

Notes:

[1] Matotan and Associations, 1985

[2] E &E, 1988

[3] Woodward-Clyde, 1991

[4] FWEC 2000

[5] TtEC, 2005

**Table 3-2 Cannon AFB, Sewage Lagoons, SWMU 101**

**Groundwater Monitoring Results 1998 through 2001**

**Well E, Upgradient Well**

**Table 3-2**
**Cannon AFB, Sewage Lagoons, SWMU 101**
**Groundwater Monitoring Results, 1998 to 2001**
**Well E, Upgradient Well**

| Location: | Well E | | | Well E | | | Well E | | | Well E | | | Well E | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample I.D.: | E/CAFB-E-0498-1 | | | E/CAFB-E | | | CAFB-E-1 | | | E/CAFB-E | | | E/CAFB-E | | |
| Collection Date: | 4/7/1998 | | | 3/2/1999 | | | 8/31/1999 | | | 3/15/2000 | | | 3/22/2001 | | |
| | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. |
| **Appendix IX Volatile Organics (ug/L)** | | | | | | | | | | | | | | | |
| Methylene Chloride | 1 | 2.7 | | 1 | ND | | 1 | 0.28 | JB | 1 | ND | | 1 | ND | |
| Tetrachloroethene | 1 | 3.7 | | 1 | 2.1 | | 1 | 1.9 | | 1 | ND | | 1 | ND | |
| Trichloroethene | 1 | ND | | 1 | ND | | 1 | 0.11 | J | 1 | 0.12 | J | 1 | ND | |
| | | | | | | | | | | | | | | | |
| **Metals, Total (mg/L)** | | | | | | | | | | | | | | | |
| Aluminum | | NA | | | NA | | | NA | | 0.10 | .0569 | B | 0.10 | 0.107 | |
| Arsenic | | NA | | | NA | | | NA | | | NA | | 0.005 | .0031 | B |
| Barium | 0.01 | 0.044 | | 0.01 | 0.0482 | | | NA | | 0.01 | 0.0512 | | 0.01 | 0.0512 | |
| Calcium | 0.20 | 37.1 | | 0.20 | 36.9 | | | NA | | 0.2 | 39.8 | | 0.2 | 47.3 | |
| Chromium | 0.005 | 0.0072 | M | 0.005 | 0.0051 | | | NA | | 0.001 | 0.0115 | | 0.001 | 0.012 | |
| Iron | 0.10 | ND | M | 0.10 | ND | | | NA | | 0.1 | 0.0966 | B | 0.1 | 0.084 | B |
| Lead | | NA | | 0.001 | 0.00047 | J | | NA | | 0.001 | 0.0114 | | 0.001 | 0.0054 | |
| Magnesium | 0.20 | 33.6 | | 0.20 | 34.5 | | | NA | | 0.2 | 37.2 | | 0.2 | 43.5 | |
| Manganese | 0.01 | ND | | 0.01 | ND | | | NA | | 0.01 | 0.004 | B | 0.01 | 0.002 | B |
| Potassium | 5 | 6.4 | | 5 | 6.2 | | | NA | | 5 | 6.92 | | 5 | 6.70 | |
| Selenium | 0.005 | ND | M | 0.005 | 0.0057 | | | NA | | 0.005 | 0.004 | B | 0.005 | 0.0052 | B |
| Sodium | 5 | 52.0 | | 5 | 53.2 | | | NA | | 5.0 | 56.4 | | 5.0 | 60.3 | |
| Vanadium | 0.01 | 0.019 | | 0.01 | 0.020 | | | NA | | 0.01 | 0.0196 | | 0.01 | 0.0018 | |
| Zinc | 0.02 | ND | | 0.02 | ND | | | NA | | 0.02 | 0.0123 | B | 0.02 | 0.0070 | B |
| | | | | | | | | | | | | | | | |
| **General Chemistry (mg/L)** | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 0.1 | 2.8 | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | |
| Nitrate | 0.1 | 2.8 | | 0.1 | ND | | 0.1 | 4.4 | | 0.1 | 1.8 | | 0.1 | 1.4 | |
| Sulfate | 5.0 | 75.0 | M | 25.0 | 60.3 | Q | 5.0 | ND | | 25.0 | 64.7 | Q | 25.0 | 81.1 | Q |
| Total Dissolved Solids | 10.0 | 401 | | 10.0 | 414 | | 10.0 | ND | | 10 | 426 | | 10 | 503 | |

µg/L micrograms per liter
mg/L miligrams per liter
ND Not Detected
NA Not Analyzed
M associated matrix spike and matrix spike duplicate results did not meet quality control acceptance criteria
q post-digestion spike recovery fell between 40 and 85 percent due to matrix interference
J result is detected below the reporting limit or is an estimated concentration
RL reporting limit
s sample diluted due to the concentration of target analytes
Q reporting limit is elevated due to high analyte levels
B Analyte detected in associated method blank

**Table 3-3 Cannon AFB, Sewage Lagoons, SWMU 101**

**Groundwater Monitoring Results 1998 through 2001**

**Well F, Downgradient Well**

**Table 3-3**
**Cannon AFB, Sewage Lagoons, SWMU 101**
**Groundwater Monitoring Results, 1998 to 2001**
**Well F, Downgradient Well**

| Location: | Well F | | | Well F | | | Well F | | | Well F | | | Well F | | | Well F | | | Well F | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample I.D.: | F/CAFB-F-0498 | | | F/CAFB-T-0498-1 (duplicate) | | | F/CAFB-F | | | CAFB-F-1 | | | CAFB-F-1 | | | CAFB-F-1 | | | CAFB-F-1 | | |
| Collection Date: | 4/8/1998 | | | 4/8/1998 | | | 3/2/1999 | | | 8/31/1999 | | | 3/2/2000 | | | 3/22/2001* | | | 8/21/2001 | | |
| | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. |
| **Volatile Organics (ug/L)** | | | | | | | | | | | | | | | | | | | | | |
| Methylene Chloride | 1 | 0.4 | J | 1 | 0.43 | J | 1 | ND | | 1 | ND | | 1 | ND | | | NA | | 1 | ND | |
| Tetrachloroethene | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | | | NA | | 1 | ND | |
| Trichloroethene | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | | 1 | .11 | J | | NA | | 1 | ND | |
| | | | | | | | | | | | | | | | | | | | | | |
| **Metals, Total (mg/L)** | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | | | | | | | | | | | | | 0.10 | .0522 | B | | NA | | 0.10 | 1.89 | |
| Barium | 0.01 | 0.042 | | 0.01 | 0.042 | | 0.01 | ND | | | NA | | 0.01 | 0.0379 | | | NA | | 0.01 | 0.055 | |
| Calcium | 0.20 | 57.6 | | 0.20 | 57.2 | | 0.20 | ND | | | NA | | 0.2 | 44.7 | | | NA | | 0.2 | NA | |
| Chromium | 0.005 | 0.0044 | JM | 0.005 | 0.0018 | JM | 0.005 | 0.0015 | | | NA | | 0.001 | 0.0022 | | | NA | | 0.001 | 0.0106 | |
| Iron | 0.10 | 0.053 | JM | 0.10 | 0.089 | JM | 0.10 | ND | | | NA | | 0.1 | 0.0278 | B | | NA | | 0.1 | 1.73 | |
| Lead | | | | | | | | | | | | | 0.001 | 0.00067 | B | | NA | | 0.001 | 0.01020 | |
| Magnesium | 0.20 | 53.8 | | 0.20 | 53.6 | | 0.20 | ND | | | NA | | 0.2 | 45 | | | NA | | 0.2 | 44 | |
| Manganese | 0.01 | 0.0098 J | J | 0.01 | 0.011 | | 0.01 | ND | | | NA | | 0.01 | ND | | | NA | | 0.01 | 0.0428 | |
| Potassium | 5 | 8.4 | | 5 | 8.1 | | 5 | ND | | | NA | | 5 | 7.55 | | | NA | | 5 | 8.38 | |
| Selenium | 0.005 | 0.0054 | qM | 0.005 | 0.0052 | qM | 0.005 | 0.0058 | | | NA | | 0.005 | 0.0088 | | | NA | | 0.005 | 0.0071 | |
| Sodium | 5 | 43.5 | | 5 | 42.8 | | 5 | 0.643 | J | | NA | | 5.0 | 42.8 | | | NA | | 5.0 | 5.0 | |
| Vanadium | 0.01 | 0.018 | | 0.01 | 0.016 | | 0.01 | ND | | | NA | | 0.01 | 0.0185 | | | NA | | 0.01 | 0.0233 | |
| Zinc | 0.02 | 0.015 | J | 0.02 | 0.019 | J | 0.02 | ND | | | NA | | 0.02 | 0.005 | B | | NA | | 0.02 | 0.0605 | |
| | | | | | | | | | | | | | | | | | | | | | |
| **General Chemistry (mg/L)** | | | | | | | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 0.1 | 2.4 | | 0.1 | 2.2 | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | | | NA | | 0.1 | ND | |
| Nitrate | 0.1 | 2.4 | | 0.1 | 2.2 | | 0.1 | ND | | 0.1 | 1.2 | | 0.1 | 1.3 | | | NA | | 0.1 | 1.4 | |
| Sulfate | 5 | 163 | sM | 5 | 164 | sM | 25 | 139 | Q | 25 | ND | | 25 | 139 | Q | | NA | | 25 | 131 | Q |
| Total Dissolved Solids | 10 | 535 | | 10 | 528 | | 10 | 506 | | 10 | ND | | 10 | 432 | | | NA | | 10 | 538 | |

µg/L micrograms per liter
mg/L miligrams per liter
ND Not Detected
NA Not Analyzed
M associated matrix spike and matrix spike duplicate results did not meet quality control acceptance criteria
q post-digestion spike recovery fell between 40 and 85 percent due to matrix interference
J result is detected below the reporting limit or is an estimated concentration
RL reporting limit
s sample diluted due to the concentration of target analytes
Q reporting limit is elevated due to high analyte levels
B Analyte detected in associated method blank
* Not sampled on 3/22/01 due to decline in water table. A sample could not be collected nor analyzed.

**Table 3-4 Cannon AFB, Sewage Lagoons, SWMU 101**

**Groundwater Monitoring Results 1998 through 2001**

**Well G, Downgradient Well**

**Table 3-4**
**Cannon AFB, Sewage Lagoons, SWMU 101**
**Groundwater Monitoring Results, 1998 to 2001**
**Well G, Downgradient Well**

| Location: | Well G | | | Well G | | | Well G | | | Well G | | | Well G | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample I.D.: | G/CAFB-G-0498 | | | G/CAFB-G | | | CAFB-G-1 | | | G/CAFB-G | | | G/CAFB-G | | |
| Collection Date: | 4/8/1998 | | | 3/2/1999 | | | 3/31/1999 | | | 3/2/2000 | | | 3/22/2001 | | |
| | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. |
| **Appendix IX Volatile Organics (ug/L)** | | | | | | | | | | | | | | | |
| Methylene Chloride | 1 | 0.2 J | | 1.0 | ND | | 1 | ND | | 1 | ND | | 1 | ND | |
| Tetrachloroethene | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | |
| | | | | | | | | | | | | | | | |
| **Metals, Total (mg/L)** | | | | | | | | | | | | | | | |
| Aluminum | | NA | | | NA | | | NA | | 0.10 | .0456 | B | 0.10 | .0826 | B |
| Barium | 0.01 | 0.032 | | 0.01 | 0.0314 | | | NA | | 0.01 | 0.0335 | | 0.01 | 0.0303 | |
| Calcium | 0.20 | 86.9 | | 0.20 | 71.9 | | | NA | | 0.2 | 69.1 | | 0.2 | 59.0 | |
| Chromium | 0.005 | 0.0018 | JM | 0.001 | 0.0076 | | | NA | | 0.001 | 0.0014 | | 0.001 | 0.0034 | |
| Iron | 0.10 | ND | M | 0.10 | ND | | | NA | | 0.1 | 0.0334 | B | 0.1 | 0.0867 | B |
| Lead | | NA | | 0.001 | 0.00088 | J | | NA | | 0.001 | 0.00044 | B | 0.001 | 0.00065 | B |
| Magnesium | 0.20 | 83.6 | | 0.20 | 70.2 | | | NA | | 0.2 | 69.8 | | 0.2 | 56.9 | |
| Manganese | 0.01 | ND | | 0.01 | ND | | | NA | | 0.01 | ND | | 0.01 | 0.00092 | B |
| Potassium | 5 | 10.0 | | 5 | 8.69 | | | NA | | 5 | 9.06 | | 5 | 7.61 | |
| Selenium | 0.005 | 0.0045 | JM | 0.005 | 0.0042 | J | | NA | | 0.005 | 0.0091 | | 0.005 | 0.0062 | |
| Sodium | 5 | 63.9 | | 5 | 60.3 | | | NA | | 5.0 | 55.6 | | 5.0 | 57.2 | |
| Vanadium | 0.01 | 0.015 | | 0.01 | 0.0158 | | | NA | | 0.01 | 0.0173 | | 0.01 | 0.0171 | |
| Zinc | 0.02 | 0.033 | | 0.02 | 0.0199 | J | | NA | | 0.02 | 0.0098 | B | 0.02 | 0.0159 | B |
| | | | | | | | | | | | | | | | |
| **General Chemistry (mg/L)** | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 0.1 | 12.1 | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | |
| Nitrate | 0.1 | 12.1 | | 0.1 | ND | | 0.1 | 4.0 | | 0.1 | 10.6 | Q | 0.1 | 5.6 | Q |
| Sulfate | 5.0 | 203 | sM | 25 | 182 | Q | 25.0 | ND | | 25 | 183 | Q | 25 | 169 | Q |
| Total Dissolved Solids | 10 | 856 | | 10 | 781 | | 10.0 | ND | | 10 | 696 | | 10 | 627 | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

µg/L micrograms per liter
mg/L miligrams per liter
ND Not Detected
NA Not Analyzed
M associated matrix spike and matrix spike duplicate results did not meet quality control acceptance criteria
q post-digestion spike recovery fell between 40 and 85 percent due to matrix interference
J result is detected below the reporting limit or is an estimated concentration
RL reporting limit
s sample diluted due to the concentration of target analytes
Q reporting limit is elevated due to high analyte levels
B Analyte detected in associated method blank

**Table 3-5 Cannon AFB, Sewage Lagoons, SWMU 101**

**Groundwater Monitoring Results 1998 through 2001**

**Well H, Downgradient Well**

**Table 3-5**
**Cannon AFB, Sewage Lagoons, SWMU 101**
**Groundwater Monitoring Results, 1998 to 2001**
**Well H, Downgradient Well**

| Location: | Well H | | | Well H | | | Well H | | | Well H | | | Well H | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample I.D.: | H/CAFB-H-0498-1 | | | H/CAFB-H | | | CAFB-H-1 | | | CAFB-H-1 | | | H/CAFB-H | | |
| Collection Date: | 4/8/1998 | | | 3/2/1999 | | | 8/31/1999 | | | 3/2/2000 | | | 3/2/2001 | | |
| | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. | RL | Result | Qual. |
| **Appendix IX Volatile Organics (ug/L)** | | | | | | | | | | | | | | | |
| Methylene Chloride | 1 | 0.5 | J | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | |
| Tetrachloroethene | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | | 1 | ND | |
| | | | | | | | | | | | | | | | |
| **Metals, Total (mg/L)** | | | | | | | | | | | | | | | |
| Aluminum | | NA | | | NA | | | NA | | 0.10 | 0.0863 | B | 0.10 | 0.1110 | |
| Arsenic | | NA | | | NA | | | NA | | | NA | | 0.10 | 0.0034 | B |
| Barium | 0.01 | 0.031 | | 0.01 | 0.0336 | | | NA | | 0.01 | 0.0303 | | 0.01 | 0.0303 | |
| Calcium | 0.20 | 44.2 | | 0.20 | 40.2 | | | NA | | 0.2 | 38.5 | | 0.2 | 43.5 | |
| Chromium | 0.005 | 0.007 | qM | 0.001 | 0.0054 | | | NA | | 0.001 | 0.0024 | | 0.001 | 0.0035 | |
| Iron | 0.10 | 0.30 | M | 0.10 | 0.284 | | | NA | | 0.1 | 0.067 | B | 0.1 | 0.0543 | B |
| Lead | | NA | | 0.001 | 0.0021 | | | NA | | 0.001 | 0.00054 | B | 0.001 | 0.00038 | B |
| Magnesium | 0.20 | 41.3 | | 0.20 | 38 | | | NA | | 0.2 | 38.0 | | 0.2 | 40.4 | |
| Manganese | 0.01 | .0073 J | | 0.01 | ND | | | NA | | 0.01 | 0.0022 | B | 0.01 | 0.0011 | B |
| Potassium | 5 | 7.0 | | 5 | 6.4 | | | NA | | 5 | 6.7 | | 5 | 6.63 | |
| Selenium | 0.005 | .0073 qM | | 0.005 | 0.0072 | | | NA | | 0.005 | 0.0066 | | 0.005 | 0.0067 | |
| Sodium | 5 | 55.0 | | 5 | 52.5 | | | NA | | 5.0 | 53.3 | | 5.0 | 57.9 | |
| Vanadium | 0.01 | 0.020 | | 0.01 | 0.0018 | | | NA | | 0.01 | 0.0216 | | 0.01 | 0.0194 | |
| Zinc | 0.02 | 0.120 | | 0.02 | 0.138 | | | NA | | 0.02 | 0.028 | | 0.02 | 0.0533 | |
| | | | | | | | | | | | | | | | |
| **General Chemistry (mg/L)** | | | | | | | | | | | | | | | |
| Nitrate + Nitrite | 0.1 | 1.3 | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | | 0.1 | ND | |
| Nitrate | 0.1 | 1.3 | | 0.1 | ND | | 0.1 | 1.1 | | 0.1 | 1.2 | | 0.1 | 1.3 | |
| Sulfate | 25 | 143 | sM | 25 | 132 | Q | 25 | ND | | 25 | 121 | Q | 25 | 126 | Q |
| Total Dissolved Solids | 10 | 459 | | 10 | 492 | | 10 | ND | | 10 | 454 | | 10 | 468 | |
| | | | | | | | | | | | | | | | |

µg/L micrograms per liter
mg/L miligrams per liter
ND Not Detected
NA Not Analyzed
M associated matrix spike and matrix spike duplicate results did not meet quality control acceptance criteria
q post-digestion spike recovery fell between 40 and 85 percent due to matrix interference
J result is detected below the reporting limit or is an estimated concentration
RL reporting limit
s sample diluted due to the concentration of target analytes
Q reporting limit is elevated due to high analyte levels
B Analyte detected in associated method blank

**Table 5-1 Summary of Risks and Hazards to Potential Human Receptors at the Sewage Lagoons (SWMU 101)[1]**

| Risk or Hazard* | North Lagoon Sludge | North Lagoon Soil | South Lagoon Sludge | South Lagoon Soil |
|---|---|---|---|---|
| **Hazard Index** | 0.046 | 0.012 | 0.033 | 0.016 |
| **Excess Lifetime Cancer Risk (ELCR)** | $3.1 \times 10^{-6}$ | $1.9 \times 10^{-6}$ | $5.5 \times 10^{-6}$ | $2.5 \times 10^{-6}$ |

*Unacceptable risk is based on a target HQ of 1.0 or a carcinogenic risk level of $1 \times 10^{-5}$ for the sum of all carcinogens at a site or if only one carcinogen is present. Arsenic was the only chemical of potential concern that exceeded the target ELCR of $1 \times 10^{-6}$ for a single chemical in sludge and soil in the north and south lagoons. Based on the data, there is negligible risk to industrial workers from exposure to sludge and soil at SWMU 101.

[1](FWEC, 2001)

**Table 5-2. Summary of Risk to Ecological Receptors at SWMU 101[1]**

| COPEC | Terrestrial Invertebrates | Plants | Deer Mouse | Mourning Dove | Least Shrew | Red-Tailed Hawk |
|---|---|---|---|---|---|---|
| North Lagoon Soil | | | | | | |
| Pesticides | | | | | | |
| Heptachlor | NA | < 1 | < 1 | < 1 | < 1 | < 1 |
| Inorganics | | | | | | |
| Arsenic | 21 | 5.3 | < 1 | < 1 | < 1 | < 1 |
| Barium | NA | 170 | 97 | < 1 | 220 | 1.6 |
| Cadmium | < 1 | 1.5 | 2.7 | < 1 | 5.9 | < 1 |
| Chromium | 96 | 1100 | < 1 | < 1 | < 1 | < 1 |
| Lead | < 1 | 3.0 | 3.8 | 4.9 | 11 | 21 |
| Nitrate/Nitrite | NA | NA | < 1 | NA | < 1 | NA |
| Selenium | < 1 | 26 | < 1 | 3.5 | 2.2 | < 1 |
| North Lagoon Sludge | | | | | | |
| VOCs | | | | | | |
| m-/p-Xylenes | NA | < 1 | < 1 | NA | < 1 | NA |
| PCBs | | | | | | |
| PCB-1260 | < 1 | < 1 | 480 | < 1 | 1100 | < 1 |
| Pesticides | | | | | | |
| alpha-BHC | NA | NA | 1 | < 1 | 2.3 | < 1 |
| beta-BHC | NA | NA | 13 | < 1 | 28 | < 1 |
| Gamma-Chlordane | NA | NA | 19 | < 1 | 43 | < 1 |
| 4,4'-DDE | NA | NA | <1 | < 1 | <1 | < 1 |
| 4,4'-DDT | NA | NA | <1 | < 1 | <1 | < 1 |
| Dieldrin | NA | NA | 810 | < 1 | 1800 | < 1 |
| Endrin Aldehyde | NA | NA | 11 | < 1 | 25 | < 1 |

| COPEC | Terrestrial Invertebrates | Plants | Deer Mouse | Mourning Dove | Least Shrew | Red-Tailed Hawk |
|---|---|---|---|---|---|---|
| Heptachlor Epoxide | NA | <1 | 7.6 | < 1 | 17 | < 1 |
| Inorganics | | | | | | |
| Arsenic | 21 | 5.3 | <1 | < 1 | < 1 | < 1 |
| Cadmium | <1 | 25 | 46 | < 1 | 100 | < 1 |
| Chromium | 170 | 1900 | <1 | < 1 | < 1 | 1.3 |
| Lead | <1 | 18 | 23 | 30 | 66 | 130 |
| Mercury | 1.6 | 11 | 240 | 7.7 | 530 | 23 |
| Nitrate/Nitrite | NA | NA | <1 | NA | < 1 | NA |
| Selenium | 1.3 | 200 | 6.9 | < 1 | 17 | < 1 |
| Silver | NA | 2700 | 10 | < 1 | 19 | < 1 |
| South Lagoon Soil | | | | | | |
| VOCs | | | | | | |
| m-/p-Xylenes | NA | < 1 | < 1 | NA | < 1 | NA |
| Pesticides | | | | | | |
| alpha-BHC | NA | NA | 530 | < 1 | < 1 | < 1 |
| gamma-BHC (Lindane) | NA | NA | < 1 | < 1 | < 1 | < 1 |
| Heptachlor | NA | <1 | < 1 | < 1 | 1 | < 1 |
| Inorganics | | | | | | |
| Arsenic | 28 | 7 | <1 | < 1 | <1 | < 1 |
| Cadmium | <1 | 5.4 | 10 | < 1 | 22 | < 1 |
| Chromium | 100 | 1100 | <1 | < 1 | <1 | < 1 |
| Lead | <1 | 2.2 | 2.8 | 3.6 | 8.1 | 15 |
| Nitrate/Nitrite | NA | NA | <1 | NA | <1 | NA |
| South Lagoon Sludge | | | | | | |
| Pesticides | | | | | | |

| COPEC | Terrestrial Invertebrates | Plants | Deer Mouse | Mourning Dove | Least Shrew | Red-Tailed Hawk |
|---|---|---|---|---|---|---|
| gamma-BHC (Lindane) | NA | NA | <1 | < 1 | <1 | < 1 |
| alpha-Chlordane | NA | NA | 5.2 | < 1 | 12 | < 1 |
| gamma-Chlordane | NA | NA | 5.5 | < 1 | 12 | < 1 |
| 4,4'-DDE | NA | NA | <1 | < 1 | <1 | < 1 |
| Dieldrin | NA | NA | 570 | < 1 | 1300 | < 1 |
| Inorganics | | | | | | |
| Arsenic | 56 | 14 | <1 | <1 | <1 | <1 |
| Barium | NA | 190 | 110 | <1 | 230 | 1.7 |
| Cadmium | 1.3 | 64 | 120 | <1 | 260 | <1 |
| Chromium | 290 | 3200 | <1 | <1 | <1 | 2.2 |
| Lead | 1.1 | 23 | 29 | 38 | 85 | 160 |
| Mercury | 1.3 | 10 | 200 | 6.7 | 460 | 5.3 |
| Nitrate/Nitrite | NA | NA | <1 | NA | <1 | NA |
| Selenium | 4.3 | 660 | 23 | <1 | 55 | <1 |
| Silver | NA | 5300 | 19 | <1 | 37 | <1 |

Notes:

BHC – hexachlorocyclohexane

COPEC – chemicals of potential ecological concern

DDE –dichlorodiphenyldichloroethylene

DDT – dichlorodiphenyltrichloroethane

NA – not available; risk was not quantitatively evaluated due to lack of toxicity value.

PCB – polychlorinated biphenyl

VOC – volatile organic chemical

[1](FWEC, 2001)