FINAL

Hydrogeologic Conceptual Site Model for Camp Stanley Storage Activity

Prepared for:

Camp Stanley Storage Activity
Boerne, Texas

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EXECUTIVE SUMMARY

BACKGROUND

This Hydrogeologic Conceptual Site Model (HCSM) report incorporates data from groundwater and remedial investigations conducted at Camp Stanley Storage Activity (CSSA) between the years 1992 and 2004. It is an endeavor to bring the findings of multiple environmental investigations into a cohesive "big picture" model that describes the hydrologic setting at CSSA, and how and where contaminants occur within the subsurface, and groundwater in particular.

The initiation of this HCSM was authorized under Air Mobility Command (AMC) Contract F11623-94-D-0024, Delivery Order (DO) RL83. This update to the HCSM was completed under the Air Force Center for Environmental Excellence (AFCEE) Contract F41624-00-D-8024, Task Order (TO) 42. The work was conducted by Parsons under the technical supervision of AFCEE and was also overseen by U.S. Environmental Protection Agency (USEPA) Region 6, Resource Conservation and Recovery Act (RCRA)-Enforcement Section, and the Texas Commission on Environmental Quality (TCEQ) since October 1993.

CSSA is located in northwestern Bexar County approximately 19 miles NW of downtown San Antonio. At one time located in a rural setting, sprawling development of the San Antonio metroplex has encroached upon the facility, placing it adjacent to residential and commercial properties. The CSSA mission, receipt, storage and issuance of ordnance, materiels, as well as, quality assurance testing and maintenance of military weapons and ammunition, is associated with the maintenance of ordnance materiel, the use of industrial solvents as a degreasing agent was implemented from the 1950s through 1990. Citrus-based solvents have now replaced chlorinated solvents. As a result of past operations, releases of tetrachloroethene (PCE) to the environment have occurred from multiple source areas within CSSA.

ENVIRONMENTAL SETTING

CSSA is characterized by a rolling terrain of hills and valleys in which nearly flat-lying limestone formations have been eroded and dissected by streams draining to the east and southeast. The general morphology of this portion of Central Texas is caused by the Balcones Escarpment which extends westward from San Antonio and northward toward Austin, Texas. Soil cover is relatively thin, and bedrock is exposed in most areas other than stream valleys. The Cretaceous-age sediments of Central Texas were deposited as onlapping sequences on a submerged marine plain. CSSA is sited over older-aged deposits of the Travis Peak and Glen Rose Formations of the Trinity Group.

The Travis Peak Formation attains a maximum thickness of about 940 feet and is divided into five members as listed in ascending stratigraphic order: Hosston Sand, Sligo Limestone, Hammett Shale, Cow Creek (CC) Limestone, and Bexar Shale (as a facies of the Hensell Sand). Overlying the Travis Peak Formation, but still a part of the Cretaceous-age Trinity Group, is the Glen Rose Limestone. Combined, these rocks form the Upper, Middle, and Lower Trinity Aquifers of Central Texas.

The Hammett Shale, which overlies the Sligo Limestone, has an average thickness of 60 feet. It is composed of dark blue to gray fossiliferous, calcareous, and dolomitic shale.

Above the Hammett Shale is the CC Limestone, a massive fossiliferous, white to gray, shaley to dolomitic limestone that attains a maximum thickness of 90 feet downdip in the area. The youngest member of the Travis Peak Formation is the Hensell Sand, locally known as the Bexar Shale facies. The shale thickness averages 60 to 80 feet, and is composed of silty dolomite, marl, calcareous shale, and shaley limestone, and thins by interfingering into the Glen Rose Formation.

The Glen Rose Formation is split into two limestone members, referred to as the Upper Glen Rose (UGR) and Lower Glen Rose (LGR). The UGR consists of beds of blue shale, limestone, and marly limestone with occasional gypsum beds (Hammond, 1984). Based on well log information, the thickness of the upper member reaches 500 feet in Bexar County. Where present, the eroded thickness of this member at CSSA can be up to 150 feet. The LGR consists of a massive fossiliferous limestone, grading upward into thin beds of limestone, marl, and shale (Ashworth, 1983). The lower member, according to area well logs, is approximately 320 feet thick in the CSSA area.

The predominant structural feature in the area is the Balcones fault zone (BFZ) escarpment. The BFZ is a series of high-angle normal faults that generally trend northeast and southwest. Total displacement in northwest Bexar County is approximately 1,200 feet. The faulting is a result of structural weakness in the underlying Paleozoic rocks and subsidence in the Gulf of Mexico basin to the southeast. The downdrop blocks outcrop as progressively younger strata from northwest to southeast across the fault zone. As part of the BFZ, normal faulting occurs near the central area and southeastern boundary of CSSA. Faulting in the limestone units has juxtaposed strata of different ages, but fault scarps and traces are almost absent on the ground surface because similar calcareous lithologies weather similarly.

HYDROGEOLOGY

The primary groundwater source at CSSA and surrounding areas is the Middle Trinity Aquifer, the most prolific producer with the best quality of water of the three Trinity Aquifers. The Middle Trinity Aquifer consists of the LGR Limestone, the Bexar Shale (as a facies of the Hensell Sand), and the CC Limestone. The average combined thickness of the aquifer members is approximately 460 feet. Most general purpose wells within this aquifer are completed as open holes without well screens to maximize groundwater withdrawal from the yielding portions of the aquifer.

In the vicinity of CSSA, the LGR portion of the Middle Trinity Aquifer derives its recharge from direct precipitation on the outcrop and stream flow infiltration. Likewise, over the same area, the Bexar Shale acts as a hydrologic barrier to vertical leakage except where faulted; therefore, most recharge to the CC Limestone comes from overlying updip formations. Where structurally compromised, it is inferred that the CC Limestone can be in natural hydraulic communication with the LGR due to the extensive BFZ faulting. The bottom of the CC Limestone forms the base of the Middle Trinity Aquifer.

For the HCSM, horizontal and vertical boundaries were established to define the model area. Horizontal boundaries were based on units in the watershed that bound the contamination area between Cibolo, Leon, and Salado Creeks. The vertical limits of the model include the lower portion of the UGR Limestone (Upper Trinity aquifer) and all of the Middle Trinity aquifer, which is bounded below by the Hammett Shale. The strata of the model area were divided into five layers based on lithologic formation, and then further divided into 13 subunits based upon hydraulic and stratigraphic character. Of the subunits, two intervals stand out as groundwater producers: the basal 60 feet of the LGR and the upper 30 feet of the CC Limestone. While other portions of the stratigraphic profile contain groundwater, their yield is low, except locally where structural or karstic features prevail.

Most water production wells are completed as open boreholes to maximize groundwater yield, and they include varying lengths of surface casing to facilitate borehole stability or isolate less desirable groundwater strata. Observation wells at CSSA consist of cased and screened wells that discretely monitor 25-foot segments of the LGR, Bexar Shale, or CC Limestone. Often, these wells are arranged in clusters at a single location. By monitoring individual members of the aquifer, an assessment regarding the occurrence and distribution of contaminants within the Middle Trinity aquifer can be ascertained.

Information regarding the subsurface was compiled from borehole data, geophysics, and surface mapping to create a conceptual stratigraphic model. Data indicate that the LGR is typically an average thickness of 320 feet, and is overlain by a thin layer of the UGR which is normally 50 feet in thickness, but the thickness depends on the local topography. However, the UGR comprises nearly 90 percent of the surface outcrop, while exposures of the LGR only typically occur in the lowlands and creek beds. The underlying Bexar Shale is normally 60 feet in thickness, and the facies do not outcrop anywhere in the Texas Hill Country. The underlying CC Limestone unit is typically 75 feet in thickness, and is known only to outcrop along the Guadalupe River to the northeast. Drilling operations typically only penetrated the upper 15 feet of the Hammett Shale for logging purposes, and was not further addressed in this study.

Extensive drilling indicated that the bulk of the main groundwater body occurred within the basal portion of the LGR and the upper portion of the CC Limestone. The occurrence of groundwater within these units was implicitly related to the massive moldic porosity and karstic features associated with reef-building events and fossiliferous biostromes capable of storing large quantities of water. Occasionally, large volumes of groundwater could also be produced from well-developed reefs above the basal unit, or from significant perched fracture or karstic features. Otherwise, groundwater yields in the UGR and the top 250 feet of the LGR are minimal. Likewise, groundwater production from the BS is minimal at best. According to the injection packer testing, the CC Limestone was found to have the potential of transmitting the greatest amount of groundwater, but its natural water quality is less desirable than that of the LGR.

Additional testing of aquifer properties employed the use of Hydrophysical logging (HpL). A good relative measure of hydrophysical properties was conducted at CS-WB04 where the well extends through the entire thickness of the Middle Trinity aquifer. The HpL interpretation estimates that 100 percent of the measured groundwater flow originates from only a total of 23 feet of permeable strata or fractures within the LGR and CC Limestone. The amount of total estimated flow from the LGR during HpL resulted in 85 percent of groundwater production originating from the basal reef complex. When considering the entire thickness of the Middle Trinity aquifer, the LGR accounted for 92 percent of the entire production at CS-WB-04, and the CC Limestone accounted for the remaining 8 percent. No measurable flow was reported from the Bexar Shale interval.

Based on measurements at observation wells, the regional groundwater flow is generally to the south-southeast. The LGR typically has a southward gradient that deviates around mounding which occurs near the central and northern portions of the facility (CS-MW4-LGR). The Bexar Shale exhibits the potential for either northward or southward flow, depending on the season. Likewise, the CC Limestone exhibits erratic flow paths, with seasonally radial flow from mounded areas, to a northeastward flow possibly related to off-post pumping along Ralph Fair Road.

Long-term monitoring shows that groundwater response to precipitation events can be swift and dramatic. Depending on the severity of a precipitation event, the groundwater response will occur within several days, or even hours. Average precipitation events do not invoke much response from shallower wells within the LGR, yet main aquifer body wells will respond within a week. Such observations indicate that the preponderance of recharge observed occurs elsewhere on the outcrop, and not necessarily within CSSA.

Using continuous datalogging devices within a multi-port well, a significant increase in the resolution of recharge mechanics was observed. As measured in a multi-port well, aquifer response to significant recharge typically occurs as an increased pressure gradient that emanates from the lower zones upwards. The mechanism by which the aquifer appears to be bottom-filling is either that recharge to the lower zones occurs elsewhere on a regional scale (perhaps at outcrop areas), or that well-developed structural conduits convey the recharge downward quickly to the bottom of the LGR.

Data recorders indicate that under intense precipitation events an inter-aquifer gradient reversal occurs, providing the mechanism by which lower strata seemingly can recharge the upper strata through a network of fractures inherent in the bedrock. Once the recharge event has subsided, the aquifer resumes its natural state of a typically downward intra-aquifer gradient.

For the entire Middle Trinity aquifer, data obtained from the on-post well clusters indicate that for most of the year, a downward vertical gradient exists within the Middle Trinity aquifer. Differences in drainage rates often leave the potential head of the Bexar Shale well above the potential head of the LGR and CC Limestone. The large differences in potential head suggest that the Bexar Shale reacts locally a confining barrier between the LGR and CC Limestone.

The average precipitation at CSSA is typically above 32 inches per year. The 30-year record (1971-2000) shows a mean annual rainfall average of 37.36 inches in Boerne, Texas. The CSSA weather station reported a 35.39 annual average between 1999 and 2002. Precipitation ranging from 17 inches to 52 inches has been reported within a single year. In an attempt to estimate an annual water balance, approximately 67 percent of the annual precipitation is expected to be lost to evapotranspiration. Another 29 percent is assumed to be lost to annual surface runoff, while the remaining 4 percent recharges the Middle Trinity aquifer (based on published literature values). Assuming these estimates are valid, CSSA can be expected to consume between 9 percent and 27 percent of its annual recharge. Likewise, within the model area between 31 percent and 95 percent of the estimated recharge volume can be consumed by the collective groundwater consumers. These values are likely biased low since groundwater is obviously removed from storage during periods of drought, meaning the discharge will exceed recharge. CSSA implements a drought management plan to better manage its groundwater resources during times of reduced precipitation.

CONTAMINANT DISTRIBUTION

Solvent contamination (PCE, trichloroethene [TCE], and *cis*-1,2-dichloroethene [*cis*-1,2-DCE]) was first detected in a water supply well at CSSA during routine monitoring by the Texas Department of Health in 1991. Between 1992 and 1999, CSSA undertook a series of investigations to identify potential source areas for the groundwater contamination, which identified Solid Waste Management Units (SWMU) B-3 and O-1 and Area of Concern (AOC)-65 as likely candidates. SWMUs O-1 and B-3 are centrally located within CSSA. SWMU O-1 was a lined oxidation pond and nearby B-3 was a landfill where spent solvents were utilized as an accelerant for burning refuse. AOC-65 is located near the post boundary in an area where ordnance maintenance and testing operations were historically conducted. Starting in 1996, the first of 45 monitoring wells were installed, and well installation has continued through September 2003.

Off-post contamination was first reported by CSSA in December 1999 at a private well adjacent to the facility. Since that time, solvent contamination has been detected above the laboratories method detection limits (MDL) in 26 off-post private and public water supplies. The U.S. Army installed seven point-of-use treatment systems at those locations where concentrations exceeded 80 percent of the federal maximum contaminant level (MCL) of 5 micrograms per liter (µg/L) for PCE and TCE. Thus far, only sporadic trace detections of vinyl chloride have been reported. The lack of widespread vinyl chloride detections indicate that the reductive chlorination processes have stalled with the production of *cis*-1,2-DCE, which indicates a lack of potential electron donors within the system.

Contamination from past disposal activities resulted in multiple groundwater units, referred to as Plume 1 (B-3 and O-1) and Plume 2 (AOC-65). The release of solvents to the environment resulted in contamination of the Middle Trinity Aquifer, which is the primary drinking water source for the area. Contamination is most widespread within the LGR water-bearing unit. Locally, the Bexar Shale serves as a confining unit between the water-bearing LGR and CC Limestone. Faults of the BFZ structurally influence and re-direct the groundwater flowpaths. Environmental studies demonstrate that most of the contamination resides within the LGR; therefore, all open borehole completions are considered to be most representative of that unit.

Originating from SWMUs B-3 and O-1, Plume 1 has advectively migrated southward to CS-1 at Camp Bullis, and west-southwest toward CSSA well fields (CS-9, CS-10, and CS-11) and several off-post public and private wells. Volatile organic compounds (VOC) concentrations over 200 µg/L are present in Middle Trinity aquifer wells near the source area. Within the source area, concentrations of cis-1,2-DCE in excess of 24,000 µg/L have been reported in near-surface perched water wells. However, contaminant concentrations are below 1 µg/L over most of the Plume 1 area. In contrast, little to no contamination within the Bexar Shale and CC Limestone has been consistently identified within Plume 1 except in association with open borehole completions. Trace concentrations associated with Plume 1 have been detected at off-post locations.

Contamination at Plume 2 originated at AOC-65, and spread southward and westward from the post. The greatest concentrations of solvents are reported at the near subsurface adjacent to the source area (13,400 µg/L at CS-WB03-UGR-01). Deeper in the subsurface, concentrations in excess of 100 µg/L have been reported in perched intervals above the main aquifer body in the

LGR. However, as evidenced by the multi-port wells, once the main aquifer body is penetrated, the concentrations are diluted to trace levels above the laboratory MDL. Off-post, concentrations in excess of MCLs have been detected in private and public wells with open borehole completions. Concentrations exceeding 30 µg/L have been reported at RFR-10 located 1,200 feet west-southwest of CSSA. Vertical profiling within RFR-10 shows that discrete intervals within uncased upper strata contribute PCE concentrations over 90 µg/L. Only sporadic, trace concentrations of solvents have been detected in Bexar Shale and CC Limestone wells within Plume 2.

OBSERVATIONS

The style of well completion can affect the amount of concentration detected at a location. At CSSA, monitoring wells were purposely designed to case off contamination present within upper strata in an effort to reduce cross-contamination between water-bearing units. This style of well completion typically results in a groundwater sample from the main portion of the aquifer that has little to no contamination present. In contrast, most off-post wells are designed to maximize yield from all portions of the aquifer, resulting in co-mingling of stratified groundwater with varying degrees of contamination. Within an open wellbore, the net effect is that perched waters with high concentrations of solvents are contaminating relatively pristine groundwater held within the main body of the aquifer. This scenario, coupled with the tendency of downward vertical flow, has potentially created pockets of cross contamination into the basal unit of the LGR, Bexar Shale, and CC Limestone members of the Middle Trinity aquifer.

Results from the AOC-65 study seem to indicate that the bulk of contamination is locked within the upper 300 feet of strata, and may have a tendency to move laterally rather than vertically. This is supported by elevated concentrations detected in the upper portions of the RFR-10 borehole. The method by which contamination is transmitted horizontally is unconfirmed, but is likely related to the extensive northeast-southwest faulting in the area, possibly secondary dissolutioning along preferential planes, and pumping of off-post wells.

RECOMMENDATIONS

To complete a truly post-wide model, additional wells with borehole information should be considered. Stratigraphic and hydraulic uncertainties exist within the south, east, and northwest portions of the facility. A series of 2-inch wells that penetrate through the LGR would assist in completing the stratigraphic model, provide additional groundwater elevation control points, and provide additional locations for aquifer screening. In addition, the apparent groundwater mounding seen at CS-MW4-LGR should be investigated and better defined. Boreholes should be logged using standard geophysical tools as well as a borehole imaging system (televiewer).

Contaminant Distribution

Plume 1 may require additional delineation to the west of the source area. Over the past several years, the center of the plume appears to have migrated westward toward well CS-D. To delineate the plume to the MDL, additional wells within the East Pasture and along Salado Creek should be considered. Off-post drilling locations to be considered would include westward within Jackson Woods and southward within Camp Bullis. So far, Plume 1 has not been defined to the east toward Camp Bullis with contaminant-free monitoring wells.

Additional investigations within Plume 2 may include additional up gradient wells for potential remediation pilot studies (push-pull), and perhaps 300-foot wells to assess and/or recover contaminated groundwater near the source area. Additional delineation to levels below the MDL would require the installation of wells southward of Leon Springs Villa and Hidden Springs Estates.

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ACRONYMS AND ABBREVIATIONS

°F	Fahrenheit
acre-ft/yr	Acre-feet per year
AEM	Aerial electromagnetic
AFCEE	Air Force Center for Environmental Excellence
AL	Action Level
AMC	Air Mobility Command
AOC	Area of concern
ARAR	Applicable or Relevant and Appropriate Requirements
BFZ	Balcones fault zone
bgs	Below ground surface
BrE	Brackett soils
BS	Bexar Shale
BtE	Brackett-Tarrant Association soils
Cb	Crawford and Bexar stony soils
CC	Cow Creek
CD	Compact disc
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/sec	Centimeters per second
CO_2	Carbon dioxide
COC	Contaminant of concern
CSSA	Camp Stanley Storage Activity
CY	Cubic Yards
DCE	*cis*-1,2-dichloroethene
DNAPL	dense, non-aqueous phase liquid
DO	Delivery Order
DoD	Department of Defense
DQO	Data quality objective
DRO	Diesel-range organics
DTM	Digital terrain model
EAA	Edwards Aquifer Authority
EM	Electromagnetic
EPA	U.S. Environmental Protection Agency
ES	Engineering Science
ft	feet
ft^2	square feet
ft/ft	Foot per foot
ft/sec	Feet per second
FM	Farm to Market
GIS	Geographic information system
gpd/ft	Gallons per day per foot
gpm	Gallons per minute
gpm/ft	Gallons per minute per foot

GPR	Ground Penetrating Radar
GPS	Geographic positioning system
GRO	Gasoline-range organics
GVA	George Veni & Associates
HCSM	Hydrogeologic conceptual site model
HS	Hammett Shale
IH	Interstate Highway
IM	Interim Measure
IP	Induced polarization
Kr	Krum complex soils
LCY	Loose cubic yards
LGR	Lower Glen Rose
LvB	Lewisville silty clay
MCL	Maximum contaminant level
mg/kg	Milligrams per kilogram
µg/L	Micrograms per liter
MSL	Mean sea level
N/A	Not available
NE	Northeast
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
NW	Northwest
NWS	National Weather Service
O&M	Operation and Maintenance
P	Precipitation
Parsons ES	Parsons Engineering Science
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethene
PIMS	Phosphate-Induced Metals Stabilization
ppbv	Parts per billion volume
PZ	Piezometer
Q_d	groundwater component of runoff
Q_s	surface component runoff
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RL	Reporting limit
RMU	Range Management Unit
RRAD	Red River Army Depot
RRS1	Risk reduction standard 1
SAWS	San Antonio Water System
SDWA	Safe Drinking Water Act
SE	Southeast
SH	State Highway

SP	Spontaneous potential
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
SW	Southwest
SWMU	Solid Waste Management Unit
TaB	Gently undulating Tarrant Association Soils
TaC	Rolling Tarrant Association Soils
TCE	Trichloroethene
TCEQ	Texas Commission on Environmental Quality
TDH	Texas Department of Health
Tf	Trinity and Frio soils
TNRCC	Texas Natural Conservation Commission
TO	Task Order
TOC	Top of casing
TPH	Total petroleum hydrocarbon
TRRP	Texas Risk Reduction Program
TWDB	Texas Water Development Board
UGR	Upper Glen Rose
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VC	Vinyl Chloride
VEW	Vapor extraction well
VLF	Very low frequency
VMP	Vapor monitoring point
VOC	Volatile organic compound