DRAFT

THREE-TIERED

LONG TERM MONITORING NETWORK

OPTIMIZATION EVALUATION

FOR

CAMP STANLEY STORAGE ACTIVITY
BOERNE, TEXAS

February, 2005

PARSONS
1700 Broadway, Suite 900

Denver, Colorado 80290

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF ACRONYMS

AFCEE	Air Force Center for Environmental Excellence
AOC	area of concern
BDCME	bromodichloromethane
BZME	toluene
BS	Bexar Shale
CC	Cow Creek
cm/sec	centimeters per second
COC	contaminant of concern
CSSA	Camp Stanley Storage Area
DCE	dichloroethene
DQO	data quality objective
ESRI	Environmental Systems Research Institute, Inc.
FM	Farm to Market Road
GIS	geographical information system
gpd	gallon per day
gpm	gallon per minute
HCSM	hydrogeologic conceptual site model
IH	Interstate Highway
LCY	lose cubic yards
LGR	Lower Glen Rose
LTM	long-term monitoring
µg/L	microgram(s) per liter
MCL	maximum contaminant level
NS	north to south cross section
PB	lead
PCE	tetrachloroethene
PQL	practical quantitation limit
PZ	piezometer
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
RMU	rifle management unit
SWMU	solid waste management unit
SVE	soil vapor extraction
TBME	bromoform
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
UGR	Upper Glen Rose
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VC	vinyl chloride
VEW	vapor extraction well
VLF	very low frequency

VOC	volatile organic compound
WB	Westbay® equipped well
WE	west to east cross section

SECTION 1

INTRODUCTION

Groundwater monitoring programs have two primary objectives (U.S. Environmental Protection Agency [USEPA], 1994; Gibbons, 1994):

1. Evaluate long-term temporal trends in contaminant concentrations at one or more points within or outside of the remediation zone, as a means of monitoring the performance of the remedial measure (*temporal objective*); and

2. Evaluate the extent to which contaminant migration is occurring, particularly if a potential exposure point for a susceptible receptor exists (*spatial objective*).

The relative success of any remediation system and its components (including the monitoring network) must be judged based on the degree to which it achieves the stated objectives of the system. Designing an effective groundwater monitoring program involves locating monitoring points and developing a site-specific strategy for groundwater sampling and analysis so as to maximize the amount of relevant information that can be obtained while minimizing incremental costs. Relevant information is that required to effectively address the temporal and spatial objectives of monitoring. The effectiveness of a monitoring network in achieving these two primary objectives can be evaluated quantitatively using statistical techniques. In addition, there may be other important considerations associated with a particular monitoring network that are most appropriately addressed through a qualitative assessment of the network. The qualitative evaluation may consider such factors as hydrostratigraphy, locations of potential receptor exposure points with respect to a dissolved contaminant plume, and the direction(s) and rate(s) of contaminant migration.

This report presents a description and evaluation of the groundwater monitoring program associated with the Camp Stanley Storage Activity (CSSA) in Boerne, Texas. A 97-well monitoring network containing 139 sampling points was evaluated to identify potential opportunities to streamline monitoring activities while still maintaining an effective monitoring program. A three-tiered approach, consisting of a qualitative evaluation, an evaluation of temporal trends in contaminant concentrations, and a statistical spatial analysis, was conducted to assess the degree to which the monitoring network addresses each of the two primary objectives of monitoring, and other important considerations. The results of the three evaluations were combined and used to assess the optimal frequency of monitoring and the spatial distribution of the components of the monitoring network. The results of the analysis were then used to develop recommendations for optimizing the monitoring program at CSSA.

SECTION 2

SITE BACKGROUND INFORMATION

The location, operational history, geology, and hydrogeology of CSSA are briefly described in the following subsections.

2.1 SITE DESCRIPTION

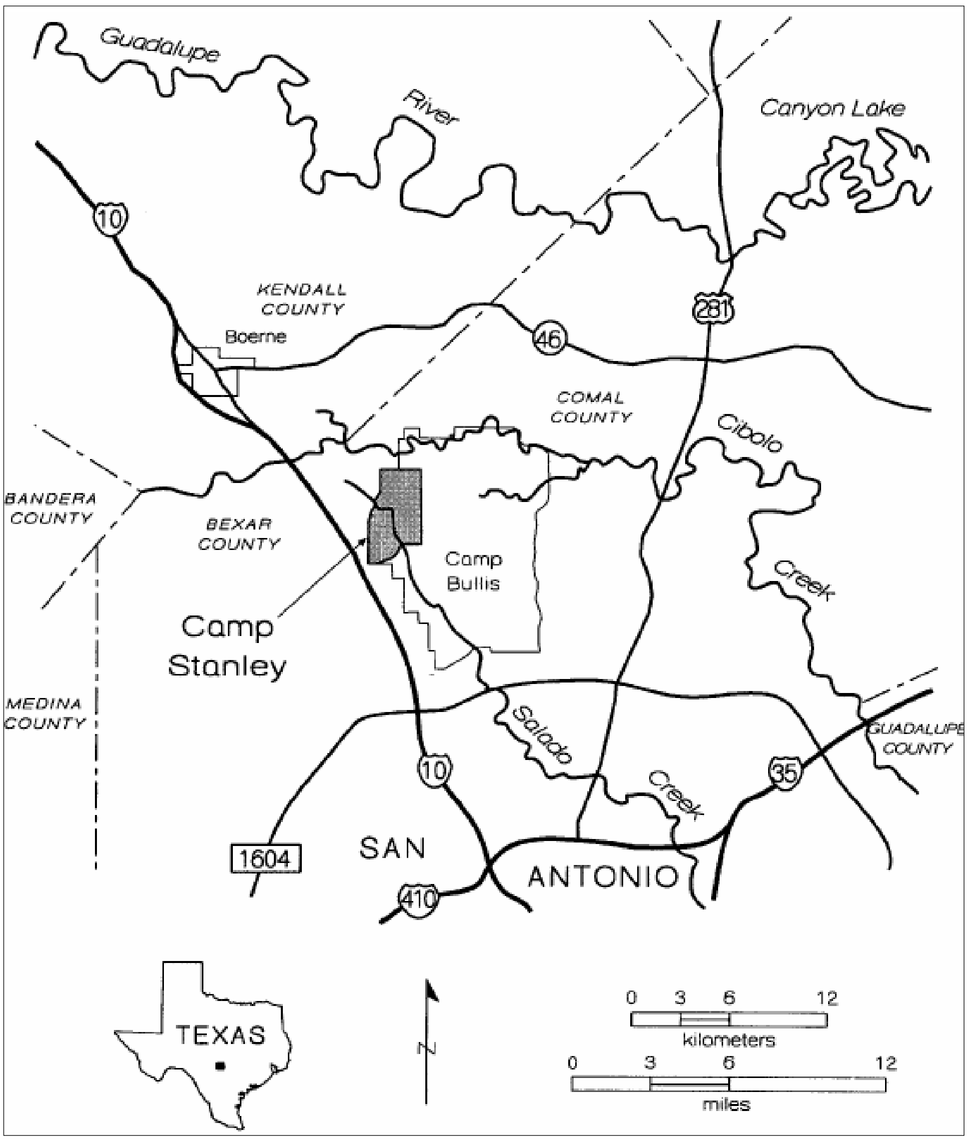
2.1.1 Site Background

CSSA is an active installation located in Bexar County, approximately 19 miles northwest of downtown San Antonio, Texas. Its higher headquarters is the Red River Army Depot in Texarkana, Texas. The mission of CSSA is the receipt, storage, and issuance of ordnance materiel as well as quality assurance testing and maintenance of military weapons and ammunition. Because of its ordnance mission, CSSA is a restricted-access facility.

CSSA consists of 4,004 acres immediately east of Farm to Market Road (FM) 3351, and approximately half a mile east of Interstate Highway (IH) 10 (Figure 2.1). Camp Bullis borders CSSA on the north, east, and southeast. The land on which CSSA is located was used for ranching and agriculture until the early 1900s. During 1906 and 1907, six tracts of land were purchased by the U.S. Government and designated the Leon Springs Military Reservation.

Land surrounding CSSA is primarily residential or used for ranching. Nearby communities and subdivisions include Leon Springs, Leon Springs Villa, Hidden Springs Estates, The Dominion, Fair Oaks Ranch, and Jackson Woods. Ranching and agricultural land is intermingled with the developed communities. The IH 10 and Ralph Fair Road intersection includes separate commercial businesses. A strip center at the northwest corner of CSSA also contains businesses that serve the city of Fair Oaks Ranch.

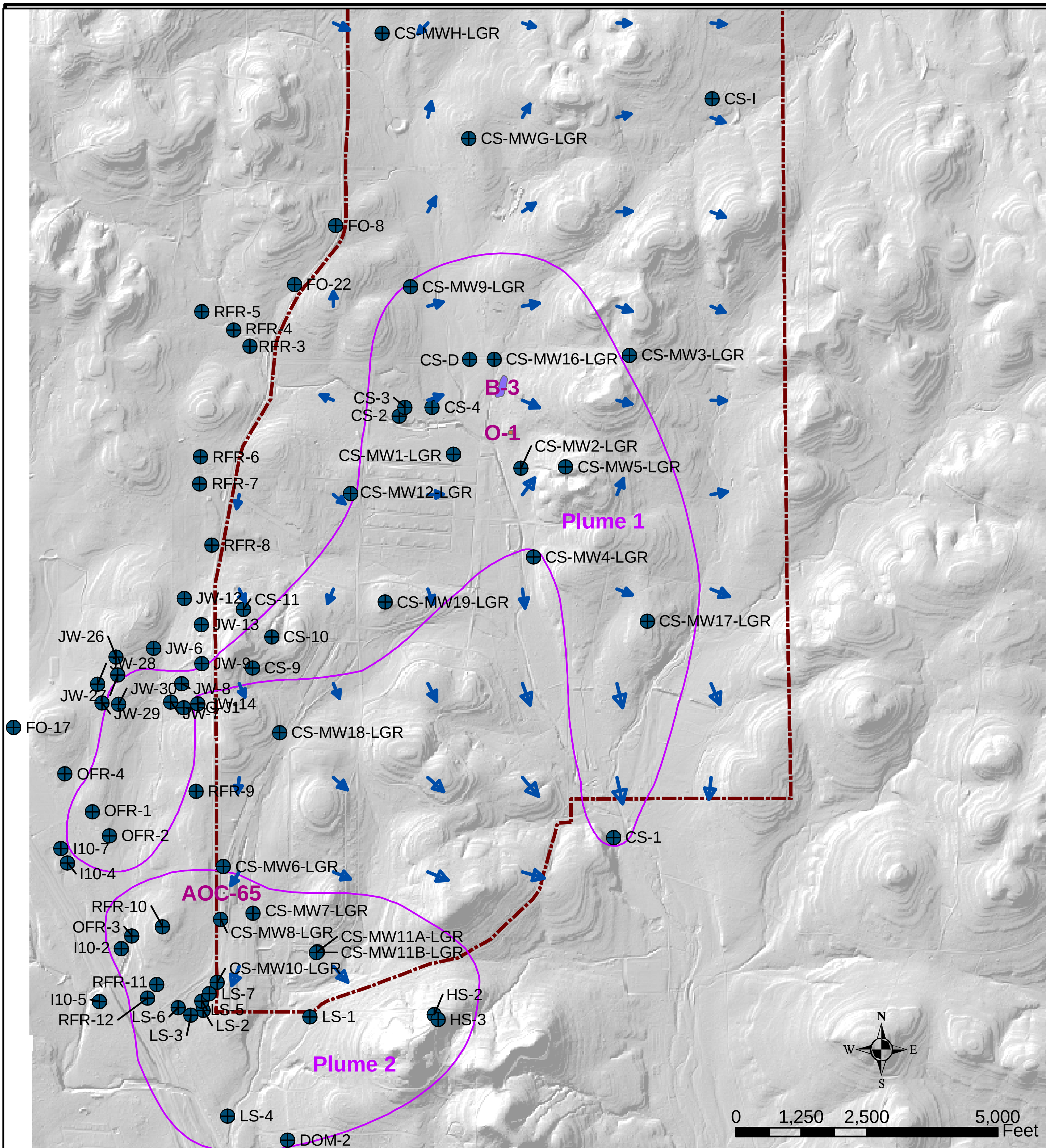
FIGURE 2.1
LOCATION OF CSSA IN BEXAR COUNTY, TEXAS
LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS



2.1.2 Investigative and Remedial Activities

In previous investigations, a total of 84 sites, including 39 Solid Waste Management Units (SWMUs), 40 areas of concern (AOC)s, and 5 Rifle Management Units (RMUs) have been identified at CSSA. Analytical data suggest that tetrachloroethene (PCE), trichloroethene (TCE), and *cis*-1,2-dichloroethene (DCE) are the primary contaminants of concern (COC) in groundwater and metals are the primary COC in soil. As of October 2004, a total of 26 SWMU and/or AOC sites have been closed. Over 60 sites have been investigated, and remediation is currently being conducted at 34 sites. However, only three sites investigated are considered to be likely sources for the groundwater contamination within the Middle Trinity aquifer. These include two SWMUs (B-3 and O-1) located near well CS-16 and AOC-65 located near the SW corner of the post. (Figure 2.2) Additional information on these site investigations is included in the CSSA Environmental Encyclopedia; specifically the *Groundwater Investigation and Associated Source Characterizations Report, SWMU B-3 Characterization* (Parsons 1996), *Interim/Stabilization Measures and Partial Facility Closure Report For SWMU O-1* (Parsons, 2000) and *AOC 65 Interim Removal Action Report* (Parsons 2003). The CSSA Environmental Encyclopedia is maintained as the Administrative Record for CSSA under the provisions of the Administrative Order on Consent issued to CSSA on May 5, 1999, pursuant to §3008(h) of the Safe Drinking Water Act (SDWA). The CSSA Environmental Encyclopedia is available in hard copy format and on the internet at www.stanley.army.mil.

SWMU B-3 was a landfill area thought to have been used primarily for garbage disposal and trash incineration. In 1991, chlorinated hydrocarbons were detected in groundwater from well CS-16 approximately 500 ft north-northwest of SWMU B-3. The concentrations were above drinking water standards and prompted several investigations aimed at identifying possible source areas that could have contributed to the contamination. Various investigations including geophysical surveying, surface and subsurface soil sampling, and soil gas sampling, indicated PCE and TCE were present at



Legend

- LGR Zone Well
- Approximate Extent of PCE Plume
- CSSA Boundary
- Groundwater Flow Direction (Dec04)

Source Areas

- AOC-65
- B-3
- O-1

FIGURE 2.2

GENERAL SITE FEATURES

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

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SWMU B-3. The presence of these chlorinated hydrocarbons indicated SWMU B-3 as a likely source area for the contamination detected in well CS-16.

Removal actions were performed at SWMU B-3 for removal of soil VOC contamination. Three drums of unknown origin were removed and disposed off-site along with 732 loose cubic yards (LCY) of hazardous media and 1,242 LCY of Class 2 non-hazardous materials. In addition, over 5,500 LCY of cover soil were properly characterized, stockpiled and used as backfill and cover.

Soil vapor extraction (SVE) pilot tests and treatability were performed at SWMU B-3 before and after the removal actions. Based on initial SVE pilot tests and the first 12 months of operations and maintenance, operation of the SVE system at SWMU B-3 resulted in the removal of approximately 290 pounds of volatile organic compounds (VOCs). Based on these findings, SVE appears to be an effective method for removing VOCs from the SWMU B-3 trenches. Additionally, SVE has been identified as a possible remedial alternative to reduce levels of residual contaminant in bedrock.

A second site identified as a possible source of contamination was the oxidation pond, also referred to as SWMU O-1. The pond was constructed in 1975 and wastes were trucked to the oxidation pond from a settling tank. The pond liner was apparently damaged during bulldozing. No records are available to indicate whether or not disposal of the sludge or residue contained in the oxidation pond occurred before damage to the liner. Due to its proximity to contaminated well CS-16, investigations were initiated at SWMU O-1 in 1995. Surface geophysical surveys, soil sampling and soil gas surveys were performed. Approximately 80 LCY of soil material were excavated during the liner investigation. A field treatability study was initiated to test the efficacy of electrokinetic treatments. Additional soils were excavated and removed in November 1999 and in 2000. Surface and subsurface soils were transported and disposed of off-site. The excavation area was backfilled and a low-permeability clay liner was constructed over the site. Six inches of topsoil were placed on top of the clay liner, and a vegetative surface was established on the topsoil. Texas Commission on Environmental Quality

(TCEQ) approved a partial facility closure of the surface soil zone located within the boundaries of SWMU O-1 in April 2002.

The third site identified as a groundwater contamination source area at CSSA was AOC-65 at the southwest corner of the base. AOC-65 included two sub-slab, concrete-lined vaults, one on the west side, one inside Building 90 and associated drain lines and ditches extending outside Building 90. A metal vat was installed in the western vault prior to 1966 and removed in 1995. The vat was used for cleaning ordnance materials inside Building 90 with chlorinated liquid solvents, such as PCE and TCE. In 1995, after removal of the former solvent vat, a metal plate was welded over the concrete vault. Use of PCE and TCE solvents were replaced by citrus-based cleaners. The use of the second vault, located within the middle of the interior of Building 90, is not known. It was backfilled and capped with concrete at an unknown date. Building 90 continues to be used for weapons cleaning and maintenance.

A soil gas survey, performed in January and February 2001, revealed a PCE plume in the soils beneath and to the south and west of Building 90 (Parsons 2001). Soil borings were advanced and sampled and monitoring wells were installed and sampled. The soil gas survey indicated the presence of a PCE contaminant plume underlying Building 90 and extending primarily to the west and southwest from the building. Based on sampling results, it appears the lateral extent of the PCE plume in the soil gas is generally confined to the immediate vicinity of Building 90. Soils in the area where the drainage line from Building 90 meets the drainage ditch contained the highest soil COC concentrations. However, in the bedrock samples (21.0 to 21.5 ft), concentrations only slightly exceeded background, suggesting that COCs are limited to the soil. Groundwater samples collected from both inside and outside the soil-gas survey plume contained PCE.

Geophysical investigations were performed to identify subsurface features such as fractures, faults, and karst dissolution that may be controlling the migration of contaminants. Identification of these features was used to direct installation of piezometers (PZ)s and an SVE system near Building 90. The geophysical methods utilized at AOC-65 include electrical resistivity, microgravity, very low frequency (VLF), EM, shear-wave seismic reflection, induced polarization (IP), and spontaneous potential (SP). These methods were selected based on their ability to detect changes in physical properties associated with fractures, faults, and karst features. The surveys were implemented in a phased approach with the results of one phase providing direction for subsequent phases. Removal of near-surface contamination and the installation of two SVE systems were conducted. Geologic correlations from core and geophysical logs indicate at least three faults in the AOC-65 area.

Near-surface soils along the former drain line and ditch were removed. Engineering controls were constructed to minimize the amount of precipitation recharge infiltrating within the source zone.

2.2 GEOLOGY AND HYDROGEOLOGY

2.2.1 Geology

The oldest and deepest known rocks in the CSSA area are Paleozoic age (225 to 570 million years ago) schists of the Ouachita structural belt. They underlie the predominant carbonate lithology of the Edwards Plateau. The Cretaceous age sediments were deposited as onlapping sequences on a submerged marine plain and, according to well logs and outcrop observations, these sediments thicken to the southeast. The Cretaceous System stratigraphy includes the Trinity Group Travis Peak Formation shallow marine deposits. The Travis Peak Formation attains a maximum thickness of about 940 ft and is divided into five members, in ascending order: the Hosston Sand, the Sligo Limestone, the Hammett Shale, the Cow Creek (CC) Limestone, and the Hensell Sand (and Bexar Shale (BS) facies). Overlying the Travis Peak Formation, but still a part of the Cretaceous-age Trinity Group, is the Glen Rose Limestone. For this study, the units of interest are the Glen Rose Limestone, BS, and CC Limestone that form the Middle Trinity aquifer.

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

It pinches out north of the study area and attains a maximum thickness of 80 ft to the south. Above the Hammett Shale is the CC Limestone, which is a massive fossiliferous, white to gray, shaley to dolomitic limestone that attains a maximum thickness of 90 ft down dip in the area. The youngest member of the Travis Peak Formation is the Hensell Sand, locally known as the BS. The shale thickness averages 60-80 ft, and is composed of silty dolomite, marl, calcareous shale, and shaley limestone, and thins by interfingering into the Glen Rose Formation.

The upper member of the Trinity Group is the Glen Rose Limestone. The Glen Rose Limestone was deposited over the Travis Peak BS and represents a thick sequence of shallow water marine shelf deposits. This formation is divided into upper and lower members. At CSSA, the Glen Rose is exposed at the surface and in stream valleys.

The Upper Glen Rose (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 ft in Bexar County. The thickness of this member at CSSA is estimated from well logs to be between 20 and 150 ft.

The Lower Glen Rose (LGR), underlying the UGR, 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 300 ft thick at CSSA. Isolated areas of reef rock have also been identified in the LGR. The boundary between the upper and lower members of the Glen Rose Limestone is defined by a widespread fossil stratigraphic marker known as the Corbula bed (Whitney, 1952). The Corbula bed is 0.5-5 ft thick and contains small pelecypod clamshells, which are three to five millimeters in diameter. Presence of the Corbula fossil indicates a slightly more saline depositional environment than fossils found above and below the Corbula. A gypsum bed has also been identified near the Corbula bed.

2.2.2 Hydrogeology

The geologic units present at CSSA were informally divided into hydrostratigraphic units to provide a framework for describing the local hydrogeology. Three aquifers are present in the area of CSSA: the Upper, Middle, and Lower Trinity aquifers. The Travis Peak Formation and the Glen Rose Formation are the principle water-bearing units. Only the Middle and Upper Trinity aquifers are addressed for this study.

The following hydrostratigraphic descriptions are based upon work performed by the USGS, in which the UGR member has been informally divided into five mappable units within Camp Bullis and CSSA. For this report, the UGR Limestone has been subdivided into five mappable intervals (UGR[A-E]). Exposures of units UGR (A, B, and C) are limited to the very highest elevations within the post, with unit A being present only atop Schasse Hill at the southern edge of CSSA. The lower two units, UGR(D and E), comprise over 83 percent of the outcrop at CSSA.

Interval UGR(A) is an approximately 120-ft-thick interval composed of alternating and interfingering medium-bedded mudstone to packstone, with evaporates occurring locally. Interval UGR(A) has been referred to as the “cavernous zone” (GVA, 2000) because of an abundance of caves in the interval. Interval UGR(A) crops out only atop Schasse Hill within the confines of CSSA. Interval UGR(B) is a 120- to 150-ft-thick interval similar to Interval UGR(A) but with appreciably less cave development and thus less permeability than the overlying interval. Overall, intervals A and B are indistinguishable based on lithology. Interval UGR(B) crops out only atop some of the larger hills (Schasse Hill, Wells Hill, and Steele Hill) within the confines of CSSA. Groundwater occurring within Intervals UGR(A and B) is laterally discontinuous and likely free of contamination. Limited recharge to the zone is through direct precipitation on the outcrop and recharge from Interval UGR(A), and much of that water is believed to be lost to seeps along the base of the outcrop. Some groundwater may leak vertically to lower strata where the outcrop is bisected by faults or fractures.

Interval UGR(C) is a solution zone that is approximately 10 to 20-ft thick. Like the underlying Interval UGR(E) at the base of the UGR, it was originally an evaporite bed. It is composed of yellow-to-white calcareous mud with some very thin mudstone layers interspersed and tends to form broad, valley-like slopes. Interval UGR(C) only crops out along the slopes of the larger hills (Schasse, Wells, and Steele) within the confines of CSSA.

Interval UGR(D) is 135 to 180 ft thick and composed of alternating beds of wackestone, packstone, and marl. Because of its high mud content, the 135 to 180-ft-thick Interval D (between the two solutioned evaporite beds (Intervals UGR[C] and UGR[E] and known locally as a "fossiliferous zone") generally has low porosity and permeability, with some local exceptions. In a few locations, some cavern porosity can be seen in outcrop along fractures. Interval UGR(D) crops out over most of CSSA (77.5 percent coverage). Most of the developed areas at CSSA are upon the Interval UGR(D) outcrop. Likewise, most of the waste management activities that have occurred at CSSA are also within this interval. However, most of the more permeable zones near the top of the unit have been eroded from CSSA, and occur only near the top of hills where less development and waste management activities have occurred. Significant recharge to the zone is through direct precipitation on the outcrop and recharge from overlying intervals. This is the first pervasive stratum across the facility that lends itself to lateral groundwater movement without being cropped out by the intersecting land surface. A significant volume of groundwater is assumed to leak vertically to lower strata where the outcrop is bisected by faults or fractures. This unit has been investigated in depth by RFI activities and groundwater investigations, as well as the background soils study prepared in the Second Revision to Evaluation of Background Metals Concentrations in Soils and Bedrock (Parsons, 2002). Groundwater contamination is known to exist within this interval near the source areas of Plumes 1 and 2.

Interval UGR(E) is a 7- to 10-ft thick solution zone that originally was an evaporite bed, but that has subsequently been dissolved, leaving behind a calcareous mud. The Corbula bed (*Corbula martinae*) lies at the base of this interval and marks the geologic contact between the Upper and LGR Limestone. The Corbula bed is a thin to very-thin-bedded grainstone. As with Interval UGR(C), this solutioned evaporite bed, which includes the Corbula bed at its base, appears to intercept the downward seepage of water. The interval acts as a lateral conduit for flow, as demonstrated by seeps observable at the surface in outcrop. Groundwater contamination is known to exist within this interval near the source areas of Plumes 1 and 2. The vapor extraction wells (VEWs) at B-3 and the shallow PZs (-2, -4, and -6) at AOC-65 are mostly completed within this depth interval, and groundwater concentrations from these wells indicate concentrations greater than those in the main plume within the LGR. At B-3 (Plume 1), *cis*-1,2-DCE has been reported in excess of 27,000 µg/L, and nearly 3,000 µg/L of PCE was reported. At AOC-65 (Plume 2), lesser concentrations of PCE generally ranging between 30 µg/L and 60 µg/L are perched about the LGR.

In the Hydrogeologic Conceptual Site Model (HCSM), the LGR Limestone has been informally divided into six intervals LGR(A-F), as described below from youngest to oldest.

Exposures of unit LGR(A) are limited to the basal portion of Salado Creek and its tributaries in the central portion of the post (covering 10.8 percent of CSSA's surface). The remaining older units do not crop out within the post. Interval LGR(A) is defined as the uppermost 50-foot sequence of LGR deposits throughout the CSSA area. The unit is characterized by alternating layers of pale yellow mudstone, wackestones, and packstones.

The top of Interval LGR(B) ranges between 30 to 50 ft beneath the UGR/LGR contact, and the interval is between 30 and 50 ft thick. The interval is characterized as a whitish fossiliferous packstone and grainstone that is evident both in lithologic and geophysical logs. During much of the year, the main aquifer level is well below the elevation of this interval. During these times, groundwater will tend to perch within this zone. Large sinkholes and other solution features have formed in this zone.

Over much of CSSA, Interval LGR(C) exists as a 60-70-foot thick sequence of thin and medium-bedded mudstones below the more permeable grain-supported limestones of Interval LGR(B). The mudstones are described as alternating layers of tannish-brown and greenish-gray bioturbated muds with a low percentage allochemical constituents (e.g., fossils). The rock is competent and highly styolitic (susceptible to diagenetic pressure solutioning). Interval LGR(C) also includes some significant reef structures to the north and south.

Interval LGR(D) is a 65-70-foot thick unit of rock that is characterized by a unique resistivity signature with respect to the overlying and underlying rocks. The change generally represents two resistive packstone layers divided by a less resistive mudstone. The upper and lower packstone layers tend to be approximately 25 ft thick, and are described as interbedded fossiliferous wackestones and packstones that are pale yellow to white in color. The middle layer is more characteristic of a bioturbated mudstone that is tan in color. The localized vugs associated with moldic porosity (fabric selective) can store and transmit limited amounts of groundwater. Interval LGR(E) is a 50-60-foot layer of tan and light brown wackestones with intermittent thin fossiliferous layers and grain-supported rock. The unit is fairly unremarkable, except for the presence of a notable vuggy packstone layer located at the base of the interval.

Interval LGR(F) comprises the main groundwater production zone within the LGR throughout CSSA. Interval LGR(F) is comprised of a 45-55-foot reef complex whose lateral extent appears to extend beneath the entire confines of CSSA. The occurrence of this reef has been well documented within boreholes drilled at CSSA and neighboring areas. The interval is described as a white to tan, very fossiliferous packstone/grainstone with high fabric selective moldic porosity. The interval is characterized by its relatively low gamma response and high resistivity response. The vuggy porosity left as a result of fossil dissolution has resulted in voids that range from several millimeters to 5 centimeters in size. In some locations, the basal 15 ft of the interval has a pronounced increase in mud content, and a color change to pale brown.

The primary permeability of Interval LGR(F) is moldic (fabric selective) porosity. Extensive testing through packer tests and discrete interval groundwater sampling indicate that the interval is capable of yielding groundwater in excess of 75 gallons per minute (gpm). Where not fabric selective porosity exists in the form of developed fractures, karst, or small caverns, groundwater production can easily exceed 150 to 300 gpm. For the monitoring well program, this interval has been the focus of the investigations where typically the basal 25 ft of the aquifer is monitored for the occurrence of contamination.

The BS has been subdivided into two intervals BS(A-B), as described below from youngest to oldest. As expected, these subunits can be quite variable over the extent of CSSA. The BS forms a relatively impermeable aquitard for the overlying LGR water bearing zones. Significant vertical water movement in the BS is anticipated to be through fractures and faults only. CSSA currently has 4 monitoring wells completed in the BS. For the purposes of this model, Interval BS(A) is defined as the uppermost 25-30-foot sequence of BS deposits throughout the HCSM area. The unit is characterized by alternating layers of pale yellow mudstone, wackestones, and packstones. The BS(A) interval appears to have low porosity and permeability with only not fabric selective fracture porosity evident and no known cavern development. Beneath much of CSSA, the top of interval BS(B) is denoted by a large increase in gamma counts, which peaks and quickly declines. An approximately 10 to 15-ft-thick oyster bioherm also appears to be predominant at the top of BS(B). The basal 20 ft of the BS consists of a platy, fissile mudstone that has an olive gray appearance. At this depth the unit is more characteristic of a shale bed that has few allochems, and a very low porosity. The BS(B) interval appears to have low porosity and permeability with only not fabric selective fracture porosity evident and no known cavern development.

The CC has been subdivided into two intervals, CC(A-B), as described below from youngest to oldest. Interval CC(A) is defined as the uppermost 50-55-foot sequence of CC deposits throughout the area. The unit is characterized by alternating layers of white and light gray packstones and grainstones. Portions of this interval can be quite permeable from either moldic (fabric selective) porosity or not fabric porosity in the form of dissolutioned vugs, voids, or fractures. Moderate to large amounts of groundwater can be expected to be produced from this interval. This zone has been identified as an interval of interest with respect to groundwater monitoring at CSSA.

The basal 20 ft of the CC Limestone represents a conformable transition with the underlying Hammett Shale. The grainstones and packstones of unit CC(A) grade into a soft olive gray silty mudstone designated unit CC(B). The contact is transitional, with numerous interbeddings between soft shaley members and more competent limestone rock. Bedding units range from a few inches to several feet in thickness. The contact with the Hammet Shale below CC(B) has been defined typically as the greatest gamma peak below the base of the BS.

Historical water level data at CSSA shows that the typical groundwater flow gradient is towards the south, with directional variations ranging from the southwest to the southeast, depending on the level of recharge. During extended periods of drought, the flow direction reflects a greater westerly component of flow.

The potentiometric surface maps from previous monitoring events indicate highly varying flow directions in the LGR. From December 2002 through June 2004, the overall direction of groundwater flow is predominately to the south-southeast. Groundwater flow in this unit is apparently influenced by groundwater mounding in the vicinity of well CS-MW4-LGR. Groundwater appears to move in several directions from this groundwater mound, which may be the result of well CS-MW4-LGR intersecting a significant recharge feature. The proximity of CS-MW4-LGR to Salado Creek is possibly the cause of a consistently higher potentiometric surface near this well. Until further control points are established, this mounding effect remains one of the most notable features of the groundwater surface. Figure 2.2 shows the general groundwater flow in the LGR zone at CSSA.

Hydraulic conductivity and transmissivity data were gathered from pumping tests conducted at drinking water wells present at CSSA. Additional hydraulic conductivity and transmissivity data were presented in prior publications. Published hydraulic conductivity values range from 1.4 x 10^{-3} to 3.5 x 10^{-3} cm/sec locally and range from 3.4 x 10^{-5} to 1.0 x 10^{-3} cm/sec regionally (Hammond, 1984). Site-specific hydraulic conductivity values ranged from 4.2 x 10^{-4} to 5.7 x 10^{-4} cm/sec (CSSA, 2001). The published transmissivity values range from 5,740 to 16,110 gpd/ft locally and 240 to 3,220 gpd/ft regionally (Hammond, 1984). Site-specific transmissivity values range from 1,600 to 2,400 gpd/ft (CSSA, 2001).

2.3 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

As a result of previous operations at SWMUs B-3, O-1 and AOC-65, releases of chlorinated VOCs to the environment have occurred from multiple source areas within CSSA. These releases have resulted in contamination of the LGR Limestone member of the middle Trinity Aquifer. Detections of solvent contamination (PCE, TCE and *cis*-1,2-DCE) were first reported in 1991. Starting in 1996, the first of 45 monitoring wells were installed. Well installation continued through September 2003. Off-post contamination was first reported by CSSA in 1999 at private well LS-7. Since that time, solvent contamination has been detected in 26 off-post private and public water supply wells. The U.S. Army has installed GAC treatment systems at eight off-post well locations where concentrations exceed 80 percent of the federal MCL (5 µg/L) for PCE and/or TCE.

The highest concentrations of the COCs PCE, TCE and/or *cis*-1,2-DCE have occurred at on-post monitoring wells CS-D, CS-MW16-LGR, CS-MW16-CC, CS-MW1-LGR, CS-MW2-LGR, in various zones of the four WB wells and in wells near Building 90 (AOC-65-MW2A, AOC-65-PZ01-LGR, AOC-65-MW1-LGR, AOC-65-PZ05-LGR, and AOC-65-MW1-LGR). A detection of cis-1,2-DCE occurred in CS-4 but no PCE or TCE was detected. Detections have occurred on-post at concentrations below the MCL in wells CS-MW9-LGR to the north, CS-MW5-LGR and CS-MW17-LGR to the east, CS-1 to the south, CS-MW10-LGR to the southwest, and CS-9, CS-10, and CS-MW18-LGR to the west. Well CS-1 is beyond the southern boundary of CSSA and is located on Camp Bullis.

The highest concentrations of the COCs PCE, TCE, and/or *cis*-1,2-DCE detected off-post occur at wells OFR-3, RFR-10, RFR-11, LS-2, LS-6, and LS-7. These wells are located approximately 1,000 to 2,000 feet from the from the CSSA southwestern boundary at Leon Springs Villa. Detections at concentrations that are below the MCL have been reported in off-post wells JW-29 located approximately 4,000 feet to the west, I10-2 located approximately 4,200 feet to the southwest, LS-4 approximately 4,200 feet to the south, and HS-2 located approximately 1,200 feet to the south.

The groundwater plume associated with SWMUs O-1 and B-3 exists in the north-central area of the base (Plume 1) and has migrated off-post to the south and west. The groundwater plume associated with AOC-65 at the southwestern boundary of the base (Plume 2) has migrated off-post and has impacted off-post drinking water sources. These plumes are the focus of this Monitoring Network Optimization (MNO) evaluation. The contaminants of concern for both plumes include PCE, TCE, and *cis*-1,2-DCE. Groundwater contamination is most widespread within the Lower Glen Rose (LGR) water-bearing unit. Previous investigations have demonstrated that most of the contamination resides within the LGR.

Within Plume 1, concentrations above the MCL for PCE and/or TCE are detected in wells CS-D, CS-MW1-LGR, CS-MW2-LGR, and the CS-MW16 cluster. Concentrations in excess of 200 µg/L for PCE and/or TCE have been reported at CS-D, CS-16-LGR, and CS-MW16-CC. This plume has advectively migrated southward to CS-1 on Camp Bullis, and west-southwest toward the CSSA drinking water wells (CS-9, CS-10, and CS-11) and to several off-post public and private wells. Over most of the plume area, contaminant concentrations are below 1 µg/L. In contrast, little to no contamination is detected in the BS and CC within Plume 1.

Contamination at Plume 2 originated at or near AOC-65 and Building 90, and has spread southward and westward from CSSA. The highest concentrations of COCs are reported adjacent to the source area (3,400 µg/L). Within the CSSA boundary, concentrations in excess of 100 µg/L have been reported in perched groundwater intervals above the main aquifer body. However, once the main aquifer body is penetrated, trace levels are reported. Off-post, concentrations in excess of the MCLs have been detected in private and public wells with open borehole completions. Concentrations exceeding 25 µg/L have been reported 1,200 ft west-southwest of CSSA at RFR-10. Vertical profiling within that well show that discrete intervals within uncased upper strata contribute PCE concentrations over 90 µg/L. Only sporadic, trace concentrations of solvents have been detected in BS and CC wells within Plume 2. The general extent of plumes 1 and 2 are shown on Figure 2.1. The groundwater monitoring program at CSSA is fully described in Section 3.

SECTION 3

LONG-TERM MONITORING PROGRAM AT CSSA

The 2004 groundwater monitoring program at CSSA was examined to identify potential opportunities for streamlining monitoring activities while still maintaining an effective monitoring program. The 2004 monitoring program at CSSA is reviewed in the following subsections.

3.1 DESCRIPTION OF MONITORING PROGRAM

The CSSA groundwater monitoring program contains 97 wells, including on-post, off-post and Westbay® (WB)-equipped wells. The WB wells have ports at multiple depths across the LGR, BS, and CC zones; the four wells have 46 distinct sampling locations that are considered separately for the LTMO analysis. Thus, the monitoring program examined in this 3-tiered LTMO evaluation includes 139 sampling locations (49 on-post wells, 44 Off-post wells, and 46 WB sampling locations. The objectives of the monitoring program at CSSA are presented in both the *Data Quality Objectives for the Groundwater Contamination Investigation,* (November, 2003) and in the CSSA *Off-post Groundwater Monitoring Response Plan* (June, 2002) and include, in part:

- Determine whether on- and off-post drinking water meets the standards for safe drinking water as prescribed under the EPA and TCEQ rules;
- Determine if VOC concentrations in on-post and off-post drinking water wells exceed values stated in project data quality objectives (DQOs) and the CSSA off-post Monitoring Response Plan;
- Determine which formation(s) in the Middle Trinity Aquifer are impacted by VOC contaminants;

- Determine the impacts of rain events, drought conditions, and groundwater recharge on concentrations and migration of VOCs in the aquifer and vadose zone.

This CSSA Groundwater Monitoring Program wells and their associated current (2004) monitoring frequencies were identified from the Quarterly Groundwater Monitoring Reports available in Volume 5 of the CSSA Environmental Encyclopedia and subsequent review by site hydrogeologist Scott Pearson. Well information is listed in Table 3.1, including hydrogeologic zone (as described in Section 2.2), current sampling frequency (as of December 2004), the first and most recent sampling events, well zone and well classification. Wells are classified into the following groups for the statistical analyses:

- LGR: Monitoring wells screened in the LGR Zone
- OPBH: On-post Open Boreholes screened across multiple hydrogeologic units
- OffBH: Off-post Open Boreholes screened across multiple hydrogeologic units
- AOC/WB: AOC-65 area wells and piezometers and WB Wells.

The 97 site wells are shown on Figures 3.1 and Figure 3.2 classified by type of well. The most recent COC concentrations for each well are shown for zones LGR, CC, and BS in Figures 3.3 through 3.5, respectively. The on and off-post open boreholes are grouped into the LGR zone for this LTMO analysis. The typical well construction for the open borehole wells includes an open borehole completion through the LGR, BS, and CC portions of the aquifer with minimal surface casing. Historical results from on-post cluster wells indicate where COCs are detected in the LGR, the corresponding BS and CC wells are typically non-detect. Detections of COCs are generally confined to the LGR with the exception of the source area. Therefore, on and off-post open boreholes are evaluated as LGR zone wells in the LTMO analysis. The WB wells and area AOC-65 wells are considered separately from the LGR, BS, and CC zones because the data from these wells are "screening level" that is not considered comparable to the validated chemical data from the other wells considered in the analysis. The AOC-65 and WB wells are analyzed separately in a vertical cross-section analysis. The location of the two

TABLE 3.1
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
On Post Monitoring Wells					
AOC65-MW1-LGR	UGR(D)	Quarterly	6/10/04	12/2/04	AOC/WB[a/]
AOC65-MW2A	UGR(D)	Quarterly	6/10/04	12/2/04	AOC/WB
AOC65-PZ01-LGR	LGR(B)	Quarterly	7/19/02	8/24/04	AOC/WB
AOC65-PZ02-LGR	UGR(D)	Quarterly	7/19/02	6/10/04	AOC/WB
AOC65-PZ03-LGR	LGR(B)	Quarterly	6/5/03	8/24/04	AOC/WB
AOC65-PZ04-LGR	UGR(D)	Quarterly	6/5/03	6/10/04	AOC/WB
AOC65-PZ05-LGR	LGR(B)	Quarterly	7/30/02	6/10/04	AOC/WB
AOC65-PZ06-LGR	UGR(D)	Quarterly	6/5/03	6/10/04	AOC/WB
CS-1	LGR(B), LGR(C),	Quarterly	8/9/91	12/2/04	OPBH[b/]
CS-10	LGR(F), BS(A),	Quarterly	8/9/91	12/3/04	OPBH
CS-11	LGR(C), LGR(D),	Quarterly	8/9/91	12/3/04	OPBH
CS-2	LGR(E), LGR(F),	Quarterly	11/3/92	12/7/04	OPBH
CS-3	LGR(E), LGR(F),	Quarterly	11/4/92	12/16/99	OPBH
CS-4	LGR(E), LGR(F),	Quarterly	12/4/91	12/7/04	OPBH
CS-9	LGR(E), LGR(F),	Quarterly	8/9/91	12/3/04	OPBH
CS-D	LGR(D), LGR(E),	Quarterly	12/4/91	12/7/04	OPBH
CS-I	LGR(E), LGR(F)	Quarterly	11/4/92	11/29/04	OPBH
CS-MW10-CC	CC(A)	Quarterly	12/13/01	12/6/04	CC[c/]
CS-MW10-LGR	LGR(F)	Quarterly	12/13/01	12/6/04	LGR[d/]
CS-MW11A-LGR	LGR(F)	Quarterly	6/17/03	12/6/04	LGR
CS-MW11B-LGR	LGR(B)	Quarterly	6/17/03	12/6/04	LGR
CS-MW12-BS	BS(A)	Quarterly	12/16/02	12/7/04	BS[e/]
CS-MW12-CC	CC(A)	Quarterly	12/16/02	12/7/04	CC
CS-MW12-LGR	LGR(F)	Quarterly	12/16/02	12/7/04	LGR
CS-MW16-CC	CC(A)	Quarterly	9/16/03	12/9/04	CC
CS-MW16-LGR	LGR(F)	Quarterly	9/30/94	12/3/04	OPBH
CS-MW17-LGR	LGR(F)	Quarterly	9/12/02	11/29/04	LGR
CS-MW18-LGR	LGR(F)	Quarterly	9/12/02	12/7/04	LGR
CS-MW19-LGR	LGR(F)	Quarterly	9/12/02	12/7/04	LGR
CS-MW1-BS	BS(A)	Quarterly	3/25/03	11/30/04	BS
CS-MW1-CC	CC(A)	Quarterly	3/25/03	11/30/04	CC
CS-MW1-LGR	LGR(F)	Quarterly	9/8/99	11/30/04	LGR
CS-MW2-CC	CC(A)	Quarterly	6/17/03	12/1/04	CC
CS-MW2-LGR	LGR(F)	Quarterly	9/9/99	12/1/04	LGR
CS-MW3-LGR	LGR(F)	Quarterly	6/14/01	11/29/04	LGR
CS-MW4-LGR	LGR(F)	Quarterly	6/14/01	12/1/04	LGR
CS-MW5-LGR	LGR(F)	Quarterly	6/14/01	12/3/04	LGR
CS-MW6-BS	BS(A)	Quarterly	6/13/01	12/1/04	BS
CS-MW6-CC	CC(A)	Quarterly	6/13/01	12/1/04	CC
CS-MW6-LGR	LGR(F)	Quarterly	6/13/01	12/1/04	LGR
CS-MW7-CC	CC(A)	Quarterly	9/13/01	12/6/04	CC
CS-MW7-LGR	LGR(F)	Quarterly	9/13/01	12/6/04	LGR
CS-MW8-CC	CC(A)	Quarterly	6/14/01	12/6/04	CC

TABLE 3.1 (Continued)
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
CS-MW8-LGR	LGR(F)	Quarterly	6/12/01	12/6/04	LGR
CS-MW9-BS	BS(A)	Quarterly	6/14/01	11/29/04	BS
CS-MW9-CC	CC(A)	Quarterly	6/14/01	11/29/04	CC
CS-MW9-LGR	LGR(F)	Quarterly	6/14/01	11/29/04	LGR
CS-MWG-LGR	LGR(C), LGR(D),	Quarterly	11/3/92	11/29/04	OPBH
CS-MWH-LGR	LGR(F)	Quarterly	11/4/92	11/29/04	LGR
Off Post Monitoring					
DOM-2	LGR, CC	Annually	9/19/01	3/2/04	OffBH[f/]
FO-17	LGR, CC	Annually	3/19/02	6/7/04	OffBH
FO-22	LGR, CC	Annually	9/18/01	12/16/04	OffBH
FO-8	LGR, CC	Annually	3/19/02	3/4/04	OffBH
FO-J1	LGR, CC	Qtrly, 1 year thru Mar 05	9/18/01	12/14/04	OffBH
HS-2	LGR, CC	Qtrly, 1 year thru Mar 05	12/19/01	12/14/04	OffBH
HS-3	LGR, CC	Annually	12/19/01	6/9/04	OffBH
I10-2	LGR, CC	Qtrly, 1 year thru Jun 05	9/19/01	12/16/04	OffBH
I10-4	LGR, CC	Qtrly, 1 year thru Mar 05	12/19/01	12/15/04	OffBH
I10-5	LGR, CC	Annually	12/6/02	12/16/04	OffBH
I10-7	LGR, CC	Annually	3/21/02	12/16/04	OffBH
JW-12	LGR, CC	Annually	9/18/01	3/4/04	OffBH
JW-13	LGR, CC	Annually	9/19/01	6/10/04	OffBH
JW-14	LGR, CC	Qtrly, 1 year thru Jun 05	9/18/01	12/14/04	OffBH
JW-26	LGR, CC	Qtrly, 1 year thru Dec 04	3/21/02	12/15/04	OffBH
JW-27	LGR, CC	Annually	6/12/03	6/9/04	OffBH
JW-28	LGR, CC	Qtrly, 1 year thru Jun 05	9/10/03	12/16/04	OffBH
JW-29	LGR, CC	Qtrly, due to location	6/11/03	12/15/04	OffBH
JW-30	LGR, CC	Qtrly, 1 year thru Mar 05	9/8/99	12/15/04	OffBH
JW-6	LGR, CC	Annually	9/19/01	6/8/04	OffBH
JW-7	LGR, CC	Qtrly, 1 year thru Jun 05	9/8/03	12/13/04	OffBH
JW-8	LGR, CC	Qtrly, 1 year thru Mar 05	6/18/03	12/16/04	OffBH
JW-9	LGR, CC	Qtrly, 1 year thru Mar 05	9/18/01	12/16/04	OffBH
LS-1	LGR, CC	Qtrly, 1 year thru Mar 05	9/17/01	6/9/04	OffBH
LS-2	LGR, CC	Qtrly, 1 year thru Jun 05	8/1/01	12/14/04	OffBH
LS-3	LGR, CC	Qtrly, 1 year thru Jun 05	8/1/01	12/14/04	OffBH
LS-4	LGR, CC	Qtrly, 1 year thru Jun 05	9/17/01	12/14/04	OffBH
LS-5	LGR, CC	Qtrly, 1 year thru Mar 05	8/1/01	12/13/04	OffBH
LS-6	LGR, CC	Qtrly, 1 year thru Jun 05	8/1/01	12/13/04	OffBH
LS-7	LGR, CC	Qtrly, 1 year thru Jun 05	12/13/99	12/13/04	OffBH
OFR-1	LGR, CC	Qtrly, 1 year thru Jun 05	12/20/01	12/15/04	OffBH
OFR-2	LGR, CC	Qtrly, 1 year thru Jun 05	3/18/02	12/15/04	OffBH
OFR-3	LGR, CC	Qtrly, 1 year thru Jun 05	10/25/01	12/13/04	OffBH
OFR-4	LGR, CC	Annually	6/12/03	3/3/04	OffBH
RFR-10	LGR, CC	Qtrly, 1 year thru Jun 05	9/19/01	12/13/04	OffBH
RFR-11	LGR, CC	Qtrly, 1 year thru Jun 05	10/4/01	12/13/04	OffBH
RFR-12	LGR, CC	Qtrly, 1 year thru Jun 05	8/30/01	12/16/04	OffBH

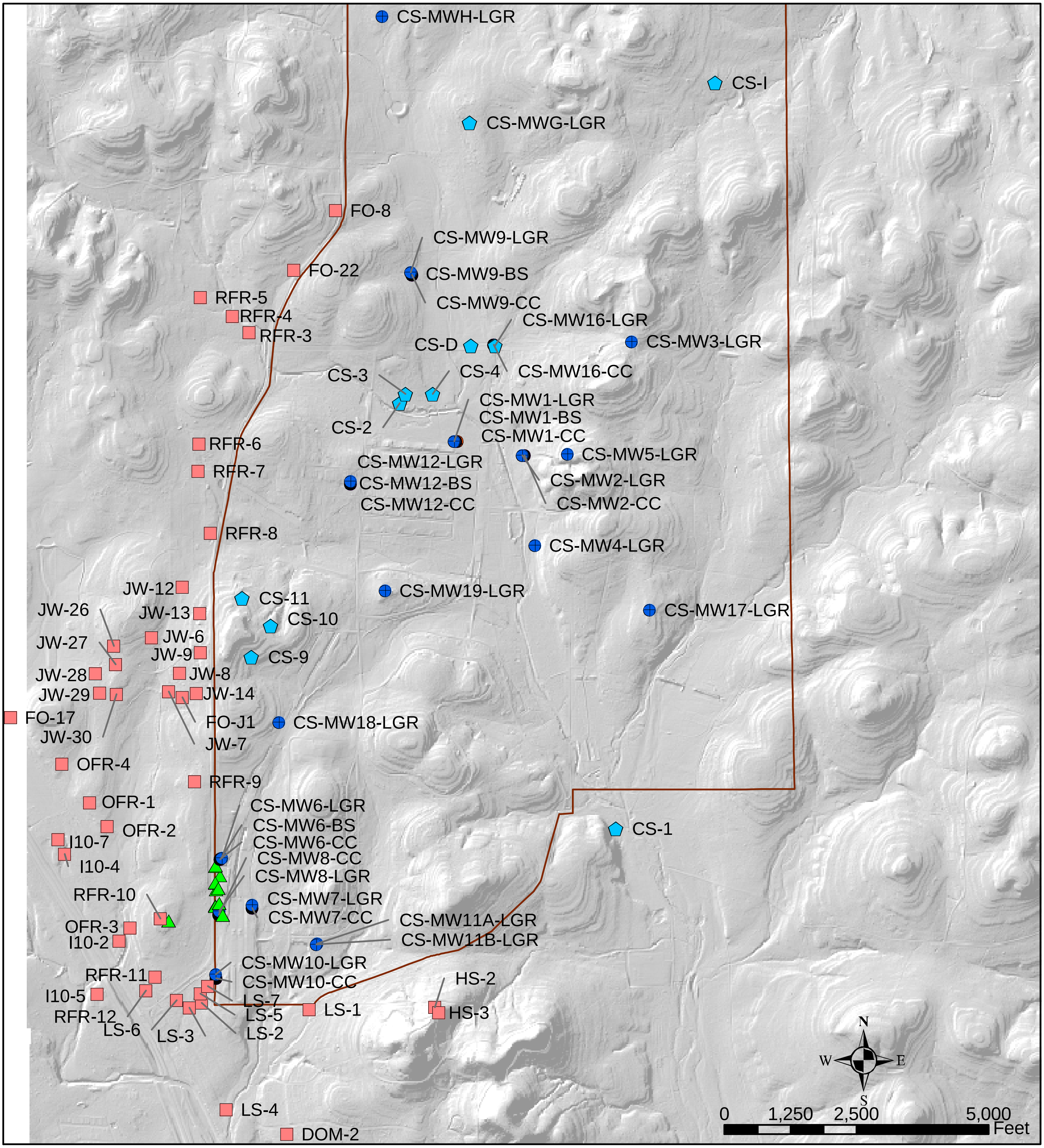
TABLE 3.1 (Continued)
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
RFR-3	LGR, CC	Qtrly, 1 year thru Dec 04	9/8/99	12/14/04	OffBH
RFR-4	LGR, CC	Annually	3/10/04	3/10/04	OffBH
RFR-5	LGR, CC	Annually	3/10/04	3/10/04	OffBH
RFR-6	LGR, CC	Annually	9/19/01	12/15/04	OffBH
RFR-7	LGR, CC	Annually	9/19/01	12/15/04	OffBH
RFR-8	LGR, CC	Annually	9/8/99	6/9/04	OffBH
RFR-9	LGR, CC	Annually	9/19/01	9/23/04	OffBH
WestBay Wells					
CS-WB01-LGR-01	LGR-01	Monthly & after rain events	9/9/03	12/27/04	AOC/WB
CS-WB01-LGR-02	LGR-02	Monthly & after rain events	9/9/03	12/27/04	AOC/WB
CS-WB01-LGR-03	LGR-03	Monthly & after rain events	9/9/03	12/27/04	AOC/WB
CS-WB01-LGR-04	LGR-04	Monthly & after rain events	9/9/03	12/27/04	AOC/WB
CS-WB01-LGR-05	LGR-05	Monthly & after rain events	9/8/03	12/27/04	AOC/WB
CS-WB01-LGR-06	LGR-06	Monthly & after rain events	9/8/03	12/27/04	AOC/WB
CS-WB01-LGR-07	LGR-07	Monthly & after rain events	9/8/03	12/27/04	AOC/WB
CS-WB01-LGR-08	LGR-08	Monthly & after rain events	9/8/03	12/27/04	AOC/WB
CS-WB01-LGR-09	LGR-09	Monthly & after rain events	9/8/03	12/27/04	AOC/WB
CS-WB01-UGR-01	UGR-01	Monthly & after rain events	11/18/04	12/2/04	AOC/WB
CS-WB02-LGR-01	LGR-01	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-02	LGR-02	Monthly & after rain events	4/16/04	12/29/04	AOC/WB
CS-WB02-LGR-03	LGR-03	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-04	LGR-04	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-05	LGR-05	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-06	LGR-06	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-07	LGR-07	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-08	LGR-08	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-LGR-09	LGR-09	Monthly & after rain events	9/9/03	12/29/04	AOC/WB
CS-WB02-UGR-01	UGR-01	Monthly & after rain events	7/2/04	12/2/04	AOC/WB
CS-WB03-LGR-01	LGR-01	Monthly & after rain events	11/18/04	11/18/04	AOC/WB
CS-WB03-LGR-02	LGR-02	Monthly & after rain events	11/30/04	12/29/04	AOC/WB
CS-WB03-LGR-03	LGR-03	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-LGR-04	LGR-04	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-LGR-05	LGR-05	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-LGR-06	LGR-06	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-LGR-07	LGR-07	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-LGR-08	LGR-08	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-LGR-09	LGR-09	Monthly & after rain events	9/10/03	12/29/04	AOC/WB
CS-WB03-UGR-01	UGR-01	Monthly & after rain events	11/18/04	12/29/04	AOC/WB
CS-WB04-BS-01	BS-01	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-BS-02	BS-02	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-CC-01	CC-01	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-CC-02	CC-02	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-CC-03	CC-03	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-LGR-01	LGR-01	Monthly & after rain events	10/16/03	12/28/04	AOC/WB

TABLE 3.1 (Continued)
CURRENT GROUNDWATER MONITORING PROGRAM
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Well ID	Vertical Zone	Current Sampling Frequency	First Sampling Event	Most Recent Data	Classification
CS-WB04-LGR-02	LGR-02	Monthly & after rain events	5/12/04	12/28/04	AOC/WB
CS-WB04-LGR-03	LGR-03	Monthly & after rain events	10/16/03	12/28/04	AOC/WB
CS-WB04-LGR-04	LGR-04	Monthly & after rain events	9/19/03	12/28/04	AOC/WB
CS-WB04-LGR-06	LGR-06	Monthly & after rain events	9/19/03	12/28/04	AOC/WB
CS-WB04-LGR-07	LGR-07	Monthly & after rain events	9/19/03	12/28/04	AOC/WB
CS-WB04-LGR-08	LGR-08	Monthly & after rain events	9/19/03	12/28/04	AOC/WB
CS-WB04-LGR-09	LGR-09	Monthly & after rain events	9/19/03	12/28/04	AOC/WB
CS-WB04-LGR-10	LGR-10	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-LGR-11	LGR-11	Monthly & after rain events	9/18/03	12/28/04	AOC/WB
CS-WB04-UGR-01	UGR-01	Monthly & after rain events	11/18/04	11/18/04	AOC/WB

[a/] AOC/WB = AOC-65 area or WestBay-Equipped well; included in vertical analysis.
[b/] OBBH = On Base Borehold; included in LGR zone analysis.
[c/] CC = Monitoring well screened in the Cow Creek zone.
[d/] LGR = Monitoring well screened in the LGR zone.
[e/] BS = Monitoring well screened in the Bexar Shale zone.
[f/] OffBH = Off Base Borehole; included in LGR zone analysis.



Legend

- LGR Zone Monitoring Wells
- BS Zone Monitoring Wells
- CC Zone Monitoring Wells
- On-Post Open Borehole
- Off-Post Open Borehole
- WestBay & AOC65 Wells*

*Note: WestBay & AOC65 Wells shown in more detail on Figure 3.2

FIGURE 3.1

GROUNDWATER MONITORING WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

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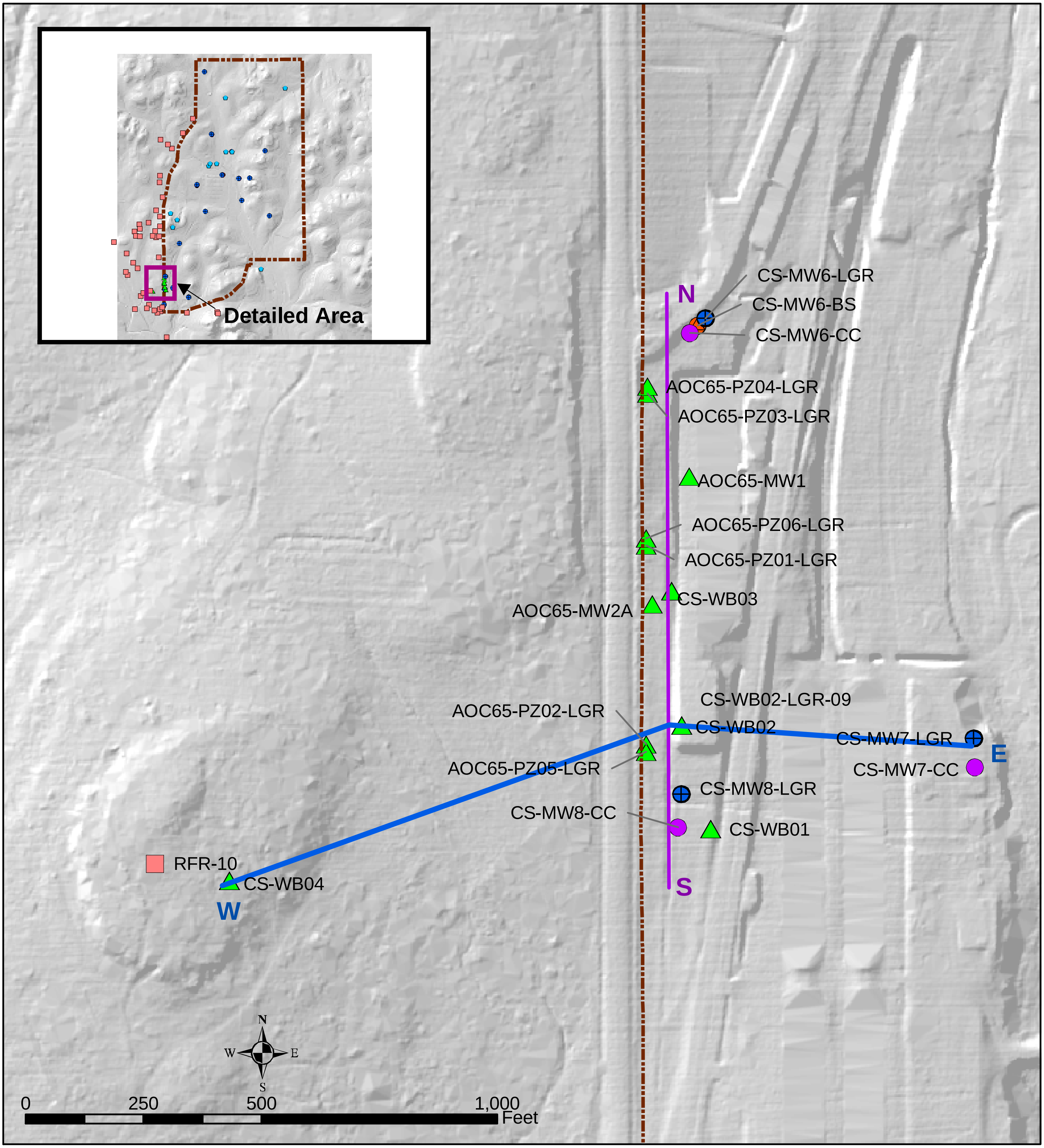


Legend

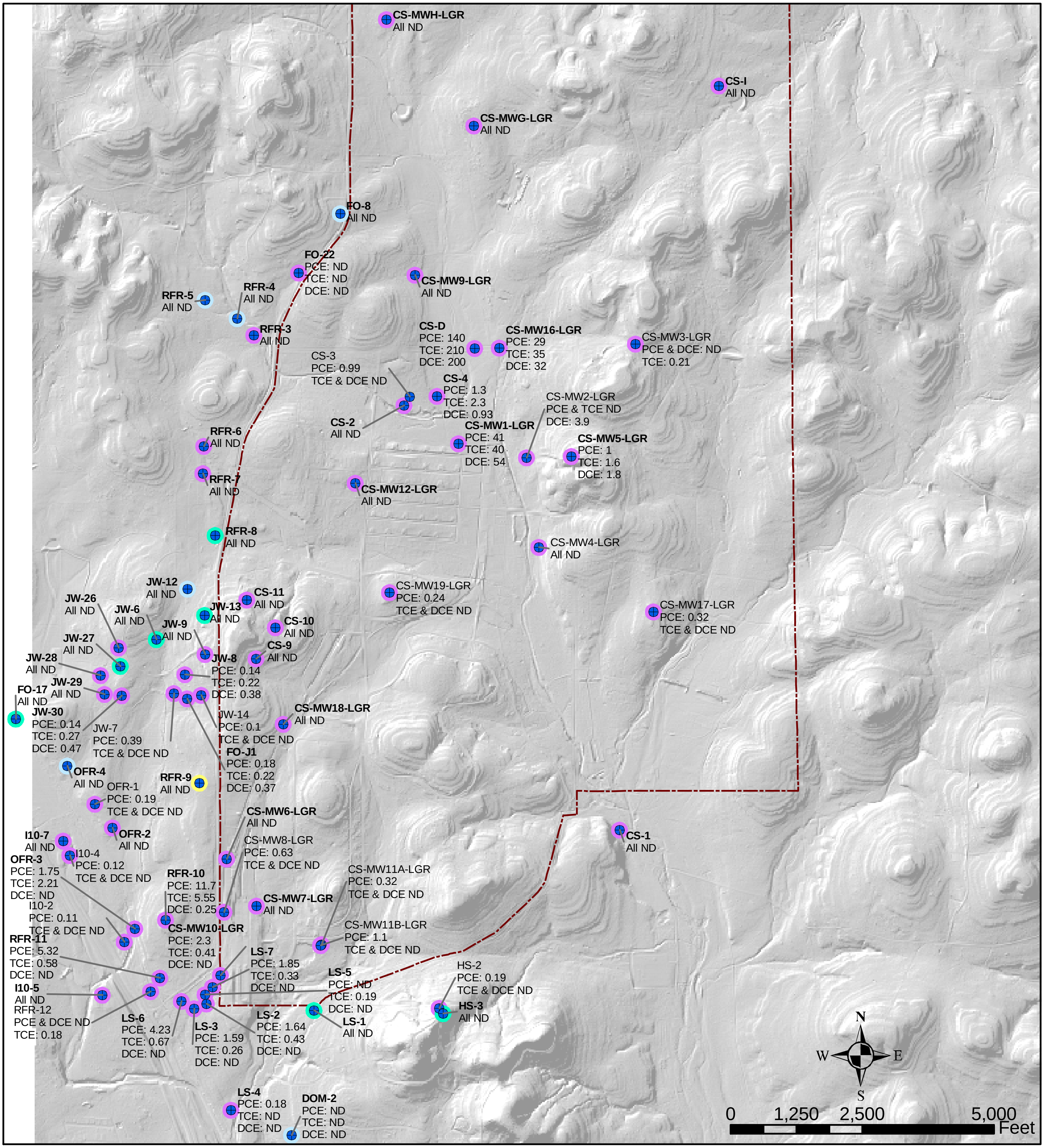
- LGR Zone Monitoring Wells
- BS Zone Monitoring Wells
- CC Zone Monitoring Wells
- North to South Cross Section
- West to East Cross Section
- Off-Post Open Borehole
- WestBay & AOC65 Wells
- Base Boundary

FIGURE 3.2

GROUNDWATER MONITORING WELLS & CROSS SECTIONS AOC65 AREA

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS



Legend

Most Recent Sampling Event

- 4Q 04
- 3Q 04
- 2Q 04
- 1Q 04

Well ID
Most Recent
COC Concentrations

ND: COC not detected
All results in ug/L

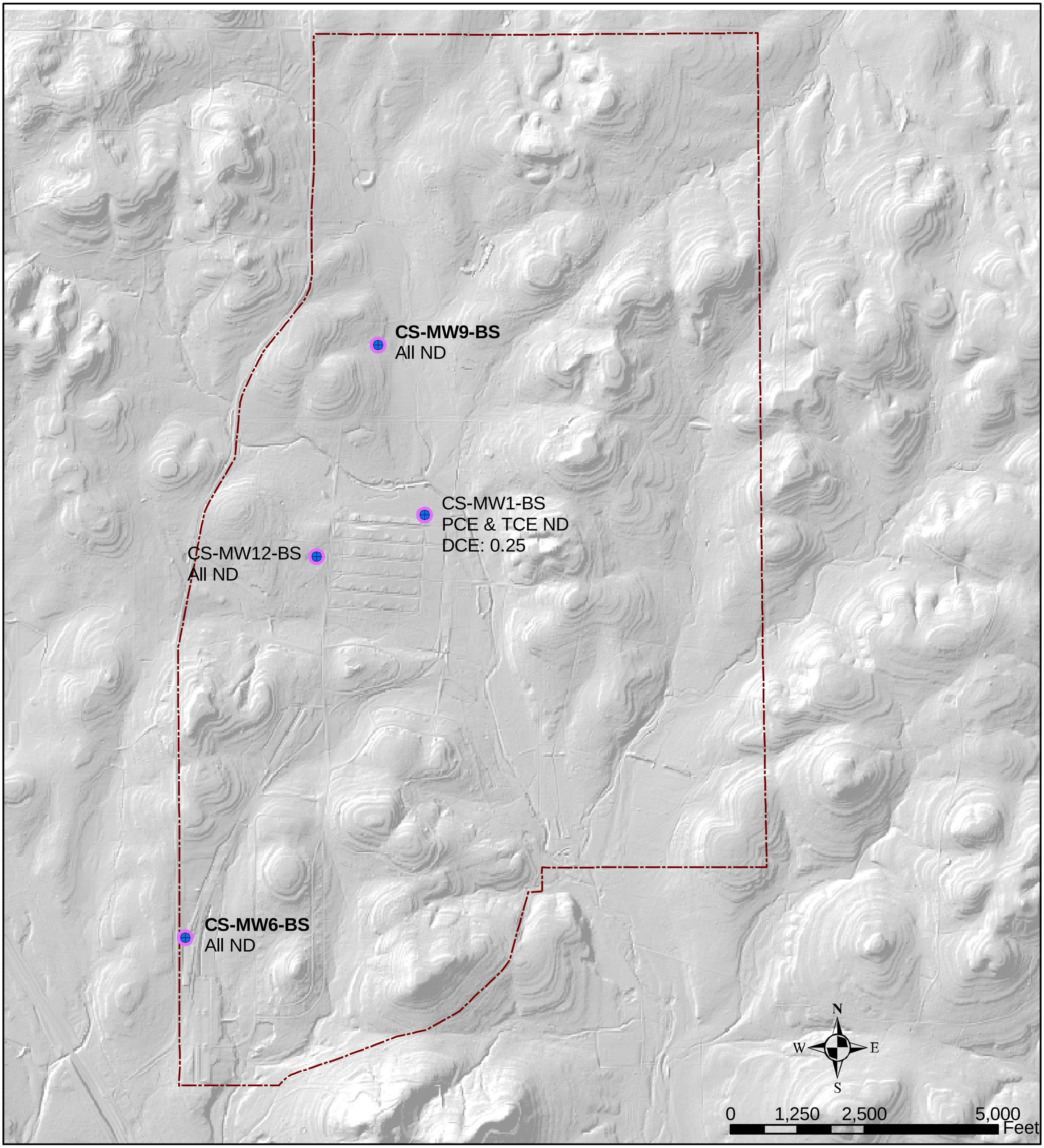
FIGURE 3.3

MOST RECENT COC CONCENTRATIONS LGR ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

s:/es/remed/LTMO/CSSA/GIS/CSSACOCsl.mxd cen 2/22/05



Legend

Most Recent Sampling Event

- 4Q 04
- 3Q 04
- 2Q 04
- 1Q 04

Well ID
Most Recent
COC Concentrations

ND: COC not detected
All results in ug/L

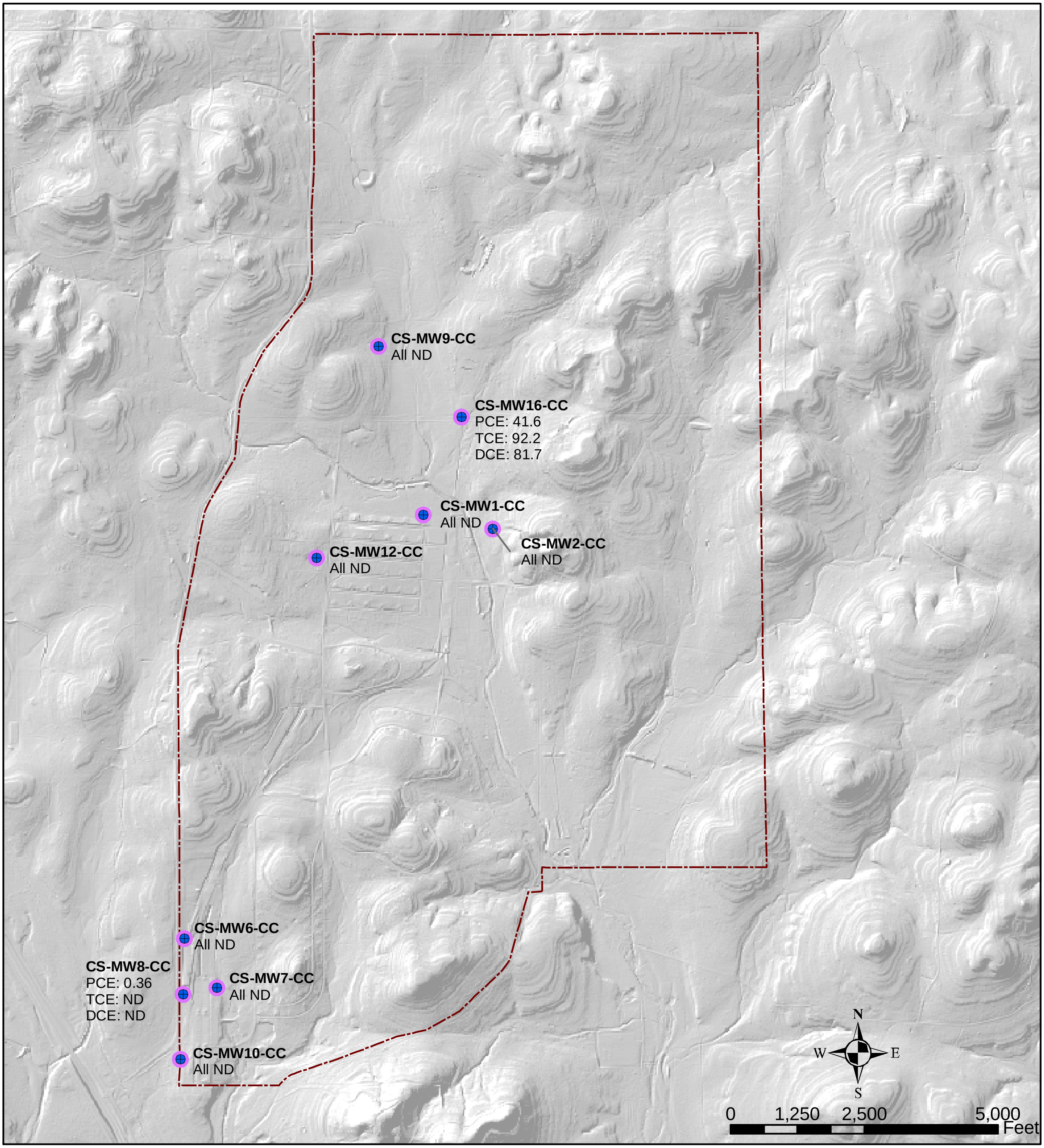
FIGURE 3.4

MOST RECENT COC CONCENTRATIONS BS ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

s:/es/remed/LTMO/CSSA/GIS/CSSACOCsl.mxd cen 2/22/05



Legend

Most Recent Sampling Event

- 4Q 04
- 3Q 04
- 2Q 04
- 1Q 04

Well ID
Most Recent
COC Concentrations

ND: COC not detected
All results in ug/L

FIGURE 3.5

MOST RECENT COC CONCENTRATIONS CC ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

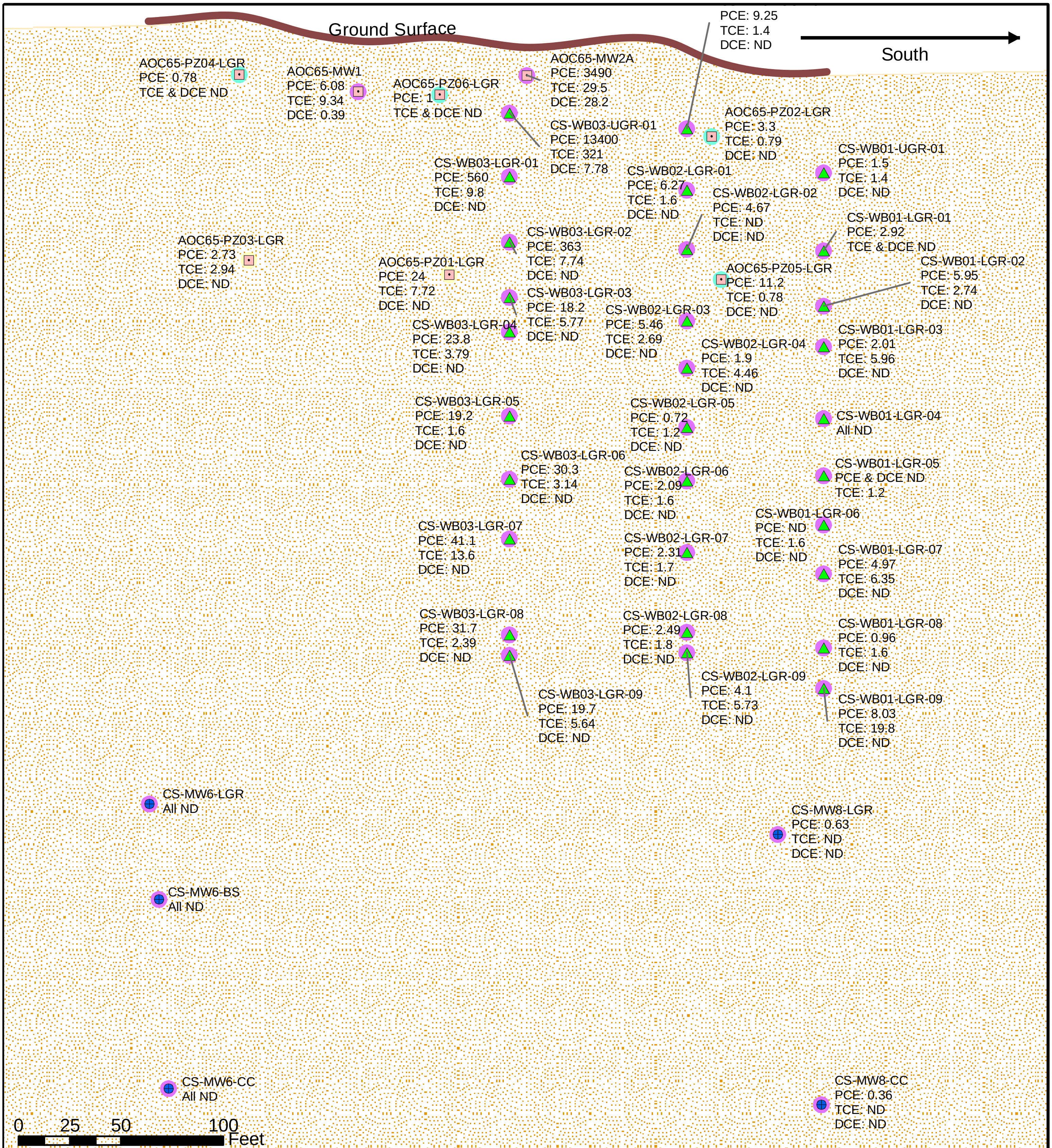
PARSONS

s:/es/remed/LTMO/CSSA/GIS/CSSACOCsl.mxd cen 2/22/05

vertical cross sections (north to south and west to east) are shown on Figure 3.2. Figures 3.6 and 3.7 display the vertical distribution of the most recent COC concentrations for wells in the north to south and west to east cross sections, respectively, along with their most recent sampling event.

3.2 SUMMARY OF ANALYTICAL DATA

In general, the CSSA groundwater plume is well-characterized both laterally and vertically. The groundwater monitoring program for this plume was evaluated using results for sampling events performed from 1991 through December 2004. The database was processed to remove duplicate data by retaining the maximum result for each duplicate sample pair. As discussed in Section 2.3, the COCs identified for CSSA include TCE, PCE, and cis-1,2-DCE. Table 3.2 presents a summary of the occurrence of potential COCs in groundwater based on the data collected from CSSA wells for all of the sampling data. Tables 3.3 through 3.8 show the summary statistics by well classification: LGR, on-post Open Boreholes (OPBH), CC Zone, BS Zone, Of-Post Open Borehole (OffBH), and Westbay®/AOC-65 wells, respectively. Tables 3.3 through 3.8 confirm that TCE, PCE, and *cis*-1,2-DCE are the main contaminants in groundwater beneath CSSA based on their on their widespread and relatively high (compared to their respective Maximum Contaminant Limit(MCL)) concentrations. Although it has been sampled for much less frequently than the primary COCs, Lead (Pb) is of potential concern because of the relatively high percentage of and number of wells with detections. Other chemicals of potential concern include bromoform (TBME) and bromodichloromethane (BDCME) because of their action levels of zero. Toluene (BZME) detections have occurred in screening level samples collected during discrete interval groundwater sampling during well installations and sporadically among definitive sampling events. Vinyl chloride (VC) has also been detected and is an indicator that the degradation of larger-chain chlorinated hydrocarbons is occurring. Although no wells have had exceedances of BZME or VC, both chemicals are of potential concern on the base, and are included in the temporal statistical analysis.



Legend

Most Recent Sampling Event
- 4Q 04
- 3Q 04
- 2Q 04

Well Type
- Monitoring Well
- AOC-65 Well
- Westbay Equipped Well

ND: COC not detected
All results in ug/L

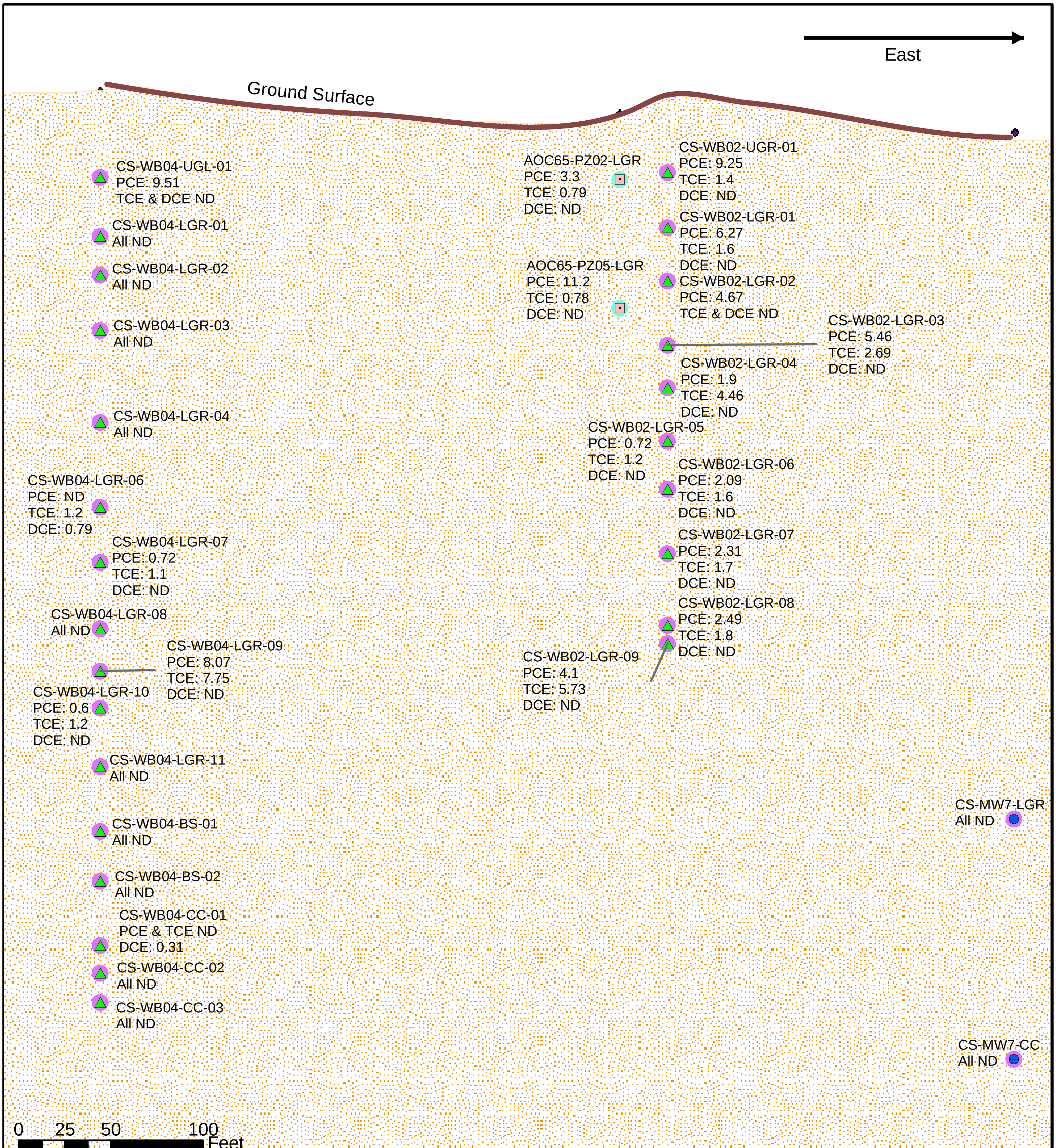
FIGURE 3.6

MOST RECENT COC CONCENTRATIONS NORTH-SOUTH CROSS SECTION AOC65 AREA

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

s:/es/remed/LTMO/CSSA/GIS/CSSAVert1.mxd cen 2/8/05



Legend

Most Recent Sampling Event
- 4Q 04
- 2Q 04

Well Type
- Monitoring Well
- AOC-65 Well
- Westbay Equipped Well

ND: COC not detected
All results in ug/L

FIGURE 3.7

MOST RECENT COC CONCENTRATIONS WEST-EAST CROSS SECTION AOC65 AREA

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

s:/es/remed/LTMO/CSSA/GIS/CSSAVertWE.mxd cen 2/8/05

TABLE 3.2
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-ALL RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Detects (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	1828	0 - 13,900	54.7%	22.6%	5	139	104	45
Trichloroethene	TCE	1826	0 - 321	47.9%	16.9%	5	139	85	35
Lead	PB	345	0 - 250	56.8%	7.0%	15	46	38	9
Dichloroethene, cis-1,2-	DCE12C	1783	0 - 290	15.5%	2.9%	70	139	44	3
Bromodichloromethane	BDCME	1073	0 - 6	1.5%	1.5%	0	85	8	8
Cadmium	CD	338	0 - 15	19.5%	0.9%	5	45	28	3
Methylene chloride	MTLNCL	1059	0 - 19	22.7%	0.8%	5	85	70	7
Nickel	NI	341	0 - 216	46.9%	0.6%	100	45	37	2
Bromoform	TBME	780	0 - 3	0.5%	0.5%	0	85	4	4
Alkalinity, Total (as CACO3)	ALK	98	211000 - 380,000	100.0%			33	33	
Alkalinity, Bicarbonate	ALKB	31	142000 - 349,000	100.0%			30	30	
Calcium	CA	53	1620 - 100,300	100.0%			35	35	
Methane	CH4	33	0.19 - 9	100.0%			33	33	
Chloride	CL	57	8000 - 32,300	100.0%			47	47	
Dichloroethene, 1,2- (total)	DCE12TOT	1	43 - 43	100.0%			1	1	
Potassium	K	55	750 - 360,000	100.0%			37	37	
Magnesium	MG	53	7.0000002 - 52,259	100.0%			35	35	
Sodium	NA	53	6070.0002 - 97,150	100.0%			35	35	
Sulfate	SO4	31	8779.9997 - 134,000	100.0%			30	30	
Total Dissolved Solids	TDS	80	130000 - 500,000	100.0%			20	20	
Barium	BA	339	0 - 300	96.5%		2,000	45	45	
Manganese	MN	55	0 - 81	96.4%			37	36	
Fluoride	F	32	0 - 2,300	93.8%			30	29	
Zinc	ZN	345	0 - 3,470,454	91.0%			45	45	
Nitrate	NO3N	30	0 - 6,330	73.3%			28	22	
Iron	FE	58	0 - 28,227	67.2%			35	30	
Arsenic	AS	343	0 - 30	61.8%		50	45	40	
Copper	CU	346	0 - 180	49.7%		1,300	45	38	

TABLE 3.2 (Continued)
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-ALL RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Detects (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Isopropanol	ISOPROH	139	0 - 41	39.6%			48	36	
Chromium	CR	343	0 - 39	34.4%		100	45	37	
Bromide	BR	31	0 - 1,060	32.3%			30	10	
Selenium	SE	25	0 - 6.0	24.0%			15	4	
Acetone	ACE	658	0 - 3,610	17.8%			61	46	
Chloroform	TCLME	1090	0 - 53	15.0%			85	21	
Nitrite	NO2N	30	0 - 1,700	13.3%			28	4	
Mercury	HG	340	0 - 1.3	12.1%		2	45	24	
Toluene	BZME	1455	0 - 40	11.6%		1,000	133	54	
Phosphorus, Total Orthophosphate	PORTHO	18	0 - 790	11.1%			16	2	
Alkalinity, Carbonate	ALKC	32	0 - 69,000	9.4%			30	3	
Dichloroethane, 1,2-	DCA12	271	0 - 0.1	6.6%			73	16	
Benzene	BZ	337	0 - 2.3	5.3%			81	10	
Dichloroethene, trans-1,2-	DCE12T	1812	0 - 12	5.2%		100	139	10	
Chloromethane	CLME	317	0 - 5.0	5.0%			75	7	
Trimethylbenzene, 1,2,4-	TMB124	244	0 - 0.3	2.9%			73	7	
Dichloroethene, 1,1-	DCE11	1052	0 - 1.0	2.7%			85	13	
Naphthalene	NAPH	769	0 - 0.9	2.5%			85	11	
Dichlorodifluoromethane	FC12	782	0 - 1.9	2.4%			85	2	
Vinyl chloride	VC	1032	0 - 1.3	2.2%			85	11	
Trimethylbenzene, 1,3,5-	TMB135	243	0 - 0.1	1.2%			71	3	
Dibromochloromethane	DBCME	1073	0 - 4.5	1.1%			85	7	
Isopropyltoluene, 4- (Cymene, p-)	CYMP	244	0 - 0.1	0.8%			71	2	
Ethylbenzene	EBZ	247	0 - 0.1	0.8%			73	2	
Styrene	STY	242	0 - 0.0	0.8%			73	2	
Trichlorobenzene, 1,2,3-	TCB123	244	0 - 0.2	0.8%			71	2	
Trichlorobenzene, 1,2,4-	TCB124	245	0 - 0.2	0.8%			73	1	

TABLE 3.2 (Continued)
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-ALL RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Detects (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Xylene, m,p-	XYLMP	247	0 - 1.2	0.8%			73	2	
Xylene, o-	XYLO	246	0 - 0.1	0.8%			73	2	
Bromochloromethane	BRCLME	243	0 - 0.1	0.4%			71	1	
Butylbenzene, N-	BTBZN	243	0 - 0.1	0.4%			71	1	
Butylbenzene, sec-	BTBZS	243	0 - 0.1	0.4%			71	1	
Butylbenzene, tert-	BTBZT	243	0 - 0.1	0.4%			71	1	
Chlorotoluene, 2-	CLBZME2	243	0 - 0.1	0.4%			71	1	
Chlorotoluene, 4-	CLBZME4	243	0 - 0.05	0.4%			71	1	
Dibromomethane	DBMA	243	0 - 0.2	0.4%			71	1	
Dichloroethane, 1,1-	DCA11	315	0 - 0.1	0.3%			75	1	
Hexachlorobutadiene	HCBU	243	0 - 0.3	0.4%			71	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 139 sampling points shown on Table 3.1

TABLE 3.3
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-LGR Wells
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	Parameter	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	234	0.0 - 41	57.7%	12.8%	5	17	15	2
Trichlorobenzene, 1,2,3-	TCE	234	0.0 - 40	38.0%	12.8%	5	17	12	2
Lead	PB	109	0.0 - 47	45.9%	3.7%	15	17	16	2
Nickel	NI	107	0.0 - 150	72.9%	0.9%	100	17	16	1
Cadmium	CD	109	0.0 - 7.0	23.9%	0.9%	5	17	11	1
Bromoform	TBME	150	0.0 - 0.1	0.7%	0.7%	0	17	1	1
Manganese	MN	27	0.8 - 35	100.0%			17	17	
Magnesium	MG	26	7.0 - 47000	100.0%			16	16	
Sodium	NA	26	6070 - 50000	100.0%			16	16	
Potassium	K	27	1200 - 35810	100.0%			17	17	
Alkalinity, Total (as CACO3)	ALK	25	270000 - 349000	100.0%			10	10	
Alkalinity, Bicarbonate	ALKB	13	142000 - 349000	100.0%			12	12	
Calcium	CA	26	6080 - 100300	100.0%			16	16	
Methane	CH4	13	0.2 - 9.2	100.0%			13	13	
Chloride	CL	25	8000 - 21310	100.0%			16	16	
Trichloroethene	TDS	14	310000 - 460000	100.0%			2	2	
Sulfate	SO4	17	8780 - 40000	100.0%			16	16	
Barium	BA	107	0.0 - 230	99.1%		2000	17	17	
Zinc	ZN	111	0.0 - 2200	91.0%			17	17	
Fluoride	F	18	0.0 - 2300	88.9%			16	15	
Nitrate	NO3N	17	0.0 - 6330	82.4%			15	14	
Arsenic	AS	110	0.0 - 5.2	72.7%		50	17	17	
Iron	FE	31	0.0 - 28227	58.1%			16	13	
Selenium	SE	4	0.0 - 6.0	50.0%			2	1	
Acetone	ACE	7	0.0 - 3610	42.9%			4	2	
Toluene	BZME	158	0.0 - 40	34.8%		1000	17	16	
Chromium	CR	110	0.0 - 14	33.6%		100	17	14	
Methylene chloride	MTLNCL	228	0.0 - 3.4	32.5%		5	17	17	
Dichloroethene, cis-1,2-	DCE12C	233	0.0 - 54	31.3%		70	17	6	
Bromide	BR	17	0.0 - 240	29.4%			16	5	

TABLE 3.3 (Continued)
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-LGR Wells
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	Parameter	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Copper	CU	111	0.0 - 110	28.8%		1300	17	14	
Nitrite	NO2N	17	0.0 - 1700	23.5%			15	4	
Chloroform	TMB124	22	0.0 - 0.3	22.7%			16	5	
Dichloroethene, trans-1,2-	DCE12T	232	0.0 - 2.5	16.8%		100	17	4	
Trichlorobenzene, 1,2,4-	TCLME	227	0.0 - 0.1	9.7%		80	17	2	
Xylene, o-	XYLO	22	0.0 - 0.1	9.1%			16	2	
Trimethylbenzene, 1,3,5-	TMB135	22	0.0 - 0.1	9.1%			16	2	
Phosphorus, Total Orthophosphate	PORTHO	11	0.0 - 790	9.1%			9	1	
Mercury	HG	108	0.0 - 0.2	7.4%		2	17	6	
Alkalinity, Carbonate	ALKC	14	0.0 - 69000	7.1%			12	1	
Xylene, m,p-	XYLMP	22	0.0 - 0.3	4.5%			16	1	
Benzene	BZ	23	0.0 - 0.0	4.3%			16	1	
Ethylbenzene	EBZ	23	0.0 - 0.1	4.3%			16	1	
Styrene	STY	23	0.0 - 0.0	4.3%			16	1	
Naphthalene	NAPH	146	0.0 - 0.9	3.4%			17	4	
Vinyl chloride	VC	225	0.0 - 0.1	1.8%		2	17	4	
Dichloroethane, 1,1-	DCE11	227	0.0 - 0.1	1.8%		70	17	4	
Dibromochloromethane	DBCME	227	0.0 - 0.0	0.4%		60	17	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 17 wells classified as "LGR" in Table 3.1.

TABLE 3.4

SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-ON BASE OPEN BORING HOLE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	286	0.0 - 230	41.3%	19.9%	5	11	10	3
Trichloroethene	TCE	289	0.0 - 300	31.5%	19.7%	5	11	7	3
Dichloroethene, cis-1,2-	DCE12C	259	0.0 - 290	22.8%	16.2%	70	11	4	2
Lead	PB	169	0.0 - 250	72.2%	11.8%	15	11	11	7
Bromodichloromethane	BDCME	285	0.0 - 4.7	2.5%	2.5%	0	11	3	3
Methylene chloride	MTLNCL	287	0.0 - 9.6	21.3%	2.1%	5	11	11	5
Cadmium	CD	165	0.0 - 15.4	20.0%	1.2%	5	11	10	2
Bromoform	TBME	114	0.0 - 3.4	0.9%	0.9%	0	11	1	1
Nickel	NI	169	0.0 - 216	35.5%	0.6%	100	11	10	1
Alkalinity, Total (as CACO3)	ALK	60	230000 - 380,000	100.0%			10	10	
Potassium	K	11	750 - 4,600	100.0%			9	9	
Magnesium	MG	11	11026 - 32,578	100.0%			9	9	
Sodium	NA	11	7059.99994 - 13,050	100.0%			9	9	
Alkalinity, Bicarbonate	ALKB	9	218500 - 285,700	100.0%			9	9	
Sulfate	SO4	3	12000 - 26,500	100.0%			3	3	
Total Dissolved Solids	TDS	53	130000 - 500,000	100.0%			10	10	
Calcium	CA	11	69000 - 96,960	100.0%			9	9	
Nitrate	NO3N	2	970.000029 - 1,000	100.0%			2	2	
Fluoride	F	3	310.000002 - 650	100.0%			3	3	
Methane	CH4	8	0.20999999 - 6.3	100.0%			8	8	
Chloride	CL	9	11000 - 26,000	100.0%			8	8	
Dichloroethene, 1,2- (total)	DCE12TOT	1	43 - 43	100.0%			1	1	
Zinc	ZN	168	0.0 - 3,470,454	97.6%			11	11	
Barium	BA	167	0.0 - 300	93.4%		2000	11	11	
Manganese	MN	11	0.0 - 81	90.9%			9	9	
Copper	CU	170	0.0 - 180	71.8%		1300	11	11	

TABLE 3.4 (Continued)

SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-ON BASE OPEN BORING HOLE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Bromide	BR	3	0.0 - 200	66.7%			3	2	
Iron	FE	11	0.0 - 6,219	63.6%			9	7	
Arsenic	AS	169	0.0 - 30	45.0%		50	11	10	
Chromium	CR	167	0.0 - 39	39.5%		100	11	10	
Chloroform	TCLME	297	0.0 - 49	25.9%		80	11	8	
Selenium	SE	17	0.0 - 4.0	23.5%			9	3	
Toluene	BZME	142	0.0 - 23	15.5%		1000	11	10	
Dichloroethene, trans-1,2-	DCE12T	297	0.0 - 12	14.8%		100	11	4	
Mercury	HG	168	0.0 - 1.3	12.5%		2	11	8	
Chloromethane	CLME	132	0.0 - 5.0	10.6%			11	5	
Dichloroethene, 1,1-	DCE11	288	0.0 - 1.0	5.9%		70	11	6	
Chlorotoluene, 2-	CLBZME2	63	0.0 - 0.1	1.6%			9	1	
Chlorotoluene, 4-	CLBZME4	63	0.0 - 0.0	1.6%			9	1	
Bromochloromethane	BRCLME	63	0.0 - 0.1	1.6%			9	1	
Dibromomethane	DBMA	63	0.0 - 0.2	1.6%			9	1	
Dibromochloromethane	DBCME	285	0.0 - 4.5	1.4%		60	11	2	
Vinyl chloride	VC	248	0.0 - 0.1	1.2%		2	11	1	
Dichloroethane, 1,1-	DCA11	130	0.0 - 0.1	0.8%			11	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 11 wells classified as "OPBH" in Table 3.1.

TABLE 3.5
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-CC ZONE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	105	0.0 - 58	12.4%	8.6%	5	9	4	1
Trichlorobenzene, 1,2,3-	TCE	106	0.0 - 120	9.4%	8.5%	5	9	2	1
Dichloroethene, cis-1,2-	DCE12C	107	0.0 - 120	10.3%	8.4%	70	9	3	1
Methylene chloride	MTLNCL	102	0.0 - 8.3	37.3%	1.0%	5	9	9	1
Alkalinity, Total (as CACO3)	ALK	7	269000 - 284000	100.0%			7	7	
Alkalinity, Bicarbonate	ALKB	7	269000 - 284000	100.0%			7	7	
Barium	BA	42	8.8 - 97	100.0%		2000	9	9	
Calcium	CA	11	1620 - 74200	100.0%			7	7	
Chloride	CL	8	12000 - 32300	100.0%			8	8	
Fluoride	F	8	610 - 1800	100.0%			8	8	
Potassium	K	12	3100 - 360000	100.0%			8	8	
Magnesium	MG	11	490 - 52259	100.0%			7	7	
Sodium	NA	11	9800 - 93000	100.0%			7	7	
Sulfate	SO4	8	37000 - 134000	100.0%			8	8	
Arsenic	AS	41	0.0 - 11	92.7%		50	9	9	
Manganese	MN	12	0.0 - 60	91.7%			8	7	
Iron	FE	11	0.0 - 520	90.9%			7	7	
Zinc	ZN	43	0.0 - 350	74.4%			9	9	
Nitrate	NO3N	8	0.0 - 480	50.0%			8	4	
Toluene	BZME	77	0.0 - 6.6	48.1%		1000	9	9	
Lead	PB	43	0.0 - 2.6	39.5%		15	9	7	
Bromide	BR	8	0.0 - 1060	37.5%			8	3	
Nickel	NI	42	0.0 - 23	35.7%		100	9	6	
Phosphorus, Total Orthophosphate	PORTHO	4	0.0 - 220	25.0%			4	1	
Copper	CU	42	0.0 - 19	23.8%		1300	9	6	
Acetone	ACE	5	0.0 - 2.7	20.0%			2	1	
Chromium	CR	43	0.0 - 17	18.6%		100	9	6	
Mercury	HG	41	0.0 - 0.2	17.1%		2	9	6	

TABLE 3.5 (Continued)
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-CC ZONE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Styrene	STY	8	0.0 - 0.0	12.5%			8	1	
Chloroform	TMB124	8	0.0 - 0.1	12.5%			8	1	
Benzene	BZ	9	0.0 - 0.0	11.1%			8	1	
Cadmium	CD	41	0.0 - 0.1	9.8%		5	9	4	
Dichloroethene, trans-1,2-	DCE12T	104	0.0 - 6.0	7.7%		100	9	1	
Vinyl chloride	VC	101	0.0 - 1.3	5.9%		2	9	3	
Dichloroethane, 1,1-	DCE11	101	0.0 - 0.6	5.9%		70	9	2	
Naphthalene	NAPH	72	0.0 - 0.3	4.2%			9	3	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 9 wells classified as "CC" in Table 3.1.

TABLE 3.6

SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-BS ZONE WELLS

LONG TERM MONITORING OPTIMIZATION

CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Alkalinity, Total (as	ALK	2	211,000 - 224,000	100.0%	0.0%		2	2	0
Alkalinity, Bicarbonate	ALKB	2	181,000 - 220,000	100.0%	0.0%		2	2	0
Alkalinity, Carbonate	ALKC	2	3,500 - 29,500	100.0%	0.0%		2	2	0
Barium	BA	19	6.9 - 59	100.0%	0.0%	2000	4	4	0
Calcium	CA	5	3,800 - 21,610	100.0%	0.0%		3	3	0
Chloride	CL	3	10,770 - 26,490	100.0%	0.0%		3	3	0
Fluoride	F	3	1,200 - 1,600	100.0%	0.0%		3	3	0
Potassium	K	5	12,920 - 82,000	100.0%	0.0%		3	3	0
Magnesium	MG	5	19,006 - 30,606	100.0%	0.0%		3	3	0
Manganese	MN	5	1.3 - 12	100.0%	0.0%		3	3	0
Sodium	NA	5	43,150 - 97,150	100.0%	0.0%		3	3	0
Sulfate	SO4	3	37,000 - 105,250	100.0%	0.0%		3	3	0
Arsenic	AS	19	0.0 - 5.6	94.7%	0.0%	50	4	4	0
Iron	FE	5	0.0 - 81	80.0%	0.0%		3	3	0
Toluene	BZME	35	0.0 - 26	71.4%	0.0%	1000	4	4	0
Zinc	ZN	19	0.0 - 85	68.4%	0.0%		4	4	0
Nitrate	NO3N	3	0.0 - 460	66.7%	0.0%		3	2	0
Methylene chloride	MTLNCL	47	0.0 - 0.8	36.2%	0.0%	5	4	4	0
Nickel	NI	19	0.0 - 11	31.6%	0.0%	100	4	4	0
Naphthalene	NAPH	33	0.0 - 0.4	30.3%	0.0%		4	3	0
Mercury	HG	19	0.0 - 0.2	26.3%	0.0%	2	4	4	0
Lead	PB	19	0.0 - 2.4	26.3%	0.0%	15	4	2	0
Chloroform	TMB124	4	0.0 - 0.1	25.0%	0.0%		4	1	0
Benzene	BZ	4	0.0 - 0.0	25.0%	0.0%		4	1	0
Ethylbenzene	EBZ	4	0.0 - 0.1	25.0%	0.0%		4	1	0
Vinyl chloride	VC	47	0.0 - 0.3	21.3%	0.0%	2	4	3	0
Copper	CU	19	0.0 - 9.0	21.1%	0.0%	1300	4	3	0
Dichloroethene, cis-1,2-	DCE12C	47	0.0 - 1.3	19.1%	0.0%	70	4	2	0
Cadmium	CD	19	0.0 - 0.0	15.8%	0.0%	5	4	3	0
Chromium	CR	19	0.0 - 5.8	15.8%	0.0%	100	4	3	0
Trichlorobenzene, 1,2,3-	TCE	47	0.0 - 0.2	12.8%	0.0%	5	4	1	0
Tetrachloroethene	PCE	47	0.0 - 0.2	2.1%	0.0%	5	4	1	0
Dichloroethane, 1,1-	DCE11	47	0.0 - 0.0	2.1%	0.0%	70	4	1	0

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 4 wells classified as "BS" in Table 3.1.

TABLE 3.7
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-OFF BASE OPEN BOREHOLE WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Wells with Results[c/]	Number of Wells with Detections	Number of Wells with MCL Exceedances
Tetrachloroethene	PCE	444	0 - 92	55.6%	9.0%	5	44	25	6
Trichloroethene	TCE	438	0 - 20	38.8%	4.1%	5	44	15	2
Bromodichloromethane	BDCME	413	0 - 5.9	2.2%	2.2%	0	44	5	5
Bromoform	TBME	408	0 - 1.1	0.5%	0.5%	0	44	2	2
Methylene chloride	MTLNCL	395	0 - 19	12.7%	0.3%	5	44	29	1
Zinc	ZN	4	22 - 204	100.0%			4	4	
Total Dissolved Solids	TDS	13	320000 - 480,000	100.0%			8	8	
Barium	BA	4	30.099999 - 36	100.0%		2000	4	4	
Alkalinity, Total (as	ALK	4	270000 - 350,000	100.0%			4	4	
Chloride	CL	12	11000 - 21,000	100.0%			12	12	
Chromium	CR	4	2.0000001 - 4.0	100.0%		100	4	4	
Copper	CU	4	4.0000002 - 13	100.0%		1300	4	4	
Methane	CH4	12	0.19 - 0.9	100.0%			12	12	
Lead	PB	5	0.0 - 4.1	40.0%		15	5	2	
Nickel	NI	4	0.0 - 2.0	25.0%		100	4	1	
Chloroform	TCLME	418	0.0 - 53	15.3%		80	44	11	
Dichloroethane, 1,2-	DCA12	175	0.0 - 0.1	10.3%			36	16	
Toluene	BZME	419	0.0 - 28	7.2%		1000	44	15	
Dichloroethene, cis-1,2-	DCE12C	424	0.0 - 1.0	7.1%		70	44	6	
Benzene	BZ	150	0.0 - 0.2	4.7%			36	5	
Dichlorodifluoromethane	FC12	411	0.0 - 1.9	4.6%			44	2	
Acetone	ACE	24	0.0 - 1.7	4.2%			8	1	
Dibromochloromethane	DBCME	413	0.0 - 2.7	1.7%		60	44	4	
Chloromethane	CLME	148	0.0 - 0.5	1.4%			36	2	
Trichlorobenzene, 1,2,4-	TCB124	149	0.0 - 0.2	1.3%			36	1	
Trichlorobenzene, 1,2,3-	TCB123	150	0.0 - 0.2	1.3%			36	2	
Isopropyltoluene, 4-	CYMP	150	0.0 - 0.1	1.3%			36	2	
Hexachlorobutadiene	HCBU	149	0.0 - 0.3	0.7%			36	1	
Trimethylbenzene, 1,3,5-	TMB135	149	0.0 - 0.1	0.7%			36	1	
Butylbenzene, tert-	BTBZT	149	0.0 - 0.1	0.7%			36	1	
Butylbenzene, sec-	BTBZS	149	0.0 - 0.1	0.7%			36	1	
Butylbenzene, N-	BTBZN	149	0.0 - 0.1	0.7%			36	1	
Vinyl chloride	XYLMP	151	0.0 - 1.2	0.7%			36	1	
Naphthalene	NAPH	407	0.0 - 0.2	0.2%			44	1	

[a/] Analytical data analyzed includes sampling results from September 2001 through December 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 44 wells classified as "OffBH" in Table 3.1.

TABLE 3.8
SUMMARY OF OCCURRENCE OF GROUNDWATER CONTAMINANTS OF CONCERN-WESTBAY AND AREA AOC-65 WELLS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Parameter	ParLabel	Total Samples[a/]	Range of Results (µg/L)[b/]	Percentage of Detects	Percentage of Samples with MCL Exceedances	MCL (µg/L)	Number of Sampling Locations with Results[c/]	Number of Sampling Locations with Detections	Number of Sampling Locations with MCL Exceedances
Tetrachloroethene	PCE	712	0.0 - 13900	68.3%	38.9%	5	54	49	33
Trichloroethene	TCE	712	0.0 - 321	71.3%	27.4%	5	54	48	27
Isoprophenol	ISOPROH	135	0.0 - 40.7	40.7%			47	36	
Acetone	ACE	622	0.0 - 1160	18.0%			47	42	
Dichloroethene, cis-1,2-	DCE12C	713	0.0 - 51	13.2%		70	54	23	
Benzene	BZ	89	0.0 - 2.32	9.0%			8	2	
Dichloroethene, trans-1,2-	DCE12T	714	0.0 - 0.79	0.4%		100	54	1	

[a/] Analytical data analyzed includes sampling results from September, 2003 through December, 2004.

[b/] µg/L = micrograms per liter.

[c/] Data includes 54 wells classified as "AOC65/WB" in Table 3.1.

SECTION 4

QUALITATIVE LTMO EVALUATION

An effective groundwater monitoring program will provide information regarding contaminant plume migration and changes in chemical concentrations through time at appropriate locations, enabling decision-makers to verify that contaminants are not endangering potential receptors, and that remediation is occurring at rates sufficient to achieve remedial action objectives (RAOs) within a reasonable time frame. The design of the monitoring program should therefore include consideration of existing receptor exposure pathways, as well as exposure pathways arising from potential future use of the groundwater.

Performance monitoring wells located within and downgradient from a plume provide a means of evaluating the effectiveness of a groundwater remedy relative to performance criteria. Long-term monitoring (LTM) of these wells also provides information about migration of the plume and temporal trends in chemical concentrations. Groundwater monitoring wells located downgradient from the leading edge of a plume (i.e., sentry wells) are used to evaluate possible changes in the extent of the plume and, if warranted, to trigger a contingency response action if contaminants are detected.

Primary factors to consider when developing a groundwater monitoring program include at a minimum:

- Aquifer heterogeneity,
- Types of contaminants,
- Distance to potential receptor exposure points,
- Groundwater seepage velocity and flow direction(s),

- Potential surface-water impacts, and
- The effects of the remediation system.

These factors will influence the locations and spacing of monitoring points and the sampling frequency. Typically, the greater the seepage velocity and the shorter the distance to receptor exposure points, the more frequently groundwater sampling should be conducted.

One of the most important purposes of LTM is to confirm that the contaminant plume is behaving as predicted. Graphical and statistical tests can be used to evaluate plume stability. If a groundwater remediation system or strategy is effective, then over the long term, groundwater-monitoring data should demonstrate a clear and meaningful decreasing trend in concentrations at appropriate monitoring points. The CSSA Groundwater Monitoring Program is conducted under the provisions of the Off-post Groundwater Monitoring Program Response Plan (June 2002) and the Data Quality Objectives for the Groundwater Monitoring Program (November 2003). The current groundwater monitoring program at CSSA was evaluated to identify potential opportunities for streamlining monitoring activities while still maintaining an effective performance and compliance monitoring program.

4.1 METHODOLOGY FOR QUALITATIVE EVALUATION OF MONITORING NETWORK

The LTMO evaluation included 139 sampling locations located CSSA. These wells, their associated hydrogeologic zones, and the 2004 monitoring frequencies are listed in Table 3.1, and their locations are depicted on Figures 3.1 and 3.2. As shown in the table, the LTMO evaluation included on-post, off-post, and WB wells.

Multiple factors were considered in developing recommendations for continuation or cessation of groundwater monitoring at each well. In some cases, a recommendation was made to continue monitoring a particular well, but at a reduced frequency. A recommendation to discontinue monitoring at a particular well based on the information reviewed does not necessarily constitute a recommendation to physically abandon the well. A change in site conditions might warrant resumption of monitoring at some time in the future at wells that are not currently recommended for continued sampling. Typical factors considered in developing recommendations to retain a well in, or remove a well from, a LTM program are summarized in Table 4.1. Typical factors considered in developing recommendations for monitoring frequency are summarized in Table 4.2.

TABLE 4.1
MONITORING NETWORK OPTIMIZATION DECISION LOGIC
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Reasons for Retaining a Well in Monitoring Network	Reasons for Removing a Well From Monitoring Network
Well is needed to further characterize the site or monitor changes in contaminant concentrations through time	Well provides spatially redundant information with a neighboring well (e.g., same constituents, and/or short distance between wells)
Well is important for defining the lateral or vertical extent of contaminants.	Well has been dry for more than 2 years[a/]
Well is needed to monitor water quality at compliance point or receptor exposure point (e.g., water supply well)	Contaminant concentrations are consistently below laboratory detection limits or cleanup goals
Well is important for defining background water quality	Well is completed in same water-bearing zone as nearby well(s)

a/ Periodic water-level monitoring should be performed in dry wells to confirm that the upper boundary of the saturated zone remains below the well screen. If the well becomes re-wetted, then its inclusion in the monitoring program should be evaluated.

TABLE 4.2
MONITORING FREQUENCY DECISION LOGIC
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

Reasons for Increasing Sampling Frequency	Reasons for Decreasing Sampling Frequency
Groundwater velocity is high	Groundwater velocity is low
Change in contaminant concentration would significantly alter a decision or course of action	Change in contaminant concentration would not significantly alter a decision or course of action
Well is necessary to monitor source area or operating remedial system	Well is distal from source area and remedial system
Cannot predict if concentrations will change significantly over time	Concentrations are not expected to change significantly over time, or contaminant levels have been below groundwater cleanup objectives for some prescribed period of time

4.2 RESULTS OF QUALITATIVE LTMO EVALUATION

The results of the qualitative evaluation of wells at CSSA are described in this subsection. The evaluation included the 139 on-post, off-post and Westbay®-equipped monitoring points listed in Table 3.1. The evaluation grouped the wells into these three classifications. The qualitative LTMO evaluation considered historical analytical results, whether the well was necessary for plume definition, and the primary use of the well (*i.e.* drinking water or monitoring). All COCs from historical monitoring were considered for the qualitative evaluation but special consideration was given to PCE, TCE and *cis*-1,2-DCE concentrations.

Table 4.3 includes recommendations for retaining or removing each well, the recommended sampling frequency, and the rationale for the recommendations. On and off-post LGR zone wells qualitative evaluation results are displayed in Figure 4.1. Overall, drinking water wells both on and off-post with results consistently below the maximum contaminant level (MCL) were recommended for annual sampling. Drinking water wells located off-post with historical detections exceeding the MCL for any COC were recommended for sampling on a quarterly schedule. On-post monitoring wells were recommended for various retention or removal states including removal from sampling, semi-annual, annual or biennial sampling frequencies.

4.2.1. On-post Wells

A total of 49 on-post monitoring wells were considered during the LTMO process for CSSA. In accordance with project DQOs, when four quarters of non-detections occur a well can be sampled less frequently. Recommendations for on-post wells included three wells recommended for annual sampling, twenty recommendations for semi-annual sampling, seventeen recommendations for biennial sampling, one well recommended for removal, and eight wells recommended for sampling as needed, based on precipitation. The recommendations and accompanying rationale for on-post wells are summarized in the following paragraphs.

TABLE 4.3
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
On Post Monitoring Wells					
AOC65-MW1-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-MW2A	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-PZ01-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-PZ02-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-PZ03-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-PZ04-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-PZ05-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
AOC65-PZ06-LGR	Quarterly	✓			Sample after rain event as defined remediation studies to characterize shallow aquifer
CS-1	Quarterly		✓	Annual	On-post drinking water supply
CS-10	Quarterly		✓	Annual	On-post drinking water supply
CS-11	Quarterly	✓		Biennial	Non-plume definition well, sample every two years
CS-2	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-3	Quarterly	✓		Remove	Spatially redundant, not recently sampled
CS-4	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-9	Quarterly		✓	Annual	On-post drinking water supply
CS-D	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-I	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW10-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW10-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW11A-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW11B-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW12-BS	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW12-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW12-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW16-CC	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW16-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW17-LGR	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW18-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW19-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW1-BS	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW1-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW1-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW2-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW2-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW3-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW4-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW5-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW6-BS	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW6-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW6-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW7-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW7-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
On Post Monitoring Wells					
CS-MW8-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW8-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MW9-BS	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW9-CC	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MW9-LGR	Quarterly		✓	Semi-annual	Plume definition well (or source characterization)
CS-MWG-LGR	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
CS-MWH-LGR	Quarterly		✓	Biennial	Non-plume definition well, sample every two years
Off Post Monitoring Wells					
DOM-2	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs[a/]
FO-17	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
FO-22	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
FO-8	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
FO-J1	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
HS-2	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
HS-3	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
I10-2	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
I10-4	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
I10-5	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
I10-7	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
JW-12	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
JW-13	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
JW-14	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-26	Qtrly, 1 year thru Dec 04		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-27	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
JW-28	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-29	Qtrly, due to location		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-30	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-6	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
JW-7	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-8	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
JW-9	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
LS-1	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
LS-2	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC
LS-3	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC
LS-4	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
LS-5	Qtrly, 1 year thru Mar 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
LS-6	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC
LS-7	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC
OFR-1	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
OFR-2	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
OFR-3	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC

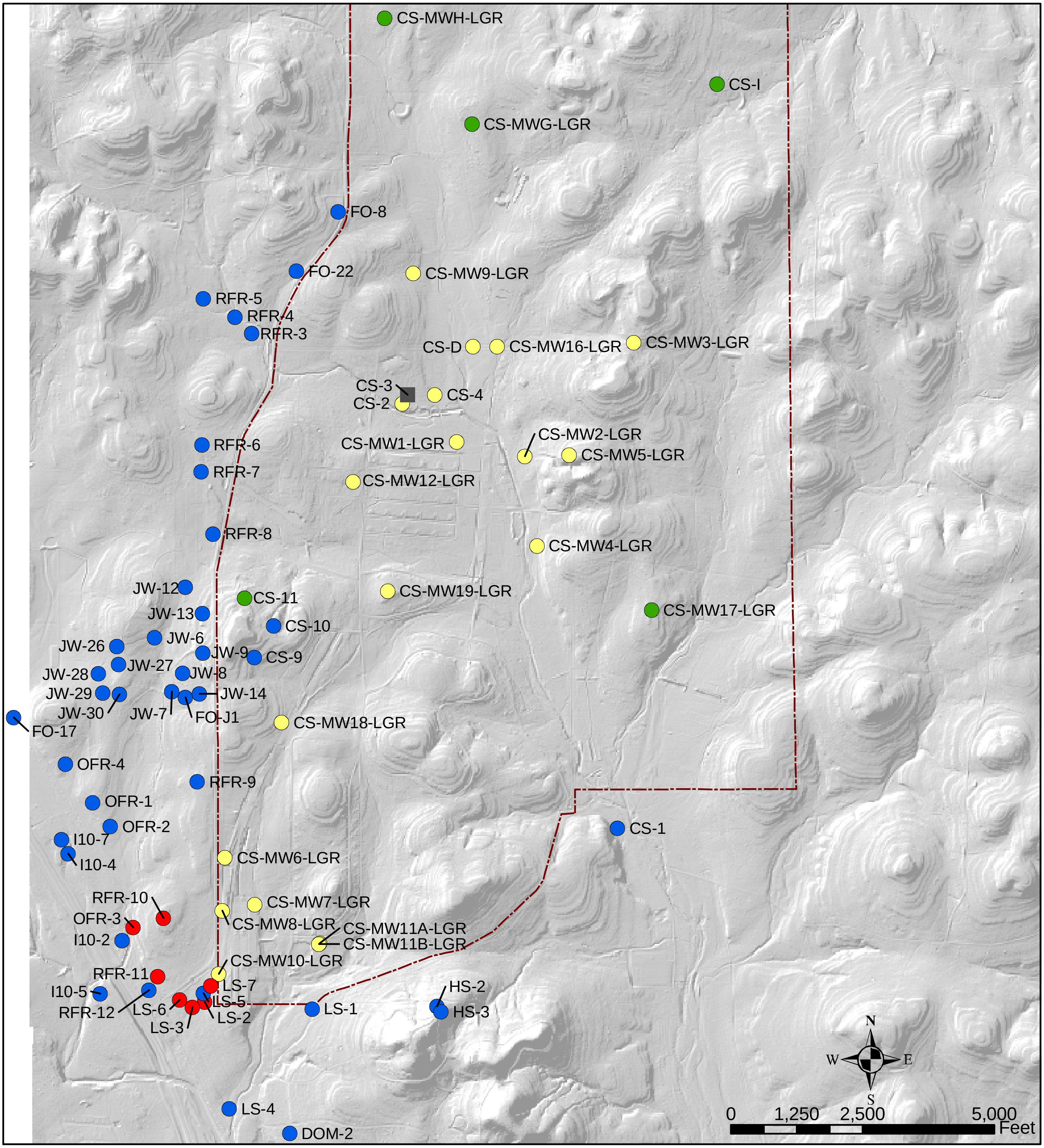
TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
On Post Monitoring Wells					
OFR-4	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
RFR-10	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC
RFR-11	Qtrly, 1 year thru Jun 05		✓	Quarterly	Plume characterization; GAC
RFR-12	Qtrly, 1 year thru Jun 05		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
RFR-3	Qtrly, 1 year thru Dec 04		✓	Annual	Historically low (F-flagged) detections, reduce frequency in accordance with DQOs
RFR-4	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
RFR-5	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
RFR-6	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
RFR-7	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
RFR-8	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
RFR-9	Annually		✓	Annual	Historically non-detect, continue sampling in accordance with DQOs
WestBay Wells					
CS-WB01-LGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-02	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-03	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-04	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-05	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-06	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-07	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-08	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-LGR-09	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB01-UGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-02	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-03	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-04	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-05	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-06	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-07	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-08	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-LGR-09	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB02-UGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-02	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-03	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-04	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-05	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-06	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-07	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-08	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-LGR-09	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB03-UGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency

TABLE 4.3 (Continued)
QUALITATIVE EVALUATION OF GROUNDWATER MONITORING NETWORK
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY, TEXAS

Well ID	Current Sampling Frequency	Qualitative Analysis			
		Remove	Retain	Monitoring Frequency Recommendation	Rationale
On Post Monitoring Wells					
CS-WB04-BS-01	Monthly & after rain events		✓	Biennial	Historically non-detect or low detections, reduce frequency
CS-WB04-BS-02	Monthly & after rain events		✓	Biennial	Historically non-detect or low detections, reduce frequency
CS-WB04-CC-01	Monthly & after rain events		✓	Biennial	Historically non-detect or low detections, reduce frequency
CS-WB04-CC-02	Monthly & after rain events		✓	Biennial	Historically non-detect or low detections, reduce frequency
CS-WB04-CC-03	Monthly & after rain events		✓	Biennial	Historically non-detect or low detections, reduce frequency
CS-WB04-LGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-02	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-03	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-04	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-06	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-07	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-08	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-09	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-10	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-LGR-11	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency
CS-WB04-UGR-01	Monthly & after rain events		✓	Semi-annual	Monthly concentrations well documented, reduce frequency

[a/] DQO = data quality objective



Legend

LGR Zone Wells

Recommended Sampling Frequency

- Quarterly
- Semi-annual
- Annual
- Biennial
- Remove

FIGURE 4.1

QUALITATIVE EVALUATION RECOMMENDATIONS LGR ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

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Three on-post drinking water wells were recommended to be retained on an annual sampling frequency. Historical detections have been below the reporting limit or non-detect and annual sampling will ensure that on-post drinking water continues to meet drinking water standards in the future. This recommendation applied to wells CS-1, CS-9, and CS-10.

Twenty wells were recommended for sampling on a semi-annual basis. For CS-2, CS-4, and CS-D, sampling has been conducted since 1991 and 1992. Well CS-MW16-LGR was sampled since 1991 and in 2002 the well was upgraded from an open borehole well to a monitoring well screened in the LGR. On-post monitoring wells CS-MW1-LGR and CS-MW2-LGR were sampled since their installation in 1997. These wells were also re-completed in 2002 and sampled quarterly through December 2004. Wells constructed in and sampled since 2001 include CS-MW3-LGR, CS-MW4-LGR, CS-MW5-LGR, CS-MW6-LGR, CS-MW7-LGR, CS-MW8-LGR, CS-MW9-LGR and CS-MW10-LGR. Wells CS-MW12-LGR, CS-MW18-LGR and CS-MW19-LGR were constructed in 2002 and sampled from installation through December 2004. Finally, of the wells recommended for semi-annual sampling, CS-MW11A-LGR, CS-MW11B-LGR, and CS-MW16-CC were installed in 2003 and sampled from installation to December 2004. Reducing the sampling frequency to semi-annual for this group of twenty wells will provide continued plume characterization information.

Seventeen wells were recommended to be sampled biennially, or every two years. This group includes twelve wells completed in the BS and CC formations. Groundwater monitoring at CSSA has consistently demonstrated that the BS and CC formations are not impacted by COCs. Well CS-MW16-CC is one exception and is located near the source area. Detections of PCE, TCE and cis-1,2-DCE in CS-MW16-CC are the only detections in a CC well. The wells completed in the LGR and recommended for biennial sampling (CS-11, CS-MWG-LGR, CS-I, CS-MWH-LGR, and CS-MW17-LGR) are not necessary for plume definition and can be retained on the reduced frequency of biennially.

Well CS-3 was recommended to be removed from the sampling program. This well was last sampled in December 1999 and prior to that was sampled for fourteen events beginning in November 1992. Both CS-2 and CS-3 are completed as open boreholes in the LGR(E) and LGR(F) zones and the two wells are located less than 200 feet apart. Sampling of CS-2 was recommended for a semi-annual basis and will provide plume characterization in this area. Sampling of CS-3 would be redundant.

Eight wells were recommended for retention to be sampled as needed. AOC-65-MW1-LGR and AOC-65-MW2A were installed to characterize the upper zones of the LGR immediately surrounding the Building 90 area and have been sampled infrequently or following periods of precipitation. Wells AOC-65-PZ01-LGR, AOC-65-PZ02-LGR, AOC-65-PZ03-LGR, AOC-65-PZ04-LGR, AOC-65-PZ05-LGR, and AOC-65-PZ06-LGR were installed for a treatability study and recharge study and were sampled after weather station data indicated that more than 1" of precipitation had occurred over a twenty-four hour period. Future sampling should also be linked to precipitation events.

4.2.2. Off-post Monitoring Wells

A total of 44 off-post drinking water wells were considered during the LTMO evaluation for CSSA. Of the 44 evaluated wells, seven are recommended to be retained on a quarterly sampling schedule and thirty-seven are recommended to be sampled at a reduced frequency of once per year. Under the DQOs currently in effect for the CSSA Groundwater Monitoring Program, the sampling frequency can be reduced as needed at selected wells based on cumulative analytical results.

The seven off-post drinking water wells to be retained on a quarterly sampling frequency have had concentrations exceeding the MCL for PCE and have been equipped with GAC water treatment systems. These wells will be retained on a quarterly schedule to continue plume characterization and include LS-2, LS-3, LS-6, LS-7, OFR-3, RFR-10, and RFR-11.

The remaining thirty-seven off-post drinking water wells evaluated have been sampled previously either quarterly or annually. Historical results show consistent concentrations so that sampling frequencies for the quarterly sampled wells can be reduced to annually as provided in the DQOs. Wells previously sampled annually but with low or no detections should be retained for annual sampling to ensure that privately owned off-post drinking water wells continue to meet drinking water standards in the future.

4.2.3 Westbay®-equipped Monitoring Wells

A total of 46 zones from four Westbay®-equipped monitoring wells were considered during the LTMO process for CSSA. There are three WB wells installed on-post and one installed off-post. WB01, WB02 and WB03 are installed near Building 90 on-post and are completed in zones UGR-01 and LGR zones 01 through 09. WB04 is installed off-post near drinking water well RFR-10 and is complete in zones UGR-01, LGR zones 01 through 11, BS-01, BS-02, CC-01, CC-02 and CC-03. These wells are equipped with the Westbay® MP38 system which allows hydraulic pressure data collection and groundwater sampling of each zone using the Westbay® MOSDAX sampling probe.

All WB zones which contained water have been sampled since September 2003 on a monthly basis with additional sampling events occurring after rainfall events of more than 1" over a twenty-four hour period. Certain zones (CS-WB04-LGR-01, CS-WB04-LGR-03, and CS-WB02-LGR-02) have occasionally been dry and were unable to be sampled. Other zones are always dry and were sampled less than four times since September 2003 (CS-WB04-LGR-02, CS-WB02-UGR-01, CS-WB01-UGR-01, CS-WB03-LGR-01, CS-WB03-UGR-01, CS-WB04-UGR-01 and CS-WB03-LGR-02). These zones only contain water following rainfall of more than 1" in duration.

Due to the historical sampling results collected monthly since September 2003 the concentrations in the LGR zones are well documented. As a result of the qualitative evaluation, the sampling frequency for all LGR zones was recommended to be reduced to semi-annually. For the BS and CC zones of the WB wells the recommended sampling frequency can also be reduced. The BS and CC zones of the WB wells are not impacted by CSSA activities and sampling can be conducted biennially.

4.2.4 Laboratory Analytical Program

For on-post and off-post wells in the CSSA monitoring program, groundwater samples currently are analyzed for VOCs using method SW8260B for the full list and method SW8260 for the short list of VOCs. On-post drinking water wells are analyzed for the full list of VOCs. The majority of historical sampling events for on-post monitoring wells have been analyzed for the short list of VOCs which includes 1,1-DCE, bromodichloromethane, bromoform, chloroform, *cis*-1,2-DCE, dibromochloromethane, dichlorodifluoromethane, methylene chloride, naphthalene, PCE, TCE, toluene, *trans*-1,2-DCE, and vinyl chloride. Metals are sampled once annually in the on-post monitoring wells and quarterly in the on-post drinking water wells. Metals are analyzed using methods SW6010B (barium, chromium, copper, nickel, zinc), SW6020 (arsenic, cadmium and lead), and SW7470A (mercury). All on-post and off-post drinking water and monitoring wells sampled quarterly receive data validation and verification in accordance with the AFCEE QAPP and the CSSA QAPP. Data packages are submitted to AFCEE chemists for review and approval.

For the Westbay equipped wells groundwater samples are analyzed for the VOCs PCE, TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, isopropanol, acetone and toluene using method SW8260B. Laboratory data packages from the Westbay samples receive an internal data validation and review but are not subject to review and approval by AFCEE.

4.2.5 LTM Program Flexibility

The LTM program recommendations summarized in Table 4.3 are based on available data regarding current (and expected future) site conditions. Changing site conditions (e.g., periods of drought or excessive rainfall) could affect plume behavior. Therefore, the LTM program should be reviewed if hydraulic conditions change significantly, and revised as necessary to adequately track changes in plume magnitude and extent over time.

SECTION 5

TEMPORAL STATISTICAL EVALUATION

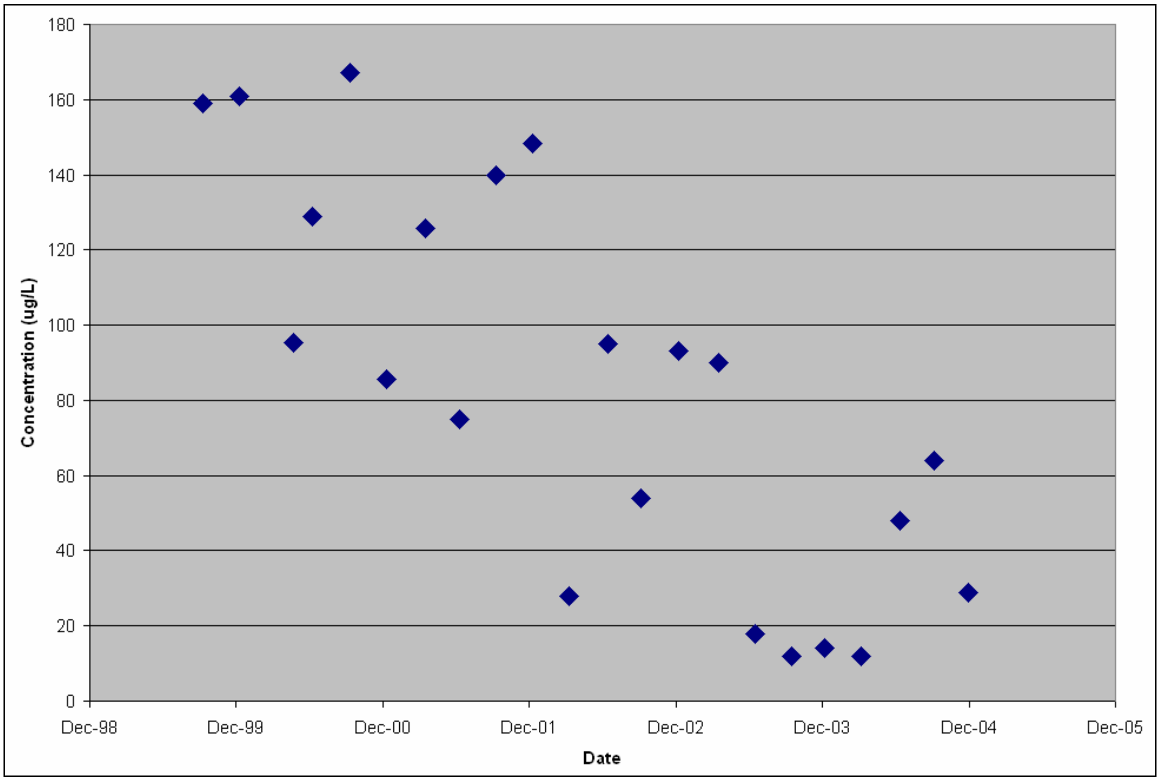
Chemical concentrations measured at different points in time (temporal data) can be examined graphically or using statistical tests, to evaluate dissolved-contaminant plume stability. If removal of chemical mass is occurring in the subsurface as a consequence of attenuation processes or operation of a remediation system, mass removal will be apparent as a decrease in chemical concentrations through time at a particular sampling location, as a decrease in chemical concentrations with increasing distance from chemical source areas, and/or as a change in the suite of chemicals detected through time or with increasing migration distance.

5.1 METHODOLOGY FOR TEMPORAL TREND ANALYSIS OF CONTAMINANT CONCENTRATIONS

Temporal chemical-concentration data can be evaluated for trends by plotting contaminant concentrations through time for individual monitoring wells (Figure 5.1), or by plotting contaminant concentrations versus downgradient distance from the contaminant source for several wells along the groundwater flowpath, over several monitoring events. Plotting temporal concentration data is recommended for any analysis of plume stability (Wiedemeier and Haas, 2000); however, visual identification of trends in plotted data may be a subjective process, particularly if (as is likely) the concentration data do not exhibit a uniform trend, but are variable through time (Figure 5.2).

The possibility of arriving at incorrect conclusions regarding plume stability on the basis of visual examination of temporal concentration data can be reduced by examining temporal trends in chemical concentrations using various statistical procedures, including regression analyses and the Mann-Kendall test for trends. The Mann-Kendall

FIGURE 5.1
PCE CONCENTRATIONS THROUGH TIME
AT WELL CS-MW16-LGR
LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS



nonparametric test (Gibbons, 1994) is well-suited for evaluation of environmental data because the sample size can be small (as few as four data points), no assumptions are made regarding the underlying statistical distribution of the data, and the test can be adapted to account for seasonal variations in the data. The Mann-Kendall test statistic can be calculated at a specified level of confidence to evaluate whether a statistically significant temporal trend is exhibited by contaminant concentrations detected through time in samples from an individual well. A negative slope (indicating decreasing contaminant concentrations through time) or a positive slope (increasing concentrations

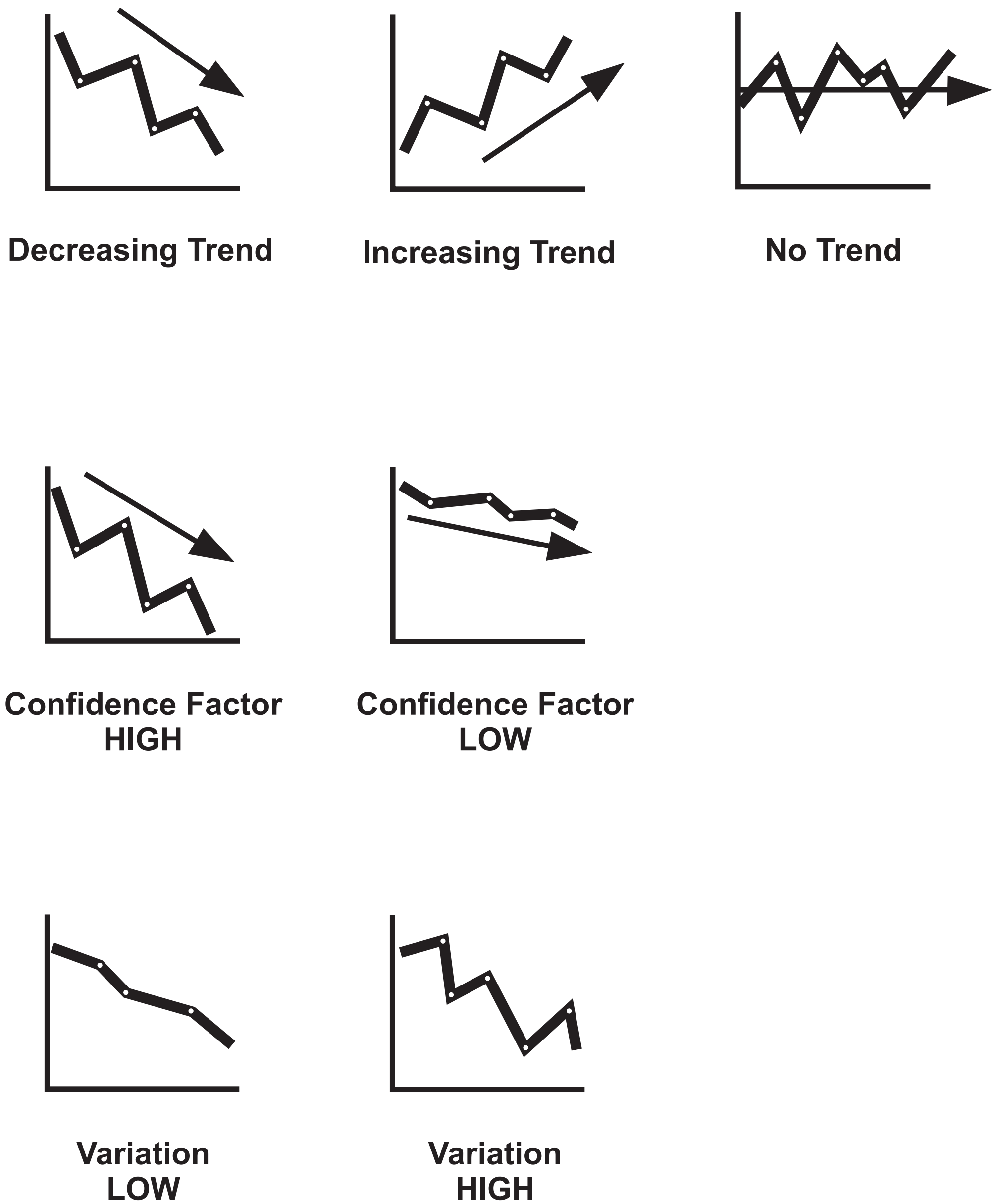


FIGURE 5.2

CONCEPTUAL REPRESENTATION OF TEMPORAL TRENDS AND TEMPORAL VARIATIONS IN CONCENTRATIONS

Long Term Monitoring Optimization
Camp Stanley, Texas

draw\739732\diffusion\williamsA.cdr pg1 nap 4/3/02 through time) provides statistical confirmation of temporal trends that may have been identified visually from plotted data (Figure 5.2). In this analysis, a 90% confidence level is used to define a statistically significant trend.

The relative value of information obtained from periodic monitoring at a particular monitoring well can be evaluated by considering the location of the well with respect to the dissolved contaminant plume and potential receptor exposure points, and the presence or absence of temporal trends in contaminant concentrations in samples collected from the well. The degree to which the amount and quality of information that can be obtained at a particular monitoring point serve the two primary (i.e., temporal and spatial) objectives of monitoring must be considered in this evaluation. For example, the continued non-detection of a target contaminant in groundwater at a particular monitoring location provides no information about temporal trends in contaminant concentrations at that location, or about the extent to which contaminant migration is occurring, unless the monitoring location lies along a groundwater flowpath between a contaminant source and a potential receptor exposure point (e.g., downgradient of a known contaminant plume). Therefore, a monitoring well having a history of contaminant concentrations below detection limits may be providing little or no useful information, depending on its location.

A trend of increasing contaminant concentrations in groundwater at a location between a contaminant source and a potential receptor exposure point may represent information critical in evaluating whether contaminants are migrating to the exposure point, thereby completing an exposure pathway. Identification of a trend of decreasing contaminant concentrations at the same location may be useful in evaluating decreases in the areal extent of dissolved contaminants, but does not represent information that is critical to the protection of a potential receptor. Similarly, a trend of decreasing contaminant concentrations in groundwater near a contaminant source may represent important information regarding the progress of remediation near, and downgradient from the source. By contrast, the absence of a statistically significant (as defined by the Mann-Kendall test with a 90% confidence level) temporal trend in contaminant concentrations at a particular location within or downgradient from a plume indicates that virtually no additional information can be obtained by frequent monitoring of groundwater at that location, in that the results of continued monitoring through time are likely to fall within the historic range of concentrations that have already been detected (Figure 5.3). Continued monitoring at locations where no temporal trend in contaminant concentrations is present serves merely to confirm the results of previous monitoring activities at that location.

The temporal trends and relative location of wells can be weighed to determine if a well should be retained, excluded, or continue in the program with reduced sampling. Figure 5.4 presents a flowchart demonstrating the methodology for utilizing trend results to draw these conclusions.

5.2 TEMPORAL EVALUATION RESULTS

The analytical data for groundwater samples collected from the 139 sample points in the CSSA LTM program from September 1991 through December 2004 were examined for temporal trends using the Mann-Kendall test. The objective of the evaluation was to identify those wells having increasing or decreasing concentration trends for each COC, and to consider the quality of information represented by the existence or absence of concentration trends in terms of the location of each monitoring point. Increasing or decreasing trends are those identified as with positive or negative slopes, respectively, by the Mann-Kendall trend analysis with a confidence level of 90%.

Summary results of Mann-Kendall temporal trend analyses for COCs in groundwater samples from CSSA are presented in Table 5.1. Trends for eight potential COCs (PCE, TCE, DCE, PB, TMBE, BDCME, BZME, and VC) were evaluated to assess the value of temporal information for each well. As implemented, the algorithm used to evaluate concentration trends assigned a value of "ND" (not detected) to those wells with sampling results that were consistently below analytical detection limits through time, rather than assigning a surrogate value corresponding to the detection limit – a procedure that could generate potentially misleading and anomalous "trends" in concentrations. In

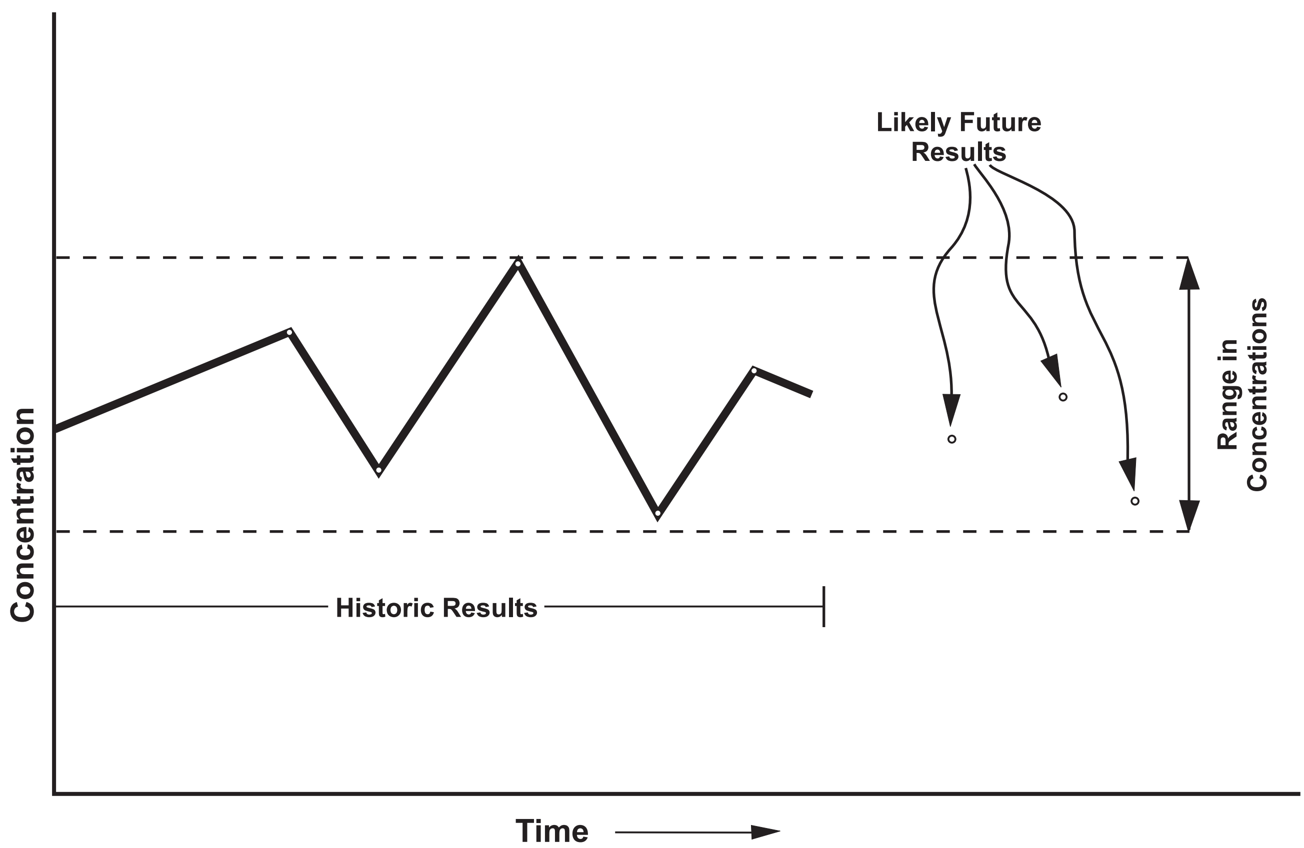


FIGURE 5.3
CONCEPTUAL REPRESENTATION OF CONTINUED MONITORING AT LOCATION WHERE NO TEMPORAL TREND IN CONCENTRATIONS IS PRESENT

Long Term Monitoring Optimization
Camp Stanley, Texas

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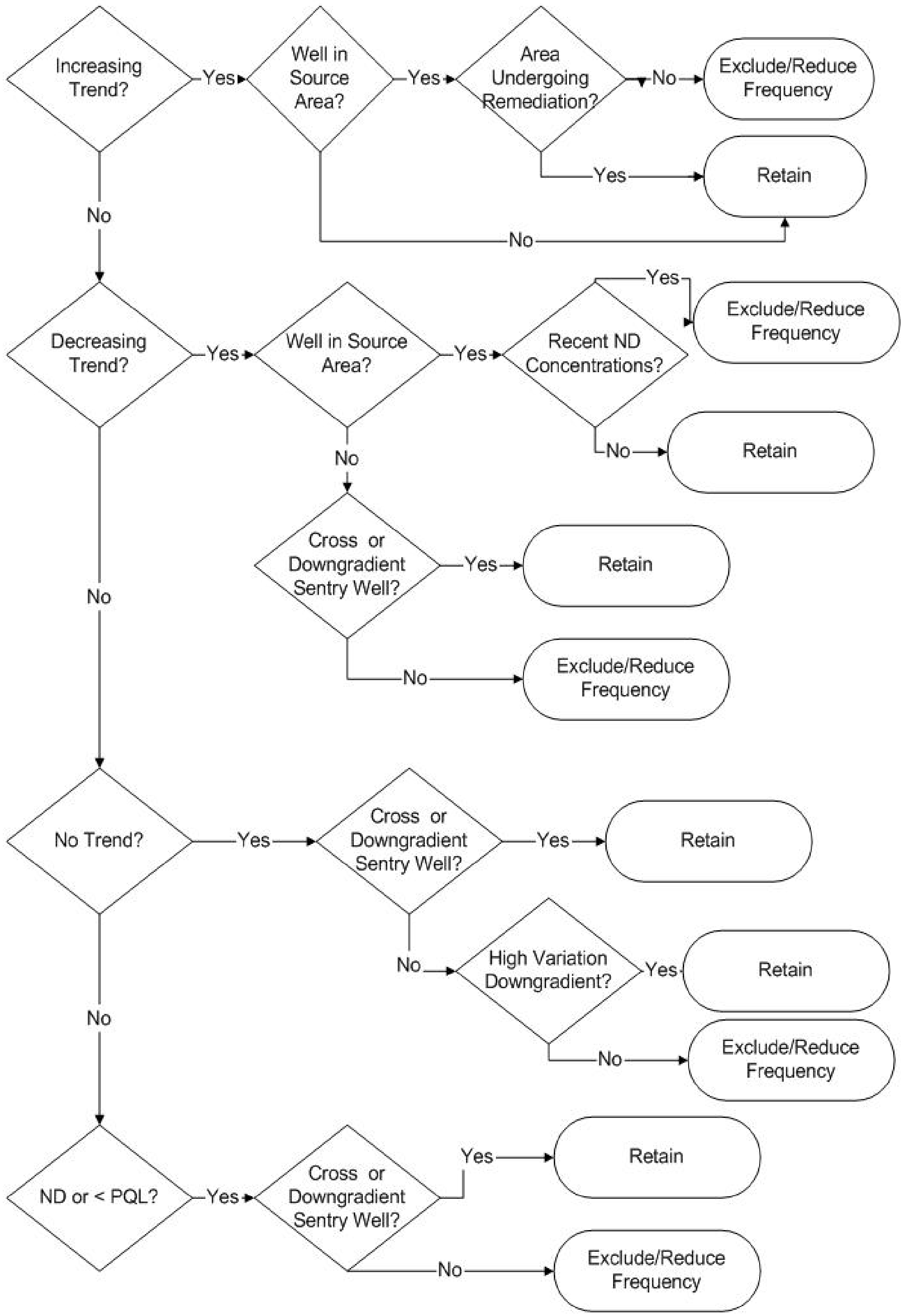


Figure 5.4

TEMPORAL TREND DECISION RATIONALE FLOWCHART

Long Term Monitoring Optimization
Camp Stanley Storage Area, Texas

PARSONS

TABLE 5.1
TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo- form	Bromodi- chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Rationale
On Post Monitoring Wells											
AOC65-MW1	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time.
AOC65-MW2A	No Trend	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	COC concentrations highly variable in source area; PCE >> MCL
AOC65-PZ01-LGR	Decreasing	Decreasing	PQL	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends downgradient; PCE and TCE > MCL.
AOC65-PZ02-LGR	Decreasing	Decreasing	PQL	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends downgradient; PCE and TCE > MCL.
AOC65-PZ03-LGR	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends upgradient; PCE and TCE near or below MCL
AOC65-PZ04-LGR	Decreasing	ND	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing PCE trends upgradient consistently below MCL
AOC65-PZ05-LGR	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing PCE trends downgradient; PCE > MCL, stable TCE
AOC65-PZ06-LGR	Decreasing	ND	ND	No Data	No Data	No Data	No Data	No Data	✓		Decreasing trends downgradient; PCE >MCL
CS-1	PQL	No Trend	ND	Decreasing	No Trend	No Trend	ND	No Trend		✓	Downgradient sentry well; one low detection of TCE in 2000, decreasing lead below MCL since 2000
CS-10	PQL	ND	ND	No Trend	ND	ND	ND	No Trend	✓		Downgradient; lead below 4ug/L since 1996; one low detection of BZME in 2003
CS-11	PQL	PQL	PQL	Increasing	ND	Decreasing	ND	No Trend		✓	Increasing downgradient lead concentration near base boundary
CS-2	No Trend	PQL	ND	No Trend	ND	ND	ND	No Trend	✓		Downgradient; only trace PCE since 1999; low Pb concentrations
CS-3	No Trend	ND	ND	No Trend	<4Meas	ND	ND	<4Meas	✓		Downgradient; well not measured since 1999 (trace PCE concentrations)
CS-4	No Trend	Increasing	Increasing	<4Meas	ND	ND	ND	PQL		✓	Increasing TCE and DCE downgradient of source well
CS-9	PQL	ND	ND	Decreasing	ND	ND	ND	Increasing	✓		Downgradient; BZME <0.2 since 6/03; lead consistently <5ug/L; all other ND or PQL.
CS-D	Increasing	Increasing	Increasing	No Trend	ND	ND	PQL	No Trend		✓	Increasing concentrations within source area undergoing remediation
CS-I	PQL	PQL	ND	No Trend	ND	Decreasing	ND	No Trend		✓	Upgradient well; BDCME ND since 1994; highly variable Pb concentrations > MCL
CS-MW10-CC	PQL	ND	ND	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; Pb concentrations <<MCL
CS-MW10-LGR	No Trend	PQL	ND	PQL	ND	ND	ND	No Trend	✓		Stable PCE trend downgradient < MCL
CS-MW11A-LGR	PQL	ND	ND	<4Meas	ND	ND	ND	PQL	✓		Downgradient well consistently ND or PQL
CS-MW11B-LGR	PQL	ND	ND	<4Meas	ND	ND	ND	PQL	✓		Downgradient well consistently ND or PQL
CS-MW12-BS	ND	ND	ND	<4Meas	ND	ND	PQL	Decreasing	✓		Downgradient (lower aquifer) well; BZME << MCL
CS-MW12-CC	ND	ND	ND	<4Meas	ND	ND	PQL	No Trend	✓		Downgradient (lower aquifer) well; BZME << MCL
CS-MW12-LGR	ND	ND	ND	<4Meas	ND	ND	ND	No Trend		✓	Downgradient sentry well; most COCs historically ND; BZME << MCL
CS-MW16-CC	No Trend	No Trend	No Trend	<4Meas	ND	ND	PQL	PQL		✓	Variable PCE, TCE, and DCE > MCL downgradient (below) source area
CS-MW16-LGR	Decreasing	Decreasing	Decreasing	PQL	ND	ND	ND	No Trend		✓	Decreasing TCE, PCE, and DCE > MCLs in source area
CS-MW17-LGR	PQL	PQL	ND	<4Meas	ND	ND	ND	Decreasing	✓		Downgradient primarliy ND or PQL; BZME << MCL
CS-MW18-LGR	PQL	PQL	ND	<4Meas	ND	ND	ND	Decreasing		✓	Downgradient sentry well; most COCs historically ND or PQL; BZME << MCL
CS-MW19-LGR	PQL	ND	ND	<4Meas	ND	ND	PQL	No Trend	✓		Downgradient; most COCs consistently ND or PQL
CS-MW1-BS	PQL	PQL	Decreasing	<4Meas	ND	ND	PQL	Decreasing	✓		Downgradient (lower aquifer) well; DCE < 1.1 ug/L
CS-MW1-CC	ND	ND	ND	<4Meas	ND	ND	PQL	PQL	✓		Downgradient (lower aquifer) well; all COCs ND or PQL
CS-MW1-LGR	No Trend	Increasing	No Trend	PQL	ND	ND	PQL	Decreasing		✓	Highly variable PCE and increasing TCE downgradient from source
CS-MW2-CC	ND	ND	ND	<4Meas	ND	ND	ND	PQL	✓		Downgradient (lower aquifer) well; all COCs ND or PQL
CS-MW2-LGR	Decreasing	Decreasing	Decreasing	PQL	ND	ND	PQL	Increasing	✓		Decreasing trends in downgradient well currently ND or << MCL; BZME << MCL
CS-MW3-LGR	PQL	PQL	ND	Decreasing	ND	ND	ND	ND	✓		Cross gradient; Pb < 2ug/L since 9/01; most COCs ND or PQL
CS-MW4-LGR	PQL	PQL	PQL	PQL	ND	ND	PQL	No Trend	✓		Downgradient; most COCs ND or PQL
CS-MW5-LGR	No Trend	No Trend	No Trend	PQL	ND	ND	ND	PQL	✓		Stable COCs downgradient
CS-MW6-BS	ND	ND	PQL	ND	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; most COCs ND or PQL; BZME << MCL
CS-MW6-CC	ND	PQL	PQL	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; most COCs ND or PQL; BZME << MCL
CS-MW6-LGR	PQL	PQL	PQL	PQL	ND	ND	ND	No Trend	✓		Upgradient well; historically <PQL or ND
CS-MW7-CC	PQL	ND	ND	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; most COCs ND or PQL; BZME << MCL
CS-MW7-LGR	PQL	PQL	ND	PQL	ND	ND	ND	No Trend		✓	Sentry well; historically <PQL or ND
CS-MW8-CC	PQL	ND	ND	PQL	ND	ND	ND	No Trend	✓		Downgradient (lower aquifer) well; most COCs ND or PQL; BZME << MCL
CS-MW8-LGR	PQL	PQL	PQL	PQL	ND	ND	ND	No Trend	✓		Downgradient; historically <PQL or ND
CS-MW9-BS	ND	ND	ND	PQL	ND	ND	PQL	PQL	✓		Downgradient (lower aquifer) well; COCs ND or PQL
CS-MW9-CC	ND	ND	PQL	ND	ND	ND	ND	PQL	✓		Downgradient (lower aquifer) well; COCs ND or PQL
CS-MW9-LGR	PQL	PQL	ND	PQL	ND	ND	ND	PQL	✓		Downgradient; historically <PQL or ND
CS-MWG-LGR	ND	ND	ND	No Trend	ND	ND	ND	PQL	✓		Upgradient well; Lead < MCL since 12/01; most COCs ND or PQL
CS-MWH-LGR	ND	ND	ND	Decreasing	PQL	ND	ND	No Trend	✓		Upgradient well; Lead < MCL since 12/01; most COCs ND or PQL

TABLE 5.1 (Continued)
TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo- form	Bromodi- chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Rationale
Off Post Monitoring Wells											
DOM-2	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND downgradient
FO-17	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
FO-22	ND	ND	ND	No Data	ND	ND	ND	ND		✓	Historically ND sentry well
FO-8	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
FO-J1	PQL	PQL	PQL	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically ND or PQL
HS-2	PQL	ND	ND	No Data	ND	ND	ND	PQL		✓	Historically ND or PQL downgradient sentry well
HS-3	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND downgradient
I10-2	PQL	PQL	ND	No Data	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well
I10-4	No Trend	PQL	ND	No Data	ND	ND	ND	ND		✓	Downgradient sentry well; 2.22ug/L PCE measurement 3/04
I10-5	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
I10-7	ND	ND	ND	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically ND or PQL
JW-12	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
JW-13	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND downgradient
JW-14	PQL	ND	ND	No Data	PQL	No Trend	ND	No Trend		✓	Downgradient; 5.93ug/L BDCME measurement 12/03
JW-26	PQL	ND	ND	No Data	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well
JW-27	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
JW-28	ND	ND	ND	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically ND or PQL
JW-29	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically ND or PQL
JW-30	PQL	PQL	PQL	<4Meas	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well
JW-6	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND downgradient
JW-7	PQL	ND	ND	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically ND or PQL
JW-8	PQL	PQL	PQL	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically ND or PQL
JW-9	PQL	ND	PQL	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically ND or PQL
LS-1	PQL	PQL	ND	No Data	PQL	PQL	ND	ND	✓		Downgradient; COCs historically ND or PQL
LS-2	Decreasing	PQL	ND	No Data	ND	PQL	ND	ND	✓		Decreasing PCE trends downgradient
LS-3	No Trend	PQL	ND	No Data	ND	ND	ND	Increasing		✓	Increasing toluene trend; variable PCE near MCL downgradient
LS-4	PQL	ND	ND	No Data	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well
LS-5	PQL	PQL	ND	No Data	ND	ND	ND	ND	✓		Downgradient; COCs historically ND or PQL
LS-6	No Trend	PQL	ND	No Data	ND	PQL	ND	PQL		✓	Variable PCE close to MCL downgradient
LS-7	No Trend	No Trend	ND	<4Meas	ND	PQL	ND	PQL		✓	Variable PCE close to MCL downgradient
OFR-1	PQL	ND	ND	No Data	ND	ND	ND	PQL		✓	Historically ND or PQL downgradient sentry well
OFR-2	PQL	ND	ND	No Data	ND	ND	ND	PQL	✓		Downgradient; COCs historically ND or PQL
OFR-3	No Trend	No Trend	PQL	No Data	ND	ND	ND	ND		✓	Variable PCE close to MCL downgradient
OFR-4	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
RFR-10	Increasing	No Trend	PQL	<4Meas	ND	ND	ND	No Trend		✓	Increasing PCE downgradient
RFR-11	No Trend	No Trend	ND	No Data	ND	ND	ND	PQL		✓	Variable PCE close to MCL downgradient
RFR-12	PQL	PQL	ND	No Data	ND	ND	ND	ND		✓	Historically ND or PQL downgradient sentry well
RFR-3	PQL	ND	ND	<4Meas	ND	ND	ND	ND	✓		Cross gradient; COCs historically ND or PQL
RFR-4	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
RFR-5	<4Meas	<4Meas	<4Meas	No Data	<4Meas	<4Meas	<4Meas	<4Meas	Not Analyzed		No recommendation due to limited data over time.
RFR-6	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND crossgradient
RFR-7	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND crossgradient
RFR-8	ND	ND	ND	<4Meas	ND	ND	ND	ND	✓		Historically ND crossgradient
RFR-9	ND	ND	ND	No Data	ND	ND	ND	ND	✓		Historically ND downgradient
WestBay Equipped Wells											
CS-WB01-LGR-01	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		Decreasing PCE downgradient near MCLs
CS-WB01-LGR-02	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		Decreasing PCE downgradient above MCLs
CS-WB01-LGR-03	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	ND		✓	Variable TCE above MCLs
CS-WB01-LGR-04	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		Decreasing PCE and TCE downgradient currently ND

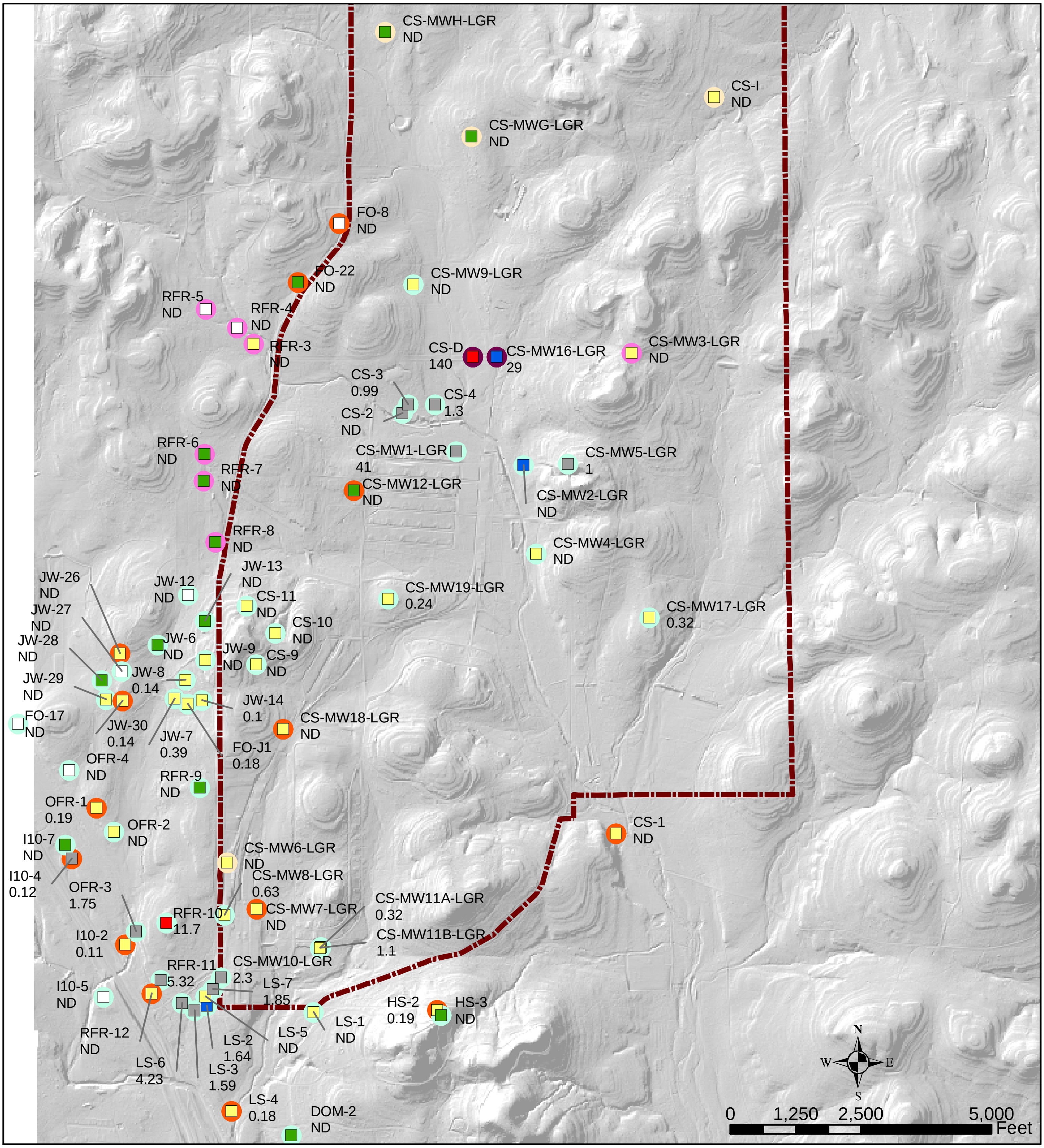
TABLE 5.1 (Continued)
TEMPORAL TREND ANALYSIS OF GROUNDWATER MONITORING RESULTS
LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	PCE	TCE	cis-1,2-DCE	Lead	Bromo- form	Bromodi- chloromethane	Vinyl Chloride	Toluene	Exclude/ Reduce	Retain	Rationale
CS-WB01-LGR-05	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	ND	✓		PCE currently ND, TCE trace, downgradient
CS-WB01-LGR-06	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	ND	✓		PCE currently ND, TCE trace, downgradient
CS-WB01-LGR-07	Increasing	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	Increasing PCE downgradient; TCE variable above MCL
CS-WB01-LGR-08	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND	✓		PCE and TCE trace, downgradient
CS-WB01-LGR-09	No Trend	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	Variable PCE and TCE downgradient above MCLs
CS-WB01-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time.
CS-WB02-LGR-01	No Trend	Decreasing	ND	No Data	No Data	No Data	No Data	ND		✓	PCE variable above MCLs downgradient
CS-WB02-LGR-02	Increasing	No Trend	ND	No Data	No Data	No Data	No Data	ND		✓	Increasing PCE downgradient
CS-WB02-LGR-03	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	No Data	ND		✓	Decreasing PCE downgradient above MCL; variable TCE near MCL downgradient
CS-WB02-LGR-04	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	ND		✓	Variable TCE near MCL downgradient
CS-WB02-LGR-05	Decreasing	No Trend	ND	No Data	No Data	No Data	No Data	ND	✓		PCE and TCE trace, downgradient
CS-WB02-LGR-06	No Trend	No Trend	ND	No Data	No Data	No Data	No Data	ND	✓		PCE and TCE <MCL, downgradient
CS-WB02-LGR-07	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		PCE and TCE decreasing downgradient
CS-WB02-LGR-08	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		PCE and TCE decreasing downgradient
CS-WB02-LGR-09	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	No Data	ND	✓		PCE and TCE decreasing downgradient; TCE > MCL
CS-WB02-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time.
CS-WB03-LGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time.
CS-WB03-LGR-02	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time.
CS-WB03-LGR-03	Decreasing	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-LGR-04	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-LGR-05	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-LGR-06	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-LGR-07	Decreasing	Increasing	No Trend	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-LGR-08	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-LGR-09	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND		✓	PCE decreasing in source area
CS-WB03-UGR-01	No Trend	No Trend	No Trend	No Data	No Data	No Data	No Data	ND		✓	High variation in source area
CS-WB04-BS-01	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		Decreasing PCE and TCE downgradient currently ND
CS-WB04-BS-02	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		Decreasing PCE and TCE downgradient currently ND
CS-WB04-CC-01	ND	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND	✓		Trace DCE and TCE downgradient;
CS-WB04-CC-02	Decreasing	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND	✓		All COCs currently ND downgradient
CS-WB04-CC-03	PQL	Decreasing	No Trend	No Data	No Data	No Data	No Data	ND	✓		All COCs currently ND downgradient
CS-WB04-LGR-01	ND	ND	ND	No Data	No Data	No Data	No Data	ND	✓		Historically ND downgradient
CS-WB04-LGR-02	ND	ND	ND	No Data	No Data	No Data	No Data	ND	✓		Historically ND downgradient
CS-WB04-LGR-03	ND	ND	ND	No Data	No Data	No Data	No Data	ND	✓		Historically ND downgradient
CS-WB04-LGR-04	ND	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		0.13 ug/L TCE measurement in 9/03, all other ND
CS-WB04-LGR-06	Decreasing	Increasing	No Trend	No Data	No Data	No Data	No Data	ND		✓	Increasing TCE downgradient
CS-WB04-LGR-07	No Trend	No Trend	No Trend	No Data	No Data	No Data	No Data	ND	✓		Stable COCs downgradient
CS-WB04-LGR-08	Decreasing	Decreasing	Decreasing	No Data	No Data	No Data	No Data	ND	✓		Decreasing COCs < MCL
CS-WB04-LGR-09	No Trend	No Trend	Decreasing	No Data	No Data	No Data	No Data	ND		✓	Variable TCE and PCE above MCLs downgradient
CS-WB04-LGR-10	No Trend	Increasing	No Trend	No Data	No Data	No Data	No Data	ND		✓	Increasing TCE downgradient
CS-WB04-LGR-11	Decreasing	Decreasing	ND	No Data	No Data	No Data	No Data	ND	✓		Decreasing PCE and TCE downgradient currently ND
CS-WB04-UGR-01	<4Meas	<4Meas	<4Meas	No Data	No Data	No Data	No Data	<4Meas	Not Analyzed		No recommendation due to limited data over time.

ND	= Constituent has not been detected during history of monitoring at inidcated well.
No Trend	= No statistically significant temporal trend in concentrations.
Increasing	= Statistically significant increasing trend in concentrations.
Decreasing	= Statistically significant decreasing trend in concentrations.
PQL	= Concentrations consistently below practical quantitation limit.
<4Meas	= Fewer than 4 measurements for COC.
No Data	= No analytical data available for well and COC.

addition, a value of “<PQL” was assigned to those constituents for which no values were measured above the practical quantitative limit (PQL), *i.e.*, all sample results were either ND or trace. For example, PCE results for groundwater samples from well CS-11 include three trace detections of 0.41 μg/L, 0.16 μg/L, and 0.062 μg/L on 6/14/00, 3/19/01, and 3/14/02, respectively, and 24 measurements in which PCE was not detected. In the absence of the “<PQL” classification category, the results of trend analysis would indicate a “no trend” result for PCE in these samples, which is primarily an artifact of the analytical procedures, and could generate false conclusions regarding concentration trends. The color-coding of the Table 5.1 entries denotes the presence/absence of temporal trends, and allows those monitoring points having nondetectable concentrations, decreasing or increasing concentrations, or no discernible trend in concentrations to be readily identified. The 14 sample points that had fewer than four analytical results for each of the COCs could not be analyzed using the Mann-Kendall trend analysis, and have a “<4Meas” and/or “No Data” designation. Figure 5.5 displays the Mann-Kendall results for PCE thematically by well for LGR zone wells, along with each well’s relative plume location designation (e.g., downgradient, upgradient).

The basis for the decision to exclude, reduce sampling or retain a well in the monitoring program based on the value of its temporal information is described in the “Rationale” column of Table 5.1, and a flow chart of the decision logic applied to the temporal trend analysis results is presented in Figure 5.4. Trend results from PCE, TCE, DCE and PB were given more weight than those from the other potential COCs given their relatively higher impact. Monitoring wells that are not considered “sentry” wells at which concentrations of COCs consistently have been non-detected or <PQL through time (e.g., CS-MW4-LGR, CS-MW10-CC, CS-MW11A-LGR, DOM-2, HS-3) represent points that do not generate useful temporal information, and typically can be recommended for exclusion or reduced monitoring. Additionally, wells located downgradient of the source area that have either decreasing concentrations or a recent history of concentrations below MCLs (e.g., CS-MW2-LGR, AOC-65-PZ05, LS-2, and CS-WB01-LGR05) will provide limited valuable temporal information in the future and



Legend

PCE Mann-Kendall Trend Result

- ND
- <PQL
- Decreasing
- Increasing
- No Trend
- <4 Measurements

Well Location within Plume

- Downgradient
- Sentry
- Source
- Upgradient
- Cross Gradient

Well ID
Most Recent
PCE Concentrations

ND: PCE not detected
All results in ug/L

FIGURE 5.5

TEMPORAL TREND RESULTS FOR PCE LCR ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

s:/es/remed/LTMO/CSSA/GIS/CSSAMK.mxd cen 2/09/05 are recommended for exclusion or reduced sampling. Conversely, monitoring wells (e.g., CS-MW16-LGR, CS-WB03-LGR04) that exhibit decreasing temporal trends in a source area with recent concentrations above MCLs are valuable and should be retained because they provide information on the effectiveness of the remediation system. Additionally, downgradient wells with increasing COC concentration trends (e.g., wells CS-4, CS-11, CS-MW1-LGR) provide valuable information about potential migration of contaminants, and should be retained. Wells with stable and/or low "no trend" results were recommended for exclusion or monitoring reduction (e.g., wells CS-MW10-LGR, CS-MW5-LGR) because continued frequent sampling would not likely yield new information, while wells with highly variable COC concentrations (e.g., wells CS-MW1-LGR, LS-6) were recommended for retention. Recommendations in wells that had different Mann-Kendall trend results for different COCs were based on the most conservative analysis.

Table 5.1 summarizes recommendations to retain 46 and exclude or reduce 79 of the 125 wells analyzed in the temporal evaluation (not including the 14 wells with fewer than four measurements) analyzed to optimize the monitoring program for CSSA. The recommendations provided in Table 5.1 are based on the evaluation of ***temporal statistical results only***, and must be used in conjunction with the results of the qualitative and spatial evaluations to generate final recommendations regarding retention of monitoring points in the LTM program, and the frequency of monitoring at particular locations at CSSA.

SECTION 6

SPATIAL STATISTICAL EVALUATION

Spatial statistical techniques also can be applied to the design and evaluation of groundwater monitoring programs to assess the quality of information generated during monitoring, and to evaluate monitoring networks. *Geostatistics*, or the Theory of Regionalized Variables (Clark, 1987; Rock, 1988; American Society of Civil Engineers Task Committee on Geostatistical Techniques in Hydrology, 1990a and 1990b), is concerned with variables having values dependent on location, and which are continuous in space, but which vary in a manner too complex for simple mathematical description. Geostatistics is based on the premise that the differences in values of a spatial variable depend only on the distances between sampling locations, and the relative orientations of sampling locations--that is, the values of a variable (e.g., chemical concentration) measured at two locations that are spatially "close together" will be more similar than values of that variable measured at two locations that are "far apart".

6.1 GEOSTATISTICAL METHODS FOR EVALUATING MONITORING NETWORKS

Ideally, application of geostatistical methods to the results of the groundwater monitoring program at CSSA could be used to estimate COC concentrations at every point within the dissolved contaminant plume, and also could be used to generate estimates of the "error," or uncertainty, associated with each estimated concentration value. Thus, the monitoring program could be optimized by using available information to identify those areas having the greatest uncertainty associated with the estimated plume extent and configuration. Conversely, sampling points could be successively eliminated from simulations, and the resulting uncertainty examined, to evaluate if significant loss of information (represented by increasing error or uncertainty in estimated chemical concentrations) occurs as the number of sampling locations is reduced. Repeated application of geostatistical estimating techniques, using tentatively identified sampling locations, then could be used to generate a sampling program that would provide an acceptable level of uncertainty regarding the distribution of COCs with the minimum possible number of samples collected. Furthermore, application of geostatistical methods can provide unbiased representations of the distribution of COCs at different locations in the subsurface, enabling the extent of COCs to be evaluated more precisely.

Fundamental to geostatistics is the concept of semivariance [$\gamma(h)$], which is a measure of the spatial dependence between sample variables (e.g., chemical concentrations) in a specified direction. Semivariance is defined for a constant spacing between samples (***h***) by:

$$\gamma(h) = \frac{1}{2n} \sum [g(x) - g(x + h)]^2 \qquad \textit{Equation 6-1}$$

Where:

$\gamma(h)$ = semivariance calculated for all samples at a distance ***h*** from each other;

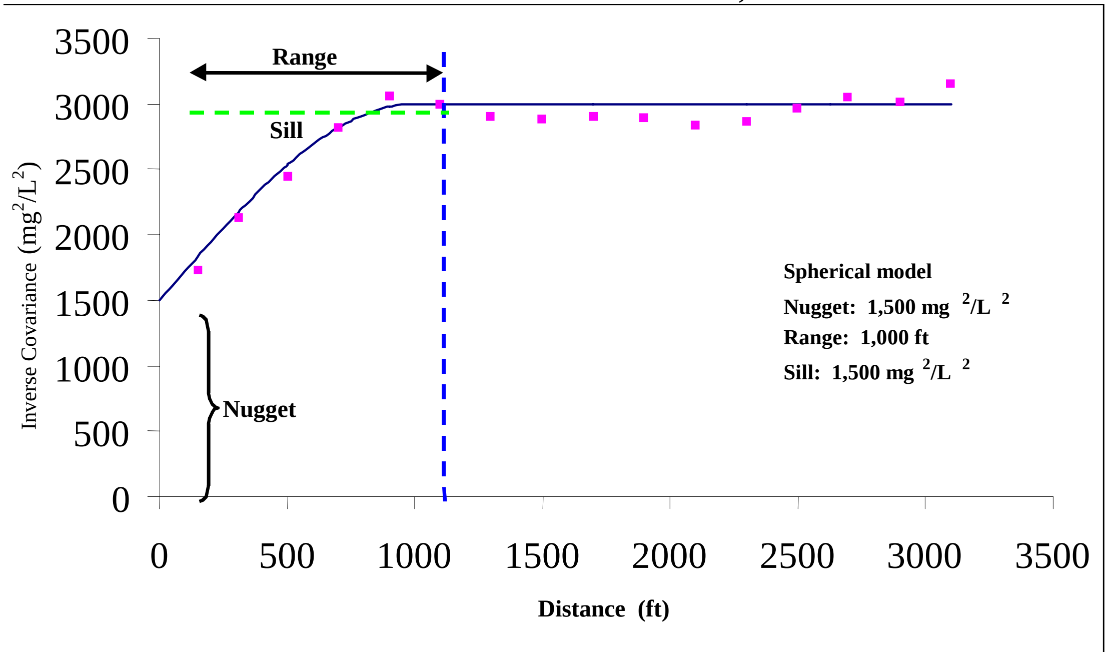
$g(x)$ = value of the variable in sample at location ***x***;

$g(x + h)$ = value of the variable in sample at a distance ***h*** from sample at location ***x***; and

n = number of samples in which the variable has been determined.

Semivariograms (plots of $\gamma(h)$ versus ***h***) are a means of depicting graphically the range of distances over which, and the degree to which, sample values at a given point are related to sample values at adjacent, or nearby, points, and conversely, indicate how close together sample points must be for a value determined at one point to be useful in predicting unknown values at other points. For $h = 0$, for example, a sample is being

FIGURE 6.1
IDEALIZED SEMVARIOGRAM MODEL
LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS



compared with itself, so normally $\gamma(0) = 0$ (the semivariance at a spacing of zero, is zero), except where a so-called nugget effect is present (Figure 6.1), which implies that sample values are highly variable at distances less than the sampling interval. Analytical variability and sampling error can contribute to the nugget. As the distance between samples increases, sample values become less and less closely related, and the semivariance, therefore, increases, until a "sill" is eventually reached, where $\gamma(h)$ equals the overall variance (i.e., the variance around the average value). The sill is reached at a sample spacing called the "range of influence," beyond which sample values are not related. Only values between points at spacings less than the range of influence can be predicted; but within that distance, the semivariogram provides the proper weightings, which apply to sample values separated by different distances.

When a semivariogram is calculated for a variable over an area (e.g., concentrations of PCE in the CSSA groundwater plume), an irregular spread of points across the semivariogram plot is the usual result (Rock, 1988). One of the most subjective tasks of geostatistical analysis is to identify a continuous, theoretical semivariogram model that most closely follows the real data. Fitting a theoretical model to calculated semivariance points is accomplished by trial-and-error, rather than by a formal statistical procedure (Davis, 1986; Clark, 1987; Rock, 1988). If a "good" model fit results, then $\boldsymbol{\gamma(h)}$ (the semivariance) can be confidently estimated for any value of $\boldsymbol{h}$, and not only at the sampled points.

6.2 SPATIAL EVALUATION OF MONITORING NETWORK AT CSSA

The sum of PCE, TCE, and cis-1,2-DCE concentrations was used as the indicator chemical for the spatial evaluation of the groundwater monitoring network at CSSA. The sum of these COCs was selected because it encompasses the largest spatial distribution of contaminants that were detected in groundwater at CSSA. The kriging evaluation examines a two-dimensional spatial “snapshot” of the data. Therefore, the most recent (2004) validated analytical data available at the start of this LTMO evaluation were used in the kriging evaluation. Three separate kriging analyses were conducted for the LGR zone wells, and sampling locations in both the north to south (NS) and west to east (WE) vertical cross sections. The spatial evaluation has a lower limit of 11 wells; thus, the BS zone and CC zone well groups did not have adequate spatial coverage for analysis, and only those included in the cross sections were included in the spatial evaluation analyses.

Of the 72 LGR monitoring wells, off-post borehole, and on-post borehole wells grouped into the LGR zone, 71 were included in the kriging evaluation. Well CS-3 was excluded because it was last sampled in 1999. The majority of wells were sampled during the 4th quarter of 2004; a few of the wells (shown on Figure 3.3) were sampled during previous quarters of the 2004. Although kriging considers a “spatial snapshot” of the wells during which sampling typically occurs at the same time, the wells sampled in previous quarters were included in the analysis because they all have trace or not detected COC results that have been stable over time.

Of the 43 sampling locations in the NS cross section, 37 were included in the kriging evaluation. The 6 AOC-65 piezometers were excluded from the spatial analysis because they were not sampled in the 4th quarter, and their sampling results vary highly over time.

Likewise, of the 30 sampling points in the WE cross section only 28 were included in the spatial evaluation because the two AOC-65 piezometers were excluded.

The commercially available geostatistical software package Geostatistical Analyst™ (an extension to the ArcView® geographic information system [GIS] software package) (Environmental Systems Research Institute, Inc. [ESRI], 2001) was used to develop a semivariogram model depicting the spatial variation in the sum of PCE, TCE and cis-1,2-DCE (Total COC) concentrations in groundwater for the selected wells in the LGR zone, NS and WE cross sections.

As semivariogram models were calculated for Total COCs (Equation 6-1), considerable scatter of the data was apparent during fitting of the models. Several data transformations (including a log transformation) were attempted to obtain a representative semivariogram model. Ultimately, the concentration data were transformed to "rank statistics," in which, for example, the 71 wells in the LGR zone were ranked from 1 to 71 according to their most recent Total COC concentration. Tie values were assigned the median rank of the set of ranked values; for example, if 5 wells had non-detected concentrations, they would each be ranked "3", the median of the set of ranks: [1,2,3,4,5]. Transformations of this type can be less sensitive to outliers, skewed distributions, or clustered data than semivariograms based on raw concentration values, and thus may enable recognition and description of the underlying spatial structure of the data in cases where ordinary data are too "noisy".

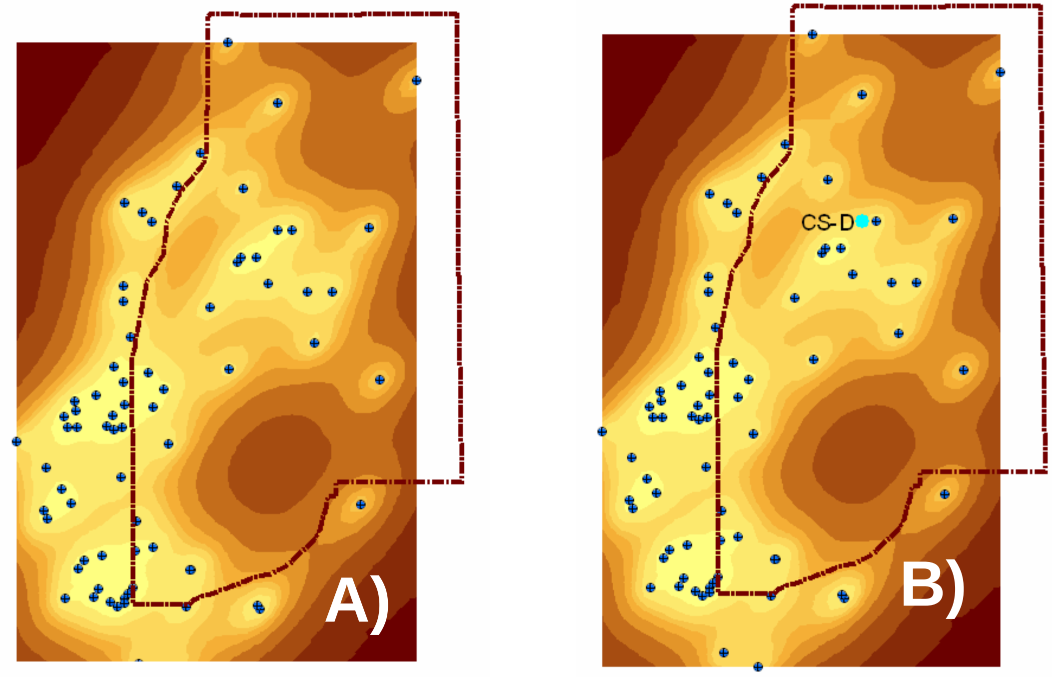
The Total COC rank statistics were used to develop semivariograms that most accurately modeled the spatial distribution of the data in the LGR zone, NS and WE cross sections. Anisotropy was incorporated into the LGR zone model to adjust for the directional influence of groundwater flow to the southwest. The parameters for best-fit semivariograms for the three spatial evaluations are listed in Table 6.1.

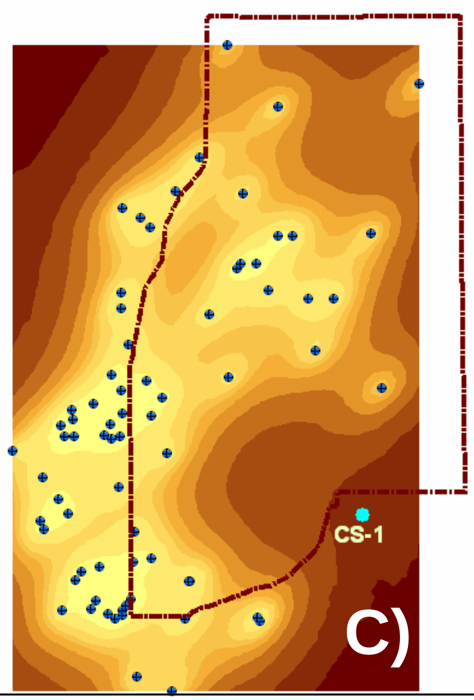
TABLE 6.1
BEST-FIT SEMVARIOGRAM MODEL PARAMETERS
LONG TERM MONITORING NETWORK OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Parameter	LGR Zone	NS Cross Section	WE Cross Section
Model	Spherical	Exponential	Spherical
Range (ft)	2500	300	410
Sill	275	155	55
Nugget	125	0	26
Minor Range (ft)	1500	NA	NA
Direction (°)	225	NA	NA

After the semivariogram models were developed, they were used in the kriging system implemented by the Geostatistical Analyst™ software package (ESRI, 2001) to develop 2-dimensional kriging realizations (estimates of the spatial distribution of Total COCs in groundwater at CSSA), and to calculate the associated kriging prediction standard errors. The median kriging standard deviation was obtained from the standard errors calculated using the entire monitoring network for each zone (e.g., the 71 wells the LGR Zone). Next, each of the wells was sequentially removed from the network, and for each resulting well network configuration, a kriging realization was completed using the Total COC concentration rankings from the remaining wells. The "missing-well" monitoring network realizations were used to calculate prediction standard errors, and the median kriging standard deviations were obtained for each "missing-well" realization and compared with the median kriging standard deviation for the "base-case" realization (obtained using the complete monitoring network), as a means of evaluating the amount of information loss (as indicated by increases in kriging error) resulting from the use of fewer monitoring points.

Figure 6.2 illustrates and example of the spatial-evaluation procedure by showing kriging prediction standard-error maps for three kriging realizations for the LGR zone wells. Each map shows the predicted standard error associated with a given group of wells based on the semivariogram parameters discussed above. Lighter colors represent





Legend

Well missing from kriging realization

Prediction Standard Error Map

Less spatial uncertainty

Greater spatial uncertainty

A) Basecase (all wells)

B) "Missing" well CS-D (relative small change in spatial uncertainty)

C) "Missing well CS-1 (relative large change in spatial uncertainty)

FIGURE 6.2

IMPACT OF MISSING WELLS ON PREDICTED STANDARD ERROR

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE ACTIVITY, TEXAS

PARSONS

areas with lower spatial uncertainty, and darker colors represent areas with higher uncertainty; regions in the vicinity of wells (i.e., data points) have the lowest associated uncertainty. Map A on Figure 6.2 shows the predicted standard error map for the "base-case" realization in which all 71 wells are included. Map B shows the realization in which well CS-D was removed from the monitoring network, and Map C shows the realization in which well CS-1 was removed. Figure 6.2 shows that when a well is removed from the network, the predicted standard error in the vicinity of the missing well increases (as indicated by a darkening of the shading in the vicinity of that well). If a "removed" (missing) well is in an area with several other wells (e.g., well CS-D; Map B on Figure 6.2), the predicted standard error may not increase as much as if a well (e.g., CS-1; Map C) is removed from an area with fewer surrounding wells.

Based on the Kriging evaluation, each well received a relative value of spatial information "test statistic" calculated from the ratio of the median "missing well" error to median "base case" error. If removal of a particular well from the monitoring network caused very little change in the resulting median kriging standard deviation, the test statistic equals one, and that well was regarded as contributing only a limited amount of information to the LTM program. Likewise, if removal of a well from the monitoring network produced larger increases in the kriging standard deviation (more than 1 percent), this was regarded as an indication that the well contributes a relatively greater amount of information, and is relatively more important to the monitoring network. At the conclusion of the kriging realizations, each well was ranked from 1 (providing the least information) to the number of wells included in the zone analysis (providing the most information), based on the amount of information (as measured by changes in median kriging standard deviation) the well contributed toward describing the spatial distribution of Total COCs, as shown in Tables 6.2 to 6.4. Wells providing the least amount of information represent possible candidates for exclusion from the monitoring network at CSSA.

TABLE 6.2
RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a/]	Kriging Metric	Kriging Ranking [b/]	Exclude	Retain
CS-I	0.98019	1	✓	
CS-MWH-LGR	0.99014	2	✓	
FO-17	0.99329	3	✓	
DOM-2	0.99977	4	✓	
CS-2	0.99997	5	✓	
CS-MW10-LGR	0.99998	6	✓	
JW-14	0.99999	7.5	✓	
LS-7	0.99999	7.5	✓	
CS-11	1.00000	13	✓	
CS-4	1.00000	13	✓	
FO-J1	1.00000	13	✓	
JW-13	1.00000	13	✓	
JW-30	1.00000	13	✓	
JW-7	1.00000	13	✓	
JW-8	1.00000	13	✓	
JW-9	1.00000	13	✓	
OFR-1	1.00000	13	✓	
RFR-10	1.00001	18	✓	
CS-MW12-LGR	1.00002	19	✓	
JW-29	1.00002	20	✓	
JW-6	1.00002	21	✓	
LS-5	1.00002	22	✓	
CS-MW1-LGR	1.00002	23	✓	
JW-27	1.00003	24.5	✓	
OFR-4	1.00003	24.5	✓	
OFR-2	1.00004	26	✓	
RFR-11	1.00005	27	-- [α/]	--
CS-10	1.00008	29	--	--
CS-9	1.00008	29	--	--
LS-2	1.00008	29	--	--
CS-MW8-LGR	1.00011	31	--	--
OFR-3	1.00013	32.5	--	--
RFR-9	1.00013	32.5	--	--
LS-6	1.00014	34	--	--
JW-12	1.00015	36	--	--
JW-28	1.00015	36	--	--
LS-3	1.00015	36	--	--
RFR-3	1.00017	38	--	--
CS-MW2-LGR	1.00018	39	--	--
RFR-8	1.00019	40	--	--

TABLE 6.2 (Continued)
RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a/]	Kriging Metric	Kriging Ranking [b/]	Exclude	Retain
RFR-12	1.00021	41	--	--
I10-2	1.00026	42	--	--
I10-7	1.00030	43	--	--
JW-26	1.00035	44	--	--
LS-1	1.00050	45		✓
FO-22	1.00052	46		✓
RFR-4	1.00058	47		✓
I10-4	1.00059	48		✓
CS-MW6-LGR	1.00085	49		✓
CS-MW7-LGR	1.00086	50		✓
CS-MW11B-LGR	1.00097	51		✓
RFR-7	1.00102	52		✓
CS-MW11A-LGR	1.00102	53		✓
CS-D	1.00102	54		✓
RFR-6	1.00155	55		✓
CS-MW16-LGR	1.00184	56		✓
I10-5	1.00188	57		✓
CS-MW5-LGR	1.00240	58		✓
LS-4	1.00288	59		✓
HS-2	1.00290	60		✓
HS-3	1.00306	61		✓
RFR-5	1.00367	62		✓
CS-MW18-LGR	1.00371	63		✓
CS-1	1.00464	64		✓
FO-8	1.00490	65		✓
CS-MW19-LGR	1.00594	66		✓
CS-MW17-LGR	1.00595	67		✓
CS-MW9-LGR	1.00645	68		✓
CS-MW3-LGR	1.00692	69		✓
CS-MW4-LGR	1.00785	70		✓
CS-MWG-LGR	1.01130	71		✓

[a/] Clustered wells included in the spatial analysis are those with the highest relative October 2002 PCE concentration.

[b/] 1= least relative amount of information; 71= most relative amount of information.

[c/] Tie values receive the median ranking of the set.

[d/] Well in the “intermediate” range; received no recommendation for removal/exclusion or retention/addition (see Section 6.2).

TABLE 6.3

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE IN THE NORTH TO SOUTH VERTICAL CROSS SECTION

THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a]	Kriging Metric	Kriging Ranking [b]	Exclude	Retain
CS-WB01-LGR-08	0.99995	1.5	✓	
CS-WB02-LGR-08	0.99995	1.5	✓	
CS-WB01-LGR-01	0.99996	4	✓	
CS-WB01-LGR-02	0.99996	4	✓	
CS-WB01-LGR-03	0.99996	4	✓	
CS-WB03-UGR-01	0.99997	6	✓	
CS-WB01-LGR-07	0.99998	7	✓	
CS-WB01-LGR-06	0.99999	8	✓	
CS-WB01-LGR-04	1.00000	11.5	✓	
CS-WB01-LGR-05	1.00000	11.5	✓	
CS-WB02-LGR-04	1.00000	11.5	✓	
CS-WB02-LGR-05	1.00000	11.5	✓	
CS-WB02-LGR-06	1.00000	11.5	✓	
CS-WB02-LGR-07	1.00000	11.5	✓	
CS-WB02-LGR-01	1.00002	16	--[d]	--
CS-WB02-LGR-02	1.00002	16	--	--
CS-WB02-LGR-03	1.00002	16	--	--
CS-WB01-LGR-09	1.00005	18	--	--
AOC65-MW2A	1.00017	19	--	--
CS-WB03-LGR-03	1.00033	20	--	--
CS-WB03-LGR-01	1.00040	21	--	--
CS-WB03-LGR-08	1.00052	22	--	--
CS-WB03-LGR-04	1.00093	23	--	--
CS-WB03-LGR-02	1.00095	24	--	--
CS-WB03-LGR-06	1.00129	25		✓
CS-WB03-LGR-05	1.00226	26		✓
CS-WB03-LGR-07	1.00243	27		✓
CS-WB02-LGR-09	1.00324	28		✓
CS-WB02-UGR-01	1.00476	29		✓
CS-WB01-UGR-01	1.00526	30		✓
CS-WB03-LGR-09	1.00735	31		✓
CS-MW6-LGR	1.01700	32		✓
CS-MW8-CC	1.01727	33		✓
CS-MW6-BS	1.02227	34		✓
CS-MW6-CC	1.02579	35		✓
AOC65-MW1	1.02903	36		✓
CS-MW8-LGR	1.04512	37		✓

[a] Clustered wells included in the spatial analysis are those with the highest relative October 2002 PCE concentration.

[b] 1= least relative amount of information; 37= most relative amount of information.

[c] Tie values receive the median ranking of the set.

[d] Well in the “intermediate” range; received no recommendation for removal/exclusion or retention/addition (see Section 6.2).

TABLE 6.4

RESULTS OF GEOSTATISTICAL EVALUATION RANKING OF WELLS BY RELATIVE VALUE OF TOTAL COC INFORMATION IN THE LGR ZONE IN THE WEST TO EAST VERTICAL CROSS SECTION

THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID [a]	Kriging Metric	Kriging Ranking [b]	Exclude	Retain
CS-WB04-LGR-09	1.00032	1	✓	
CS-WB04-LGR-10	1.00034	2	✓	
CS-WB04-BS-01	1.00038	3	✓	
CS-WB04-BS-02	1.00038	4	✓	
CS-WB04-LGR-11	1.00039	5	✓	
CS-WB04-LGR-08	1.00042	6	✓	
CS-WB04-CC-01	1.00043	7	✓	
CS-WB04-CC-02	1.00051	8	✓	
CS-WB04-LGR-02	1.00063	9	✓	
CS-WB04-LGR-01	1.00064	10	--[d]	--
CS-WB04-LGR-07	1.00069	11	--	--
CS-WB02-LGR-04	1.00074	12	--	--
CS-WB04-LGR-03	1.00082	13.5	--	--
CS-WB02-LGR-03	1.00082	13.5	--	--
CS-WB04-LGR-06	1.00084	15	--	--
CS-WB02-LGR-05	1.00090	16	--	--
CS-WB04-CC-03	1.00096	17.5	--	--
CS-WB02-LGR-02	1.00096	17.5	--	--
CS-WB04-LGR-04	1.00102	19		✓
CS-WB02-LGR-06	1.00111	20		✓
CS-WB02-LGR-01	1.00112	21		✓
CS-WB04-UGL-01	1.00116	22		✓
CS-WB02-LGR-07	1.00185	23		✓
CS-WB02-UGR-01	1.00188	24		✓
CS-WB02-LGR-08	1.00461	25		✓
CS-WB02-LGR-09	1.00706	26		✓
CS-MW7-CC	1.00918	27		✓
CS-MW7-LGR	1.01900	28		✓

[a] Clustered wells included in the spatial analysis are those with the highest relative October 2002 PCE concentration.

[b] 1= least relative amount of information; 28= most relative amount of information.

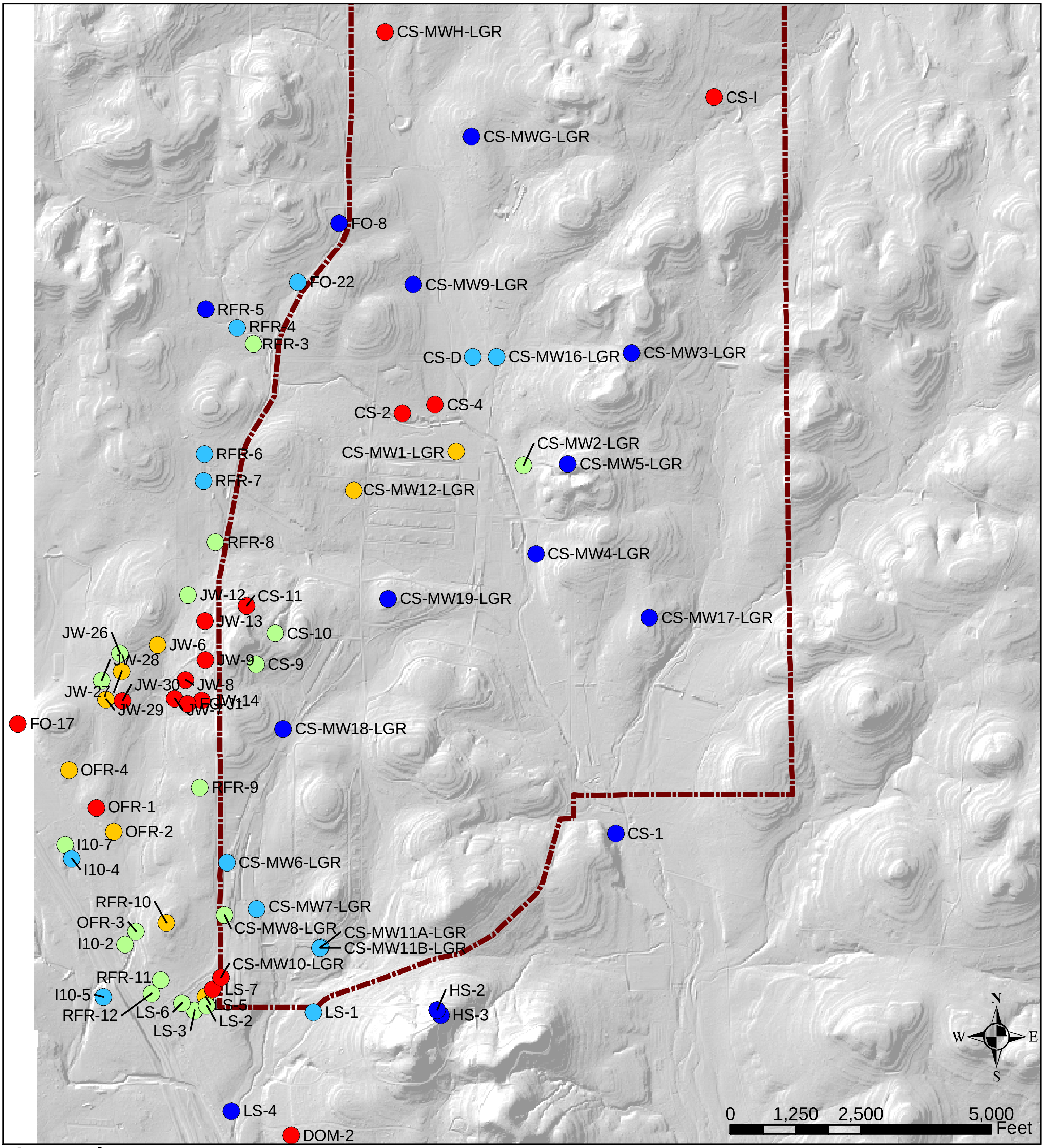
[c] Tie values receive the median ranking of the set.

[d] Well in the “intermediate” range; received no recommendation for removal/exclusion or retention/addition (see Section 6.2).

6.3 SPATIAL STATISTICAL EVALUATION RESULTS

6.3.1 Kriging Ranking Results

Figures 6.3 through 6.5 and Tables 6.2 to 6.4 present the test statistics and associated rankings of the evaluated subset of monitoring locations in the LGR zones, NS and WE cross-sections, respectively, based on the relative value of recent Total COCs information provided by each well, as calculated based on the kriging realizations. Examination of these results indicate that monitoring wells in close proximity to several other monitoring wells (e.g., red color coding on Figures 6.2 to 6.4) generally provide relatively lesser amounts of information than do wells at greater distances from other wells, or wells located in areas having limited numbers of monitoring points (e.g., blue color coding on Figures 6.2 to 6.4). This is intuitively obvious, but the analysis allows the most valuable and least valuable wells to be identified quantitatively. For example, Table 6.2 identifies the wells ranked at or below 26 that provide the relative least amount of information, and the wells ranked at or above 45 that provide the greatest amount of relative information regarding the occurrence and distribution of Total COCs in groundwater among those wells included in the kriging analysis. The lowest-ranked wells are potential candidates for exclusion from the CSSA groundwater monitoring program, and the highest-ranked wells are candidates for retention in the monitoring program, intermediate-ranked wells receive no recommendation for removal or retention in the monitoring program based on the spatial analysis.



Legend

Kriging Rankings

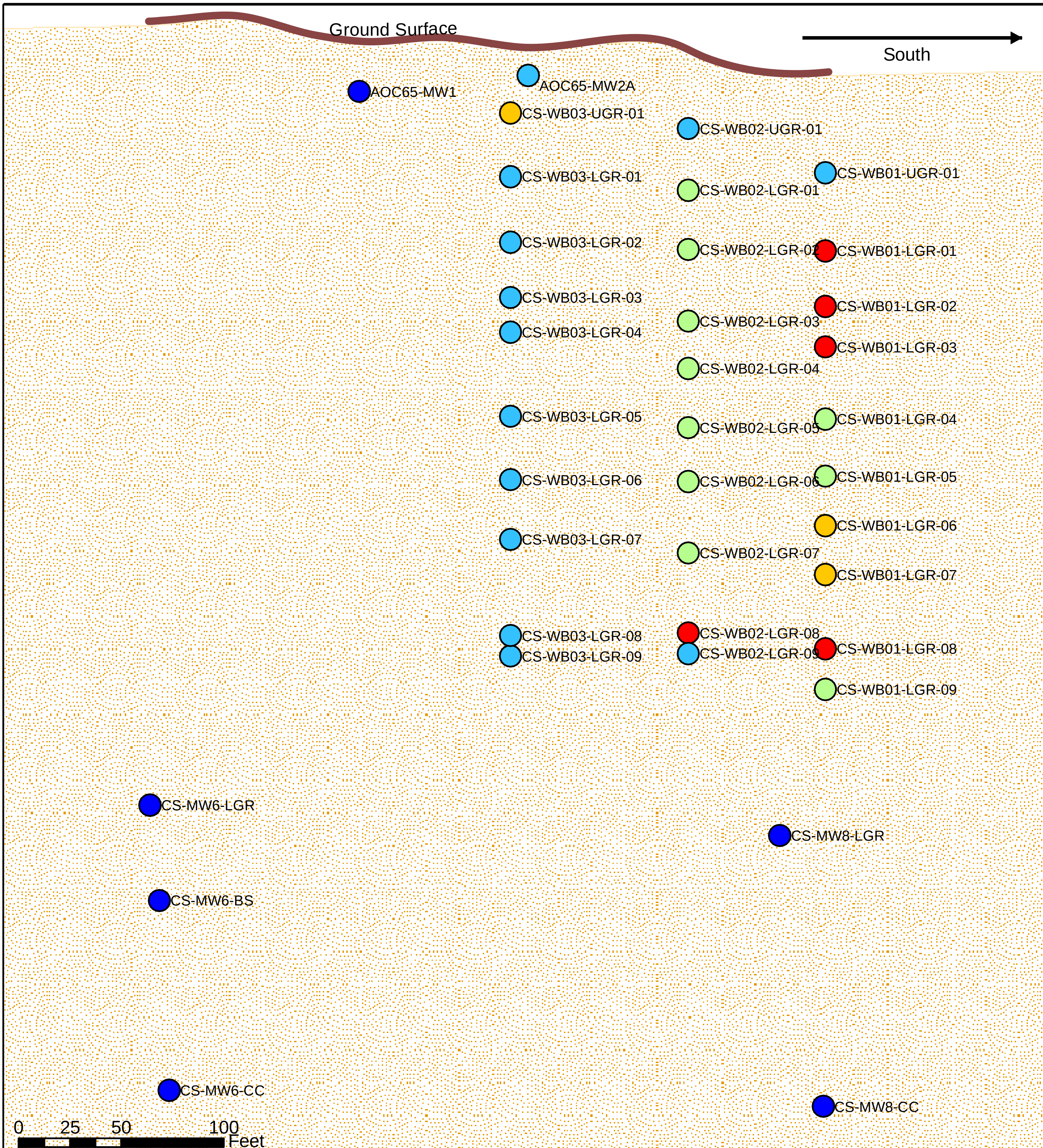
- 1 - 15 — Least value of spatial information
- 16 - 26
- 27 - 44
- 45 - 57
- 58 - 71 — Most value of spatial information

FIGURE 6.3

GEOSTATISTICAL EVALUATION RESULTS SHOWING RELATIVE VALUE OF SPATIAL INFORMATION ON TOTAL COC DISTRIBUTION LCR ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS



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Kriging Rankings

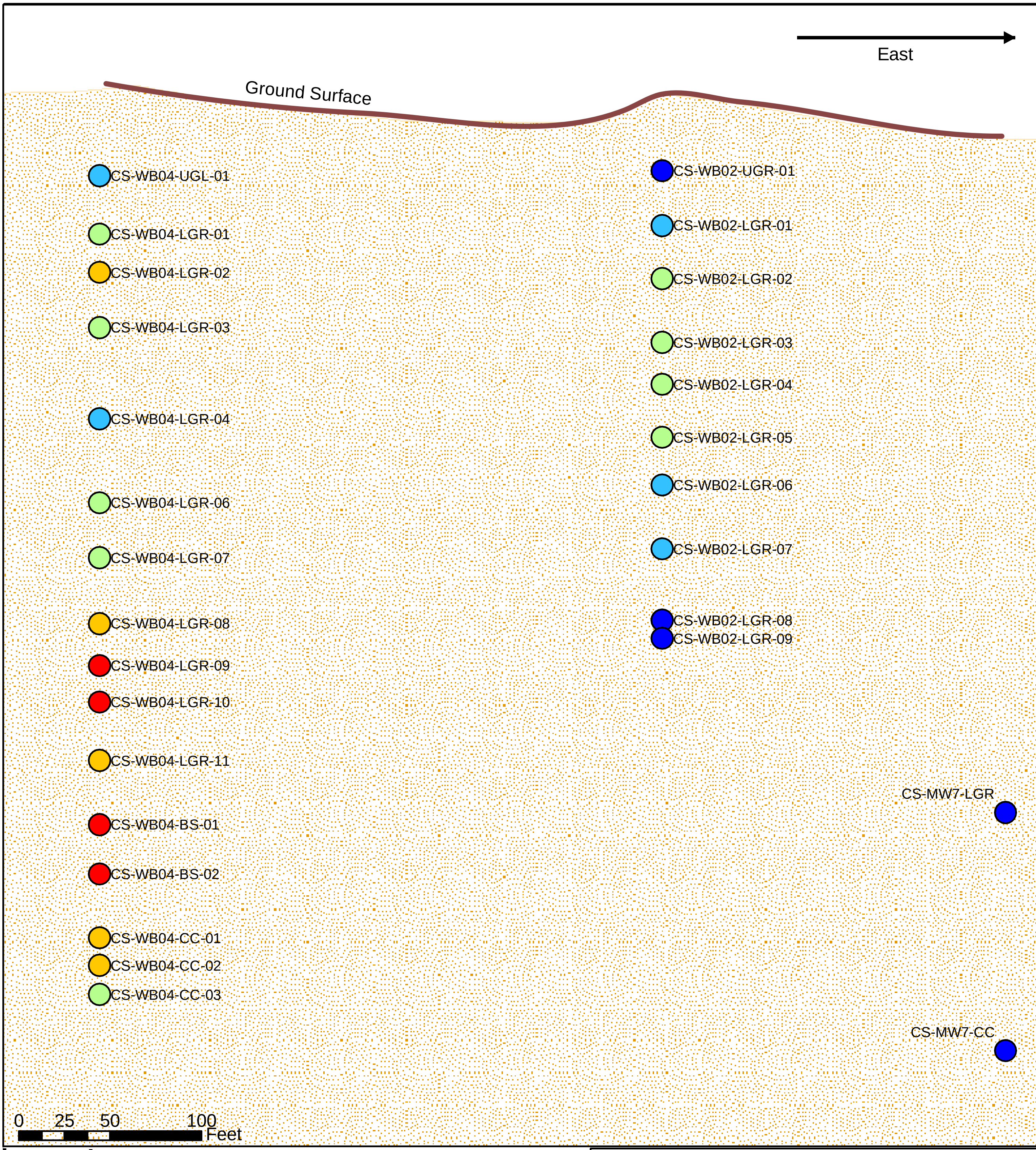
- 2 - 5 Least value of spatial information
- 6 - 9
- 10 - 18
- 19 - 31
- 32 - 37 Most value of spatial information

FIGURE 6.4

GEOSTATISTICAL EVALUATION RESULTS SHOWING RELATIVE VALUE OF SPATIAL INFORMATION ON TOTAL COC DISTRIBUTION NORTH TO SOUTH CROSS SECTION

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS



Legend

Kriging Rankings

- 1 - 4 Least value of spatial information
- 5 - 9
- 10 - 18
- 19 - 23
- 24 - 28 Most value of spatial information

FIGURE 6.5

GEOSTATISTICAL EVALUATION RESULTS SHOWING RELATIVE VALUE OF SPATIAL INFORMATION ON TOTAL COC DISTRIBUTION WEST TO EAST CROSS SECTION

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

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SECTION 7

SUMMARY OF THREE-TIERED LONG TERM MONITORING OPTIMIZATION EVALUATION

The 139 sampling points at CSSA were evaluated using qualitative hydrogeologic information, temporal statistical techniques, and spatial statistics. As each tier of the evaluation was performed, monitoring points that provide relatively greater amounts of information regarding the occurrence and distribution of COCs in groundwater were identified, and were distinguished from those monitoring points that provide relatively lesser amounts of information. In this section, the results of the evaluations are combined to generate a refined monitoring program that potentially could provide information sufficient to address the primary objectives of monitoring, at reduced cost. Monitoring wells not retained in the refined monitoring network could be removed from the monitoring program with relatively little loss of information. The results of the qualitative, temporal, and spatial evaluations are summarized in Table 7.1, along with the final recommendations for sampling point retention or exclusion and final sample frequency. Figure 7.1 shows the final recommendations for the LGR zone wells. The results of the evaluations were combined and summarized in accordance with the following decision logic:

1. Each well retained in the monitoring network on the basis of the qualitative hydrogeologic evaluation is recommended to be retained in the refined monitoring program.

TABLE 7.1
SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	Current Sampling Frequency	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			
		Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	Rationale
On Post Monitoring Wells												
AOC65-MW1-LGR	Quarterly	✓		Sample after major rain event	Not Analyzed			↓[a/]		✓	Sample after major rain event	Statistics confirm qualitative evaluation
AOC65-MW2A	Quarterly	✓		Sample after major rain event		✓	--[b/]	--		✓	Sample after major rain event	Statistics confirm qualitative evaluation
AOC65-PZ01-LGR	Quarterly	✓		Sample after major rain event	✓		Not Included		✓		Exclude	Exclude well based on statistics
AOC65-PZ02-LGR	Quarterly	✓		Sample after major rain event	✓		Not Included		✓		Exclude	Exclude well based on statistics
AOC65-PZ03-LGR	Quarterly	✓		Sample after major rain event	✓		Not Included		✓		Exclude	Exclude well based on statistics
AOC65-PZ04-LGR	Quarterly	✓		Sample after major rain event	✓		Not Included		✓		Exclude	Exclude well based on statistics
AOC65-PZ05-LGR	Quarterly	✓		Sample after major rain event	✓		Not Included		✓		Exclude	Exclude well based on statistics
AOC65-PZ06-LGR	Quarterly	✓		Sample after major rain event	✓		Not Included		✓		Exclude	Exclude well based on statistics
CS-1	Quarterly		✓	Annual		✓		✓		✓	Annual	Statistics confirm qualitative evaluation
CS-10	Quarterly		✓	Annual	✓		--	--		✓	Annual	Qualitative factor (drinking water well) overrides statistic recommendations
CS-11	Quarterly	✓		Biennial		✓	✓			✓	Annual	Increase sampling frequency due to temporal trend
CS-2	Quarterly		✓	Semi-annual	✓		✓		✓		Annual	Decrease sampling frequency due to statistics results
CS-3	Not Sampled	✓		Remove	✓		Not Included		✓		Exclude	Statistics confirm qualitative evaluation
CS-4	Quarterly		✓	Semi-annual		✓	✓			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-9	Quarterly		✓	Annual	✓		--	--		✓	Annual	Qualitative factor (drinking water well) overrides statistic recommendations
CS-D	Quarterly		✓	Semi-annual		✓		✓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-I	Quarterly		✓	Biennial		✓	✓			✓	Annual	Increase sampling frequency due to temporal trend
CS-MW10-CC	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Statistics confirm qualitative evaluation
CS-MW10-LGR	Quarterly		✓	Semi-annual	✓		✓			✓	Annual	Decrease sampling frequency due to statistics results
CS-MW11A-LGR	Quarterly		✓	Semi-annual	✓			✓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-MW11B-LGR	Quarterly		✓	Semi-annual	✓			✓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-MW12-BS	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Statistics confirm qualitative evaluation
CS-MW12-CC	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Statistics confirm qualitative evaluation
CS-MW12-LGR	Quarterly		✓	Semi-annual		✓	✓			✓	Annual	Decrease sampling frequency due to statistics results (ND sentry well)
CS-MW16-CC	Quarterly		✓	Semi-annual		✓	Not Included			✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-MW16-LGR	Quarterly		✓	Semi-annual		✓		✓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-MW17-LGR	Quarterly		✓	Biennial	✓			✓		✓	Annual	Increase sampling frequency due to spatial result
CS-MW18-LGR	Quarterly		✓	Semi-annual		✓		✓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-MW19-LGR	Quarterly		✓	Semi-annual	✓			✓			Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-MW1-BS	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Statistics confirm qualitative evaluation
CS-MW1-CC	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Statistics confirm qualitative evaluation
CS-MW1-LGR	Quarterly		✓	Semi-annual		✓	✓			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-MW2-CC	Quarterly		✓	Biennial	✓					✓	Biennial	Statistics confirm qualitative evaluation
CS-MW2-LGR	Quarterly		✓	Semi-annual	✓		--	--		✓	Semi-Annual	Qualitative factor (recompleted well) overrides statistic recommendations
CS-MW3-LGR	Quarterly		✓	Semi-annual	✓			✓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-MW4-LGR	Quarterly		✓	Semi-annual	✓			✓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-MW5-LGR	Quarterly		✓	Semi-annual	✓			✓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-MW6-BS	Quarterly		✓	Biennial	✓			↓		✓	Biennial	Temporal statistics confirm qualitative evaluation
CS-MW6-CC	Quarterly		✓	Biennial	✓			↓		✓	Biennial	Temporal statistics confirm qualitative evaluation
CS-MW6-LGR	Quarterly		✓	Semi-annual	✓			✓↓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation

TABLE 7.1 (Continued)
SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	Current Sampling Frequency	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			
		Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	Rationale
CS-MW7-CC	Quarterly		✓	Biennial	✓			→[c/]		✓	Biennial	Temporal statistics confirm qualitative evaluation
CS-MW7-LGR	Quarterly		✓	Semi-annual		✓		✓→		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-MW8-CC	Quarterly		✓	Biennial	✓			↓		✓	Biennial	Temporal statistics confirm qualitative evaluation
CS-MW8-LGR	Quarterly		✓	Semi-annual	✓		--	--↓		✓	Annual	Decrease sampling frequency due to statistics results
CS-MW9-BS	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Temporal statistics confirm qualitative evaluation
CS-MW9-CC	Quarterly		✓	Biennial	✓		Not Included			✓	Biennial	Temporal statistics confirm qualitative evaluation
CS-MW9-LGR	Quarterly		✓	Semi-annual	✓			✓			Semi-annual	Spatial statistics confirm qualitative evaluation
CS-MWG-LGR	Quarterly		✓	Biennial	✓			✓		✓	Annual	Increase sampling frequency due to spatial result
CS-MWH-LGR	Quarterly		✓	Biennial	✓		✓			✓	Biennial	Statistics confirm qualitative evaluation
Off Post Monitoring Wells												
DOM-2	Annually		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
FO-17	Annually		✓	Annual	Not Analyzed		✓			✓	Biennial	Decrease sampling frequency due to statistics results
FO-22	Annually		✓	Annual		✓		✓		✓	Annual	Statistics confirm qualitative evaluation
FO-8	Annually		✓	Annual	Not Analyzed			✓		✓	Annual	Spatial statistics confirm qualitative evaluation
FO-J1	Qtrly, 1 year thru Mar 05		✓	Annual	✓		✓			✓	Annual	Decrease sampling frequency due to statistics results
HS-2	Qtrly, 1 year thru Mar 05		✓	Annual		✓		✓		✓	Annual	Statistics confirm qualitative evaluation
HS-3	Annually		✓	Annual	✓			✓		✓	Annual	Spatial statistics confirm qualitative evaluation
I10-2	Qtrly, 1 year thru Jun 05		✓	Annual		✓	--	--		✓	Annual	Temporal statistics confirm qualitative evaluation
I10-4	Qtrly, 1 year thru Mar 05		✓	Annual		✓		✓		✓	Annual	Statistics confirm qualitative evaluation
I10-5	Annually		✓	Annual	Not Analyzed			✓		✓	Annual	Spatial statistics confirm qualitative evaluation
I10-7	Annually		✓	Annual	✓		--	--		✓	Biennial	Decrease sampling frequency due to statistics results
JW-12	Annually		✓	Annual	Not Analyzed		--	--		✓	Biennial	Decrease sampling frequency due to statistics results
JW-13	Annually		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
JW-14	Qtrly, 1 year thru Jun 05		✓	Annual		✓	✓			✓	Biennial	Temporal statistics confirm qualitative evaluation
JW-26	Qtrly, 1 year thru Dec 04		✓	Annual		✓	--	--		✓	Annual	Temporal statistics confirm qualitative evaluation
JW-27	Annually		✓	Annual	Not Analyzed		✓			✓	Biennial	Decrease sampling frequency due to statistics results
JW-28	Qtrly, 1 year thru Jun 05		✓	Annual	✓		--	--		✓	Biennial	Decrease sampling frequency due to statistics results
JW-29	Qtrly, due to location		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
JW-30	Qtrly, 1 year thru Mar 05		✓	Annual		✓	✓			✓	Annual	Temporal statistics confirm qualitative evaluation
JW-6	Annually		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
JW-7	Qtrly, 1 year thru Jun 05		✓	Annual	✓		✓			✓	Annual	Qualitative factor overrides statistic recommendations
JW-8	Qtrly, 1 year thru Mar 05		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
JW-9	Qtrly, 1 year thru Mar 05		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
LS-1	Qtrly, 1 year thru Mar 05		✓	Annual	✓			✓		✓	Annual	Spatial statistics confirm qualitative evaluation
LS-2	Qtrly, 1 year thru Jun 05		✓	Quarterly	✓		--	--		✓	Quarterly	Qualitative factor (GAC well)overrides statistic recommendations
LS-3	Qtrly, 1 year thru Jun 05		✓	Quarterly		✓	--	--		✓	Quarterly	Temporal statistics confirm qualitative evaluation
LS-4	Qtrly, 1 year thru Jun 05		✓	Annual		✓		✓		✓	Annual	Statistics confirm qualitative evaluation
LS-5	Qtrly, 1 year thru Mar 05		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
LS-6	Qtrly, 1 year thru Jun 05		✓	Quarterly		✓	--	--		✓	Quarterly	Temporal statistics confirm qualitative evaluation
LS-7	Qtrly, 1 year thru Jun 05		✓	Quarterly		✓	✓			✓	Quarterly	Temporal statistics confirm qualitative evaluation
OFR-1	Qtrly, 1 year thru Jun 05		✓	Annual		✓	✓			✓	Annual	Temporal statistics confirm qualitative evaluation
OFR-2	Qtrly, 1 year thru Jun 05		✓	Annual	✓		✓			✓	Biennial	Decrease sampling frequency due to statistics results
OFR-3	Qtrly, 1 year thru Jun 05		✓	Quarterly		✓	--	--		✓	Quarterly	Temporal statistics confirm qualitative evaluation
OFR-4	Annually		✓	Annual	Not Analyzed		✓			✓	Biennial	Decrease sampling frequency due to statistics results
RFR-10	Qtrly, 1 year thru Jun 05		✓	Quarterly		✓	✓			✓	Quarterly	Temporal statistics confirm qualitative evaluation
RFR-11	Qtrly, 1 year thru Jun 05		✓	Quarterly		✓	--[d/]	--		✓	Quarterly	Temporal statistics confirm qualitative evaluation
RFR-12	Qtrly, 1 year thru Jun 05		✓	Annual		✓	--	--		✓	Annual	Temporal statistics confirm qualitative evaluation

TABLE 7.1 (Continued)

SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM

THREE-TIERED LONG TERM MONITORING OPTIMIZATION

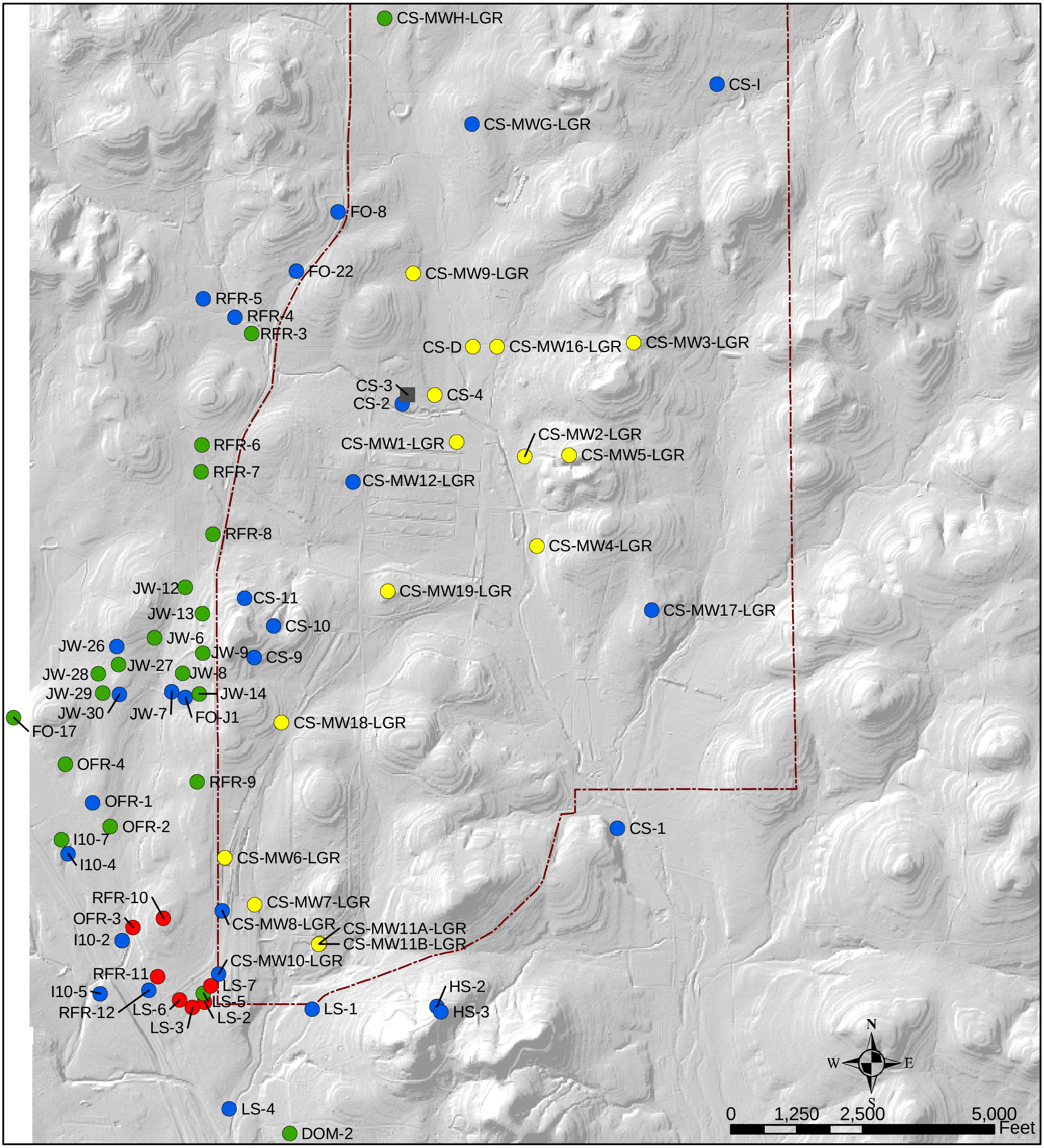
CAMP STANLEY STORAGE AREA, TEXAS

Well ID		Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			
	Current Sampling Frequency	Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	Rationale
RFR-3	Qtrly, 1 year thru Dec 04		✓	Annual	✓		--	--		✓	Biennial	Decrease sampling frequency due to statistics results
RFR-4	Annually		✓	Annual	Not Analyzed			✓		✓	Annual	Spatial statistics confirm qualitative evaluation
RFR-5	Annually		✓	Annual	Not Analyzed			✓		✓	Annual	Spatial statistics confirm qualitative evaluation
RFR-6	Annually		✓	Annual	✓			✓		✓	Biennial	Decrease sampling frequency due to temporal statistics results
RFR-7	Annually		✓	Annual	✓			✓		✓	Biennial	Decrease sampling frequency due to temporal statistics results
RFR-8	Annually		✓	Annual	✓		--	--		✓	Biennial	Decrease sampling frequency due to statistics results
RFR-9	Annually		✓	Annual	✓		--	--		✓	Biennial	Decrease sampling frequency due to statistics results
WestBay Wells												
CS-WB01-LGR-01	Monthly & after rain events		✓	Semi-annual	✓		↓			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB01-LGR-02	Monthly & after rain events		✓	Semi-annual	✓		↓			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB01-LGR-03	Monthly & after rain events		✓	Semi-annual		✓	↓			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB01-LGR-04	Monthly & after rain events		✓	Semi-annual	✓		↓			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB01-LGR-05	Monthly & after rain events		✓	Semi-annual	✓		↓			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB01-LGR-06	Monthly & after rain events		✓	Semi-annual	✓		↓			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB01-LGR-07	Monthly & after rain events		✓	Semi-annual		✓	↓			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB01-LGR-08	Monthly & after rain events		✓	Semi-annual	✓		↓			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB01-LGR-09	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB01-UGR-01	Monthly & after rain events		✓	Semi-annual	Not Analyzed			↓		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-WB02-LGR-01	Monthly & after rain events		✓	Semi-annual		✓	--	--→		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-WB02-LGR-02	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB02-LGR-03	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB02-LGR-04	Monthly & after rain events		✓	Semi-annual		✓	↓--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB02-LGR-05	Monthly & after rain events		✓	Semi-annual	✓		↓--	--		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB02-LGR-06	Monthly & after rain events		✓	Semi-annual	✓		↓	→		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB02-LGR-07	Monthly & after rain events		✓	Semi-annual	✓		↓	→		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB02-LGR-08	Monthly & after rain events		✓	Semi-annual	✓		↓	→		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB02-LGR-09	Monthly & after rain events		✓	Semi-annual	✓			↓→		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-WB02-UGR-01	Monthly & after rain events		✓	Semi-annual	Not Analyzed			↓→		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation
CS-WB03-LGR-01	Monthly & after rain events		✓	Semi-annual	Not Analyzed		--	--		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB03-LGR-02	Monthly & after rain events		✓	Semi-annual	Not Analyzed		--	--		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB03-LGR-03	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB03-LGR-04	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB03-LGR-05	Monthly & after rain events		✓	Semi-annual		✓		↓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-WB03-LGR-06	Monthly & after rain events		✓	Semi-annual		✓		↓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-WB03-LGR-07	Monthly & after rain events		✓	Semi-annual		✓		↓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-WB03-LGR-08	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-WB03-LGR-09	Monthly & after rain events		✓	Semi-annual		✓		↓		✓	Semi-Annual	Statistics confirm qualitative evaluation
CS-WB03-UGR-01	Monthly & after rain events		✓	Semi-annual		✓	↓			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB04-BS-01	Monthly & after rain events		✓	Biennial	✓		→			✓	Biennial	Statistics confirm qualitative evaluation
CS-WB04-BS-02	Monthly & after rain events		✓	Biennial	✓		→			✓	Biennial	Statistics confirm qualitative evaluation
CS-WB04-CC-01	Monthly & after rain events		✓	Biennial	✓		→			✓	Biennial	Statistics confirm qualitative evaluation
CS-WB04-CC-02	Monthly & after rain events		✓	Biennial	✓		→			✓	Biennial	Statistics confirm qualitative evaluation
CS-WB04-CC-03	Monthly & after rain events		✓	Biennial	✓		--	--		✓	Biennial	Statistics confirm qualitative evaluation
CS-WB04-LGR-01	Monthly & after rain events		✓	Semi-annual	✓		--	--		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB04-LGR-02	Monthly & after rain events		✓	Semi-annual	✓		→			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB04-LGR-03	Monthly & after rain events		✓	Semi-annual	✓		--	--		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB04-LGR-04	Monthly & after rain events		✓	Semi-annual	✓			→		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation

TABLE 7.1 (Continued)
SUMMARY OF LONG TERM MONITORING OPTIMIZATION EVALUATION OF CURRENT GROUNDWATER MONITORING PROGRAM
THREE-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Well ID	Current Sampling Frequency	Qualitative Evaluation			Temporal Evaluation		Spatial Evaluation		Summary			
		Exclude	Retain	Recommended Monitoring Frequency	Exclude/ Reduce	Retain	Exclude	Retain	Exclude	Retain	Recommended Monitoring Frequency	Rationale
CS-WB04-LGR-06	Monthly & after rain events		✓	Semi-annual		✓	--	--		✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB04-LGR-07	Monthly & after rain events		✓	Semi-annual	✓		--	--		✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB04-LGR-08	Monthly & after rain events		✓	Semi-annual	✓		→			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB04-LGR-09	Monthly & after rain events		✓	Semi-annual		✓	→			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB04-LGR-10	Monthly & after rain events		✓	Semi-annual		✓	→			✓	Semi-Annual	Temporal statistics confirm qualitative evaluation
CS-WB04-LGR-11	Monthly & after rain events		✓	Semi-annual	✓		→			✓	Semi-Annual	Qualitative factor overrides statistic recommendations
CS-WB04-UGR-01	Monthly & after rain events		✓	Semi-annual	Not Analyzed			→		✓	Semi-Annual	Spatial statistics confirm qualitative evaluation

[a/] Spatial recommendation result from North to South vertical cross section analysis that do not impact LGR zone well summary evaluation results.
[b/] Well in the “intermediate” range; received no recommendation for removal/exclusion or retention/addition in spatial evaluation
[c/] Spatial recommendation result from West to East vertical cross section analysis that do not impact LGR zone well summary evaluation results.



Legend

Recommended Sampling Frequency

- Quarterly
- Semi-Annual
- Annual
- Biennial
- Exclude

FIGURE 7.1

COMBINED EVALUATION RECOMMENDATIONS LGR ZONE WELLS

LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

PARSONS

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2. Those wells recommended for removal from the monitoring program on the basis of all three evaluations, or on the basis of the qualitative and temporal evaluations (with no recommendation resulting from the spatial evaluation) should be removed from the monitoring program.

3. If a well is recommended for removal based on the qualitative evaluation and recommended for retention based on the temporal or spatial evaluation, the final recommendation is based on a case-by-case review of well information.

4. If a well is recommended for retention based on the qualitative evaluation and recommended for removal based on the temporal and spatial evaluation, the recommended sampling frequency is based on a case-by-case review of well information.

It should be noted, as stated in number four above, the final recommended monitoring frequencies shown in Table 7.1 are not, in all cases, the same as those recommended as a result of the qualitative evaluation (Table 4.3). In the CSSA qualitative evaluation, few wells were recommended for exclusion from the monitoring network, while many were recommended for reduced sampling frequency. Thus, the temporal and spatial statistical evaluation results were primarily used to confirm or adjust qualitative monitoring frequency recommendations. The justification for these modifications is provided in the "Rationale" column in Table 7.1, and fall into the following general categories:

- *Temporal and/or spatial statistical results confirm the sampling frequency recommendations from the qualitative evaluation.* For example, well CS-D is recommended for retention by both the temporal and spatial statistical results; thus, the statistics confirm the semi-annual sampling frequency. Likewise, well CS-MWH-LGR is recommended for exclusion from the network by both the temporal and spatial statistical results; thus, the statistics confirm the low biennial sampling frequency.

- *Decrease sampling frequency due to statistics results.* For example, well CS-2 is recommended for semi-annual sampling in the qualitative evaluation; however, the well was recommended for exclusion/reduction in the temporal evaluation because it has had only trace PCE since 1999 and was determined to be of relatively little importance in the spatial evaluation. Therefore, annual sampling is recommended in the summary evaluation.

- *Qualitative factor overrides statistics recommendations.* Well CS-10 is similar to CS-2, in that the statistical evaluations showed it to be contributing limited temporal and spatial information to the monitoring network. However, the qualitative annual sampling recommendation was due to the fact that the well is a drinking water supply well, which was not considered by the statistics, so the summary recommendation remains at an annual frequency. Similarly, analysis of several WB sampling points resulted in statistics that would support less frequent monitoring (e.g., CS-WB01-LGR-04, CS-WB01-LGR-05), yet it was determined to maintain semi-annual sampling at all of the WB wells due to qualitative considerations and to continue plume characterization in the immediate area of Building 90.

- *Increase sampling frequency due to statistical recommendations.* For example, well CS-11 was recommended for biennial sampling in the qualitative evaluation; however, the temporal evaluation revealed increasing lead concentrations trends downgradient. Therefore, the well was recommended for annual sampling in the summary evaluation.

In addition to the above situations, it should be noted that spatial statistical results obtained during the two vertical cross section analyses (shown with a ➔ or 🡅 in Table 7.1) were only applicable to the Westbay® and AOC-65 wells, and did not influence the summary result of the BS and CC wells included in the analysis.

A breakdown of the final well and frequency recommendations is shown in Table 7.2, along with the original 2004 sampling breakdown (shown in parentheses) for the on-post, off-post, AOC-65 area and WB wells.

TABLE 7.2
SUMMARY OF REVISED AND ORIGINAL MONITORING PROGRAM
3-TIERED LONG TERM MONITORING OPTIMIZATION
CAMP STANLEY STORAGE AREA, TEXAS

Type of Well	Monitoring Frequency						Total Sampling Points
	Not Sampled	Biennial	Annual	Semi-Annual	Quart-erly	After Rain Event	
On-post	1 (1)	13	11	16	(40)		**40 (40)**
Off-post		20	17(18)		7(26)		**44 (44)**
AOC-65	6				(8)	2	**2 (8)**
Westbay®				46		46 (46[b])	**46 (46)**
Total Wells	**7 (1)**	**33**	**28 (18)**	**52**	**7 (74)**	**48 (46)[c]**	**132 (138)**

[a] 2004 sampling frequency corresponding to Table 3.1 shown in parentheses.
[b] WB wells previously sampled monthly & after a rain event.
[c] WB wells sampled after rain event also sampled periodically not included in total sampling points.

The LTMO analysis supports the exclusion of well CS-3 that is currently not included in the monitoring program. In addition, the AOC-65 area piezometers are recommended for exclusion from the monitoring program, and the AOC-65 area monitoring wells are recommended to be sampled only after major rain events. All 46 WB sampling points are recommended to be reduced from monthly sampling to semi-annual sampling. The temporal and vertical cross section spatial analysis results could potentially be used to evaluate the importance of continued sampling within subzones.

For the on-post and off-post wells, the LTMO results indicate that a refined monitoring program consisting of the same 88 wells sampled less frequently (33 wells sampled biennially, 28 sampled annually, 16 sampled annually, and 7 sampled quarterly) would be adequate to address the two primary objectives of monitoring listed in Section 1. This refined on and off-post monitoring network would result in an average of 104.5 (49.5 on-post and 55 off-post) well-sampling events per year, compared to 242 (120 on-post and 122 off-post) well-sampling events per year under the 2004 monitoring program. Reducing WB sampling from monthly to semi-annually would reduce the number of sampling events from 528 to 88 events per year. A well-sampling event is defined as a single sampling of a single well. ***Implementing these recommendations for optimizing the LTM monitoring program at CSSA would reduce the number of on- and off-post well-sampling events per year by approximately 57% percent and the WB sampling events per year by approximately 88% percent.***

SECTION 8

REFERENCES

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