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Quality Assurance Project Plan
for
Mustard Gas Burial Ground Resource Conservation and Recovery Act Phase III RCRA Facility Investigation
Volume I of II

Naval Surface Warfare Center Crane
Crane, Indiana

Southern Division Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Orders 0131 and 0158

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QUALITY ASSURANCE PROJECT PLAN
MUSTARD GAS BURIAL GROUND
RESOURCE CONSERVATION AND RECOVERY ACT
PHASE III RCRA FACILITY INVESTIGATION

NAVAL SURFACE WARFARE CENTER, CRANE
CRANE, INDIANA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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ACRONYMS AND ABBREVIATONS

%R	percent recovery
AMSL	above mean sea level
AWQC	Ambient Water Quality Criteria
BERA	baseline ecological risk assessment
BG	background
bgs	below ground surface
BRA	baseline risk assessment
BTAG	Biological Technical Assistance Group
CAAA	Crane Army Ammunition Activity
CDI	chronic daily intake
CEC	cation exchange capacity
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
cm	centimeter
CMS	Corrective Measures Study
COC	chemical of concern or chain of custody
COPC	chemical of potential concern
cpm	counts per minute
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency exposure
CTO	contract task order
DO	dissolved oxygen
DOD	Department of Defense
dpm	disintegrations per minute
DPT	direct push technology
DQO	data quality objective
DRMO	Defense Reutilization and Marketing Operations
DUP	duplicate
ECBC	Edgewood Chemical Biological Center
EDQL	Ecological Data Quality Level
EF	equivalency factor

EM	electromagnetometer
EMR	environmental monitoring reports
EPA	Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
ESM	Environmental Site Manager
EU	exposure unit
FD	field duplicate
FID	flame ionization detector
FOL	Field Operations Leader
GC	gas chromatograph or gas chromatography
GC/MS	gas chromatograph/mass spectrometer or gas chromatography/mass spectrometry
GPS	Global positioning system
GW	ground water
HASP	Health and Safety Plan
HD	mustard gas
HHRA	human health risk assessment
HI	Hazard Index
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC	high performance liquid chromatograph (or chromatography)
HQ	Hazard Quotient
HSM	Health and Safety Manager
HWY	highway
IA	Installation Assessment
IAS	Initial Assessment Study
ICR	incremental cancer risk
ICP/AES	inductively coupled plasma/atomic emission spectrometer or inductively coupled plasma/atomic emission spectroscopy
IDEM	Indiana Department of Environmental Management
IDL	instrument detection limit
IDW	Investigation derived waste
kg	kilogram
L	liter
LCS	laboratory control sample
LOAEL	lowest-observed-adverse-effect-level
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual

MCL	Maximum Contaminant Level
MDA	Minimum detectable activity
MDL	method detection limit
mg	milligram
MGBG	Mustard Gas Burial Ground
MS	matrix spike
MSD	matrix spike duplicate
msl	mean sea level
NA	not applicable
NAD	Naval Ammunition Depot
NAVSEASYSCOM	Naval Sea Systems Command
NEESA	Naval Engineering and Environmental Support
NFA	no further action
NFEC	United States Navy Southern Division Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effects level
NRC	Nuclear Regulatory Commission
NSWC	Naval Surface Warfare Center
NTU	nephelometric turbidity unit
NWSC	Naval Weapons Support Center
ORNL	Oak Ridge National Laboratory
ORP	oxidation reduction potential
PARCC	precision, accuracy, representativeness, completeness, and comparability
PBA	Primary Burial Area
PCA	1,1,2,2-tetrachloroethane
PCB	polychlorinated biphenyl
pCi	picoCurie
PDS	post-digestion spike
PE	performance evaluation
PID	photionization detector
PM	preventive maintenance or Project Manager
PRG	Preliminary Remediation Goal
PVC	polyvinyl chloride
QA	quality assurance

QAM	Quality Assurance Manager
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RBC	risk-based concentration
RBSL	risk-based screening level
RBTL	risk-based target level
RCRA	Resource Conservation and Recovery Act
RCWM	recovered chemical warfare material
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
RfD	reference dose
RFI	RCRA Facility Investigation
RL	reporting limit
RME	reasonable maximum exposure
RPD	relative percent difference
RPM	Remedial Project Manager
RSK	R. S. Kerr Environmental Research Laboratory
RSO	Radiation Safety Officer
SAP	Sampling and Analysis Plan
SB	soil boring
SD	sediment
SDG	sample delivery group
SDWA	Safe Drinking Water Act
SED	sediment
SERA	screening-level ecological risk assessment
SIM	selective ion monitoring
SOP	standard operating procedure
SOUTHDIV	Southern Division
SOW	statement of work
SRM	Standard Reference Material
SS	surface soil
SSL	Soil Screening Level or Sediment Screening Level
SU	subsurface soil
SSO	Site Safety Officer
SSSL	Surface Soil Screening Level

SVOC	semivolatile organic compound
SW	surface water
SWLO	Southwest Laboratory of Oklahoma
SWMU	solid waste management unit
SWSL	Surface Water Screening Level
TAL	Target Analyte List
TBD	to be determined
TCE	trichloroethene
TNT	trinitrotoluene
TOC	total organic carbon
TOM	Task Order Manager
TOX	total organic halogen
TRV	Terrestrial Reference Values
TSS	total suspended solids
TtNUS	Tetra Tech NUS, Inc.
UCL	upper confidence limit
ug	microgram
uS	microSiemen
USACEWES	United States Army Corps of Engineers Waterways Experiment Station
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UXO	unexploded ordnance
VOC	volatile organic chemical
WQS	Water Quality Standard

1.0 PROJECT DESCRIPTION

This Phase III investigation is being conducted in accordance with applicable Resource Conservation and Recovery Act (RCRA) Corrective Action requirements, including the need for RCRA Facility Investigations (RFIs) to be conducted at the Naval Surface Warfare Center (NSWC) Crane, Crane, Indiana. Those requirements are specified in the NSWC Crane RCRA hazardous waste management permit originally issued on December, 29 1989 and renewed on September 14, 1995 (U.S. EPA, 1995b). This investigation will provide data on select organic and inorganic chemical concentrations in surface soils, subsurface soils, sediment, surface water and ground water at the NSWC Crane Mustard Gas Burial Ground (MGBG), which is also known as solid waste management unit (SWMU) 01/12. The MGBG is inactive, although environmental investigations have taken place at this SWMU as recently as 1995.

Documented burial of mustard gas (HD) bombs, thorium nitrate, and research and development chemicals occurred at the MGBG from after World War II into the 1960s. "HD" is a military designation for distilled mustard gas. "Mustard gas" is a misnomer because, at normal temperatures and pressures, HD is a viscous liquid rather than a gas. A "burster charge" in the mustard gas bomb causes the liquid to be dispersed in a fine mist which can then be inhaled directly as though it were a gas, and which settles on foliage to pose a dermal contact hazard. Thorium (a component of thorium nitrate) is naturally radioactive and could pose a radiological as well as chemical hazard if present in unacceptable quantities.

Exhumation of buried materials in 1974 and 1980 emphasized eliminating the threat of mustard gas and unexploded ordnance at SWMU 01/12. These burial and exhumation activities resulted in at least one release of HD to soil, which was subsequently decontaminated. Personnel involved with past exhumation operations believe that all HD releases have been cleaned up either through removal of contaminated media or decontamination of contaminated media, and that all buried ordnance has been exhumed and disposed of off site (see Appendix A). This is consistent with a 1995 geophysical survey, which indicates only two subsurface anomalies remaining at the site (United States Army Corps of Engineers Waterways Experiment Station [USACEWES], 1997). One of the anomalies is easily explained as a discarded horse trough and metal fence posts (Appendix A). The other anomaly is believed to be buried trash (Appendix A). Burial activities are described as having been of short duration with a hole being dug, material being dumped into the hole, and the hole being filled in with gravel or earth (Appendix A).

Despite the documentation of individual burial events and locations of buried material, a ground water monitoring program conducted from 1981 through 1986 identified halogenated solvents and other chemicals that are not specifically documented as having been disposed at SWMU 01/12. The presence

of these chemicals indicates that not all chemical releases at the MGBG have been documented with regard to nature and quantity of release. Additional information on historical site operations is provided in Section 1.3 of this Quality Assurance Project Plan (QAPP).

PROJECT PROBLEM STATEMENT

Because of known chemical releases (including at least one radioactive chemical) and at least one apparent undocumented release at the MGBG (stated above), human and ecological receptors could be exposed to unacceptable health risks caused by chemicals associated with operations at the MGBG. The health risks are expected to be confined primarily to aqueous and solid media because only minimal airborne release pathways (e.g., occasional minor resuspension of dust or release of volatile chemicals) are anticipated.

The degree of risk to a human or ecological receptor is determined based on the nature of contamination and the frequency, duration, and nature of exposure to contaminants. Consequently, it is important to understand where receptors could be exposed to the contaminants. This requires that the extent of contamination be established. In this context, extent will be established relative to numerical risk-based criteria. A risk evaluation will be conducted for human and ecological receptors in contaminated areas to determine whether risks posed by exposure of those receptors to site contaminants is unacceptable. Plausible land use scenarios were considered when identifying the receptors that could be at risk.

1.1 INTRODUCTION

NSWC Crane is a U.S. Navy installation located within U.S. Environmental Protection Agency (EPA), Region 5. TtNUS has prepared this QAPP on behalf of the U.S. Navy Southern Division Naval Facilities Engineering Command (SOUTHDIV) and NSWC Crane to comply with U.S. EPA Region 5 requirements. Those requirements, described in Section 1.1.3, govern all aspects of RCRA environmental investigations. In accordance with those requirements, project planning followed the U.S. EPA Data Quality Objectives (DQO) process (U.S. EPA, 2000). That process requires explicit statements of the problem to be solved, the spatial and temporal boundaries related to the problem, the measurements to be made in solving the problem and, when applicable, quantitative specifications of the tolerances for making decision errors. It culminates in a specification of decision rules and in a sampling and analysis plan designed to solve the stated problem.

This QAPP presents the project organization, objectives, planned activities, and specific quality assurance/quality control (QA/QC) procedures associated with sample collection and analysis for the

investigation. Specific protocols for sample collection, sample handling and storage, chain of custody, chemical analyses, and data evaluation and assessment are described. These protocols are specified to assure that the data generated during this investigation are of the expected quality necessary to support project objectives.

This QAPP was prepared under Contract Number N62467-94-D-0888, Contract Task Order (CTO) Number 0131. It was augmented under CTO 158/158A (see Section 1.1.4).

1.1.1 Project Objectives and Decision Statement

Past sampling, although limited, identified the presence of select contaminants at concentrations greater than proposed risk-based target levels (RBTLs) at the MGBG. RBTLs are further discussed in Section 1.4.1.2. However, the previously delineated extent of contamination could have expanded or diminished over the past 15 years. The extent that chemical releases have impacted surface water, sediment, and soils has not been determined. This investigation is designed to further delineate the nature and extent of contamination in surface water, ground water, soil, and sediment. It is also designed to implement a baseline human health risk assessment and a screening-level ecological risk assessment, including Navy Step 3A (see Section 1.4.3). Because of these two general objectives, two decision statements have been developed for this project, each of which applies to multiple environmental media. The decision statements that will facilitate attainment of the project objectives are as follow:

> From ground water, seep, surface water, soil, and sediment data, determine the nature and extent of chemical and radiological contaminant concentrations that exceed applicable screening levels in each environmental medium (surface soil, subsurface soil, sediment, ground water, and surface water).
>
> Determine whether contamination associated with the MGBG poses an unacceptable risk to human or ecological receptors through the use of a baseline human health risk assessment and a screening-level ecological risk assessment. If risks are unacceptable, consider conducting a baseline ecological risk assessment or implementing a Corrective Measures Study (CMS) to reduce the risks to acceptable levels. If risks are acceptable, take no further action.

1.1.2 Project Status/Phase

At least one round of sampling is expected for this investigation with additional sampling rounds possible to determine the extent of contamination. The need for additional sampling rounds will depend on

whether the extent of contamination is established within prescribed bounds during the first and subsequent sampling rounds. The strategy for all sampling rounds is similar when establishing extent of contamination. Chemical and radiochemical concentrations will be compared to appropriate risk-based concentrations and background (or upgradient/upstream) concentrations. The spatial regions in soils and ground water over which the chemical of potential concern (COPC) concentrations change from greater than numerical criteria to less than numerical criteria will be bounded. Appropriate risk-based concentrations and background (upstream/upgradient) concentrations are described in Sections 1.1.3 and 1.4.1.2. For surface water and sediment, establishing nature and extent of contamination will depend on the availability of surface water and sediment, because water is ephemeral and the drainage channels at the MGBG are well scoured.

The data analyses and approach to reconciling data with project objectives are described in Section 12.4 and throughout this document. Sections 1.5 and 4.0 present the sampling plan design and rationale for the number of soil samples for this project.

1.1.3 QAPP Preparation Guidelines

This QAPP has been prepared in accordance with the "U.S. EPA Region 5 QAPP Policy" (U.S. EPA, 1998b), which includes instructions for preparing RFI QAPPs. The "Example RCRA QAPP," included in the policy (U.S. EPA, 1998b), was followed closely. Also followed closely for establishing the QA/QC requirements specified in this QAPP was the Naval Facilities Engineering Service Center (NFESC) guidance document entitled "Navy Installation Restoration Laboratory Quality Assurance Guide" (NFESC, 1996). The NFESC guidance specifies criteria for acceptable laboratory performance and monitoring of that performance. U.S. EPA human health risk-based screening levels (RBSLs) and U.S. EPA Region 5 ecological data quality levels (EDQLs) were considered in developing this QAPP, especially when selecting sampling and analytical methods to measure target analyte concentrations in the media of interest. All QA/QC procedures are structured in accordance with applicable U.S. EPA Region 5 requirements, regulations, guidance, and technical standards.

Additional guidance regarding development of this QAPP was obtained through a formal "pre-QAPP" meeting associated with the "Base-wide Background Soil Investigation for NSWC Crane," held on 2 March 1999 at U.S. EPA Region 5 offices in Chicago, Illinois. Representatives from U.S. EPA Region 5, SOUTHDIV, NSWC Crane, and TtNUS met to introduce and discuss technical issues associated with QAPP preparation at that meeting. A followup telephone conversation among the same parties was conducted on 14 April 1999 to resolve outstanding issues. A pre-QAPP meeting was also held on 23 February 2000 specifically to reach agreement on the overall technical approach for this MGBG Phase

III RFI. The analyte lists were discussed, and the overall technical approach was agreed upon with minor changes. In a series of more recent conversations between the Navy and EPA Region 5 between October 2000 and April 2001 adjustments were made to the analyte lists and analysis strategy. Those minor changes and all other issue resolutions from previous discussions have been addressed in this document.

Comparability of soils inorganic chemical data between this investigation and the "Base-wide Background Soil Investigation for NSWC Crane" is important to interpreting the data and making background comparisons. Therefore, MGBG soil samples will be treated in a manner similar to those collected for the background investigation. Data comparability is discussed further in other sections of this QAPP.

1.1.4 Organization of the QAPP

This QAPP follows the U.S. EPA Region 5 model QAPP format with minor exceptions (U.S. EPA, 1998b). An effort has been made to ensure that the flow of information from one section to another is logical, while adhering to U.S. EPA Region 5 requirements. Project requirements are delineated in the QAPP body which includes Section 15.0, an addendum added in June 2001 that is specific to the excavation of two geophysical anomalies and which is funded under CTO 158/158A. The QAPP body is supplemented with detailed descriptions or collections of data in the appendices, including: a site reconnaissance report (Appendix A), historical data (Appendix B), risk-based screening levels used in deriving decisionmaking criteria (Appendix C), risk assessment methodologies (Appendices D and E), the project data management scheme (Appendix F), an example checklist for auditing field activities (Appendix G), and standard operating procedures (SOPs) governing field and laboratory activities (Appendices H and I). The Table of Contents provides an overview of the document organization. Tables and figures are placed at the end of each section in which they are first referenced.

1.2 SITE/FACILITY DESCRIPTION

This section is a presentation of background information, general site characteristics of the NSWC Crane facility, and physical site characteristics specific to the MGBG. It discusses such topics as site location, facility size and borders, natural and manmade features, climatology, topography, local hydrology and hydrogeology, surrounding land use, and ecological communities and habitats.

1.2.1 Location, Size and Borders

NSWC Crane is located in a rural, sparsely populated region of south-central Indiana, approximately 75 miles southwest of Indianapolis, 60 miles northwest of Louisville, Kentucky, and immediately east of Burns City and Crane Village, Indiana. A location map of the NSWC Crane facility is provided as Figure

1-1. NSWC Crane encompasses approximately 62,463 acres or approximately 98 square miles of the northern portion of Martin County and smaller portions of Greene, Daviess, and Lawrence Counties.

The MGBG is located in the southeast quadrant of NSWC Crane (a remote portion of the facility) adjacent to Crane Highway (HWY)-251 (a gravel road), which is accessible from the asphalt-paved Crane HWY-161 (Figure 1-2). The MGBG is located in the southwest quarter (SW ¼) of section 24, township T4N, range R4W (Lat. 38° 45' 55", Longitude 86° 48' 32") (USGS, 1978). It is an approximately 2-acre, almost rectangular area situated between two earth-covered, aboveground magazines (numbered 1407 and 1409), each of which is located at least 50 feet from the former MGBG fence line. Until April 1995, the MGBG area was bounded by a perimeter fence. In April 1995, the USACEWES removed the fence and most trees within the boundary in preparation for a geophysical survey to be conducted at the MGBG. To delineate the boundary of the MGBG after removal of the perimeter fence, one creosoted timber (corner post) was placed at each corner. Those corner posts were still present at the site in January 2000 as documented in Appendix A.

Located within the MGBG is the primary burial area (PBA), which is approximately 0.2-acre in size. This was the location of ordnance burials and most other known waste disposal activities. Although this area once shared its northern fence line with the MGBG, the primary burial area fence has been removed completely. Available documentation indicates that, based on past investigations and exhumations, no hazardous materials were buried outside of the PBA (NSWC Crane, 1980).

A previously identified chlorinated solvent plume in ground water was determined to extend at least 460 feet northwest from the MGBG. Chemical concentration data are discussed further in Section 1.3.4. The natural features of the MGBG have changed over the past 50 years. Some changes have been imposed (e.g., clearing of vegetation), while others have resulted from the natural succession of vegetation. Consisting of relatively dense brush and grasses, significant vegetation currently covers the MGBG.

1.2.2 Land Use Classification

The economic base of communities surrounding NSWC Crane is in transition from agriculture, mining, and quarrying to manufacturing and service industries. The patterns of settlement, population statistics, and median income are similar throughout the region (TtNUS, 2000a). Because most of the region is covered by vegetation, the area is classified as rural (TtNUS, 2000a).

There is no state or local planning within the vicinity of NSWC Crane. The only zoning and land use regulations are in the municipalities in the region. None of the municipalities are close enough to impact NSWC Crane. None of the areas adjacent to NSWC Crane are zoned, and zoning is not anticipated in the near future. No known land use or community actions are being considered or proposed at this time (TtNUS, 2000a).

1.2.3 Climatology and Meteorology

NSWC Crane is located in a warm, temperate climatic zone. In general, the summers are warm and humid, and winters are mild with occasional short cold periods. The temperature ranges from an average maximum July temperature of 89°F to an average minimum January temperature of 26°F. Precipitation is fairly evenly distributed throughout the calendar year, with the maximum precipitation occurring during the spring and early summer. The average annual precipitation at the facility is 44 inches, consisting of 42 inches of rain and 15 inches of snow. The average humidity ranges from 40 to 90 percent in summer and 60 to 90 percent in winter. Long-term climatological records for the area indicate that the monthly prevailing wind direction is from the southwest from April through December, and is from the northwest during January through March (National Oceanic and Atmospheric Administration [NOAA], 1988). The annual prevailing wind direction for the region is from the southwest, and the annual average wind speed for the area is about 9.6 miles per hour. Figure 1-3 is a wind rose summarizing the wind direction and mean wind speed distribution for the Indianapolis International Airport over a 5-year period (1985-1989).

1.2.4 Physiography, Topography and Ground Cover

NSWC Crane is located in the unglaciated area of the Crawford Uplands Physiographic Province. This province is a rugged, highly vegetated, dissected plateau bounded by the Mitchell Plain Physiographic Province to the east and the Wabash Lowland Physiographic Province to the west (Murphy and Wade, 1995). The Mitchell Plain is a low dissected limestone plateau characterized by sinkholes and karst topographic features. The boundary between the Crawford Upland and the Mitchell Plain is marked by the highly irregular, eastern-facing Chester Escarpment. Springs, caverns, caves, and other solution weathering features can be found along this escarpment and on the eastern edge of the NSWC Crane facility. The boundary between the Crawford Upland and the Wabash Lowland near the western boundary of NSWC Crane is gradual (Murphy and Wade, 1995). The terrain is predominantly rolling with moderately incised stream valleys throughout and occasional flat areas in the central and northern portions of NSWC Crane. The elevations across NSWC Crane range from about 500 feet above mean sea level (AMSL) to about 850 feet AMSL. Topographic relief in the Crawford Upland generally ranges from 100 to

350 feet. Greater relief exists in the eastern part of NSWC Crane near the Chester Escarpment (Murphy and Wade, 1995).

The MGBG lies on a northwest-southeast trending ridge crest. The surface elevation at the burial ground ranges from approximately 660 to 680 feet AMSL (Figure 1-4). A deeply-incised drainage channel lies about 525 feet north of the MGBG. The elevation along this channel is approximately 530 to 580 feet AMSL. Another deeply-incised channel lies about 1200 feet south-southwest of the MGBG, and its elevation is about 510 to 560 feet AMSL as it passes south of the MGBG. Total relief in the immediate vicinity of the MGBG is approximately 150 feet. The steepest slopes near the MGBG occur on the north side and are about 30 percent.

During a site reconnaissance on 18 January 2000 (Appendix A), the site was observed to be heavily vegetated with grasses and shrubs ranging from 1 to 5 feet high. The MGBG crowns at approximately 5 to 10 feet above the elevation of HWY-251. Some small saplings were scattered over the site, but they did not exceed about 7 feet in height except at the tree lines on the northern, eastern, and southern edges of the site. The areas east and west of the site are vegetated with a very dense cover of shrubs and grasses. The land rolls off to lower elevations on the northeast edge of the site and toward the southwest of HWY 251. At the northeast end of the MGBG northern edge was a mound of earth with some scrap material.

The area to the north (including the northeast corner of the site) is heavily wooded with mature deciduous trees including oaks, maples, sycamore, and American beech. The forest understory consisted of sparse patches of ground vegetation (i.e., ferns, grasses, moss). The drainage channel to the north was dry at the time of the site visit (except for some small pools of standing water). Based on the scoured nature of the channel, it appears to experience heavy flows during rain events. The stream bed was approximately 10 feet wide, and the substrate was sand and exposed rocks. Two primary drainage ditches (both dry) led from the site area down to this intermittent drainage channel.

Crude roads have been cut into the hillside north and west of the site for installation of ground water monitoring wells (Figure 1-5). As a result, terraces exist at various elevations on the north hillside of the site. The terraces are essentially parallel to the northern edge of the site, with wells located on each terrace. The terraces extend to the west of the site. Vertical distances between terraces are estimated to be about 10 to 25 feet. Access to the wells is good, with each terrace generally 8 feet to 15 feet wide, and only grass and dirt are present on the terraces. Two connecting roads, one located between the MGBG and Magazine 1409, and the other west of Magazine 1409, join the terraces in a vertical direction.

On the southeast side of the MGBG, between the MGBG and HWY-251, are a few scrap piles with asphalt, concrete, and earth visible among the trees. The piles were approximately 2 to 5 feet high. A drainage ditch immediately north of and parallel to HWY-251 lies between the road and the southern border of the MGBG. At least one culvert transports site runoff via the drainage ditch, under the road, and into the intermittent drainage channel located about 400 feet south-southwest of the MGBG. The ditch was dry at the time of the site visit. The south-southwest stream bed was not observed during the site reconnaissance because heavy vegetation and ice on the ground made the footing treacherous.

The area south of HWY-251 is heavily wooded with mature deciduous trees including oaks, maples, sycamore, and American beech. The forest understory consisted of vegetation including vines with thorns.

1.2.5 Geology and Stratigraphy

The unconsolidated overburden deposits at NWSC Crane generally range from 0 feet to 65 feet thick (Nohrstedt et al., 1998). These deposits generally consist of two types: Quaternary- and Pleistocene-age alluvial and colluvial deposits near the floodplains of streams, and unconsolidated residual soil and loess on sides and tops of ridges. The U.S. Department of Agriculture (USDA) has classified soils of Martin County (McElrath, 1988). Residual soils on or near the tops of ridges are generally classified as Zanesville or Wellston silt loams. These residual soils are characterized as well-drained to moderately-drained. They have a brown organic silt loam at the surface (typically about 8 inches thick), which is underlain by 42 to 48 inches of mottled tan, gray, and yellow clay with varying percentages of sand and silt. Occasionally, a clay hardpan occurs between 25 and 32 inches below ground surface (bgs). The Wells-Berks-Gilpin soil complex is found on all of the hillsides near the MGBG (McElrath, 1988). This soil complex forms on very steep to moderately steep slopes and is well drained. In a typical profile, 1 to 2 inches of dark gray to brown silt loam is found at the surface. The subsurface soil is composed of light to dark yellowish-brown, silty loam to silty clay loam. All of these soils contain about 15 percent to 35 percent clay.

Bedrock underlying the Crane facility consists of sedimentary rocks from the Lower Pennsylvanian-age Mansfield Formation (Raccoon Creek Group) and the Upper Mississippian-age Stephensport and West Baden Groups (Figure 1-6). The Mansfield Formation (uppermost bedrock) consists of alternating beds of shales (e.g., black shale and carbonaceous shale), sandstone, mudstone, siltstone, and thin discontinuous coal units and is typically about 110 feet thick or more (USACEWES, 1991). The Stephensport Group includes a number of sandstone and limestone formations, including the Big Clifty Sandstone and the Beech Creek Limestone (Figure 1-6). The Stephensport Group is generally 130 to

190 feet thick. The underlying West Baden Group also consists of limestone, shale, and sandstone units, and is generally 60 to 140 feet thick.

The base of the Mansfield Formation is probably at about 500 to 550 feet AMSL at the MGBG. Based on structural mapping of the Beech Creek Limestone, and the base of the Stephensport Group should be at about 400 to 420 feet AMSL near the MGBG (NEESA, 1983). The Upper Mississippian bedrock formations crop out near the bottom of the major stream channels. The sideslopes and upland areas over most of NWSC Crane are composed of Mansfield Formation, as shown in Figure 1-7. The bedrock formations dip west-southwest at about 25 feet per mile.

1.2.6 Hydrology and Hydrogeology

The surface drainage at NSWC Crane has formed a dense, dendritic pattern throughout the installation. Most of the major streams flow in a general southward or southwestward direction. Seven primary creeks in five drainage basins carry surface water off the installation, where they eventually drain into the East Fork of the White River and then to the Wabash River to the southwest. Figure 1-8 shows the basins and drainages of NSWC Crane. The MGBG is located in Drainage Basin IV. Runoff from the MGBG drains into two unnamed tributaries of Goldsberry Hollow, which drain west-southwest about 1.2 miles before they enter Boggs Creek (Figure 1-8). Boggs Creek then flows southward into a large reservoir located at the southern boundary of NWSC Crane. From the reservoir, Boggs Creek continues to flow south about 6 miles where it joins the East Fork of the White River. The Boggs Creek basin (Basin No. IV, Figure 1-8) drains roughly 70 percent of NWSC Crane.

Ground water in the unglaciated southwestern portion of Indiana is generally contained in fractures and joint openings of limestone and sandstone aquifers. Aquifers are generally isolated from one another vertically by less permeable shale and siltstone units. Ground water enters the aquifers as infiltration through outcrops, and flows by gravity down the dip of the strata or locally in directions controlled by the potentiometric gradients.

Shallow ground water flow patterns are expected to mimic topography; highest ground water elevations are typically found along ridge crests, and ground water flow is lateral toward the major stream or tributary valleys. Contours of ground water elevations measured at the MGBC on September 14, 1983, are presented in Figure 1-9. Recharge to the shallow ground water system occurs over most of the uplands and sideslopes. Ground water moves downward and then laterally, where it discharges to the deeper stream valleys as springs, seeps, and baseflow.

The measured depth to ground water at the MGBG generally ranged from 5 feet to 40 feet bgs, and averaged 15.5 feet bgs. Seasonal fluctuations of ground water levels rarely exceed 2 feet in individual wells. Past studies (Dunbar, 1984) at the MGBG have shown that ground water flow is to the north and northwest (Figure 1-9). There is presumably a downward hydraulic gradient at MGBG (Figure 1-10) that may have caused some contaminants to migrate vertically downward, but this has not been fully characterized. Based on the elevation of the study area relative to the surrounding area and the data shown on Figure 1-9, ground water may flow radially from the study area. This potential radial flow pattern requires that background samples for ground water not be collected immediately adjacent to the MGBG, but further away from the MGBG in areas that are known or suspected to be unaffected by the MGBG and other Navy operations.

1.2.7 Ecological Communities and Habitat

A biological characterization of NSWC Crane, including a listing of plants and animals found at the facility, is presented in the Installation Assessment (U.S. Army, 1978) and the Initial Assessment Study (IAS) (NEESA, 1983), and is summarized in the Environmental Monitoring Reports (Halliburton NUS, 1992a, 1992b and 1992c). Ecological receptors (listed in Section 1.4.3.1) that may inhabit NSWC Crane and are protected under the U.S. Endangered Species Act, Indiana Department of Natural Resources Heritage Data Center, or the U.S. Fish and Wildlife Service are listed by species in the RCRA Facility Permit (U.S. EPA, 1995b).

1.3 FACILITY HISTORY AND BACKGROUND

This section provides an overview of the site operations, summarizes past environmental investigations at the MGBG, and evaluates historical data gathered from the past investigations.

1.3.1 Facility Operational History

NSWC Crane provides materiel, technical, and logistical support to the Navy for equipment, weapons systems, and expendable and non-expendable ordnance items. Early in 1940, Congress passed the first supplemental National Defense Appropriation Act. This act provided $5 million for new inland ammunition production facilities, $3 million of which were earmarked to build a Navy ammunition depot at Burns City on the site of the White River Project. Factors weighing in favor of the Burns City site were a remote location that was free of congested areas, hilly terrain ideal for magazine construction and camouflage, Lake Greenwood which could supply water for the facility, and the distance from the eastern seaboard, thus minimizing the danger of enemy attack.

The facility was commissioned on 1 December 1941 as the Naval Ammunition Depot (NAD), Burns City. Its initial mission was to prepare, load, renovate, receive, store, and issue all types of ammunition, including pyrotechnics (i.e., flares) and illuminating projectiles, and act as a principal supply source at a most critical time—the early days of World War II. In May 1943, the depot was renamed the Naval Ammunition Depot, Crane, in honor of Commodore William Montgomery Crane, the Navy's first chief of the Bureau of Ordnance. The name changed again in 1975 to the Naval Weapons Support Center (NWSC) to reflect the facility's growing involvement in high-technology weapons systems. In 1977, the Secretary of Defense combined all conventional ammunition acquisition under the responsibility of a single service. The ammunition production and storage function was given to the Army, and the Crane Army Ammunition Activity (CAAA) was established as a Crane tenant to accomplish this task for Naval ammunition. In 1992, based on changing missions and alignment, the facility name was changed to the Naval Surface Warfare Center (NSWC) Crane.

The Army has assumed ordnance production, storage, and related responsibilities under the single-service management directive. All environmental activities on the installation, including permitting activities, remain the responsibility of the Navy. Although ordnance production and storage still resides on base, Crane serves a modern and sophisticated Navy as a recognized leader in diverse and highly technical product lines, such as microwave devices, acoustic sensors, small arms, and microelectronics technology. The Base has used and continues to use sealed radiological sources that are returned to the manufacturer for cleaning, recalibration, etc. All such sources are tracked and accounted for under normal operations. Some of the previously mentioned pyrotechnic devices contained radioactive thorium. The Army currently exists as a tenant activity on the base, as do all major branches of the Department of Defense, including the Coast Guard and the Defense Reutilization and Marketing Operations (DRMO).

1.3.2 Mustard Gas Burial Ground Operational History

The MGBG was used between the end of World War II and 1956 for disposal of materials such as mustard munitions and other select items (USACEWES, 1991). The disposals were in the form of shallow burials, typically within 5 feet of the surface. In addition, burial of aged laboratory chemicals is documented to have occurred in 1967. Three types of hazards have been identified at the site:

- Aerial mustard bombs (without the explosives)
- Thorium nitrate powder (in pyrotechnic flares)
- Unspecified laboratory chemical wastes

The thorium nitrate and illuminant material containing thorium or thorium salts was buried as waste from a research and development effort in the development of pyrotechnic devices. The unspecified chemical wastes are documented to have comprised "some ninety (few ounces each) quantities of aged laboratory chemicals on May 18, 1967" (Fitch, 1974). The disposal was designed to encourage decomposition of the small amounts of chemical waste by effecting close contact with soil and moisture.

Within the site are several burial areas that were marked or remarked in 1955 and 1956 with signs detailing the contents, or in some cases, the authority under which burial was performed. The signs marking these burial sites had limited details as to the buried contents. Those signs were removed during the exhumation activities described in the next section.

1.3.3 Waste Exhumation History

A chemical safety survey was conducted in March 1973 by the Department of Defense (DOD) Explosive Safety Board, which recommended that all hazards buried at the site be excavated so that the site could be certified safe (USACEWES, 1991). Two exhumations were undertaken to remove all buried hazards at the MGBG (U.S. Navy, 1980). The exhumation locations estimated from historical information are depicted on Figure 1-11. The first of these exhumation efforts took place in May 1974. This particular effort uncovered 10 aerial bombs (three of which contained chemical agent) and seven 55-gallon drums-worth of thorium nitrate-contaminated soil, illumination devices (i.e., flares), and other debris. HD was released to the ground from one bomb which was leaking. The released chemical agent was decomposed by reacting it with solid hypochlorite and hypochlorite solution. Vent pipes were placed in the excavation to release hydrogen chloride gas that is formed during the reaction, then the excavation was backfilled with earth. The evacuation of hydrogen chloride through the vent pipes helps to ensure complete decomposition of the HD. The bombs and radioactive materials were secured and placed into Magazine 1403 at the intersection of HWY-251 and HWY-161, approximately 0.5 miles southeast of the MGBG (U.S. Navy, 1974). No chemical or radiological releases are documented in relation to this transfer, and no such releases are suspected to have occurred. In 1975, all of the exhumed radioactive material was sent to a Nuclear Regulatory Commission (NRC)-licensed burial ground in Barnwell, South Carolina.

In 1980, three additional locations within the MGBG were identified to be thorium nitrate burial areas (U.S. Navy, 1980). On 15 September 1980, these three locations were targeted by the Naval Sea Systems Command (NAVSEASYSCOM) for exhumation. This particular exhumation effort proceeded through 24 September 1980. The goal of the exhumation effort was to properly remove the known material, rid the area of any chemical warfare weapons, and return the land to its original condition. During this effort, a

magnetometer survey was completed. Six additional empty bombs, one mustard gas identification kit, an unspecified quantity of thorium nitrate, and illumination candle debris were found and processed. The six newly exhumed bomb casings and original 10 aerial bombs exhumed in 1974 were dismantled, decontaminated using a steam cleaning and chemical soaking process, burned with thermite, and prepared for transport and disposal (U.S. Navy, 1980). Ultimate disposal was at the NSWC Crane landfill. The mustard gas identification kit is described as "...a chemical gas I.D. [identification] kit container which contained six ounces of HD in a laboratory glass flask with a glass stopper. This material was apparently a laboratory sample and totally unlike standard I.D. sets" (U.S. Navy, 1980). This identification kit was also processed by steam cleaning and decomposing the HD by soaking it in a hypochlorite solution, followed by thermite burning and disposal (U.S. Navy, 1980).

As a result of these exhumation efforts, the MGBG was cleared for future investigations, with the assurance that all ordnance items had been removed from the site and the risk of exposure to live mustard agent was extremely small (U.S. Navy, 1980). A copy of a memorandum from the NSWC Crane Explosives Safety Officer specifying these assurances is provided in Appendix A. Also included in Appendix A is a memorandum from the NSWC Crane Explosives Safety Officer identifying one of two anomalies found during the 1995 USACEWES geophysical survey.

1.3.4 Evaluation of Historical Data

As outlined previously, multiple environmental investigations and surveys have been conducted at the MGBG. These past investigations are summarized in Table 1-1. No soil samples from the site are known to have been analyzed in a laboratory. Field testing for mustard gas and soils screening for gamma radiation were performed during previous waste exhumations.

In 1981, a ground water (GW) monitoring program was undertaken with the installation and sampling of five monitoring wells. Between 1982 and 1983, 12 additional wells were installed and sampled. In 1983, 10 more wells were installed and sampled. Another well was added prior to 1993, bringing the total number of monitoring wells at the MGBG to 28. Since 1986, none of the wells at the site have been sampled.

The locations of these wells are shown on Figure 1-5. The "WES" numbering scheme for 27 of the wells identifies them as having been installed by the USACEWES. The numbers following "WES" indicate the site ("01" followed by a hyphen), the sequential well number (next number followed by a hyphen), and the two-digit year of well installation. The numbering scheme was later changed to indicate the same information in the following format: Site identifier (two digits), well installer code (e.g., "C" for

USACEWES), two-digit sequential well number followed by a hyphen, and the two-digit year of well installation.

A summary of available ground water analytical results is presented in Table 1-2, and the data are presented in Appendix B. Several halogenated solvents have been detected in the wells, particularly trichloroethene (TCE) and 1,1,2,2-tetrachloroethane (PCA). Figure 1-5 shows historical ground water sampling locations at the MGBG and summarizes total organic halogen (TOX) analytical results. Because several chlorinated and brominated organic compounds were detected in the wells, TOX values are listed on Figure 1-5, rather than individual analyte concentrations, to indicate the general levels of contamination in each well. Based on the concentrations of individual compounds (Table 1-2) and the TOX data (Figure 1-5), the highest levels of contamination were found in well WES 1-2-81, located about 40 feet north of the MGBG perimeter. Chlorinated organic compounds were found in many other wells to the north, northwest, and west of the burial ground. The concentrations of volatile chemicals in well WES 1-2-81 appear to have decreased between 1982 and 1984. The concentrations generally decreased in a northwesterly direction, which corroborates the expected northwesterly ground water flow direction.

The ground water well chemistry data is more than 15 years old, and no quality control data are available as a means to assess the data quality. Therefore, the ground water data have been used only to support project planning for additional data collection and will not be used to make project decisions related to the current nature and extent of contamination or to human health or ecological risk. For similar reasons, radiological data from past investigations have also been used only to support project planning.

Geophysical surveys conducted in conjunction with past exhumations (1974 and 1980) no longer reflect site conditions because the conditions were changed by the exhumations. The associated exhumation reports were used to corroborate site boundaries but will not be used to assess the nature and extent of contamination or human health or ecological risk.

In 1995, a comprehensive surface geophysical survey was performed over the entire MGBG area (USACEWES, 1997). The equipment used to conduct the 1995 investigation included an electromagnetometer (EM) 31, an EM 61, and GEM Systems GSM-19. The EM 31 measures two components of an induced magnetic field: the quadrature phase component and the inphase component. The EM 61 is a metal detector capable of detecting both ferrous and nonferrous metallic objects, and the GSM-19 measures the total field intensity of the local magnetic field. The investigation identified two strong anomalies and a linear array of small regular-spaced anomalies. The first strong anomaly was approximately 10 feet in diameter and 1 to 2 feet deep. It was believed to have been caused by ferrous material because it was also detected by the magnetometer. The second strong anomaly was smaller,

approximately 2 to 3 feet in diameter and caused by nonferrous metallic material, and it was interpreted to be approximately 1.5 feet deep. The series of small anomalies was detected along an old fence line, and led to the conclusion that the anomalies were caused by the remnants of metal fence posts, consistent with the regular spacing of the anomalies.

A review of the 1995 USACEWES geophysical survey was conducted recently to evaluate whether additional geophysical surveys would be warranted during this Phase III RFI. With the assurances outlined in the memorandum from the NSWC Crane Explosives Safety Officer (Appendix A), the review concluded that no additional geophysical investigations are needed. However, as a precautionary measure, geophysical surveys by trained unexploded ordnance (UXO) personnel are warranted at sampling locations within the former MGBG fence line during this Phase III RFI to address localized anomalies during intrusive activities.

1.3.5 Current Site Status

No chemical burials at the MGBG are documented to have occurred since 1967. Nevertheless, the potential exists for chemicals to have been released since that time because the MGBG is in a remote location of NSWC Crane and some debris piles are evident (Appendix A). Moreover, Figure 1-5 indicates that elevated concentrations of organic solvents were detected in ground water at the MGBG from 1981 through 1986. Because of ground water movement and natural degradation of organic chemicals in the environment, it is expected that the contaminant plume configuration and concentrations of organic chemicals have changed. Similar expectations are held for inorganic chemicals disposed of at the site, especially because of chemical migration that would be caused by rain water percolating through the soil and subsequent ground water transport. While the limited chemical data support ground water flow expectations, chemical contamination at this site could be quite varied in nature.

Based on the 1995 geophysical survey review described in Section 1.3.4, the 1995 USACEWES geophysical survey is expected to represent current site geophysical conditions. The two identified geophysical anomalies are tentatively attributed to a 10-foot-diameter metal horse tub and steel fence posts discarded in one of the exhumation locations, and another metallic object of unknown origin and composition also unrelated to ordnance (Appendix A). Accordingly, the expectation of encountering buried ordnance at the MGBG, including mustard gas-related ordnance, is low. It follows that the chance of encountering hazardous concentrations of mustard gas is also low. The chance of encountering hazardous concentrations of thorium is assumed to be greater because of a potential for thorium nitrate to have been discarded directly on the ground and to have sorbed strongly to the soil. Precautions will be taken to ensure the safety of site workers during sampling events with regard to all reasonably potential

hazards, including the potential for exposure to unexpected concentrations of mustard gas and radiochemical hazards. These preconditions include screening for HD and radiation hazards and a requirement to wear personal protective equipment commensurate with the potential hazards. The reader is referred to the appended health and safety plan (HASP) (TtNUS, 2001).

Exhumations involved the backfilling of some excavation areas with earth and gravel (Fitch, 1974). This large-grained backfill could provide a conduit for chemical migration to deeper soils and even ground water. The earth and gravel are expected to have been relatively free of contaminants, although this is not documented.

Recent communications with the Indiana Department of Public Health, the Nuclear Regulatory Commission and the Navy Radiological Affairs Support Office were initiated to determine whether radionuclides other than those associated with natural thorium are likely to have been buried at the MGBG. Burial of such other radionuclides is unlikely but has not been ruled out with certainty.

1.4 INTENDED DATA USES

This section provides a detailed description of the project target parameters and intended data uses.

1.4.1 Project Target Parameters

Table 1-3 summarizes project target parameters for each medium (ground water, surface water, surface soil, subsurface soil, and sediment) and the associated intended data uses. The specified data uses are linked to the decision statements presented in Section 1.1.1. Data used to determine the nature and extent of contamination will also be used to evaluate human health and ecological risk. While anthropogenic non-thorium radionuclides are not expected at the MGBG, nonthorium-related radionuclides will be investigated. Gamma spectrometric analysis of soils will be conducted to test the assumption that thorium and its radioactive daughters are the only radionuclides buried at the MGBG.

All field and laboratory target parameter results greater than or equal to method detection limits (MDLs) will be reported. MDLs for field parameters are based on method or test kit capabilities and specifications. Analytical results for analytes that are less than applicable MDLs will be reported with a "U" flag. The "U" flag signifies that the parameter was analyzed for but was not detected at a concentration greater than or equal to the MDL. Laboratory MDLs are based in part on best professional judgment and on statistical computations in accordance with 40 Code of Federal Regulations (CFR) Part 136, Appendix B. Sample-specific laboratory MDLs will be computed for each sample to account for variations in the MDL that are

caused by factors such as sample moisture content, the size of the sample aliquot used in the analysis, and dilutions. This reference requires the MDL to be computed as the standard deviation of replicate analysis results multiplied by the appropriate Student's t-value (see SWLO SOP GA-113 in Appendix I). Minimum detectable activities (MDAs) for radiochemical analyses are computed in accordance with SOP RA-122, which is found in Appendix I and are dependent on laboratory background activities and radiochemical counting times.

1.4.1.1 Field Parameters

Several field measurements will be made for this investigation. As previously noted, Table 1-3 summarizes all project target parameters and the associated intended data uses. Table 1-4 also indicates which measurements will be made in the field and presents MDLs, as applicable, for the aqueous target parameters measured in the field.

1.4.1.2 Laboratory Parameters

Laboratory analyses will be used to estimate target analyte concentrations in ground water, surface water, surface soil, subsurface soil, and sediment. Use of target analyte data for decisionmaking is described in Sections 1.4.2, 1.4.3, 1.4.4, and 12.4.

Part of the data use includes comparing metal concentrations in soil at the MGBG to soil background concentrations. However, the background concentrations will not be known until the "Base-Wide Background Soil Investigation for NSWC Crane" is completed. The anticipated completion date for that investigation is Summer 2000.

The data use also includes comparing the analytical data to risk-based target levels (RBTLs), which are action levels derived from human health and ecological risk-based screening levels (RBSLs). The RBTL is the lowest (i.e., most conservative) RBSL. Following is a list of sources for the RBSLs applicable to this project:

<u>Ground Water and Surface Water RBSLs</u>

- Federal Maximum Contaminant Levels (MCLs)
- U.S. EPA Region 9 Preliminary Remediation Goals (PRGs) for Tap Water
- Indiana Department of Environmental Management (IDEM) Tier I Default Residential and Commercial/Industrial Ground Water Closure Levels

- U.S. EPA Region 5 Ecological Data Quality Levels (EDQLs) for Surface Water
- Federal Ambient Water Quality Criteria (AWQC) for Freshwater
- PRGs for Radiologicals Assuming Receptor Exposure to Tap Water (calculated per methodology presented in RAGS Part B)

The same list of RBSLs will be applied to both ground water and surface water because ground water discharges to surface water at the MGBG.

Soil and Sediment RBSLs

- U.S. EPA Generic Soil Screening Levels (SSLs) for Ingestion, Inhalation, and Migration to Ground Water
- U.S. EPA Region 9 PRGs for Residential and Industrial Land Use
- IDEM Tier I Default Residential and Commercial/Industrial Soil Closure Levels
- U.S. EPA Region 5 EDQLs for Soil (applicable to surface soil samples only)
- U.S. EPA Region 5 EDQLs for Sediment (applicable to sediment samples only)
- PRGs for Radiologicals Assuming Receptor Exposure to Soil (calculated per methodology presented in RAGS Part B)

Tabular presentations of the RBSLs are provided in Appendix C. Table 1-5 lists the laboratory parameters, analytical methods, laboratory detection and reporting limits (RLs), and RBTLs for water (applicable to both ground and surface water), soil, and sediment. MDLs are generally less than reporting limits. Measurement uncertainty is so great at concentrations less than the MDL that the presence of an analyte cannot be asserted with reasonable confidence in that concentration range. Thus, results less than the MDL represent analytes that are classified as "non-detects." As concentration increases, the *relative* measurement uncertainty typically decreases up to the RL. Analyte concentrations greater than RLs are generally reported with a relatively high degree of accuracy (i.e., the reported value is within about 20 or 30 percent of the true value). The uncertainty varies from analyte to analyte and is not typically quantified for individual analytes. The uncertainty associated with results between the MDL and RL is comparatively high, but also varies from analyte to analyte. This can cause problems when interpreting data, especially when comparing two values. However, the decision to report to concentrations as little as MDLs was made to provide the greatest chance for achieving the RBTLs in Table 1-5. Despite this relatively aggressive reporting convention, several RBTLs in both aqueous and solid media are still unattainable. TtNUS has worked closely with the subcontracted analytical laboratories to select and optimize analytical methods in an effort to attain, to the greatest extent possible,

laboratory MDLs (or even RLs) that are less than or equal to the RBTLs. Analytes for which the MDL is greater than the RBTL for either aqueous or solid matrix are identified in Table 1-5 with an asterisk.

The classification of a chemical as "not detected" does not necessarily mean that the chemical is "absent." Moreover, if the detection limit for a chemical is greater than the RBTL the chemical could go undetected yet be present at the site at a concentration greater than or equal to the RBTL. This concern was addressed in a phone call on 13 June 2000 involving the U.S. EPA Region 5, the Navy, the ECBC laboratory and TtNUS. The discussion centered around the fact that many MDLs listed in Table 1-5 exceed the corresponding RBTLs. Agreement was reached that a good faith effort has been made to establish MDLs low enough to meet RBTLs and that the MDLs listed in Table 1-5 represent the best reasonable effort with current technology to achieve MDLs equal to or less than RBTLs. Also acknowledged was that other pertinent factors should be considered when evaluating site data for decisionmaking. Those factors include the frequency at which a particular chemical is detected, the absolute concentration of the chemical, the spatial distribution of the chemical, and the applicability of the listed RBTL. The potential need to consult an ecologist was raised because many RBTLs reflect ecological data quality levels that are less than human health risk-based levels. For this project, an ecological risk assessor will be consulted in lieu of an ecologist. The consensus opinion was that the risk assessors will consider the pertinent factors listed above when conducting the risk assessment. Part of those considerations may be the inclusion of more than one risk scenario. One scenario would correspond to the use of the conservative RBTLs listed in Table 1-5, and another scenario would likely include a less conservative but potentially more realistic site-specific exposure scenario that would correspond to greater risk-based values that more closely match the achievable MDLs.

1.4.2 Human Health Risk Assessment

A Baseline human health risk assessment will be prepared to estimate risks to current or hypothetical future receptors at the MGBG. Consideration of human health risks from exposure to potentially contaminated environmental media is required and supports the decision statements presented in Section 1.1.1. The baseline risk assessment will evaluate both chemical and radiological COPCs selected for the environmental media samples.

This section presents an overview of the risk assessment methodology, including a conceptual site model (CSM) that will be used to evaluate chemical concentrations in environmental media for the RFI at the MGBG. The detailed risk assessment methodology is presented in Appendix D. The methodology considers risk assessment protocols established by U.S. EPA Region 5 and the IDEM. The following components of a baseline risk assessment (BRA) are addressed:

- Data Evaluation Protocol (including data usability assessment; COPC selection)
- Exposure Assessment (including CSM)
- Toxicity Assessment
- Risk Characterization
- Uncertainty Analysis

Relevant human receptors, exposure units (EUs), and decision rules are discussed. The exposure units represent the areas or volumes of potentially contaminated environmental media to which receptors can be exposed. The decision rules specify how data will be used to evaluate risks to receptors that are exposed to contaminants.

1.4.2.1 Data Evaluation Protocol

Data evaluation, the first component of a baseline human health risk assessment, is a two-step, media-specific task involving the compilation and evaluation of analytical data. The first step involves the compilation of the analytical database and an evaluation of data usability for purposes of human health risk assessment. (A "data usability" evaluation is recommended in U.S. EPA RAGS Part D). The second step of the data evaluation is the selection of a medium–specific list of COPCs, which will be used to quantitatively or qualitatively determine potential human health risks for site media. COPCs are selected based on a comparison of site contaminant concentrations to conservative toxicity screening values and background (or upstream/upgradient) concentrations. The following standards, criteria, and risk-based concentrations (RBCs) will be used as the basis of the toxicity screening values:

- Federal Safe Drinking Water Act (SDWA) MCLs for Public Drinking Water Supplies
- U. S. EPA Region 9 PRGs for Tap Water and Soil
- IDEM (Tier I Default Closure Levels (soils/ground water) for Residential Land Use
- U. S. EPA Soil Screening Levels for Soil Ingestion, Transfer from Soils to Air, and Migration from Soils to Groundwater

These standards, criteria, and RBCs are referenced and defined in Appendix C.

1.4.2.2 Exposure Assessment Protocol

The exposure assessment component of a baseline human health risk assessment defines and provides a means to evaluate, quantitatively or qualitatively, the type and magnitude of human exposure to

chemicals present at or migrating from a site. A foundation of the exposure assessment is the CSM, which identifies site characteristics including potential contaminant sources, contaminant release mechanisms, transport routes, receptors, and other appropriate information. The CSM must consider both current and future land use. (A detailed CSM discussion is presented in Appendix D). Estimated chemical and radiological intakes developed during the exposure assessment are evaluated in the risk characterization to produce quantitative estimates of cancer and non-cancer risk.

Sources of Environmental Contamination

Based on historical site data and sampling, the following parameters are among the site-related chemical and radiological contaminants known to be present or potentially present in environmental media within the study area:

- Mustard gas and its degradation products (1,4-thioxane; 1,4-dithiane; and thiodiglycol)
- Thorium nitrate, other metal salts, and other laboratory chemicals
- Volatile organic chemicals (VOCs) including but not limited to 1,1,2,2-trichloroethane, 1,2-dichloroethane, bromoform, dibromochloromethane, and trichloroethene

Potential Contaminant Migration Routes

Based on available historical information and a review of the existing (but limited) ground water data for the site, a release of hazardous constituents to environmental media has occurred as a result of historical site operations. For example, the existing historical ground water data indicate the presence of several halogenated VOCs at concentrations exceeding 1000 micrograms per liter (µg/L). These data indicate that VOCs may have been disposed of at (or upgradient of) the study area and have migrated to the ground water via infiltration and percolation. Depth to ground water ranges from 5 feet to 40 feet bgs across the MGBG. The shallower water depths may facilitate transport of chemicals from soils to ground water. The study area is a ground water recharge area. Based on the elevation of the study area versus the surrounding area and the historical ground water data, ground water may flow radially from the MGBG.

Assuming that surface and subsurface soil contamination has occurred as a result of waste disposal at the MGBG and that contaminants have migrated to ground water, additional plausible contaminant release and migration mechanisms are as follow:

- Discharge of ground water to surface water and sediments, such as the intermittent drainage channels north and south of the MGBG.

- Surface water and sediment runoff to the drainage culverts and intermittent drainage channels north and south of the MGBG. (On-site surface soil contaminants may also migrate to off-site soils as a result of overland flow of surface waters)

- Migration of contaminants in ground water (i.e., lateral migration) to potential receptor locations beyond the MGBG boundary and the NSWC Crane boundary.

- Migration of fugitive dusts and VOCs from surface soils (and subsurface soils if construction/excavation activities occur).

Potential Current and Future Receptors of Concern and Exposure Pathways

NSWC Crane is an active naval base and will remain active for the foreseeable future. The MGBG is no longer used as a disposal area and is likely to be used for military or recreational purposes in the future. However, for purposes of completeness, the baseline risk assessment will consider receptor exposure under residential, industrial, and recreational land use scenarios. Based on current and potential future land use, the following potential receptors may be exposed to contaminated environmental media at the site:

- Trespassers – A plausible receptor under current and future land use. Although access to the base is controlled, once inside the base access to the site is not limited by any physical constraints (the fence at the MGBG has been removed). In addition, hunting activities are permitted at the base. Because the site is remote and surrounded by forested areas, hunters (particularly adolescents) may trespass onto the site. This receptor may be exposed to potentially contaminated surface soil (0 to 2 feet bgs) (incidental ingestion; dermal contact), air (inhalation), surface water (dermal contact), and sediments (incidental ingestion; dermal contact) in the intermittent streams. However, because of the intermittent nature of the streams, exposure to surface waters and waterborne sediments is likely to be very limited. Direct contact with ground water or subsurface soils is not anticipated for this receptor.

- Maintenance Workers – A likely receptor under future land use. This includes adult military or civilian personnel assigned duties within the MGBG (e.g., groundskeeping activities). This receptor could be exposed to surface soils (incidental ingestion; dermal contact) and air (inhalation). Direct contact with

ground water or subsurface soils or exposure to surface water or sediments is not anticipated for this receptor.

- Construction Workers – A plausible receptor under future land use. No construction activities are currently planned at the MGBG. Additionally, the shallow depth to ground water in some sections of the MGBG area would likely preclude excavation and construction. However, excavation and construction is plausible in other sections of the MGBG area. Consequently, this receptor could be exposed to surface and subsurface soils (to an estimated maximum depth of 10 feet bgs) (incidental ingestion; dermal contact), ground water (dermal contact), and air (inhalation). Exposure to surface water and sediments is not expected for the construction worker.

- Occupational Worker – A plausible receptor under future land use. This includes adult military or civilian personnel assigned to work at the former MGBG. This receptor could be exposed to surface soil (incidental ingestion; dermal contact) and air (inhalation). It is anticipated that this receptor would not be exposed to subsurface soils, ground water, surface waters, or sediments. This receptor is expected to be exposed on a more frequent basis than the maintenance or construction worker.

- Recreational Users – A plausible receptor under future land use. If NSWC Crane were to close, the most likely scenario is that the property would be converted to a park. A recreational user may be exposed to potentially contaminated surface soil (0 to 2 feet bgs) (incidental ingestion; dermal contact), air (inhalation), and surface water (dermal contact) and sediments (incidental ingestion; dermal contact) in the intermittent streams. However, because of the intermittent nature of the streams, exposure to surface water and waterborne sediments is expected to be very limited. Direct contact with ground water and subsurface soils is not anticipated for this receptor. NSWC Crane is not expected to close because principal Base operations, the demilitarization of munitions, are critical to the support of the U.S. Naval fleet.

- Residents – An unlikely receptor under future land use. Although this scenario is highly unlikely, a future residential scenario is typically evaluated in a risk assessment for decisionmaking purposes. For example, the need for deed restrictions at a site may be eliminated prior to site closure if minimal risks are estimated for residential receptors. It is assumed that a hypothetical resident may be exposed to surface soils over a 2-acre area or larger (incidental ingestion; dermal contract), ground water (ingestion, dermal contact), surface water (dermal contact), air (inhalation), and sediment (incidental ingestion; dermal contact).

In addition to the preceding exposure pathways, the baseline risk assessment will evaluate direct radiation exposure to radiological COPCs in surface and subsurface soils. Details regarding the assumed receptor characteristics (e.g., intake rate, frequency, duration of exposure) are defined in Appendix D, which presents the methodologies for human health risk assessment.

Calculation of Exposure Point Concentrations

The exposure point concentration (EPC), which is calculated for COPCs only, is an estimate of the chemical and radionuclide concentrations within an EU likely to be contacted over time by a receptor and is used to estimate exposure intakes. The following paragraphs discuss the EUs to be evaluated and the guidelines for calculating the EPC.

The entire MGBG plus an area extending approximately 20 feet in all directions (approximately 2 acres) will be considered the EU for soils. Surface soils will extend to a depth of 2 feet; subsurface soil will be all soil from a depth of 2 feet to 10 feet or bedrock, whichever is shallower. A 2-acre EU area is considered a reasonable EU size based on the current and anticipated land use for the study area (i.e., military/industrial) and the rural nature of the area surrounding the base (i.e., farmland). The 20-foot extension of the MGBG perimeter facilitates the assessment of contamination that extends beyond the former MGBG fence line, but does not extend so far into expected uncontaminated regions that the EU concentrations are artificially reduced. Additional EUs may be defined if, based on the first soil sampling event, significant soil contamination is noted beyond the MGBG study area.

As detailed below, the EPC for a receptor hypothetically using or otherwise exposed to ground water underlying the MGBG study area will be the arithmetic average of wells in the highly concentrated area of the plume potentially underlying the study area. If it is determined that a ground water contaminant plume is or may be moving beyond the study area boundaries, EPCs for ground water at receptor locations beyond the study area may be estimated using modeling techniques or by installing and monitoring additional wells. These ground water receptor locations may include the study area boundary and the facility boundary. The locations will be selected, if necessary, based on the concentrations detected within the MGBG area (i.e., the observed or potential contaminant loading to or within the ground water aquifer), the aquifer characteristics (e.g., flow, direction), and the chemical and physical nature of contaminants detected in the ground water. The U.S. EPA Region 5 will be consulted when making these decisions.

The EU for receptors potentially exposed to surface waters and sediments will include all sampled locations in the drainage ditches and streams downstream of the MGBG. The EU for surface waters and

sediments is likely to include the two or three depositional areas proximal to, but downstream of, the study area. It is assumed that the depositional areas will be separated by at least 100 feet. Additional EUs may be defined if, based on the first surface water and sediment sampling event, significant sediment contamination is noted beyond the MGBG study area.

The following guidelines will be used to calculate the EPCs:

- If a soil, surface water, or sediment data set for an EU contains fewer than 10 samples, the EPC for the reasonable maximum exposure (RME) and central tendency exposure (CTE) case will be defined as the maximum detected concentration.

- If a soil, surface water, or sediment data set for an EU contains 10 or more samples, the 95 percent upper confidence limit (UCL) on the arithmetic mean, which will be based on the distribution of the data set, will be selected as the EPC for the RME and CTE case. Conventional statistical methods (e.g., the Shapiro-Wilk W-Test, the *t*- and *H*-statistic based UCL calculation) will be used to determine the distribution and UCL. The "best fit" distribution (normal or lognormal) will be assumed if the data set distribution is undefined. However, the EPCs calculated assuming a lognormal distribution will be reviewed and re-calculated (if necessary) as recommended in a recent EPA reference to assure that the *H*-statistic based UCL is not an over-prediction of the EPC (U.S. EPA, 1997b). If the calculated 95 percent UCL exceeds the maximum detected concentration, the maximum concentration will be used as the EPC. If enough data are available and a qualified statistician judges bootstrapping to present a more realistic estimation of risk, the bootstrapping technique described in the U.S. EPA 1997 reference will be used.

- Assuming that multiple rounds of ground water samples will be collected from site monitoring wells, and that no temporal concentration trend is obvious, the EPC for a ground water receptor will be the arithmetic average of wells in the highly concentrated area of the plume. If a temporal trend is noted, the EPC will be based on the most recent ground water sampling event only.

Sample and duplicate analytical results will be averaged for statistical use. Data values less than sample-specific detection limits will be substituted with one-half the detection limit. It should be noted that EPCs for ground water may also be developed for specific receptor locations (e.g., the facility boundary), as necessary, using ground water modeling techniques.

Chemical and Radionuclide Intake Estimation

The methodologies and techniques used to estimate exposure intakes are presented in Appendix D of this QAPP. Intakes for the identified potential receptor groups will be calculated using current U.S. EPA risk assessment guidance and presented in the risk assessment spreadsheets. Risk assessment results will be presented using the U.S. EPA RAGS Part D tables format.

1.4.2.3 Toxicity Assessment Protocol

The objective of a toxicity assessment is to identify the potential for human health hazards and adverse effects in exposed populations. Quantitative estimates of the relationship between the magnitude and type of exposures and the severity or probability of human health effects will be defined for the identified COPCs. Quantitative toxicity values (cancer slope factors [CSFs] and reference doses [RfDs]) determined during this component of the risk assessment will be integrated with outputs of the exposure assessment to characterize the potential for adverse health effects for each receptor group. The literature sources for the oral and inhalation toxicity criteria are identified in Appendix D. Methodology that will be used to calculate toxicity criteria for the dermal route of exposure is also presented in Appendix D.

1.4.2.4 Risk Characterization Protocol

Potential risks (noncarcinogenic and carcinogenic) for human receptors resulting from the potential exposures outlined in the exposure assessment are quantitatively determined during the risk characterization component of the baseline human health risk assessment (HHRA). Both RME and CTE estimates will be generated. The quantitative estimates of risk are calculated in accordance with the risk assessment methods outlined in U.S. EPA guidance (U.S. EPA, 1989). Lifetime cancer risks are expressed in the form of dimensionless probabilities, referred to as incremental cancer risks (ICRs), based on CSFs. For example, a cancer risk estimate (ICR) of 1×10^{-6} indicates that an exposed receptor has a one-in-one-million chance of developing cancer, in addition to the cancer risk from non-site-related contaminants. Noncarcinogenic risk estimates are presented in the form of a Hazard Quotient (HQ) that is determined by computing the ratio of an intake for a COPC with an appropriate published RfD for the COPC. (A Hazard Index [HI] is generated by summing individual HQs for all COPCs). Carcinogenic and noncarcinogenic risk estimates are calculated per the equations presented in Appendix D.

To interpret the quantitative risk estimates and to aid risk managers in determining the need for remediation, quantitative risk estimates will be compared to typical EPA risk benchmarks. The U.S. EPA has defined a "target cancer risk" range of 1×10^{-4} to 1×10^{-6} (i.e., a one-in-ten-thousand to one-in-one-

million chance of developing cancer). HQs and HIs are typically evaluated using a value of 1.0. Generally, adverse noncarcinogenic health effects are not anticipated if an HQ or HI, developed on a target organ/effect-specific basis, does not exceed 1.0.

As a general guideline, a "no further action" recommendation will be forwarded to the Navy, the State of Indiana, and the EPA, if the cancer risk estimates and total HIs (developed on a target organ/target effect basis) for receptors of concern do not exceed $1x10^{-4}$ and 1.0, respectively. Otherwise, the need for remedial action (including institutional controls) will be evaluated in the Corrective Measures Study (CMS). However, as indicated in EPA RAGS Part D, the upper boundary of the acceptable risk range is not a discrete limit at exactly $1x10^{-4}$. "Risks slightly greater than $1x10^{-4}$ may be considered to be acceptable (i.e., protective) if justified based on site-specific conditions, including any uncertainties about the nature and extent of contamination and associated risks." Consequently, a "no further action" recommendation may forwarded even when the $1x\ 10^{-4}$ risk benchmark is exceeded. The following factors will be considered in this determination:

- The magnitude of the media-specific risk estimates.

- Significant uncertainties in the baseline human health risk assessment that would tend to overestimate baseline risk assessment results. Uncertainties in the baseline human health risk assessment intake estimates (and their impact on the risk estimates) may be evaluated using "probabilistic risk assessment" techniques. Uncertainties associated with the toxicity criteria would be evaluated qualitatively.

- Significant uncertainties in the EPC estimates that would tend to overestimate baseline risk assessment results.

1.4.2.5 Human Health Risk Uncertainty Analysis

The baseline risk assessment will include an uncertainty analysis that qualitatively addresses major sources of uncertainty in the data evaluation, exposure assessment, toxicity assessment, and risk characterization. The major sources of uncertainty that will be discussed are presented in Appendix D. As noted above, probabilistic risk assessment techniques may be used to provide risk managers with a more comprehensive understanding of the uncertainty associated with the quantitative risk assessment results.

1.4.3 Ecological Risk Assessment

This section of the QAPP outlines the methodology that will be followed for completing the screening-level ecological risk assessment (SERA). The goal of the SERA is to provide an initial screening of the analytical data to determine which contaminants need to be evaluated further as part of a baseline ecological risk assessment (BERA), if any. A phased approach to the SERA will be used at the site. The approach relies first on environmental chemistry data and field observations for the preliminary assessments. Biological sampling or testing may be conducted if further work is needed.

This SERA will consist of the first two of eight steps required in the EPA guidance (U.S. EPA, 1997a and 1998a) and Step 3A (the first step of the BERA) of the Navy Policy for Conducting Ecological Risk Assessments. Figure 1-12 presents the Navy's Ecological Risk Assessment Tiered Approach (U.S. Navy, 1999). The first two steps are the screening-level assessment. Step 3A is the first step of the BERA and consists of refining the list of COPCs that were retained following the SERA, as discussed in Section 1.4.3.3. Steps 3b through 7 will be conducted if additional evaluations or investigations are necessary. Finally, Step 8, Risk Management, will be incorporated throughout the ecological risk assessment (ERA) process in cooperation with the Region 5 Biological Technical Assistance Group (BTAG).

The first phase in the ERA process is the screening-level risk assessment. In this phase, conservative exposure estimates are made for grouped or individual ecological receptors, and these exposures are compared to screening levels and threshold toxicity values. The SERA includes the following considerations, which are described in subsequent subsections of this QAPP:

- Screening-level problem formulation
- Screening-level ecological effects evaluation
- Screening-level exposure estimate
- Screening-level risk calculation

1.4.3.1 Screening-Level Problem Formulation

Screening-level problem formulation includes identification of potential receptor groups, COPCs, and the mechanisms for fate and transport, and toxicity. The complete exposure pathways that exist on a site are determined at this point to facilitate receptor selection. As part of receptor identification, site habitats and potential ecological receptors are described.

Environmental Setting

Section 1.2 of this QAPP presents the environmental setting at the site. Based on the habitat at the site, and the observation of one potential burrow, it is likely that small mammals and birds are present at the site.

Exposure Pathways

Based on the historical site operations, soil is the primary source of contaminants. The contaminants may migrate from soil to ground water after the contaminants leach from the soil. In addition, contaminants from the site can enter surface water bodies via overland runoff and erosion, or through ground water discharge. Finally, contaminants can enter the air via the emission of volatile chemicals or through wind erosion and dust resupsension. The following paragraphs discuss each of these exposure pathways.

Ground Water

Currently, no discharge points have been identified for ground water potentially contaminated with site-related contaminants have been identified. No seeps were observed during the 18 January 2000 site visit, and the intermittent stream north of the site was dry. In addition, the two large drainage ditches from the site to the northern intermittent stream, and one drainage ditch from the site to the southern intermittent stream were dry during the site visit. Because the intermittent stream south of the MGBG has not been inspected, it is not known whether ground water was discharging to this stream. However, because ecological receptors are not directly exposed to ground water (prior to it discharging from a seep or as surface water), this pathway will not be evaluated in the SERA. Ground water discharge to a seep or to the intermittent streams is discussed below.

Seep/Surface Water

Contaminants in the ground water may discharge as a seep or to a surface water body. Contaminants in the soil may also enter the intermittent streams via overland flow. Based on the surrounding habitat, and the presence of small mammals and birds, it is possible that these species use the seeps as a source of drinking water. However, unless the seeps represent a potential source of drinking water (i.e., pooled water), a complete exposure pathway will not occur.

It is unlikely that the northern stream would support a healthy benthic macroinvertebrate or fish population because of the intermittent nature of the stream. However, contaminants from the site could migrate to

locations further downstream that do support benthic macroinvertebrates and fish. These receptors could be exposed to the water by direct contact with and incidental ingestion of water. Potential receptors in the southern stream are not known but are expected to be similar to those associated with the northern stream.

Amphibians are likely to inhabit the intermittent streams both to the north and south of the site; reptiles are likely to inhabit these aquatic environments, as well as surrounding terrestrial habitats. Amphibians and reptiles could be exposed to contaminants in the surface water by direct contact or ingestion of water.

Surface Soil

Several groups of terrestrial ecological receptors can be exposed to contaminants in the surface soil. Invertebrates such as earthworms are exposed to the contaminants as they move through the soil, and ingest soil particles while searching for food. Plants are exposed to the contaminants via direct contact as contaminants are absorbed through the roots and then translocate to different parts of the plants (i.e., leaves, seeds).

Small mammals may be exposed to contaminants in the soil via several exposure routes. They may be exposed by direct contact as they search for food or burrow into the soil. However, exposure of terrestrial wildlife to contaminants in the soil via dermal contact is unlikely to represent a major exposure pathway because fur, feathers, and chitinous exoskeletons are expected to minimize transfer of contaminants across dermal tissue (note that this may not be true for amphibians). Therefore, the dermal pathway will not be evaluated in the SERA. Small mammals may also be exposed to contaminants in the soil via incidental ingestion of soil and ingestion of plants or invertebrates that have accumulated contaminants from the soil. These pathways will be evaluated in the SERA.

Larger, predatory species such as the red fox and red-tailed hawk can be exposed to site contaminants in the soil by ingesting small mammals that have accumulated contaminants. However, because of the relatively small size of the site (approximately 2 acres), the site would only occupy 1 or 2 percent of the predators' home range. Therefore, these receptors will not be evaluated in the SERA unless contaminants were found to extend over a much larger area.

Air

The inhalation pathway will not be evaluated because air concentrations are expected to be minimal given that most of the site is grass covered. Also, inhalation pathways typically are not evaluated in SERAs because of the uncertainty in exposures and effects concentrations.

Endpoints

Assessment endpoints are an explicit expression of the environmental value that is to be protected (EPA 1997a). The selection of these endpoints is based on the habitats present, the migration pathways of probable contaminants, and the routes that contaminants may take to enter receptors.

As discussed in Section 1.2.4, the habitat at and adjacent to the site consists of forested areas, open fields with grasses, and potential aquatic habitats. For this SERA the assessment endpoints are protection of the following groups of receptors from adverse effects of contaminants on their growth, survival, and reproduction:

- Soil invertebrates
- Terrestrial vegetation
- Herbivorous mammals
- Herbivorous birds
- Soil invertebrate-eating birds
- Soil invertebrate-eating mammals
- Omnivorous mammals
- Omnivorous birds
- Benthic invertebrates
- Fish (potential receptor only)

Appendix E presents more information on each of these assessment endpoints, including identification of protected or endangered species such as the Indiana bat.

Measurement endpoints are used to evaluate assessment endpoints (i.e., mortality, growth, and reproduction). The following measures of effects will be used to evaluate the assessment endpoints in this SERA, where applicable.

- Soil screening values – Mortality, growth, and reproduction of plants and soil invertebrates will be evaluated by comparing the measured concentrations (maxima and averages) of chemicals in the surface soil to screening values designed to be protective of ecological receptors.

- No observed adverse effects levels (NOAELs) for surrogate wildlife species - Mortality, reproductive, or developmental effects of birds and mammals will be evaluated by comparing the estimated ingested dose (based on conservative and average assumptions) from contaminants in the surface water, surface soil, plants, or invertebrates to these levels.

- Sediment screening values – Mortality of benthic macroinvertebrates will be evaluated by comparing the measured concentrations (maxima and averages) of chemicals in the sediment to screening values designed to be protective of ecological receptors.

- Surface water screening values – Mortality and other adverse effects (i.e., growth, feeding rates, behavioral changes) of aquatic organisms will be evaluated by comparing the measured concentrations (maxima and averages) of chemicals in the surface water to screening values designed to be protective of ecological receptors.

1.4.3.2 Ecological Effects Evaluation

The preliminary ecological effects evaluation examines the relationship between the magnitude of exposure to a chemical and the nature and magnitude of adverse effects resulting from exposure. In addition to being a toxicity study, it may also describe apparent effects seen during the site visit. Toxicity thresholds are usually expressed in units of concentration when the medium of concern is in intimate contact with the receptor, such as surface water for pelagic organisms or soil for soil invertebrates. For other receptors, such as terrestrial vertebrates, toxicity data are typically available as doses, with units equal to mass of contaminant per unit of body mass per unit of time (usually milligrams per kilogram per day [mg/kg/day]). For the SERA, conservatively low toxicity thresholds are used to evaluate the potential for adverse ecological effects. However, less conservative thresholds used in the BERA may be more appropriate for determining potential risks to the ecological receptors.

As the first step in the ecological effects evaluation, COPCs will be selected by comparing the contaminant concentrations in the surface water, sediment, and surface soil samples to Region 5 EDQLs (U.S. EPA, Region 5, 1999b). The following items summarize the procedures that will be used in the MGBG-specific SERAs to select COPCs. Calcium, magnesium, potassium, and sodium will not be retained as COPCs in any medium because of their relatively low toxicity to ecological receptors, and

their high natural variability in concentrations. Contaminants without EDQLs will be retained as COPCs but they may only be evaluated qualitatively. If a chemical is non-detected at the reporting limit in all of the samples in a particular media, and the reporting limit exceeds the EDQL, the chemical will not be quantitatively carried through the risk assessment as a COPC. However, the chemical, its reporting limit, and the EDQL will be summarized in a table and qualitatively discussed in the uncertainty analysis section. If a chemical is detected in at least one sample at levels greater than the reporting limit, one-half of the reporting limit will be substituted for the non-detects for calculating summary statistics (e.g., mean concentrations). The ecological COPC selection decision rules are described in Section 1.4.4.3.

Seep, Surface Water, and Sediment for Benthic Macroinvertebrates, Fish, and Terrestrial Wildlife

- Inorganic and organic contaminants with maximum concentrations that do not exceed EDQLs will not be retained as COPCs.

- Inorganic contaminants with maximum concentrations that do not exceed the maximum upstream or upgradient concentrations will not be retained as COPCs.

Surface water EDQLs were not established for the protection of wildlife ingesting water. However, based on the very low and conservative EDQLs for surface water, contaminants that do not exceed the EDQL are not expected to be toxic to terrestrial wildlife.

Surface Soil for Invertebrates, Plants, and Terrestrial Wildlife

- Inorganic and organic contaminants with maximum concentrations that do not exceed EDQLs will not be retained as COPCs.

- Inorganic contaminants with maximum concentrations that do not exceed the site-specific background concentrations will not be retained as COPCs.

The use of U.S. EPA Region 5 EPA EDQLs incorporates the screening-level exposure estimate and screening-level risk calculation during the COPC selection process. Therefore, these are not presented as separate steps in this QAPP.

Contaminants that are retained as COPCs will be further evaluated as part of Step 3A of the eight-step ERA process (Navy, 1999). This will be done by using additional toxicity data in a weight-of-evidence

approach to determine potential impacts to the ecological receptors. The following sections present the additional data sources that will be used to evaluate the COPCs.

1.4.3.3 Step 3A – Refinement of COPCs

Step 3A consists of refining the list of COPCs from the SERA using less conservative screening values to more realistically estimate potential risks to ecological receptors (i.e., plants, invertebrates, and aquatic receptors). For example, for all the media, both maximum and average concentrations will be compared to the benchmark values because most receptors (other than immobile plants) will have an average exposure to contaminants as they move across the surface water, sediment, or soil. This evaluation may include (but is not necessarily limited to) a consideration of the following factors:

- Magnitude of criterion exceedence: Although risks may not relate directly to the magnitude of a criterion exceedence, the magnitude may be one item used in a weight-of-evidence approach to determine the need for further site evaluation.

- Frequency of chemical detection: A chemical that is detected at a low frequency typically will be of less concern than a chemical detected at higher frequency provided that the toxicity and concentrations of the constituents are similar. All else being equal, chemicals detected frequently will be given greater consideration than those detected relatively infrequently.

- Contaminant bioavailability: Many contaminants (especially metals) are present in the environment in forms that are typically not bioavailable, and the limited bioavailability will be considered when evaluating the exposures of receptors to site contaminants.

- Habitat: Although exceedences of criteria may occur, potential risks to ecological receptors may be minimal if there is little habitat for those receptors. Therefore, the extent of habitat will be used qualitatively when considering the site for additional evaluation.

<u>Alternate Benchmarks and Evaluations</u>

The following sections present some alternate benchmarks and evaluations that will be conducted as part of Step 3A.

Terrestrial Plants and Invertebrates

Risks to terrestrial plants and invertebrates resulting from exposure to the COPCs will be evaluated by comparing the contaminant concentrations in the surface soil to alternate soil benchmark values. These alternate benchmarks will be designated as Surface Soil Screening Levels (SSSLs). Currently, neither Indiana nor U.S. EPA has developed ecological SSSLs. The following list presents the SSSLs that have been developed by a few groups or agencies. Additional details explaining the origin and basis for the alternate benchmarks are provided in Appendix E.

- Dutch Intervention Values and Target Values – Soil Quality Standards (MHSPE, 1994)
- Canadian Soil Quality Guidelines (CCME, 1997)
- Oak Ridge National Laboratory (ORNL) Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision (Efroymson et al., 1997a)
- ORNL Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision (Efroymson et al., 1997b)

Seeps/Surface Water

Water Quality Standards (WQSs) for surface water have been developed for Indiana (IDEM, 1998). These are the primary enforceable surface water standards for the MGBG. In addition, U.S. EPA has established AWQC for several contaminants. Other, non-regulatory surface water screening values will be used to evaluate the surface water data that do not have WQSs or AWQC. All values will be collectively referred to as surface water screening levels (SWSLs) in this SERA. The following presents the SWSLs that will be used in this evaluation. Additional details explaining the origin and basis for the alternate benchmarks are provided in Appendix E.

- Indiana Water Quality Standards (IDEM, 1998)
- Ambient Water Quality Criteria (U.S. EPA, 1999a)
- Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota, 1996 Revision (Suter and Tsao, 1996)

- "Eco Update-Ecotox Thresholds" (U.S. EPA, 1996)

- "Radiological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota at Oak Ridge National Laboratory," Oak Ridge, Tennessee (U.S. DOE, 1998)

Sediment

Indiana has not established sediment screening levels (SSLs) for any contaminants, and U.S. EPA has established SSLs for only a few contaminants. Therefore, other, non-regulatory alternate benchmarks will be used to evaluate the sediment data. SSLs based on freshwater studies will be used where available. The following list presents the SSLs that will be used in this evaluation. Additional details on the SSLs are presented in Appendix E.

- "Eco Update-Ecotox Thresholds" (U.S. EPA, 1996)

- "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (OMOE, 1993)

- "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments" (Long et al., 1995)

- "Radiological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota at Oak Ridge National Laboratory," Oak Ridge, Tennessee (U.S. DOE, 1998)

Contaminants that exceed the SSLs also will be compared to background contaminant levels developed in the "Sediment Background Concentration Distributions of 172 Potential Pollutants in Indiana" (Wente, 1994). The term "background" was interpreted in that document as "the concentration that would be present in the absence of any particular pollutant source." Background values will be used as additional information in the weight-of-evidence approach for evaluating the sediments.

Terrestrial Wildlife

Most of the above-mentioned additional surface soil standards and benchmarks are not designed to screen out risks to terrestrial wildlife via ingestion of soil, plants, and invertebrates. Therefore, in addition

to comparing the soil concentrations to toxicity values for terrestrial invertebrates and plants, a terrestrial intake model (food chain) will used to estimate the exposure of terrestrial receptors to the COPCs.

Risks to terrestrial receptors posed by COPCs in the soil will be determined by estimating the chronic daily intake (CDI) and comparing the CDI to Toxicity Reference Values (TRVs) representing acceptable daily doses in mg/kg/day. The TRVs will be developed from NOAELs and Lowest-Observed-Adverse-Effect-Levels (LOAELs) obtained from wildlife studies, if available (see Appendix E). Most TRVs will come from the ORNL "Toxicological Benchmarks for Wildlife: 1996 Revision" (Sample et al., 1996). Toxicity data in the Agency for Toxic Substances and Disease Registry toxicity profiles and Integrated Risk Information System printouts will be used, when necessary.

Appropriate scaling factors to convert a NOAEL from one species to a NOAEL for another species will be used as detailed in Appendix E. If a subchronic study is used to develop the TRV, the final value will be multiplied by a factor of 0.1 to account for uncertainty between subchronic and chronic effects. Also, if a LOAEL study is used to develop the NOAEL TRV, then the LOAEL will be multiplied by a factor of 0.1 to obtain the NOAEL. Finally, the estimated doses will incorporate literature-based soil–to-plant and soil-to-earthworm bioaccumulation factors.

The lower bound of the threshold effects is based on consistently conservative assumptions and NOAEL toxicity values (U.S. EPA, 1997a). This bound will present the highest potential risks. The upper bound is based on observed impacts or predictions that ecological effects could occur and is developed using consistent assumptions, site-specific data, LOAEL toxicity values, or an impact evaluation (U.S. EPA, 1998a). This bound will present the average potential risk. Both the upper and lower bounds will be evaluated in the SERA to provide the overall range of potential risks as presented in the following table:

Conservative Scenario	Alternate Scenario
95% UCL, surface water, or sediment concentration	Average soil, surface water, or sediment concentration
Highest receptor body weight for NOAEL calculation	Average receptor body weight for NOAEL calculation
Lowest receptor body weight for CDI calculation	Average receptor body weight for CDI calculation
Highest receptor ingestion rate	Average receptor ingestion rate
Use of NOAELS	Use of LOAELs
Receptors that spend 100% of their time at the site	Receptor's home range taken into account

The exposure assumptions (i.e., ingestion rate, body weight) will be obtained from the Wildlife Exposure Factors Handbook (U.S. EPA, 1993a) or other literature sources, if necessary.

1.4.3.4 Ecological Risk Characterization

The risk characterization is the final phase of a risk assessment and compares the exposure to the ecological effects. This phase evaluates the likelihood that adverse effects will occur as a result of exposure to a stressor.

A Hazard Quotient (HQ) approach will be used to characterize the risk to terrestrial receptors. This approach characterizes the potential effects by comparing exposure concentrations to the effects data. A HQ of greater than 1.0 is considered to indicate a potential risk. However, the HQ is not an expression of probability, and the meaning of values greater than 1.0 must be interpreted in light of attendant uncertainties in risk management.

1.4.3.5 Ecological Risk Uncertainty Analysis

Uncertainties are associated with most steps of an ERA, from selecting endpoints, collecting data, and evaluating toxicity. The following topics summarize some of the uncertainties associated with an ERA. The uncertainties are discussed in more detail in Appendix E.

Assessment and Measurement Endpoints: Measurement endpoints are used to evaluate the assessment endpoints based on measurements pertaining to representative species or other indicators. There is uncertainty in this prediction because the species or indicators may not accurately represent the assessment endpoints. Species for measurement endpoints are deliberately selected to be sensitive rather than insensitive to contaminants.

Exposure Characterization: The contaminant dose to terrestrial wildlife is calculated using an equation that incorporates ingestion rates, body weights, bioaccumulation factors, and other exposure factors. Because these exposure factors are obtained from literature studies or predicted using various equations, there is uncertainty when they are applied to other sites. There is also uncertainty in the chemical concentration data used for exposure estimates.

Ecological Effects Data: There is uncertainty in some of the ecological effects data because they are typically developed in a laboratory for species that may or may not be present at the site. In addition, for some media (i.e., sediment, soil) often only a few studies are available, or the guideline value is based on highly variable data.

Risk Characterization: Risks are projected if a HQ is greater than or equal to unity regardless of the magnitude of the HQ. Also, there is uncertainty in how the predicted risks to a species at the site translate into risk to the population in the area as a whole.

1.4.4 Decision Rules

Based on site-specific factors described above, and the DQO process outputs, this section describes how the data will be used for making decisions concerning the nature and extent of chemicals at the site, and risk to human health and ecological receptors. Decision rules are designed to be technically defensible and practical to implement. Risk-based decision rules must also relate to the appropriate EUs (these relate to project boundaries). Nature and extent decision rules should relate COPCs to EU considerations because mapping of contaminant concentrations that are greater than conservative risk-based screening criteria serves little purpose if the contaminants do not pose a risk to receptors. The decision making process is summarized below and is supplemented with decision flow charts where appropriate.

Chemical concentrations will be compared to risk-based concentrations (RBTLs or EDQLs) and background/upgradient concentrations to select COPCs. For "nature and extent" determinations, risk contours will be plotted. The contours will represent COPC concentrations that are greater than background concentrations and that correspond to risk levels equal to 10^{-4} or a hazard index (HI) greater than 1.0, whichever occurs furthest from the perceived contaminant source in a given direction. Contours less than or greater than these risk levels may also be plotted for perspective to aid in interpreting the data. Human health and ecological risks will be computed within an EU boundary and compared to unacceptable risk levels to determine whether an unacceptable risk exists within the EU.

For this project, the primary EU consists of the area encompassing the MGBG and 20 feet beyond the previous MGBG fence line. The total EU area is approximately 2 acres. If contamination extends beyond that boundary, the actual EU may be either reshaped or relocated to coincide with the contaminated area, or additional EUs may be established to encompass contamination extending beyond the 2-acre area. Any reshaping or relocation of the EU will not change the size of the EU materially, as the EU size is based on receptor behavior. For ground water and soils, site conditions are not expected to change during the time frame of this investigation, so no particular temporal considerations are necessary. For seeps, surface water, and sediment, the ability to collect samples will be affected by rain events. However, risk impacts associated with these media are expected to be relatively low, so sampling will not be specifically timed to coincide with rain events.

1.4.4.1 Definition

The decision rule is a statement that integrates DQO planning process outputs into a concise summary of how data will be interpreted when making decisions about the site being investigated. In this case, several decision rules have been developed to address the multiple project objectives and media under investigation. The decision rules form a basis for establishing a sampling plan design that enables data of the correct type, quantity, and quality to be collected for attaining project objectives. Where contouring is incorporated into the decision rule, it is understood that the contoured surface indicates the perimeter bounding a three-dimensional volume that represents concentrations in excess of the indicated action level. RBTLs are media-specific, so the applicable medium-specific RBTL will be used for a given environmental medium when making decisions.

1.4.4.2 Background Concentrations

Selecting COPCs and determining the "nature and extent of COPCs" require comparisons of site data to "background" concentrations. Background concentrations are concentrations that would exist in the absence of influence from site operations. For mobile media such as ground water, surface water and sediment the background concentration is represented by concentrations upstream or upgradient of the MGBG. When upgradient concentrations cannot be obtained because of flow patterns, side gradient (cross gradient) concentrations are the next best choice. For soils, background concentrations are the concentrations found in soils that are not influenced by site operations.

For inorganic chemicals and radionuclides in soil, the background concentrations will be the soil background values determined in the NSWC base-wide background soil investigation. The background data set corresponding to soil having physical characteristics (i.e., grain size, depositional environment and depth) that most closely represents the SWMU samples will be used. Radioactive thorium was not assessed as part the NSWC base-wide background soil investigation; however, isotopic thorium concentrations will be computed from chemical thorium analyses by using the natural relative abundances and specific activity of naturally occurring thorium (see Section 12.4). Isotopic thorium data will also be obtained for a single background location during this investigation for comparison to the thorium radioisotopic values computed from the background investigation data. If the values from this investigation do not match the background investigation values within established measurement uncertainty, professional judgment will be used to determine which values most represent background for this investigation. For COPC selection, organic chemicals will be assumed to have zero concentration in background soils.

For inorganics, organics, and radionuclides in ground water, surface water, and sediment, the background concentrations will be the water or sediment upstream or upgradient (or cross gradient) concentrations.

Background locations for sediment, ground water, and surface water have been selected to represent locations not influenced by site operations. If data from the selected locations indicate that any of those media do not represent background concentrations, the Navy may consult with the U.S. EPA Region 5 to agree on the most appropriate course of action.

1.4.4.3 Decision Rules for Establishing Chemicals of Potential Concern

Ideally, multiple analyses would be performed at a given sampling location and statistical analyses based on the multiple results at each location would be possible when using data to identify COPCs. However, the multiple objectives of this investigation make a different approach more feasible. The COPCs will be established by comparing measured chemical concentrations to RBTLs (human health risk), EDQLs (ecological health risk) and background values, as appropriate. When, for a particular medium, only one or two data values are available for a given analyte at a given sampling location, maximum values may be used for comparisons. If at least three data values are available for a given analyte at a given sampling location, statistical analyses will be done to compare data sets. Statistical comparisons will be conducted at the 5% significance level. The text below is written in terms of both the statistical and maximum values approaches based on expected conditions. The applicable decision rules are presented on Figures 1-13 through 1-17 and are explained briefly below:

- A chemical detected in ground water (human health risk only) will be selected as a COPC for ground water if the maximum detected concentration in any well exceeds RBTLs (organics, inorganics, and radionuclides), and the Wilcoxen Rank Sum (WRS) test at 5% significance indicates that the site contaminant concentration is statistically greater than the upgradient/side gradient concentration (inorganic and radionuclides only).

- A chemical detected in surface water (or sediment) will be selected as a COPC for surface water (sediment) if the maximum detected concentration in any drainage channel exceeds the RBTL (human health risk) or EDQL (ecological risk) for surface water (or sediment) (organics, inorganics and radionuclides), and the maximum upstream background concentration (inorganics and radionuclides only).

- A chemical detected in soil will be selected as a COPC for soil if any detected chemical concentration exceeds the applicable RBTL (human health risk) or EDQL (ecological risk in surface soil only) for soils (organics, inorganics and radionuclides), and the WRS test at 5% significance indicates that the site concentration is statistically greater than the corresponding background concentrations (inorganics and radionuclides only). The background data set used for these comparisons will be that which most closely matches the site data in terms of depositional environment, depth and grain size.

If a chemical does not have an RBTL or EDQL, the chemical will be evaluated qualitatively for inclusion as a COPC. Those evaluations will be based on professional judgment that takes into account the number of times the chemical was detected, the magnitudes of the observed concentrations, the spatial distributions of the detected values, and the toxicities of similar chemicals. Individual chemicals may be eliminated as COPCs if they are detected at a frequency less than 5 percent in any given medium but only if there are no other indications that the chemical would pose an unacceptable risk to receptors. For example, chemicals that exhibit unusually high concentrations may be retained as COPCs on that basis at the discretion of the human health or ecological risk assessor. If a chemical is non-detected at the detection limit in all of the samples in a particular medium, and the detection limit exceeds the risk-based level, the chemical will be qualitatively discussed in the uncertainty analysis section.

1.4.4.4 Decision Rules for Establishing the Nature and Extent of COPCs

The concept of nature and extent conveys the notion that a concentration gradient decreases radially from a contamination source. If multiple contamination sources exist, multiple independent or overlapping regions of contamination will exist. This is likely for heterogeneous media such as soil. Also, such concentration distributions are expected at the MGBG which has been excavated multiple times and the excavations backfilled with gravel and earth. For MGBG soils, the excavations are expected to have created areas of low chemical concentrations within potentially more contaminated regions, if the excavations did not completely remove contaminated soil. In any event, the nature and extent concept implies that a region exists within which COPC concentrations may be declared to present a potentially unacceptable risk to receptors and outside of which unacceptable risk is not expected to exist.

A receptor's behavior translates into the receptor roaming a geographical area (or volume) called the EU. The receptor risk reflects the combined effect of exposure to both contaminated and uncontaminated regions within the EU. The relative proportions of the EU that are covered by contaminated and uncontaminated regions, and the contaminant concentrations within those areas, influence the magnitude of risk incurred. Even if multiple localized regions of elevated contaminant concentrations exist within the EU, the risk to the receptor may be acceptable. The computation of risk levels to receptors considers

both the nature and extent of contamination and each receptor's EU. EUs may differ for individual receptors, so a representative EU is used for each receptor based on receptor behavior. The extent of contamination is based on human health risk comparisons.

Geostatistical kriging will be used, if appropriate, to estimate contaminant concentration boundaries in ground water and soil because it takes advantage of an entire data set and the spatial relationships among individual concentration values, rather than relying on individual data points. The appropriateness of kriging will be assessed by evaluating the spatial distributions of the data and the semivariogram which relates the variability of the concentration values to the distance between sampling points.

Ground Water and Soil Nature and Extent

The decision rules for ground water and soil are presented on Figure 1-18.

Solid samples will not be collected from bedrock or from beyond the MGBG study area boundary without discussions between the Navy and EPA.

Surface Water and Sediment Nature and Extent

The extent of surface water contamination will not be determined for any drainage channel surface water in which water is not present during the sampling event. However, sediments will be sampled, if available, regardless of the availability of water in the drainage channels.

The decision rules for surface water and sediment are presented on Figure 1-19. Seeps are included in the evaluation of surface water.

Failure to Establish Nature and Extent Within Two Sampling Rounds

If the COPC extent boundary is not identified within two rounds of sampling, the Navy will seek consultation with the EPA to discuss the need for additional sampling. The following will be considered:

- The expected contribution to risk estimates of the as yet unbounded region of contamination
- The practicality of obtaining samples from the unbounded region
- The number of sampling locations exceeding screening criteria
- Other factors that are pertinent to the evaluation but could not be anticipated in advance

1.4.4.5 Decision Rules for Risk-Based Evaluation

The human health and ecological risk assessment methodologies are summarized in Sections 1.4.2 and 1.4.3, respectively. The decision rules for those methodologies are presented graphically on Figures 1-20 and 1-21. EPCs in the figures refer to those established in Section 1.4.2.2.

1.5 SAMPLING LOCATIONS AND RATIONALES

1.5.1 Rationale for the Selected Number of Soil Samples

Statistical calculations may be used to compute the number of radiological measurements, *N and M*, required in soils at both the EU and the background areas, respectively. Representative of these calculations is the following equation designed for comparing site data to background radiation levels (MARSSIM, 1997). The intent is to estimate the number of samples required to limit the two possible types of decision errors, Type I and Type II, when deciding whether site radiation levels exceed background levels.

$$N = M = \frac{1}{2}\frac{\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{\frac{\Delta}{\sigma}(P_r - 0.5)^2}$$

where: α = the probability of committing a Type I decision error (i.e., declaring the site to not exceed the radiological background level when it actually exceeds the background level)

β = the probability of committing a Type II decision error (i.e., declaring the site to exceed the radiological background level when it actually does not the background level)

$Z_{1-\alpha}$ = the statistical *z*-score corresponding to the α probability of committing a Type I decision error

$Z_{1-\beta}$ = the statistical *z* -score corresponding to the β probability of committing a Type II decision error

P_r = the probability that a random site radiation measurement will exceed a random radiation measurement in the background area (assuming equal areas for background and site)

Δ = the smallest detectable difference between site and background radiation levels

σ = the estimated or known standard deviation of the radiological measurements

Control over decisionmaking errors is gained by specifying Δ and the tolerable error rates, α and β. The *z*-scores and P_r derive from these specifications, and σ must be known or estimated. The more accurate

the estimate of σ, the more valid the calculations. When little or no data are available to provide a basis for estimating σ, a lot of effort should not be spent in computing a required number of samples by such equations. That is the case for Round 1 of this project. Also borne in mind was that the NSWC Crane background soil Investigation yielded initial estimates of at least five samples in seven of nine soil groups, based on depositional environment, depth and grain size. Two soil groups yielded only one background value.

MGBG soil data are not available for radiological and non-radiological parameters. Therefore, the value of σ is unknown and to use the above equation some assumptions were made. The ratio of Δ/σ is assumed to equal 2.5. The value of P_r is determined by the Δ/σ ratio. For a Δ/σ ratio of 2.5, P_r equals 0.961428. Assuming relatively conservative values of 0.05 for both α and β, the corresponding *z*-scores are each 1.645, and the values of *N* and *M* may be computed:

$$N = M = \frac{1}{2}\frac{(1.645+1.645)^2}{2.5(0.961428-0.5)^2}$$

$$N = M = 11$$

To gain perspective on these values, more conservative values of $\alpha = \beta = 0.025$ yield $N = M = 15$.

For a given level of statistical power (translating to decisionmaking confidence), the total number of samples ($M + N$) is a minimum when $M = N$. If *M* and *N* are not equal, the decsionmaking power is comparatively less for the same total number of samples. However, delineation of contamination is a goal of this project and collecting the same number of samples from both the MGBG and background areas would disproportionately limit the resources available for sampling the MGBG. To address the goals of delineating contamination and performing risk evaluations, an imbalance in the sampling density of background and MGBG areas was allowed. The number of background radiological determinations will be limited to three in the first round of sampling. To offset the loss of statistical power resulting from the imbalance, the initial round of sampling within the MGBG is planned to yield 60 samples deriving from three samples at each of 20 sampling locations. Twenty samples will be surface soil samples and 40 samples will be subsurface samples.

The "extra" (i.e., beyond $M = N = 11$) MGBG samples will provide good sampling resolution in all directions and should preserve adequate statistical power for decisionmaking. The "extra" samples also provide a built in compensation for potentially not being able to analyze some samples because of their

mustard gas content. This is discussed further in Section 4.0. It is expected that the "extra" samples will also help to accommodate the differences among soil types by allowing soils to be grouped according to depositional environment, depth and grain size when making the necessary data comparisons.

For non-radiological parameters the number of soil samples to be collected in Round 1 as computed above was accepted without alteration because the lack of non-radiological data prevents refining these calculations. The sampling locations for surface and subsurface soils are presented in Section 4.0. The numbers of samples required for subsequent sampling rounds, if any, will be based on the need to fill data gaps.

1.5.2 Rationale for the Selected Number of Water Samples

The past ground water analytical data probably do not accurately reflect current site conditions. Therefore, the number of ground water samples to be collected and analyzed was constrained by the number of existing wells and was influenced by professional judgment used in selecting additional well locations. In the first round of sampling, one sample will be collected from each existing ground water monitoring well, including background wells. Additional well sampling will be based on the need to fill data gaps, which will be determined after Round 1. Surface water and sediment are expected to pose less of a risk to receptors than groundwater and soils, at least in part because of their limited availability. Therefore, one sample will be collected from each of a limited number of surface water and sediment locations if those media are present. A limited amount of judgmental sampling is also allowed at the discretion of the FOL to accommodate site-specific conditions during field activities. The sampling locations for water are presented in Section 4.0. The numbers of samples required for subsequent sampling rounds, if any, will be based on the need to fill data gaps.

1.6 PROJECT SCHEDULE

The project schedule is presented on Figure 1-22.

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TABLE 1-1

MUSTARD GAS BURIAL GROUND HISTORICAL INVESTIGATION SUMMARY NSWC CRANE, CRANE, INDIANA PAGE 1 OF 2

Event	Summary/Conclusions
March 1973 Chemical Safety Survey	• Unknowns were identified regarding chemical agent and explosives content of munitions disposed of at the MGBG. • Recommendation was to recover the chemical munitions and render the area safe.
1974 Exhumation	• Enough thorium/illuminant materials and other bomb-related hardware was recovered to fill seven 55-gallon drums. Items found included 92 pyrotechnic devices buried approximately 2.5 feet to 5.5 feet deep. All radioactive waste was thought to have been removed and sent to an NRC-licensed burial ground (Barnwell, SC) in 1975. • Ten HD bombs were exhumed. Of those, seven had evidently been cleaned of HD prior to burial. One more contained HD from which an unspecified quantity of HD was released to the ground. The released HD was reacted with hypochlorite solution to decompose the HD and the excavation was back-filled with vent pipes in place to release hydrogen chloride gas formed during the decompositon reaction. Two other bombs were suspected to contain HD. Detected HD was about 40% pure, evidently undergoing chemical decomposition. Exhumation was terminated and transferred to Army personnel. In 1976, hardware from seven bombs was transferred to Magazine 1403; the three remaining bombs were wrapped in plastic and overpacked in 8-inch propellant charge shipping containers, then also stored in Magazine 1403. • Exhumation personnel recommended resuming exhumation of four other areas in Autumn when temperatures are lower and the chance of HD overpressure in the bombs is limited.
1977 Magnetometer Survey	• New metal contacts were identified both inside and outside the MGBG and were plotted.
1980 Exhumation	• Metal contacts plotted in 1977 as being *outside* of MGBG were innocuous (barbed wire and "junk"). • Most metal contacts *within* the MGBG detected during the 1977 survey were also junk or barbed wire. • Six items removed from plots marked "mustard" of various poundages were empty M70A1 aerial bombs. Otherwise, no connection between the pounds of material recorded and live agent was found. Only mud (no live chemical agent) was found inside the six aerial bombs. • No trace of agent was found in soils surrounding the empty bombs (analysis was done using a field test kit). • The three bombs suspected in 1974 of containing mustard gas contained approximately 3, 1.5, and 0 gallons of agent, respectively. None was found to be full of agent, indicating that they were partially overlooked when bombs were drained of HD prior to burial. Some agent, which was spilled on the ground, was decontaminated with HTH chlorine solution. • Most of material found was illuminating device hardware/composition remaining from a research and development project. • One HD identification kit containing 6 oz of HD was exhumed. • An unidentified quantity of radioactive waste was located apart from the other buried material in a configuration illustrating a simple "stack type" burial. • Three additional thorium nitrate burial areas were located. • Three 55-gallon drums were filled with radioactive thorium nitrate containers.

TABLE 1-1

MUSTARD GAS BURIAL GROUND HISTORICAL INVESTIGATION SUMMARY NSWC CRANE, CRANE, INDIANA PAGE 2 OF 2

Event	Summary/Conclusions
1980 Exhumation (Continued)	• The MGBG site was declared "not to pose an environmental insult." • Thorium nitrate disposal sites located at the NSWC Crane were considered to have been decontaminated and were approved by the Navy for release for radiologically unrestricted use.
1995 Geophysical Survey (complete MGBG area)	• The objective was to detect and delineate anomalies indicating buried structures, objects, or disturbed zones with past hazardous waste burial. • EM and magnetic surveys were used. • Two anomalies were identified that were unexplained.
18 January 2000 site reconnaissance and related communications	• Site "historian" explains that one of two anomalies identified during the 1995 geophysical survey as a discarded metal horse tub and collection of steel fence posts. The nature of the second anomaly was not identified, but is asserted not to be ordnance-related.

TABLE 1-2

GROUND WATER DATA
SUMMARY FOR 1981 TO 1986
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 2

Parameter	Detection Frequency	Minimum Non-detected Conc'n	Maximum Non-detected Conc'n	Minimum Overall Conc'n	Maximum Overall Conc'n	Overall Concentration Range	Non-detects Concentration Range	Maximum Concentration Location[date]	Average of Detected Results	Average of All Results
VOLATILES (ug/L)										
1,1,1-Trichloroethane	11/22	1	1	1	29	1 - 29	1	01-14-[01/31/83]	9.09	4.80
1,1,2,2-Tetrachloroethane	29/39	0	1	7	589000	7 - 589000	0 - 1	01-02-[11/18/82]	24478.24	18201.87
1,1,2-Trichloroethane	12/21	1	5.2	2.2	341	2.2 - 341	1 - 5.2	01-12-[01/25/83]	44.34	25.65
1,1-Dichloroethene	4/24	1	1	1	65	1 - 65	1	01-02-[10/05/82]	18.50	3.50
1,2-Dichloroethane	11/30	1	1	3	4070	3 - 4070	1	01-02-[11/18/82]	573.45	210.58
1,3-Dichloropropene	1/7	1	1	1000	1000	1000	1	01-16-[02/15/83]	1000.00	143.29
Benzene	4/25	0	1	1	5	1 - 5	0 - 1	01-26-[01/28/86]	2.75	0.80
Bromoform	1/25	0	2	8600	8600	8600	0 - 2	01-02-[10/05/82]	8600.00	344.66
Carbon Tetrachloride	1/22	0	1	34	34	34	0 - 1	01-02-[10/05/82]	34.00	2.00
Chlorobenzene	1/22	1	1	6	6	6	1	01-02-[10/05/82]	6.00	0.75
Chlorodibromomethane	2/15	1	1	61	3040	61 - 3040	1	01-02-[11/18/82]	1550.50	207.17
Chloroform	21/39	0	5	2	2000	2 - 2000	0 - 5	01-02-[10/05/82]	109.36	59.26
Ethylbenzene	1/16	1	1	10.5	10.5	10.5	1	01-22-[01/08/85]	10.50	1.13
Methylene Chloride	16/31	1	10	1	47	1 - 47	1 - 10	01-02-[10/05/82]	9.50	5.29
Tetrachloroethane	1/1	0	0	7.1	7.1	7.1	0	01-19-[01/08/85]	7.10	7.10
Tetrachloroethene	11/24	0	3.8	0.1	4200	0.1 - 4200	0 - 3.8	01-02-[11/18/82]	652.93	299.57
Toluene	2/19	1	1	5	5.1	5 - 5.1	1	01-22-[01/08/85]	5.05	0.98
Trans-1,2-dichloroethene	16/28	0	1	3	2650	3 - 2650	0 - 1	01-02-[11/18/82]	320.44	183.29
Trichloroethene	37/45	0	644	1	133000	1 - 133000	0 - 644	01-02-[11/18/82]	5867.76	4831.82
Trichlorofluoromethane	4/20	0.1	1	2	19	2 - 19	0.1 - 1	01-14-[01/31/83]	7.25	1.83
Tetrahydrofuran	3/3	0	0	11	93	11 - 93	0	01-15-[01/28/86]	51.00	51.00
INORGANICS (ug/L)										
Arsenic	1/20	10	10	10	10	10	10	01-05-[10/05/82]	10.00	5.25
Iron	33/46	20	1000	30	7280	30 - 7280	20 - 1000	01-21-[01/08/85]	795.15	584.89
Iron, Total	17/23	10	20	10	18000	10 - 18000	10 - 20	01-15-[01/28/86]	2930.59	2168.26
Manganese	76/82	5	30	10	7000	10 - 7000	5 - 30	01-04-[03/23/82], 01-04-[07/18/82]	1889.47	1751.86
Mercury	4/20	0.2	0.7	0.2	1.1	0.2 - 1.1	0.2 - 0.7	01-05-[10/05/82]	0.60	0.21
Silver	1/20	10	10	10	10	10	10	01-03-[03/23/82]	10.00	5.25
Sodium	66/66	0	0	3800	210000	3800 - 210000	0	01-05-[03/23/82]	60869.70	60869.70
RADIONUCLIDES (pCi/L)										
Gross Alpha	1/20	2.89	10.8	4.59	4.59	4.59	2.89 - 10.8	01-02-[11/30/81]	4.59	2.99
Gross Beta	15/20	1.55	2.12	1.51	6.27	1.51 - 6.27	1.55 - 2.12	01-05-[11/30/81]	3.09	2.55
Radium-226	11/15	0.23	0.34	0.17	0.48	0.17 - 0.48	0.23 - 0.34	01-05-[03/23/82]	0.29	0.25
MISCELLANEOUS PARAMETERS (mg/L)										
Chloride	54/66	1	1	1	110	1 - 110	1	01-02-[10/05/82]	33.99	27.90
Conductance, Field (uS/cm)	41/41	0	0	145	6400	145 - 6400	0	01-27-[06/10/85]	1128.93	1128.93

TABLE 1-2

GROUND WATER DATA
SUMMARY FOR 1981 TO 1986
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2

Parameter	Detection Frequency	Minimum Non-detected Conc'n	Maximum Non-detected Conc'n	Minimum Overall Conc'n	Maximum Overall Conc'n	Overall Concentration Range	Non-detects Concentration Range	Maximum Concentration Location[date]	Average of Detected Results	Average of All Results
Fluoride	17/20	0.1	0.1	0.1	0.26	0.1 - 0.26	0.1	01-04-[07/20/82], 01-04-[10/05/82]	0.18	0.16
Nitrate/nitrite, As N	15/20	0.05	0.05	0.05	0.18	0.05 - 0.18	0.05	01-04-[10/05/82]	0.11	0.09
Organic Bromine	6/65	0.002	0.01	0.005	0.016	0.005 - 0.016	0.002 - 0.01	01-03-[01/31/84]	0.01	0.00
Organic Chlorine	52/68	0.01	0.01	0.01	48	0.01 - 48	0.01	01-02-[06/03/86]	2.41	1.85
Organic Iodine	33/68	0.002	0.5	0.002	0.15	0.002 - 0.15	0.002 - 0.5	01-02-[06/07/84]	0.02	0.02
pH (unitless)	41/41	0	0	6.1	7	6.1 - 7 .	0	01-03-[01/28/86], 01-09-[01/29/86], 01-10-[01/30/86], 01-10-[06/04/86]	6.59	6.59
pH, Field (unitless)	88/88	0	0	5.7	7.7	5.7 - 7.7	0	01-11-[01/07/85]	6.62	6.62
Phenols	22/66	0.004	0.05	0.01	0.17	0.01 - 0.17	0.004 - 0.05	01-02-[07/20/82]	0.03	0.02
Specific Conductivity uS/cm	81/81	0	0	-1300	2520	-1300 - 2520	0	01-05-[02/22/83]	1160.89	1160.89
Sulfate	82/82	0	0	15	990	15 - 990	0	01-23-[01/07/85]	358.16	358.16
Total Coliform (PHM)	6/8	1	1	2	9	2 - 9	1	01-04-[03/05/82], 01-04-[11/30/81]	5.33	4.13
Total Organic Carbon	99/123	0.5	2	0.8	72	0.8 - 72	0.5 - 2	01-05-[07/27/83], 01-05-[10/05/82]	12.97	10.55
Total Organic Halogens	64/71	0	0.01	0.0063	104	0.0063 - 104	0 - 0.01	01-02-[07/20/82]	2.90	2.61

ug/L = micrograms per liter
pCi/L = picoCuries per liter
mg/L = milligrams per liter

TABLE 1-3

PROJECT TARGET PARAMETERS AND RATIONALES
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 4

Parameter	Environmental Medium[1]					Intended Data Use[2]
	GW[2]	SW	SS	SB	SD	
Appendix IX herbicides (except in deepest subsurface soil interval unless previous sampling reveals concentrations of concern at contamination boundary)	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Appendix IX pest/PCBs (except in deepest subsurface soil interval unless previous sampling reveals concentrations of concern at contamination boundary)	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Appendix IX SVOCs (excluding organophosphorus pesticides)	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Appendix IX VOCs	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Explosives (8330 list)	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Mustard gas (HD) and its degradation products	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Target Analyte List (TAL) metals plus Sn, Sr, dissolved	X	X				To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Target Analyte List (TAL) metals plus Sn, Sr, total	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Thorium-228, -230, -232, dissolved	X	X				To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Thorium-228, -230, -232, total	X	X	X	X	X	To establish absence or presence and extent of contamination. Evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Nitrate (f)	X		X	X		To establish absence or presence and extent of contamination resulting from thorium nitrate burial. Nitrate should be more diffuse than thorium and should be more easily detected as a derivative of thorium nitrate. Evaluate risks to potential human receptors from potentially site-related contaminants.

TABLE 1-3

PROJECT TARGET PARAMETERS AND RATIONALES
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 4

Parameter	Environmental Medium[1]					Intended Data Use[2]
	GW[2]	SW	SS	SB	SD	
Select Gamma Emitters				X		To test assumption that thorium and daughters are the only radionuclides buried at the MGBG. Rationale is also to nature and extent and to evaluate risks.
Total Organic Carbon (TOC)	X		X	X[3]	X	To evaluate fate and transport of contaminants and to corroborate absence or presence of contamination. Indication of bioavailability of chemicals in sediment.
Cation Exchange Capacity			X	X	X	To evaluate fate and transport of contaminants. Also, indication of bioavailability of chemicals in surface soil.
Mustard Gas (f)			X	X	X	To screen for mustard gas to determine whether samples can be shipped for analysis.
Depositional Environment (f)			X	X		To identify soil sampling locations in the horizontal direction for comparison to background concentrations classified according to depositional environment.
Dissolved Oxygen (f)	X					To evaluate natural attenuation and fate and transport. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Flow Rate (f)		X				To establish transient rate and absence or presence of contaminants for interpretation of surface water chemical concentrations. Semiquantitative parameter only.
Grain Size (f)				X	X	To establish which background data set is most comparable for background comparisons. To evaluate fate and transport of contaminants.
Hardness (not measured; calculated from Ca and Mg results)	X	X				To evaluate water quality and to calculate water quality standards.
Oxidation-Reduction Potential (ORP) (f)	X					To evaluate natural attenuation and fate and transport of contaminants. To evaluate water quality.
pH (f - water samples only)	X	X	X	X	X	For soil/sediment, to obtain information on mobility of chemicals (especially metals). Measured to establish well stabilization prior to collecting ground water samples. Generally useful for data interpretation and potential future uses.
pH (fixed laboratory analysis)			X[3]	X[3]		To obtain information on mobility of chemicals (especially metals).
Sample Depth/location (f)	X	X	X	X	X	To identify sample locations in the vertical and horizontal direction.
Specific Conductance (f)	X					To establish well stabilization prior to collecting ground water samples.
Temperature (f)	X					To establish well stabilization prior to collecting ground water samples. Also measured because pH and specific conductivity are temperature dependent.
Total Suspended Solids (TSS)		X				To evaluate water quality and to determine if contaminant concentrations are reflective of suspended solids concentrations.

TABLE 1-3

PROJECT TARGET PARAMETERS AND RATIONALES
NSWC CRANE, CRANE, INDIANA
PAGE 3 OF 4

Parameter	Environmental Medium[1]					Intended Data Use[2]
	GW[2]	SW	SS	SB	SD	
Turbidity (f)	X	X				To establish well stabilization prior to collecting ground water samples. Measured to estimate whether total contaminant concentrations are attributable to suspended solids.
Water Level (f)	X	X[4]				To calculate potentiometric surface, groundwater velocity and hydraulic gradient
Gross alpha	X	X				To establish absence or presence and extent of contamination. Qualitatively evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Gross beta	X	X				To establish absence or presence and extent of contamination. Qualitatively evaluate risks to potential receptors (human health and ecological) from potentially site-related contaminants.
Alkalinity (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Carbon dioxide (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Chloride	X					To help quantify dechlorination and natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Iron (2+) (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Manganese (2+) (f)	X					To be used to identify electron acceptor for natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Hydrogen Sulfide (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Sulfide (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Nitrite (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Sulfate (f)	X					To evaluate fate and transport of contaminants as well as natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Methane	X					To help quantify dechlorination and natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.

TABLE 1-3

PROJECT TARGET PARAMETERS AND RATIONALES
NSWC CRANE, CRANE, INDIANA
PAGE 4 OF 4

Parameter	Environmental Medium[1]					Intended Data Use[2]
	GW[2]	SW	SS	SB	SD	
Ethane	X					To help quantify dechlorination and natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.
Ethene	X					To help quantify dechlorination and natural attenuation. Only needed if chlorinated organic solvents are detected at concentrations of concern.

(f) Field analysis
1 Seeps will be sampled as part of surface water sampling.
2 GW samples collected for natural attenuation will only be collected in sampling rounds beyond Round 1.
3 Only necessary for approximately 1/3 of soil samples.
4 Need stream elevations surveyed also (two to four points) for ground water model and flow calculations.

GW – ground water
SW – surface water
SS – surface soil
SB – subsurface soil
SD – sediment

TABLE 1-4

**AQUEOUS FIELD TARGET PARAMETERS
AND METHOD DETECTION LIMITS
NSWC CRANE, CRANE, INDIANA**

Parameter	Reporting Limit (mg/L, unless otherwise noted)
Alkalinity	10
Carbon Dioxide	10
Dissolved Oxygen	0.1
Iron (2+) (ferrous iron)	0.2
Flow Rate	NA
Hydrogen Sulfide	0.1
Manganese (2+)	0.12
Nitrate	0.01
Nitrite	0.005
Oxidation Reduction Potential (ORP)	NA
pH	NA
Specific Conductance	0.02 uS/cm
Sulfate	4.9
Sulfide	0.01
Temperature	0.1°C
Turbidity	1 NTU
Water Level	0.01 foot

NA – Not applicable
mg/L = milligrams per liter
uS/cm = microSiemens per centimeter
NTU = nephelometric turbidity unit
°C = degrees Celsius

TABLE 1-5

LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
PAGE 1 OF 7

Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
EXPLOSIVES SW-846 METHOD 8330							
1,3,5-Trinitrobenzene	0.078	0.65	1100	0.0274	0.5	1800	1800
1,3-Dinitrobenzene	0.0629	0.65	2.36	0.0268	0.5	0.655	0.000924
2,4,6-Trinitrotoluene (TNT)	0.0938	0.65	2.2	0.0876	0.5	16	16
2,4-Dinitrotoluene	0.17	0.65	1.2	0.0131	0.5	0.00004	0.00004
2,6-Dinitrotoluene	0.323	0.65	1.2	0.0262	0.5	0.00003	0.00003
2-Amino-4,6-dinitrotoluene	0.228	0.65	2	0.0529	0.5	--	--
2-Nitrotoluene	0.134	0.65	61	0.0283	0.5	370	370
3-Nitrotoluene	0.211	0.65	61	0.0407	0.5	370	370
4-Amino-2,6-dinitrotoluene	0.189	0.65	--[2]	0.115	0.5	--	--
4-Nitrotoluene	0.136	0.65	61	0.0289	0.5	370	370
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.0812	0.65	0.61	0.0282	0.5	4.4	4.4
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	0.168	0.65	360	0.0827	0.5	610	610
Nitrobenzene	0.0773	0.65	3.4	0.0255	0.5	0.007	0.007
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	0.0541	0.65	1800	0.0305	0.5	3100	3100
MUSTARD GAS AND DEGRADATION PRODUCTS							
Bis(2-chloroethyl)sulfide (HD)	20	200	2	0.02	0.2	2.6	2.6
1,4-Dithiane	11	200	360	0.02	0.2	610	610
1,4-Thioxane	11	200	370	0.02	0.2	1700	1700
Thiodiglycol	78.7	200	370	0.133	0.2	1800	1800
APPENDIX IX METALS SW-846 Method 6010B Trace							
Antimony	2.6	7.8	6	0.29	0.87	0.1423	0.3
Arsenic	2.2	6.6	0.045	0.27	0.87	0.39	0.0059
Barium	0.6	1.8	2000	0.13	0.39	1.04	82
Beryllium	0.2	0.6	4	0.06	0.18	0.1	0.1
Cadmium	0.6	1.8	0.66	0.05	0.15	0.00222	0.4
Chromium (total)	0.6	1.8	11	0.19	0.57	2	2
Cobalt	1.1	3.3	5	0.2	0.6	0.14	50
Copper	1.1	3.3	5	0.2	0.6	2.96	16
Lead	1.3	3.9	1.3	0.23	0.69	0.0537	31
Mercury (SW-846 Method 7470A/7471A)	0.06	0.18	0.0013	0.012	0.036	0.073	0.1
Nickel	0.9	2.7	29	0.24	7.2	7	7
Selenium	2.9	8.7	5	0.39	1.17	0.0277	0.3
Silver	2	6	1	0.27	0.81	2	0.5
Thallium	3.2	9.6	0.56	0.31	0.93	0.04	0.04
Tin	25	75	73	0.6	1.8	7.62	45000
Vanadium	1	3	19	0.12	0.36	1.59	300
Zinc	6.3	18.9	58.9	1.1	3.3	6.62	120
MISCELLANEOUS METALS SW-846 METHOD 6010B Trace							
Aluminum	18.2	54.6	87	3.3	9.9	76000	76000
Calcium	23	69	--	9.3	27.9	--	--
Iron	36	108	300	2.9	8.7	23000	23000
Magnesium	81	243	--	9	27.9	--	--
Manganese	1.2	3.6	50	0.02	0.06	1800	1800
Potassium	225	675	--	25.8	77.4	--	--
Sodium	102	306	--	16.1	48.3	--	--
Strontium	0.2	0.6	22000	0.08	0.24	47000	47000

TABLE 1-5

LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
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Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
APPENDIX IX VOLATILE ORGANIC COMPOUNDS SW-846 METHOD 8260B							
1,1,1-Trichloroethane	0.1	1	88	0.0008	0.005	0.1	0.1
1,1,1,2-Tetrachloroethane	0.1	1	0.43	0.0006	0.005	0.05	0.01089
1,1,2,2-Tetrachloroethane	0.1	1	0.055	0.0006	0.005	0.0002	0.0002
1,1,2-Trichloroethane	0.3	1	0.2	0.0007	0.005	0.0009	0.0009
1,2,3-Trichloropropane	0.3	1	0.0016	0.0018	0.005	0.0014	0.0014
1,1-Dichloroethane	0.1	1	47	0.0009	0.005	1	0.000575
1,1-Dichloroethene	0.1	1	0.046	0.0011	0.005	0.003	0.003
1,2-Dibromo-3-chloropropane	0.3	1	0.048	0.0019	0.005	0.0352	0.02
1,2-Dibromoethane	0.8	1	0.00076	0.0006	0.005	0.0069	0.0069
1,2-Dichloroethane	0.1	1	0.12	0.0009	0.005	0.001	0.001
1,2-Dichloropropane	0.2	1	0.16	0.0007	0.005	0.001	0.001
1,4-Dioxane	100	100	6.1	0.025	0.5	2.05	0.00000543
2-Butanone	1	5	1900	0.0045	0.005	10	0.13696
2-Chloro-1,3-butadiene (chloroprene)	1	1	14	0.0009	0.005	0.0029	0.00106
2-Hexanone	1.4	5	1500	0.0023	0.005	12.6	1.01
4-Methyl-2-pentanone	2.4	5	160	0.0024	0.005	443	0.54437
Acetone	3.2	5	610	0.0046	0.005	0.8	0.45337
Acetonitrile	18.1	40	79	0.0019	0.2	1.37	0.13905
Acrolein	21	10	0.042	0.013	0.05	0.00027	0.0000144
Acrylonitrile	13	10	0.039	0.008	0.05	0.02393	0.0000157
Allyl chloride (3-chloro-1-propene)	2.2	5	1800	0.0008	0.005	0.01338	0.000266
Benzene	0.1	1	0.41	0.0006	0.005	0.002	0.002
Bromodichloromethane	0.2	1	0.18	0.0008	0.005	0.03	0.00113
Bromoform	0.2	1	8.5	0.0013	0.005	0.04	0.04
Bromomethane	0.3	1	8.7	0.005	0.005	0.01	0.01
Carbon disulfide	1	1	84.1	0.0008	0.005	0.0941	0.134
Carbon tetrachloride	0.1	1	0.17	0.0009	0.005	0.003	0.003
Chlorobenzene	0.1	1	10	0.0007	0.005	0.07	0.0619
Chloroethane	0.5	1	4.6	0.0018	0.005	3	3
Chloroform	0.1	1	0.16	0.0009	0.005	0.03	0.027
Chloromethane	0.3	1	1.5	0.0006	0.005	1.2	0.0000785
cis-1,2-Dichloroethene	0.5	1	61	0.0009	0.005	0.02	0.02
cis-1,3-Dichloropropene	0.6	5	0.081	0.0008	0.005	0.0002	0.0002
Dibromochloromethane	0.1	1	0.13	0.0007	0.005	0.02	0.02
Dibromomethane	0.2	1	61	0.0006	0.005	65	0.0000859
Dichlorodifluoromethane	0.7	1	390	0.0008	0.005	39.5	0.00133
Ethylbenzene	0.1	1	17.2	0.0007	0.005	0.7	0.0001
Ethyl methacrylate	1.1	1	550	0.0009	0.005	30	0.000602
Isobutanol	0.7	40	1800	0.053	0.2	20.8	3.35
Methacrylonitrile	13	20	1	0.01	0.1	0.0571	0.0000297
Methylene chloride	0.2	1	4.3	0.0017	0.005	0.001	0.001
Methyl iodide	0.8	1	--	0.0017	0.005	--	--
Methyl methacrylate	1.7	1	1400	0.0015	0.005	984	0.168
Pentachloroethane	3.3	5	56.4	0.0013	0.005	10.7	0.689
Propionitrile	2	20	6080	0.01	0.1	0.0498	0.115
Styrene	0.1	1	56	0.0006	0.005	0.2	0.2
Tetrachloroethene	0.2	1	1.1	0.001	0.005	0.003	0.003

TABLE 1-5

LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
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Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
Toluene	0.1	1	253	0.0006	0.005	0.6	0.6
trans-1,2-Dichloroethene	0.1	1	100	0.0007	0.005	0.03	0.03
trans-1,3-Dichloropropene	2.8	10	0.081	0.0008	0.005	0.0002	0.0002
trans-1,4-Dichloro-2-butene	1.5	1	0.0012	0.0016	0.005	--	0.00182
Trichloroethene	0.1	1	1.6	0.001	0.005	0.003	0.003
Trichlorofluoromethane	0.4	1	1300	0.0021	0.005	16.4	0.00307
Vinyl acetate	1.8	5	248	0.0023	0.005	2.3	0.013
Vinyl chloride	0.4	1	0.02	0.006	0.005	0.0007	0.0007
Total Xylenes	2.1	5	117	0.0018	0.005	9	1.88
APPENDIX IX SEMIVOLATILE ORGANIC COMPOUNDS SW-846 METHOD 8270C							
1,2,4,5-Tetrachlorobenzene	3	10	11	0.092	0.33	2.02	18
1,2,4-Trichlorobenzene	3	10	69.2	0.047	0.33	0.3	0.3
1,2-Dichlorobenzene	4	10	11	0.035	0.33	0.9	0.231
1,3-Dichlorobenzene	3	10	5.5	0.035	0.33	0.42	0.42
1,4-Dichlorobenzene	4	10	0.5	0.04	0.33	0.1	0.1
1,4-Naphthoquinone	1	10	--	0.059	0.33	--	--
1,4-Phenylenediamine	--	25	6900	0.308	0.83	6.16	0.00000568
1-Naphthylamine	2	10	0.67	0.169	0.33	--	--
2,3,4,6-Tetrachlorophenol	5	10	14.1	0.096	0.33	0.199	1.51
2,4,5-Trichlorophenol	7	25	3600	0.109	0.83	14	0.0856
2,4,6-Trichlorophenol	6	10	2	0.065	0.33	0.008	0.008
2,4-Dichlorophenol	5	10	18	0.114	0.33	0.05	0.05
2,4-Dimethylphenol	6	10	100	0.182	0.33	0.01	0.305
2,4-Dinitrophenol	6	25	4.07	0.384	0.83	0.01	0.00133
2,6-Dichlorophenol	3	10	--	0.104	0.33	1.17	0.00394
2-Acetylaminofluorene	1	10	535	0.073	0.33	0.596	0.0153
2-Chloronaphthalene	4	10	0.396	0.056	0.33	0.0122	0.417
2-Chlorophenol	5	10	8.8	0.069	0.33	0.2	0.0117
2-Methylnaphthalene	3	10	330	0.0032	0.33	3.24	0.0202
2-Methylphenol	6	10	1800	0.126	0.33	0.8	0.000826
2-Naphthylamine	4	10	--	0.194	0.33	3.03	0.00174
2-Nitroaniline	6	25	2.1	0.128	0.83	3.5	0.000222
2-Nitrophenol	8	10	13.5	0.068	0.33	1.6	0.00777
2-Picoline	5	10	3790	0.25	0.33	9.9	0.753
3,3'-Dichlorobenzidine	3	10	0.15	0.234	0.33	0.0003	0.0003
3,3'-Dimethylbenzidine	8	10	0.0073	0.144	0.33	0.053	0.002
3-Methylcholanthrene	1	10	0.0891	0.384	0.33	0.0779	8190
3-Methylphenol[3]	5	10	1800	0.079	0.33	163	0.000808
4-Methylphenol[3]	5	10	180	0.13	0.33	3.49	0.000845
3-Nitroaniline	6	25	--	0.217	0.83	3.16	0.000222
4,6-Dinitro-2-methylphenol	6	25	2.3	0.144	0.83	0.144	0.0104
4-Aminobiphenyl	1	10	--	0.135	0.33	0.00305	0.00566
4-Bromophenyl phenyl ether	6	10	1.5	0.044	0.33	--	1.68
4-Chloro-3-methylphenol	7	10	20	0.231	0.33	7.95	0.388
4-Chloroaniline	6	10	150	0.186	0.33	0.03	0.03
4-Chlorophenyl phenyl ether	4	10	--	0.116	0.33	--	0.656
4-Nitroaniline	3	25	--	0.348	0.83	21.9	0.000222

TABLE 1-5

LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
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Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
4-Nitrophenol	6	25	35	0.374	0.83	5.12	0.00778
4-Nitroquinoline-1-oxide	19	25	--	0.783	0.83	0.122	0.00124
5-Nitro-o-toluidine	2	10	2	0.086	0.33	8.73	0.000845
7,12-Dimethylbenz(a)anthracene	2	10	--	0.249	0.33	--	--
Acetophenone	2	10	0.042	0.052	0.33	0.49	0.246
Aniline	7	10	0.44	0.14	0.33	0.0568	0.0000338
Aramite	2	25	2.7	0.043	0.83	19	0.00000111
Benzyl alcohol	7	10	281	0.271	0.33	65.8	0.0339
Bis(2-chloroethoxy)methane	4	10	6400	0.064	0.33	0.302	0.35
Bis(2-chloroethyl)ether	5	10	0.0098	0.049	0.33	0.00002	0.00002
Bis(2-chloroisopropyl)ether	5	10	0.27	0.058	0.33	0.027	0.027
Bis(2-ethylhexyl)phthalate	5	10	2.1	0.071	0.33	0.926	0.182
Butyl benzyl phthalate	4	10	49	0.063	0.33	0.239	4.19
Chlorobenzilate	1	10	0.25	0.051	0.33	1.8	0.86
Diallate	1	10	1.1	0.046	0.33	0.452	0.00151
Di-n-butyl phthalate	4	10	3	0.113	0.33	0.15	0.111
Di-n-octyl phthalate	5	10	20	0.191	0.33	709	40.6
Dibenzofuran	4	10	20	0.071	0.33	290	1.52
Diethyl phthalate	5	10	3	0.142	0.33	23	0.00804
p-(Dimethylamino)azobenzene	1	10	--	0.024	0.33	--	--
a,a-Dimethylphenethylamine	13	25	37	0.153	0.83	61	61
Dimethyl phthalate	6	10	73	0.115	0.33	734	0.025
Diphenylamine[4]	1	10	413	0.111	0.33	1.01	0.0346
Ethyl methane sulfonate	2	10	--	0.059	0.33	--	--
Hexachlorobenzene	5	10	0.00024	0.047	0.33	0.1	0.02
Hexachlorobutadiene	3	10	0.223	0.047	0.33	0.034	0.1
Hexachlorocyclopentadiene	1	10	50	0.086	0.33	0.755	0.901
Hexachloroethane	3	10	4.8	0.04	0.33	0.02	0.02
Hexachlorophene	373	400	0.228	4.76	13	0.199	18
Hexachloropropene	5	10	20	0.126	0.33	--	0.0002
Isodrin	1	10	0.0309	0.057	0.33	0.00332	0.0552
Isophorone	5	10	71	0.068	0.33	0.03	0.03
Isosafrole	1	10	--	0.058	0.33	9.94	0.00412
Kepone	1	25	0.0037	0.072	0.83	0.027	0.00331
Methapyrilene	16	25	--	0.215	0.83	2.78	0.0000144
Methyl methane sulfonate	2	25	--	0.172	0.83	--	--
n-Nitrosodi-n-butylamine	2	10	0.002	0.045	0.33	0.024	0.024
n-Nitrosodiethylamine	2	10	0.00045	0.07	0.33	0.0032	0.0032
n-Nitrosodimethylamine	2	10	0.0013	0.121	0.33	0.0000321	0.00000275
n-Nitrosodi-n-propylamine	6	10	0.0096	0.09	0.33	0.000002	0.000002
n-Nitrosomethylethylamine	7	10	0.0031	0.125	0.33	0.00166	0.00000485
n-Nitrosomorpholine	1	10	--	0.063	0.33	0.0706	0.0000037
n-Nitrosopiperidine	1	10	--	0.073	0.33	0.00665	0.0000226
n-Nitrosopyrrolidine	2	10	0.032	0.073	0.33	0.0126	0.000000908
Pentachlorobenzene	4	10	0.47	0.038	0.33	0.497	1.26
Pentachloronitrobenzene	1	25	0.26	0.059	0.83	1.9	1.9
Phenacetin	1	10	--	0.051	0.33	11.7	0.00225
Phenol	4	10	100	0.099	0.33	5	0.0273

TABLE 1-5

LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
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Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
Pronamide	1	10	160	0.047	0.33	0.0136	0.0016
Pyridine	2	10	37	0.221	0.33	1.03	0.106
Safrole	1	10	40	0.078	0.33	0.404	0.165
o-Toluidine	2	10	0.28	0.086	0.33	2	0.000199
O,O,O-Triethyl phosphorothioate	1	10	58.3	0.087	0.33	--	--
POLYNUCLEAR AROMATIC HYDROCARBONS SW-846 8310							
Acenaphthene	0.071	0.2	9.9	0.0039	0.01	29	0.00671
Acenaphthylene	0.046	0.2	370	0.008	0.01	682	0.00587
Anthracene	0.075	0.2	0.029	0.0033	0.01	51	0.0469
Benzo(a)anthracene	0.066	0.2	0.092	0.0039	0.01	0.08	0.0317
Benzo(a)pyrene	0.084	0.2	0.0092	0.0042	0.01	0.062	0.0319
Benzo(b)fluoranthene	0.058	0.2	0.092	0.0057	0.01	0.2	0.2
Benzo(g,h,i)perylene	0.11	0.2	6.2	0.0048	0.01	119	0.17
Benzo(k)fluoranthene	0.066	0.2	0.0056	0.005	0.01	2	0.24
Chrysene	0.11	0.2	0.033	0.0048	0.01	4.73	0.0571
Dibenzo(a,h)anthracene	0.056	0.2	0.0016	0.0037	0.01	0.062	0.00622
Fluoranthene	0.081	0.2	8.1	0.0038	0.01	122	0.111
Fluorene	0.059	0.2	3.9	0.0037	0.01	28	0.0212
Indeno(1,2,3-cd)pyrene	0.061	0.2	0.092	0.0032	0.01	0.62	0.2
Naphthalene	0.07	0.2	6.2	0.0079	0.01	0.0994	0.0346
Phenanthrene	0.098	0.2	2.1	0.004	0.01	45.7	0.0419
Pyrene	0.12	0.2	0.3	0.0041	0.01	78.5	0.053
APPENDIX IX ORGANOCHLORINE PESTICIDES SW-846 METHOD 8081A							
Aldrin	0.0024	0.04	0.004	0.000059	0.0013	0.00332	0.002
Alpha-BHC	0.0019	0.04	0.011	0.00014	0.0013	0.00003	0.00003
Alpha-chlordane	0.0026	0.04	0.00029	0.000067	0.0013	0.224	0.0045
Beta-BHC	0.0093	0.04	0.037	0.0007	0.0013	0.0001	0.0001
4,4'-DDD	0.0093	0.08	0.0011	0.0011	0.0025	0.758	0.00553
4,4'-DDE	0.0044	0.08	4.51E-09	0.0012	0.0025	0.596	0.00142
4,4'-DDT	0.0036	0.08	0.001	0.00031	0.0025	0.0175	0.00119
Delta-BHC	0.0019	0.04	0.011	0.000076	0.0013	9.94	71.5
Dieldrin	0.0038	0.08	0.000026	0.0003	0.0025	0.0002	0.0002
Endosulfan I	0.0024	0.04	0.003	0.000086	0.0013	0.119	0.000175
Endosulfan II	0.0039	0.08	0.003	0.00032	0.0025	0.119	0.000104
Endosulfan sulfate	0.0042	0.08	0.22	0.001	0.0025	0.0358	0.0346
Endrin	0.0042	0.08	0.002	0.00035	0.0025	0.0101	0.00267
Endrin aldehyde	0.0054	0.08	0.15	0.00018	0.0025	0.0105	3.2
Gamma-BHC (Lindane)	0.0019	0.04	0.01	0.00023	0.0013	0.0005	0.0005
Gamma-chlordane	0.004	0.04	0.00029	0.0002	0.0013	0.224	0.0045
Heptachlor	0.0074	0.04	0.00039	0.00014	0.0013	0.00598	0.0006
Heptachlor epoxide	0.0022	0.04	0.00048	0.00071	0.0013	0.03	0.0006
Methoxychlor	0.046	0.38	0.005	0.0021	0.0125	0.0199	0.00359
Toxaphene	0.55	2.5	0.0002	0.038	0.083	0.119	0.000109

TABLE 1-5

LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
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Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
APPENDIX IX PCBs SW-846 METHOD 8082							
Aroclor-1016	0.097	1	0.000029	0.0022	0.033	0.68	0.0341
Aroclor-1221	0.22	1	0.000029	0.0035	0.033	0.22	0.0341
Aroclor-1232	0.097	1	0.000029	0.0033	0.033	0.22	0.0341
Aroclor-1242	0.12	1	0.000029	0.0059	0.033	0.22	0.0341
Aroclor-1248	0.2	1	0.000029	0.0085	0.033	0.22	0.0341
Aroclor-1254	0.12	1	0.000029	0.0027	0.033	0.22	0.0341
Aroclor-1260	0.074	1	0.000029	0.0009	0.033	0.22	0.0341
APPENDIX IX HERBICIDES SW-846 METHOD 8151A							
2,4-D	0.61	2.5	70	0.01	0.7	0.0273	0.00579
2,4,5-T	0.23	0.8	360	0.0033	0.01	0.596	58.7
2,4,5-TP (Silvex)	0.18	0.5	50	0.0018	0.01	0.109	7.35
Dinoseb	0.45	1	0.39	0.011	0.02	0.0218	0.01178
Pentachlorophenol	0.16	0.5	0.56	0.0022	0.01	0.001	0.001
MISCELLANEOUS PARAMETERS							
Chloride	0.16	0.2	230000	ANR[5]	ANR[5]	ANR[5]	ANR[5]
Gross Alpha EPA 900	--	10 (pCi/L)	15 (pCi/L)	ANR[5]	ANR[5]	ANR[5]	ANR[5]
Gross Beta EPA 900	--	5 (pCi/L)	4 (mrem)	ANR[5]	ANR[5]	ANR[5]	ANR[5]
Hardness Standard Methods 2340B calculation	NA	NA	--	ANR[5]	ANR[5]	ANR[5]	ANR[5]
pH SW-846 9045C	ANR[6]	ANR[6]	--	ANR[5]	ANR[5]	NA[6]	NA[6]
Total Organic Carbon SW-846 9060/Lloyd Kahn	0.3	1	--	74	500	NA[6]	NA[6]
Total Suspended Solids EPA 160.1	2.5	4	--	ANR[5]	ANR[5]	ANR[5]	ANR[5]
RADIONUCLIDES ALPHA SPECTROSCOPY, EPA 907, EMSL-LV-0539-17, March 1979							
Thorium-228	--	.08 (pCi/L)	0.087 pCi/L	--	.08 (pCi/g)	0.00074 (pCi/g)	0.00074 (pCi/g)
Thorium-230	--	.08 (pCi/L)	0.37 pCi/L	--	.08 (pCi/g)	5.7 (pCi/g)	5.7 (pCi/g)
Thorium-232	--	.08 (pCi/L)	0.028 pCi/L	--	.08 (pCi/g)	0.00049 (pCi/g)	0.00049 (pCi/g)
RADIONUCLIDES GAMMA SPECTROSCOPY							
Potassium-40 (1460)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)	0.14(pCi/g)	
Thallium-208 (583)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Thallium-208 (860)	NA[6]	NA[6]	NA[6]	NA[6]	1.0 (pCi/g)	23000 (pCi/g)	
Lead-210 (46)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)		
Lead-212 (238)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	0.063 (pCi/g)	
Lead-214 (352)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Lead-214(295)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	46000 (pCi/g)	
Bismuth-212 (727)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)	8200 (pCi/g)	
Bismuth-214 (609)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	23000 (pCi/g)	
Bismuth-214 (1764)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)		
Bismuth-214 (1120)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)		
Radium-226 (186) [7]	NA[6]	NA[6]	NA[6]	NA[6]	1.0 (pCi/g)	0.069 (pCi/g)	
Actinium-228 (911)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)		
Actinium-228 (969)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)		
Actinium-228 (338)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)	730 (pCi/g)	
Thorium-234 (63)	NA[6]	NA[6]	NA[6]	NA[6]	1.0 (pCi/g)	2200 (pCi/g)	
Thorium-234 (92)	NA[6]	NA[6]	NA[6]	NA[6]	1.0 (pCi/g)		
Uranium-235 (143)	NA[6]	NA[6]	NA[6]	NA[6]	0.50 (pCi/g)	0.21 (pCi/g)	

TABLE 1-5

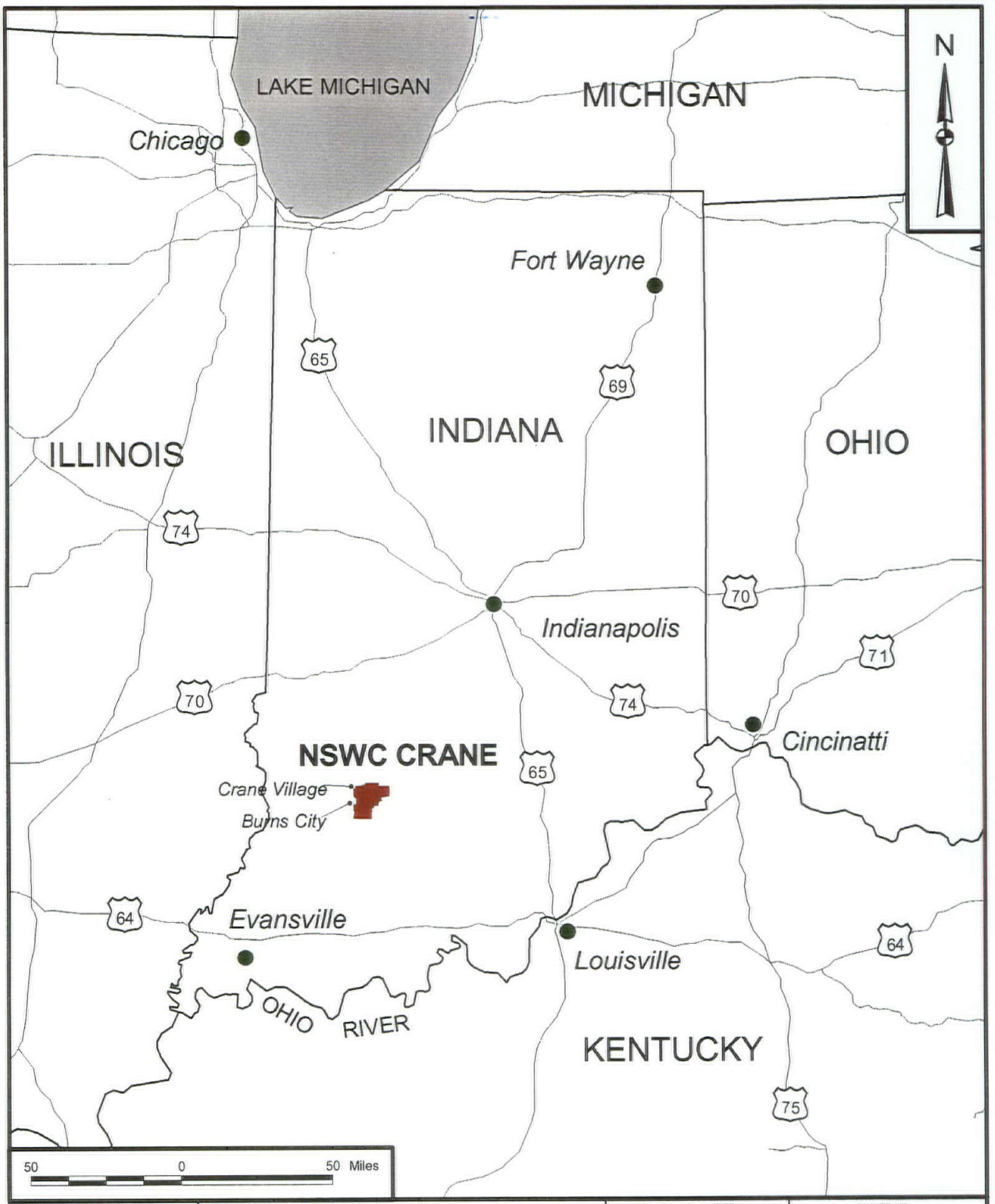
LABORATORY ANALYTICAL PARAMETERS, DETECTION AND REPORTING LIMITS, AND
RISK-BASED TARGET LEVELS
NSWC CRANE, CRANE , INDIANA
PAGE 7 OF 7

Parameter	Aqueous Matrix			Solid Matrix			
	Laboratory MDL (ug/L)	Laboratory RL (ug/L)	Risk-Based Target Level[1] (ug/L)	Laboratory MDL (mg/kg)	Laboratory RL (mg/kg)	Risk-Based Soil Target Level[1] (mg/kg)	Risk-Based Sediment Target Level[1] (mg/kg)
Cobalt-60 (1332)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	0.036 (pCi/g)	
Cobalt-60 (1173)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Cesium-137 (662)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	0.061(pCi/g)	
Europium-154 (123)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	0.05 (pCi/g)	
Europium-154 (1274)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Europium-154 (723)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Europium-154 (1004)	NA[6]	NA[6]	NA[6]	NA[6]	0.20 (pCi/g)		
Europium-154 (873)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Europium-154 (996)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Europium-155 (87)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)	3.8 (pCi/g)	
Europium-155 (860)	NA[6]	NA[6]	NA[6]	NA[6]	0.10 (pCi/g)		
Protactinium-243 (1001)	NA[6]	NA[6]	NA[6]	NA[6]	3.0 (pCi/g)	1.5E+07 (pCi/g)	

MDL = method detection limit
RL = reporting limit
µg/L = micrograms per liter.
mg/kg = milligrams per kilogram.
mg/L = milligrams per liter.
pCi/L = picoCuries per liter.
mrem = millirem-equivalent man.

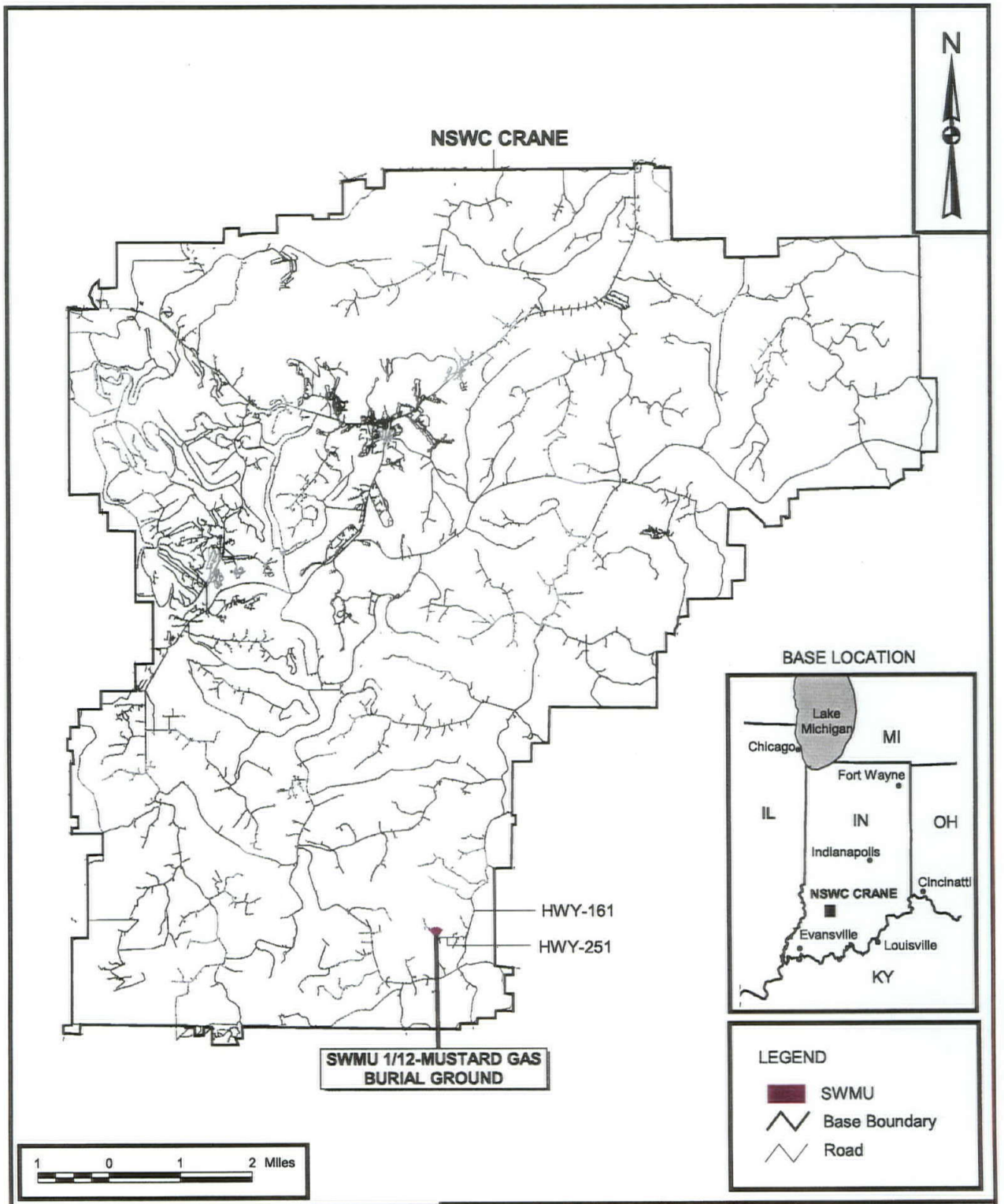
Shading indicates those chemicals for which the laboratory MDL or RL exceeds the risk-based target level for the project.

1. Value is based on the lowest human health or ecological risk-based criteria as presented in Appendix C.
2. Risk-based target level is not provided because human and ecological risk-based criteria are not available for this parameter.
3. 3-Methylphenol and 4-methylphenol coelute; therefore, one analytical result for 3-, 4-methylphenol will be reported.
4. N-Nitrosodiphenylamine is more toxic than diphenylamine. However, n-nitrosodiphenylamine rapidly degrades to diphenylamine. Therefore, only diphenylamine will be reported, but results for diphenylamine will be treated as n-nitrosodiphenylamine during risk assessment.
5. Analysis not required
6. Not applicable.
7. Reported value will not have been corrected for possible U-235 interferences.



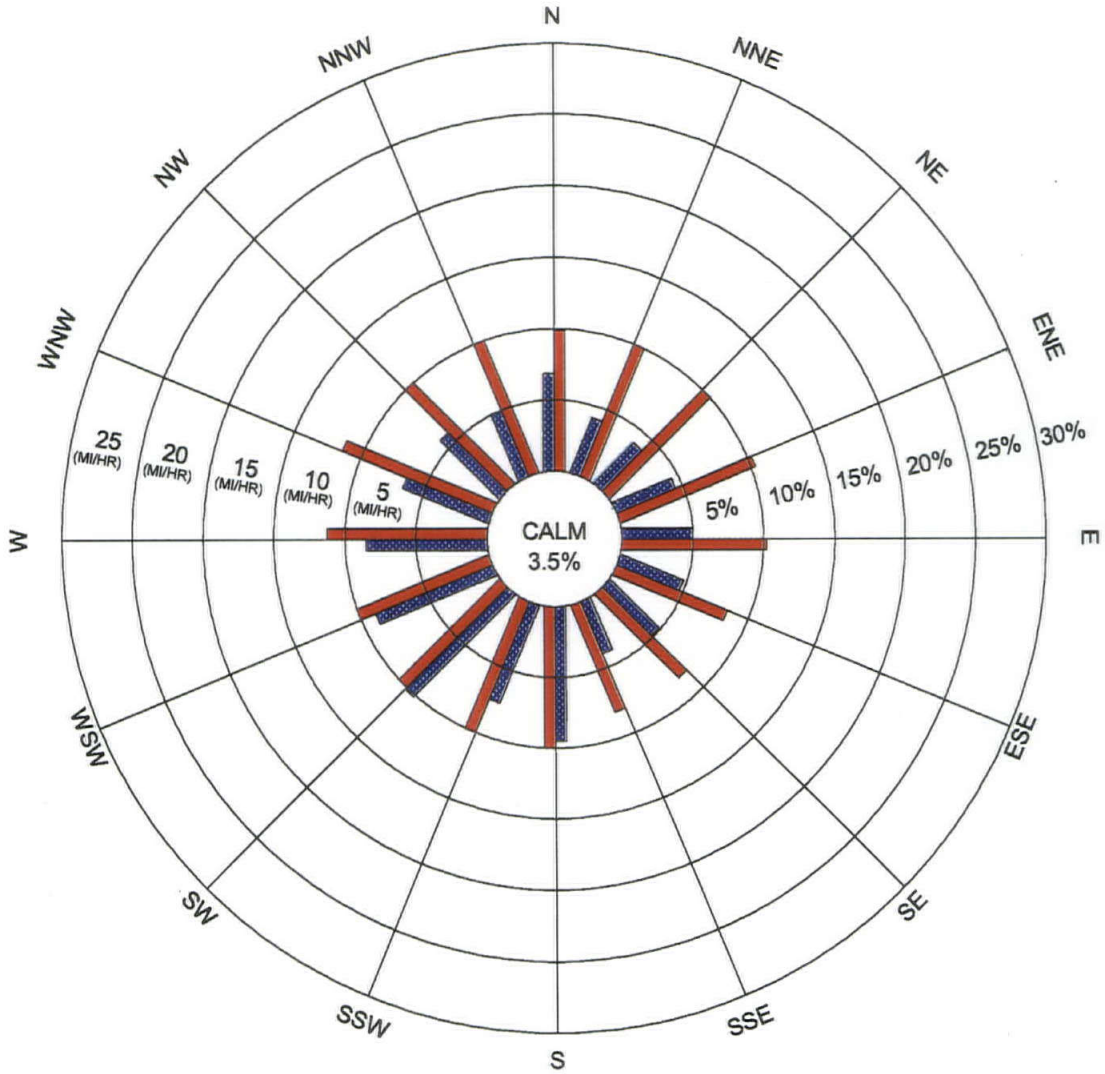
DRAWN BY J. LAMEY DATE 3/9/00	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504	OWNER NO. CTO 131
CHECKED BY J. SCHUBERT DATE 5/1/00	GENERAL LOCATION MAP NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY T. JOHNSTON DATE 5/2/00	
COST/SCHEDULE-AREA		APPROVED BY — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 1-1	REV 1

P:\GIS\NSWC_CRANE\0087.APR GENERAL LOCATION MAP MJJ 06/26/00



DRAWN BY J. LAMEY DATE 2/9/00	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504	OWNER NO. CTO 131
CHECKED BY J. SCHUBERT DATE 5/1/00	SITE LOCATION MUSTARD GAS BURIAL GROUND NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY T. JOHNSTON DATE 5/2/00	
COST/SCHEDULE-AREA		APPROVED BY — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 1-2	REV —

P:\GIS\NSWC_CRANE\SWMU01.APR SITE LOCATION 5/4/00 JAL



LEGEND

WIND DIRECTION FREQUENCY (PERCENT)
(DIRECTION FROM WHICH THE WIND IS BLOWING)

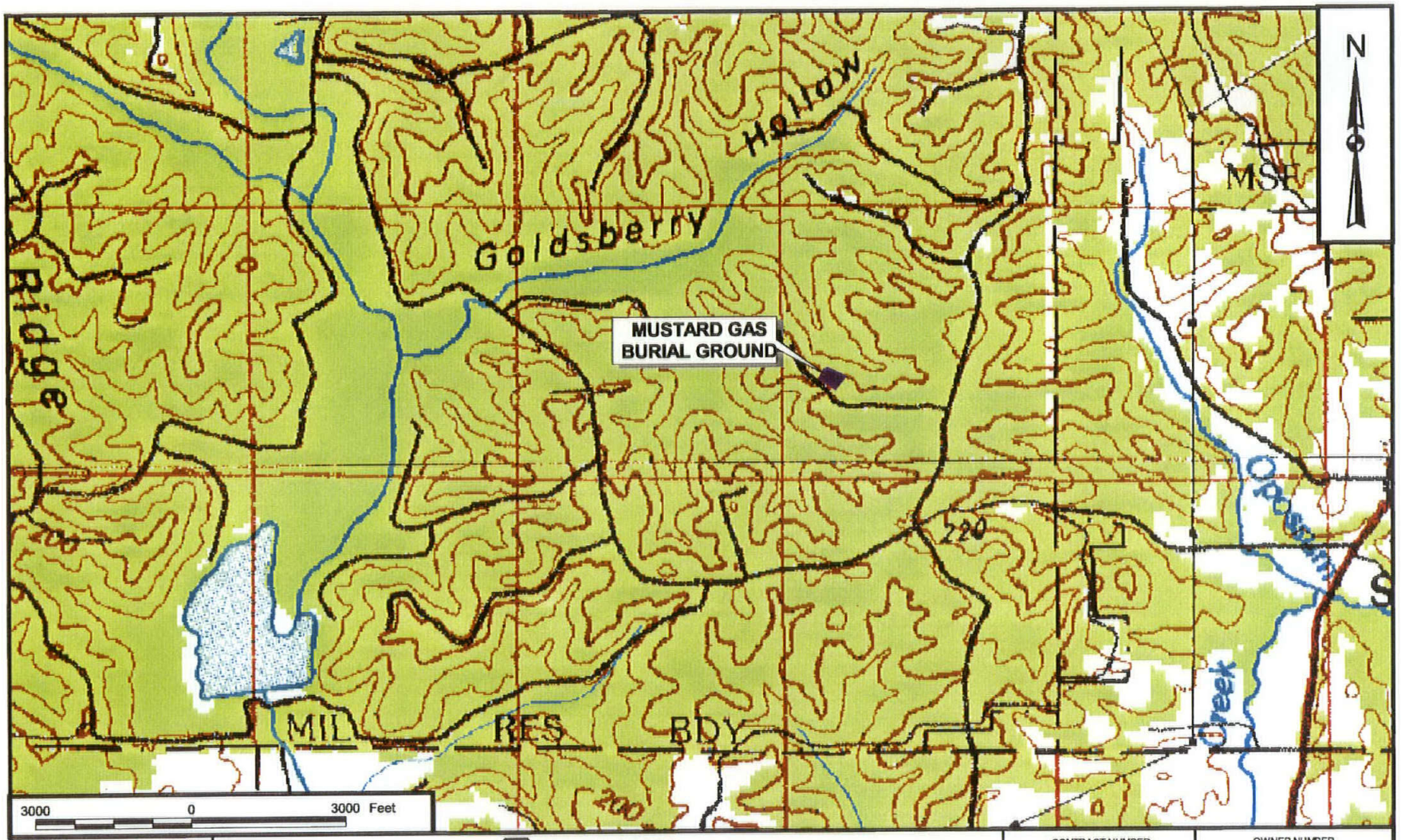
MEAN WIND SPEED (MI/HR)

DATA SOURCE: INDIANAPOLIS, INDIANA AIRPORT

PERIOD OF RECORD: 1985-1989
43,824 OBSERVATIONS

DRAWN BY HJP	DATE 2/4/00	FIVE-YEAR WINDROSE SUMMARY FOR INDIANAPOLIS, INDIANA NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	CONTRACT NUMBER N0504
CHECKED BY J. SCHUBERT	DATE 5/1/00		APPROVED BY T. JOHNSTON — DATE 5/2/00
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1-3 — REV 1

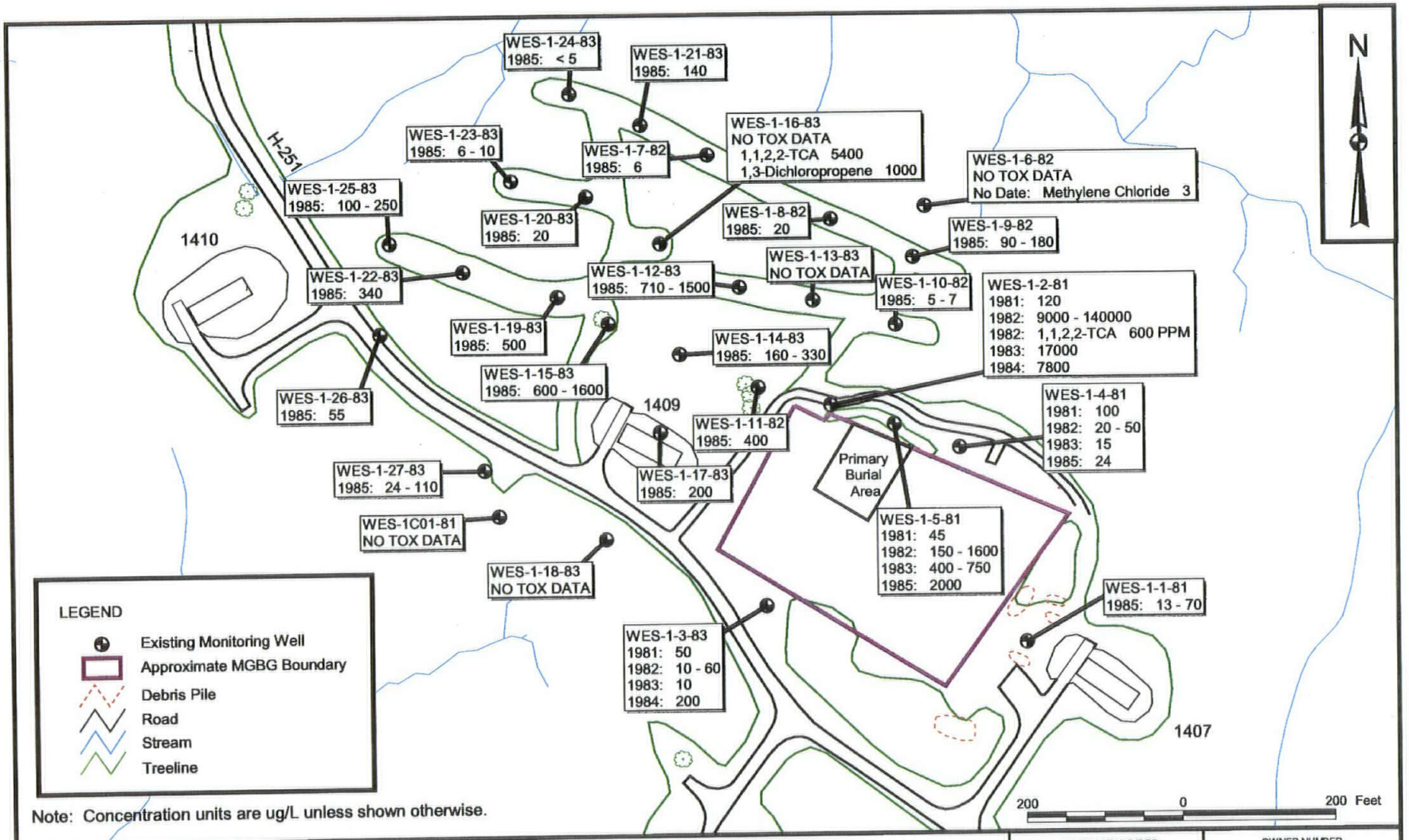
P:\GIS\NSWC_CRANE\SWMU01.APR WIND ROW DIAGRAM 4/26/00 JAL



DRAWN BY J. LAMEY DATE 2/9/00	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504	OWNER NUMBER CTO 131
CHECKED BY J. SCHUBERT DATE 5/1/00	SURROUNDING TOPOGRAPHY MUSTARD GAS BURIAL GROUND NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY T. JOHNSTON	DATE 5/2/00
COST/SCHEDULE-AREA		APPROVED BY —	DATE —
SCALE AS NOTED		DRAWING NO. FIGURE 1-4	REV 0

P:\GIS\NSWC_CRANE\SWMU01.APR SITE MAP-QUAD 5/4/00 JAL

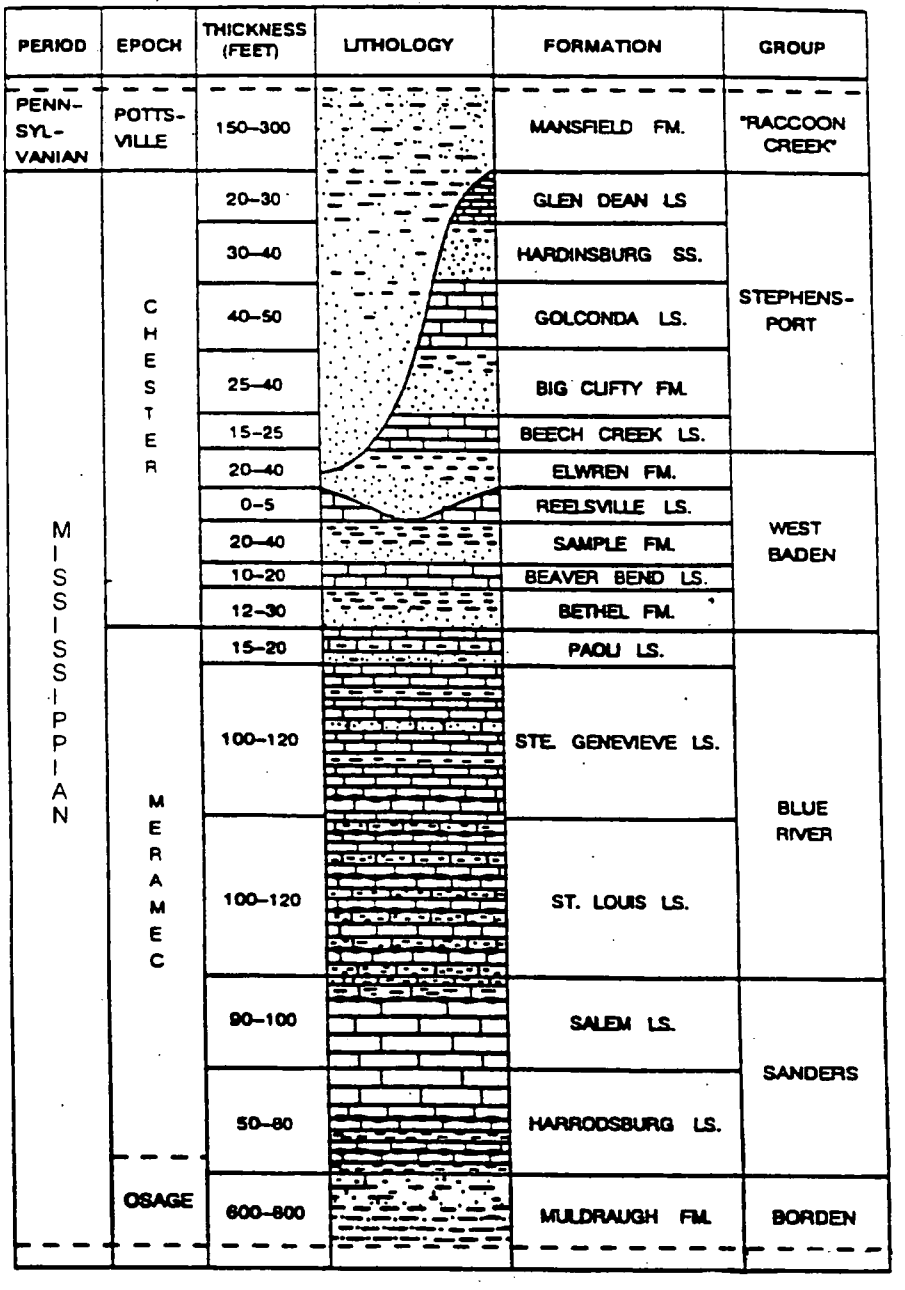
NSWC Crar
QAP
Revision:
Date: May 20(
Section:
Page 71 of 9



Note: Concentration units are ug/L unless shown otherwise.

DRAWN BY J. LAMEY DATE 3/22/00	Tetra Tech NUS, Inc.	CONTRACT NUMBER 0504	OWNER NUMBER 0131
CHECKED BY J. SCHUBERT DATE 5/7/01	MONITORING WELLS AND ASSOCIATED TOTAL ORGANIC HALOGEN (TOX) DATA (APPROXIMATE) 1981 - 1986 MUSTARD GAS BURIAL GROUND NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY T. JOHNSTON	DATE 5/7/01
COST/SCHEDULE-AREA		APPROVED BY —	DATE —
SCALE AS NOTED		DRAWING NO. FIGURE 1-5	REV 0

P:\GIS\NSWC_CRANE\SWMU01.APR TOTAL ORGANIC HALOGEN DATA 5/7/01 JAL



Source: Draft Report, RCRA Facility Investigation
Phase II Groundwater Release Assessment, SWMU 06/09
Demolition Area and Phase III Release
Characterization SWMU 07/09 Old Rifle Range
November 1995-Figure 11 by William L. Murphy and Roy Wade

Source: Palmer, 1969; Cited in Murphy and Wade, 1995

DRAWN BY J. LAMEY DATE 4/26/00	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504	OWNER NO. CTO 131
CHECKED BY J. SCHUBERT DATE 5/1/00	STRATIGRAPHIC COLUMN NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY T. JOHNSTON DATE 5/2/00	
COST/SCHEDULE-AREA		APPROVED BY — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 1-6	REV 1

P:\GIS\NSWC_CRANE\SWMU01.APR STRATIGRAPHIC COLUMN 5/4/00 JAL

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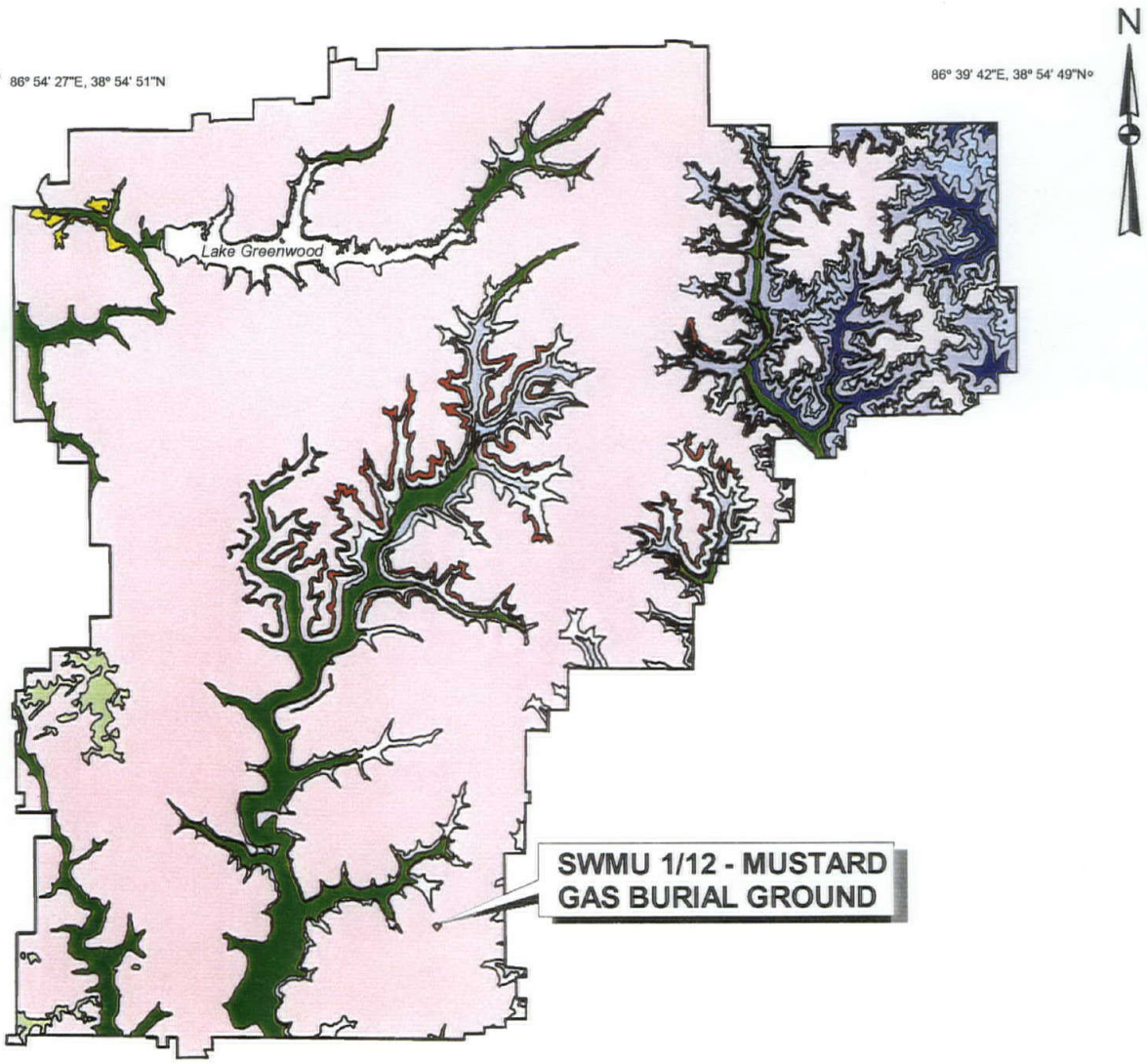


86° 54' 29"E, 38° 44' 8"N

Explanation of Geology

86° 46' 4"E, 38° 44' 7"N

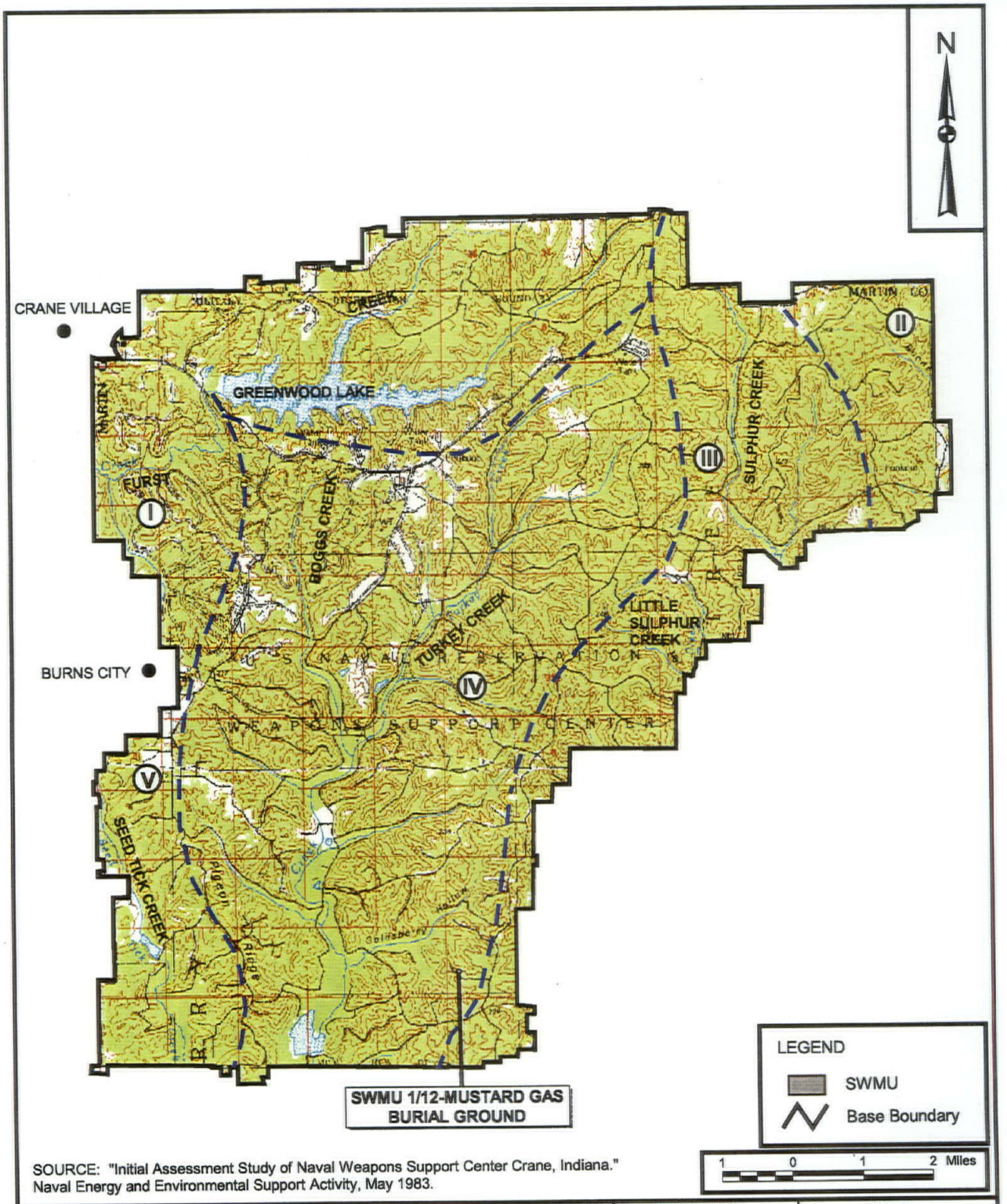
Qal	*Alluvium*
Ql	*Loess*
Qo	*Glacial Outwash*
P	*Raccoon Creek Group and undifferentiated*
Ps	*Sandstone-dominated horizon of Lower Pennsylvanian*
M6	*Glenn Dean Ls, Hardinsburg Fm, Haney Ls, Indian Springs Shale Mbr, and undifferentiated*
M5	*Sandstone member of the Big Clifty Fm*
M4	*Beech Creek Ls*
M3	*Elwren Fm, Reelsville Ls, upper Sample Fm, and undifferentiated*
M2	*Lower part of Sample Fm, Beaver Bend Ls, Bethel Fm, and undifferentiated*
M1	*Paoli Ls, Ste Genevieve Ls, and undifferentiated*

12000 0 12000 Feet

(Modified from Blunck, 1995)

DRAWN BY D. PERRY	DATE 15-MAR-99	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504 / OWNER NO. CTO 131
CHECKED BY J. SCHUBERT	DATE 5/1/00	SURFICIAL GEOLOGY MAP NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY — / DATE —
COST/SCHEDULE-AREA			APPROVED BY — / DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1-7 / REV 0

P:\GIS\NSWC_CRANE\0087.APR 06/26/00 MJJ SURFICIAL GEOLOGY MAP LAYOUT

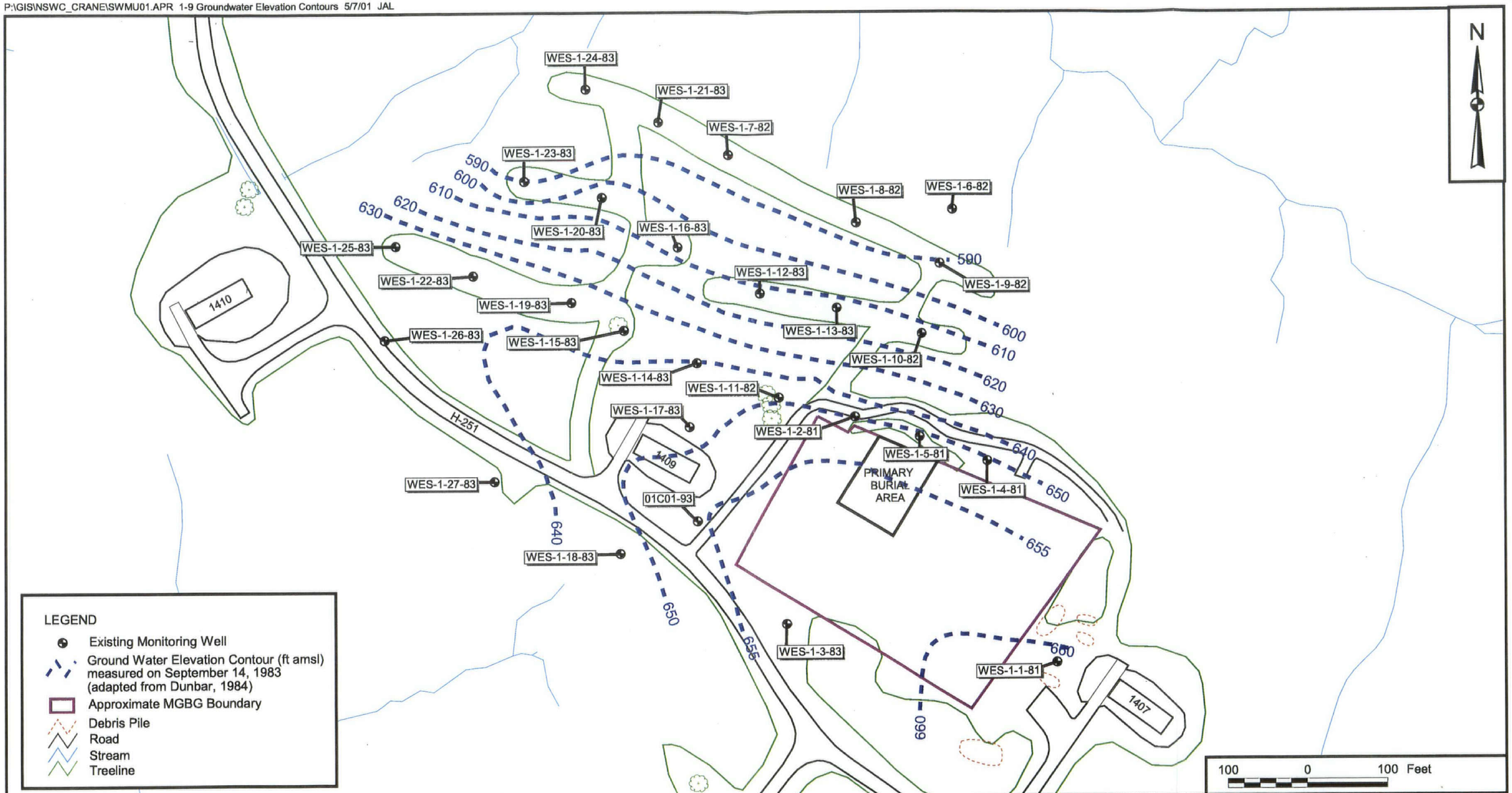


SOURCE: "Initial Assessment Study of Naval Weapons Support Center Crane, Indiana." Naval Energy and Environmental Support Activity, May 1983.

DRAWN BY J. LAMEY DATE 4/19/99	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504	OWNER NO. CTO 131
CHECKED BY J. SCHUBERT DATE 5/1/00	SURFACE DRAINAGE AT THE NAVAL SURFACE WARFARE CENTER CRANE ,INDIANA	APPROVED BY T. JOHNSTON DATE 5/2/00	
COST/SCHEDULE-AREA		APPROVED BY — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 1-8	REV 0

P:\GIS\NSWC_CRANE\0087.APR JAL 7/7/00 SURFACE DRAINAGE LAYOUT

P:\GIS\NSWC_CRANE\SWMU01.APR 1-9 Groundwater Elevation Contours 5/7/01 JAL



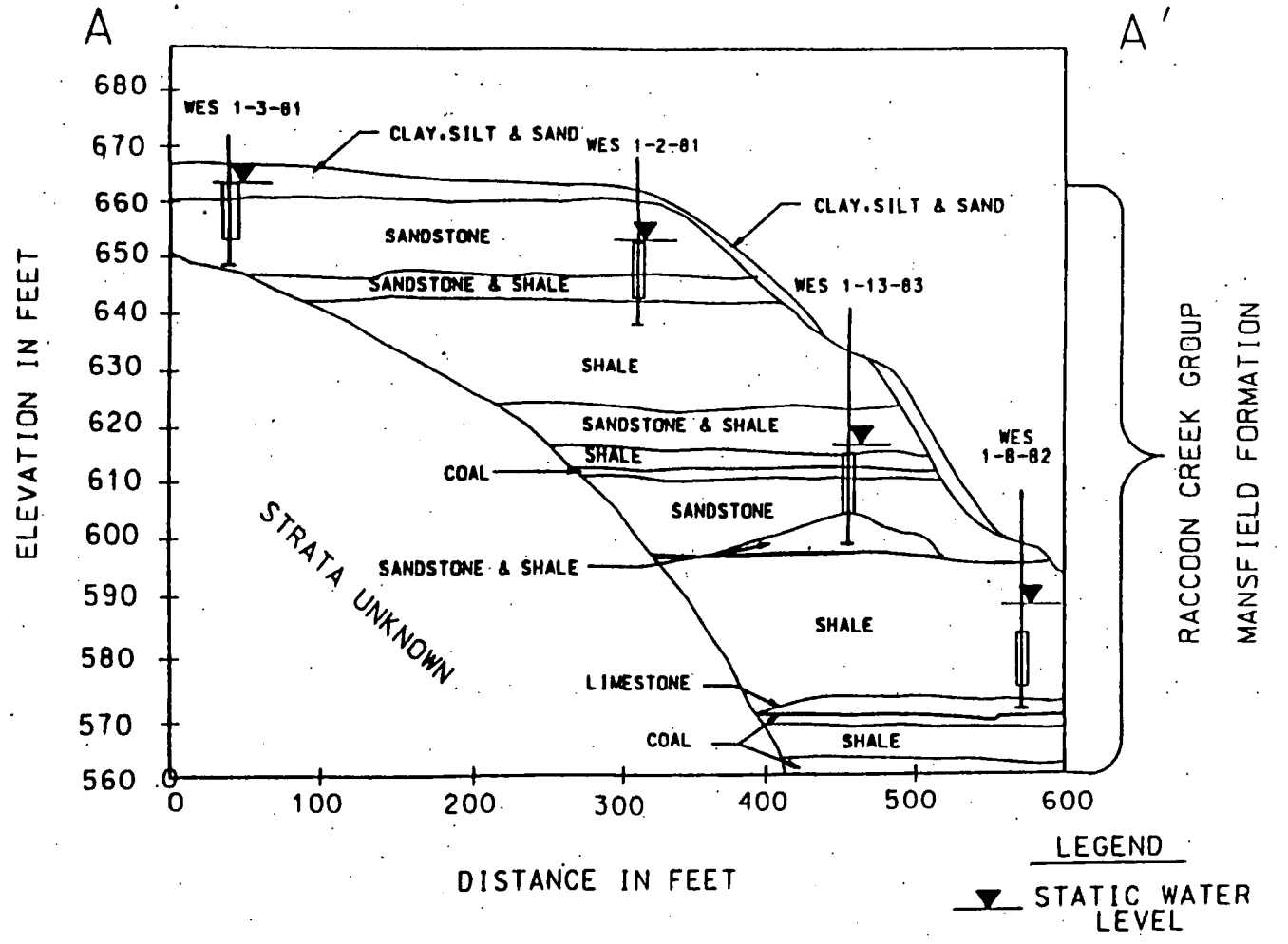
NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY	DATE
J. LAMEY	4/3/00
CHECKED BY	DATE
J. SCHUBERT	5/7/01
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

Tetra Tech NUS, Inc.

GROUND WATER ELEVATION CONTOURS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

CONTRACT NUMBER	OWNER NUMBER
0504	0131
APPROVED BY	DATE
T. JOHNSTON	5/7/01
APPROVED BY	DATE
—	—
DRAWING NO.	REV
FIGURE 1-9	0



DRAWN BY J. LAMEY — DATE 4/26/00	Tetra Tech NUS, Inc.	CONTRACT NUMBER N0504	OWNER NUMBER CTO 131
CHECKED BY J. SCHUBERT — DATE 5/1/00	LOCALIZED GROUNDWATER ELEVATIONS MUSTARD GAS BURIAL GROUNDS NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY T. JOHNSTON	DATE 5/2/00
COST/SCHEDULE-AREA		APPROVED BY —	DATE —
SCALE AS NOTED		DRAWING NO. FIGURE 1-10	REV 1

P:\GIS\NSWC_CRANE\SWMU01.APR LOCALIZED GW ELEVATIONS 7/7/00 JAL

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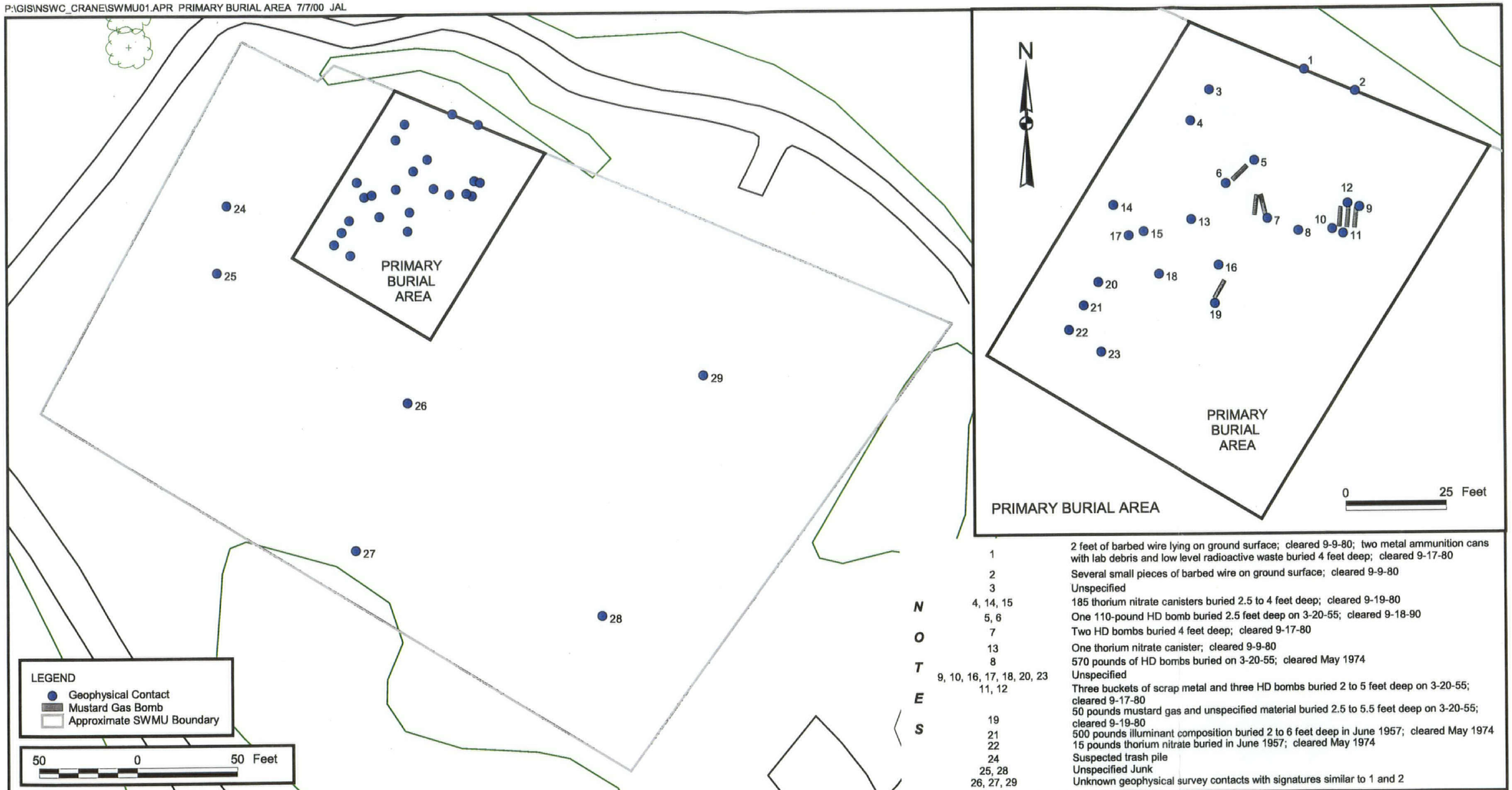


NOTES

1	2 feet of barbed wire lying on ground surface; cleared 9-9-80; two metal ammunition cans with lab debris and low level radioactive waste buried 4 feet deep; cleared 9-17-80
2	Several small pieces of barbed wire on ground surface; cleared 9-9-80
3	Unspecified
4, 14, 15	185 thorium nitrate canisters buried 2.5 to 4 feet deep; cleared 9-19-80
5, 6	One 110-pound HD bomb buried 2.5 feet deep on 3-20-55; cleared 9-18-90
7	Two HD bombs buried 4 feet deep; cleared 9-17-80
13	One thorium nitrate canister; cleared 9-9-80
8	570 pounds of HD bombs buried on 3-20-55; cleared May 1974
9, 10, 16, 17, 18, 20, 23	Unspecified
11, 12	Three buckets of scrap metal and three HD bombs buried 2 to 5 feet deep on 3-20-55; cleared 9-17-80
19	50 pounds mustard gas and unspecified material buried 2.5 to 5.5 feet deep on 3-20-55; cleared 9-19-80
21	500 pounds illuminant composition buried 2 to 6 feet deep in June 1957; cleared May 1974
22	15 pounds thorium nitrate buried in June 1957; cleared May 1974
24	Suspected trash pile
25, 28	Unspecified Junk
26, 27, 29	Unknown geophysical survey contacts with signatures similar to 1 and 2

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY J. LAMEY	DATE 4/25/00
CHECKED BY J. SCHUBERT	DATE 5/1/00
COST/SCHEDULE-AREA	
SCALE AS NOTED	

Tetra Tech NUS, Inc.

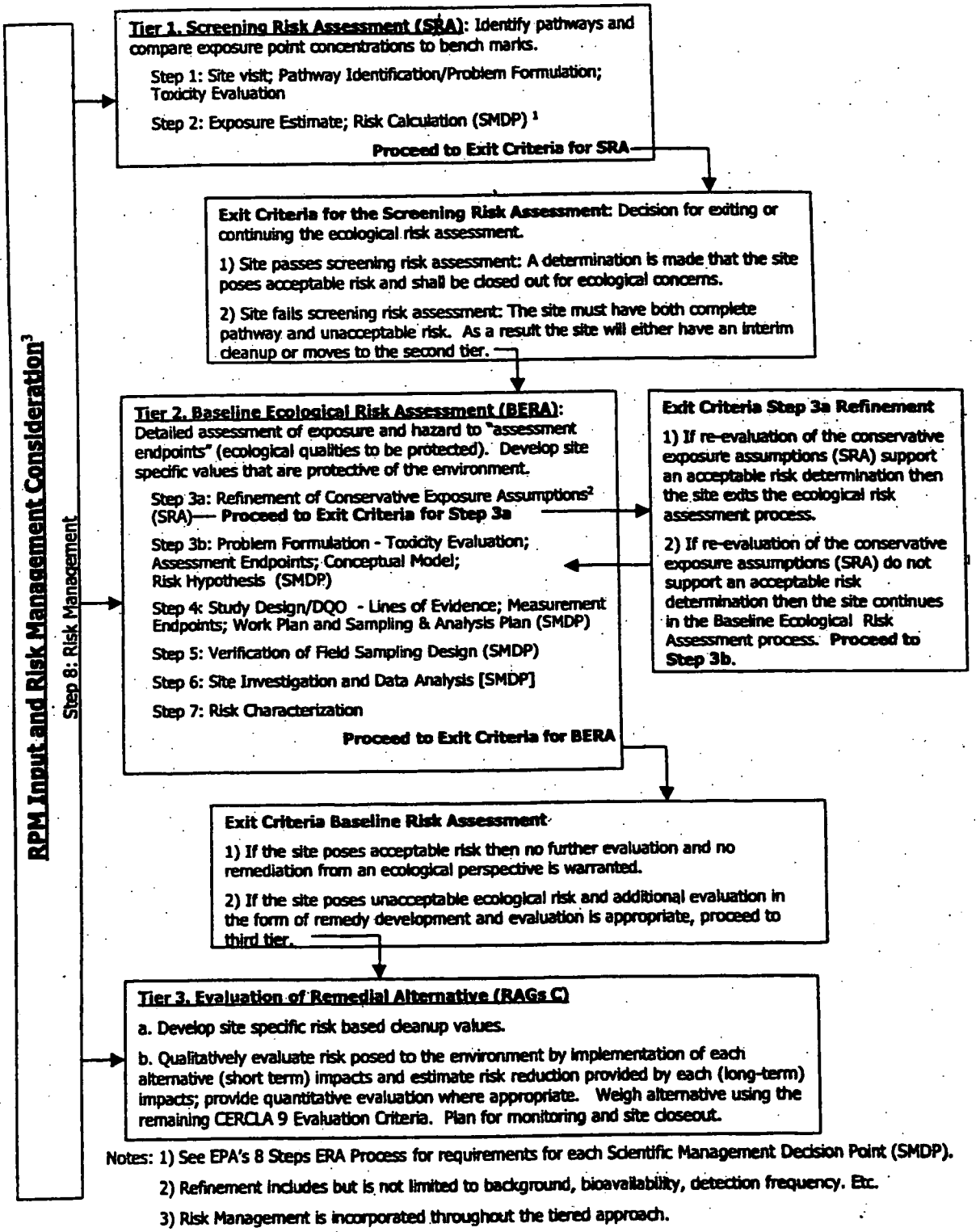
PREVIOUSLY EXHUMED GEOPHYSICAL CONTACTS
(ESTIMATED LOCATIONS)
MUSTARD GAS BURIAL GROUND
NAVAL SURFACE WARFACE CENTER
CRANE, INDIANA

CONTRACT NUMBER N0504	OWNER NUMBER CTO 131
APPROVED BY T. JOHNSTON	DATE 5/2/00
APPROVED BY —	DATE —
DRAWING NO. FIGURE 1-11	REV 0

FIGURE 1-12

NAVY'S ECOLOGICAL RISK ASSESSMENT TIERED APPROACH

NSWC CRANE, CRANE, INDIANA



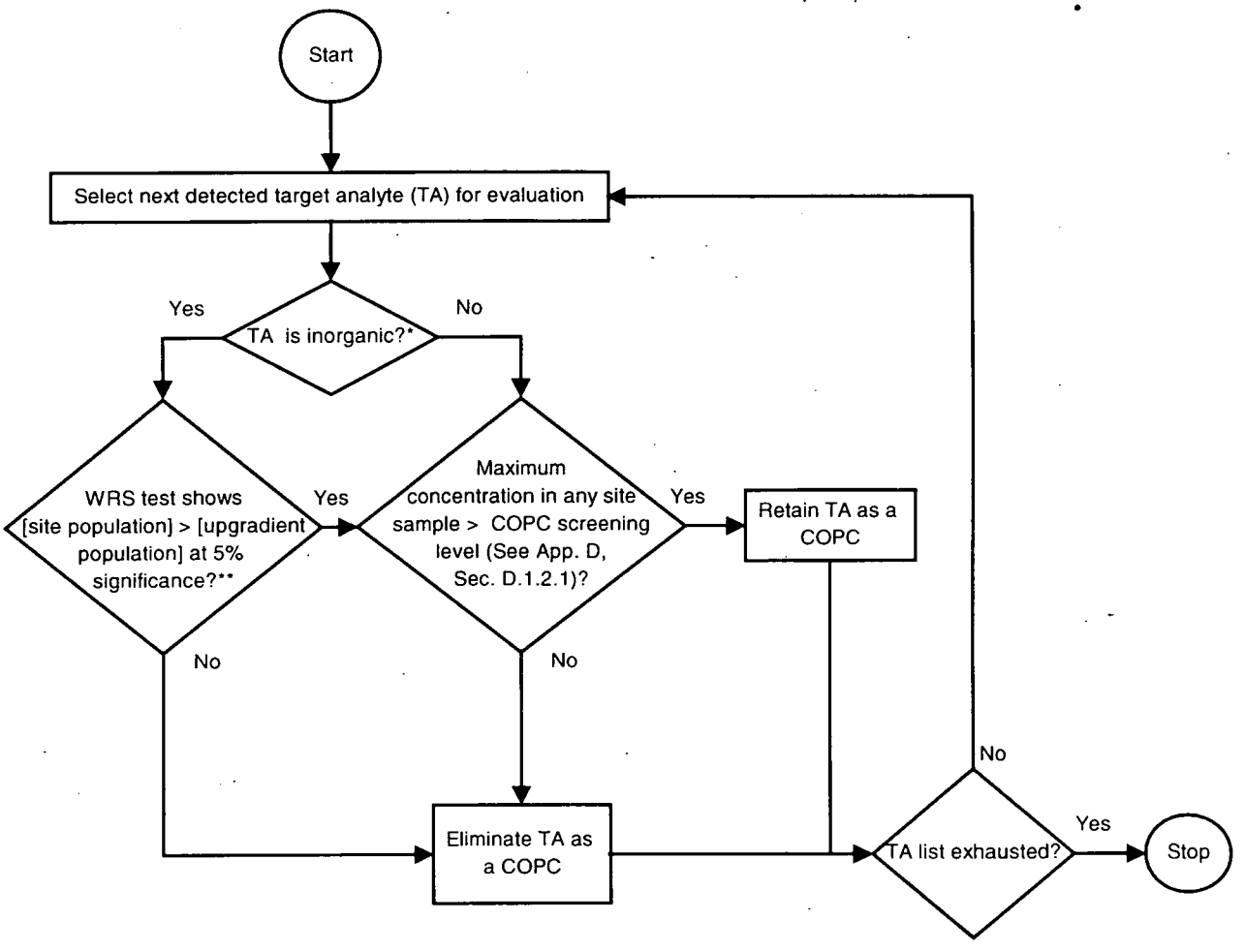
Notes: 1) See EPA's 8 Steps ERA Process for requirements for each Scientific Management Decision Point (SMDP).

2) Refinement includes but is not limited to background, bioavailability, detection frequency. Etc.

3) Risk Management is incorporated throughout the tiered approach.

FIGURE 1-13

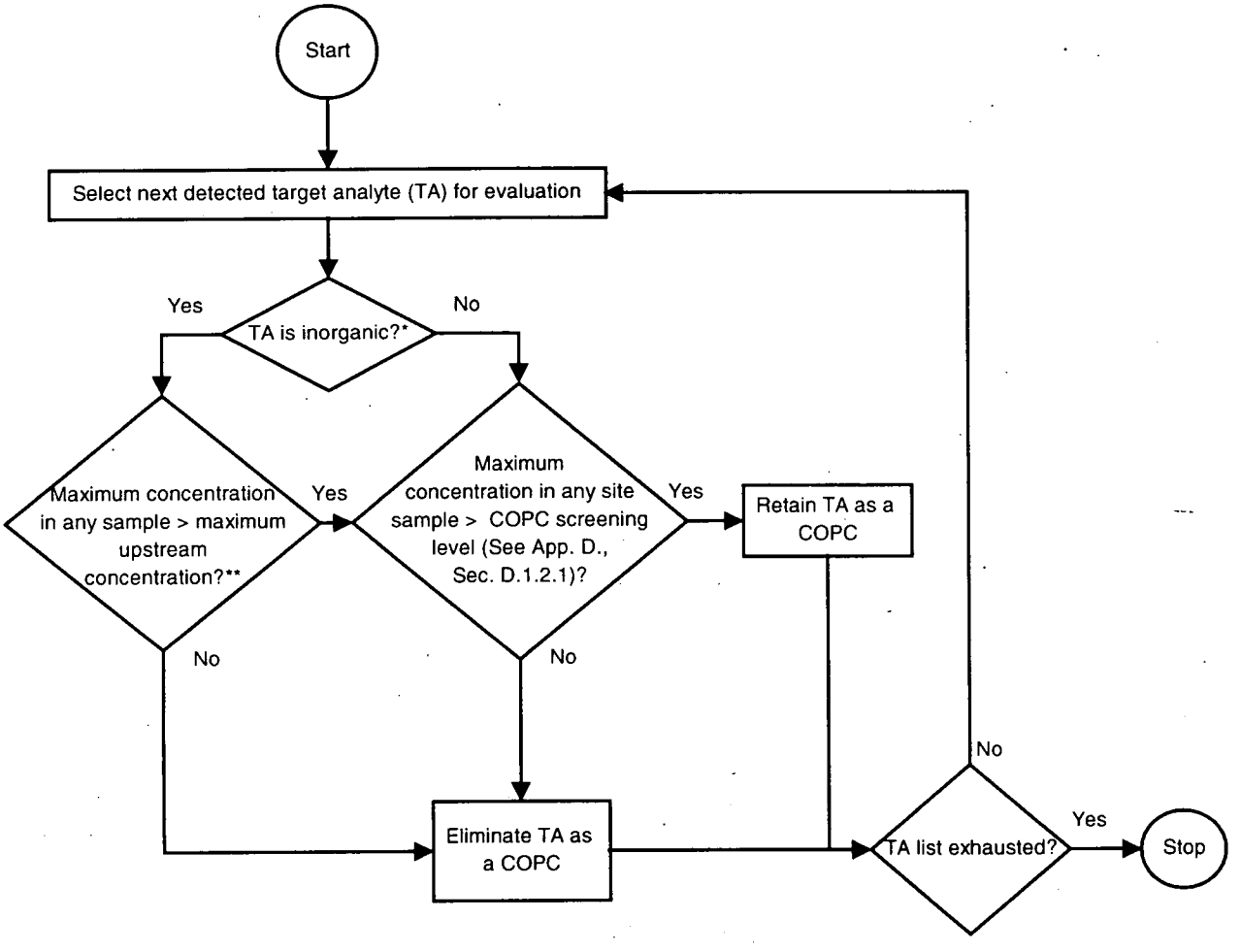
HUMAN HEALTH RISK ASSESSMENT COPC SELECTION IN GROUND WATER NSWC CRANE, CRANE, INDIANA



COPC = Chemical of potential concern
RBTL = Risk-based target level
WRS = Wilcoxon Rank Sum
* "Inorganic" includes radionuclides. For radiouclides comparisons will be based on radiological activities.
** The upgradient population will be represented by samples from upgradient monitoring wells. Sample depths for site and upgradient wells will be matched as closely as practicable to represent corresponding aquifers/depths.

FIGURE 1-14

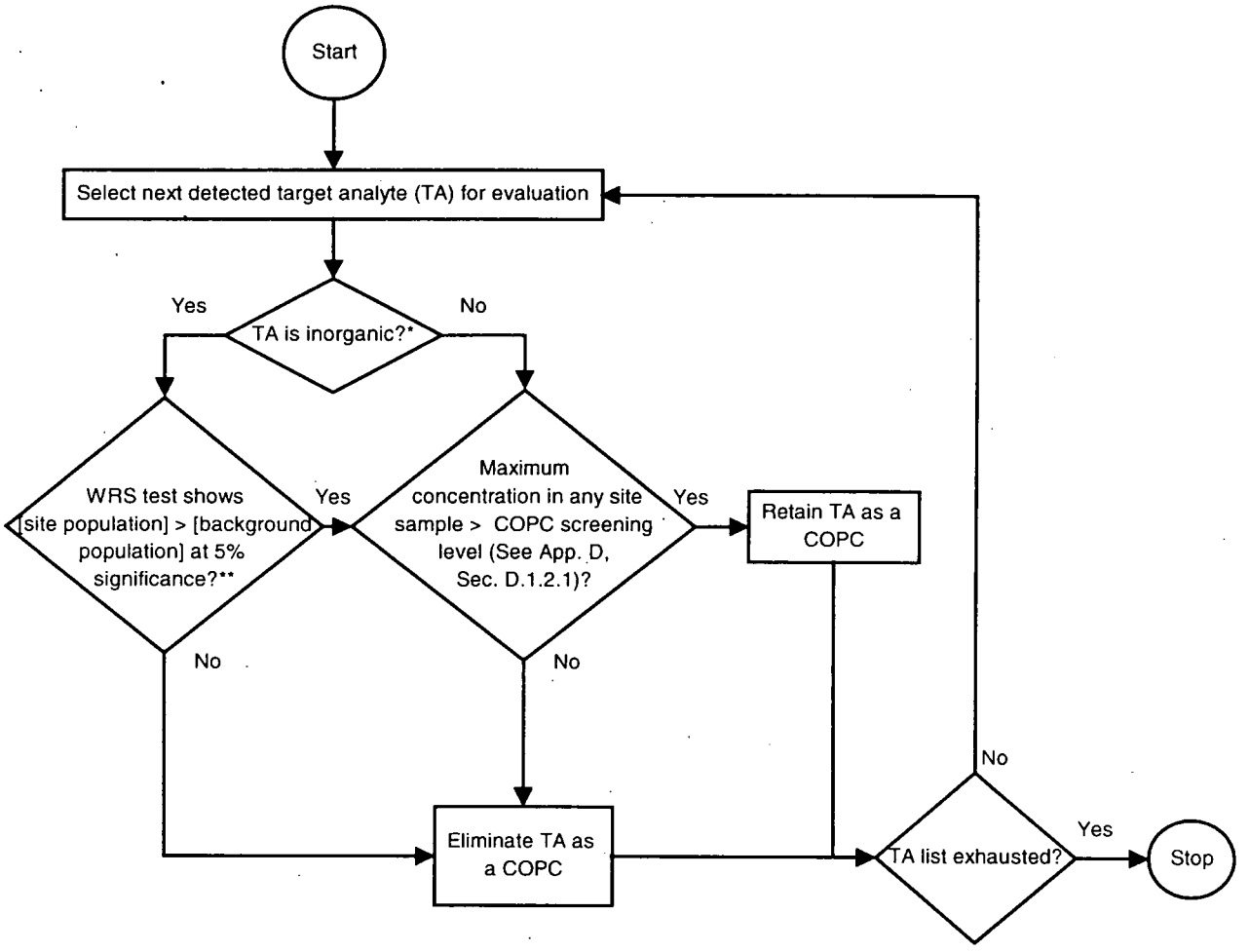
HUMAN HEALTH RISK ASSESSMENT COPC SELECTION IN SURFACE WATER AND SEDIMENT. NSWC CRANE, CRANE, INDIANA



COPC = Chemical of potential concern
RBTL = Risk-based target level
WRS = Wilcoxon Rank Sum
* "Inorganic" includes radionuclides. For radionuclides comparisons will be based on radiological activities.
**If upgradient sediment is unavailable, the background population will be represented by soil data from the NSWC Basewide Background Soil Investigation that most closely matches the sediment.

FIGURE 1-15

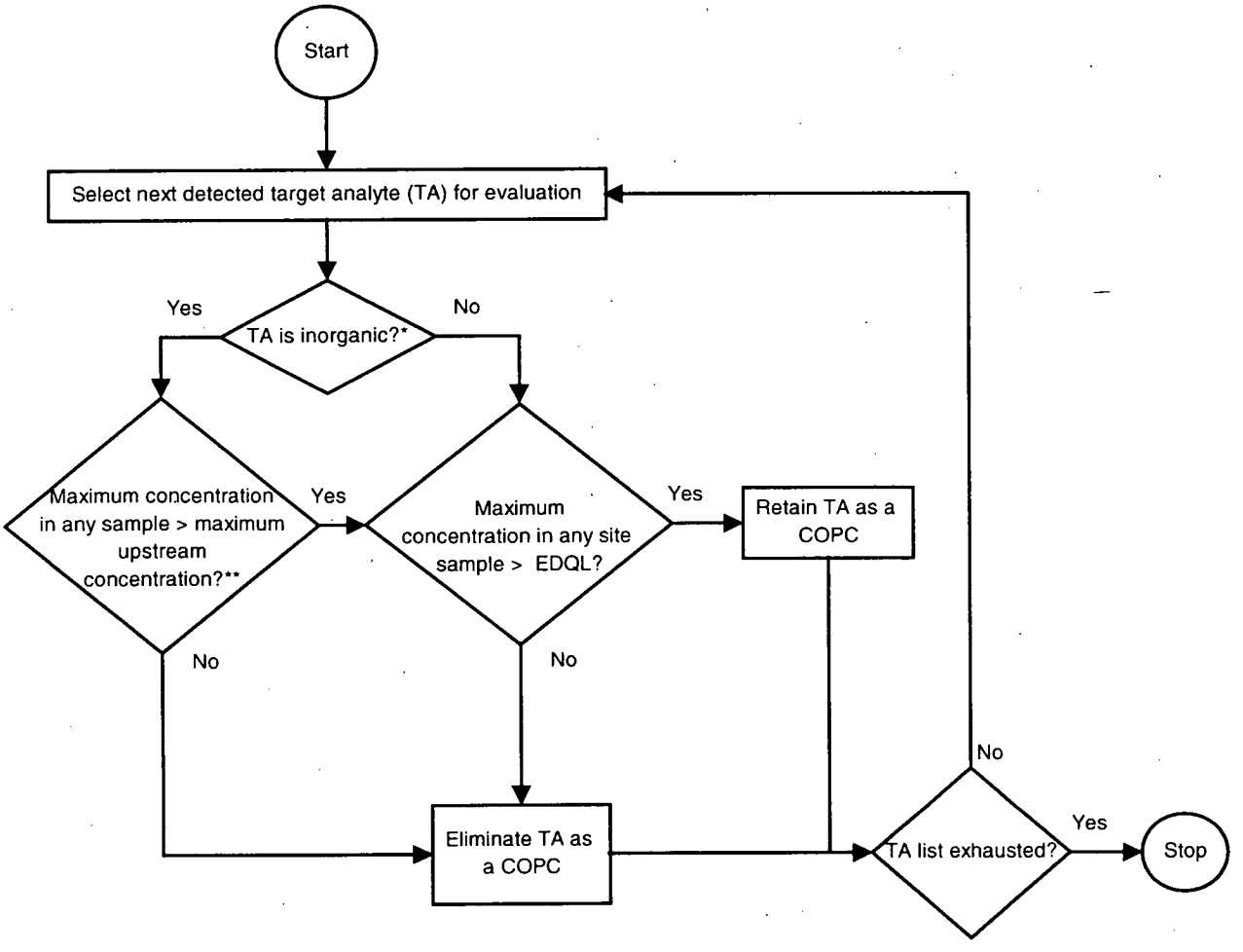
HUMAN HEALTH RISK ASSESSMENT COPC SELECTION IN SURFACE AND SUBSURFACE SOIL NSWC CRANE, CRANE, INDIANA



COPC = Chemical of potential concern
RBTL = Risk-based target level
WRS = Wilcoxon Rank Sum
* "Inorganic" includes radionuclides. For radionuclides comparisons will be based on radiological activities.
** The background population will be represented by soil data from the NSWC Basewide Background Soil Investigation that most closely matches the site soil in terms of depositional environment, depth and grain size. If multiple soil types are present at the site, multiple background soil types will be used, as necessary, to obtain a reasonable match for each site soil type.

FIGURE 1-16

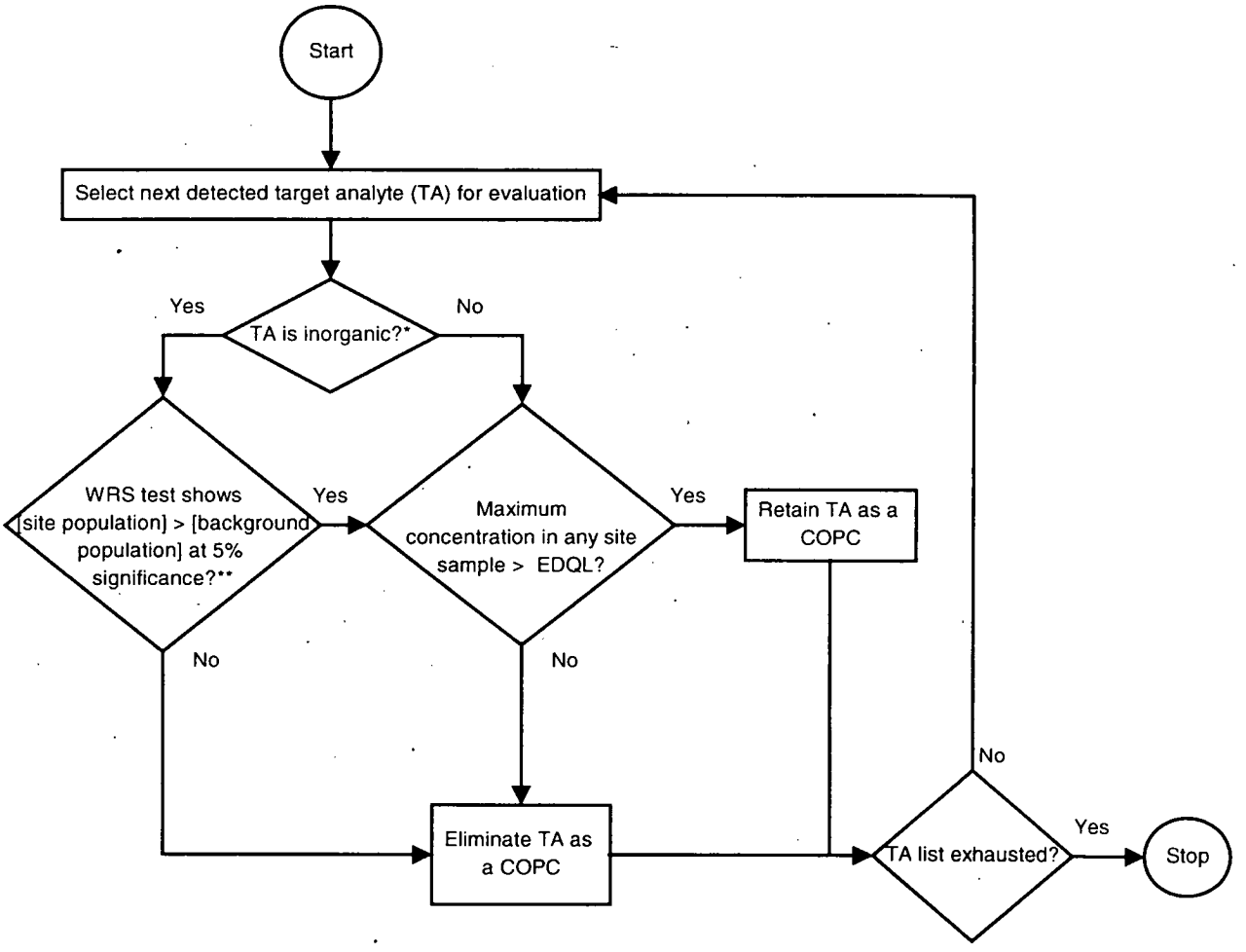
**ECOLOGICAL RISK ASSESSMENT COPC SELECTION
SURFACE WATER, SEDIMENT AND SEEPS
NSWC CRANE, CRANE, INDIANA**



COPC = Chemical of potential concern
RBTL = Risk-based target level
WRS = Wilcoxon Rank Sum
* "Inorganic" includes radionuclides. For radionuclides comparisons will be based on radiological activities.
**If upgradient sediment is unavailable, the background population will be represented by soil data from the NSWC Basewide Background Soil Investigation that most closely matches the sediment.

FIGURE 1-17

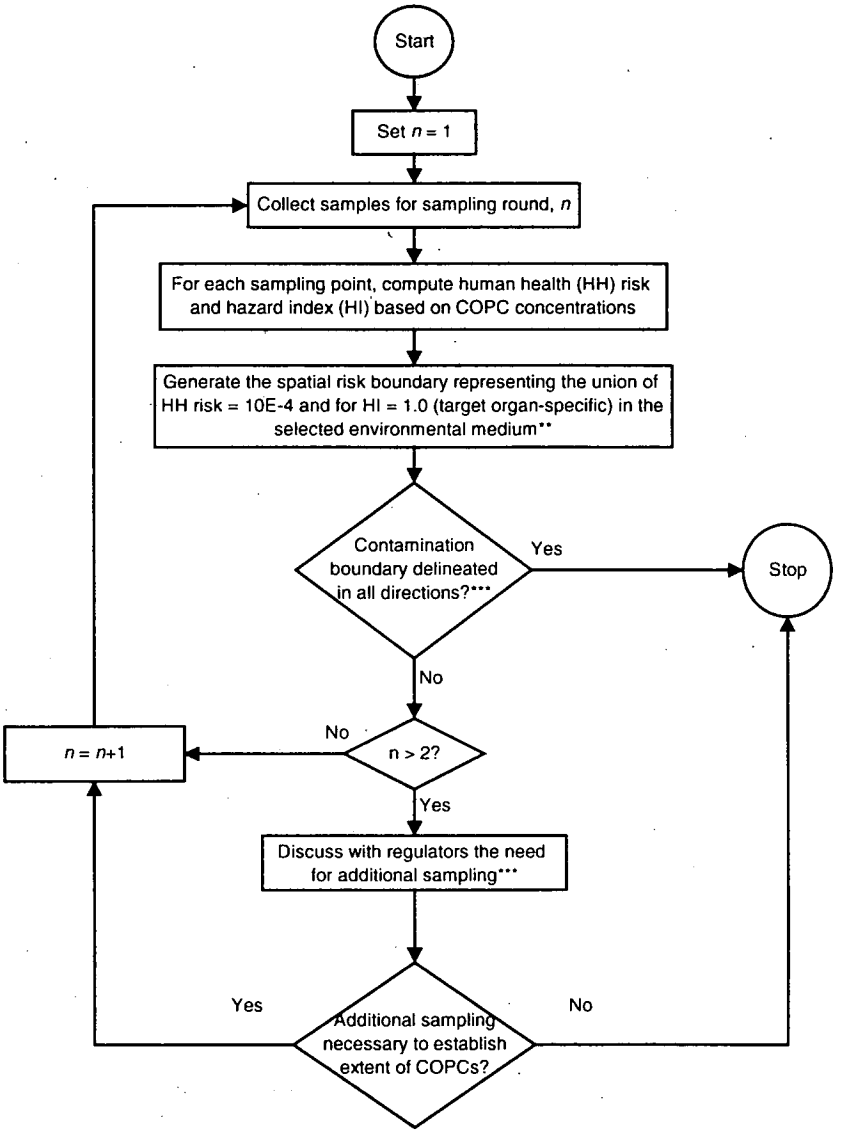
ECOLOGICAL RISK ASSESSMENT COPC SELECTION FOR SURFACE SOIL NSWC CRANE, CRANE, INDIANA



COPC = Chemical of potential concern
RBTL = Risk-based target level
WRS = Wilcoxon Rank Sum
* "Inorganic" includes radionuclides. For radionuclides comparisons will be based on radiological activities.
** The background population will be represented by soil data from the NSWC Basewide Background Soil Investigation that most closely matches the site soil in terms of depositional environment, depth and grain size. If multiple soil types are present at the site, multiple background soil types will be used, as necessary, to obtain a reasonable match for each site soil type.

FIGURE 1-18

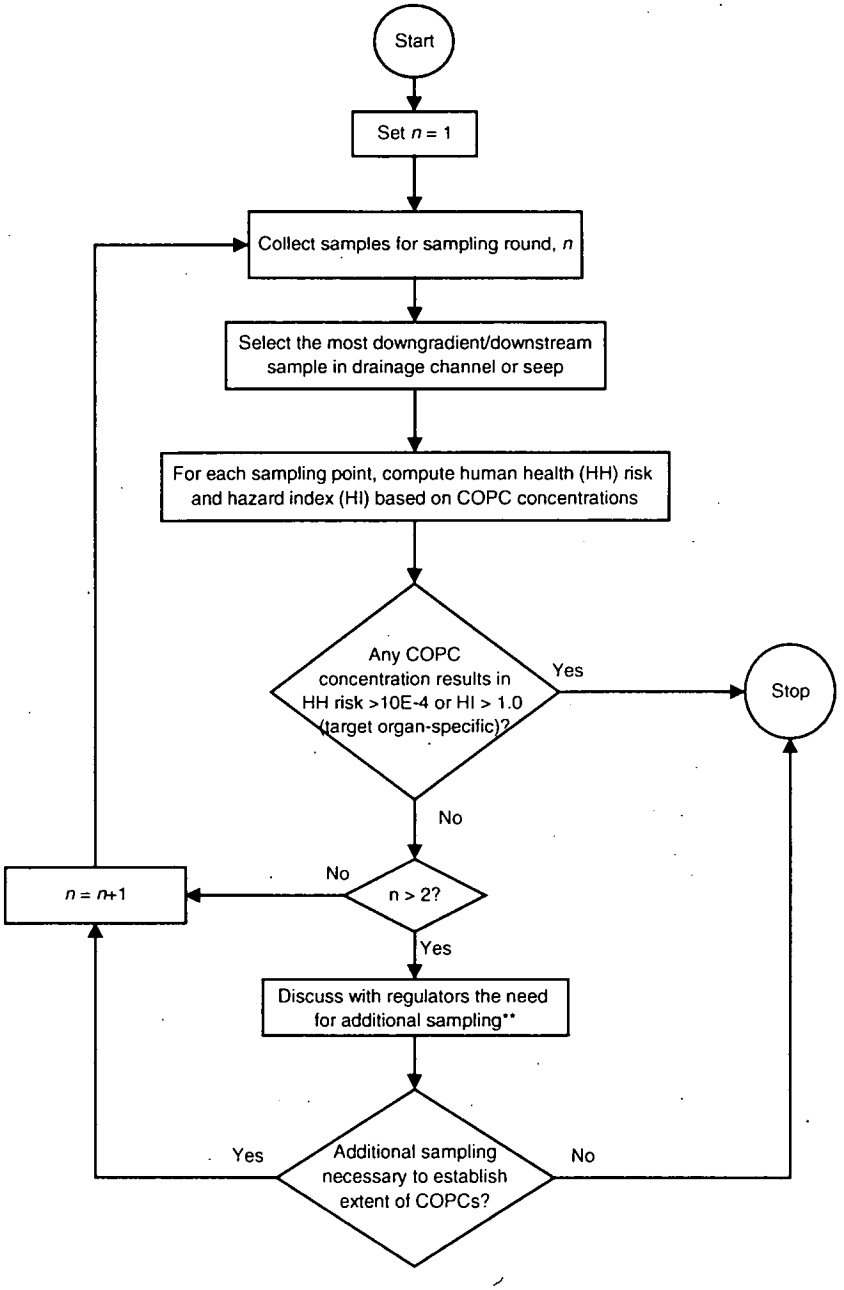
DECISION RULE FOR ESTABLISHING NATURE AND EXTENT OF COPCS IN GROUND WATER AND SOILS* NSWC CRANE, CRANE, INDIANA



*This decision diagram will be applied to each environmental medium individually.
** For surface soils, the risk boundary will be a two-dimensional boundary based on COPC concentrations to a depth of 2 feet. For subsurface soils, the risk boundary will be a three-dimensional boundry based on [COPC]s at > 2 feet deep. For ground water, risk will be computed for each well location based on [COPC]s in the ground water.
*** The spatial risk boundary representing 1E-4 cumulative human health (HH) risk and the spatial hazard boundary representing a Hazard Index (HI)=1.0 will be generated and plotted separately. Once plotted, the best fit boundary including both the HH risk = 1E-4 and HI=1.0 will be generated to represent the union of HH risk and HI. This decision will be based on professional judgment with consultation between the Navy and EPA.

FIGURE 1-19

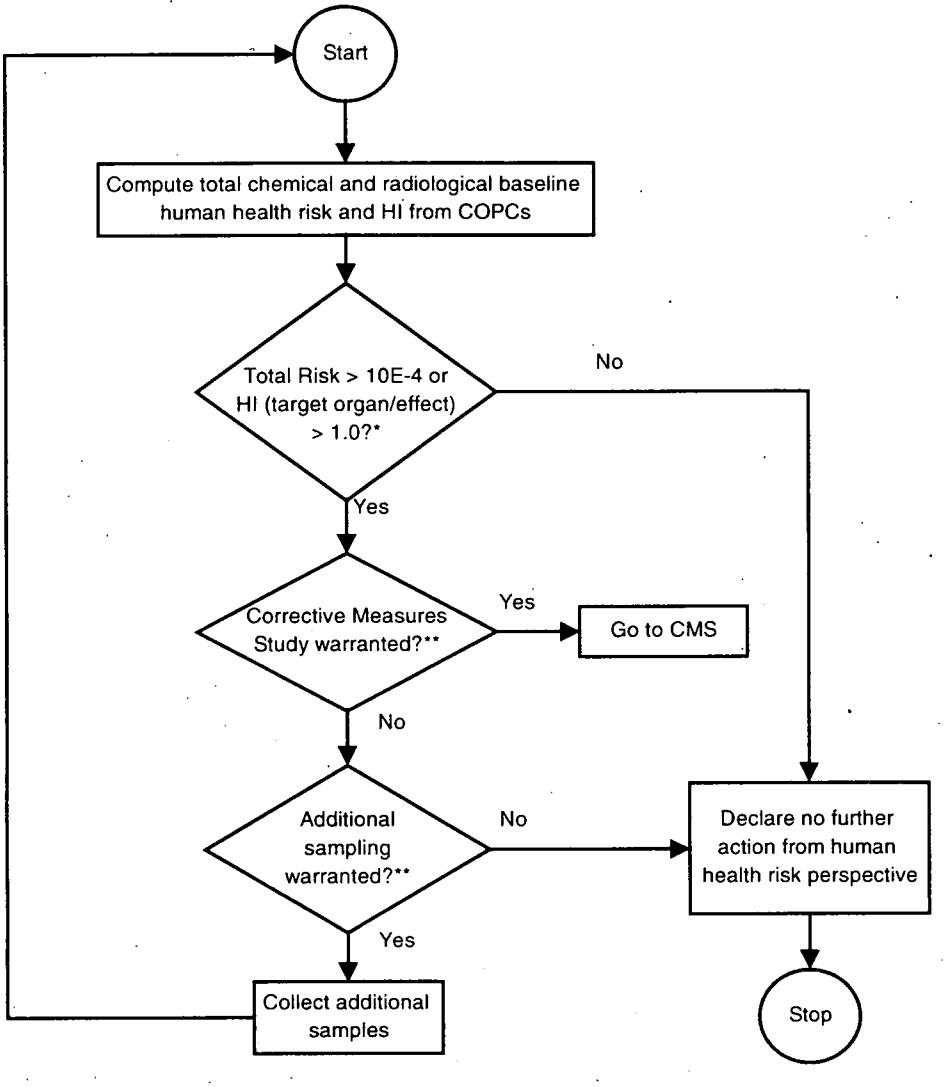
DECISION RULE FOR ESTABLISHING NATURE AND EXTENT OF COPCS IN SURFACE WATER AND SEDIMENT NSWC CRANE, CRANE, INDIANA



*This decision diagram will be applied to each environmental medium individually.
** See text for topics to be considered in these deliberations.

FIGURE 1-20

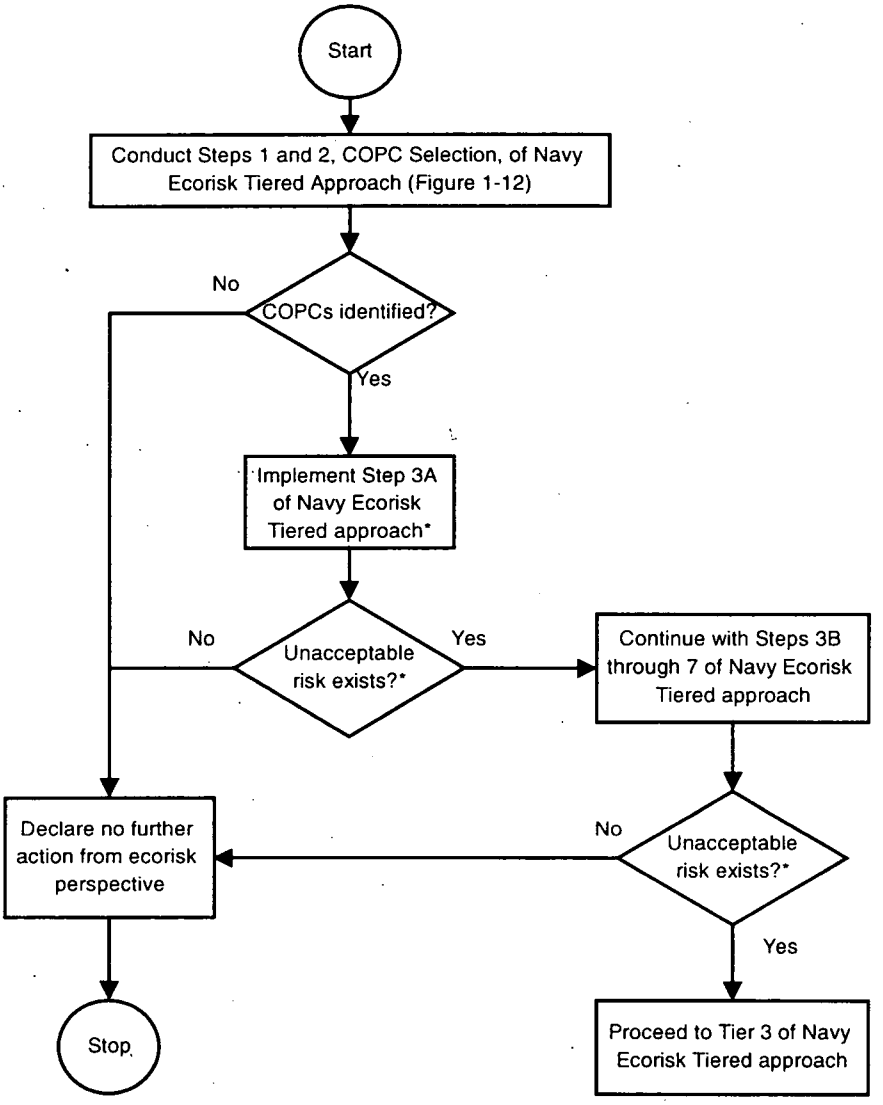
BASELINE HUMAN HEALTH RISK ASSESSMENT DECISION FLOW
NSWC CRANE, CRANE, INDIANA



COPC = Chemical of potential concern
CMS = Corrective Measures Study
HI = Hazard Index
* Computed total risk values are the cumulative chemical and radiological risks for all media. The computed risk values will be based on the exposure point concentrations explained in the text, Section 1.4.2.2.
**See text, Section 1.4.2.4.

FIGURE 1-21

SCREENING--LEVEL AND STEP 3A ECOLOGICAL RISK ASSESSMENT DECISION FLOW NSWC CRANE, CRANE, INDIANA

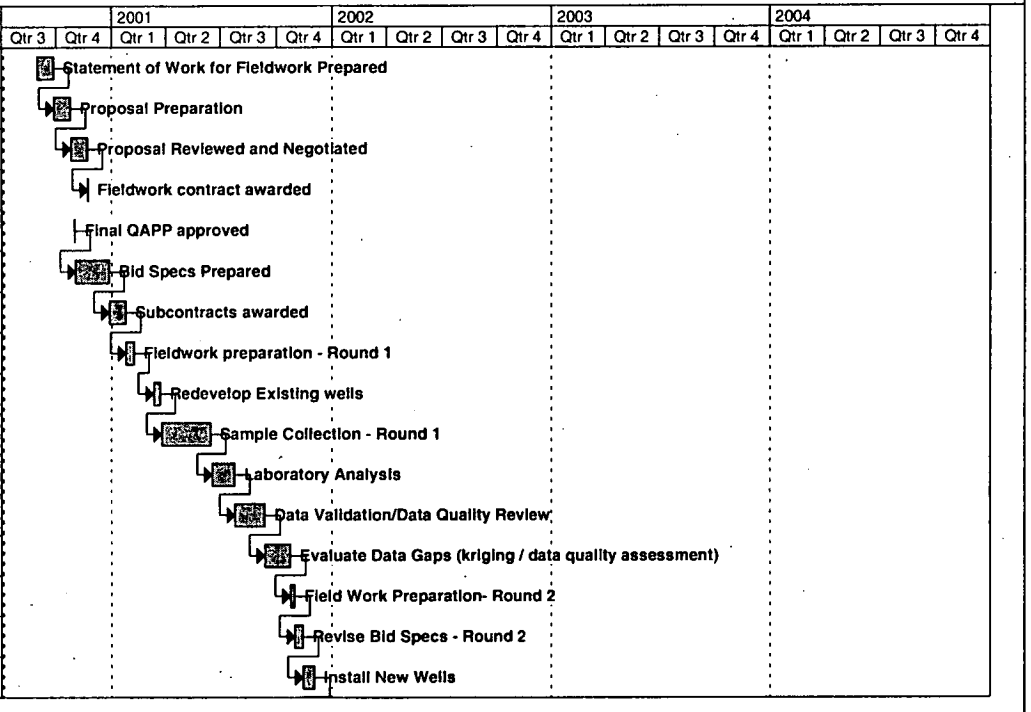


* This evaluation will include, but not be limited to, consideration of habitat, magnitude of risk-level exceedences, bioavailability of COPCs, and frequency of COPC detection.

FIGURE 1-22

MUSTARD GAS BURIAL GROUND FIELD IMPLEMENTATION SCHEDULE
NSWC CRANE, CRANE, INDIANA
PAGE 1 of 2

ID	Task Name	Duration	Start	Finish
1	Statement of Work for Fieldwork Prepared	4 wks	Thu 8/31/00	Wed 9/27/00
2	Proposal Preparation	4 wks	Thu 9/28/00	Wed 10/25/00
3	Proposal Reviewed and Negotiated	4 wks	Thu 10/26/00	Wed 11/22/00
4	Fieldwork Contract Awarded	1 day	Thu 11/23/00	Thu 11/23/00
5	Final QAPP Approved	1 day	Wed 11/1/00	Wed 11/1/00
6	Geophysical, Soil Boring, and Lab Bid Specs Prepared	8 wks	Thu 11/2/00	Wed 12/27/00
7	Subcontracts Awarded	4 wks	Thu 12/28/00	Wed 1/24/01
8	Field Work Preparation - Round 1	10 days	Thu 1/25/01	Wed 2/7/01
9	Redevelop Existing wells	10 days	Mon 3/12/01	Fri 3/23/01
10	Sample Collection GW, Soils, Sed, & SW - Round 1	60 days	Mon 3/26/01	Fri 6/15/01
11	Laboratory Analysis	28 days	Mon 6/18/01	Wed 7/25/01
12	Data Validation/Data Quality Review	35 days	Thu 7/26/01	Wed 9/12/01
13	Evaluate Data Gaps (kriging / data quality assessment)	30 days	Thu 9/13/01	Wed 10/24/01
14	Field Work Preparation - Round 2	5 days	Thu 10/25/01	Wed 10/31/01
15	Revise Bid Specs and/or modify contracts - Round 2	10 days	Thu 11/1/01	Wed 11/14/01
16	Install New Wells if necessary	13 days	Thu 11/15/01	Mon 12/3/01



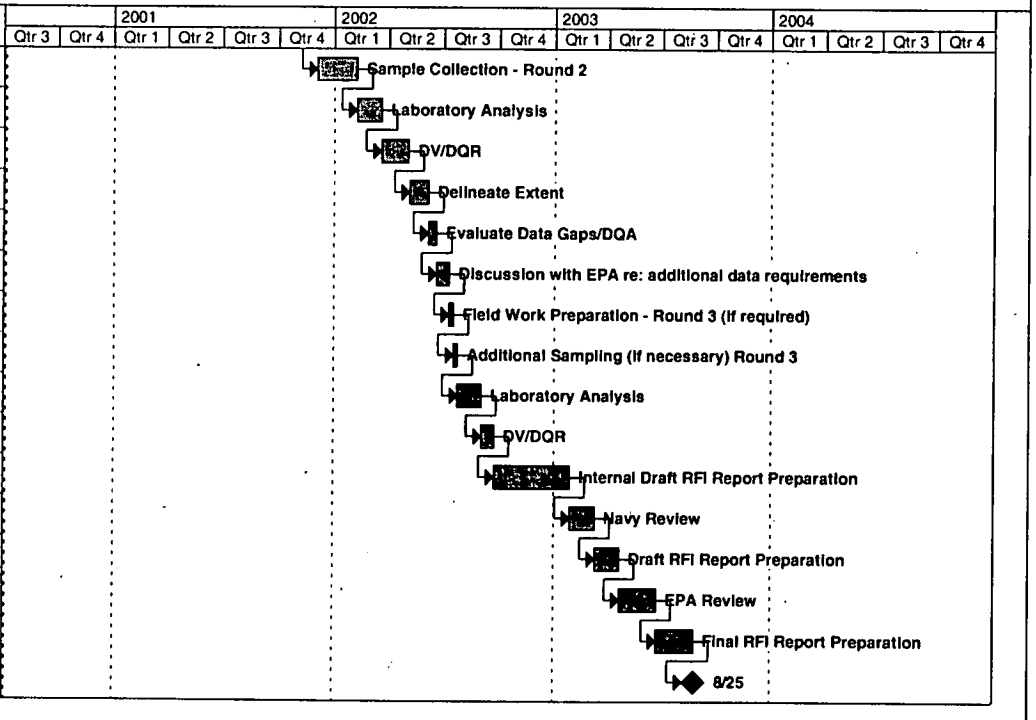
Project: Proposed Schedule
Date: Mon 7/3/00

Task		Milestone		Rolled Up Split		External Tasks	
Split		Summary		Rolled Up Milestone		Project Summary	
Progress		Rolled Up Task		Rolled Up Progress			

FIGURE 1-22

MUSTARD GAS BURIAL GROUND FIELD IMPLEMENTATION SCHEDULE
NSWC CRANE, CRANE, INDIANA
PAGE 2 of 2

ID	Task Name	Duration	Start	Finish
17	Sample Collection GW, Soils, Sed, & SW - Round 2	48 days	Tue 12/4/01	Thu 2/7/02
18	Laboratory Analysis	28 days	Fri 2/8/02	Tue 3/19/02
19	Data Validation/Data Quality Review	33 days	Wed 3/20/02	Fri 5/3/02
20	Krig Data to Delineate Extent	23 days	Mon 5/6/02	Wed 6/5/02
21	Evaluate Results for Data Gaps/Data Quality Assessment	10 days	Thu 6/6/02	Wed 6/19/02
22	Discussion with EPA Regarding Additional Data Requirements	15 days	Thu 6/20/02	Wed 7/10/02
23	Field Work Preparation - Round 3 (if required)	5 days	Thu 7/11/02	Wed 7/17/02
24	Additional Sampling (if necessary) Round 3	5 days	Thu 7/18/02	Wed 7/24/02
25	Laboratory Analysis	28 days	Thu 7/25/02	Mon 9/2/02
26	Data Validation/Data Quality Review	15 days	Tue 9/3/02	Mon 9/23/02
27	Internal Draft Phase III RFI Report Preparation	90 days	Tue 9/24/02	Mon 1/27/03
28	Navy Review	30 days	Tue 1/28/03	Mon 3/10/03
29	Draft Phase III RFI Report Preparation	30 days	Tue 3/11/03	Mon 4/21/03
30	EPA Review	45 days	Tue 4/22/03	Mon 6/23/03
31	Final Phase III RFI Report Preparation	45 days	Tue 6/24/03	Mon 8/25/03
32	Submit Final Phase III RFI Report	0 days	Mon 8/25/03	Mon 8/25/03



Project: Proposed Schedule
Date: Mon 7/3/00

Task		Milestone		Rolled Up Split		External Tasks	
Split		Summary		Rolled Up Milestone		Project Summary	
Progress		Rolled Up Task		Rolled Up Progress			

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

This section presents the project management and organization for this Phase III multimedia RFI at the MGBG at NSWC Crane. Discussed in the following subsections are the staffing and coordination requirements.

2.1 MANAGEMENT

TtNUS, on behalf of the U.S. Navy, is responsible for the overall management, implementation of contract field activities, and preparation of the MGBG Phase III multimedia RFI QAPP. Personnel from the Navy will be actively involved and will coordinate with TtNUS personnel in a number of areas. The authorities and organizational relationships of key personnel are depicted on Figure 2-1. Corresponding addresses and telephone numbers of key personnel are listed by organization in Table 2-1. Responsibilities for program management, project management, field operations, and laboratory operations are discussed in the following sections. It is intended that the individuals named will perform the designated responsibilities to the extent that the specific person is available to perform the stated activities.

2.1.1 U.S. EPA Project Manager

The U.S. EPA Project Manager (PM), Mr. Peter Ramanauskas, will oversee the implementation of the MGBG Phase III multimedia RFI at NSWC Crane. The U.S. EPA PM represents the Agency's interests and will provide input from this perspective and lend general historical and technical assistance to NSWC Crane field activities.

2.1.2 Indiana Department of Environmental Management

The IDEM Hazardous Waste representatives, Mr. Doug Griffin and Mr. Marty Harmless, will oversee the implementation of this Phase III RFI investigation. They represent IDEM's interests and will provide input from this perspective.

2.1.3 Navy Project Managers

The Navy remedial Project Manager (RPM), Mr. Bill Gates, acts as the focal representative for the U.S. Navy, providing management, technical direction, and oversight for all NSWC Crane project activities performed by contractors (i.e., TtNUS) and their subcontractors. In matters such as facilitation of site

access, and oversight, etc., the Navy RPM is assisted by the NSWC Environmental Site Manager (ESM), Mr. Tom Brent. Additional responsibilities of the RPM are as follows:

- Define project objectives and develop a detailed QAPP schedule
- Establish project policy and procedures to address the specific needs of the project as a whole, as well as the objectives of each task
- Acquire and apply technical resources (i.e., contractors) as needed to ensure performance within budget and schedule constraints
- Interface with the U.S. Army to the degree necessary required to meet project objectives
- Review the work performed on each task to ensure its quality, responsiveness, and timeliness
- Review and analyze overall task performance with respect to planned requirements and authorizations
- Approve all reports (deliverables) before their submittal to U.S. EPA Region 5
- Ultimately be responsible for the preparation and quality of interim and final reports,
- Represent the project team at meetings and public hearings

2.1.4 Contractor Project Management

Program Manager

The TtNUS Navy Southern Division Comprehensive Long-Term Environmental Action Navy (CLEAN) Program Manager, Debbie Wroblewski, provides operations, technical, and administrative leadership, and oversees and supports quality policies. The Program Manager assigns project Task Order Managers (TOMs) and oversees their performance. The Program Manager also ensures the availability of technical and support resources for program operations, and maintains consistency in procedures and projects among CTO assignments. In these matters, the Program Manager is assisted by the TOM.

Task Order Manager

The TtNUS TOM, Dr. Tom Johnston, has overall responsibility for ensuring that the project meets U.S. EPA and IDEM objectives, and Navy and TtNUS quality standards. The TOM is responsible for the preparation and distribution of the QAPP at the direction of the Navy RPM to all parties connected with the project, including any subcontractors. The TOM will report to the Navy RPM and is responsible for technical QC and project oversight. Additional responsibilities of the TOM are as follows:

- Ensuring timely resolution of project-related technical, quality, safety, or waste management issues
- Functioning as the primary interface with the Navy RPM and NSWC Crane Environmental Site Manager, field and office personnel, and subcontractor points-of-contact
- Ensuring that health and safety issues related to this project are communicated effectively to all personnel and off-site laboratories
- Monitoring and evaluating subcontractor laboratory performance
- Coordinating and overseeing work performed by field and office technical staff (including data validation, statistical evaluations, and report preparation)
- Coordinating and overseeing maintenance of all project records
- Coordinating and overseeing review of project deliverables
- Preparing and issuing final deliverables to the Navy
- Approving the implementation of corrective actions

Project Chemist

The TtNUS Project Chemist, Ms. Linda Karsonovich has the overall responsibility for ensuring that the project meets objectives from the standpoint of laboratory performance. The Project Chemist is responsible for the technical preparation of laboratory statements of work (SOWs) and work releases. All subcontractor Laboratory Project Managers will report to the Project Chemist. The Project Chemist will report to the TOM. Additional responsibilities of the Project Chemist are:

- Providing technical advice to the team on matters of project chemistry
- Monitoring and evaluating subcontractor laboratory performance
- Ensuring timely resolution of laboratory-related technical, quality, or other issues effecting project goals
- Functioning as the primary interface with all subcontracted laboratories and the TOM
- Coordinating and overseeing work performed by all subcontracted laboratories
- Coordinating and overseeing review of laboratory deliverables
- Recommending appropriate laboratory corrective actions

Health and Safety Manager

The TtNUS Health and Safety Manager (HSM), Mr. Matt Soltis, is responsible for the following:

- Providing technical advice to the TOM on matters of health and safety
- Overseeing the development and review of the Health and Safety Plan (HASP)
- Implementing the HASP
- Assigning the Site Safety Officer (SSO) and supervising his/her performance
- Conducting Health and Safety audits
- Preparing Health and Safety reports for management

2.2 QUALITY ASSURANCE

This section identifies the QA responsibilities for this MGBG RFI. Responsibilities of U.S. EPA Region 5, TtNUS, and the analytical laboratories are discussed.

2.2.1 U.S. EPA Region 5 Quality Assurance Coordinator

The U.S. EPA Region 5 RCRA Quality Assurance Coordinator (RQAC), Mr. Allen Debus, has the responsibility to review and approve the QAPP and to provide overall QA support and review. Additional responsibilities may include the following:

- Coordinating external performance and system audits of the contracted laboratory
- Reviewing and evaluating analytical field and laboratory procedures

2.2.2 TtNUS QA Manager

The TtNUS Quality Assurance Manager (QAM), Mr. Paul Frank, is responsible for overall QA for the project, and reports directly to the TtNUS Program Manager. He acts on behalf of the U.S. Navy for project quality assurance. The QAM is responsible for the following:

- Developing, maintaining, and monitoring QA policies and procedures
- Providing training to TtNUS staff in QA/QC policies and procedures
- Conducting systems and performance audits to monitor compliance with environmental regulations, contractual requirements, QAPP requirements, and corporate policies and procedures
- Auditing project records
- Monitoring subcontractor quality controls and records
- Assisting in the development of corrective action plans; ensuring correction of nonconformances reported in internal or external audits
- Overseeing the implementation of the QAPP
- Overseeing and reviewing the development and revision of the QAPP
- Overseeing the responsibilities of the TtNUS Site QA/QC Advisor
- Preparing QA reports for management

2.2.3 TtNUS Project QA Chemist

The TtNUS Project Chemist, Ms. Linda Karsonovich, supports the TOM in preparing and reviewing the QAPP, coordinating work performed by office technical staff, and resolving matters concerning project chemistry. The Project Chemist also supports the Project QA Advisor on matters of QA/QC.

2.2.4 TtNUS Project QA Advisor

The TtNUS Project QA Advisor, Mr. Joe Samchuck, supports the TOM in preparing and reviewing the QAPP, and conducting data assessments. The Project QA Advisor communicates directly with the QAM on matters of QA/QC.

2.2.5 TtNUS Data Validation Manager

The TtNUS Data Validation Manager, Mr. Joseph Samchuck, is responsible for all data validation and data review activities. The Data Validation Manager is responsible for ensuring that analytical laboratory data are reviewed and validated in accordance with analytical project objectives as outlined in the Project QAPP. The following items summarize principle areas of responsibility:

- Reviews compliance of the analtyical laboratory to methods and analytical requirements as outlined in the QAPP and laboratory specification
- Ensures completeness of analytical deliverables both electronic and hardcopy
- Ensures data validation qualification is conducted in accordance with EPA Regional requirements
- Performs a Quality Assurance review of all validation reports and validated analytical data
- Reviews and approves all validation qualifications entered into the electronic database
- Conducts verification and accounting for all samples, analyte fractions, and analytical parameters
- Approves final qualified analytical database

2.2.6 Laboratory Responsibilities

Samples collected as part of this investigation will be analyzed for at least three separate classes of parameters including; recovered chemical warfare materials (RCWM), in this case limited to mustard gas; radiological analyses; and RCRA chemical analyses. Two laboratories have been selected to perform these specialized services.

- Mustard Gas analyses will be performed by the Edgewood Chemical Biological Center (ECBC) Monitoring Branch Analytical Laboratory located at 5183 Blackhawk Road, AMSSB-RCM-CM Bldg. E3330 Room 184, Edgewood, MD 21010-5425, phone number 410-436-8428.

- Radiological, RCRA and miscellaneous analyses will be performed by Southwest Laboratory of Oklahoma, Inc. (SWLO), located at 1700 West Albany, Broken Arrow, Oklahoma 74012, phone number 918-251-2858, fax number 918-251-2599.

The subcontracted laboratories are responsible for analyzing all samples in accordance with the analytical methods and additional requirements specified in this QAPP. The analytical laboratories' will also be responsible for properly disposing of unused sample aliquots in accordance with applicable regulations. Responsibilities of key laboratory personnel for each contracted laboratory are outlined in the following paragraphs.

ECBC Laboratory Project Manager

The ECBC laboratory Project Manager, Mr. Tom Rosso, will report directly to the TtNUS Project Chemist and will be responsible for the following:

- Ensuring that laboratory health and safety measures to reduce exposures to mustard gas are followed and that all analytical staff are aware of the potential hazards associated with samples submitted as part of this RFI
- Ensuring that laboratory health and safety measures to reduce exposures to other hazards that may also be present (e.g., radiation) are followed and that all analytical staff are aware of the potential hazards associated with samples submitted as part of this RFI
- Ensure that method and project-specific requirements are properly communicated and understood by laboratory personnel
- Ensuring that all laboratory resources are available on an as-required basis
- Monitoring analytical and project QA requirements
- Reviewing data packages for completeness, clarity, and compliance with project requirements
- Informing the TtNUS TOM or his designee of project status on a weekly basis and of any sample receipt or analytical problems
- Ensuring timeliness of deliverables as specified in contract documents

ECBC Laboratory Quality Assurance Officer

The ECBC laboratory QA Officer (QAO), Mr. Paul Stewart, has the overall responsibility for ensuring that data quality standards are achieved throughout the analytical process. The laboratory QAO will be independent of the laboratory production operations, but will communicate data issues through the Laboratory Project Manager. In addition, the Laboratory QAO will be responsible for the following:

- Overseeing laboratory QA, including documentation of laboratory activities
- Conducting detailed data review
- Determining whether to implement laboratory corrective actions
- Defining appropriate laboratory QA procedures
- Preparing laboratory standard operating procedures (SOPs)

QA will be provided by the Laboratory Project Manager and QAO prior to release of data to TtNUS.

ECBC Laboratory Technical Staff

The laboratory technical staff will be responsible for sample analyses and identification of corrective actions. They will also be responsible for handling samples in accordance with the potential health and safety hazards that these samples may pose to themselves and other laboratory personnel. The project analytical staff will have accountability to the laboratory Project Manager.

Radiological and RCRA SWLO Laboratory Project Managers

The SWLO PMs, Mr. Kent Surface and Ms. Sandy Grovenstein, will report directly to the TtNUS Project Chemist and will be responsible for:

- Ensuring that laboratory health and safety measures to reduce exposures to radiation hazards are followed and that all analytical staff are aware of the potential hazards associated with samples submitted as part of this RFI.

- Ensuring that laboratory health and safety measures to reduce exposures to other hazards that may also be present (e.g., mustard gas) are followed and that all analytical staff are aware of the potential hazards associated with samples submitted as part of this RFI.

- Ensuring that method and project-specific requirements are properly communicated and understood by laboratory personnel
- Ensuring that all laboratory resources are available on an as-required basis
- Monitoring analytical and project QA requirements
- Reviewing data packages for completeness, clarity, and compliance with project requirements
- Informing the TtNUS TOM or his designee of project status on a weekly basis and of any sample receipt or analytical problems
- Ensuring the timeliness of deliverables as specified in contract documents

Radiological and RCRA SWLO Laboratory Quality Assurance Officer

The laboratory QAO, Mr. Chuck Hoover, has the overall responsibility for ensuring that data quality standards are achieved throughout the analytical process. The laboratory QAO will be independent of the laboratory production operations, but will communicate data issues through the laboratory RCRA and radiological analysis Project Managers. In addition, the Laboratory QAO will be responsible for the following:

- Overseeing laboratory QA, including documentation of laboratory activities
- Conducting detailed data review
- Determining whether to implement laboratory corrective actions
- Defining appropriate laboratory QA procedures
- Preparing laboratory SOPs

QA will be provided by the laboratory Project Managers and QAO prior to release of data to TtNUS.

Radiological and RCRA SWLO Laboratory Technical Staff

The SWLO technical staff will be responsible for sample analyses and identification of corrective actions. They will also be responsible for handling samples in accordance with the potential health and safety hazards that these samples may pose to themselves and other laboratory personnel. The project

analytical staff will have accountability to the laboratory RCRA and radiological analysis Project Managers, as appropriate.

2.3 FIELD INVESTIGATION

TtNUS will be responsible for all field activities related to this RFI. The TtNUS field team will be organized according to the activities planned. Field team members will be selected based on the type and extent of effort required. All team members will be appropriately skilled and trained for the tasks they are assigned to perform. The team will consist of a combination of the following personnel:

- Field Operations Leader (FOL)
- Site QA/QC Advisor
- Site Safety Officer
- Site UXO Specialist
- Field Technical Staff
- Field Radiation Safety Officer

2.3.1 Field Operations Leader

The FOL is responsible for coordinating all on-site personnel and for providing technical assistance, when required. The FOL, or designee, will coordinate and lead all sampling activities and will ensure the availability and maintenance of all sampling materials and equipment. The FOL is responsible for completing all sampling, field and chain of custody documentation, will assume custody of all samples, and will ensure the proper handling and shipping of samples. The FOL will report directly to the TtNUS TOM. Specific FOL responsibilities include the following:

- Ensuring that all Health and Safety requirements unique to this site are implemented, including those for mustard gas and radiological hazards

- Functioning as the communications link between field staff members, Site Safety Officer, UXO Specialist, the NSWC Crane Environmental Site Manager, and the TOM

- Alerting off-site analytical laboratories of special health and safety hazards associated with environmental samples

- Overseeing the mobilization and demobilization of all field equipment and subcontractors

- Coordinating and managing the Field Technical Staff
- Adhering to the work schedules provided by the TOM
- Ensuring the proper maintenance of the site logbook, field logbook, and field recordkeeping
- Initiating field task modification requests when necessary
- Identifying and resolving problems in the field; resolving difficulties via consultation with the NSWC Crane Environmental Site Manager; implementing and documenting corrective action procedures, and providing communication between the field team and project management

2.3.2 Site QA/QC Advisor

The FOL (or his designee) will act as the site QA/QC Advisor, and will be responsible for ensuring adherence to all QA/QC requirements as defined in the QAPP. Strict adherence to these procedures is critical to the collection of acceptable and representative data. The following is a summary of the Site QA/QC Advisor's responsibilities:

- Ensuring that field QC samples are collected at the proper frequency
- Ensuring that additional volumes of sample are supplied to the analytical laboratory with the proper frequency to accommodate laboratory QA/QC analyses
- Ensuring that measuring and test equipment are calibrated, used, and maintained in accordance with applicable procedures and technical standards
- Acting as liaison between site personnel, laboratory personnel, and the QAM
- Managing bottleware shipments and overseeing field preservation

2.3.3 Site Safety Officer

Based on the unique hazards associated with this investigation, including potential exposure to mustard gas, radiation, and UXO, a member of the TtNUS Health and Safety Department will serve as the SSO.

The duties of the SSO are detailed in the HASP. The SSO has stop-work authority, which can be executed upon the determination of an imminent safety hazard.

2.3.4 Site UXO Specialist

Based on the potential for UXO hazards associated with this investigation, a TtNUS UXO Specialist will be on-site at all times that invasive activities are being conducted. The duties of the UXO Specialist are detailed in the HASP and in TtNUS SOP HS-2.0. The UXO Specialist has stop-work authority, which can be executed upon the determination of an imminent UXO safety hazard.

2.3.5 Radiation Safety Officer

Based on the potential radiation hazards associated with this investigation, the TtNUS Health and Safety SSO will also serve as the Radiation Safety Officer (RSO). The duties of the RSO/SSO are detailed in the HASP. The RSO/SSO has stop-work authority, which can be executed upon the determination of an imminent safety hazard.

2.3.6 Field Technical Staff

The field technical staff for this project will be drawn from TtNUS's pool of qualified personnel. All of the designated field team members will be experienced professionals who possess the degree of specialization and technical competence required to effectively and efficiently perform the required work.

Field staff are responsible for complying with field-related requirements as presented in the QAPP and the HASP.

2.4 SPECIAL TRAINING REQUIREMENTS AND CERTIFICATIONS

All field personnel will have appropriate training to conduct the field activities to which they are assigned. Additionally, each site worker will be required to have completed a 40-hour course (and 8-hour refresher, if applicable) in Health and Safety Training as described under Occupational Safety and Health Administration (OSHA) 29 CFR 1910.120(b)(4). The UXO Specialist will be certified in accordance with TtNUS SOP HS-2.0, which is appended to the HASP.

The ECBC Laboratory has not completed the laboratory evaluation process required as part of the NFESC QA Program and described in the "Navy Installation Restoration Laboratory Quality Assurance Guide" (NFESC, 1996). However, the ECBC laboratory is the ultimate national authority on mustard gas

and other chemical warfare agent analyses and is responsible for certifying other laboratories to perform mustard gas and related analyses. These qualifications are viewed as justification for exempting the ECBC Monitoring Branch Analytical Laboratory from the NFESC evaluation process for mustard gas and degradate analyses.

SWLO has successfully completed the laboratory evaluation process required as part of the NFESC QA Program and described in the "Navy Installation Restoration Laboratory Quality Assurance Guide" (NFESC, 1996).

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TABLE 2-1

KEY MUSTARD GAS BURIAL GROUND PROJECT PERSONNEL NAMES, PHONE NUMBERS AND ADDRESSES NSWC CRANE, CRANE, INDIANA PAGE 1 OF 3

PERSON / TITLE / ORGANIZATION	ADDRESS	TELEPHONE
Peter Ramanauskas Project Manager U.S. EPA Region 5	EPA Region 5 77 West Jackson Blvd. Chicago, Illinois 60604	(312) 886-7890 FAX: (312) 353-4788
Allen Debus QA Coordinator U.S. EPA Region 5	EPA Region 5 77 West Jackson Blvd. Chicago, IL 60604	(312) 886-6186
Marty Harmless Office of Solid and Hazardous Waste Management IDEM	Office of Solid and Hazardous Waste Management 100 N. Senate Avenue Indianapolis, Indiana 46206-6015	(317) 234-0597
Doug Griffin Corrective Action Section Office of Land Quality Hazardous Waste Permits IDEM	Corrective Action Section Office of Land Quality Hazardous Waste Permits 100 N. Senate Avenue P. O. Box 6015 Indianapolis, IN 46206-6015	(317) 233-2710
Bill Gates Remedial Project Manager U.S. Navy SOUTHNAVFACENGCOM	Department of Navy SOUTHNAVFACENGCOM Code 1864 2155 Eagle Drive Charleston, SC 29406	(843) 820-7360 FAX: (843) 820-7465
Tom Brent Environmental Site Manager NSWC Crane	NSWC Crane Code 095 B-3245 300 Highway 361 Crane, Indiana 47522-5009	(812) 854-6160 FAX: (812) 854-4177
Debbie Wroblewski Program Manager Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220-2745	(412) 921-8968 FAX: (412) 921-4040
Paul Frank Quality Assurance Manager Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220-2745	(412) 921-8950 FAX: (412) 921-4040
Matt Soltis Health and Safety Manager Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220-2745	(412) 921-8912 FAX: (412) 921-4040
Tom Johnston Task Order Manager Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220-2745	(412) 921-8615 FAX: (412) 921-4040
Keith Simpson Field Operations Leader Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220-2745	(412) 921-8131 FAX: (412) 921-4040

TABLE 2-1

KEY MUSTARD GAS BURIAL GROUND PROJECT PERSONNEL NAMES, PHONE NUMBERS AND ADDRESSES NSWC CRANE, CRANE, INDIANA PAGE 2 OF 3

PERSON / TITLE / ORGANIZATION	ADDRESS	TELEPHONE
Joseph Samchuck Data Validation Manager Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220	(412) 921-8510 FAX: (412) 921-4040
Andrew Kendrick Program Geologist Tetra Tech NUS	Tetra Tech NUS 661 Andersen Drive Pittsburgh, PA 15220-2745	(412) 921-8623 FAX: (412) 921-4040
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TABLE 2-1

**KEY MUSTARD GAS BURIAL GROUND PROJECT PERSONNEL
NAMES, PHONE NUMBERS AND ADDRESSES
NSWC CRANE, CRANE, INDIANA
PAGE 3 OF 3**

PERSON / TITLE / ORGANIZATION	ADDRESS	TELEPHONE
Sandy Grovenstein Project Manager SWLO RCRA Chemical Laboratory	Southwest Laboratory of Oklahoma, Inc. 1700 West Albany Broken Arrow, OK 74012	(918)251-2858 ext. 141 FAX: (918) 251-2599
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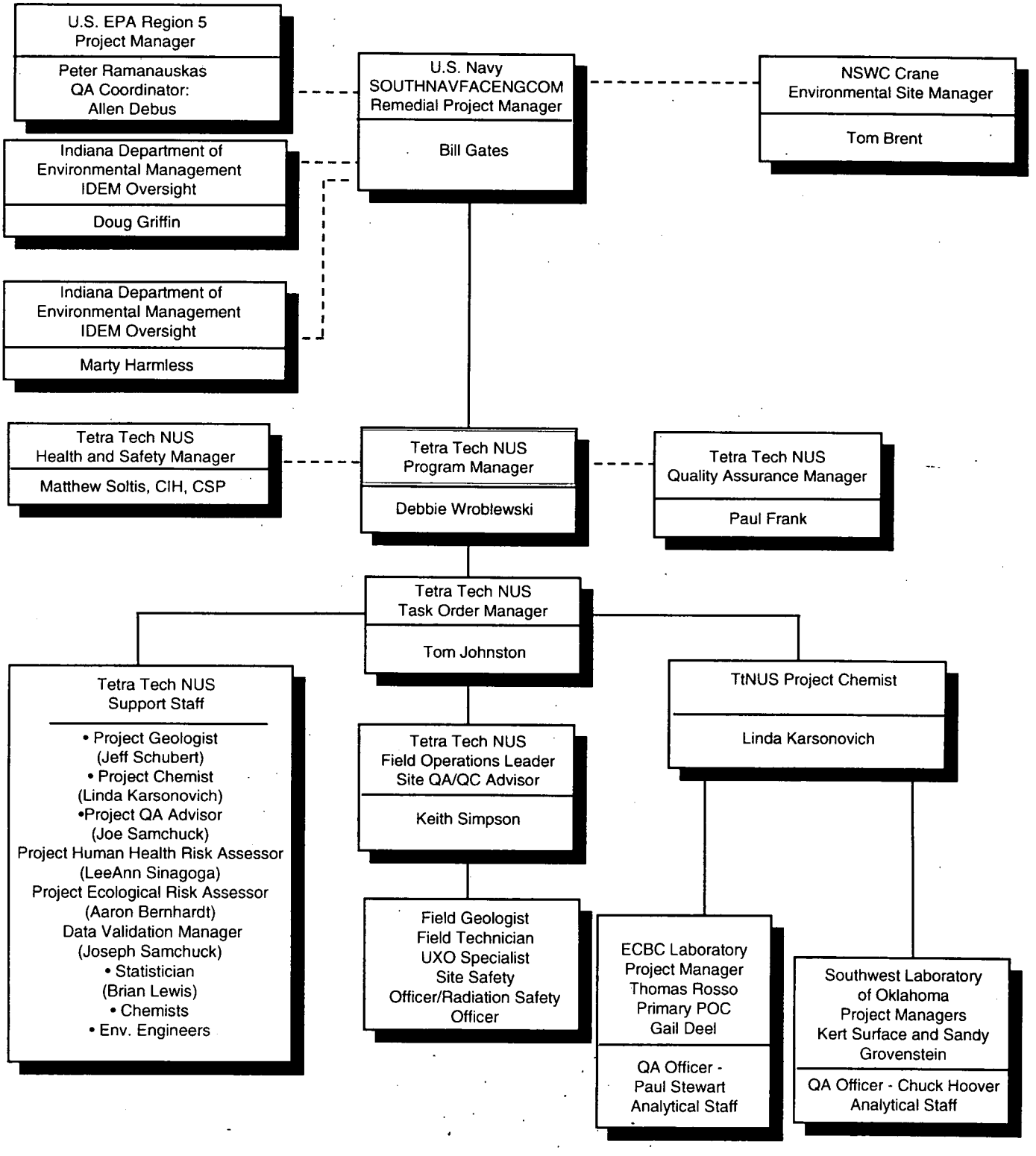
FIGURE 2-1

PROJECT ORGANIZATION CHART
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA



3.0 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

The overall QA objective for this project is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, data management, and reporting that will yield results sufficient to support the attainment of the project objectives specified in Section 1.0. Intended data uses, including the list of project target parameters, are described in Section 1.4 of this QAPP. How decisionmaking will be based on data comparisons is described in the decision rules of Section 1.4.4 and in Section 12.4. Specific procedures for sampling, chain-of-custody, laboratory instrument calibration, laboratory analysis, internal QC, reporting of data, audits, preventive maintenance of field and laboratory equipment, data management, corrective action, and reporting to management are described in the remaining sections of this QAPP. As part of those evaluations, statistical parameters such as data set variances will be computed to provide direct insight into the variability of target analyte data in soils and ground water. The overall QC level of effort is described in Section 3.6.

The PARCC parameters (precision, accuracy, representativeness, comparability, and completeness) are qualitative and quantitative statements regarding the quality characteristics of the data used to support project objectives and ultimately, environmental decisions. These parameters are presented in the remainder of this section. QC samples used to evaluate performance and their frequencies of use are described in Section 8.1 (field QC samples) and Section 8.2 (laboratory QC samples). Equations used to compute accuracy, precision, and completeness values are provided in Sections 12.1 through 12.3. PARCC parameters will be evaluated for each sampling round.

3.1 PRECISION

3.1.1 Definition

Precision is a measure of the degree to which two or more measurements are in agreement and describes the reproducibility of measurements of the same parameter for samples analyzed under similar conditions. A fundamental tenet of using precision measurements for QC is that precision will be bounded by known limits. Results outside these predetermined limits trigger corrective actions.

By definition, chemical solutions are uniform in composition. Therefore, ignoring any imprecision caused by the sample matrix, the variability of analytical results for water samples should be relatively low unless suspended material or sample handling and storage introduce additional imprecision. Precision acceptance criteria for aqueous duplicate samples have been assigned accordingly in Tables 3-2, 3-4, 3-6, 3-8, 3-10, 3-12, 3-14, 3-16, 3-18.

Because of the inherent and unknown heterogeneity of soil and sediment samples, the precision of soil and sediment field duplicate samples will not be used for QC, but will be compared to laboratory precision estimates to gain perspective on the natural heterogeneity of the soil or sediment. Although precision for soil and sediment samples will not be used for QC purposes, acceptance criteria have been incorporated into Tables 3-2, 3-4, 3-6, 3-8, 3-10, 3-12, 3-14, 3-16 and 3-18 as a means of warning data users when the measures of precision are becoming relatively large.

3.1.2 Field Precision Objectives

Field precision is assessed by collecting and measuring field duplicates at a rate of 1 duplicate per 10 environmental samples. Acceptance limits for field duplicate precision are provided in Table 3-1. This precision estimate encompasses the combined uncertainty associated with sample collection, homogenization, splitting, handling, laboratory and field storage (as applicable), preparation for analysis, and analysis. In contrast, precision estimates obtained from analyzing duplicate laboratory samples incorporate only homogenization, subsampling, preparation for analysis, laboratory storage (if applicable), and analysis uncertainties. Consequently, the field precision estimates [i.e., relative percent difference (RPD) values] should equal or exceed the laboratory precision estimates, on average, for each analyte. If field duplicate precision is significantly different from laboratory duplicate precision, the underlying cause will be investigated to determine whether the observed difference could be artifacts of sampling and analysis. Considerations given to this effort include the following:

- The scale of subsampling for laboratory precision estimates relative to the scale of field duplicate sample size
- Analytical measurement precision
- Precision for repeat analysis of the same solid laboratory control sample (LCS)
- Estimated environmental sample grain size relative to LCS grain size
- Potential natural soil heterogeneity
- Concentration level of the analyte

3.1.3 Laboratory Precision Objectives

Laboratory precision QC samples [i.e., laboratory duplicates for inorganic chemicals and matrix spike duplicates (MSDs) for organic chemicals] will be analyzed with a minimum frequency of 5 percent (i.e., 1 QC sample per 20 environmental samples). Laboratory precision is measured by comparing RPD values to precision control limits specified in Table 3-1.

3.2 ACCURACY

3.2.1 Definition

Accuracy is the degree of agreement between an observed value and an accepted reference value. This parameter is assessed by measuring spiked samples [e.g., surrogate spikes or matrix spikes (MSs)] or well-characterized samples of certified analyte concentrations (e.g., LCSs) and by measuring blanks. Accuracy measurements are designed to detect biases resulting from sample handling and analysis. Equations for determining accuracy of an individual MS and a surrogate spike or LCS for this project are provided in Section 12.1. The equations in Section 12.1 do not apply to blank samples, however, because division by zero (the expected amount or added amount) causes the calculated value to be infinite. Instead, acceptance criteria are designed to limit the tolerable amount of contamination while recognizing that non-zero results for blanks are likely, if only because of random error in the measurement process. The laboratory analytical SOPs (Appendix I) limit tolerable blank concentrations. The bias computations for individual MSs, LCSs, and method blanks will be used to control the analysis process by triggering corrective actions as specified in Table 3-1.

3.2.2 Field Accuracy Objectives

Accuracy requirements for field measurements are typically ensured through control over the sample collection and handling and through routine instrument calibration. In addition, after field measurements are completed, check standards are commonly analyzed to verify continued acceptable calibrations. The acceptance criteria are specified in the field SOPs included in Appendix H for measuring those parameters. Accuracy of grain size and depositional environment classifications for soils is ensured by requiring that a qualified field geologist makes those classifications. Field test kits are used in accordance with the test kit manufacturer's instructions that are included in the kits.

Accuracy is also typically monitored through the use of blanks to detect cross-contamination and by monitoring adherence to procedures that prevent sample contamination or degradation. The frequencies for collecting blanks are presented in Table 3-1. Equipment rinsate blanks shall be collected for this investigation to assess cross-contamination via sample collection equipment. Ambient condition blanks will not be collected unless site conditions during sampling (e.g., generation of fugitive dust) indicate a need to assess infiltration of airborne contaminants into sampling containers. Source water blanks will be collected to monitor the purity of water used to decontaminate sampling equipment. Trip blanks, used to gauge whether cross-contamination is occurring during sample storage and transport, will be placed into

each cooler containing samples to be analyzed for VOCs. Accuracy shall also be assured qualitatively through adherence to all sample handling, preservation, and holding time requirements.

3.2.3 Laboratory Accuracy Objectives

Accuracy in the laboratory is measured through the comparison of a spiked sample or LCS result to a known or calculated value and is expressed as a percent recovery (%R). It is also assessed by monitoring the analytical recovery of select surrogate compounds added to samples that are analyzed by organic chromatographic methods. MS and surrogate compound analyses measure the combined accuracy effects of the sample matrix, sample preparation, and sample measurement. LCSs are used to assess the accuracy of laboratory operations with minimal sample matrix effects. Post-digestion spikes (PDSs) are used to assess the accuracy of the analytical measurement on the sample extract or digestate. Each spike sample shall be spiked with representative project target analytes for the analysis being performed to ensure that accuracy measures are obtained for each target analyte. Spiking concentrations shall equal or approximate the default concentrations detailed in the applicable sample preparation or analysis SOPs. LCS and MS analyses are performed at a frequency no less than 1 per 20 associated samples of like matrix. Laboratory accuracy is assessed by comparing calculated %R values to accuracy control limits specified in Tables 3-1 through 3-19.

Radiological thorium analyses do not incorporate MSs. Instead, a radioactive tracer is added to each sample to monitor analyte recovery.

3.3 COMPLETENESS

3.3.1 Definition

Completeness is a measure of the amount of usable, valid analytical data obtained compared to the amount expected to be obtained. Completeness is expressed as a percentage.

3.3.2 Field Completeness Objectives

Field completeness is a measure of the amount of valid field measurements obtained from all the field measurements taken in the project. Documentation of sample location and depth is planned for each soil and ground water sample. Documentation of grain size and depositional environment is also planned for each soil sample. A completeness criterion of 100 percent applies to these measurements. However, the 100 percent completeness criterion for depositional environment and grain size may be reduced, depending on whether these factors are significant for background comparisons, as determined under the

"Base-Wide Background Soil Investigation for NSWC Crane." Furthermore, failure to document grain size and depositional environment may be recoverable by inspecting field logs and site maps, or through laboratory measurement once the samples are received by the laboratory. Failure to obtain 100 percent of these measurements for field samples may indicate a need for corrective actions designed to recover the missing information. Failure to recover the information will constitute a need to resample, unless the missing data are judged not to adversely affect attainment of project objectives.

Turbidity in ground water is a critical parameter that must be determined prior to sampling to establish attainment of equilibrium, and its completeness criterion is 100 percent. There are no completeness criteria for dissolved oxygen, flow rate, nitrate, oxidation-reduction potential, pH, specific conductance, temperature, water level, or monitored natural attenuation (MNA) parameters. All of these parameters are non-critical parameters that are either used to establish stable sampling conditions or to evaluate the potential efficacy of monitored natural attenuation as a remedial option. MNA parameters (identified in Table 1-3, Page 3 of 4) will not be determined in Round 1. The MNA parameters will be determined in sampling rounds subsequent to Round 1 if chlorinated organic solvents are detected at concentrations of concern.

3.3.3 Laboratory Completeness Objectives

Laboratory completeness is a measure of the amount of usable, valid laboratory measurements per matrix obtained for each target analyte. Usable, valid results are those that are judged, after data assessment, to represent the sampling populations and to have not been disqualified for use through data validation or data assessment.

Laboratory completeness objectives are 90 percent for each critical target analyte per sample matrix (soil and water). The use of kriging (i.e., geostatistical contouring), which can interpolate missing values, may mitigate some adverse effects experienced from loss of data. Furthermore, the impact of missing soil data cannot be quantified in advance of sampling because the impact will depend on which data are missing. The impact of the loss of any other particular datum on attainment of project objectives will be evaluated during data assessment.

Qualifications on the use of data caused by incomplete data sets will be documented in the soils RFI report.

3.4 REPRESENTATIVENESS

3.4.1 Definition

Representativeness is an expression of the degree to which the data accurately and precisely represent a characteristic of a population or environmental condition existing at the site. Adherence to the sampling and analysis plan (SAP) in Section 4.0 and use of standardized sampling, handling, preparation, analysis, and reporting procedures ensures that the final data accurately represent the desired populations. Representativeness will be evaluated during data assessment to determine whether each datum belongs to the observed data distribution through outlier testing. The statistical tests to be used are described in Section 12.4. Any anomalies will be investigated to assess their impact on statistical computations.

3.4.2 Measures to Ensure Representativeness of Field Data

Representativeness depends on the proper design of the sampling program and will be satisfied by ensuring that the SAP (Section 4.0) is followed and that proper sampling techniques are used. Sample collection will strictly adhere to soil type descriptions a soil sample representing the appropriate depth interval will be placed into each sample container. Well stabilization parameters (dissolved oxygen, pH, specific conductance, temperature, turbidity) will be monitored to ensure that ground water wells have attained equilibrium prior to sampling.

3.4.3 Measures to Ensure Representativeness of Lab Data

Representativeness in the laboratory is ensured or evaluated by using the proper analytical procedures, meeting prescribed sample holding times, and analyzing and evaluating field duplicate samples relative to laboratory duplicates. During development of this QAPP, measures to ensure representativeness of the data generated included considering past operations, aerial photographs, existing analytical data, physical setting, soil depositional environments, monitoring well placement, spatial coverage of the proposed sampling locations, accessibility to sampling locations, and constraints inherent to the RCRA program. The rationale of the sampling network is presented in detail in Section 4.0.

3.5 COMPARABILITY

3.5.1 Definition

Comparability is defined as the confidence with which one data set can be compared to another (e.g., between sampling points and between sampling events). Comparability is achieved by using standardized sampling and analysis methods and data reporting formats (including use of consistent units

of measure), and by ensuring that reporting and detection limits are sufficiently low to satisfy project detection and quantitation criteria for the duration of the project. The RLs and detection limits anticipated for this project are presented in Table 1-5. Additionally, consideration was given to seasonal conditions and other environmental variations that could exist to influence analytical results, but no such influences appear to exist for this investigation that would indicate a need to collect samples at times other than those planned for this investigation.

3.5.2 Measures to Ensure Comparability of Field Data

Comparability depends on the proper design of the sampling program and will be satisfied by ensuring that Section 4.0 of this QAPP is followed and that proper sampling techniques are used. The rationale behind the SAP design is found in Section 4.0.

3.5.3 Measures to Ensure Comparability of Laboratory Data

Planned analytical data will be comparable when similar sampling and analytical methods are used and documented for each sampling round. The use of soil sampling and analysis methods in this investigation that are comparable in performance to those used in the "Base-Wide Background Soil Investigation for NSWC Crane" should limit the need to consider biases when making soil data set comparisons for metals. Results will be reported in units that ensure comparability with previous data. The units used for the laboratory measurements are further explained in Section 9.1.2 of this QAPP.

3.6 LEVEL OF QUALITY CONTROL EFFORT

Several QC samples will be analyzed for this project to provide a means to assess field and laboratory performance. Field QC samples consist of field duplicates, equipment rinsate blanks, source water blanks, temperature blanks, trip blanks (VOC analyses only) and, at the discretion of the FOL, ambient condition blanks. These QC checks are described in Section 8.1. Each type of field QC sample undergoes the same preservation, analysis, and reporting procedures as the related environmental samples. Frequencies of field QC sample collection and analysis are presented in Table 3-1. The types and numbers of QC samples to be collected in the field are presented in Table 4-2.

Laboratory QC encompasses a host of other checks performed during sample preparation and analysis, as described in Section 8.2. Frequencies for laboratory QC checks are provided in Table 3-1 and in the method-specific laboratory SOPs appended to this QAPP (Appendix C).

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TABLE 3-1

NON-CALIBRATION QC SAMPLE USAGE FREQUENCIES, ACCEPTANCE LIMITS AND CORRECTIVE ACTIONS NSWC CRANE, CRANE, INDIANA PAGE 1 OF 2

QC Sample Type	Collection Frequency	Acceptance Limits	Corrective Action
Field Duplicate	1 per 10 investigative samples collected.	Aqueous = 30% RPD Soil/Sediment = 50% RPD	Qualify data according to data validation requirements.
Equipment Rinsate Blank	1 per 10 investigative samples collected, with a minimum of 1 per day of sampling, per non-disposable sampling device/instrument. For pre-cleaned, dedicated, and/or disposable equipment (i.e., disposable plastic trowels, etc.), one rinsate blank will be collected and analyzed at a frequency of 1 per lot or "batch blank" for a specific equipment type.	< RL (soil and water)	Identify source of contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Source Water Blank	1 per each source of water used for sampling equipment decontamination.	< RL (soil and water)	Identify source of contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Ambient Condition Blanks	At discretion of FOL.	< RL (soil and water)	Identify source of contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Trip Blanks	1 per cooler of VOC samples.	< RL (soil and water)	Identify source of volatiles contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Radioactive Tracer	At least 1 radioactive tracer must be added to each sample analyzed by alpha spectroscopy.	20% to 105%	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Internal Standard	At least one internal standard per sample for GC/MS analyses.	Retention times stable to ±30 seconds and area counts stable to within a factor of 2.	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.

TABLE 3-1

NON-CALIBRATION QC SAMPLE USAGE FREQUENCIES, ACCEPTANCE LIMITS AND CORRECTIVE ACTIONS NSWC CRANE, CRANE, INDIANA PAGE 2 OF 2

QC Sample Type	Collection Frequency	Acceptance Limits	Corrective Action
Laboratory Control Sample	1 per 20 environmental samples per matrix	See Tables 3-3, 3-5, 3-7, 3-9, 3-11, 3-13, 3-15, 3-17, and 3-19	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Laboratory Duplicate	1 per 20 environmental samples analyzed for inorganic target analytes.	See Tables 3-4 and 3-18	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Laboratory Method Blank	1 per 20 environmental samples or per preparation batch, whichever is more frequent.	< RL (soil and water)	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Matrix Spike*	1 per 20 environmental samples.	See Tables 3-2, 3-4, 3-6, 3-8, 3-10, 3-12, 3-14, 3-16, and 3-18	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Matrix Spike Duplicate*	1 per 20 environmental samples analyzed for organic target analytes	See Tables 3-2, 3-6, 3-8, 3-10, 3-14, 3-16	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Post-digestion Spike	Only if out-of-control matrix spike exists (metals only).	100 ± 20%	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Surrogate	At least 1 per sample for organic chromatographic analyses (GC, GC/MS, and HPLC).	See Tables 3-2, 3-6, 3-8, 3-10, 3-12, 3-14, 3-16, and 3-18	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.
Temperature Blank	1 blank per sample cooler.	4 ± 2 °C	Laboratory action taken per applicable analytical SOP. TtNUS action taken per validation protocols and Section 12.4.

* Matrix spikes and matrix spike duplicates are not analyzed in the field, but additional sample material must be collected in the field to ensure that the laboratory has enough material for spiking and duplicate analysis. See Table 4-3 for details regarding the extra volume required.

FOL = Filed operations leader
VOC = volatile organic chemical
RL = reporting limit
RPD = relative percent difference
GC/MS = gas chromatography/mass spectrometry
HPLC = high performance liquid chromatography
°C = degrees Celsius

TABLE 3-2

QUALITY CONTROL LIMITS
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
ENERGETIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
ENERGETIC COMPOUNDS BY SW-846 METHOD 8330				
1,3,5-Trinitrobenzene	57-130	50	56-129	30
1,3-Dinitrobenzene	74-122	50	76-122	30
2,4,6-Trinitrotoluene	44-124	50	76-137	30
2,4-Dinitrotoluene	59-120	50	72-123	30
2,6-Dinitrotoluene	58-125	50	80-118	30
2-Amino-4,6-dinitrotoluene	60-140	50	60-140	40
2-Nitrotoluene	79-124	50	74-130	30
3-Nitrotoluene	79-121	50	72-126	30
4-Amino-2,6-dinitrotoluene	60-140	50	60-140	40
4-Nitrotoluene	74-128	50	78-116	30
HMX	54-128	50	44-145	30
Nitrobenzene	70-135	50	82-111	30
RDX	66-109	50	65-139	30
Tetryl	32-119	50	76-120	30
3,4-Dinitrobenzene (surrogate)	60-140	NA(1)	60-140	NA(1)

1 Not applicable.
%R = Percent recovery
RPD = Relative percent difference

TABLE 3-3

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
ENERGETIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix Accuracy (%R)	Aqueous Matrix Low Range Accuracy (%R)	Aqueous Matrix High Range Accuracy (%R)
ENERGETIC COMPOUNDS BY SW-846 METHOD 8330			
1,3,5-Trinitrobenzene	64-125	24-129	74-118
1,3-Dinitrobenzene	82-118	22-117	79-132
2,4,6-Trinitrotoluene	75-118	45-118	61-145
2,4-Dinitrotoluene	74-126	35-119	70-131
2,6-Dinitrotoluene	78-117	34-126	77-125
2-Amino-4,6-dinitrotoluene	60-140	60-140	60-140
2-Nitrotoluene	78-123	27-119	70-131
3-Nitrotoluene	78-121	27-115	71-127
4-Amino-2,6-dinitrotoluene	60-140	60-140	60-140
4-Nitrotoluene	79-125	28-118	73-116
HMX	57-137	28-117	46-151
Nitrobenzene	69-143	18-119	68-135
RDX	77-113	25-114	72-114
Tetryl	23-124	25-119	58-120

1 In-house QC limits provided by SWLO meet or exceed these criteria.
%R = Percent recovery

TABLE 3-4

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE AND LABORATORY DUPLICATE SAMPLES
METALS ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy[2] (%R)	Precision[3] (RPD)	Accuracy[2] (%R)	Precision[3] (RPD)
APPENDIX IX METALS BY SW-846 METHOD 6010B Trace				
Antimony	75-125	50	75-125	30
Arsenic	75-125	50	75-125	30
Barium	75-125	50	75-125	30
Beryllium	75-125	50	75-125	30
Cadmium	75-125	50	75-125	30
Chromium (total)	75-125	50	75-125	30
Cobalt	75-125	50	75-125	30
Copper	75-125	50	75-125	30
Lead	75-125	50	75-125	30
Mercury (SW-846 Method 7470A/7471A)	75-125	50	75-125	30
Nickel	75-125	50	75-125	30
Selenium	75-125	50	75-125	30
Silver	75-125	50	75-125	30
Thallium	75-125	50	75-125	30
Tin	75-125	50	75-125	30
Vanadium	75-125	50	75-125	30
Zinc	75-125	50	75-125	30
MISCELLANEOUS METALS BY SW-846 METHOD 6010B				
Aluminum	75-125	50	75-125	30
Calcium	75-125	50	75-125	30
Iron	75-125	50	75-125	30
Magnesium	75-125	50	75-125	30
Manganese	75-125	50	75-125	30
Potassium	75-125	50	75-125	30
Sodium	75-125	50	75-125	30
Strontium	75-125	50	75-125	30

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 These acceptance limits apply to spikes that augment the native sample analyte concentration by at least 25 percent.
3 These acceptance limits apply to original and duplicate sample concentrations >5x RL. If one or both of the results is <5x RL, the acceptance criterion is ± RL. If one of the results is a non-detect, the reported %RPD will be 200%.

%R = Percent recovery
RPD = Relative percent difference

TABLE 3-5

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
METALS ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix Accuracy (%R)[2]	Aqueous Matrix Accuracy (%R)[2]
APPENDIX IX METALS BY SW-846 METHOD 6010B Trace		
Antimony	75-125	80-120
Arsenic	75-125	80-120
Barium	75-125	80-120
Beryllium	75-125	80-120
Cadmium	75-125	80-120
Chromium (total)	75-125	80-120
Cobalt	75-125	80-120
Copper	75-125	80-120
Lead	75-125	80-120
Mercury (SW-846 Method 7470A/7471A)	75-125	80-120
Nickel	75-125	80-120
Selenium	75-125	80-120
Silver	75-125	80-120
Thallium	75-125	80-120
Tin	75-125	80-120
Vanadium	75-125	80-120
Zinc	75-125	80-120
MISCELLANEOUS METALS BY SW-846 METHOD 6010B		
Aluminum	75-125	80-120
Calcium	75-125	80-120
Iron	75-125	80-120
Magnesium	75-125	80-120
Manganese	75-125	80-120
Potassium	75-125	80-120
Sodium	75-125	80-120
Strontium	75-125	80-120

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 The laboratory may use a purchased standard reference material (SRM) in place of a LCS. If a SRM is used, the acceptance limits provided by the supplier of the SRM may be used unless the SRM limits are wider than the acceptance limits provided in this table. If the SRM limits are wider, the laboratory must use the acceptance limits provided in this table.
%R = Percent recovery

TABLE 3-6

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
VOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 2

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
VOLATILE ORGANIC COMPOUNDS BY SW-846 METHOD 8260B				
1,1,1-Trichloroethane	70-124	30	59-130	20
1,1,2,2-Tetrachloroethane	50-143	30	59-139	20
1,1,2-Trichloroethane	64-136	30	68-131	20
1,1-Dichloroethane	67-124	30	60-133	20
1,1-Dichloroethene	66-122	30	58-135	20
1,2-Dichloroethane	63-131	30	61-136	20
1,2-Dichloroethane-D4 (surrogate)	80-120	NA[2]	80-120	NA[2]
1,2-Dichloropropane	72-128	30	66-135	20
1,4-Dioxane	10-200	40	10-200	40
2-Butanone	20-180	30	44-152	20
2-Hexanone	38-155	30	55-142	20
4-Bromofluorobenzene (surrogate)	74-121	NA[2]	86-115	NA[2]
4-Methyl-2-pentanone	45-151	30	56-146	20
Acetone	55-152	30	36-154	20
Acetonitrile	60-140	20	60-140	20
Benzene	74-126	30	64-128	20
Bromodichloromethane	69-132	30	63-134	20
Bromoform	45-154	30	61-135	20
Bromomethane	58-141	30	46-143	20
Carbon disulfide	76-128	30	73-120	20
Carbon tetrachloride	66-132	30	61-129	20
Chlorobenzene	74-125	30	62-132	20
Chloroethane	49-154	30	59-142	20
Chloroform	57-136	30	61-133	20
Chloromethane	36-151	30	47-150	20
cis-1,2-Dichloroethene	71-124	30	61-134	20
cis-1,3-Dichloropropene	73-125	30	65-129	20
Dibromochloromethane	66-136	30	64-131	20
Dibromodifluoromethane	80-120	NA[2]	86-118	NA[2]
Dibromofluoromethane (surrogate)	60-140	NA[1]	65-135	NA[2]
Ethylbenzene	50-149	30	60-131	20
Isobutyl alcohol	(3)	(3)	(3)	(3)
Methylene chloride	61-138	30	59-134	20

TABLE 3-6

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
VOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
Propionitrile	60-140	20	60-140	20
Styrene	72-131	30	61-136	20
Tetrachloroethene	58-142	30	62-133	20
Toluene	73-126	30	59-134	20
Toluene-D8 (surrogate)	81-117	NA[2]	88-110	NA[2]
trans-1,2-Dichloroethene	70-123	30	59-134	20
trans-1,3-Dichloropropene	70-129	30	64-130	20
Trichloroethene	66-138	30	64-128	20
Vinyl chloride	49-161	30	53-138	20
Xylenes (Total)	44-151	30	72-132	20

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 Not applicable
%R = Percent recovery
RPD = Relative percent difference

TABLE 3-7

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
VOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 2

Chemical	Solid Matrix Accuracy (%R)	Aqueous Matrix Accuracy (%R)
VOLATILE ORGANIC COMPOUNDS BY SW-846 METHOD 8260B		
1,1,1-Trichlorethane	70-124	59-130
1,1,2,2-Tetrachloroethane	50-143	59-139
1,1,2-Trichlorethane	64-136	68-131
1,1-Dichloroethane	67-124	60-133
1,1-Dichloroethene	66-122	58-135
1,2-Dichloroethane	63-131	61-136
1,2-Dichloropropane	72-128	66-135
1,4-dioxane	10-200	10-200
2-Butanone	20-180	44-152
2-Hexanone	38-155	55-142
4-Methyl-2-pentanone	45-151	56-146
Acetone	55-152	36-154
Acetonitrile	60-140	60-140
Benzene	74-126	64-128
Bromodichloromethane	69-132	63-134
Bromoform	45-154	61-135
Bromomethane	58-141	46-143
Bromobenzene	76-128	73-120
Carbon Tetrachloride	66-132	61-129
Chlorobenzene	74-125	62-132
Chloroethane	49-154	59-142
Chloroform	57-136	61-133
Chloromethane	36-151	47-150
cis-1,2-Dichloroethene	71-124	61-134
cis-1,3-Dichloropropene	73-125	65-129
Dibromochloromethane	66-136	64-131
Ethylbenzene	50-149	60-131
Isobutyl alcohol	(3)	(3)
Methylene Chloride	61-138	59-134
Styrene	72-131	61-136
Tetrachloroethene	58-142	62-133
Toluene	73-126	59-134
trans-1,2-Dichloroethene	70-123	59-134
trans-1,3-Dichloropropene	70-129	64-130

TABLE 3-7

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
VOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2

Chemical	Solid Matrix Accuracy (%R)	Aqueous Matrix Accuracy (%R)
Trichloroethene	66-138	64-128
Vinyl Chloride	49-161	53-138

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 Not applicable
3 No laboratory derived limits available.
%R = Percent recovery

TABLE 3-8

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
SEMIVOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 3

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
SEMIVOLATILE ORGANIC COMPOUNDS BY SW-846 METHOD 8270C				
1,2,4-Trichlorobenzene*	46-108	40	17-109	30
1,2-Dichlorobenzene	51-104	40	31-83	30
1,3-Dichlorobenzene	42-108	40	28-80	30
1,4-Dichlorobenzene*	34-107	40	14-110	30
2,4,5-Trichlorophenol	37-118	40	47-117	30
2,4,6-Trichlorophenol	34-118	40	43-117	30
2,4-Dichlorophenol	46-110	40	53-84	30
2,4-Dimethylphenol	42-108	40	15-78	30
2,4-Dinitrophenol	47-138	40	48-133	30
2-Chloronaphthalene	35-112	40	49-88	30
2-Chlorophenol*	8-128	40	18-111	30
2-Methylnaphthalene	31-115	40	33-97	30
2-Methylphenol	45-115	40	29-124	30
2-Nitroaniline	32-126	40	53-104	30
2-Nitrophenol	42-108	40	56-89	30
3,3'-Dichlorobenzidine	34-131	70	44-156	30
3-Nitroaniline	1-204	40	0-497	30
4,6-Dinitro-2-methylphenol	25-136	40	49-121	30
4-Bromophenyl phenyl ether	36-118	40	58-94	30
4-Chloro-3-methylphenol*	10-135	40	23-115	30
4-Chloroaniline	14-97	45	35-119	30
4-Chlorophenyl phenyl ether	31-119	40	55-89	30
4-Methylphenol	46-117	40	25-121	30
4-Nitroaniline	43-151	40	0-239	30
4-Nitrophenol*	19-142	40	9-117	30
Bis(2-chloroethoxy)methane	47-112	40	54-89	30
Bis(2-chloroethyl)ether	42-121	40	51-95	30
Bis(2-chloroisopropyl)ether	48-115	40	43-96	30
Bis(2-ethylhexyl)phthalate	36-117	40	54-105	30
Butyl benzyl phthalate	62-122	40	33-107	30
Dibenzofuran	33-115	40	54-87	30
Diethyl phthalate	36-118	40	0-105	35

TABLE 3-8

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
SEMIVOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 3

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
Dimethyl phthalate	35-118	40	0-107	30
Di-n-butyl phthalate	34-118	40	27-106	30
Di-n-octyl phthalate	40-116	40	46-116	35
Hexachlorobenzene	34-109	40	8-115	30
Hexachlorobutadiene	17-77	40	0-104	30
Hexachlorocyclopentadiene	45-104	40	7-117	30
Hexachloroethane	17-77	40	0-104	30
Hexachlorophene	20-150	40	35-140	40
Isophorone	48-114	40	53-92	30
n-Nitroso-di-n-propylamine*	36-124	40	15-123	30
n-Nitrosodiphenylamine	25-135	40	29-123	30
Pentachlorophenol*	7-157	43	23-139	30
Phenol	3-141	40	2-103	30
2-Fluorobiphenyl (surrogate)	30-115	NA[2]	43-116	NA[2]
2-Fluorophenol (surrogate)	25-121	NA[2]	21-100	NA[2]
2,4,6-Tribromophenol (surrogate)	19-122	NA[2]	10-123	NA[2]
Nitrobenzene-d5 (surrogate)	23-120	NA[2]	34-114	NA[2]
Phenol-d5 (surrogate)	24-113	NA[2]	10-94	NA[2]
p-Terphenyl-d14 (surrogate)	18-137	NA[2]	33-141	NA[2]
POLYNUCLEAR AROMATIC HYDROCARBONS BY SW-846 METHOD 8310				
Acenaphthylene	27-122	40	29-131	40
Acenaphthene*	54-125	40	40-126	40
Anthracene	47-125	40	22-147	40
Benzo(a)anthracene	41-129	40	34-137	40
Benzo(a)pyrene	31-138	40	28-143	40
Benzo(b)fluoranthene	39-122	40	33-131	40
Benzo(k)fluoranthene	48-132	40	56-137	40
Benzo(g,h,i)perylene	53-125	40	52-130	40
Chrysene	64-127	40	54-122	40
Dibenzo(a,h)anthracene	57-128	40	53-133	40
Fluoranthene	51-127	40	50-130	40
Fluorene	60-129	40	32-109	40
Indeno(1,2,3-c,d)pyrene	30-140	40	39-103	40

TABLE 3-8

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
SEMIVOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 3 OF 3

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
Naphthalene	50-129	40	20-113	40
Phenanthrene	46-127	40	23-112	40
Pyrene*	42-130	40	25-105	40
2-Fluorobiphenyl (surrogate)	64-113	NA[2]	20-131	NA[2]
p-Terphenyl (surrogate)	66-125	NA[2]	43-139	NA[2]

1 This is the full spiking list which is used when a full spike is performed. Representative compounds that are spiked routinely are marked with an asterisk (*). In-house QC limits provided by SWLO meet or exceed these limits.
2 Not applicable
%R = Percent recovery
RPD = Relative percent difference

TABLE 3-9

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
SEMIVOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 2

Chemical	Solid Matrix	Aqueous Matrix
	Accuracy (%R)	Accuracy (%R)
SEMIVOLATILE ORGANIC COMPOUNDS BY SW-846 METHOD 8270C		
1,2,4-Trichlorobenzene	46-108	17-109
1,2-Dichlorobenzene	51-104	31-83
1,3-Dichlorobenzene	42-108	28-80
1,4-Dichlorobenzene	34-107	14-110
2,4,5-Trichlorophenol	37-118	47-117
2,4,6-Trichlorophenol	34-118	43-117
2,4-Dichlorophenol	46-110	53-84
2,4-Dimethylphenol	42-108	15-78
2,4-Dinitrophenol	47-138	48-133
2-Chloronaphthalene	35-112	49-88
2-Chlorophenol	8-128	18-111
2-Methylnaphthalene	31-115	33-97
2-Methylphenol	45-115	29-124
2-Nitroaniline	32-126	53-104
2-Nitrophenol	42-108	56-89
3,3'-Dichlorobenzidine	34-131	44-156
3-Nitroaniline	1-204	0-497
4,6-Dinitro-2-methylphenol	25-136	49-121
4-Bromophenyl-phenylether	36-118	58-94
4-Chloro-3-methylphenol	10-135	23-115
4-Chloroaniline	14-97	35-119
4-Chlorophenyl-phenylether	31-119	55- 89
4-Methylphenol	46-117	25-121
4-Nitroaniline	43-151	0-239
4-Nitrophenol	19-142	9-117
bis(2-Chloroethoxy)methane	47-112	54-89
bis(2-Chloroethyl)ether	42-121	51-95
bis(2-Chloroisopropyl)ether	48-115	43-96
bis(2-Ethylhexyl)phthalate	36-117	54-105
Buytylbenzylphthalate	62-122	33-107
Dibenzofuran	33-115	54-87
Diethylphthalate	36-118	0-105
Dimethylphthalate	35-118	0-107

TABLE 3-9

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
SEMIVOLATILE ORGANIC COMPOUND ANALYSES
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2

Chemical	Solid Matrix	Aqueous Matrix
	Accuracy (%R)	Accuracy (%R)
Di-n-butylphthalate	34-118	27-106
Di-n-octylphthalate	40-116	46-116
Hexachlorobenzene	34-118	48-111
Hexachlorobutadiene	34-109	8-115
Hexachlorocyclopentadiene	17-77	0-104
Hexachloroethane	45-106	7-117
Hexachlorophene	25-150	30-140
Isophorone	48-114	53-92
N-Nitroso-di-n-propylamine	36-124	15-123
N-Nitrosodiphenylamine	25-135	29-123
Pentachlorophenol	7-157	23-139
Phenol	3-141	2-103
POLYNUCLEAR AROMATIC HYDROCARBONS BY SW-846 METHOD 8310		
Acenaphthylene	10-139	50-118
Acenaphthene	32-136	50-112
Anthracene	34-138	47-122
Benzo(a)anthracene	27-141	43-128
Benzo(a)pyrene	40-132	57-122
Benzo(b)fluoranthene	16-126	24-149
Benzo(k)fluoranthene	58-128	54-138
Benzo(g,h,i)perylene	50-136	30-136
Chrysene	44-145	60-130
Dibenzo(a,h)anthracene	55-147	61-134
Fluoranthene	34-165	47-137
Fluorene	45-123	59-130
Indeno(1,2,3-c,d)pyrene	24-123	32-132
Naphthalene	26-160	58-128
Phenanthrene	40-145	42-127
Pyrene	59-130	60-126

1 In-house QC limits provided by SWLO meet or exceed these limits.
%R = Percent recovery

TABLE 3-10

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
ORGANOCHLORINE PESTICIDE AND PCB ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
ORGANOCHLORINE PESTICIDES AND PCBs BY SW-846 METHOD 8081A/8082				
4,4'-DDD	30-168	50	53-140	50
4,4'-DDE	45-128	50	53-124	50
4,4'-DDT	44-157	50	30-162	50
Aldrin	33-119	50	35-127	50
Alpha-BHC	47-122	50	30-156	50
Alpha-Chlordane	43-135	50	53-117	50
Beta-BHC	37-125	50	43-127	50
Delta-BHC	42-140	50	38-148	50
dieldrin	42-134	50	44-138	50
Endosulfan I	20-119	50	19-114	50
Endosulfan II	23-134	50	37-110	50
Endosulfan Sulfate	11-170	50	43-140	50
Endrin	23-170	50	27-172	50
Endrin Aldehyde	10-170	50	52-140	50
Gamma-BHC (Lindane)	42-129	50	30-156	50
Gamma-Chlordane	25-156	50	43-128	50
Heptachlor	10-170	50	20-164	50
Heptachlor Epoxide	40-124	50	41-122	50
Methoxychlor	59-156	50	56-152	50
Toxaphene	NA[2]	NA[2]	NA[2]	NA[2]
Aroclor 1016	53-100	50	45-98	50
Aroclor 1221	NA[2]	NA[2]	NA[2]	NA[2]
Aroclor 1232	NA[2]	NA[2]	NA[2]	NA[2]
Aroclor 1242	NA[2]	NA[2]	NA[2]	NA[2]
Aroclor 1248	NA[2]	NA[2]	NA[2]	NA[2]
Aroclor 1254	NA[2]	NA[2]	NA[2]	NA[2]
Aroclor 1260	50-107	50	47-106	50
Decachlorobiphenyl (surrogate)	52-143	NA[2]	58-127	NA
Tetrachloro-m-xylene (surrogate)	47-118	NA	38-124	NA

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 Not applicable.
%R = Percent recovery
RPD = Relative percent difference

TABLE 3-11

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
ORGANOCHLORINE PESTICIDE AND PCB ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix	Aqueous Matrix
	Accuracy (%R)	Accuracy (%R)
ORGANOCHLORINE PESTICIDES AND PCBs BY SW-846 METHOD 8081A/8082		
4,4'-DDD	30-168	53-140
4,4'-DDE	45-128	53-124
4,4'-DDT	44-157	30-162
Aldrin	33-119	35-127
Alpha-BHC	47-122	30-156
Alpha-Chlordane	43-135	53-117
Beta-BHC	37-125	43-127
Delta-BHC	42-140	38-148
dieldrin	42-134	44-138
Endosulfan I	20-119	19-114
Endosulfan II	23-134	37-110
Endosulfan Sulfate	11-170	43-140
Endrin	23-170	27-172
Endrin Aldehyde	10-170	52-140
Gamma-BHC (Lindane)	42-129	30-156
Gamma-Chlordane	25-156	43-128
Heptachlor	10-170	20-164
Heptachlor Epoxide	40-124	41-122
Methoxychlor	59-156	56-152

1 In-house QC limits provided by SWLO meet or exceed these limits.
%R = Percent recovery

TABLE 3-12

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
HERBICIDE ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
HERBICIDES BY SW-846 METHOD 8151A				
2,4-D	19-113	55	34-128	45
2,4,5-T	D-129	55	8-130	45
2,4,5-TP (Silvex)	32-129	55	28-157	45
Dinoseb	D-96	85	6-104	85
2,4-Dichlorophenylaceticacid (surrogate)	30-133	NA[2]	49-130	NA[2]

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 Not applicable.
%R = Percent recovery
RPD = Relative percent difference

TABLE 3-13

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
HERBICIDE ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix Accuracy (%R)	Aqueous Matrix Accuracy (%R)
HERBICIDES BY SW-846 METHOD 8151A		
2,4-D	19-113	34-128
2,4,5-T	0-129	8-130
2,4,5-TP (Silvex)	32-129	28-157
Dinoseb	0-96	6-104
2,6-Dichlorobenzoic acid (surrogate)	28-93	27-111
2,4-Dichlorophenylaceticacid (surrogate)	4-149	0-179

1 In-house QC limits provided by SWLO meet or exceed these limits.
%R = Percent recovery

TABLE 3-14

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND RADIOACTIVE TRACERS
RADIONUCLIDE ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (EF)	Accuracy (%R)	Precision (EF)
RADIONUCLIDES BY ALPHA SPECTROSCOPY (EPA 907, EMSL-LV-0539)				
Thorium-228	NA	NA	NA	NA
Thorium-230	NA	NA	NA	NA
Thorium-232	NA	NA	NA	NA
Thorium-229 (Tracer)	20-105	NA	20-105	NA

1 In-house QC limits provided by SWLO meet or exceed these limits.
%R = Percent recovery
EF = Equivalency factor
NA = Not Applicable

TABLE 3-15

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
RADIONUCLIDE ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix Accuracy (%R)	Aqueous Matrix Accuracy (%R)
RADIONUCLIDES		
Thorium-228 (Alpha Spectroscopy)	NA	NA
Thorium-230 (Alpha Spectroscopy)	75 - 100	75-100
Thorium-232 (Alpha Spectroscopy)	NA	NA
Cesium-137 (Gamma Spectrometry)	75-125	75-125

1 In-house QC limits provided by SWLO meet or exceed these limits.
%R = Percent recovery
NA = Not Applicable

TABLE 3-16

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES AND SURROGATE SPIKES
SULFUR MUSTARD GAS/DEGRADATES ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)	Accuracy (%R)	Precision (RPD)
SULFUR MUSTARD GAS AND DEGRADATES (ECBC METHOD)				
Bis(2-chloroethyl)sulfide	50-130	30%	50-130	30%
1,4-Thioxane	50-130	30%	50-130	30%
1,4-Dithiane	50-130	30%	50-130	30%
Thiodiglycol	20-130	30%	20-139	30%
Chloroethyl ethyl sulfide (surrogate for all analyses except thiodiglycol)	20-130	NA	20-130	NA
Thiodipropanol (surrogate for thiodiglycol analysis only)	21-130 33-92	50	20-130 48-89	50

1 In-house QC limits provided by the ECBC laboratory meet or exceed these limits.
%R = Percent recovery
RPD = Relative percent difference
NA = Not Applicable

TABLE 3-17

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
SULFUR MUSTARD GAS/DEGRADATES ANALYSES
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix Accuracy (%R)	Aqueous Matrix Accuracy (%R)
SULFUR MUSTARD GAS AND DEGRADATES (ECBC METHOD)		
Bis(2-chloroethyl)sulfide, Mustard Gas	50-130	50-130
1,4-Thioxane	50-130	50-130
1,4-Dithiane	50-130	50-130
Thiodiglycol	20-130	20-130

1 In-house QC limits provided by the ECBC laboratory meet or exceed these limits.
%R = Percent recovery

TABLE 3-18

QUALITY CONTROL LIMITS[1]
MATRIX SPIKE AND LABORATORY DUPLICATE SAMPLES
MISCELLANEOUS PARAMETERS
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix		Aqueous Matrix	
	Accuracy (%R)	Precision (RPD)[5]	Accuracy (%R)	Precision (RPD)[5]
MISCELLANEOUS PARAMETERS				
Hardness (Calculation, Standard Method 2340B)	ANR[2]	ANR[2]	NA[3]	NA[3]
Total Organic Carbon (SW-846 9060)	50-150	50	75-125	25
Total Suspended Solids (EPA 160.1)	ANR[2]	ANR[2]	NA	20
CEC (SW-846 Method 9081)	TBD[4]	50	ANR[2]	ANR[2]
Chloride	ANR[2]	ANR[2]	75-125	25
Methane (dissolved)	ANR[2]	ANR[2]	50-150	50
Ethane (dissolved)	ANR[2]	ANR[2]	50-150	50
Ethene (dissolved)	ANR[2]	ANR[2]	50-150	50
Gross Alpha	ANR[2]	ANR[2]	ANR[2]	<1.5 [6]
Gross Beta	ANR[2]	ANR[2]	ANR[2]	<1.5 [6]

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 Analysis not required.
3 Not applicable.
4 To be determined.
5 These acceptance limits apply to original and duplicate sample concentrations >5x RL. If one or both of the results is <5x RL, the acceptance criterion is ± 5x RL. If one of the results is a non-detect, the reported percent RPD will be 200%.
6 Corresponds to an equivalency factor calculation rather than RPD.
%R = Percent recovery
RPD = Relative percent difference

TABLE 3-19

QUALITY CONTROL LIMITS[1]
LABORATORY CONTROL SAMPLES
MISCELLANEOUS PARAMETERS
NSWC CRANE, CRANE, INDIANA

Chemical	Solid Matrix[2] Accuracy (%R)	Aqueous Matrix[2] Accuracy (%R)
MISCELLANEOUS PARAMETERS		
Hardness (Calculation, Standard Method 2340B)	ANR[3]	NA[4]
Total Organic Carbon (SW-846 9060)	50-150	80-120
Total Suspended Solids (EPA 160.1)	ANR[3]	NA[4]
CEC (SW-846 Method 9081)	NA[4]	ANR[3]
Chloride	75-125	75-125
Methane (dissolved)	ANR[3]	60-140
Ethane (dissolved)	ANR[3]	60-140
Ethene (dissolved)	ANR[3]	60-140
Gross Alpha	ANR[3]	75-125
Gross Beta	ANR[3]	75-125

1 In-house QC limits provided by SWLO meet or exceed these limits.
2 The laboratory may use a purchased standard reference material (SRM) in place of a LCS. If a SRM is used, the acceptance limits provided by the supplier of the SRM may be used unless the SRM limits are wider than the acceptance limits provided in this table. If the SRM limits are wider, the laboratory must use the acceptance limits provided as this table.
3 Analysis not required
4 Not applicable.
%R = Percent recovery

4.0 SAMPLING AND ANALYSIS PLAN

CAUTION

Historical records indicate a past existence of health and safety hazards at the MGBG that are relatively uncommon, including mustard gas and radiation. As described in Section 1 of this QAPP, acute risks to health and safety due to these hazards are reported to have been removed. However, precautions necessary to preclude unnecessary health and safety risks must be followed as presented in the attendant HASP.

4.1 GENERAL APPROACH

The burial of mustard gas (HD) bombs, thorium nitrate, and unknown research and development chemicals occurred at the MGBG between the 1940s and 1960s. Extensive geophysical surveys and exhumation of HD bombs occurred in 1974 and 1980. Based on interviews of base personnel and historical records, it is believed that no explosives or other unexploded ordnance (UXO) were ever buried in the MGBG, nor has any ever been discovered there during the exhumations. It is also thought that all HD and demilitarized bombs have been exhumed from the MGBG. However, some thorium nitrate as well as unknown laboratory and experimental chemicals may still be present in the MGBG. In the early 1980s, 27 monitoring wells were installed around the MGBG, and a plume of chlorinated organic contaminants was discovered in the ground water, which was migrating primarily northwestward. The chemical contaminants that are potentially present at the site include HD and its degradation products, chlorinated solvents, and natural thorium isotopes (i.e., Th-232 and -228) and related decay products. In addition, other chemicals used in making flares, small quantities of miscellaneous laboratory chemicals, and other unknown chemicals may have been disposed of at the site.

Sampling and analyses will be performed in stages (rounds) during this field investigation to determine the nature and extent of contamination in the following media: surface soil, subsurface soil, ground water, surface water, and sediment. Data will be further used to estimate the level of human health and ecological risks associated with the MGBG. The staged sampling should assure decisionmakers of progress toward attaining project objectives, and should afford the earliest opportunity for declaring attainment of those objectives. Sampling rounds that may be required beyond Round 1 are expected to involve limited sampling and analyses by taking advantage of knowledge gained during the preceding sampling rounds. If project objectives are not attained within two rounds of sampling, the Navy will discuss with U.S. EPA Region 5 the need for additional sampling and analyses.

Sampling Round 1 will include surface soil, subsurface soil, ground water, surface water, and sediment and a wide variety of analyses. The types of analyses to be performed on these samples is wide-ranging and commensurate with what is known and suspected about the types or quantities of chemicals that were buried in the MGBG. Analytes to be evaluated in each environmental medium are listed in Table 1-3.

This chapter describes sampling locations and rationales for Round 1 activities, the general approach for sampling locations and activities for the subsequent Round 2 investigations, and the equipment and procedures to be used for collecting, handling, preserving, and shipping the samples to the analytical laboratories. The text references SOPs (located in Appendix H) and the HASP, when applicable.

Prior to sampling, the TOM will ensure that all field personnel read and understand the QAPP and HASP, the FOL will ensure that all required field equipment for non-health and safety operations is available and operational, and the SSO will ensure that all health and safety-related equipment is available and operational.

4.2 SAMPLE IDENTIFICATION SYSTEM

All samples will be properly labeled with an adhesive-backed sample label affixed to each sample container in accordance with SOP CTO131-7. The sample labels will include the following information: project name, project location, sample tracking number, sampling date, sampling time, type of analysis required, matrix type, preservative, initials of sampler, and the name of the analytical laboratory to which the sample will be submitted.

Each sample collected will be assigned a unique sample tracking number. The sample tracking number for soils is a four-segment, alphanumeric code beginning with the site designation ("01" represents SWMU 01/12), and followed by codes for the sample medium, sample location, and sample depth. The sample tracking number for the other media (sediment, surface water, and ground water) is also a four-segment, alphanumeric code identifying the site ("01"), sample medium, and sample location. These numbering schemes are described in SOP CTO131-7. For groundwater samples, the well numbers for wells have been abbreviated in the sample IDs. For example, the first sample obtained from well WES-1-9-82 is designated as 01-GW-09-01. "WES-1-9-82" is abbreviated as "01-09". Any other pertinent information regarding sample identification will be recorded in the field logbooks and sample log sheets.

The sampling time recorded on the chain-of-custody form and labels for duplicate samples will be 0000 so that the duplicate samples are "blind" to the laboratory. Notes detailing the sample number, time, date, and type will be recorded on the sample log sheets and will document the location of the duplicate sample (sample log sheets are not provided to the laboratory).

Matrix spike and matrix spike duplicate (MS/MSD) samples will be designated on the field documentation forms and chain-of-custody form (see SOP CTO131-25).

4.3 UXO, HD, AND RADIOLOGICAL CLEARANCE

Although the potential for encountering buried UXO is low, the specific locations for drilling or other intrusive activities must first be cleared for the presence of UXO. Clearance for UXO will consist of the following steps:

(1) Scan the ground surface in the vicinity of the proposed drilling location with a magnetic locator.
(2) Drill vertically and sample two feet of soil.
(3) Remove the drilling and soil sampling equipment from the hole and move it at least 20 feet away from the hole.
(4) Scan for magnetic anomalies in the newly-drilled section of the hole.
(5) Repeat steps 2, 3, and 4 until a depth of ten feet is reached.

Waste burial is believed to be no deeper than 6 feet bgs, but clearance to 10 feet is being performed as a precautionary measure. Details regarding UXO clearance are found in SOP CTO131-1, located in Appendix H. The types of geophysical equipment that will be used to perform the UXO clearance are listed in Table 4-1.

Field personnel performing sampling activities in the MGBG could be exposed to HD, radioactivity, and organic vapors. During the process of UXO clearance, soils will also be scanned and screened for HD, radioactivity, and VOCs. Soil cores will be brought to the surface using Geoprobe® sampling equipment (SOP CTO131-5). The soil cores will be scanned for gross beta and gamma activity (SOP CTO131-2). Samples will be collected every 2 feet and screened for HD using the headspace screening method (SOP CTO131-3). The soil will also be scanned for VOCs using a photoionization detector (PID), as described in detail in SOP CTO131-4. All measurements made with the field instruments and visual observations concerning the soil materials brought to the surface will be recorded on borehole log sheets. Any encounters with metallic objects or discolored soil materials, any positive detections of HD, or any

above-background measurements of VOCs or radioactivity shall be immediately reported to the FOL and the SSO and appropriate actions shall be taken as specified in the HASP.

If the field screening shows no radioactivity greater than background levels, no detectable VOCs, and no detectable HD, excess soil core materials may be placed back down the hole and tamped so that the hole is filled back to the ground surface. If field measurements exhibit radioactivity levels or VOCs exceeding the background level, or detectable HD, all soil materials from the affected depth interval will be placed in a plastic-lined 55-gallon drum and labeled in accordance with SOP CTO131-27. The drum and its contents will be stored at the MGBG until laboratory analyses of the soil confirm whether contaminants are present in the soil. Proper disposal of the soil will occur, as discussed in Section 4.12 and SOP CTO131-27. The remaining hole will be backfilled with a mixture of clean soil and bentonite pellets, and will be tamped periodically as it is filled.

The location of every hole will be marked with a wooden lath and flagging, and a hole number will be marked on the lath. In addition, a 2-by 2-inch wooden stake, 6 inches long, will be driven into the ground at the center of the backfilled borehole. This stake will have a piece of bright-colored flagging tacked onto its top, and the hole number indelibly marked on the side of the stake.

4.4 ROUND 1 SAMPLING LOCATIONS, ANALYSES, AND RATIONALES

This section presents sampling locations, QA samples to be collected, analyses to be performed, and rationale for the Round 1 sampling and analytical program. Details regarding the equipment and procedures for collecting, preserving, packaging, and shipping the samples are included in Section 4.6 and SOP CTO131-24 in Appendix H.

4.4.1 Surface and Subsurface Soils

It is believed that all HD bombs and most of the thorium nitrate encountered during previous exhumations of the MGBG have been removed from the site. The following surface and subsurface soil sampling activities are intended to determine whether any significant quantities of waste materials remain at the MGBG, and the identities of any contaminants. Twenty boreholes will be located within the area encompassed by a perimeter extending 20 feet in all directions beyond the former MGBG fence line. With a density of 20 boreholes over an area of approximately 2 acres, small, localized areas of contaminants could go undetected. However, 20 boreholes with three soil samples from each borehole (60 total soil samples) was considered an adequate number of samples to cover the MGBG with reasonable density to detect remaining contamination that might be an environmental problem (see

Section 1.5.1). The potential for not detecting localized areas of contaminants is mitigated by the sampling planned for the other environmental media and by the allowance for additional sampling rounds, as necessary.

The locations of the 20 boreholes in the MGBG area are shown on Figure 4-1. The boreholes are numbered 01SB01 through 01SB20. The Primary Burial Area (PBA) located within the MGBG is about 8,300 square feet in area. It was divided into four sampling cells by connecting the midpoints of each side of the PBA (each cell represents approximately 2,075 square feet). Each sampling cell was divided further into a 10-by-10 array of subcells. One subcell within each sampling cell was selected as the borehole location. Subcell selection was based on randomly selected subcell coordinate pairs using a uniform random number generator (Microsoft Excel 97 SR-2 [h]). The remaining MGBG area, plus a perimeter area extending 20 feet beyond the former MGBG fence line, is about 107,200 square feet in area. This area was divided into 16 sampling cells, each about 6,700 square feet (Figure 4-1). Within each of these sampling cells, a borehole location was selected in a manner similar to that used for the PBA borehole locations. The density of boreholes in the PBA (one hole per 2,075 square feet) is about three times greater than the density of boreholes in the remainder of the MGBG (one hole per 6,700 square feet). The greater borehole density in the PBA was selected because most burials were associated with this area. This soil sampling design constitutes a stratified random design.

Past exhumations have resulted in former burial locations being backfilled with ostensibly clean fill material (Figure 1-10). However, exact locations and depths of backfill, the physical characteristics of the backfill soil, and the presence of contaminants if any in the fill area are not well documented and not well known. Hence, soil cores and samples will be collected from both native and backfilled soil materials, without bias. Encountering refusal will be justification for relocating the boring within the same sampling cell to obtain a sample that is representative of the cell.

Once all of the borehole locations have been established in the field, the UXO clearance activities, as discussed in the previous section, will be performed in conjunction with the soil boring and sampling activities.

Surface and subsurface soil sampling will be performed using direct-push technology (DPT). Geoprobe®, or similar sampling equipment, will be used to hydraulically push a steel coring tube into the ground and remove an intact 2-foot long soil core contained in a clear acetate liner. Details regarding soil sampling equipment and procedures are included in Section 4.6.2 and SOP CTO131-5.

Three soil samples will be collected from each borehole from the following nominal depth intervals: 0 to 2, 2 to 6, and 6 to10 feet bgs. If bedrock is shallower than the bottom of a depth interval, sampling will stop at the bedrock. Surface soils are defined as soils 0 to 2 feet bgs, and subsurface soils are defined as any soils 2 to10 feet bgs. Soil samples will be collected even if the borehole advances into a saturated zone. The subsurface soils will be divided into the two depth intervals (2 to 6 and 6 to10 feet bgs) because the wastes were typically buried at shallow depths (5 feet or less). Thus, there is greater potential to detect contaminants in the upper subsurface soil zone. Subsurface soils are being collected at 6 to10 ft bgs in order to characterize the vertical distribution profile of detected contaminants and in support of the screening level human health risk assessment. However, some contaminants (e.g., pesticides and herbicides) are viewed as unlikely to be present at the 6 to10 foot interval because of the expected deposition mechanism of surface applications to the ground. Soil from the deepest interval will be analyzed for these chemicals during Round 2 only if Round 1 analyses show the chemicals to be present in the intermediate interval.

Three soil samples will be collected from each of 20 boreholes (01SB01 through 01SB20) within the MGBG, yielding a total of 60 surface and subsurface soil samples from that area. These samples are listed in Table 4-2. As discussed in SOP CTO131-7, the "01" in the sample identification scheme represents the MGBG site (i.e., SWMU 01/12); the "SS" and "SB" represent surface and subsurface soils, respectively. The borehole number is listed next. Finally, the top and bottom depths, in feet bgs, of the sampling intervals (i.e., 0002, 0206, or 0610) complete the sample identification numbers.

The analyses to be performed on each soil sample are listed in Table 4-2. Each of the soil samples will be analyzed for VOCs, SVOCs, explosives, HD, metals, and thorium isotopes because the potential for any of these contaminant groups to be present at the MGBG is probably greater than the other contaminant groups. There is less expectation that herbicides, pesticides, and PCBs are present at the site, so only the upper two soil intervals (40 samples total) will be tested for these analytes. Only the middle interval of the PBA will be analyzed by gamma spectrometry to test the assumption that non-thorium-related radionuclides were not disposed at the MGBG. Cation exchange capacity (CEC) and soil pH are being measured to characterize the general nature of the soil materials for later assessment of metals solubility and mobility. These two parameters are being analyzed in samples taken from six boreholes — two boreholes from the PBA and four boreholes located in the remainder of the MGBG. The boreholes chosen for these analyses are listed in Table 4-2.

The soil background concentrations for organic contaminants are assumed to be zero for purposes of COPC selection. The background concentrations for metals in soils at NSWC Crane have been investigated and reported in the document, "Basewide Background Soil Investigation, Naval Surface

Warfare Center Crane, Crane, Indiana" (TtNUS, 2000). The background soil metals concentrations will be compared to metal concentrations detected at the MGBG to determine whether any above-background concentrations are present. Total thorium concentrations were determined as part of the background soils investigation, but no background radioactivities for thorium radioisotopes have been determined for NSWC Crane. Therefore, a background soil borehole (01SB21) will be drilled and three soil samples from that borehole will be analyzed for thorium-228, -230, and -232. Those radioactivities will be compared with total concentration data for thorium from the background investigation to determine whether a correlation exists between isotopic radioactivities and total concentration data. Ten Pennsylvanian subsurface soil samples collected previously for the NSWC Crane Soil Background Investigation will be analyzed by gamma spectrometry to provide a point of comparison to determine whether gamma spectrometry radionuclides are present at concentrations greater than background concentrations. In addition, total organic carbon (TOC) is being analyzed for the three samples from 01SB21, so that data on the fraction of organic carbon content of the soils (f_{oc}) are available if it is necessary to evaluate the mobility of contaminants in the soil. The location of the background soil boring is near the background monitoring wells that are to be installed (See Section 4.4.2).

The total number of soil samples to be analyzed for each analyte group is listed in Table 4-3. These numbers of analyses should be sufficient to determine whether any of the analytes are present in the MGBG, at what depths the contaminants are most likely to occur, and the concentrations that might be present. Additional soil sampling and analysis may be necessary during Round 2 in order to better characterize the maximum concentrations and the extent of contamination for each contaminant of concern (COC).

QA/QC samples will be collected during Round 1 at frequencies listed in Table 4-3. Duplicate samples and rinsate blanks will be collected at a rate of 1 for every 10 regular soil samples and analyzed for the same analytes as the corresponding soil samples. However, rinsate blanks will not be analyzed for TOC, CEC, and pH. Matrix spike and matrix spike duplicates will be collected and analyzed in the fixed laboratory at a rate of 1 per every 20 soil samples, except that these QA/QC samples will not be analyzed for thorium isotopes, TOC, CEC, and pH. A trip blank will be placed in every cooler containing samples destined for VOC analyses. It is estimated that soil sampling will occur over a 5-day period; therefore five trip blanks will be sent to the laboratory and analyzed for VOCs. The total number of Round 1 soil analyses for each analyte group is tabulated in Table 4-3.

4.4.2 Ground Water

Between 1981 and 1984, the USACEWES installed 27 monitoring wells in bedrock in the vicinity of the MGBG (Figure 4-2). Ground water samples from select wells were collected and analyzed periodically between 1981 and 1986. The historical data for these wells are included in Appendix B and the data are summarized in Table 1-2. One additional well (01CO1-93) was installed in 1993. Construction details for all 28 monitoring wells are summarized in Table 4-4. These wells have not been sampled in 14 years or more. Therefore, an attempt will be made to locate, repair, redevelop, and sample each of these 28 wells at the beginning of the Round 1 operations.

Two new background monitoring wells (01T01, 01T02) will be installed during Round 1 in order to characterize background water quality. Additional wells may be needed to better characterize contaminant distributions and to support risk assessment. Whether or not such additional wells will be needed depends on the results obtained from sampling the existing 28 wells. Nevertheless four provisional well locations have been anticipated should the need for additional wells arise. Installation of provisional wells is subject to Navy approval. The proposed locations of the two background and four provisional site wells are shown on Figure 4-2 and 4-3.

As explained in Section 1.2.6, ground water could be flowing radially from the MGBG. The two background monitoring wells (01T01 and 01T02) will be located about 800 feet southeast of the center of the MGBG (Figure 4-3). This location is hydrologically upgradient or cross-gradient of the MGBG (see Figure 1-9), so these wells will act as background monitoring wells. Background well 01T01 will be screened from about 45 to 55 feet bgs (Table 4-5). Background well 01T02 will be located adjacent to the first, but will be screened at about 95 to 105 feet bgs. Thus, a shallow and an intermediate monitoring well will be used to characterize background ground water quality in the Pennsylvanian strata. In addition, this well pair will provide information about the hydraulic properties and the vertical hydraulic gradient in the bedrock along the crest of the ridge southeast of the MGBG.

Two of the provisional shallow monitoring wells (01T03 and 01T04) are tentatively planned for installation within the MGBG (Figure 4-2) because it is not known to what degree the MGBG currently acts as a source for ground water contamination. Therefore, these two shallow monitoring wells (screen interval about 30-40 feet bgs or 630-640 feet amsl) may be installed to determine what contaminants, if any, are still migrating downward from the MGBG (i.e., contaminants might not be leaching from the burial plot at present; ground water contamination around the MGBG might be solely due to past disposal and migration of solvents). One well (01T03) would be located in the northwest quadrant of the MGBG (west of the PBA). The second well (01T04) would be located near the center of the MGBG (southeast of the

PBA). In addition to ground water quality data, these two wells would also provide information regarding ground water elevations, and hydraulic properties of the Pennsylvanian rock units directly under the MGBG. As stated previously, the actual installation of these wells will depend on the analytical results for ground water samples obtained from the existing wells.

Two provisional deep wells (screen interval: about 540-550 feet amsl) are tentatively planned for installation about 250 feet northwest and southwest of the PBA. New well 01T06 will be located slightly west of existing shallow well WES-1-12-83, and new well 01T05 will be located south of existing well WES-1-18-83 (Figure 4-2). These proposed wells would allow the characterization of ground water quality in Pennsylvanian rock strata below the wells that currently exist. The two new wells would also provide information on lithologic characteristics, ground water elevations, vertical hydraulic gradients, and hydraulic properties of the deeper Pennsylvanian rock units. These two wells may or may not be installed depending on the results of the ground water analyses performed on the existing wells.

During Round 1, a maximum of 34 monitoring wells (28 existing, 2 background and possibly 4 new provisional wells) is planned to be developed, sampled, and analyzed. This number will be less if: (1) any of the existing wells cannot be found, or are damaged beyond repair, or (2) one or more of the provisional wells are not installed.

When soil borings are drilled using the Geoprobe®, 10 of the 20 holes (even-numbered borings) will be advanced to the bedrock surface (about 12 to 15 feet bgs). If the soils are saturated and perched ground water is present on the bedrock surface, then a ground water sample will be collected using a slotted sampling head, Teflon® tubing, and a peristaltic pump per SOP CTO 131-9. This perched water (if present) will be viewed as an integrator of contaminants leaching from the overburden under natural conditions. This water should also help to indicate the rate of vertical water movement in the overburden and into bedrock. It is not known how many times shallow perched ground water will be encountered in these Geoprobe® holes. It is possible that water will be encountered in none of them. For planning purposes, the sampling team will be prepared to collected ground water samples from three of the holes.

Table 4-6 lists the 37 ground water samples that could potentially be collected during Round 1 and the analyses that will be performed on each sample. During low-flow well sampling, the temperature, specific conductance, pH, dissolved oxygen, oxidation-reduction potential (ORP), and turbidity of the ground water will be measured and recorded for each well. Sample aliquots will be collected from each well, and laboratory analyses for VOCs, metals (total), gross alpha, and gross beta will be performed. The VOCs will be analyzed in every sample because chlorinated VOCs were detected in nearly all of the existing wells prior to 1986. To determine the current extent of VOC concentrations and the center of the plume,

VOC concentrations in each of the wells will be quantified. Over the past 14 years, VOC concentrations in some wells may have decreased due to degradation, and some concentrations may have actually increased due to plume migration or creation of new mass resulting from parent decay. Thus, the concentration distribution could have changed significantly over the past 14 years.

Metals will be analyzed in every well sample because the mobility of some metals is relatively great, and the exact nature of chemicals disposed of in the MGBG is unknown. If the turbidity of the well water samples cannot be reduced below 5 NTUs during low-flow sampling, then an aliquot of water will be filtered (SOP CTO131-19) and analyzed for dissolved metals in addition to total metals.

Every well sample will be analyzed for gross alpha and gross beta because these parameters are good general indicators of radionuclides present in ground water and RBTLs are available for those parameters. If measurements of gross alpha or beta greater than background are detected in a given sample, then alpha spectroscopic analysis may be performed at the discretion of the TOM in order to identify and quantify the specific radionuclides present in the ground water.

SVOCs, herbicides, pesticides, PCBs, HD, explosives, and thorium isotopes will be analyzed in 10 of the existing wells, the two background wells, any installed provisional wells, and the 3 anticipated samples from soil borings (a maximum of 19 samples). It is not anticipated that these contaminants will be found in ground water, so measuring them in the well samples closest to the MGBG and in a few wells away from the MGBG should be sufficient to determine whether these contaminants are present or absent from within and adjacent to the MGBG.

Total organic carbon (TOC) is being measured in about one-third of the samples collected. These data will provide information on the concentrations of natural organic carbon present in the ground water, and the concentrations of organic carbon present in the contaminant plume emanating from the MGBG. This information will be used to provide initial estimates of the potential effectiveness of natural attenuation of organic contaminants due to biodegradation.

The total number of ground water samples to be analyzed for each analyte group are listed in Table 4-7. The numbers of field QA/QC samples to be collected and analyzed are also listed in Table 4-7. One duplicate sample will be collected for every 10 ground water samples. Note: The duplicate samples will be preferentially collected for monitoring wells that appear to be contaminated (based on visual evidence, odor, or screening data). One matrix spike and matrix spike duplicate will be collected and analyzed for every 20 ground water samples analyzed. One rinsate sample will be collected and analyzed each day of ground water sampling activities; this number is estimated to be up to 6 days for some analyses (the

rinsate blanks are only analyzed for the parameters being analyzed on the samples for each specific day). A trip blank will be included with each cooler containing samples for VOC analysis; it is estimated that six of these will be necessary. Two source water blanks (tap water and distilled water) will be analyzed during the Round 1 field effort to establish whether contaminants may be present in the water used for steam cleaning and decontamination of sampling equipment.

4.4.3 Surface Water

The MGBG is located along the crest of a ridge. Surface drainage from the site likely flows to the north and southwest (Figure 4-3). The two unnamed streambeds receiving surface drainage from the site are intermittent and only flow during storm events, and perhaps between storm events in the wet season when ground water elevations are high (i.e., when baseflow is occurring). Both of these unnamed intermittent streams discharge into Goldsbury Hollow (Figure 1-4), which in turn flows into Boggs Creek (Figure 1-8). Surface water samples collected from the unnamed tributaries during low flow will help determine whether contaminants in the ground water system at the MGBG are discharging to and affecting the surface water system. Intended surface water sampling locations are shown on Figure 4-3.

Samples 01-SW-01 and 01-SW-02 will be collected from the north tributary, upstream and downstream, respectively, of the MGBG, if flow is occurring in the gully during a nonstorm period when field personnel are present. In the gully leading southwest away from the MGBG, a surface water sample (01-SW-03) will be collected near the mouth of the gully (Figure 4-3) if flow is occurring when sampling personnel are present. Samples 01-SW-04 and 01-SW-05 will be collected from the southern unnamed creek, upstream and downstream of the MGBG, respectively, if water is flowing at those locations. If surface water is not flowing at locations 01SW02 or 01SW05, then the sampling points will be moved up to 800 feet farther downstream in order to locate where ground water might be discharging to the surface streams and collect samples of the ground water base flow.

In addition to the five samples possibly collected in the drainage channels and gullies, two ground water seep samples may be collected if seeps or springs are found relatively close to the MGBG (e.g., within a 1200-foot radius) and the seeps are flowing to some extent (i.e., water is not stagnant).

Each surface water sample will be analyzed for the analyte groups listed in Table 4-8. Comparisons between samples 01-SW-01 and 01-SW-02, and between samples 01-SW-04 and 01-SW-05 will be made (if samples can be collected) in order to compare upstream and downstream water quality in each of the unnamed tributaries of Goldsbury Hollow.

A total of five to seven surface water samples will be collected during Round 1 (Table 4-9). In addition, one field duplicate, one trip blank, one matrix spike, and one matrix spike duplicate will be necessary for QA/QC purposes (Table 4-9). No rinsate blanks will be collected because disposable sampling equipment will be used. The field duplicate will be analyzed for all parameters, except field parameters. The trip blank will be analyzed only for VOCs. The MS and MSD will be analyzed for all parameters, except thorium isotopes, total suspended solids, gross alpha, gross beta, and field parameters. The total number of analyses, including QA samples, are tabulated in Table 4-9.

4.4.4 Sediment

Sediment and sorbed contaminants may have been eroded from the surface of the MGBG and washed down the hillside to the north and southwest of the MGBG. A total of six sediment samples will be collected north of the MGBG, including two (01-SD-05 and 01-SD-06) in the ruts of the dirt roads just north of the MGBG (Figure 4-2), two in the gullies leading downhill from the MGBG (01-SD-03 and 01-SD-04, Figure 4-3), and two in the unnamed tributary upstream and downstream of the MGBG (01-SD-01 and 01-SD-02, respectively, Figure 4-3). On the south side of the MGBG, two sediment samples (01-SD-07 and 01-SD-08, Figure 4-2) will be collected from along the road ditch on the north side of the road. Two discretionary samples may be collected if the FOL determines that sediment is leaving the site by another route, or that sediment is accumulating in a low spot and could lead to direct exposure. Therefore, a total of 8 to 10 sediment samples are planned during the Round 1 investigations.

Each of the sediment samples will be analyzed for the full suite of analytes listed in Table 4-10. One field duplicate, one trip blank, one rinsate blank, one matrix spike, and one matrix spike duplicate will be necessary for QA/QC purposes (Table 4-11). The field duplicate will be analyzed for all parameters. The trip blank will be analyzed only for VOCs. The MS and MSD will be analyzed for all parameters, except thorium isotopes, total organic carbon, CEC, and pH. The total number of laboratory analyses, including QA samples, are tabulated in Table 4-11.

4.4.5 Evaluation of Round 1 Data

When Round 1 data have been received from the analytical laboratory and have been validated, the data will be reviewed and evaluated to determine the nature and extent of contamination in each of the four environmental media: soils, sediment, surface water, and ground water. If the nature and extent of COPCs in any of the four media is not well defined or not understood, then additional sampling and characterization may be necessary during Round 2.

A frequency of detects (FOD) table will be prepared as described in Section 12.4. The spatial distribution of COPC concentrations in soil and ground water will be mapped via geostatistical kriging (if appropriate) using the best-fit semi-variogram. Decision rules for identifying COPCs and establishing the extent of contamination in all media are presented in Sections 1.4.4.3 and 1.4.4.4, respectively.

If the risk-based contour demarking regions of acceptable and unacceptable risk extends laterally or vertically beyond the outermost extent of sample collection, it is assumed that the extent of contamination has not been fully defined. In that case, additional ground water and soil sampling may be necessary at a distance farther from the MGBG (i.e., the assumed contaminant source). The need for additional wells and ground water samples may be tempered if a hydrologic flow barrier is present to prevent additional lateral migration of the contaminant in the ground water flow system. The unnamed tributary streams that presumably receive ground water discharge would act as such a barrier. The likelihood of contaminants flowing in Pennsylvanian strata underneath the streams is remote. The streams are assumed to be receptors of ground water flow and barriers to more extensive ground water migration; contaminants are not expected to flow in ground water north of the northern ephemeral stream, nor is it considered possible to flow southward beyond the southern ephemeral stream. Thus, extending the monitoring well network farther north or northwest would not be of much value because the existing wells already extend over a large portion of the distance in that direction. If contamination is found to be migrating southwestward in the ground water system, then installation of additional wells and additional well sampling might be warranted in that direction during Round 2.

For surface water and sediment data, if contamination has been detected in the samples collected farthest downstream, then additional samples may need to be collected. If contamination is detected in surface water or sediment closer to the site, additional samples may need to be collected downstream to confirm that contaminant migration of the contaminants is localized.

4.5 ROUND 2 SAMPLING LOCATIONS AND RATIONALE

If, after evaluation of the Round 1 data, it is determined that sufficient data have been collected to adequately define the nature and extent of contamination, and that the data collected are of sufficient quantity and quality to perform human health and ecological risk assessments, then no additional sampling or other field activities will be conducted. In this case, no additional sampling rounds will occur and the completion of the RFI report will proceed.

If additional soil sampling is warranted, then a Geoprobe® rig will be remobilized to the site to collect additional soil cores for sampling Round 2.

If it is determined that additional monitoring wells (beyond any provisional wells installed during Round 1) are needed to define the extent of contamination, then these wells will be installed during Round 2. Installation of Round 2 wells will only be done subject to Navy approval.

During Round 2, it might be necessary to resample some of the monitoring wells already in place and to perform new analyses. For example, it might be necessary to perform analyses for chlorinated solvent breakdown products (e.g., ethene, ethane, and carbon dioxide) and to characterize ground water for reducing conditions and electron acceptors (e.g., sulfate, sulfide, nitrate, ammonia, ferrous/ferric iron). These type of data will be needed to evaluate the biodegradation potential for chlorinated solvents in the ground water system.

4.6 INVESTIGATION EQUIPMENT AND PROCEDURES

4.6.1 UXO Clearance of Drilling Sites

Before drilling or other intrusive activities begin, the locations of such activities will be subjected to a surface survey using a GA-72CV magnetic locator, or equivalent instrument. If a magnetic anomaly is apparent during the surface survey, then the drilling location will be moved 5 feet away and the surface survey will be performed once more. Once the near-surface materials have been deemed clear of metallic objects, then Geoprobe® drilling into the subsurface can proceed. The geophysical instrument used for downhole detection of metallic objects is a MG-220 magnetic gradiometer (Table 4-1). After each 2-foot interval of soil core has been removed from a borehole, the instrument will be lowered down the hole and will be used to detect magnetic anomalies. Soil coring and magnetic surveying will proceed downward to 8 feet bgs. If a rock or other obstruction prevents the advancement of the hole to 8 feet, the location will be moved, and a new hole started. Advancing the borehole to 8 feet bgs allows clearance of the hole to a depth of 10 feet because the radius of detection of the magnetometer is 2 feet deeper than the bottom of the hole. Details regarding the equipment and procedures used for detecting magnetic anomalies are included in SOP CTO131-1 (Appendix H). The geophysical equipment used to perform surveys for UXO clearance are listed in Table 4-1.

Because HD, radionuclides, and VOCs may be present in the soil column, it will be necessary to screen the soils as they are brought to the surface for HD, gross beta and gamma radiation, and VOCs. This information is also needed to classify the soils extracted from the holes and help assess how they should be stored and disposed of.

As each soil core is removed from a borehole, it will be scanned for gross beta and gamma radiation (SOP CTO131-2). After slicing the soil core liner open, the soils will be scanned to determine if significant VOC concentrations are present in the soils (SOP CTO131-4). In addition, for each soil sampling interval that is brought to the surface, the material from that interval will be mixed and a portion will be placed in a jar and screened for the presence of HD using the headspace screening method (SOP CTO131-3). All of these measurements will be recorded on a borehole log form (SOP CTO131-6, Appendix H). A new form will be used for each hole.

Once a location has been completely cleared and sampled, then the hole must be backfilled. If the soil screening data for radioactivity, VOCs, and HD show no detectable levels of these parameters, then the excess soil core material will be considered clean and will be placed back in the hole. The soil will be tamped every foot or two in order to get all of the materials back down the hole and to reduce the permeability of the disturbed materials in the hole as much as possible.

If screening data indicate the presence of HD or VOCs, or above-background levels of radioactivity, then the excess soil material may not be placed back in the hole. It must be placed in a plastic garbage bag and tagged, then placed in a plastic-lined 55-gallon drum for storage until soil analyses can determine whether actual contamination is present in the soil (SOP CTO 131-27). The hole will be filled with bentonite pellets. General waste management practices are described in Section 4.12.

When a borehole has been sampled and backfilled, it will be identified by a tall wooden lath driven into the soil near the borehole; a 2-by-2-inch inch wooden stake will be driven into the center of the backfilled borehole. The stake and the lath will both have brightly-colored flagging attached to them to increase visibility, and both will be labeled by a waterproof marker with a unique soil boring number, corresponding to the borehole log containing the survey data for the hole.

4.6.2 DPT Sampling for Surface Soils, Subsurface Soils, and Ground Water

DPT (e.g., Geoprobe®) will be used to collect surface soils, subsurface soils, and shallow ground water samples from the unconsolidated overburden. The procedure for soil sampling using DPT is included in SOP CTO131-5. The soil depositional area corresponding to one of the depositional areas identified in the "NSWC Crane Base-wide Background Soil Investigation" should be established by the project geologist prior to or during field activities. A new acetate liner will be used for each 2-foot section of soil core. As each soil core is removed from the ground, it will be scanned for radioactivity (gross beta and gamma) and VOCs. The soil core will be visually inspected and logged by the field geologist, noting the soil texture, grain size (sand, silt or clay), color (and any unusual discoloration), and moisture content.

For the first soil interval in each borehole (i.e., 0 to 2 feet bgs), the PID will be used to scan the soil core for the presence of VOCs. The soil cores will be logged by a geologist (SOP CTO131-6). A discrete soil sample will be collected between the depths of 0.5 to 2.0 feet bgs in the soil core (not 0 to 0.5 feet bgs) for VOC analysis using an EnCore™ Sampler (SOP CTO131-8). The VOC sample will be collected from the point along the soil core (0.5 to 2.0 feet bgs) that had the greatest PID reading. If no PID readings are greater than background, then the VOC sample will be collected from any discolored area of the soil or from the midpoint of the core. Once the sample for VOC analysis has been collected, the 0- to 2-foot soil core interval will be placed in a stainless steel mixing bowl; rocks, gravel, and other coarse debris will be removed; the sample will be mixed; and appropriate jars will be filled and properly labeled. Details regarding the collection and labeling of soil samples are included in SOPs CTO131-9 and CTO131-7. A portion of the soil sample will be placed in a jar and will be used in the field for headspace screening for HD (SOP CTO131-3). This sample portion should be screened as soon as possible after collection. The grain size of each soil sample shall be classified as sand, silt, or clay.

When the soil cores for 2 to 4 feet and 4 to 6 feet have been brought to the surface, they will be scanned for radioactivity and VOCs in the same manner as the 0- to 2-foot interval. The soil cores will be logged by a geologist (SOP CTO131-6). The VOC EnCore™ samples will be collected from the point in the soil cores that display the highest PID reading. If no PID reading is greater than background, then the VOC samples will be collected from a discolored soil zone or from approximately 4 feet deep (i.e., the bottom of the 2- to 4-foot soil core). The remainder of the two soil cores will be mixed together in a stainless steel mixing bowl, rocks, gravel, and other coarse debris will be removed, and the soil will be thoroughly mixed. A portion of the soil sample will be placed in a jar and will be used in the field for headspace screening for HD. This sample portion should be as soon as possible after collection. Other sample jars will be filled as appropriate (Table 4-2) and properly labeled.

Soil cores from 6 to 8 feet and from 8 to10 feet will be collected and composited together after they are screened and logged and the VOC samples have been collected. The same screening, logging, and sampling activities will occur as described above for the 2 to 6 foot interval. The grain size of each soil sample shall be classified as sand, silt or clay.

For each Geoprobe® hole, a total of three soil samples will be collected (0- to 2-, 2- to 6-, and 6- to10-foot intervals). For soil samples, the appropriate containers to be used for each sample aliquot are listed in Table 4-12. Once the samples are properly containerized, labeled, tagged, and bagged (see SOP CTO131-24), they should be placed in a cooler containing ice until the samples can be properly packaged and prepared for shipment (Section 4.7).

For each cooler containing soil samples identified for VOC analysis (i.e., Encore™ samplers), a trip blank must also be stored in the cooler and continuously accompany the VOC samples until they have been analyzed. As samples are added to a cooler, the chain-of-custody form should be updated to include each new sample container (per SOP CTO131-25; see also Section 5.0).

One duplicate soil sample shall be collected for every 10 soil samples. Soil duplicates will be collected for those samples that have the greatest probability of containing contaminants (e.g., elevated levels of VOCs as indicated by the PID reading). The duplicate samples should be placed in the same types of containers and handled in the same manner as the regular soil samples. The duplicate samples will be given unique QC sample IDs (see SOP CTO131-7). One rinsate blank will be collected for every 10 soil samples. The soil cores will be collected in new, clean, acetate liners. After samples are collected for VOC analyses, the cores will be mixed in a stainless steel bowl with a stainless steel spoon. For soil samples, the rinsate blank will consist of running distilled water over a decontaminated spoon into a decontaminated mixing bowl. This water will be used to fill sample bottles for the rinsate blank. This process will continue until all of the necessary bottles are filled for the rinsate sample (see Tables 4-3 and 4-13).

For each even-numbered soil boring (e.g., SB02, SB04, SB06, etc.), the Geoprobe® coring will continue past 10 feet and will go as far as 16 feet bgs but not into bedrock. The soil cores will be scanned for VOCs and radioactivity, and the cores will be logged by the field geologist. If the soils are wet at the bottom of the hole, this is an indication that ground water is perched on top of the bedrock surface. An attempt will be made to collect a sample of this perched ground water using a drive point assembly designed for that purpose, Teflon® tubing, and a peristaltic pump. If adequate quantities of ground water can be obtained from the drive point, then a ground water sample will be collected and analyzed for the parameters listed in Table 4-6. The appropriate bottle(s) to be filled and preserved for each analyte group is listed in Table 4-13. Because large quantities of water are needed to fill the appropriate containers, the saturated soil horizon must be permeable enough to transmit an adequate rate of water to the drive point. Details regarding the collection of ground water samples using DPT are included in SOP CTO131-9.

For each cooler containing samples identified for VOC analysis, a trip blank must be included in the cooler. The trip blank will continuously accompany the VOC samples until they have been analyzed. As samples are added to a cooler, the chain-of-custody form will be updated to include each new sample container (see Section 5.0 and SOP CTO131-25).

4.6.3 Inspection and Repair of Existing Monitoring Wells

Twenty-seven monitoring wells were installed between 1981 and 1986 in the vicinity of the MGBG. Some of these wells have broken casing, bent casing, missing caps, no locks, broken locks, and other problems. It is possible that some of the wells have obstructions down in the casing. In addition, it is likely that some of the wells may contain enough sediment at the bottom such that the well screen may be partially or totally clogged. Therefore, at the beginning of Round 1 activities, the existing wells will be located, inspected, and repaired if possible. For example, broken or bent PVC viser pipes above the ground surface will be sawed off and new riser pipes will be added. Wells that cannot be redeveloped or repaired in Round 1 will not be sampled. The need to install additional wells will be determined by any data gaps that exist after the first sampling round. Caps and locks will be replaced if necessary. The height of casing above ground surface and the depth to the bottom of every well will be measured and recorded. This information will be compared to the boring logs and well construction logs to confirm that the wells are open through the screen interval. These activities are addressed in SOP CTO131-11. Each of the existing wells will need to be redeveloped (SOP CTO131-15) before any sampling can occur.

4.6.4 Well Drilling and Installation

Two new background wells will be installed and four provisional monitoring wells may be installed during Round 1. The approximate depths of the new wells are listed in Table 4-5. Two holes, identified as 01T02 and 01T06 on Figure 4-2 (if installed), will be cored their entire length (2-inch diameter or larger). One complete core at the location of well 01C01 was used previously to characterize the lithology of the Pennsylvania-age rock units at the MGBG (Hansen and Barnhill, 1993). These two cores are proposed to better characterize the stratigraphy, fracture distribution, and other features of the Pennsylvanian-age rock units over an extended area. Procedures for drilling and logging a borehole in rock are included in SOP CTO131-12. After these two holes have been cored, they will be enlarged to a diameter of approximately 7 inches using an air rotary drill rig. The other four boreholes will be drilled using the air rotary drill rig. The approximate total depths for each borehole are listed in Table 4-5. Geologic logging of the four boreholes that are not cored will be based on the rock chips brought up with the circulating air (SOP CTO131-12). In addition, the rates of water produced during drilling will be carefully observed in order to identify rock zones that might be fractured and have above-average permeability characteristics.

To minimize dust problems and to eliminate potential exposure of drilling and sampling personnel to airborne contaminants while drilling the two boreholes in the MGBG area (Figure 4-2), a rotary auger will be used at the beginning of each borehole to drill through the unconsolidated overburden before rock drilling commences. An 8- to 10-inch steel casing will be placed through the overburden, seated into the

bedrock surface, and grouted into place. These outer casings will minimize the potential for vertical contaminant migration associated with well installation and the potential exposure of drilling and sampling personnel to airborne contaminants generated during drilling. **Also, the two boreholes in the MGBG area will be drilled down through holes previously cleared for UXO so that no additional UXO clearance will be necessary.**

4.6.5 Packer Testing of Uncased Boreholes

A double inflatable packer assembly attached to the drill string of the drilling rig will be used to hydraulically test specific sections of each new uncased borehole. The procedures for conducting a packer test are presented in SOP CTO131-13. The packer assembly will be thoroughly decontaminated before being placed in a borehole. The inflatable packers will be set at 20 feet apart (i.e., the vertical section of rock tested in a single test is 20 feet). The packer assembly will be lowered down the borehole so that the packers isolate a section of the hole that was identified during drilling as being fractured or yielded above-average rates of ground water during drilling. About two to three different zones will be tested for each hole. The number and depths of the zones to be tested will be determined by the FOL and lead field geologist based on their best judgement.

The packer tests will be the pump-out type, where ground water is pumped out of the hole from the isolated section of borehole. A pump positioned between the two packers will pump water out of the packed-off interval. Thus, no external water will be introduced to the holes during the packer tests. The flow rate of water discharging from the pump and the hydraulic pressure within the pack-off interval will be measured frequently during the test. The pumping rate shall be held nearly constant. Initially, the pumping rate will be at a low level (e.g., 1 gallon per minute or less). If this pumping rate can be sustained for 15 minutes and the water level stabilizes, then the rate will be increased to about 5 gallon per minute. This rate will be maintained and hydraulic head monitored for another 15 minutes. After 15 minutes, the pumping rate can be increased if the aquifer can sustain the increased rate and the FOL or lead geologist determine that a higher rate is necessary.

The data will be used to determine a hydraulic conductivity value for the rock material. It will also be used to help choose a suitable interval in the hole for the installation of the monitoring well screen. The screen for each well should be placed near its target depth (see Table 4-5), but in an interval that is permeable and likely to be connected to a fracture network.

4.6.6 Installation of Monitoring Wells

A permanent monitoring well will be installed in the two background wells and each of the four provisional boreholes if they are installed. The wells will be constructed of 2-inch-diameter, schedule 40, flush joint, polyvinyl chloride (PVC) riser pipe and screen (SOP CTO131-14). In each well, the screen will be 10 feet long and have a slot size of 0.02 inches (factory slotted). All riser pipe and screen sections will be new and certified clean. Each well will consist of 10 feet of slotted screen and enough solid riser pipe above, so that the riser will extend about 2.5 feet above the ground surface. The riser pipe in each well will extend from the ground surface to at least 15 feet below the bedrock/overburden interface and will be grouted into place. This will ensure no vertical migration of contaminants from the overburden downward into bedrock.

A sand filter pack will be placed around the annulus of the well screen, from the bottom of the hole upward to 3 feet above the top of the well screen. Three feet of bentonite chips will be placed above the sandpack, and will be allowed to wet and expand for at least 3 hours before grout is added to the hole. After at least 3 hours has elapsed, the remainder of the well annulus will be filled up to the ground surface with a cement-bentonite grout mixture. A tremie pipe will be used to place grout in the well annulus to help ensure a good seal around the well annulus. The black steel protective casing discussed in Section 4.6.5 will be installed through the overburden before bedrock drilling commences. The outer casing will extend no more than 4 inches above the inner PVC well cap. The steel casing will have a hinged cap, or removable cap, and a padlock. A 6-in thick, 3-by-3-feet concrete surface pad will be placed around the well at ground surface. In addition, three barrier posts will be installed around the concrete pad. Details regarding well construction, sand pack and grout materials, the outer protective casing, the well pad, and the protective barrier posts are included in SOP CTO131-14.

4.6.7 Well Development

All existing and new monitoring wells will be developed in accordance with SOP CTO131-15 to remove fine sediment from inside and around the well screens. The method to perform well development can be either vigorous on-and-off pumping, or surge block and pumping. Field measurements of pH, specific conductance, temperature, and turbidity will be performed at 5 to 10 minute intervals on the water retrieved from the well, in accordance with SOP CTO131-18. Well development will continue until three consecutive readings of pH, specific conductance, and temperature are within 10 percent of each other, and three consecutive turbidity readings are within 5 nephelometric turbidity units (NTUs) of each other. If these criteria cannot be met after five well volumes of water have been removed, then one additional well volume will be removed and well development will be considered complete.

All water removed from the well during the development process will be stored in a portable holding tank (already present at NSWC Crane) until ground water samples from the wells have been analyzed. The analytical reports will be submitted to the NSWC Crane water treatment plant for review. If acceptable, the development water will be discharged to the plant for treatment and disposal (SOP CTO131-27).

4.6.8 Water Quality Field Measurements

Field measurements of water quality parameters, including pH, specific conductance, ORP, temperature, dissolved oxygen (DO), and turbidity, will be performed on ground water in a flow-through cell attached to a pump discharge line. These measurements will be performed during well development (Section 4.6.7) and low-flow well sampling (Section 4.6.9). These field measurements will be made using a YSI 6-Series Environmental Monitoring System or equivalent type of instrument. Turbidity measurements will be made using a LaMotte turbidity meter or equivalent. Calibration and measurements made with the field instruments will be in accordance with Section 6.1 and SOP CTO131-18.

Each calibration of an instrument will be recorded on an equipment calibration log sheet. Water quality measurements, along with date, time, instrument operator, and visual and other observations (e.g., weather conditions) will be recorded on well development logs, sample collection logs, or field notebooks, as appropriate.

4.6.9 Low-Flow Sampling of Monitoring Wells

Low-flow sampling procedures will be used to collect ground water samples from existing wells and new wells (SOP CTO131-17 and -19). The depth to ground water in many of the wells is greater than 20 feet. In well WES-1-6-82, the depth to water is nearly 70 feet (Table 4-4). Therefore, a compressed air bladder pump or submersible pump will be used to slowly pump ground water from the well at about 100 milliliters per minute (mL/minute). Low-flow pumping will proceed for 2 to 4 hours, but will continue until readings of water temperature, pH, specific conductance, dissolved oxygen, Eh, and turbidity stabilize. Appropriate sample bottles shall be filled directly from the pump discharge tube (see Tables 4-6 and 4-13). The bottles will be properly labeled, tagged, bagged, and placed in an ice-filled cooler as quickly as possible (SOPs CTO131-7 and -24). A ground water collection log sheet must be completed for each ground water sample collected (SOP CTO131-19).

The wells will be sampled in order of least contaminated to most contaminated, based on historical data. This approach will lessen the possibility of incurring cross contamination between wells. After each

ground water sample is collected, the pump must be decontaminated (SOP CTO 131-26). For every 10 ground water samples that are collected, a rinsate blank sample must be collected to ensure that decontamination of the pumps is effectively accomplished. The rinsate blank will be collected by pumping distilled water through the pump and placing the pump discharge water directly into sample jars. The appropriate sample jars and preservatives for each analyte group are listed in Table 4-13.

For each cooler containing samples identified for VOC analysis, a trip blank must be included in the cooler. The trip blank will accompany the VOC samples until they have been analyzed for VOCs. As samples are added to a cooler, the chain-of-custody form should be updated to include each new sample container (SOP CTO131-25).

4.6.10 Ground Water Level Measurements

Water-level measurements and total well depth soundings will be obtained at each of the 27 existing monitoring wells before and after they are redeveloped. When the eight new wells have been installed and developed, water-level measurements will be performed on all wells. All water-level measurements will be taken within a 24-hour period of consistent weather conditions. All water-level measurements will be taken using an electronic water-level meter (per SOP CTO131-16). Water-level elevations will be recorded to within a 0.01-foot accuracy from a marked reference point on the well riser pipe. Detailed procedures regarding water-level measurements are included in SOP CTO131-16.

Water levels will be recorded on a TtNUS water-level form. A blank water-level form is provided in SOP CTO131-16 for reference purposes.

The water-level meter will be decontaminated between each well; decontamination procedures are addressed in SOP CTO131-26.

4.6.11 Surface Water Sampling

Surface water samples will be collected as grab samples from surface water drainages, ground water seeps, and springs in accordance with SOP CTO131-21. At the sampling locations identified in Section 4.4.3 and Figure 4-3, flow rates in the drainages, seeps, and springs are expected to be very small. Therefore, it will be assumed that the water flowing at these locations are thoroughly mixed. Water sample bottles will be filled directly in the flowing water. If the depth of water is not sufficient to lower the bottles into the water without stirring up bottom sediment, then a decontaminated shovel will be used to dig a depression (i.e., a small pool) about 2 feet deep where the water can accumulate and pass through.

After suspended sediment in the pool has settled out or is carried downstream, the water sample will be collected. The sample bottles will be filled in the order that they appear in Table 4-13. A filtered water sample (when required in accordance with SOP CTO131-21) will be collected for dissolved metals analysis by drawing water into a plastic syringe and forcing it through a 0.45-µm filter cartridge directly into a sample container. The bottles will be properly labeled (SOP CTO131-7), tagged, bagged, and placed in an ice-filled cooler.

Field water quality measurements (see Section 4.6.8) will be made at each sampling location immediately after a sample has been collected. These data will be recorded on the sample collection log sheet.

4.6.12 Sediment Sampling

Sediment samples will be collected as grab samples from surface water drainages and road ditches in accordance with SOP CTO131-22. At the sampling locations identified in Section 4.4.4 and on Figures 4-2 and 4-3, flow rates in the drainages and ditches are expected to be very small or nonexistent. If no water is flowing at a sampling location, then the sample may be collected where fine sediment has accumulated. If water is flowing at the sampling location, then the sample should be collected at the edge of the flowing water where fine sediment has accumulated. The appropriate sample jars will be filled directly from the sediment surface using disposable plastic spoons. No sample material should be collected from a depth greater than 6 inches.

As samples are added to a cooler, the chain-of-custody form should be updated to include each new sample container (SOP CTO131-25). A sample collection log sheet will be completed for each sediment sample collected. These logs will note the date, time, sampling personnel, weather conditions, flow conditions at the sampling location, and include a complete description of the sampling location (see SOP CTO131-22). A 2-by-2-inch wooden stake with attached flagging material shall be driven into the sampling location, and the sample identification number shall be marked on the stake with a black waterproof marker. This will be done so that the sampling location can be revisited at a later date, if necessary, for surveying or resampling purposes.

4.7 QUALITY CONTROL SAMPLES

This section focuses on field QC samples that will be collected as part of this environmental investigation. Field QC samples include field duplicates, source water blanks, equipment rinsate blanks, and trip blanks. Tables 4-3, 4-7, 4-9, and 4-11 present the types and numbers of required field QC samples to be collected for soil, ground water, surface water, and sediment sampling activities, respectively, during

Round 1. Section 8.1 provides definitions and details for these and all other QC checks to be used during this investigation. Field QC sample requirements for field duplicates, source water blanks, equipment rinsate blanks, and trip blanks required for this project are described below:

Field Duplicates. Field duplicates are obtained during a single act of sampling and are used to assess the overall precision of the sampling and analysis program. Duplicate samples will be collected at a rate of 1 for every 10 environmental samples of each type of environmental medium. All duplicate samples will be analyzed for the same parameters in the laboratory as their environmental sample counterparts. Duplicate samples will be preferentially collected where field evidence (i.e., PID reading, gross beta and gamma readings, or odor) indicates that contamination is likely to be present in the environmental sample.

Equipment Rinsate Blanks. Equipment rinsate blanks will be obtained under representative field conditions by running analyte-free water through sample collection equipment after decontamination and placing it in the appropriate sample containers for analysis. Equipment rinsate blanks will be collected for non-dedicated equipment for all sampling rounds. For surface and subsurface soil sampling activities, rinsate blanks will be collected by running analyte-free water over a decontaminated stainless steel bowl and mixing spoon; these items are used to mix soil prior to being placed in sample jars. For ground water samples, analyte-free water will be pumped through a decontaminated pump and tubing that will be used for ground water sampling. Equipment rinsate blanks will not be required for surface water and sediment samples. Surface water samples will be collected directly from the surface water body, and only a new disposable spoon will be used to collect sediment samples.

Source Water Blanks. Source water blanks will be obtained by sampling each water source (e.g., potable water and distilled water) used for decontamination activities during the field investigation. Source water blanks will be used to determine if the water or the laboratory bottles are contributing to sample contamination. Source water blanks will be collected for each type of water used for decontamination and will be submitted at a frequency of one per sampling event. Source water blanks, as applicable, will be analyzed for the entire suite of parameters under investigation. It is anticipated that two source water blanks will be collected during Round 1 – one potable water sample and one sample of distilled water used for decontamination.

Trip Blanks. Trip blank samples are 40-mL glass vials that contain analyte-free water and are prepared by the analytical laboratory prior to the start of field activities. They should be stored in a sealed container until they are needed. During sampling activities, one trip blank, consisting of one vial, shall be placed in each cooler that contains environmental samples destined for VOC analysis. The trip blank shall be

properly labeled, and added to the chain-of-custody form belonging to the cooler. Trip blanks are only analyzed for VOCs.

Temperature Blanks. These blanks are vials of water inserted into each cooler. The temperature of the temperature blank is measured prior to shipping the cooler to the laboratory and upon receipt at the laboratory to verify that samples were properly cooled during transit.

4.8 SAMPLE HANDLING, PACKAGING, AND SHIPPING

4.8.1 Sample Preservation

Preservation requirements for each of the chemicals of interest are provided in Tables 4-12 and 4-13. All soil and sediment samples require only to be cooled to 4 ± 2°C; no chemical preservatives are necessary. Sample bottles for aqueous samples will contain the proper amounts and types of preservatives prior to being shipped to NSWC Crane (Table 4-13). The preservatives placed in the sample bottles will be certified that they are free of analytes being tested in the samples. All samples will be promptly chilled with ice to 4 °C ± 2°C and packaged in an insulated cooler. Each cooler will include a temperature blank. Ice will be sealed in containers to prevent water leakage. Samples will not be frozen.

4.8.2 Sample Labeling

Before samples are packaged, the sample labels and tags should be checked to ensure that all information on the label and tag is complete and correct (SOP CTO131-7). This information should be checked to ensure that it matches the information placed on the sample collection log sheets and the chain-of-custody form.

4.8.3 Sample Packaging

Each sample container will be placed in a zip-lock bag to prevent cross-contamination or leakage. The zip-lock bag will be placed in a bubble-wrap sleeve to protect from breakage. Only shipping containers that meet all applicable state and federal standards for safe shipment will be used. Cube ice will be placed in plastic bags and placed around and between the samples in sufficient quantity to ensure that the samples remain chilled (4 °C ± 2 °C) during transport to the analytical laboratory.

The completed field chain-of-custody document will be signed, placed in a sealed plastic envelope, and taped to the top inside cover of the shipping container (SOP CTO131-25). For samples sent to Southwest Laboratory of Oklahoma, a reminder will be included with the chain of custody document that

the laboratory should not analyze samples until fixed laboratory mustard gas analysis demonstrates the absence of detectable mustard gas concentrations in the samples.

SOP CTO131-24 provides a detailed description of sample handling, packaging, and shipping procedures required for this project. The FOL will be responsible for ensuring the completion of the following forms:

Sample Labels
Chain-of-custody Forms
Custody Seals for Coolers
Shipping Labels for Coolers
Express Mail Air Bills

4.8.4 Sample Shipping

Shipping containers (i.e., coolers) will be sealed with nylon strapping tape in at least two places, and custody seals will be signed, dated, and affixed in a manner that will allow the receiver to quickly identify any tampering that may have occurred during transport to the laboratory (SOPs CTO131-24 and -25).

Shipment will be made by a public courier at the next scheduled pickup following completion of sample collection. Copies of the Express Mail Air Bills should be retained by the FOL for tracking purposes, if needed, and for communications with the laboratory. Air Bills will be retained for the Permanent Record File.

4.8.5 Sample Custody

Custody of samples must be maintained and documented at all times as per SOP CTO131-25, beginning with the collection of samples in the field. Sample custody procedures are addressed in Section 5.0.

4.9 RECORD KEEPING

Standard forms, field notebooks, and a field log book will be used to record all sample collection activities, field measurements, observations concerning site conditions, and other project-related information. These records include sample log sheets, daily activity records, field logbooks, drilling and well completion log sheets, and field instrument calibration log sheets, among others. More details regarding record keeping are included in SOP CTO131-25.

4.9.1 Field Log Books

Bound, weatherproof field notebooks shall be maintained by sampling personnel. All information related to sampling and other field activities will be recorded in field notebooks. This information will include, but is not limited to, sampling time, weather conditions, unusual events, field measurements, and descriptions of photographs.

A bound, weatherproof logbook shall be maintained by the FOL. This book will contain a summary of each day's activities and will reference the field notebooks when applicable.

4.9.2 Drilling and Well Completion Logs

A drilling log will be completed for every hand auger, DPT, and rotary drill hole that occurs during these field activities. A geologist will complete the borehole log, which will include information regarding date, time, personnel, drilling and sampling equipment, geologic materials encountered, fracture locations and density in bedrock (where appropriate), color, texture, odors, and readings made with the screening instruments (see SOPs CTO131-6 and CTO131-12.

A well completion log will be completed for every monitoring well that is constructed. These logs will include information concerning the date, time of events, quantities of construction materials used, lengths and diameters of riser pipe and well screen placed in the well, and other information, as described in SOP CTO131-14.

4.9.3 Well Development Log Sheets

During the development or redevelopment of each monitoring well, the date, time of events, development method and equipment, personnel present, amounts of water produced, measurements made by field water quality meters, and depths to water will be recorded on a well development log sheet, as described in SOP CTO131-15.

4.9.4 Equipment Calibration Logs

An equipment calibration log sheet will be used to record each time an instrument is calibrated or recalibrated, or calibration is checked against a standard or background. The procedures and standards to be used for instrument calibration are discussed in Section 6.1 and each instrument's SOP contained in Appendix H.

4.9.5 Sample Collection Logs

One sample collection log sheet will be completed for every environmental sample, every duplicate sample, and every field blank sample collected during the field activities. Only the MS and MSD samples do not require their own individual sample collection log sheet.

4.9.6 Chain-of-Custody Forms

A chain-of-custody form will be completed for every cooler that contains samples being shipped to an off-site laboratory for analyses. These forms are a record of the people having custody of the samples from the time the samples are collected to the time they are analyzed and disposed of (see SOP CTO131-25). The completed field chain-of-custody document will be signed, placed in a sealed plastic envelope, and taped to the top inside cover of the shipping container before it is shipped. A copy of the document will be retained by the FOL.

4.9.7 Shipping Forms/Airbills

Copies of all forms and/or airbills related to the shipment of coolers will be retained by the FOL in order to trace the shipment, if necessary, and to communicate with the receiving laboratory.

4.9.8 Permanent Record File

At completion of the field activities, the FOL shall submit to the TOM all field records, data, field notebooks, logbooks, COC records, sample log sheets, daily activity logs, and other records concerning the project, including all of the forms and log sheets listed above. The FOL will check these records for legibility and completeness prior to submitting them to the TOM. These forms, data, and field notes will become part of the permanent project record.

4.10 SURVEYING

The horizontal and vertical locations of all monitoring wells and boreholes will be surveyed. The horizontal location will be surveyed to the Indiana State Plane Coordinates within the nearest foot and referenced to the 1983 North American Datum (NAD83). The vertical elevations of the ground surface and top-of-casing will be measured to the nearest 0.1 foot. A global positioning system (GPS) or other suitable surveying device will be used to identify horizontal locations of each of the surface water and sediment samples collected.

4.11 EQUIPMENT DECONTAMINATION

All equipment used to collect soil and ground water samples will be decontaminated in accordance with SOP CTO131-26. All decontamination fluids will be placed in the wastewater storage tank until the wastewater can be analyzed. If accepted, the wastewater will be discharged to the NSWC Crane water treatment plant where it will be treated prior to disposal (see SOP CTO131-27).

4.12 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

It is anticipated that this investigation will generate the following types of potentially contaminated residues or investigation-derived waste (IDW):

- Personal protective equipment (PPE) and ground water sample tubing
- Well development and purge fluids
- Equipment decontamination fluids
- Waste soils from soil borings

IDW will be handled as described below:

PPE - All PPE will be double-bagged and placed in trash receptacles at the facility.

Well Development and Purge Fluids - All well development and purge fluids will be collected and stored on-site in a 300- and 1,200-gallon plastic holding tank until appropriate IDW analyses are completed. A portable holding tank is already in place at NSWC Crane. Provided that IDW analyses are acceptable as described below, development and purge fluids will be discharged to the NSWC Crane permitted sanitary sewer system. The 1,200-gallon tank will be situated at a semi-permanent location near an access to the wastewater treatment plant. Purge and development fluids will be collected on-site in a 300-gallon portable holding tank attached to a truck or a smaller polyethylene container, as appropriate. The fluids will be transported daily to the 1,200-gallon holding tank and transferred from the portable 300-gallon tank using a submersible pump. The main fluid storage tank (1,200-gallon) will be sealed and labeled with contents, date, and origins of waste. An IDW sample will be collected from the 1,200-gallon tank at the completion of the sampling event and analyzed for gamma spectrometry radionuclides. NSWC Crane will review the analytical results to determine if the IDW fluids can be treated on-site via the wastewater treatment facility or if they must be treated or disposed of off-site. Progress of the laboratory analyses will be monitored by the TOM to confirm that the IDW fluids are not stored on-site for over 90 days. The laboratory turnaround time for the IDW sample analyses is 28 days, which should be sufficient time to

identify a potential problem before corrective action is required. NSWC Crane will take possession of the IDW water after receipt of the analytical results.

Equipment Decontamination Fluids - All decontamination fluids will be combined with well development and purge fluids and handled in the same manner.

Waste Soils from Soil Borings – For each soil boring or drill hole, the soils obtained from the holes will be scanned for VOCs, HD, and beta and gamma radiation. If all readings from these screening instruments are at background levels and HD is not detectable, the soil cuttings and excess core material will be placed back down the hole and tamped for compaction.

If a field instrument or the HD screening procedure indicates that contaminants may be present in the excess soil materials, then the excess soils from these holes will be placed in black plastic trash bags, labeled, and then placed in 55-gallon sealable drums. The bags will be tagged and the drums will be clearly labeled regarding the dates, locations and depths from where the soils originated, and the personnel (including phone number) placing the soil in the drum. When analytical results are received back from the laboratory concerning contaminant concentrations, then decisions will be made as to how to dispose of the soil materials, SOP CTO131-27.

Tubing Used for Development, Purging, or Sampling - All tubing used to develop, purge, or sample a well will be double-bagged and placed in a trash receptacle at the facility.

4.13 SAFETY

Health and safety issues and concerns are critically important during any field investigation involving drilling, UXO, hazardous wastes, radioactive wastes, and chemical warfare agents. Sampling team members working at the site must be fully aware of the potential dangers involved with sampling activities, must be trained and prepared to deal with problems or health-related issues as they arise, and should minimize to the greatest possible extent the potential for exposure to harmful chemicals or accidents. To ensure that field activities are performed at a high level of safety, the following are included in the health and safety activities related to the sampling program.

4.13.1 Health and Safety Plan

A separate HASP has been prepared describing specific health and safety requirements, concerns, and information related to the site activities. This document must be read and understood by each person

working at the site. Each worker or visitor to the site must sign an acknowledgment that he or she has read and understands the HASP.

4.13.2 Health and Safety Training

All workers involved with the site investigations shall have successfully completed the OSHA-mandated, 40-hour health and safety training, and follow-up annual 8-hour refresher courses when appropriate.

4.13.3 Personal Protective Clothing and Equipment

Workers at the site must be part of a medical monitoring program and be medically approved to perform their duties without physical limitations. Protective clothing and equipment, as specified in the HASP, will be worn while performing site activities.

4.13.4 Safety Meetings

Safety meetings will be held among on-site workers whenever the SSO feels it is appropriate. The SSO will discuss safety issues related to activities being performed, and will make site workers aware of any new conditions that could potentially affect health or safety.

4.14 ORGANIZATION AND LOGISTICS OF FIELD INVESTIGATIONS

4.14.1 Personnel

The duties, responsibilities, and line of command for each person working on the project are described in Section 2.0 and displayed on Figure 2-1. Persons working on the project should be intimately familiar with their roles and responsibilities. In addition, they should be familiar with the mechanisms and procedures for coordinating tasks, improving communications, and reporting incidences or irregularities. The FOL is responsible for coordinating all on-site personnel and activities (Section 2.3.1). The SSO is responsible for health and safety monitoring and ensures that the HASP is adhered to during all field activities (Section 2.3.3). The SSO, the UXO Specialist, and the Radiation Safety Officer have the authority to stop work if an imminent safety hazard is encountered (Section 2.3).

4.14.2 Subcontractors

Subcontractors will perform site activities involving drilling, packer testing, well installation, and surveying. The FOL will direct all subcontractor activities.

4.14.3 Mobilization and Demobilization

Following approval of the QAPP, TtNUS will begin mobilization activities. All field team members will review the QAPP (including the HASP) prior to mobilization. In addition, a field team orientation meeting will be held to familiarize personnel with the scope of the field activities. Items to be presented during that meeting include:

- Identification of the QAPP, including the HASP and applicable field SOPs (Appendix H)
- Site-specific safety concerns and requirements
- Project objectives
- Sampling designs and strategies for soil and ground water (including the relationship of soils data for this project to NSWC Crane background soil data)
- Site-specific particulars of field operations (e.g., locations of utilities, physical access to sampling location, communication mechanisms, lines of authority and responsibility, scheduling requirements, sample shipping concerns, etc.)
- Subcontractor coordination
- Field decision authority
- Site access requirements
- Travel requirements

The FOL will coordinate the mobilization activities for this project. The equipment required for the field activities will be mobilized from the TtNUS Pittsburgh office or the field office trailer at NSWC Crane. The MGBG is in a fairly remote area of the base. As a result, electricity is not available on-site. Therefore, power for electric pumps and all other electric-powered equipment, if required, will be supplied from portable gas-powered generators. It is presently anticipated that no portable gas-powered equipment will be used during field operations, but if conditions arise that require such equipment, an application for their use will be made to the NSWC Crane Fire Department.

The FOL and crew will demobilize from the site upon completion of the field operations and transport field equipment back to the Pittsburgh office, as necessary. All areas will be thoroughly checked; trash will be removed and disposed of. All drums containing IDW will be checked to ensure that lids are secured and proper labels have been attached to the drums.

4.14.4 Time Schedule

Roughly 70 working days have been scheduled to perform Round 1 field activities at the site (Figure 1-20). The activities will be performed in approximately the following order:

1. Repair and redevelop existing wells.
2. Sample existing wells.
3. Perform UXO clearance, drill soil borings and collect soil samples.
4. Collect surface water and sediment samples.
5. Drill and install new background monitoring wells.
6. Sample new background monitoring wells.

Activities 2 and 3 will overlap each other.

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TABLE 4-1

FIELD SCREENING AND MEASUREMENTS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Parameter	Equipment	Method	Calibration
Unexploded Ordnance (Surface)	GA-72CV Magnetic Locator	SOP CTO131-1	Per Manufacturer
Unexploded Ordnance (Sub-surface)	MG-220 Magnetic Gradiometer	SOP CTO131-1	Per Manufacturer
Mustard Gas bis(2-chloroethyl)sulfide	Chemical Agent Identification Kit (M18A2); Individual Chemical Agent Detector (ICAD)	SOP CTO131-3	Per Manufacturer
Radioactivity	Ludlum Model 2221[1] scaler/ratemeter; Ludlum Model 44-10[2] shielded pancake GM beta/gamma probe (2" x 2" NaI); and a strontium-90 beta source disk[3]; Ludlum Model 3 count rate meter with Model 44-9 pancake beta/gamma detector and Model 43-5 50 cm^2 alpha scintillator (for sample shipment screening); Ludlum Model 12S Micro-R meter or equivalent (for sample shipment screening).	SOP CTO131-2	Per Manufacturer
Volatile Organics	Perkin-Elmer Photovac 2020 Photoionization Detector	SOP CTO131-4	Per Manufacturer
pH, Temperature, oxidation-reduction potential, specific conductance, dissolved oxygen (water quality parameters)[4]	YSI 6-Series Environmental Monitoring System	SOP CTO131-18	Per Manufacturer
Turbidity (water quality parameter)[4]	LaMotte Turbidity Meter	SOP CTO131-18	Per Manufacturer
Alkalinity, CO_2, dissolved oxygen[5]	CHEMetrics Titrets	Test Kit Instructions[7]	Per Manufacturer
H_2S, Fe^{+2}, NO_3, NO_2, SO_4, S^{-2} (natural attenuation parameters)[5]	HACH DR-800 Colorimeter (or equivalent)	Test Kit Instructions[7]	Per Manufacturer
Water-Level Measurements	Heron Dipper-T (or equivalent)[6]	SOP CTO131-16	Per Manufacturer

1 The Eberline Model ESP-1 scaler/ratemeter may be substituted.
2 The Eberline Model HP210L shielded pancake GM beta/gamma probe may be substituted.
3 The source disk should have an activity near 20,000 disintegrations per minute (dpm).
4 Field measurements used to establish well stabilization prior to collecting ground water samples.
5 These MNA field parameters will not be measured during Round 1 activities. They may be measured during subsequent rounds if chlorinated organic solvents are detected in Round 1.
6 Any electronic water-level indicator may be used with the capability of measuring to depths of 200 feet.
7 Test kit instructions will be used to ensure that the most current and applicable procedure is followed.

TABLE 4-2

SOIL SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 4

Sample No.	VOC[1]	SVOC[1,2]	Herbicides[1]	Pesticides[1]	PCBs[1]	Explosives[3]	HD[4]	Metals[5]	Thorium[6]	TOC[7]	CEC[8]	pH	Gamma Spectrometry
01-SS-01-0002	X	X	X	X	X	X	X	X	X		X	X	
01-SB-01-0206	X	X	X	X	X	X	X	X	X		X	X	X
01-SB-01-0610	X	X				X	X	X	X		X	X	
01-SS-02-0002	X	X	X	X	X	X	X	X	X				
01-SB-02-0206	X	X	X	X	X	X	X	X	X				X
01-SB-02-0610	X	X				X	X	X	X				
01-SS-03-0002	X	X	X	X	X	X	X	X	X		X	X	
01-SB-03-0206	X	X	X	X	X	X	X	X	X		X	X	X
01-SB-03-0610	X	X				X	X	X	X		X	X	
01-SS-04-0002	X	X	X	X	X	X	X	X	X				
01-SB-04-0206	X	X	X	X	X	X	X	X	X				X
01-SB-04-0610	X	X				X	X	X	X				
01-SS-05-0002	X	X	X	X	X	X	X	X	X		X	X	
01-SB-05-0206	X	X	X	X	X	X	X	X	X		X	X	
01-SB-05-0610	X	X				X	X	X	X		X	X	
01-SS-06-0002	X	X	X	X	X	X	X	X	X				
01-SB-06-0206	X	X	X	X	X	X	X	X	X				
01-SB-06-0610	X	X				X	X	X	X				
01-SS-07-0002	X	X	X	X	X	X	X	X	X		X	X	
01-SB-07-0206	X	X	X	X	X	X	X	X	X		X	X	
01-SB-07-0610	X	X				X	X	X	X		X	X	
01-SS-08-0002	X	X	X	X	X	X	X	X	X				
01-SB-08-0206	X	X	X	X	X	X	X	X	X				
01-SB-08-0610	X	X				X	X	X	X				

TABLE 4-2

SOIL SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 4

Sample No.	VOC[1]	SVOC[1,2]	Herbicides[1]	Pesticides[1]	PCBs[1]	Explosives[3]	HD[4]	Metals[5]	Thorium[6]	TOC[7]	CEC[8]	pH	Gamma Spectrometry
01-SS-09-0002	X	X	X	X	X	X	X	X	X				
01-SB-09-0206	X	X	X	X	X	X	X	X	X				
01-SB-09-0610	X	X				X	X	X	X				
01-SS-10-0002	X	X	X	X	X	X	X	X	X				
01-SB-10-0206	X	X	X	X	X	X	X	X	X				
01-SB-10-0610	X	X				X	X	X	X				
01-SS-11-0002	X	X	X	X	X	X	X	X	X				
01-SB-11-0206	X	X	X	X	X	X	X	X	X				
01-SB-11-0610	X	X				X	X	X	X				
01-SS-12-0002	X	X	X	X	X	X	X	X	X				
01-SB-12-0206	X	X	X	X	X	X	X	X	X				
01-SB-12-0610	X	X				X	X	X	X				
01-SS-13-0002	X	X	X	X	X	X	X	X	X		X	X	
01-SB-13-0206	X	X	X	X	X	X	X	X	X		X	X	
01-SB-13-0610	X	X				X	X	X	X		X	X	
01-SS-14--0002	X	X	X	X	X	X	X	X	X				
01-SB-14-0206	X	X	X	X	X	X	X	X	X				
01-SB-14-0610	X	X				X	X	X	X				
01-SS-15-0002	X	X	X	X	X	X	X	X	X				
01-SB-15-0206	X	X	X	X	X	X	X	X	X				
01-SB-15-0610	X	X				X	X	X	X				
01-SS-16-0002	X	X	X	X	X	X	X	X	X				
01-SB-16-0206	X	X	X	X	X	X	X	X	X				
01-SB-16-0610	X	X				X	X	X	X				

TABLE 4-2

SOIL SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 3 OF 4

Sample No.	VOC[1]	SVOC[1,2]	Herbicides[1]	Pesticides[1]	PCBs[1]	Explosives[3]	HD[4]	Metals[5]	Thorium[6]	TOC[7]	CEC[8]	pH	Gamma Spectrometry
01-SS-17-0002	X	X	X	X	X	X	X	X	X				
01-SB-17-0206	X	X	X	X	X	X	X	X	X				
01-SB-17-0610	X	X				X	X	X	X				
01-SS-18-0002	X	X	X	X	X	X	X	X	X				
01-SB-18-0206	X	X	X	X	X	X	X	X	X				
01-SB-18-0610	X	X				X	X	X	X				
01-SS-19-0002	X	X	X	X	X	X	X	X	X				
01-SB-19-0206	X	X	X	X	X	X	X	X	X				
01-SB-19-0610	X	X				X	X	X	X				
01-SS-20-0002	X	X	X	X	X	X	X	X	X		X	X	
01-SB-20-0206	X	X	X	X	X	X	X	X	X		X	X	
01-SB-20-0610	X	X				X	X	X	X		X	X	
01-SS-21-0002									X	X			
01-SB-21-0206									X	X			
01-SB-21-0610									X	X			
BG1SBP0103 [9]													X
BG1SBP0204 [9]													X
BG1SBP0206 [9]													X
BG1SBP0305 [9]													X
BG1SBP0406 [9]													X
BG1SBP0505 [9]													X
BG1SBP0603 [9]													X
BG1SBP0804 [9]													X
BG1SBP0806 [9]													X

TABLE 4-2

SOIL SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 4 OF 4

Sample No.	VOC[1]	SVOC[1,2]	Herbicides[1]	Pesticides[1]	PCBs[1]	Explosives[3]	HD[4]	Metals[5]	Thorium[6]	TOC[7]	CEC[8]	pH	Gamma Spectrometry
BG1SBP1004 [9]													X
BGFD11069901 [9]													X
Totals	60	60	40	40	40	60	60	60	63	3	18	18	15

1 Appendix IX.
2 Excluding organophosphorus pesticides.
3 SW-846 Method 8330 list.
4 Mustard gas and its degradation products.
5 TAL metals plus Sr and Sn (total).
6 Thorium-228, -230, -232 isotopes (total).
7 Total organic carbon.
8 Cation exchange capacity.
9 These samples were collected as part of the NSWC Crane Basewide Soil Background investigation and will be shipped separately from Laucks Laboratory, Seattle, WA to SWLO.

TABLE 4-3

SUMMARY OF SOIL ANALYSES AND QUALITY CONTROL SAMPLES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Parameter[1]	Samples	Field Duplicates[2]	Trip Blanks[3]	Rinsate Blanks[4]	Source Water Blanks[5]	Matrix Spikes/ Matrix Spike Duplicates[6]	Total
Appendix IX Herbicides	40	4	NA	4	0	2/2	52
Appendix IX Pesticides/PCBs	40	4	NA	4	0	2/2	52
Appendix IX SVOCs (excluding organophosphorus pesticides)	60	6	NA	6	0	3/3	78
Appendix IX VOCs	60	6	5	6	0	3/3	83
Explosives (8330 list)	60	6	NA	6	0	3/3	78
bis(2-chloroethyl)sulfide (Mustard Gas) (HD) and its degradation products	60	6	NA	6	0	3/3	78
TAL Metals plus Sr and Sn (total)	60	6	NA	6	0	3/0	75
Thorium-228, -230, -232 (total)	63	7	NA	7	0	NA	77
Total Organic Carbon (TOC)	3	1	NA	0	0	NA	4
Cation Exchange Capacity (CEC)	18	2	NA	0	0	NA	20
pH	18	2	NA	0	0	NA	20

NA Not Applicable

1 See Table 1-5 of this QAPP for MGBG-specific analysis requirements and analyte lists.
2 Field duplicates will be collected at a frequency of 1 per every 10 samples. Field duplicates are not applicable (NA) for field measurements.
3 Trip blanks will be submitted for analysis at a frequency of one per cooler containing samples for volatile organics analysis. Because the number of sample coolers shipped may vary, the number of trip blanks are estimated to be five.
4 Rinsate blanks will be collected at a frequency of 1 per every 10 samples when using reusable equipment. For disposable equipment one rinsate blank will be collected per lot number for each type of equipment.
5 Source water blanks are to be analyzed, but are listed in Table 4-6 with the ground water QA/QC samples.
6 Matrix spike (MS) and matrix spike duplicate (MSD) samples will be collected at a frequency of 1 per every 20 samples. MS/MSDs are not applicable (NA) for field analyses.

TABLE 4-4

SUMMARY OF MONITORING WELL CONSTRUCTION DETAILS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Monitoring Well Number[1]	Date Installed	Horizontal Location[2]		Ground Surface Elevation (feet-AMSL)	Top of PVC Casing Elevation (feet-AMSL)	Well Depth from Top of PVC Casing (feet)	Screen Length (feet)	Well Screen Interval		Well Screen Interval		Ground water Depth & Elevation		
		Northing	Easting					Depth to Top (feet-bgs)	Depth to Bottom (feet-bgs)	Elevation of Top (feet-AMSL)	Elevation of Bottom (feet-AMSL)	Date Measured[3]	Depth to Water (feet)	Ground water Elevation[4] (feet-AMSL)
WES-1-1-81	1981	460547	578084	683.14	686.14	51.0	9.63	33.14	42.77	650.00	640.37	09/14/83	26.05	660.09
WES-1-2-81	1981	460856	577831	664.04	667.04	25.8	9.36	8.24	17.60	655.80	646.44	09/14/83	13.50	653.54
WES-1-3-81	1981	460596	577746	667.43	670.43	21.6	9.42	3.99	13.41	663.44	654.02	09/14/83	12.53	657.90
WES-1-4-81	1981	460800	577998	669.95	672.95	34.0	9.21	16.47	25.68	653.48	644.27	09/14/83	16.28	656.67
WES-1-5-81	1981	460831	577913	665.69	668.69	33.6	9.12	16.18	25.30	649.51	640.39	09/14/83	15.35	653.34
WES-1-6-82	11/12/82	461115	577955	596.02	599.02	93.0	9.38	75.02	84.40	521.00	511.62	07/20/83	69.70	529.32
WES-1-7-82	11/14/82	461184	577674	603.45	606.45	31.0	9.38	12.61	21.99	590.84	581.46	09/14/83	17.94	588.51
WES-1-8-82	11/15/82	461099	577833	601.99	604.99	31.2	9.32	13.63	22.95	588.36	579.04	09/14/83	15.67	589.32
WES-1-9-82	11/17/82	461048	577939	610.18	613.18	35.0	9.38	17.40	26.78	592.78	583.40	09/14/83	22.38	590.80
WES-1-10-82	01/22/83	460960	577916	636.77	639.77	43.0	9.40	25.25	34.65	611.52	602.12	09/14/83	26.45	613.32
WES-1-11-82	01/08/83	460880	577737	656.34	659.34	22.6	8.63	6.72	15.35	649.62	640.99	09/14/83	9.04	650.30
WES-1-12-83	01/19/83	461011	577714	634.05	637.05	41.0	9.41	23.26	32.67	610.79	601.38	09/14/83	25.85	611.20
WES-1-13-83	01/22/83	460993	577809	634.98	637.98	38.0	9.45	19.97	29.42	615.01	605.56	09/14/83	25.08	612.90
WES-1-14-83	01/26/83	460924	577635	656.14	659.14	39.0	9.53	21.12	30.65	635.02	625.49	09/14/83	16.84	642.30
WES-1-15-83	02/10/83	460965	577543	663.01	666.01	40.0	9.50	22.10	31.60	640.91	631.41	09/14/83	27.03	638.98
WES-1-16-83	02/11/83	461069	577611	641.94	644.94	41.5	9.25	23.75	33.00	618.19	608.94	09/14/83	35.25	609.69
WES-1-17-83	02/12/83	460823	577609	662.54	665.54	41.0	9.30	23.25	32.55	639.29	629.99	09/14/83	19.70	645.84
WES-1-18-83	06/18/83	460685	577538	658.40	661.40	32.0	9.29	14.3	23.59	644.10	634.81	09/14/83	14.58	646.82
WES-1-19-83	06/18/83	461000	577478	656.79	659.79	33.2	9.0	15.7	24.70	641.09	632.09	09/14/83	20.35	639.44
WES-1-20-83	06/21/83	461131	577516	631.35	634.35	39.1	9.34	21.35	30.69	610.00	600.66	09/14/83	28.00	606.35
WES-1-21-83	06/21/83	461225	577587	603.82	606.82	41.2	9.01	23.74	32.75	580.08	571.07	09/14/83	18.24	588.58
WES-1-22-83	07/09/83	461034	577355	653.55	656.55	38.0	9.15	20.5	29.65	633.05	623.90	09/14/83	17.55	639.00
WES-1-23-83	07/11/83	461152	577419	625.81	628.81	48.0	9.07	30.51	39.58	595.30	586.23	09/14/83	40.05	588.76
WES-1-24-83	07/09/83	461267	577496	600.57	603.57	33.4	9.41	15.62	25.03	584.95	575.54	09/14/83	15.18	588.39
WES-1-25-83	08/06/83	461072	577259	654.16	657.16	34.2	8.37	17.42	25.79	636.74	628.37	09/14/83	20.10	637.06
WES-1-26-83	08/06/83	460954	577245	670.21	673.21	58.0	9.12	40.45	49.57	629.76	620.64	09/14/83	35.25	637.96
WES-1-27-83	08/10/83	460776	577381	659.75	662.75	43.0	9.0	25.55	34.55	634.20	625.20	09/14/83	23.86	638.89
1C01-93	1993	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1 All wells were installed by the USACEWES and screened in the Pennsylvanian formation.
2 Referenced to the Indiana State Plane Coordinates, Zone 1302 (West), NAD 83.
3 Most recent round of water level data (Dunbar, April 1984, Appendix D).
4 Referenced to top of PVC casing.

Notes:
BGS - below ground surface
AMSL - Above mean sea level
PVC - polyvinyl chloride
NA - not available
Elevations are relative to Mean Sea Level, NGVD 29.

TABLE 4-5

PHYSICAL CHARACTERISTICS OF NEW MONITORING WELLS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Monitoring Well Number[1]	Approximate Ground Surface Elevation (feet AMSL)	Approximate Total Depth (feet bgs)	Screen Length (feet)	Approximate Well Screen Elevation[2]	
				Top (feet AMSL)	Bottom (feet AMSL)
BACKGROUND WELLS					
01T01-00	685	55	10	640	630
01T02-00	685	105	10	590	580
PROVISIONAL WELLS					
01T03-00	671	41	10	640	630
01T04-00	671	41	10	640	630
01T05-00	642	100	10	540	550
01T06-00	656	116	10	540	550

amsl Above Mean Sea Level
bgs below ground surface

1 See figures 4-2 and 4-3 for approximate well locations.
2 Depths will vary depending on the rock types and fracture distributions encountered in each borehole.

TABLE 4-6

GROUND WATER SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 2

Monitoring Well Location	VOC (1)	Metal (2)	Gross Alpha	Gross Beta	SVOC (1,3)	Herbicides (1)	Pest/ PCBs (1)	HD (4)	Explosives (5)	Thorium (T&D)(6)	TOC (7)
WES-1-1-81	X	X	X	X	X	X	X	X	X	X	X
WES-1-2-81	X	X	X	X	X	X	X	X	X	X	X
WES-1-3-81	X	X	X	X	X	X	X	X	X	X	X
WES-1-4-81	X	X	X	X	X	X	X	X	X	X	X
WES-1-5-81	X	X	X	X	X	X	X	X	X	X	X
WES-1-6-82	X	X	X	X	X	X	X	X	X	X	X
WES-1-7-82	X	X	X	X							
WES-1-8-82	X	X	X	X							
WES-1-9-82	X	X	X	X							
WES-1-10-82	X	X	X	X							
WES-1-11-82	X	X	X	X	X	X	X	X	X	X	
WES-1-12-83	X	X	X	X							
WES-1-13-83	X	X	X	X							
WES-1-14-83	X	X	X	X							
WES-1-15-83	X	X	X	X							
WES-1-16-83	X	X	X	X							
WES-1-17-83	X	X	X	X	X	X	X	X	X	X	
WES-1-18-83	X	X	X	X	X	X	X	X	X	X	
WES-1-19-83	X	X	X	X							
WES-1-20-83	X	X	X	X							
WES-1-21-83	X	X	X	X							
WES-1-22-83	X	X	X	X							
WES-1-23-83	X	X	X	X							
WES-1-24-83	X	X	X	X							
WES-1-25-83	X	X	X	X	X	X	X	X	X	X	
WES-1-26-83	X	X	X	X							
WES-1-27-83	X	X	X	X							
01-C01-93	X	X	X	X	X	X	X	X	X	X	X
01T01	X	X	X	X	X	X	X	X	X	X	X
01T02	X	X	X	X	X	X	X	X	X	X	X
01T03	X	X	X	X	X	X	X	X	X	X	X
01T04	X	X	X	X	X	X	X	X	X	X	X
01T05	X	X	X	X	X	X	X	X	X	X	X
01T06	X	X	X	X	X	X	X	X	X	X	X
01-SBXX(8)	X	X	X	X	X	X	X	X	X	X	

TABLE 4-6

GROUND WATER SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2

Monitoring Well Location	VOC (1)	Metal (2)	Gross Alpha	Gross Beta	SVOC (1,3)	Herbicides (1)	Pest/ PCBs (1)	HD (4)	Explosives (5)	Thorium (T&D)(6)	TOC (7)
01-SBXX(8)	X	X	X	X	X	X	X	X	X	X	
01-SBXX(8)	X	X	X	X	X	X	X	X	X	X	
Totals	30-37	30-37	30-37	30-37	20	20	20	20	20	20	12

1 Appendix IX.
2 Target Analyte List metals plus Sr and Sn. Unfiltered sample will be analyzed for total metals. If turbidity of water is greater than 5 NTUs, a filtered sample will also be collected and analyzed for dissolved metals.
3 Excluding organophosphorus pesticides.
4 Mustard gas and its degradation products.
5 SW-846 Method 8330 list.
6 Thorium-228, -230, -232 isotopes. Unfiltered sample (T) will be analyzed for total thorium isotopes. If turbidity of water is greater than 5 NTUs, a filtered sample (D) will also be collected and analyzed for dissolved thorium isotopes.
7 Total organic carbon.
8 Ground water taken from the bottom of soil borings (i.e., perched ground water), if encountered. These are discretionary samples.

TABLE 4-7

SUMMARY OF GROUND WATER ANALYSES AND QUALITY CONTROL SAMPLES, ROUND 1 MUSTARD GAS BURIAL GROUND NSWC CRANE, CRANE, INDIANA

Parameter[1]	Samples	Field Duplicates[2]	Trip Blanks[3]	Rinsate Blanks[4]	Source Water Blanks[5]	Matrix Spike/ Matrix Spike Duplicates[6]	Total[7]
Appendix IX Herbicides	17-20	2	NA	3	2	1/1	26-29
Appendix IX Pesticides/PCBs	17-20	2	NA	3	2	1/1	26-29
Appendix IX SVOCs[8]	17-20	2	NA	3	2	1/1	26-29
Appendix IX VOCs	34-37	4	6	6	2	2/2	56-59
Explosives[9]	17-20	2	NA	3	2	1/1	26-29
bis(2-chloroethyl)sulfide (Mustard Gas) (HD) and degradates[10]	17-20	2	NA	3	2	1/1	26-29
TAL Metals plus Sr and Sn (total)[11]	34-37	4	NA	6	2	2/2	50-53
Thorium-228, -230,-232 (total)[12]	17-20	2	NA	3	2	NA	24-26
Total Organic Carbon (TOC)	12	1	NA	3	2	NA	18
Gross Alpha	34-37	4	NA	6	2	NA	46-49
Gross Beta	34-37	4	NA	6	2	NA	46-49
Field Parameters[13]	34-37	NA	NA	NA	NA	NA	34-37

NA Not Applicable
1 See Table 1-5 of this QAPP for MGBG-specific analytical requirements and analyte lists.
2 Field duplicates will be collected at a frequency of 1 per every 10 samples. Field duplicates are not applicable for field parameters.
3 Trip blanks will be submitted for analysis at a frequency of one per cooler containing samples for VOC analysis. These amounts are estimates and may vary.
4 Rinsate blanks will be collected at a frequency of 1 per every 10 samples, with a minimum of one per day of sampling, per sampling device/instrument. These amounts are estimates and may vary.
5 Source water blanks consist of analyte-free water and potable water used for decontamination. Source water blanks are not applicable for field parameters.
6 Matrix spike (MS) and matrix spike duplicate (MSD) samples will be collected at a frequency of 1 per every 20 samples. MS/MSDs are not applicable for field parameters.
7 Totals may vary due to estimates made for trip blanks and rinsate blanks.
8 Excluding organophosphorus pesticides.
9 SW-846 Method 8330 list.
10 Thiodiglycol analysis will be performed on a sample only if HD, 1,4-thioxane, or 1,4-dithiane are detected in that sample.
11 TAL metals plus Sr and Sn. Unfiltered sample will be analyzed for total metals. If turbidity of water is greater than 5 NTUs, a filtered sample will also be collected and analyzed for dissolved metals.
12 Unfiltered sample will be analyzed for total thorium-228, -230, -232 isotopes. If turbidity of water is greater than 5 NTUs, a filtered sample will also be collected and analyzed for dissolved thorium-228, -230, -232 isotopes.
13 Field parameters measured with a water quality meter to determine well stabilization prior to sampling; includes pH, specific conductance, turbidity, temperature, dissolved oxygen (DO), and oxidation-reduction potential (ORP).

TABLE 4-8

SURFACE WATER AND SEEP SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Location	VOC (1)	SVOC (1,2)	Herbicides (1)	Pest/PCB (1)	Explosives (3)	HD (4)	Metals(5)		Thorium (6)	TSS	Gross Alpha	Gross Beta	Field Parameters(7)
							Total	Dissolved					
01-SW-01-01	X	X	X	X	X	X	X	X	X	X	X	X	X
01-SW-02-01	X	X	X	X	X	X	X	X	X	X	X	X	X
01-SW-03-01	X	X	X	X	X	X	X	X	X	X	X	X	X
01-SW-04-01	X	X	X	X	X	X	X	X	X	X	X	X	X
01-SW-05-01	X	X	X	X	X	X	X	X	X	X	X	X	X
01-SP-01-01(8)	X	X	X	X	X	X	X	X	X	X	X	X	X
01-SP-02-01(8)	X	X	X	X	X	X	X	X	X	X	X	X	X
Totals	7	7	7	7	7	7	7	7	7	7	7	7	7

1 Appendix IX.
2 Excluding organophosphorus pesticides.
3 SW-846 Method 8330 list.
4 Mustard gas and its degradation products.
5 TAL metals plus Sr and Sn.
6 Thorium-228, -230, -232 isotopes (total and dissolved).
7 Field parameters include pH, specific conductance, turbidity, temperature, dissolved oxygen (DO), and oxidation-reduction potential (ORP).
8 Discretionary samples to be collected if seeps are located near the 01BG.

VOC = volatile organic compound
SVOC = semivolatile organic compound
Pest = pesticide
PCB = polychlorinated biphenyl
HD = mustard gas
TSS = total suspended solids

TABLE 4-9

SUMMARY OF SURFACE WATER AND SEEP ANALYSES AND QUALITY CONTROL SAMPLES, ROUND 1 MUSTARD GAS BURIAL GROUND NSWC CRANE, CRANE, INDIANA

Parameter[1]	Samples	Field Duplicates[2]	Trip Blanks[3]	Matrix Spikes/ Matrix Spike Duplicates[4]	Total
Appendix IX Herbicides	5-7	1	NA	1/1	8-10
Appendix IX Pesticides/Polychlorinated Biphenyls	5-7	1	NA	1/1	8-10
Appendix IX Semivolatile Organic Compounds[5]	5-7	1	NA	1/1	8-10
Appendix IX Volatile Organic Compounds	5-7	1	1	1/1	9-11
Explosives (SW-846 Method 8330 list)	5-7	1	NA	1/1	8-10
bis(2-chloroethyl)sulfide (Mustard Gas) (HD) and degradates[6]	5-7	1	NA	1/1	8-10
Target Analyte List (TAL) Metals plus strontium and tin (total)[7]	5-7	1	NA	1/1	8-10
Target Analyte List (TAL) Metals plus strontium and tin (dissolvedl)[7]	5-7	1	NA	1/1	8-10
Thorium-228, -230, -232 (total)[8]	5-7	1	NA	NA	6-8
Total Suspended Solids	5-7	1	NA	NA	6-8
Gross Alpha	5-7	1	NA	NA	6-8
Gross Beta	5-7	1	NA	NA	6-8
Field Parameters[9]	5-7	NA	NA	NA	6-8

NA Not Applicable

1 See Table 1-5 of this QAPP for MGBG-specific analytical requirements and analytes lists.
2 Field duplicates will be collected at a frequency of 1 per every 10 samples. Field duplicates are not applicable for field parameters.
3 Trip blanks will be submitted for analysis at a frequency of one per cooler containing samples for VOC analysis.
4 Matrix spike (MS) and matrix spike duplicate (MSD) samples will be collected at a frequency of 1 per every 20 samples. MS/MSDs are not applicable for field parameters.
5 Excluding organophosphorus pesticides.
6 Thiociglycol analysis will be performed on a sample only if HD, 1,4-thioxane, or 1,4-dithiane are detected in that sample.
7 TAL metals plus Sr and Sn.
8 Unfiltered sample will be analyzed (i.e., total thorium-228, -230, -232). If turbidity of water is greater than 5 NTUs, a filtered sample will also be collected and analyzed (i.e., dissolved thorium-228, -230, -232).
9 Field parameters measured with a water quality meter; includes pH, specific conductance, turbidity, temperature, dissolved oxygen (DO), and oxidation-reduction potential (ORP).

TABLE 4-10

SUMMARY OF SEDIMENT SAMPLES AND LABORATORY ANALYSES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Location	VOC[1]	SVOC[1,2]	Herbicides[1]	Pesticides/PCBs[1]	Explosives[3]	HD[4]	Metals[5]	Thorium[6]	TOC[7]	CEC[8]	pH
01-SD-01	X	X	X	X	X	X	X	X	X	X	X
01-SD-02	X	X	X	X	X	X	X	X	X	X	X
01-SD-03	X	X	X	X	X	X	X	X	X	X	X
01-SD-04	X	X	X	X	X	X	X	X	X	X	X
01-SD-05	X	X	X	X	X	X	X	X	X	X	X
01-SD-06	X	X	X	X	X	X	X	X	X	X	X
01-SD-07	X	X	X	X	X	X	X	X	X	X	X
01-SD-08	X	X	X	X	X	X	X	X	X	X	X
01-SD-09 [9]	X	X	X	X	X	X	X	X	X	X	X
01-SD-10 [9]	X	X	X	X	X	X	X	X	X	X	X
Totals	10	10	10	10	10	10	10	10	10	10	10

1 Appendix IX.
2 Excluding organophophorus pesticides.
3 SW-846 Method 8330 list.
4 Mustard gas and its degradation products.
5 Target Analyte List metals plus strontium and tin
6 Thorium-228, -230, -232 isotopes.
7 TOC = Total organic carbon
8 CEC = Cation exchange capacity.
9 Samples are discretionary; specific locations have not been identified.

NA Not Applicable
PCBs = polychlorinated biphenyls
SVOC = semivolatile organic compounds
VOC = volatile organic compounds

TABLE 4-11

SUMMARY OF SEDIMENT ANALYSES AND QUALITY CONTROL SAMPLES, ROUND 1
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

Parameter[1]	Samples	Field Duplicates[2]	Trip Blanks[3]	Rinsate Blanks[4]	Source Water Blanks[5]	Matrix Spikes/ Matrix Spike Duplicates[6]	Total
Appendix IX Herbicides	8-10	1	NA	1	0	1/1	12-14
Appendix IX Pesticides/PCBs	8-10	1	NA	1	0	1/1	12-14
Appendix IX SVOCs (excluding organophosphorus pesticides)	8-10	1	NA	1	0	1/1	12-14
Appendix IX VOCs	8-10	1	1	1	0	1/1	13-15
Explosives (SW-846 Method 8330 list)	8-10	1	NA	1	0	1/1	12-14
bis(2-chloroethyl)sulfide (Mustard Gas) (HD) and its degradation products	8-10	1	NA	1	0	1/1	12-14
TAL Metals plus Sr and Sn (total)	8-10	1	NA	1	0	1/0	11-13
Thorium-228, -230, -232 (total)	8-10	1	NA	1	0	0/0	10-12
Total Organic Carbon (TOC)	8-10	1	NA	1	0	0/0	10-12
Cation Exchange Capacity (CEC)	8-10	1	NA	0	0	0/0	9-11
pH	8-10	1	NA	0	0	0/0	9-11

1 See Table 1-5 of this QAPP for MGBG-specific analysis requirements and analytes lists.
2 Field duplicates will be collected at a frequency of 1 per every 10 samples. Field duplicates are not applicable (NA) for field measurements.
3 Trip blanks will be submitted for analysis at a frequency of one per cooler containing samples for volatile organics analysis. Because the number of sample coolers shipped may vary, the number of trip blanks is estimated to be four.
4 Rinsate blanks will be collected at a frequency of 1 per every 10 samples, with a minimum of 1 per day per sampling device/instrument.
5 Source water blanks are to be analyzed, but are listed in Table 4-6 with the ground water QA/QC samples.
6 Matrix spike (MS) and matrix spike duplicate (MSD) samples will be collected at a frequency of 1 per every 20 samples. MS/MSDs are not applicable (NA) for field analysis.

NA Not Applicable
PCBs = polychlorinated biphenyls
SVOCs = semivolatile organic compounds
TAL = Target Analyte List
VOCs = volatile organic compounds

TABLE 4-12

SUMMARY OF SAMPLE ANALYSES, CONTAINER TYPES AND VOLUMES, PRESERVATION REQUIREMENTS, HOLDING TIMES AND ANALYTICAL LABORATORY FOR SOILS AND SEDIMENTS MUSTARD GAS BURIAL GROUND NSWC CRANE, CRANE, INDIANA

Parameter	Sample Container	Container Volume	Preservation	Maximum Holding Time[1]	Analytical Laboratory[2]
Explosives	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Extraction 14 days; analysis within 40 days of extraction	SWLO
Appendix IX Herbicides	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Extraction 14 days; analysis within 40 days of extraction	SWLO
Appendix IX Pesticides/Polychlorinated biphenyls (PCBs)	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Extraction 14 days; analysis within 40 days of extraction	SWLO
Appendix IX Volatile Organic Compounds	4 Encore™ samplers	Four 5-gram containers	Cool to 4 °C	48 hours to preservation; 14 days to analysis	SWLO
bis(2-chloroethyl)sulfide (Mustard gas) (HD) and its degradation products	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Extraction 10 days; analysis within 40 days of extraction	ECBC
Appendix IX Semivolatile Organic Compounds (excluding organophosphorus pesticides)	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Extraction 14 days; analysis within 40 days of extraction	SWLO
Target Analyte List Metals plus tin and strontium (total)	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Within 180 days; mercury within 28 days	SWLO
Thorium-228,-230,-232 (total) and gamma spectrometry	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Within 180 days	SWLO
Total Organic Carbon (TOC)	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	28 days	SWLO
Cation Exchange Capacity (CEC)	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	Indefinite	SWLO
pH	Wide-mouth jar, Teflon-lined plastic cap	8 ounce	Cool to 4 °C	As soon as possible	SWLO

1 All holding times are from date of collection.

2 SWLO = Southwest Laboratory of Oklahoma; ECBC = Edgewood Chemical Biological Center

TABLE 4-13

SUMMARY OF SAMPLE ANALYSES, CONTAINER TYPES AND VOLUMES, PRESERVATION REQUIREMENTS, HOLDING TIMES, AND ANALYTICAL LABORATORY FOR AQUEOUS SAMPLES MUSTARD GAS BURIAL GROUND NSWC CRANE, CRANE, INDIANA PAGE 1 OF 2

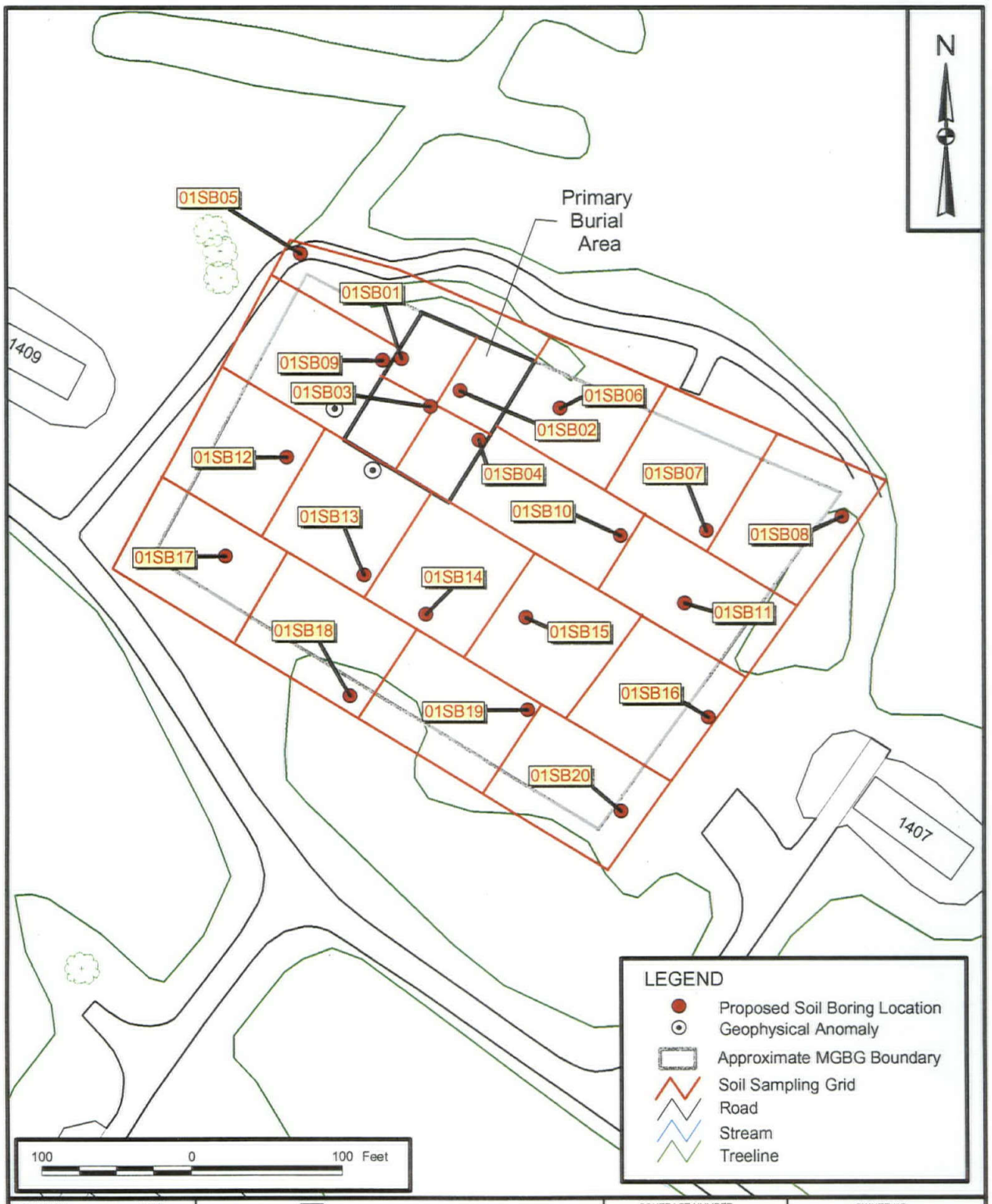
Parameter	Sample Container	Container Volume	Preservation[1]	Maximum Holding Time[2]	Analytical Laboratory[3]
Explosives	Amber glass, Teflon-lined cap	(2) 1000 mL	Cool to 4 °C, dark	Extraction 7 days; analysis within 40 days of extraction	SWLO
Appendix IX Herbicides	Amber glass, Teflon-lined cap	(2) 1000 mL	Cool to 4 °C, dark	Extraction 7 days; analysis within 40 days of extraction	SWLO
Appendix IX Organochlorine Pesticides/Polychlorinated biphenyls (PCBs)	Amber glass, Teflon-lined cap	(2) 1000 mL	Cool to 4 °C, dark	Extraction 7 days; analysis within 40 days of extraction	SWLO
Appendix IX Volatile Organic Compounds	Glass, black phenolic plastic screw cap, Teflon-lined septum	(6) 40 mL	Cool to 4 °C, dark, zero headspace, HCl to pH <2	14 days	SWLO
bis(2-chloroethyl)sulfide (Mustard gas) (HD) and its degradation products	Amber glass, Teflon-lined cap	(2) 1000 mL	Cool to 4 °C, dark	Extraction 10 days; analysis within 40 days of extraction	ECBC
Appendix IX Semivolatile Organic Compounds (excluding organophosphorus pesticides)	Amber glass, Teflon-lined cap	(2) 1000 mL	Cool to 4 °C, dark	Extraction 7 days; analysis within 40 days of extraction	SWLO
Target Analyte List Metals plus tin and strontium (total)	Polyethylene, plastic cap w/ plastic liner	1000 mL	Cool to 4 °C, HNO_3 to pH <2	Within 180 days; mercury within 28 days	SWLO
Target Analyte List Metals plus tin and strontium (dissolved)	Polyethylene, plastic cap w/ plastic liner	1000 mL	Cool to 4 °C, HNO_3 to pH <2	Within 180 days; mercury within 28 days	SWLO
Thorium-228, -230, -232 (total)	Polyethylene, plastic cap w/ plastic liner	1000 mL	Cool to 4 °C, HNO_3 to pH <2	Within 180 days;	SWLO
Thorium-228, -230, -232 (dissolved)	Polyethylene, plastic cap w/ plastic liner	1000 mL	Cool to 4 °C, HNO_3 to pH <2	Within 180 days;	SWLO
Gross alpha	Polyethylene, plastic cap w/ plastic liner	1000 mL	Cool to 4 °C, HNO_3 to pH <2	Within 180 days;	SWLO

TABLE 4-13

SUMMARY OF SAMPLE ANALYSES, CONTAINER TYPES AND VOLUMES, PRESERVATION REQUIREMENTS, HOLDING TIMES, AND ANALYTICAL LABORATORY FOR AQUEOUS SAMPLES
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2

Parameter	Sample Container	Container Volume	Preservation[1]	Maximum Holding Time[2]	Analytical Laboratory[3]
Gross beta	Polyethylene, plastic cap w/ plastic liner	1000 mL	Cool to 4 °C, HNO_3 to pH <2	Within 180 days;	SWLO
Total Organic Carbon (TOC)	Amber glass, septa cap	125 mL	Cool to 4 °C, H_2SO_4 to pH <2	28 days	SWLO
Total Suspended Solids (TSS)	Polyethylene, plastic cap w/ plastic liner	500 mL	Cool to 4 °C	7 days	SWLO

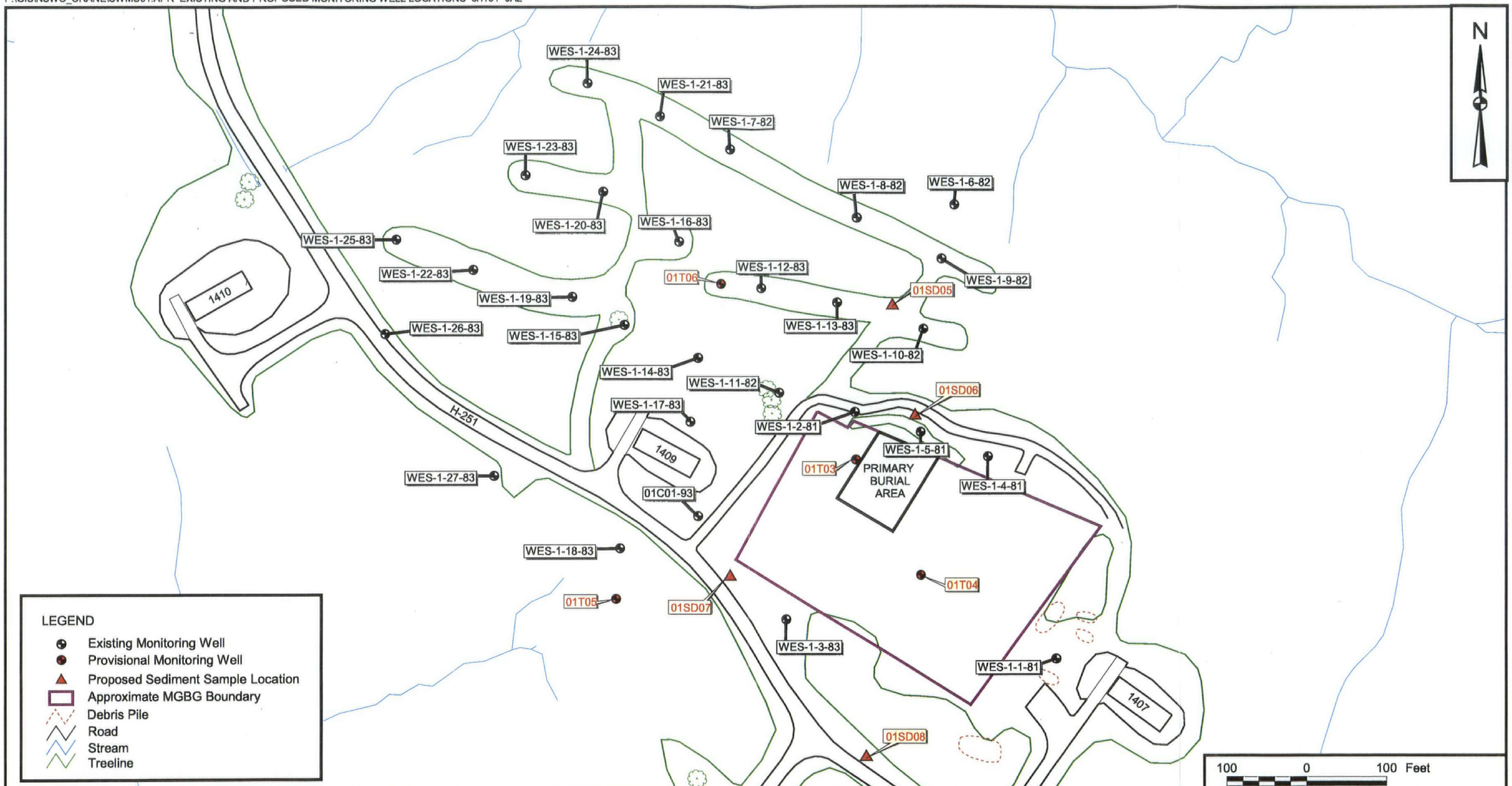
Note: Aqueous samples include ground water, surface water, and seeps.
1 HCl = Hydrochloric acid, H_2SO_4 = Sulfuric Acid, HNO_3 = Nitric Acid.
2 All holding times are from date of collection.
3 SWLO = Southwest Laboratory of Oklahoma; ECBC = Edgewood Chemical Biological Center
mL = milliliters



DRAWN BY	DATE	Tetra Tech NUS, Inc.	CONTRACT NUMBER	OWNER NO.
J. LAMEY	3/29/00		N0504	CTO 131
CHECKED BY	DATE	SOIL BOREHOLE LOCATIONS MUSTARD GAS BURIAL GROUND NAVAL SURFACE WARFARE CENTER CRANE, INDIANA	APPROVED BY	DATE
J. SCHUBERT	5/1/00		T. JOHNSTON	5/2/00
COST/SCHEDULE-AREA			APPROVED BY	DATE
			—	—
SCALE			DRAWING NO.	REV
AS NOTED			FIGURE 4-1	—

P:\GIS\NSWC_CRANE\SWMU01.APR SOIL SAMPLING LOCATIONS 27Jun00 MJJ

P:\GIS\NSWC_CRANE\SWMU01.APR EXISTING AND PROPOSED MONITORING WELL LOCATIONS 5/7/01 JAL



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY J. LAMEY	DATE 4/3/00
CHECKED BY J. SCHUBERT	DATE 5/7/01
COST/SCHEDULE-AREA	
SCALE AS NOTED	

Tetra Tech NUS, Inc.

MONITORING WELL LOCATIONS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

CONTRACT NUMBER 0504	OWNER NUMBER 0131
APPROVED BY T. JOHNSTON	DATE 5/7/01
APPROVED BY —	DATE —
DRAWING NO. FIGURE 4-2	REV 0

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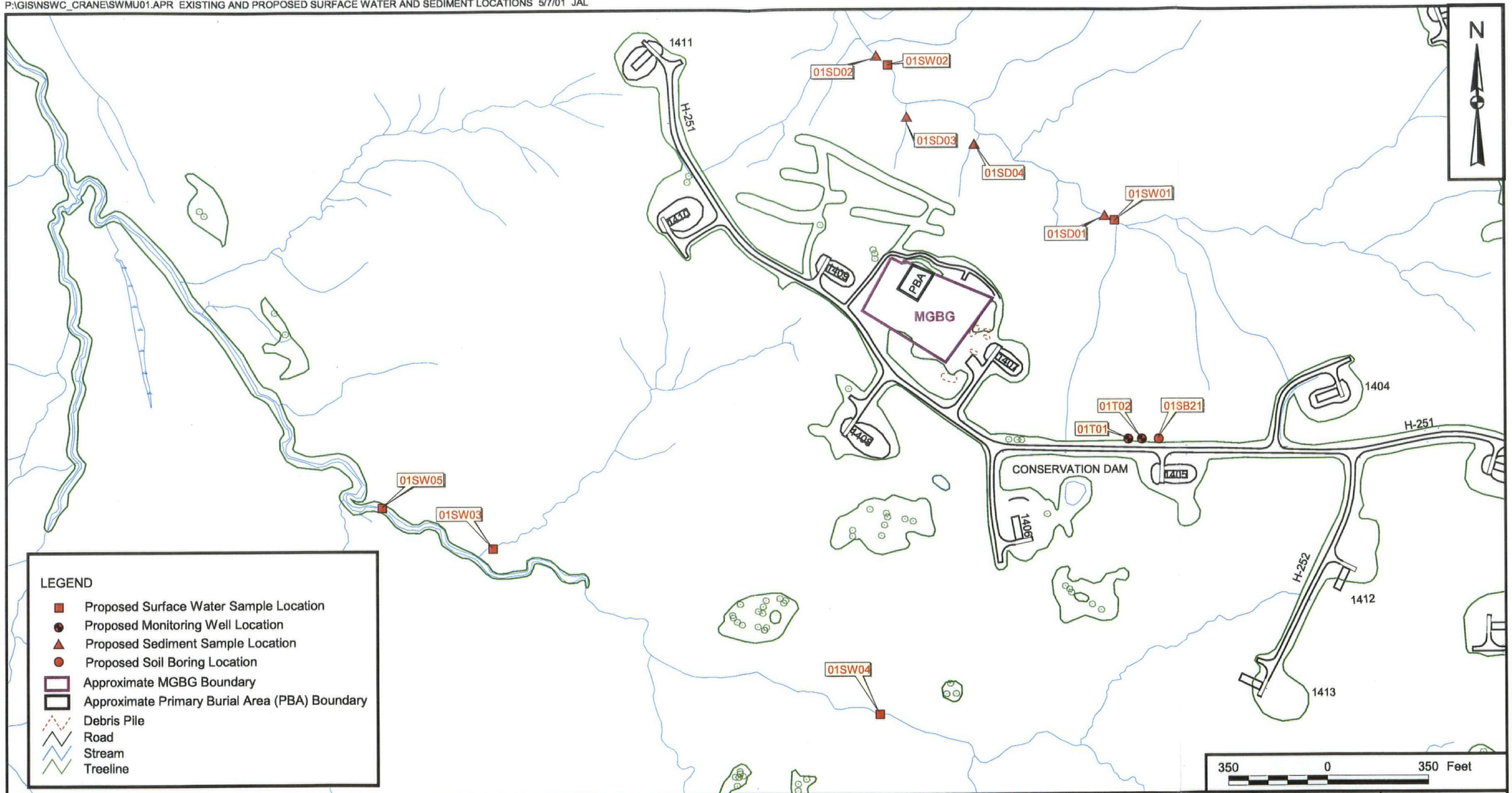


NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY J. LAMEY	DATE 4/3/00
CHECKED BY J. SCHUBERT	DATE 5/7/01
COST/SCHEDULE-AREA	
SCALE AS NOTED	

Tetra Tech NUS, Inc.

SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

CONTRACT NUMBER 0504	OWNER NUMBER 0131
APPROVED BY T. JOHNSTON	DATE 5/7/01
APPROVED BY —	DATE —
DRAWING NO. FIGURE 4-3	REV 0

5.0 CUSTODY PROCEDURES

Documented sample custody is one of several factors necessary for the admissibility of environmental data as evidence in a court of law. Custody procedures help to satisfy the two major requirements for admissibility: relevance and authenticity. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files. Final evidence files, including all original laboratory reports and purge files, are maintained under document control in a secure area. A sample or evidence file is under custody when any one of the following conditions is satisfied:

- The item is in the actual physical possession of an authorized person.
- The item is in view of the person after being in his or her possession.
- The item was placed in a secure area to prevent tampering.
- The item is in a designated and identified secure area with access restricted to authorized personnel only.

The chain of custody (COC) form is a multi-part, standardized form used to summarize and document pertinent sample information, such as sample identification and type, sample matrix, date and time of collection, preservation, and requested analyses. Furthermore, through the sequential signatures of various sample custodians (e.g., sampler, airbill number, laboratory sample custodian), the COC form documents sample custody and tracking. Laboratory custody procedures will ensure that sample integrity is not compromised from the time of receipt at the laboratory until final data are reported to TtNUS. This requires that the laboratory control all sample handling and storage conditions and circumstances. Custody procedures apply to all environmental and associated field QC samples obtained as part of the data collection system.

5.1 FIELD CUSTODY PROCEDURES

The FOL (or designee) is responsible for the care and custody of the samples collected until they are relinquished to the laboratory or entrusted to a commercial courier. Together, field logbooks and sample documentation including COC forms provide a record that should allow a technically qualified individual to reconstruct significant field activities without resorting to memory. COC forms are completed to the fullest extent possible for each sample cooler used for shipment. The forms are legibly completed with waterproof ink, and are signed and dated by the sampler. COC forms will include the following information: project name, sample number, time collected, matrix, designated analyses, type of sample, preservative, and name of sampler. Pertinent notes or comments, such as positive results during sample

screening, are also indicated on the COC form. An example COC form is included in SOP CTO 131-4 (Appendix H).

Information similar to that contained on the COC form is provided on the sample label, which is securely attached to the sample bottle. In addition, sample tags will be affixed to the sample bottles and returned by the analytical laboratory for inclusion in the final evidence file. Sample labels and tags will include, at a minimum, the following information: sample number, date and time of collection, analysis required for the sample aliquot in the associated sample container, and a space for the laboratory sample number. The procedures for sample numbering by TtNUS are described in SOP CTO 131-10 (Appendix H). The procedures for sample numbering by SWLO and the ECBC Laboratory are described in the applicable laboratory SOPs (Appendix I).

Site conditions during sampling and the care with which samples are handled may factor into the degree to which samples represent the media from which they are collected. This, in turn, could affect the ability of decision makers to make accurate and timely decisions concerning the contamination status of the site. As appropriate, logbooks are assigned to, and maintained by, key field team personnel. The logbooks are used to record daily conditions and activities such as weather conditions, dates and times of significant events, level of PPE used, boring activities, actual sample collection locations, photographs taken, problems encountered during field activities, chemical screening results, and corrective actions taken to overcome problems. In addition, the names of site visitors and the purposes of their visits shall be recorded. Field logbook assignments shall be recorded in the site logbook or other central file whose location is known by the FOL and TOM. All field logbook assignments, use, control, and archiving are governed by SOP CTO 131-25 (Appendix H). Examples of all forms to be used during sampling activities are also provided in SOP CTO 131-6 (Appendix H). During field activities the FOL is responsible for the maintenance and security of all field records. At the completion of field activities, the FOL will forward all field records to the TtNUS TOM. All field sample records will eventually be docketed into the final evidence file.

SOPs CTO 131-2, CTO131-3 and CTO 131-24 (Appendix H) describe procedures for sample screening, packaging, and shipment. A temperature blank shall be included in each cooler containing samples for use by the laboratory upon receipt. Each cooler that contains samples to be analyzed for VOCs shall also include a trip blank. Each cooler shall be taped shut with strapping tape in at least two places to prevent tampering. Custody seals shall be attached as described in SOP CTO 131-25 so that the seals must be broken to open the cooler. Shipment will be made by a public courier at the next scheduled pickup following completion of sample collection. Radioactive samples must be shipped in accordance with additional labeling requirements specified in SOP CTO 131-2.

The following procedures will be used when transferring custody of samples. As previously noted, individual custody records will accompany each sample cooler. The methods of shipment, courier name, and other pertinent information will be entered in the remarks section of the custody record. When transferring samples, the individuals relinquishing and receiving the samples will sign, date, and note the time on the COC record. The original record (top copy of the multi-part form) will accompany the shipments and the field sampler will retain a copy. This record documents the sample custody transfer from the sampler to the laboratory, often through another person or agency (common courier). After COC records have been placed within sealed shipping coolers, the signed courier airbills will serve to document COC. When samples arrive at the laboratory, internal laboratory sample custody procedures will be followed (see Section 5.2).

5.2 LABORATORY CUSTODY PROCEDURES

When the analytical laboratory receives a shipment of samples, the laboratory's sample custodian will verify that the correct number of coolers has been received. The custodian will examine each cooler's custody seals to verify that they are intact and that the integrity of the environmental samples has been maintained. The custodian will then open each cooler and measure its internal temperature by measuring the temperature of the temperature blank. The temperature reading will be documented in the comments column of the COC form. The sample custodian will then sign the COC form and examine the contents of the cooler. Identification of broken sample containers or discrepancies between the COC form and sample labels will be recorded. The laboratory will retain the original field COC forms, providing copies of the forms with the final data package deliverable. All problems or discrepancies noted during sample receipt will be promptly reported to the TtNUS TOM. Samples will be logged into the laboratory information management system. Other pertinent issues relating to laboratory sample custody and tracking are presented in the following laboratory SOPs (Appendix I):

SWLO:

SOP SWL-GA-106	Archival and Retrieval of Sample Documentation
SOP SWL-GA-110	Laboratory Documentation of Sample Custody
SOP SWL-GA-115	Sample Custodian
SOP SWL-GA-124	LIMS for Sample Receiving
SOP SWL-GA-135	Sample Login Review

The SWLO shall ensure that samples are not analyzed for radiological or chemical parameters until approval for such analyses is received from the TOM or his designee. However, samples received in Encore® samples for VOC analysis may be preserved upon laboratory receipt at the samples to ensure compliiance with holding times as presented in table 4-12.

ECBC Laboratory:

Monitoring branch soil and water quality assurance/quality control (QA/QC) plan.

5.3 FINAL EVIDENCE FILES

The Administrative Record at NSWC Crane will be the repository for all documents that constitute evidence relevant to sampling and analysis activities as described in this QAPP. NSWC Crane will be the custodian of the evidence file and will maintain the contents of these files, including all relevant records, reports, logs, field logbooks, pictures, subcontractor reports, and data reviews in a secure, limited- access location and under custody of the NSWC Crane Environmental Site Manager. The control file will include at a minimum:

- Field logbooks
- Field data and data deliverables
- Photographs and negatives
- Drawings
- Soil boring logs
- Laboratory data deliverables
- Data validation reports
- Data assessment reports
- Progress reports, QA reports, interim project reports, etc.
- All custody documentation (tags, forms, airbills, etc.)

Upon completion of the contract, all files associated with this investigation will be maintained in the Administrative Record at NSWC Crane and will be available for inspection by the regulatory agencies for 50 years. Prior to disposal of all administrative records, the records will be offered to U.S. EPA.

6.0 CALIBRATION PROCEDURES AND FREQUENCY

All instrumentation used to perform chemical measurements must be properly calibrated prior to use in order to obtain valid and usable results. Instruments used in the field and in the laboratory will be calibrated in accordance with the procedures governing the use of the instruments. Field SOPs are included in Appendix H, and laboratory SOPs are included in Appendix I. For this investigation, field instrument calibration is described in Section 6.1, and laboratory instrument calibration is outlined in Section 6.2.

6.1 FIELD INSTRUMENT CALIBRATION

Various instruments will be required for field measurements during this investigation and include the following:

- Multi-parameter water quality meter
- LaMotte turbidity meter
- Electronic water level meter
- Photoionization detector
- Ludlum Model 12S Micro-R meter or equivalent
- Ludlum Model 2221 scaler/ratemeter (or an Eberline Model ESP-1 scaler/ratemeter)
- Ludlum Model 44-9 shielded pancake GM beta/gamma probe (or an Eberline Model HP210L shielded pancake GM beta/gamma probe)
- Ludlum Model 43-5 50 cm squared alpha scintillator
- GA-72CV magnetic locator
- MG-220 magnetic gradiometer
- HACH DR-800 colorimeter (or equivalent)
- Mustard gas screening instruments as specified in the HASP

Instruments used in the field will be calibrated in accordance with the procedures outlined in specific SOPs (water quality meter and PID) and the manufacturer's calibration procedures. Calibration of each instrument will be documented on a separate Equipment Calibration Log Form (Appendix H). During calibration, an appropriate maintenance check will be performed on each piece of equipment. If damaged or defective parts are identified during the maintenance check and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until the

defective parts are repaired or replaced. If the instrument cannot be repaired, a replacement will be procured from the supplier.

Calibration of the HACH DR-800 colorimeter (or equivalent) will be accomplished through accuracy checks performed for each required parameter. Accuracy checks include one or more of standard additions, standard solutions, and reagent blank analyses. The purpose of accuracy checks is to check the performance of the reagents, the colorimeter, and the analytical procedure. Information on the type of accuracy check, its associated parameter, and the QC associated with the accuracy check is included in the test kit used to perform the analysis. Test kits do not require calibration by field personnel. To ensure proper operation, they must be used within the specified holding times.

The electronic water-level meters will be calibrated prior to field use and periodically at the discretion of the FOL. They will be calibrated by comparison of meter markings with a steel tape measure.

6.2 LABORATORY INSTRUMENT CALIBRATION

Calibration procedures for metals analyses by ICP/AES begin with a periodic establishment of the useful linear response range, followed by routine daily calibrations. The daily calibrations consist of at least one blank and one calibration standard, an initial calibration verification, and continuing calibration verification standards/blanks, with each batch of samples analyzed. In all cases, an independently prepared standard (i.e., from a second source or a different lot number from the primary source) will be used as a calibration verification solution or as the MS spiking mix.

Organic chemical analyses (including mustard gas and mustard gas degradate analyses) begin with an initial calibration of the gas chromatograph (GC), high performance liquid chromatograph (HPLC), or gas chromatograph/mass spectrometer (GC/MS) system with an initial calibration curve that establishes the instrument responses as functions of analyte concentration. The initial calibration curves incorporate a calibration blank and a series of calibration standards for the target analytes and any applicable internal standards or surrogate compounds. On a routine basis, a continuing calibration is performed in which the validity of the calibration curve is checked with a known chemical standard from a source independent of the initial calibration standards. This continuing calibration standard contains the target analytes of interest and any applicable internal standards and surrogate compounds. The internal standards compensate for variations in analytical response that may occur in individual chromatographic analyses. The surrogate compounds provide a means to assess the efficiency of analyte extraction and analysis for each sample.

Calibrations for radiochemical analyses include detector efficiency calculations, detector resolution checks, energy *versus* detector channel correlations, and background count determinations. Gross alpha and beta calibrations include self-absorption curve determinations to estimate the loss of efficiency from self-absorption. Continuing calibration check standards are analyzed periodically to verify acceptable calibration status. Consistent with industry standards, radioactive tracers are used to adjust final alpha spectroscopy results for loss of analyte during sample preparation.

All standards used to calibrate analytical instruments must be obtained from the National Institute of Standards and Technology (NIST) or through a reliable commercial supplier with a proven record for quality standards. All commercially supplied standards will be traceable to NIST reference standards, where possible, and appropriate pedigree documentation will be obtained from the supplier. In cases where documentation is not available, the laboratory will analyze the standard and compare the results to a U.S. EPA-known or previous NIST-traceable standard.

Calibrations and associated documentation are required for all laboratory instruments. The documentation for calibrations performed in-house shall identify the person performing the calibration, the instrument being calibrated, the standards used for calibration and their concentration values or other pertinent calibration values, the source of the calibration standards, and the date of calibration. Certain instruments (e.g., balances) may be calibrated by a third party. In those cases, the details of calibration as described above and a certification of acceptable performance shall be obtained from the third party. The period during which the calibration is valid may appear in the calibration record or may be governed by the SOP.

Calibration procedures, frequency requirements, acceptance criteria, and conditions that require recalibration are described for each analytical procedure in the applicable laboratory SOPs included in Appendix I.

7.0 ANALYTICAL AND MEASUREMENT PROCEDURES

Field measurements and laboratory analytical procedures are discussed in this section.

7.1 FIELD MEASUREMENT PROCEDURES

Chemical and physical parameters to be measured using field instrumentation include pH, specific conductance, temperature, turbidity, nitrate, nitrite, sulfate, dissolved oxygen, surface water flow rate; oxidation–reduction potential (ORP), alkalinity, carbon dioxide, ferrous iron (Fe^{2+}), manganous ion (Mn^{2+}) hydrogen sulfide, sulfide, grain size, depositional environment, sample depth, location, and water-level elevation. The field target parameters and the rationales for including them in the analysis scheme are presented in Table 1-3. Measurement of field parameters is described in Section 4.0. Calibration of field instruments is discussed in Section 6.0 and in individual field measurement SOPs (Appendix H). Except for the well stabilization measurements, measurements for dissolved oxygen, oxidation-reduction potential, pH, specific conductance, temperature and turbidity will be reserved for sampling rounds beyond Round1.

7.2 LABORATORY ANALYTICAL AND MEASUREMENT PROCEDURES

Table 7-1 summarizes of the laboratory analytical methods and associated laboratory SOPs to be used during this investigation. Laboratory SOPs are included in Appendix I of this QAPP.

7.2.1 List of Project Target Compounds and Detection Limits

A list of the laboratory target analytes; project-specific risk-based target levels; and laboratory-specific MDLs (organic compounds and miscellaneous parameters), minimum detectable activities (MDAs - for radionuclides, gross alpha, and gross beta), and RLs is provided in Table 1-5. The MDLs shown have been determined experimentally using the procedures described in SWLO SOP SWL-GA-113, and the ECBC HD and HD degradation analysis SOPs which are included in Appendix I of this QAPP. The procedures for determining MDLs are based on the method provided in 40 CFR Part 136 Appendix B. The MDAs provided for the thorium isotopes, gross alpha, and gross beta are based on calculations detailed in SWLO SOP SW-RD-122. All environmental data will be reported to the analyte's laboratory-specific MDL or MDA, as applicable. MDLs will be adjusted on a sample-by-sample basis, as necessary, based on dilutions, sample volume and, for soil samples, percent moisture.

7.2.2 List of Associated Quality Control Samples

Field and laboratory QC samples to be analyzed in support of this project are identified in Section 8.0. The analytical SOPs included in Appendix I of this QAPP address minimum QC requirements for each associated analytical method. The SOPs include calibration QC requirements. Details on QC sample usage are provided in Section 8.0.

TABLE 7-1

**SUMMARY OF ORGANIC, INORGANIC, AND MISCELLANEOUS ANALYTICAL PROCEDURES
SOLID AND AQUEOUS SAMPLES
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 2**

Analytical Parameter[1]	Preparation Method	Analytical Method	Preparation/Analytical SOP(s)[2]
Explosives	SW-846 8330	SW-846 8330	SWL-OE-410/ SWL-OL-200
Bis(2-chloroethyl)sulfide, 1,4-Thioxane, 1,4-Dithiane	ECBC Method 04/08/98	ECBC Method 04/08/98	ECBC Method 04/08/98
Thiodiglycol	ECBC Method 12/08/00	ECBC Method 12/08/00	ECBC Method 12/08/00
Metals	Aqueous SW-846 Method 3010A Solid SW-846 Method 3050B (HCl option)	SW-846 Method 6010B Trace	SWL-IN-205
Mercury	Aqueous SW-846 Method 7470A Solid SW-846 Method 7471A	Aqueous SW-846 Method 7470A Solid SW-846 Method 7471A	SWL-IN-207
Radionuclides (Thorium-228, 230, 232)	Aqueous EPA 907, EMSL-LV-0539-17, March 1979 Solid EPA 907, EMSL-LV-0539-17, March 1979	Aqueous EPA 907, EMSL-LV-0539-17, March 1979 Solid EPA 907, EMSL-LV-0539-17, March 1979	Aqueous SWL-RD-120 Solid SWL-RD-126/ SWL-RD-120
Appendix IX Volatile Organic Compounds	Aqueous SW-846 Method 5030 (25 ml purge) Solid SW-846 Method 5035 (5 g purge)	SW-846 Method 8260B (25 ml purge or 5 gram sample)	Aqueous SWL-OV-304 Solid SWL-OV-303
Appendix IX Semivolatile Organic Compounds	Aqueous SW-846 Method 3510C/3520C Solid SW-846 Method 3550B	SW-846 Method 8270C	SWL-OE-500/ SWL-OS-500

TABLE 7-1

**SUMMARY OF ORGANIC, INORGANIC, AND MISCELLANEOUS ANALYTICAL PROCEDURES
SOLID AND AQUEOUS SAMPLES
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 2**

Analytical Parameter[1]	Preparation Method	Analytical Method	Preparation/Analytical SOP(s)[2]
Polynuclear Aromatic Hydrocarbons	Aqueous SW-846 Method 3510C/3520C Solid SW-846 Method 3550B	SW-846 Method 8310	SWL-OE-204/ SWL-OL-201
Appendix IX Organochlorine Pesticides	Aqueous SW-846 Method 3510C/3520C Solid SW-846 Method 3550B	SW-846 Method 8081A	SWL-OE-408/ SWL-OP-414
Appendix IX PCBs	Aqueous SW-846 Method 3510C/3520C Solid SW-846 Method 3550B	SW-846 Method 8082	SWL-OE-407/ SWL-OP-415
Appendix IX Herbicides	SW-846 Method 8151A	SW-846 Method 8151A	SWL-OE-411/ SWL-OP-407
Cation Exchange Capacity (solid only)	SW-846 Method 9081	SW-846 Method 9081	SWL-IN-212
Chloride (aqueous only)	EPA Method 325.3	EPA Method 325.3	SWL-IN-505
Gross Alpha and Gross Beta (aqueous only)	EPA 900	EPA 900	SWL-RD-101
Gamma Spectrometry	SWL-RD-125	SWL-RD-125	SWL-RD-125
Hardness (aqueous only)	Standard Methods 2340B Calculation	Standard Methods 2340B Calculation	No SOP Necessary
Dissolved Gases	RSK SOP 175	RSK SOP 175	SWL-OA-107
Total Organic Carbon	Aqueous SW-846 9060 Solid Lloyd Kahn	Aqueous SW-846 9060 Solid Lloyd Kahn	Aqueous SWL-IN-310 Solid SWL-IN-311
Total Suspended Solids	EPA 160.1	EPA 160.1	SWL-IN-600
pH (Soil/sediment only)	SW-846 9045C	SW-846 9045C	SWL-IN-405

1. Refer to Table 1-5 of Section 1.0 for lists of analytes where analyte groups are identified in this table."
2. Laboratory SOPs are included in Appendix C of this QAPP.

8.0 INTERNAL QUALITY CONTROL CHECKS

Field and laboratory QC samples will be analyzed routinely to evaluate overall data quality. This section provides information regarding those internal QC checks. Laboratory QC samples are addressed in Sections 3.2, 6.0, and 8.2, and Table 3-1 of this QAPP. Section 3.2 addresses field and laboratory QC sample types and level of effort; Section 6.0 addresses instrument calibrations; Section 8.2 addresses non-calibration analytical QC of the laboratories. Table 3-1 summarizes analysis frequencies and associated corrective actions for the routine field and laboratory non-calibration QC samples. Tables 4-3, 4-7, 4-9 and 4-11 of Section 4.0 present the numbers of QC samples that are anticipated to be collected in the field.

8.1 FIELD QUALITY CONTROL CHECKS

TtNUS has established a QC program designed to monitor and assess the quality of field work performed during environmental investigations. That program includes the use of various types of QC samples as indicated in Table 3-1. Some of the samples are identified in Table 3-1 as requiring additional sample material to be collected in the field even though the actual field QC check is performed in the laboratory.

The field QC samples consist of field duplicates, trip blanks, equipment rinsate blanks, source water blanks, temperature blanks, and, at the discretion of the FOL, ambient condition blanks. Temperature blanks will be included in each cooler submitted to the laboratory to monitor sample storage conditions prior to arrival at the laboratory. With the exception of temperature blanks, each type of field QC sample undergoes the same preservation, analysis, and reporting procedures as the related environmental samples. The types of field QC samples to be used for this project are described in detail in Sections 8.1.1 through 8.1.6. Target precision and accuracy values, as applicable, for field QC samples are presented in Table 3-1.

8.1.1 Source Water Blanks

Source water blanks are obtained by sampling the analyte-free water and potable water sources used for decontaminating sampling equipment. Source water blanks are used to determine whether the analyte-free water (used for sampling equipment decontamination procedures) or the potable water (used for steam cleaning) may be contributing to sample contamination.

8.1.2 Field Duplicates

Field duplicates will be collected and analyzed for chemical constituents to measure the cumulative uncertainty (i.e., precision) of the sample collection, splitting, handling, storage, preparation, and analysis operations, as well as natural sample heterogeneity that is not eliminated through simple mixing in the field. Field duplicates are two samples prepared by mixing a volume of sample and splitting it into two separate sample containers that are labeled as individual field samples. For ground water and surface water sampling, field duplicates will be generated by collecting individual water samples from the same well or water source in rapid succession rather than splitting a given volume of water. Field duplicates are labeled as individual environmental samples and are not identified to the laboratory as duplicate samples.

8.1.3 Rinsate Blanks

Equipment rinsate blanks or rinsate blanks are obtained under representative field conditions by collecting the rinse water generated by running analyte-free water through sample collection equipment after sampling and decontamination and prior to use. These blanks will be collected to indicate the potential for sample cross-contamination through the use of improperly cleaned sampling equipment.

8.1.4 Trip Blanks

Trip blanks are samples of deionized water that are analyzed for VOCs. These blanks are used to indicate the potential for cross contamination of the samples by VOCs during sample shipment.

8.1.5 Ambient Condition Blanks

Ambient condition blanks are samples of deionized water poured from one container to another in the field to detect the infiltration of airborne contaminants into field samples. These samples will be used at the discretion of the FOL if the FOL believes that such infiltration is a possibility based on site conditions.

8.1.6 Temperature Blanks

Temperature blanks are vials of water inserted into each sample cooler prior to shipment from the field. The temperature of the temperature blank is measured prior to shipment and upon receipt at the laboratory to assess whether samples were properly cooled during transit.

8.2 LABORATORY QUALITY CONTROL CHECKS

SWLO and the ECBC laboratory operate QC programs that ensure the reliability and validity of the analyses performed at the laboratory. The laboratories' QA plans describe the policies, organization, objectives, QC activities, and specific QA functions used by each laboratory. All analytical procedures are documented as SOPs. Each analytical SOP specifies minimum QC requirements for the procedure. As previously noted, SOPs for all analyses to be performed during this investigation are included in Appendix I of this QAPP. Table 7-1 lists the SOPs associated with each analytical procedure. In addition, the laboratories maintain SOPs regarding general laboratory QA operations. Several of these SOPs, as applicable, are also included in Appendix I. The Table of Contents included in Appendix I lists titles and corresponding numbers for all laboratory SOPs contained in the appendix.

Internal laboratory analytical QC requirements beyond those used for instrument calibration QC are highlighted in the remainder of this section. Additional QC requirements, specific to the NFESC QA Program, are also specified, as applicable, for each of the QC checks. Target precision and accuracy values (control limits) are presented in Tables 3-2 through 3-19. The applicable analytical SOPs should be consulted for calibration QC measures.

8.2.1 Laboratory Control Samples

LCSs provide a means to monitor the overall performance of each step during the analysis, including the sample preparation. These are solid samples (soil analyses) or blank spikes (water analyses) that contain concentrations of analytes that are known with a specified degree of certainty.

Based on the requirements of the NFESC QA program, LCSs for metals analyses must contain all analytes of interest, whereas LCSs for multiple-analyte organic methods must contain at least two targeted analytes from each major class of compounds subject to analysis. Target analytes for LCSs are listed in Tables 3-3, 3-5, 3-7, 3-9, 3-11, 3-13, 3-15, 3-17, and 3-19 and the LCSs will incorporate the analytes in these tables.

Based on NFESC QA program requirements, if recovery of an LCS falls outside the control limits (see Tables 3-3, 3-5, 3-7, 3-9, 3-11, 3-13, 3-15, 3-17, and 3-19), the laboratory will reject the data for the analytical batch and take corrective action. The associated samples, extracts, or digestates may be reanalyzed a single time, and if the LCS recoveries meet acceptance criteria, the data will be reported. If LCS analyte recovery is still outside the acceptance limits, the associated samples in the preparation batch will be reprocessed, if sufficient sample is available and holding times have not lapsed. If re-

preparation or reanalysis is not possible, the data will be flagged and the sample delivery group (SDG) narrative will include details of the failed LCS.

8.2.2 Laboratory Duplicates

Laboratory duplicates will be analyzed for metals, radionuclides, and miscellaneous parameters (hardness, TOC, TSS, pH, CEC, chloride, gross alpha, and gross beta) to measure the cumulative uncertainty (i.e., precision) of the sample handling, subsampling, preparation, laboratory storage, and analysis operations within the laboratory, as well as sample heterogeneity that is not eliminated through simple mixing in the laboratory. Laboratory duplicates are two subsamples obtained by the laboratory analyst after mixing the sample. If chemical analysis RPD values or radiological EF values exceed QC limits for laboratory duplicates (Tables 3-4 and 3-18), the analytical process will be investigated to assess whether the observed RPD or EF value is an indication of a deficient analytical system or of excess sample heterogeneity.

8.2.3 Internal Standards and Radioactive Tracers

Internal standards are added to each sample analyzed by GC/MS to ensure that the analysis sensitivity and response are stable during every analytical run. Internal standard area counts for samples and blanks must not vary by more than a factor of two (- 50% to + 100%) from the associated 12-hour calibration standard.

Radioactive tracer nuclides are added to samples undergoing alpha spectroscopic analysis to compensate for sample loss during sample preparation. The tracer recovery acceptance range is 20 percent to 105 percent.

8.2.4 Laboratory Method Blanks

Laboratory method blanks or preparation blanks are an analyte-free matrix prepared and analyzed in accordance with the analytical method employed to determine whether contaminants originating from laboratory sources have been introduced and have affected environmental sample analyses. Analyte-free water is used as a blank for water analyses. A method blank for organic soil sample analysis consists of an aliquot of sand (or in some cases sodium sulfate) that is subjected to the same preparation and analysis as the environmental samples. The solid method blank results are presented on a dry-weight basis assuming 100 percent solids. Native soils devoid of acid leachable metals do not exist. Therefore, a method blank for inorganic soil sample analysis consists of an aliquot of analyte-free water that is subjected to the same preparation and analysis procedures as the environmental samples

undergoing analysis. The aqueous results are normalized to a fictitious soil sample and presented on a dry-weight basis assuming 100 percent solids.

Acceptance criteria for laboratory method blanks and corrective actions for non-compliant results are described in the applicable analytical SOPs included in Appendix I. Under no circumstances should laboratory method blank contaminant values be subtracted from environmental sample analytical results. However, radiological analysis results are corrected for the contribution of background radiation to the measured environmental sample radioactivity.

8.2.5 Matrix Spikes

MSs are environmental samples to which known quantities of analytes are added prior to sample preparation (digestion or extraction). These samples provide information about the heterogeneity of the samples as well as the effect of the sample matrix on the sample digestion and measurement methodology.

Matrix spikes, to conform to NFESC requirements, will contain as many representative analytes as practicable. For many analyses, the spiking list will consist of most of all Target analytes. For SVOC analyses a shortened spiking list will be used (see Table 3-8). Matrix spikes are not used in alpha spectroscopic analyses.

If the MS recovery is not within applicable control limits (Tables 3-2, 3-4, 3-6, 3-8, 2-10, 3-12, 3-14, 3-16, and 3-18), the laboratory will assess the batch to determine whether the spike results are attributable to a matrix effect or are the result of other problems in the analytical process. Based on NFESC requirements, if all the batch QC elements that are not affected by the sample matrix are in control (e.g., method blank, LCS, calibration checks) and if there is no evidence that spiking was not properly performed, the poor spike recovery may be attributed to matrix effects. In this case, the associated data will be flagged, but repreparation and reanalysis will not be required. If any of the batch QC elements which are not affected by the sample matrix are out of control, or if there is any evidence that spiking may have been improperly performed, the MS sample will be reprocessed through the entire analytical sequence. If insufficient sample is available, or if holding times have passed, the laboratory will flag the associated data. Details of noncompliant and laboratory duplicate results will be included in the SDG narrative.

8.2.6 Matrix Spike Duplicates

MSDs are duplicates of matrix spikes and are used for estimating the precision of organic target analyte analyses. They are used in lieu of simple duplicate samples because native environmental samples frequently do not exhibit detectable levels of organic target analytes, which otherwise prevents the calculation of RPD values. Precision criteria for MSDs are presented in Tables 3-2, 3-6, 3-8, 3-10, 3-12, 3-14, 3-16, and 3-18.

8.2.7 Post Digestion Spikes

PDSs are similar to MSs except that the sample digestate, rather than the original soil sample, is spiked. These spikes are analyzed only for metal target analytes if the matrix spike recovery falls outside control limits. Comparing %Rs for PDSs and MSs helps to identify where in the analytical process accuracy problems are occurring. PDSs will contain all target analytes of interest and will be used to assist in determining whether unacceptable MS recoveries are a result of matrix effects.

8.2.8 Surrogates

Surrogates are organic compounds (typically brominated, fluorinated, or isotopically labeled) that are similar in nature to the compounds of concern and are not likely to be present in environmental media. They are spiked into each sample, standard, and method blank before analysis, and are used in organic chromatographic analytical procedures as a check of method effectiveness. Corrective actions for noncompliant surrogate recoveries are presented in the relevant SOPs included in Appendix I of this QAPP. Details of noncompliant surrogate recoveries will be included in the SDG narrative. Accuracy criteria for surrogates are included in Tables 3-2, 3-6, 3-8, 3-10, 3-12, 3-14, and 3-16.

8.2.9 Additional Laboratory QC Checks

Additional internal laboratory QC checks include mass tuning for GC/MS analysis, second-column confirmation for GC and HPLC analyses, source checks for radiological analyses, etc. Specific QC requirements for each of these QC checks are provided in the applicable SOPs included in Appendix I of this QAPP.

9.0 DATA REDUCTION, VALIDATION, AND REPORTING

This section describes the procedures to be used for data reduction, validation, and reporting. Data generated during the course of the field investigations will be maintained in hard copy form in the Administrative Record at NSWC Crane.

9.1 DATA REDUCTION

9.1.1 Field Data Reduction Procedures

All field logs containing observations will be inspected and approved by the FOL. All field observations will be recorded in the logs immediately after observations are made. Limited data reduction will be required in the field.

Concentration measurements will be reported in the units indicated in Table 1-4.

If errors are made in recording or transcribing observations, erroneous observations will be legibly crossed out using a single line, initialed, dated by the field member, and corrected in a space adjacent to the crossed-out entry. The FOL is responsible for assuring that errors are identified and assessed relative to the intent of the QAPP.

Errors judged to affect the use of the sample results within the context of this investigation shall be brought to the immediate attention of the TOM.

9.1.2 Laboratory Data Reduction Procedures

Data reduction will be completed by SWLO and the ECBC laboratory in accordance with the method-specific laboratory SOPs included in Appendix I. In addition, data are reviewed in accordance with the laboratory QA plans.

Laboratory analytical data will be reported using standard concentration units to ensure comparability with previous analytical results. Ground water and surface water sample results will be reported in units of micrograms per liter (µg/L); soil and sediment sample results will be reported on a dry-weight basis in units of micrograms per kilogram (µg/kg) for organic parameters and milligrams per kilogram (mg/kg) for inorganic parameters. Radiological analyses results will be reported in units of picoCuries per liter (pCi/L) for water samples and picoCuries per gram (pCi/g) for soil and sediment samples.

9.2 DATA VALIDATION

Validation of field measurements and laboratory analytical data are presented in this section.

9.2.1 Procedures Used to Validate Field Data

Field measurements will not be subjected to a formal data validation process. Validation of field data will be limited to real time inspection by the FOL of observations relative to actual site conditions and activities. In addition, field technicians will ensure that the equipment used for sample collection is performing adequately via compliance with the applicable SOPs.

9.2.2 Procedures Used to Validate Laboratory Data

One hundred percent of the laboratory analytical data will be subjected to data validation to ensure that the data are of evidentiary quality. Validation of analytical data will be completed by the TtNUS Environmental Chemistry/Toxicology Department located in the TtNUS Pittsburgh office. Final review and approval of validation deliverables will be completed by the department's Data Validation Manager.

Prior to statistical analyses, analytical results will be validated *versus* the applicable analytical methods, the SOPs included in Appendix I, and the requirements of this QAPP. Validation of these data will conform to the U.S. EPA Region 5 Standard Operating Procedures for Validation of CLP Inorganic and Organic Data (U.S. EPA, 1993b/c) and the National Functional Guidelines for Inorganic and Organic Data Review (U.S. EPA, 1994a/b) to the greatest extent practicable. Data validators will review the chemical analytical data packages submitted by the laboratory. The data validators will check that the data were obtained using approved methodology, that the appropriate level of QC and reporting was conducted, and that the results are in conformance with QC criteria.

On the basis of the data validation results, the data validator will generate a report describing detected data limitations. The report will be reviewed internally by the Data Validation Manager prior to submittal to the TOM. Data review will be extended beyond this routine validation by involving the project chemist, statistician, and risk assessor, as appropriate, to examine the data for anomalies (See Section 12.4). This additional review may result in more detailed inspections of the data to determine the cause of, and to rectify, individual anomalies. The impact of data qualifiers on data usability will also be assessed, and any qualifications that are indicated during use of the data shall be documented in the RFI report.

The data validation process will provide an estimate of the number of usable data points. This completeness check will be effected by computing the number of data points that are rejected relative to the total number of data points for a given analyte in a given environmental medium. Completeness is address in Section 12.3.

9.3 DATA REPORTING

9.3.1 Field Data Reporting

Field data will be transcribed from the site logbook or sample logsheets to the electronic database and will be reviewed for accuracy by an independent reviewer.

All records regarding field measurements (i.e., field logbooks, sampling logbooks, and sample logsheets) will be placed in the TtNUS central files upon completion of the field effort. Entry of these results in the database will require removal of these records from the files. Outcards (date, person, subject matter) will be used to document the removal of any such documentation from the files. After database entry is complete, all records will be copied for placement in the TtNUS central files. All original records will be sent to NSWC Crane for inclusion in the final evidence files, as described in Section 5.3.

9.3.2 Laboratory Data Reporting

To achieve the investigation objectives, a confirmational level of analytical quality is needed. This provides the highest level of data quality necessary to address potential risks. These analyses require full documentation of the chosen analytical methods and sample preparation steps, data packages, and data validation sufficient to provide defensible data. QC must be sufficient to define the overall precision and accuracy of these procedures. Therefore, data reported by SWLO for all analytical fractions will be in a CLP-like reporting format. The hardcopy data format generated by the ECBC laboratory may deviate from a CLP-like format but will contain sufficient information to reconstruct the analytical process. Hard copy data deliverables shall be generated at the time of analysis. All pertinent QC data (including raw data and summary forms for blanks, standards analysis, calibration information, etc.), will be provided for all analyses. Case narratives will be provided for each SDG. SOP SWL-GA-106 and the ECBC laboratory SOPs and QA plans (Appendix I) provide further details regarding the information that will be included in hardcopy data packages produced by the laboratories.

Validation will be completed using the hard copy data. After validation the validated data will be reviewed by the Data Validation Manager, and the validation qualifiers will be entered into the electronic database and will be subjected to independent review for accuracy. During this review process, the electronic

database printout also will be compared with the hard copy data to ensure that the hard copy data and electronic data are consistent.

9.3.3 Project Reports

With each round of data collection, data will be summarized and assessed to determine whether additional data collection is required for determining the extent of contamination at the MGBG. A Phase III RFI report will be issued summarizing the findings of the investigation when no more data collection is necessary. If detected, the location, concentrations and boundaries of representative contaminants will be described and depicted on summary maps and diagrams, as appropriate. The results of ground water data evaluations used to estimate ground water contaminant concentrations relative to RBTLs and background values at the MGBG will be summarized. The evaluation of soil data will also be presented summarizing the measured soil concentrations relative to background soil concentrations and RBTLs. Discussions with U. S. EPA Region 5 concerning the need for future investigations will be summarized, and, if appropriate, recommendations for future investigations will be presented.

Recipients of the Phase III RFI report will include EPA Region 5, IDEM, Navy SOUTHDIV, and NSWC Crane.

9.4 DATA ACQUISITION REQUIREMENTS AND DATA MANAGEMENT

The overall data management scheme and specific requirements for database content, format and integrity are presented in the TtNUS CTO-131 Data Management Plan (Appendix F). A brief summary is presented in the following paragraphs.

Data acquisition and management will begin with the identification and collection of past data and newly acquired project samples. The samples will be labeled and tagged, packaged for shipment, and shipped to the analytical laboratory in accordance with TtNUS SOPs provided in Appendix H. The samples will be received at the laboratory and analyzed, the analytical results will be reported by the analyst along with QC check data, and the data will be reviewed within the laboratory, in accordance with laboratory SOPs provided in Appendix I. Data will then be transmitted from the laboratory in both hardcopy and electronic formats according to laboratory SOPs provided in Appendix I. The data deliverable requirements are specified in TtNUS's basic ordering agreements with analytical laboratories. This agreement requires the analytical laboratory to provide data in both hardcopy and electronic form. Upon receipt by TtNUS, the data will be validated, analyzed, assessed, and ultimately archived.

The electronic database will include pertinent sampling information such as sample number, sampling date, and sampling point location, as well as analytical information. Sample-specific MDLs will be reported for nondetected analytes. Units will be clearly summarized in the database and will conform to those identified in Section 9.1.2. The original electronic diskettes and data validation reports for this investigation will be maintained in the Administrative Record at NSWC Crane, and copies will be maintained in TtNUS central files.

10.0 PERFORMANCE AND SYSTEM AUDITS

Performance and system audits will be conducted periodically to ensure that work is being implemented in accordance with the approved QAPP and in an overall satisfactory manner. Some examples of pertinent audits are as follows:

- The FOL will supervise and check daily that the field observations are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and fieldwork is documented accurately and neatly.

- The TOM will maintain contact with the FOL and Data Validation Manager to ensure that management of the acquired data proceeds in an organized and expeditious manner.

Details regarding additional audit responsibilities, frequency, and procedures are provided in the remainder of this section. Field performance and system audits are addressed in Section 10.1. Laboratory performance and system audits are addressed in Section 10.2.

10.1 FIELD PERFORMANCE AND SYSTEM AUDITS

This section presents the responsibilities, frequencies, and procedures associated with internal and external field performance and system audits.

10.1.1 Internal Field Audits

10.1.1.1 Internal Field Audit Responsibilities

In addition to the daily checks performed by the FOL, the TtNUS QAM or designee may conduct an independent performance and system audit of field activities. Such audits are scheduled as part of the NSWC Crane RCRA Environmental Investigation Program, which includes this and other environmental projects, with individual projects being selected for audit by the QAM without the involvement of the TOM. If a formal field audit is conducted for this study, the QAM (or designee) will be responsible for ensuring that sample collection, handling, and shipping protocols, as well as equipment decontamination and field documentation procedures, are being performed in accordance with the approved QAPP and SOPs.

10.1.1.2 Internal Field Audit Frequency

As explained in Section 10.1.1.1, internal field audits are scheduled as part of the NSWC Crane RCRA Environmental Investigation Program, which includes this and other environmental projects. Individual projects are selected for audit by the QAM without the involvement of the TOM.

10.1.1.3 Internal Field Audit Procedure

Internal field audits will be conducted in accordance with the following procedure:

- Prior to an audit, the auditor will prepare a detailed checklist to be used as an auditing guide. An example audit checklist is provided in Appendix G.
- Upon arrival at the audit location, the auditor shall conduct a pre-audit meeting with the responsible management of the organization or project to be reviewed.
- Field audits will include a review of required project documentation (logbooks, sample log sheets, etc.) and field operations (sample COC, sample handling, etc.) to evaluate completeness and compliance with applicable SOPs.
- The audit checklist will be used to record observations including any noted nonconformances.
- A formal post-audit debriefing will be conducted, and potential immediate corrective actions will be discussed.
- The auditor will generate a formal audit report that will address corrective actions. The auditor will provide this report to the TOM.
- The TOM will ensure that all corrective actions are addressed and will provide written verification of corrective action implementation to the auditor.
- The auditor will manage corrective action verification and audit closure.

- The following audit records will be maintained by the QAM:

  - Audit checklists
  - Audit reports
  - Response evaluations
  - Verification of corrective actions
  - Follow-up checklists and audit reports

10.1.2 External Field Audits

10.1.2.1 External Field Audit Responsibilities

IDEM, U.S. EPA Region 5, or both may conduct external field audits.

10.1.2.2 External Field Audit Frequency

External field audits may be conducted at any time during field activities at the discretion of IDEM and U.S. EPA Region 5. If an audit is to be conducted, scheduling should be coordinated through the TtNUS QAM to ensure that personnel and equipment are available as necessary. Personnel being audited may or may not be informed of the impending audit at the discretion and request of the auditing body.

10.1.2.3 Overview of the External Field Audit Process

External audit procedures are at the discretion of U.S. EPA Region 5 and IDEM.

10.2 LABORATORY PERFORMANCE AND SYSTEMS AUDITS

This section presents the responsibilities, frequencies, and procedures associated with internal and external laboratory performance and system audits.

10.2.1 Internal Laboratory Audits

10.2.1.1 Internal Laboratory Audit Responsibilities

The QAO or appropriate designee of the subcontracted laboratory performs routine internal audits of the laboratory. The U.S. Navy, through the NFESC, also conducts internal laboratory audits. TtNUS holds no responsibility for such audits. Performance and system audits of laboratories are coordinated through the NFESC by an independent QA contractor. It is the responsibility of the NFESC and its contractor to

ensure that the subcontracted laboratories comply with good laboratory practices and the general requirements of all analytical services provided by the laboratories.

10.2.1.2 Internal Laboratory Audit Frequency

Internal audits are performed approximately annually at SWLO and the ECBC laboratory. In addition, each laboratory department at SWLO and the ECBC laboratory analyzes blind performance evaluation (PE) samples as described in their applicable SOPs (Appendix I) and QA plans.

The U.S. Navy completes internal laboratory performance and system audits for each contracted laboratory on an 18-month schedule.

10.2.1.3 Internal Laboratory Audit Procedures

Internal systems audits are conducted to detect any problems in sample flow, analytical procedures, or documentation and to ensure adherence to laboratory SOPs. The internal audit procedures for SWLO and the ECBC laboratory are presented in Appendix I.

Internal U.S. Navy laboratory audit procedures, as performed by a Navy contractor, include a pre-screening process that requires review of the laboratory's QA plan, analysis of performance evaluation samples, generation of data deliverables for those samples, an on-site technical systems audit of the laboratory, and satisfactory resolution of all deficiencies and findings.

10.2.2 External Laboratory Audits

10.2.2.1 External Laboratory Audit Responsibilities

IDEM and U.S. EPA Region 5 may perform external audits at their discretion. U.S. EPA Region 5 has recently audited SWLO, for another related U.S. Navy Crane project, and the outcome was favorable. The ECBC laboratory has not been evaluated by U.S. EPA Region 5.

SWLO is also involved in various other external audits and performance evaluation studies throughout the year, as required, to maintain certifications and approvals by other regulatory agencies or programs. The ECBC laboratory is the national approval authority for certifying other laboratories to perform mustard gas and mustard gas degradate analyses.

10.2.2.2 External Laboratory Audit Frequency

U.S. EPA Region 5 or IDEM may conduct an external laboratory audit prior to or during sampling and analysis activities.

10.2.2.3 Overview of the External Laboratory Audit Process

External audit procedures are at the discretion of U.S. EPA Region 5 and IDEM. External laboratory audits may include (but are not limited to) review of laboratory analytical procedures, laboratory on-site audits, and submission of PE samples to the laboratory for analysis.

11.0 PREVENTIVE MAINTENANCE PROCEDURES

Equipment used to collect samples will be maintained in accordance with the manufacturers' operation and maintenance manuals. Equipment and instruments will be calibrated in accordance with the procedures and at the frequency presented in Section 6.0. Preventive maintenance for field and laboratory equipment is addressed in the remainder of this section.

11.1 FIELD EQUIPMENT PREVENTIVE MAINTENANCE

The TtNUS equipment manager and the equipment operator will be responsible for ensuring that equipment is operating properly prior to use and that routine maintenance is performed and documented. Field measurements of pH, specific conductance, temperature, and turbidity in ground water will be measured using an electronic instrument. Maintenance procedures for the instrument are detailed in SOP CTO131-4. Any problems encountered while operating the instrument will be recorded in the field logbook, including a description of the symptoms and corrective actions taken. If problems with the equipment are detected and service is required, the equipment will be logged, tagged, and segregated from equipment in proper working order. Use of the equipment will not resume until the problem is corrected.

11.2 LABORATORY INSTRUMENT PREVENTIVE MAINTENANCE

Proper maintenance of laboratory instruments and equipment is essential. Depending on manufacturers' recommendations, maintenance intervals are established for each instrument. All instruments will be labeled with a model number and serial number, and a maintenance logbook will be maintained for each instrument. Personnel will be alert to the maintenance status of the equipment they are using at all times. Table 11-1 provides a summary of preventive maintenance procedures performed by SWLO and the ECBC laboratory for key analytical instruments and equipment associated with this project.

The use of manufacturer-recommended grades or better of supporting supplies and reagents is also a form of preventive maintenance. For example, gases used in the ICP instruments are of sufficient grade to minimize fouling of the instrument. The routine use of other supporting supplies from reputable manufacturers will assist in averting unnecessary periods of instrument downtime. An inventory of critical spare parts will also be maintained by the laboratory to minimize instrument downtime.

11.3 INSPECTION/ACCEPTANCE REQUIREMENTS FOR SUPPLIES AND CONSUMABLES

All field equipment shall be inspected prior to use to ensure that necessary parts are available. Most equipment planned for use in this project is simple, with few to no moving parts. Therefore, a visual inspection prior to use shall be sufficient to ensure that the equipment is suitable for use. This visual inspection shall occur during mobilization and during each use by the person using the equipment.

Laboratory inspection and acceptance requirements are provided in the laboratory Quality Assurance Plans. The plans present the following specifications for inspection and acceptance of supplies and consumables:

- Requirements to follow individual SOP specifications for grades of chemicals necessary to achieve acceptable analytical performance. SOPs are required to detail the necessary grade of chemicals, including compressed gases.

- Requirements to obtain primary chemical standards from reliable sources that use calibrated glassware in the preparation of the standards and to maintain all certificates supplied with the standards. Emphasis is on obtaining NIST-traceable standards where possible.

- Storage of chemical standards in accordance with applicable SOPs and in a manner that preserves their integrity.

- Routine monitoring of deionized water and other solvents to ensure that analytical systems, samples, and standards are not contaminated.

- Requirements to record the date received and the date opened on each container of chemical used for analysis.

TABLE 11-1

PREVENTIVE MAINTENANCE FOR SWLO AND THE ECBC LABORATORY ANALYTICAL AND SUPPORT INSTRUMENTS NSWC CRANE, CRANE, INDIANA PAGE 1 OF 2

Instrument	Preventive Maintenance	Maintenance Frequency
HPLC (SWLO)		
GC/MS (SWLO)	Change Pump oil.	Every 6 months
	Change Septum	As Needed
	Clean source and rods, check power supplies in QEM box, clean inside and outside of printer, general cleaning of instrument.	As needed
ECBC	Service in accordance with manufacturer specifications under the contractor maintenance agreement.	As needed
GC (SWLO)	Change carrier and make-up gas filters	As needed
	Change trap, clean flame ionization detector (FID) jet, trim column.	As needed
ICP/AES (SWLO)	Service Intercooler.	Annually.
	Rinse and clean nebulizer cap and spray chamber.	Monthly or as needed.
	Clean torch, vacuum filters.	Bi-monthly.
	Profile instrument, examine autosampler tubing and replace as needed.	Daily.
	Empty rinse container, fill rinse water reservoir.	As needed.
Mercury Analyzer (SWLO)	Check and replace pump tubing, check and replace membrane, check and clean windows.	As needed.
Spectro-photometer (SWLO)	Clean sample compartment.	Semi-annually.
	Check wavelength calibration.	Annually.
Ion Chromato-graph (SWLO)	Replace pump seals.	Annually.
	Lubricate analytical pump motor.	Semi-annually
	Check chromatography module and all gas lines for leaks.	Every run
	Clean conductivity detector cell electrodes, check cell calibration.	Monthly
	Replace bed supports, clean columns, clean membrane supressor, replace autosampler pipette tip.	As needed.

TABLE 11-1

PREVENTIVE MAINTENANCE FOR SWLO AND THE ECBC LABORATORY ANALYTICAL AND SUPPORT INSTRUMENTS NSWC CRANE, CRANE, INDIANA PAGE 2 OF 2

Instrument	Preventive Maintenance	Maintenance Frequency
Alpha Spectrophoto-meter (thorium isotopes, gross alpha, gross beta) (SWLO)	Clean detectors	As needed
Ion Analyzer (SWLO)	Clean RAS sampler and sample trays Flush manifold Clean proportioning pump rollers Replace flared tubing Check / Replace O-Rings	Daily Daily Weekly Monthly Monthly / As Needed
TOC Analyzer (SWLO)	Replace pump tubing. Change other tubing, change furnace tubes, change LiOH tube, change tin trap, adjust optical balance, change septum, change permeation dryer tubing Change IR filter screen, change gas tubing	Each run. As needed Check monthly.
Refrigerators (SWLO)	Monitor temperature	Daily.
Ovens (SWLO)	Monitor temperature	Daily.
Balances (SWLO) (ECBC)	Certify Class S weights Routine service by outside party Certify and/or service in accordance with the Test, Measurement and Evaluation Division of the Army Calibration System.	Annually. Annually. Annually.
Thermometers (SWLO) (ECBC)	Calibrate against NIST thermometer Recertify NIST Thermometer Certify and/or service in accordance with the Test, Measurement and Evaluation Division of the Army Calibration System.	Annually. Annually. Annually.
Micropipets (SWLO)	Check gravimetrically Clean o-rings	Monthly. As needed.

12.0 SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY, AND COMPLETENESS

Compliance with quantitative QC objectives for laboratory accuracy and precision as outlined in Tables 3-2 through 3-19 will be evaluated during data validation (Section 9.0). Compliance with completeness objectives for field and laboratory data will be computed. Sections 12.1 and 12.2 present equations to be used for computing accuracy and precision values, respectively. Section 12.3 describes the means and presents the equation for determining completeness. Section 12.4 addresses the overall data assessment process.

In general, data validation requires that data be evaluated batch by batch based on the results of quality indicators for the respective batches. Section 12.4 presents additional data quality considerations to be evaluated after data validation. These considerations are designed to incorporate data quality factors that extend beyond evaluation of the simple quantitative estimators for precision, accuracy, and completeness.

12.1 ACCURACY ASSESSMENT

Sample collection accuracy cannot be evaluated because there is no standard by which to judge such accuracy. Instead of a quantitative evaluation of sample collection accuracy, compliance with field SOPs as described in Appendix H will be the metric. Background comparisons of data generated by similar sampling and analysis methods incorporate similar biases and are expected to be directly comparable without any adjustments or compensations.

The accuracy of chemical analyses will be assessed through the use of surrogate spikes, MSs, PDSs, LCSs, calibration check standards, internal standards, and blanks. Blanks will be used to infer the potential for positive biases because of contamination. To assure the accuracy of the analytical procedures, at least 1 of every 20 environmental samples will be spiked with known amounts of target analytes (i.e., MSs) prior to preparation for analysis. The spiked samples will be analyzed and the concentrations of each target analyte observed in the spiked sample will be compared to the reported value of the analyte in the unspiked sample to determine the %R of the analyte. Control charts are plotted by the laboratory for each target analyte and are kept on matrix- and analyte-specific bases. The %R for a spiked sample is calculated by using the following formula:

$$\%R = \frac{\text{Amount in Spiked Sample} - \text{Amount in Sample}}{\text{Known Amount Added}} \times 100\%$$

As discussed in Section 3.2.3, LCSs and surrogate spikes are also analyzed to assess accuracy. The %R calculation for LCSs and surrogate spikes is as follows:

$$\%R = \frac{\text{Experimental Concentration}}{\text{Certified or Known Concentration}} \times 100\%$$

Radioactive Th-229 is used as a tracer in alpha spectroscopic measurements. Results are adjusted based on the recovery of Th-229 and matrix spikes are not used in this analysis.

12.2 PRECISION ASSESSMENT

As presented in Section 3.1.3, laboratory duplicate samples (for inorganic analyses) and MSD samples (for organic analyses) will be prepared and analyzed at a minimum frequency of 1 per every 20 environmental samples per matrix. As described in Section 3.1.2, field duplicate samples also will be collected at a minimum frequency of 1 per 10 environmental samples per matrix. The RPD between a sample or MS (Sample 1) and its duplicate or MSD (Sample 2) is calculated for chemical analyses using to the following formula:

$$RPD = \frac{|\text{Amount in Sample 1} - \text{Amount in Sample 2}|}{0.5\,(\text{Amount in Sample 1} + \text{Amount in Sample 2})} \times 100\%$$

For radiological analyses, the RPD is replaced by the Equivalency Factor, EF, which is computed using the following equation:

$$EF = \frac{|\text{Result} - \text{Duplicate Result}|}{\sqrt{(SE)^2 + (DE)^2}}$$

where: SE = error estimate for the sample result
DE = error estimate for the duplicate sample result

12.3 COMPLETENESS ASSESSMENT

Completeness for this project will be determined based on the number of sample results for each target analyte and each sample type that are usable as determined through data validation and data assessment. Data values rejected during data validation (indicated by an "R" or "UR" flag) will be considered unusable unless additional review and documentation by one or more technical team members demonstrates that the rejection was erroneous. To monitor completeness, the number of usable, valid results for each soil type and analyte will be counted and compared to the completeness objectives in Sections 3.3.2 and 3.3.3.

Percent completeness will be calculated using the following equation:

$$\%\,\text{Completeness} = \frac{(\text{number of valid measurements})}{(\text{number of measurements planned})} \times 100\%$$

Because the many parameters to be measured for this project are interrelated in many different ways, a single completeness criterion cannot be established for the project. Instead, the ability to attain project objectives will be evaluated at the end of each sampling round by how effectively the necessary decisions and data evaluations can be made.

12.4 DATA ASSESSMENT

The assessment of data obtained from this investigation is a critical part of determining the next step in data collection and decision making. It must be determined whether the data are of appropriate type, quality, quantity, and representativeness to support the project objectives. The effect of the loss of data deemed unacceptable for use, for whatever reason, will be evaluated.

Radiological thorium analyses will be reported in radiological units of measurement. These measurements are related to the chemical concentration through specific activities and isotopic relative natural abundances. All naturally occurring thorium is essentially 100% Th-232 (i.e., Th-232 = 100% natural relative abundance). Traces of other thorium isotopes do exist and can be measured, but they are not present in appreciable quantities in natural thorium. Presumably, any thorium used to manufacture thorium nitrate is purified naturally occurring thorium. Using this information and the specific activity of natural Thorium (0.22 uCi/g Th-Nat) the measured thorium activity can be related to total thorium concentration using the following equation:

$$\text{Total Th Concentration, } \frac{\text{g Th} - \text{Nat}}{\text{g sample}} = \frac{\text{uCi}}{\text{g sample}} \times \frac{\text{g Th} - \text{Nat}}{0.22 \text{ uCi}}$$

Where Th-Nat is natural Thorium (specific activity = 0.22 µg/Ci/g)

12.4.1 Reconciliation with Data Quality Objectives

Field data will be examined immediately after generation for errors. Laboratory data will be examined upon receipt from the laboratory in a series of evaluations. The first step will be a data verification and validation as described in Section 9.0.

After data validation, the data will be reconciled with DQOs to determine whether sufficient data of acceptable quality are available for decisionmaking. In addition to the evaluations described in Sections 12.1 through 12.3, a series of inspections and statistical analyses will be performed to estimate several of the data set characteristics. The statistical evaluations will include simple summary statistics for target analytes, such as the maximum concentration, minimum concentration, number of samples exhibiting no detectable analyte, the number of samples exhibiting detectable analytes, and the proportion of samples with detectable and undetectable analytes. The data will be presented in a tabular format similar to that of Table 1-2. These inspections and statistical analyses will be designed to:

- Identify deviations, if any, from the field sampling SOPs (inspection).
- Identify deviations, if any, from the laboratory analytical SOPs (inspection).
- Identify deviations, if any, from the QAPP (inspection).
- Identify deviations, if any, from the data validation process (inspection).
- Identify and explain the impacts of elevated MDLs and IDLs (inspection).
- Identify unusable data (i.e., data qualified as "R") (inspection).
- Evaluate project assumptions such as "ground water flow is to the northwest" (inspection).
- Characterize data set distributions (e.g., Shapiro-Wilk W test) if enough data are available (statistics).

- Identify unanticipated data set characteristics such as a laboratory variance greater than the sampling variance (i.e., ANOVA, *t*-test) if enough data are available (statistics).

- Identify and evaluate potential data outliers (95% confidence goodness-of-fit test on probability plot data). The plotted data will be transformed, if necessary, depending on the observed distribution. (statistics).

- Evaluate adherence to investigation objectives and decision rules (inspection and statistics, as applicable).

- Ensure completion of corrective actions (inspection).

- Evaluate effects of deviations from planned procedures and processes on the interpretation and utility of the data (inspection and statistics, as applicable).

- Identify the existence of remaining data gaps (inspection/statistics).

For statistical comparisons and mathematical manipulations, analytes that are not detected at the applicable sample-specific MDL will be represented by a concentration equal to one-half the sample-specific MDL.

Statistical tests for outlier validity will be based on "Procedural Guidance for Statistically Analyzing Environmental Background Data" (NFEC, 1998). Potential outliers will be removed if a review of field and laboratory documents indicates that the results are true outliers. If no identifiable reason for the outlier can be identified, the datum will not be removed from the data set.

If necessary, investigation objectives may be revised in anticipation of additional data collection.

The suitability of any given statistical test will be assessed based on the completeness of the data sets and the conditions observed at the site. For example, when a single data value is available for soils or water samples at a given sampling location, statistical tests cannot be conducted for that individual sampling location. However, pooling of data across sampling locations may be possible and, if logical to do so, may be implemented at the discretion of the TOM. For example, when evaluating COPCs, multiple soil sample results of a given depth and grain size within a depositional environment may be pooled for statistical comparison to the background data set from soil of the same depth, grain size and depositional environment. Statistical testing will generally be conducted at the 5% significance level. Statistical

testing at other significance levels may also be warranted to provide perspective on the results of testing a 5% significance. If other significance levels are used, they will be supported with rationales for their use.

13.0 CORRECTIVE ACTION

The TtNUS QA/QC program requires that any and all personnel noting conditions adverse to quality should report these conditions immediately to the TOM and QAM. These parties, in turn, are charged with implementing appropriate corrective action in a timely manner. It is ultimately the responsibility of the QAM to document all findings and corrective actions taken and to monitor the effectiveness of the corrective measures performed. A brief summary of corrective actions for some specific field and laboratory QC check samples is presented in Section 3.0, Table 3-1.

13.1 FIELD CORRECTIVE ACTION

Field nonconformances or conditions adverse to quality must be identified and corrected as quickly as possible so that work integrity or product quality is not compromised. The need for corrective action may arise based on deviations from project plans and procedures, adverse field conditions, or other unforeseen circumstances. Corrective action needs may become apparent during the performance of daily work tasks or as a consequence of internal or external field audits.

Corrective action may include resampling and may involve amending previously approved field procedures. Minor modifications to field activities, such as the collection of additional samples, will be initiated at the discretion of the FOL, subject to on-site approval by NSWC Crane personnel. Major modifications, such as the elimination of a sampling point or other situations that affect compliance with or achievement of DQOs, must be approved and documented via a Field Task Modification Request (FTMR). Approval of the corrective action will be obtained by the U.S. Navy (in conjunction with U.S. EPA Region 5 and IDEM). The FOL is responsible for initiating FTMRs. A FTMR will be prepared for all deviations from the project plan documents, as applicable. An example FTMR is provided in SOP CTO131-4 (Appendix H). Copies of all FTMRs will be maintained with the on-site project planning documents and will be placed in the final evidence file.

13.2 LABORATORY CORRECTIVE ACTION

In general, laboratory corrective actions are warranted whenever an out-of-control event or potential out-of-control event is noted. The specific corrective action taken depends on the specific analysis and the nature of the event. Generally, the following occurrences alert laboratory personnel that corrective action may be necessary:

- QC data are outside established warning or control limits
- Method blank analyses yield concentrations of target analytes above acceptable levels
- Undesirable trends are detected in spike %Rs or in duplicate RPDs
- There is an unexplained change in compound detection capability
- Inquiries concerning data quality are received
- Deficiencies are detected by laboratory QA staff during audits or from PE sample test results

Any corrective action taken above the analyst level that cannot be performed immediately at the instrument will be documented. Corrective actions typically are documented for out-of-control situations in accordance with laboratory procedures.

Laboratory corrective actions must be documented and included as part of the final evidence file. The TtNUS TOM will be informed of all major corrective actions that do not bring DQO-related nonconformances into conformance with project DQOs. The TtNUS TOM will advise all levels of project management in accordance with Section 14.0 of this QAPP.

13.3 CORRECTIVE ACTION DURING DATA VALIDATION AND DATA ASSESSMENT

The need for corrective action may become apparent during data validation, interpretation, or presentation activities. Rework (i.e., resampling or reanalysis), a change in work procedures, or additional or refresher training are possible corrective actions relevant to data evaluation activities. The TOM will be responsible for approving the implementation of a corrective action and ensuring that it is documented appropriately. Analytical data may be qualified during data validation to alert data users of the potential that particular analytical results are potentially deficient relative to expected performance standards. Such validation practices are described in Section 9.2. When conducting data assessment for project decisionmaking, a number of situation-dependent qualifications of data or decisions are possible. The number of possible situations or conditions precludes enumeration of all possible corrective actions; however the approach used to identify and impose such qualifications is described in Section 12.4.

14.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

QA reports to management will be provided in four primary formats during the course of this investigation: data validation reports, reports summarizing accomplishments and QA/QC issues during the field investigation, project-wide progress reports, and laboratory QA reports. The report frequencies, content, preparers, and recipients are summarized in Table 14-1.

Data validation reports will address all major and minor laboratory noncompliances as well as noted sample matrix effects. In the event that major problems occur with the analytical laboratory (e.g., repeated or extreme holding time exceedances or calibration noncompliances, etc.), the Data Validation Manager will notify the TOM, QAM, Program Manager, Technical Coordinator, and Laboratory Services Coordinator. Such notifications (if necessary) are typically provided via internal memoranda and are placed in the project file. These reports contain a summary of the noncompliance, a synopsis of the impact on individual projects, and recommendations regarding corrective action and compensation adjustments. Corrective actions for major noncompliances are initiated at the program level.

The FOL will provide the TOM with daily verbal field progress reports during the course of the sampling event. These reports will explain accomplishments, deviations from the QAPP, upcoming activities, and a QA summary. The TOM provides a monthly progress report to the Navy which addresses the project budget, schedule, accomplishments, planned activities, and QA/QC issues and intended corrective actions.

SWLO and the ECBC laboratory will provide a QA report to TtNUS if QC limits are updated or if other significant plan deviations resulted from unanticipated circumstances. Because MDLs will be included in the analytical data packages for NSWC Crane samples, it is not necessary for the laboratories to include updated MDLs in their QA reports unless the updates result in MDLs which exceed RBTLs.

TABLE 14-1

SUMMARY OF REPORTS
NSWC CRANE, CRANE, INDIANA

Report	Content	Preparer	Frequency of Submittal	Recipient(s)
Data Validation Report	All major and minor laboratory noncompliances as well as noted sample matrix effects.	Data Validation Manager or designee	Per SDG	TOM, project file
Major Analysis Problem Identification Report (internal memorandum)	Notification of persistent or major problems with analytical laboratory performance. Summary of the noncompliances, a synopsis of the impact on the project, and recommendations regarding corrective action and compensation adjustments.	Data Validation Manager or designee	When persistent analysis problems are detected	TOM, QAM, Program Manager, Technical Coordinator, Laboratory Services Coordinator, project file
Project Monthly Progress Report	Summary of the project budget, schedule, accomplishments, planned activities, and QA/QC issues and intended corrective actions.	TOM	Monthly for duration of project	Navy, project file
Field Progress Reports	Accomplishments, deviations from the SAP, upcoming activities, and a QA summary.	FOL	Daily, verbal, during the course of sampling	TOM
Laboratory QA Report	Summary of updated QC limits or significant deviations from planned activities/performance.	SWLO and ECBC laboratory	When QC limits are updated or when other significant plan deviations result from unanticipated circumstances	TtNUS, project file; U.S. EPA Region 5, if changes in RLs cause them to exceed RBTLs or if QAPP deviations impact DQOs

SDG = Sample Delivery Group
TOM = Task Order Manager
QAM = Quality Assurance Manager
RL = Reporting Limit
FOL = Field Operations Leader
SAP = Sampling and Analysis Plan

15.0 QAPP ADDENDUM: GEOPHYSICAL ANOMALY EXCAVATIONS

15.1 PROBLEM STATEMENT

During the 1995 USACEWES geophysical survey at the MGBG, two anomalies were detected and mapped (USACEWES, 1997). Although the anomalies are identified in the historical record as debris, they remain a concern for NSWC Crane because of their presence at the site. The concern is that some people could believe that the anomalies are mustard gas bombs or ordnance-related debris.

Consequently, the scope of work for the MGBG environmental investigation was expanded to include removal of the objects causing the anomalies. There is no expectation that the anomalies are associated with chemical or radiological contamination, although the potential for such association exists. The excavations are a voluntary action undertaken by the Navy to provide additional assurance that conditions at the MGBG are, or can be rendered, protective of human health and the environment.

The RFI QAPP, which comprises the bulk of this document, was developed under CTO 131 and was made final in May, 2001. CTO 158 is the vehicle under which the field work to implement the CTO 131 QAPP was planned to be conducted. The expanded scope of work to include the anomaly investigations was issued under CTO 158A. To maximize efficiencies, the anomaly investigations and the RFI were combined into one field effort. For convenience the CTO 158/158A pair are hereafter referred to as CTO 158.

All CTO 158 activities, if not specified explicitly in this addendum, are to be carried out in accordance with requirements and procedures delineated in the CTO 131 QAPP, and the attendant health and safety plan which has also been revised to address the anomaly excavations. The cover and title pages of the QAPP and HASP have been changed to read "CTO 131 and 158" to indicate that they are hybrids of these CTOs. All cross-references to document sections are cross-references to sections of the CTO 131 QAPP unless explicitly stated otherwise.

The protocols delineated below are subject to change based on field conditions and the best professional judgment of the Senior UXO Specialist or the SSO, with concurrence from the TOM and the Navy. All changes must be documented in the field log book.

15.2 PURPOSE

This addendum governs excavation within the MGBG (just outside the Primary Burial Area (PBA)) to uncover the two anomalies detected in the 1995 USACEWES geophysical survey, followed by removal and disposal of the contacts generating the anomalies. If anomalies are associated with ordnance (this is not expected), stop operations and re-evaluate with the Navy and EPA Region 5. Note the PBA is where documented HD bomb burial occurred and where HD bombs were found. Thorium or thorium-containing material (radioactive) was also buried in the PBA. Neither of the two geophysical contacts is located within the PBA but the large (horse trough) contact is located on the southern edge of the PBA.

15.3 RESPONSIBILITIES

The UXO Supervisor, who is responsible for the control and operation of the UXO Excavation Team, will supervise all excavation and trenching operations. UXO Specialists will perform all excavation and trenching work. All personnel working at an excavation site will have additional training in these procedures and in the hazards and precautions necessary to safely perform excavation work. The Task Order Manager (TOM) will have a copy of 29 CFR 1926 on hand at the project site.

- Approval – The TOM will approve all excavation and trenching operations and indicate the time the excavation and trenching activities will occur. Immediately prior to performing the excavation and trenching, clearance will again be obtained, by radio or other means, from the UXO Supervisor in charge of the excavation.

- Access Security – All access routes into the site will be secured by barricades to prevent access during excavation and trenching operations. (Other means may be used to secure the area if so directed by the TOM.)

- Visual Check – A visual check of the site area will be performed prior to initiating the excavation and trenching operations to ensure the area is clear of personnel.

- All Clear – Immediately upon completion of the excavation and disposal, notify the TOM of the results of the operation (successful or if hazards still exist). If successful, the TOM will notify other work sites and other personnel of the "all clear" signal.

15.4 REQUIRED EQUIPMENT/ITEMS

The following is a list of the equipment required for the excavations:

15.4.1 Geophysical survey instruments as specified in SOP CTO 131-1.

15.4.2 Shovels, picks, or other manual digging equipment suitable for excavating shallow anomalies.

15.4.3 Earth moving machinery (e.g., a backhoe) for excavating deep anomalies.

15.4.4 Field screening equipment as specified in QAPP Table 4-1 and SOPs CTO131-2, CTO131-3 and CTO131-4.

15.4.5 Decontamination equipment as specified in QAPP Section 4.11.

15.4.6 Personal Protective equipment as specified in the HASP.

15.4.7 Communication equipment as specified in the HASP.

15.5 SAFETY REQUIREMENTS

The following safety requirements will be enforced at all times.

15.5.1 The Health and Safety Plan (HASP) will apply to all excavation activities. In the event that the HASP must be modified, the modifications will be documented.

15.5.2 Only qualified UXO personnel will be allowed in the area during excavation operations. A two-person team must be in the area. UXO qualifications are contained in USACE, Data Item Description (DID) OE-025, Personnel/Work Standards (USACE, 1986).

15.5.3 If an excavation is greater than 4-foot deep, personnel will not enter the excavation unless the excavation is properly shored or sloped.

15.6 OVERALL EXCAVATION STRATEGY

This section explains the general excavation strategy for shallow anomalies. Refer to Section 15.7.0 for the specific excavation instructions.

15.6.1 General Excavation and Trenching Procedures – Depths Estimated at 12 Inches or Less

This section explains the general excavation strategy for shallow anomalies. Refer to Section 15.7.0 for the specific excavation instructions.

If the magnetometer reading indicates that the top of suspected UXO is at a depth of 12 inches or less, then hand excavation methods will be used.

Using a small shovel, trenching tool or some other tool that is easily controlled by hand, carefully remove the dirt or debris from the top of the "hit". Once the item(s) is/are found, use your hand and, as necessary, a small brush or wood spatula to remove enough dirt or debris from around the item to be able to identify the item. After all anomalies from the excavation are removed and/or disposed of, the bottom of the excavation will be sampled and the samples will be submitted to SWLO and the ECBC laboratory for analyses (See Step 15.7.2.8). The UXO Supervisor will determine disposition of the item.

15.6.2 General Excavation and Trenching Procedures – Depths Estimated at More Than 12 Inches

This section explains the general excavation strategy for deep anomalies. Refer to Section 15.7.0 for the specific excavation instructions.

Anomalies located at depths greater than 12 inches may be excavated using heavy equipment at the discretion of the UXO Supervisor.

Prior to performing excavation using heavy equipment, the locations of underground and overhead utility installations such as sewer, electric, natural gas, telephone, fuel and water must be identified. Utilities will be cleared by NSWC Crane prior to the start of the excavations.

Care must be taken not to damage the environment when performing heavy equipment operations. When a tree, building, boulder, historical site, above ground utility or other encumbrance affects the safety of personnel excavating an anomaly, the TOM will be contacted to coordinate appropriate actions with the NSWC Crane base contact. When allowed, encumbrances will be removed prior to any excavation or trenching work.

After all anomalies from the excavation are removed and/or disposed of, the bottom of the excavation will be sampled and the samples will be submitted to SWLO and the ECBC laboratory for analyses (See Step 15.7.2.8). The excavation will then be backfilled and regraded.

Earth moving machinery (EMM) will only be used for excavations when the top of the geophysical contact is estimated to be deeper than 12 inches below ground surface. When EMM is used, it will only be operated in areas that are swept and cleared. While excavating, the use of EMM will be conducted only to reach a position of approximately 12 inches from the suspected UXO. This position will be obtained by excavating layers of no more than 12 inches. Between excavating each layer, the magnetometer will be used to estimate the depth of the "hit". Once it is estimated that the item is at a depth of slightly more

than 12 inches, the procedures for excavating items from depths of less than 12 inches (as judged by the UXO Supervisor), as outlined previously, will be used.

When the EMM is being activated, all other personnel other than the operator will be positioned at a safe location, unless the UXO Supervisor determines, for safety reasons, to guide the EMM operation.

The EMM will be moved to a safe location prior to starting manual excavation procedures.

If more than one EMM is operating at a work site, the EMMs will be separated by at least 100 meters.

All shoring, if required, will be supervised by a qualified engineer and follow the requirements as set forth in 29 CFR 1926 Subpart p.

15.7 SPECIFIC TRENCHING REQUIREMENTS

The review of historical data indicates that there is a potential for the anomalies that are to be excavated to be contaminated with UXO, residual mustard gas and radioactive materials. Special precautions and procedures will be followed during the excavation.

15.7.1 PERSONNEL

UXO qualified personnel consisting of a two person team, will conduct the excavation. The SSO will collect samples periodically to screen the excavated soils for VOCs, HD and radioactivity. All non-UXO personnel will be evacuated to a safe distance. Excavation operations will be stopped when other personnel are allowed into the area for monitoring. Only when the area is clear, will excavation operations resume. During the excavation operation, even when stopped, essential personnel only will be allowed into the area.

15.7.2 EXCAVATION BY LIFTS AND HEALTH AND SAFETY SCREENING

The excavation of the anomalies will be accomplished in 12-inch lifts until the objects causing the anomalies are encountered, and identified. To accomplish this in a safe manner, the following procedures will be utilized:

15.7.2.1 The anomalies will be re-acquired by geophysical methods and marked. QAPP Figure 4-1 illustrates the approximate anomaly locations as identified in the 1995 USACWES geophysical survey.

15.7.2.2 The two anomaly areas and the surrounding work areas will be surface-cleared by UXO qualified personnel. If UXO is encountered, proper notification will be made to the FOL, and the area will be evacuated. Personnel will not be allowed back into the area until the all clear is given by the Senior UXO person on site.

15.7.2.3 After the surface clearance is complete, soil samples will be collected down to a depth of approximately 12 inches using a hand auger. These samples will be screened for HD, radioactivity and VOCs, in accordance with the Health and Safety Plan. If the samples from this first 12 inches of soil cover are "clean" (i.e., no "hits" for contamination), the soil will be set aside to be used as clean cover for backfilling, and work will progress to the next step. If there are positive "hits" the work will be stopped, the area will be evacuated, and proper notifications made to the TOM and the NSWC Crane base contact. Work will not resume until a plan of action has been determined and the notice to proceed is given by the TOM.

Note:
Soil exhibiting positive hits will be considered "dirty" and will be segregated from clean soils by placing it in a drum or other suitable container.

Note:
It is anticipated that three soil samples per lift will be collected and screened in the large anomaly area. Only one sample per lift will be collected from the small anomaly area. This screening strategy may be changed with FOL approval based on site conditions. Factors to consider include: depth of anomaly, area being excavated, number of "hits" for any of the screened analytes (radiation, HD and VOCs).

15.7.2.4 If all screening indicates that the lift of soil that was just removed is clean, the clean soil will be placed on plastic sheeting to be returned to the excavation upon completing the investigation.

15.7.2.5 If continuation of excavation is permitted in accordance with Step 15.7.2.3, excavation will proceed in 12-inch lifts **until the floor of the excavation is within slightly more than 12 inches of the top of the item to be removed.** Repeat Steps 15.7.2.2 through 15.7.2.4 until the item(s) causing the anomaly is (are) located and identified. **The last 12-inch lift of soil will be removed manually (See Section 15.6.1)** to ensure that EMM does not impact the item(s) to be removed.

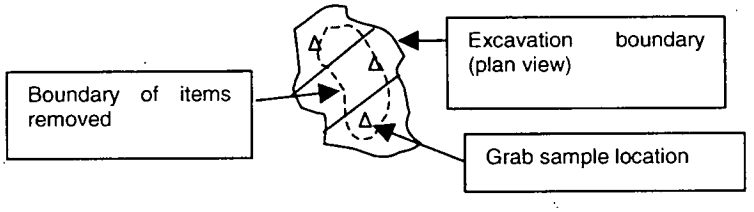
15.7.2.6 IDW will be managed in accordance with QAPP Section 4.12.

15.7.2.7 After the items are identified, and if they can be moved safely, they will be removed from the excavation and prepared for proper disposal. If the items are not safe to move, the area will be evacuated, proper notification will be made to the NSWC Crane base contact and a plan of action will be developed for addressing the removal of the items.

15.7.2.8 When an excavation has been cleared of all items:

15.7.2.8.1 The excavation floor will be sectioned approximately into thirds.

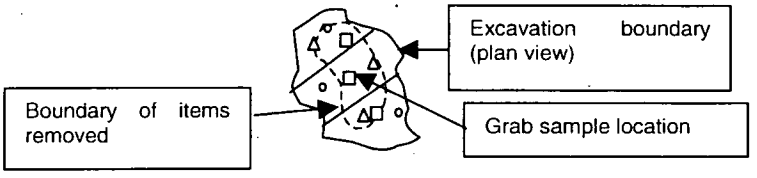
15.7.2.8.2 A grab sample will be collected from each of the thirds immediately below or adjacent to the geophysical contacts that have been removed. VOC samples will be removed from the grab sample indicating the greatest VOC concentration as determined by field screening. The remaining grab sample aliquots will be mixed in approximately equal proportions (determined by visual inspection) in the field to form a composite soil sample. The objective of the sampling will be to collect a representation of the excavation floor immediately below and adjacent to the removed contact(s). The sampling may follow a randomization or may be selected using professional judgment. If professional judgment is used, the sampler shall ensure that the composite sample represents the soils below and adjacent to the removed items (with wide spatial coverage of the bottom of the excavation) as shown in this example figure:



Note:

If an excavation is greater than 4-feet deep the sampling will occur by removing samples from the bucket of the excavator rather than entering the hole. The intent will be to represent the average contaminant concentrations from the floor of the excavation immediately below and adjacent to the items(s) removed from the excavation. Thus, the backhoe bucket should collect such representative soil samples and at least three grab samples should be collected from the bucket and composited.

15.7.2.8.3 This composite sampling will be done only once in the small excavation. In the large excavation the composite sampling will be repeated two times to yield three composite soil samples. The next figure shows an example of how composite samples might be allocated (each shape represents grab samples for a different composite sample).



15.7.2.8.4 Samples will be identified in accordance with SOP CTO131-7 and will be screened for radioactivity, HD, and VOCs in accordance with SOPs CTO131-2, CTO131-3, CTO131-4, respectively. Sample preservation and container requirements can be found in QAPP Table 4-12.

15.7.2.8.5 Each of the four composite soil samples and the four individual grab samples will be submitted to SWLO or ECBC for analysis as indicated in the table below:

Fixed Laboratory Soil Sample Analysis Scheme

	Sample Type		
Analyte Fraction	**Composite Sample**	**Individual Grab Sample**	**No. of Samples**
VOC	NA	SWLO	4, (4 EnCore samplers per sample)
SVOC	SWLO	NA	4
bis(2-chloroethyl sulfide) (mustard gas) and its degradation products	ECBC	NA	4
Metals	SWLO	NA	4
pH	SWLO	NA	4
Thorium-228, 230, 232	SWLO	NA	4

ECBC = Edgewood Chemical Biological Center laboratory
NA = Not Applicable
SVOC = Semivolatile organic chemical
SWLO = Southwest Laboratory of Oklahoma
VOC = Volatile organic compound

15.7.2.8.6 The samples will be packaged and shipped to the analytical laboratory in accordance with QAPP Section 4.8 and SOP CTO131-24.

Note:

Herbicides, pesticides, PCBs, explosives, cation exchange capacity, and total organic carbon, although required analyses for other MGBG soil samples, are excluded from the analysis scheme because they do not have a significant impact on hazardous waste classification and or are not expected to be present in hazardous concentrations in these soil samples. Gamma spectrometry is excluded because there is no indication that gamma spectrometric radionuclides other than those related to natural thorium were buried at the MGBG. If the sample analyses from the PBA (which include gamma spectrometry) indicates otherwise, this logic will be re-examined. The results of the composite sample analyses will be used to characterize the soils from the excavations to determine whether the soils are hazardous waste and must be re-excavated for disposal.

Note:

It is believed that the soils at the bottom of each excavation best represent the level of contamination of the soils in the pit because contaminants should have washed into the deeper soils from any contamination associated with the items that were removed. For each excavation, the analytical results will be averaged across all samples collected from the floor of the excavation. These average concentrations will be compared to TCLP limits after adjusting for the difference between the use of total analysis results and the regulatory TCLP limits (i.e., TCLP limits X 20). Exceedance of the adjusted TCLP limits is not expected, hence the decision to replace the soils in the excavations pending analysis. If any average analyte concentrations exceeds its TCLP limit in an excavation, the soil will be removed from the excavation(s) and disposed of as hazardous waste.

15.7.2.9 After the excavation has been cleared of all items and sampling of the excavation floor is completed, the excavation will be back filled. Soil from the excavation will, if clean (as determined through field screening), be used as back fill. If the soil is not clean, back fill material from another source may be obtained. Alternatively, especially if the excavation is shallow, the area may be regraded to match surrounding grade. For deeper excavations (i.e., excavations that would leave a noticeable depression when regraded), the FOL and NSWC Crane Base Contact will be responsible for deciding the best restoration option (e.g., simple regrading or backfilling with clean fill from another source).

15.7.2.10 At a minimum, each corner of each excavation will be surveyed to determine the northing and easting coordinates for incorporation into the NSWC Crane GIS database. Surveying will meet the technical requirements of QAPP Section 4.10.

15.8 EQUIPMENT DECONTAMINATION

Refer to QAPP Section 4.11 for decontamination requirements.

15.9 SCHEDULE

The Anomaly Excavations are planned to occur during the third shift of field work. The excavations and sampling are planned for a two-day duration. This schedule may be adjusted to optimize efficiencies in the field work.

REFERENCES

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APPENDIX A

SITE RECONNAISSSANCE REPORT
AND
MEMORANDA SUMMARIZING MUSTARD GAS AND ORDNANCE STATUS OF THE MUSTARD GAS BURIAL GROUND

Part 1. Site Reconnaissance Report, NSWC Crane Mustard Gas Burial Ground, 21 January, 2000, Tetra Tech NUS, Inc., Final. Note: Photographs are on file at TtNUS and will become part of the final evidence file upon completion of the project.

Part 2. Memorandum (with two attachments) from Mr. Thomas J. Brent, NSWC Crane Environmental Protection Specialist, to Mr. Tom Johnston, TtNUS Task Order Manager for NSWC Crane Mustard Gas Burial Ground Investigation concerning past exhumations at the NSWC Crane Mustard Gas Burial Ground conducted in 1974 and 1980, dated 21 January, 2000.

APPENDIX A

PART 1

PART 1

NSWC CRANE MUSTARD GAS BURIAL GROUND SITE RECONNAISSANCE REPORT

REPORT DATE: 1-21-2000

(FINAL)

Reconnaissance Date: 1-18-2000

TtNUS Participants: T. Johnston, A. Bernhardt, J. Schubert

Purpose of Site Visit:

1. View the MGBG and surrounding terrain in person,
2. Take photographs and notes related to the site,
3. Interview Natural Resources personnel concerning known or potentially impacted wildlife species impacted by the MGBG and MGBG future investigations,
4. Interview Dale Groh (NSWC Crane Safety) and potentially others concerning past site investigations, especially ordnance and mustard gas exhumations,
5. View aerial photographs of MGBG

Arrival: Checked into Base BOQ at approximately 7:30 pm on 1-17-00.

We (Bernhardt, Johnston, Schubert) met Tom Brent at 8:30 am at building 3245. After a short discussion about the day's agenda Tom Brent took us to the Natural Resources building to view all available aerial photographs of the MGBG from the 1940s through 1998. Several different sets of photographs (black and white, and color) were viewed from that time frame. We unanimously elected not to obtain copies of any of the photographs because they did not appear to add significantly to our knowledge base of the MGBG.

SITE DESCRIPTION

At approximately 10:00 am Tom Brent took us to the MGBG for a site walkover. We walked the site, and took photographs (digital and film) and notes. The site is at the top of a ridge to the northeast of the access road (HWY 251) and is flanked by magazines 1409 on the northwestern end and 1407 to the southeastern end. The majority of the site (the previously fenced in area) is an open area that is vegetated with a dense layer of shrubs and grasses. The area appears to be mowed at least once per year, but the grasses/shrubs were 1 to 4 feet high at the time of the site visit. The MGBG proper is

elevated 5 to 10 feet relative to the elevation of HGWY 251 leading to the site. Some small trees (saplings) were scattered over the site, but the vegetation did not exceed about 7 feet in height, except at the tree lines on the northern, eastern and southern edges of the site. The areas to the east and west of the site are vegetated with a very dense layer of shrubs and grasses. Gravel HWY 251 borders the site to the south-southwest. The western/southern side of HWY 251 slopes steeply down to an intermittent stream. The area to the north-northeast of the site also slopes steeply down to an intermittent stream. The land rolls off on the NE edge of the site and toward the SW of HWY 251 (Gravel). Toward the NE end of the northern edge was a mound of earth with some scrap material.

The area to the north (including the northeast corner of the site) is heavily wooded with mature deciduous trees including oaks (red, white and black), sycamore, and American beech. The understory in the forest consisted of sparse patches of ground vegetation (i.e., ferns, grasses, moss). The intermittent stream was dry at the time of the site visit (with the exception of some small pools of standing water), however, based on the scoured sediment, it appears to have heavy flows during rain events. The stream bed was approximately 10 feet wide, and the substrate was sand/exposed rocks. There were two primary drainage ditches (both were dry) leading from the site area down to the intermittent stream.

Roadways had evidently been cut into the hillside north and west of the site for installation of GW monitoring wells. As a result, several terraces exist at various elevations on the north hillside of the site. The terraces are essentially parallel to the northern edge of the site with wells located on each terrace. The terraces extend to the west of the site. Vertical distances between terraces are estimated to be about 10 to 25 feet. Access to the wells is good, with each terrace generally eight feet to 15 feet wide and only grass and dirt on the terraces. Two connecting roads, between MGBG and Magazine 1409, and to the west of Magazine 1409, join the terraces in a vertical direction.

To the SE side of the site between the site and HWY 251 were a few scrap piles with asphalt, concrete and earth visible. The piles were approximately two to five feet high. There is a depression (drainage ditch) immediately north of HWY 251 and parallel to HWY 251 that lies between the road and the southwestern border of the site. There was at least one culvert that transported runoff from the site, under the road, and into the intermittent stream via the drainage ditch. The ditch was dry at the time of the site visit. The area to the south of HWY 251 is heavily wooded with mature deciduous trees including oaks (read, white and black), sycamore, and American beech. The understory in the forest consisted of vegetation including vines with thorns. The intermittent stream was not inspected during the site visit because of the heavy vegetation and an ice storm the previous evening made the footing treacherous.

Based on the habitat at the site, and the observation of one potential burrow, it is likely that small mammals and birds are present at the site.

The GW monitoring well WES-1-6-82 standpipe was broken off just above ground level. The WES-1-11-81 standpipe was broken off approximately one foot above ground level. Otherwise, the well standpipes were intact and locked shut to limit access. The wooden corner posts of the site were standing but no fence remains, either for the MGBG proper or the Primary Burial Ground area within the MGBG proper. One metal fence post and an additional wooden fence post were also observed to be standing along the northern edge of the site. Toward the northwest corner of the northern edge of the site is a vent pipe installed during an earlier exhumation. The pipe protrudes approximately one foot above grade. Two other vent pipes from that exhumation were not located, possibly broken off during maintenance of the site.

PHOTOGRAPH INDEX (DIGITAL CAMERA):

182. Looking toward SE corner of site (HWY 251 through trees), Aaron and Jeff walking toward rubble piles.
183. Looking toward NE corner of site (Tom Brent) in center of photo.
184. Standing within trees between HWY 251 and the site, looking at rubble piles.
185. Looking over rubble piles toward Magazine 1407 in background. Vantage point is same as photo 3.
186. SE Corner post, Magazine 1407 in background.
187. Looking toward western end of site, Magazine 1409 in background.
188. WES-1-4-81 to north of site.
189. Looking south from near well WES-1-4-81. The well is a few feet lower than the top of the site.
190. Looking east toward WES-1-5-81 from near WES-1-4-81. Note relatively thin tree line along northern edge of the site.
191. Drainage on northern edge of site (a little difficult to make it out) about one third of the distance from Tom Brent to Jeff Schubert. Starts as shallow depression and becomes better defined as elevation drops over the edge of the photo.
192. Looking toward WES-1-2-81 from west of WES 1-5-81 (Magazine 1409 in background to left and WES 1-11-81 is just below hilltop to right of WES 1-5-81).
193. Looking back toward WES 1-2-81 (foreground) and WES 1-5-81 with Northwest corner post in background and elevated above WES 1-2-81.
194. Looking down roadway between sells WES 1-11-81 and WES 1-2-81, looking northeast.

195. Aaron standing in large drainage (about 10 feet wide) that intersects previously identified drainage. No running water in this or the other drainage. This drainage is well scoured indicating rapid water flow during storm events.
196. Zoom of large drainage with Aaron in it.
197. Vent pipe with stick protruding near north edge of site.
198. Beginning of pan sequence (three photos). Magazine 1409 in background, looking southwest from northwest corner of site near vent pipe (about 60 feet east of NW corner post)
199. Second in pan sequence. Looking southwest toward HWY 251 (not visible).
200. Third in pan sequence. Looking south. Last photo on digital camera.

PHOTOGRAPH INDEX (DISPOSABLE FILM CAMERA CD):

022_18. Bad picture.
022_25 thru 022_22. A pan series from right (west, 022_25) to left (South, 022_22) on HWY 251, then West to North.
022_20. Looking east toward intersection of HWY 251 and HWY161. Note Magazine 1407 in background to northeast. Drainage ditch is on other side of car.
022_21. Looking over shallow drainage along road toward Magazine 1409.
022_19. Intersection of HWY 251 (gravel, where car is) and HWY 161 (paved)

INTERVIEW MEETING (12:30 PM):

Attendees were Dale Groh [NSWC Crane Safety], Tom Brent [NSWC Crane Site Manager], Christine Freeman [NSWC Crane Env. Protection Office], Jeff Schubert [TtNUS CTO131 geologist/hydrologist], Tom Johnston [TtNUS CTO131 TOM/chemist]

Tom Johnston began with an overview of what TtNUS knew about the burial ground. A site summary, as presented in the meeting, is Attachment 1 to this document. Tom Johnston and Jeff Schubert explained that TtNUS was on an information gathering mission to better understand the past investigative and exhumation activities, as well as the current status of the site, especially regarding the existence of mustard gas, thorium and unexploded ordnance.

Dale Groh explained that the MGBG was established after inception of the magazines. The MGBG perimeter fence was erected sometime after the magazines were installed but the date of fence installation is not known. Another fence was installed within the MGBG fence to delineate the primary burial area. It was within this primary burial area that mustard gas bombs were buried. Upon burial, signs

were posted to identify the locations of the mustard gas bombs and the approximate quantity of material buried. Other objects were also buried in this area (see below).

Dale explained that the 1974 the geophysical survey was confined to the Primary Burial Area within the MGBG. In 1980, the geophysical survey (Phase II B) covered the entire MGBG. No munitions were detected in this investigation, as explained in the After Action Report. Several metallic junk items were found during past exhumations, as well as canisters of thorium nitrate and bombs. (Tom Johnston later obtained some additional diagrams of the site that show the locations from which those items were exhumed). As a result, no UXO clearance should be needed for the site investigation. The geophysical survey went to about a 10-foot depth but objects were generally buried at shallower depths (e.g., some within a couple of feet of ground surface).

The objective of the 1980 action was to remove the threat of unexploded ordnance and mustard gas. No unexploded ordnance was found. Dale explained that mustard gas concerns remaining at the MGBG should be minimal and would result only from minimal residual mustard gas that persisted after decontamination of previously identified mustard gas spills. Any residual mustard gas should be at non-hazardous concentrations. **Action Item:** Tom Johnston asked Dale to write a letter to Tom Brent to that effect and he agreed, with expected completion and submittal by Friday, 1/21/00. When asked about the two anomalies identified during the 1995 geophysical survey, Dale indicated that he would review the 1995 geophysical survey data relative to the 1980 After Action Report and try to reconcile any disagreements. He would include a summary of his findings in his letter to Tom Brent.

Note: All bombs suspected of being buried at the site and all bombs exhumed from the site were devoid of explosives. Most bombs had been emptied of mustard gas prior to burial as evident from their condition upon exhumation.

Radiological surveys were conducted only in areas known or suspected to have had thorium and related compounds buried. No NRC or EPA involvement was experienced at that time. There was supposedly no wholesale chemical disposal at the MGBG and burials were relatively quick with a hole being dug, material being dumped into the hole, and the hole being filled in with gravel and earth.

Dale explained that only hypochlorite solution (and not solutions containing organic solvents) had been used to decontaminate mustard gas spills. He also explained that strontium was only used in the capacity of a chemical and not for its radiological properties. There should be no radiological concerns (e.g., SR-90) with regard to strontium. Thorium, however, may have been used for both radiological and chemical properties. Dale's recollection was that use of chemicals such as thorium compounds was quite

varied. Tom Brent explained that thorium oxide had been encountered at the site and I suggested that that could be consistent with reports of gray powder having been exhumed (another thought not introduced at the meeting is that thorium metal can also be a gray powder).

Dale believes that non-ordnance hot spots do exist, but they are not likely to be mustard gas. Instead, he suspects that thorium and related deposits still exist, as well as some metallic junk.

It is probable that some chemical solvents had been disposed at the MGBG without documentation. The 1967 R&D chemical disposal is likely to have been primarily solids, but not necessarily. The location of the documented research and development chemical burial in 1967 is unknown.

Some wells have been drilled at Crane for groundwater production. Over 300 old homeowner wells were present at Crane before land was acquired for the Base. **Action Item:** Tom Brent will get information concerning well locations and use for Jeff Schubert, or will advise Jeff Schubert to obtain that information from site personnel. Information might be obtainable from David Poynter (812-854-5930).

NOTES RELATED TO H&S QUESTIONS (SEE ATTACHMENT 2):

- There are no gates in place near the MGBG other than the Bedford gate. However, we could restrict access to the MGBG along HWY 161, especially. The Army would still need to have access to magazines along HWY 251.
- Not sure of closest meteorological station. **Action Item:** Tom Johnston will check with TtNUS office personnel about this.
- Good access to wells is present, etc. Additional roadways might need to be cleared, especially if new wells must be installed in vegetated areas.
- No utilities are available at MGBG. Closest electrical service is near the fire tower (north of MGBG and too far away to be a practical electrical source). However, roadways for transport of potable water, toilets are available and were established for the 1980 investigation (have since been removed).
- Staging area access should not be a significant problem as HWY 152 and 161 are easily traveled.
- Copperheads, an occasional rattlesnake and, perhaps, other snakes could be encountered during field work, especially if brush is not cleared.
- The 1980 investigation used the road leading to magazine 1407 and nearby area as a staging area for IDW, resource deployment, etc. A trailer was set up there, as well.
- Emergency on-base services who respond in the event of an emergency would be Fire, Security, and EOD. Full-service fire department is available and EMS service is available. Response time is

minutes or more. Two-way radio communication could be established between Base personnel and TtNUS.

- EOD will not provide training to TtNUS personnel for emergency response because there is no way to bring TtNUS personnel to the level of proficiency that EOD personnel have. Instead, situations beyond capability of TtNUS personnel would default to base personnel jurisdiction. **Action Item:** TtNUS needs to establish points of contact with base personnel for this. TtNUS needs to consult other H&S plans for Crane for this or similar information.
- Tom Brent is the primary point of contact for arranging for special services.
- It is not clear that special monitoring equipment for mustard gas would be available at the site. **Action Item:** Tom Brent will try to check with Kathy Andrews to determine whether the developmental chemical agent "sniffer" could be used at the site. However, the need for this could be minimized if we believe mustard gas is not a H&S threat at the site.
- Concerning spill containment kits, TtNUS should bring all necessary equipment to the site.

MEETING WITH DAVID POYNTER AND STEVEN ANDREWS FROM NATURAL RESOURCES

Endangered Species

The primary endangered species at the site is the Indiana Bat which has widespread distribution across the base. **Action Item:** Steve can send me a copy of the study. Because of this, there are the following restrictions on cutting down trees:

- Trees larger that 3 or 4" in diameter (they needed to check) cannot be cut down between April 15th and September 15th, because that is when the bats roost in the tree bark.
- After September 15th there are no restrictions except that no shagged bark hickory trees can be cut down.
- Any tree removal (>3 or 4") needs approval first. However, the Base is in the process of obtaining a basewide exemption to allow 10 acres of trees (total) to be cut down across the Base. They hope to have it by the end of the summer. Trees still may not be cut down between April 15th and September 15th.
- Trees larger that 3 or 4" in diameter may not be cut down within 50 feet of an intermittent stream, of within 100 feet of a perennial stream any time throughout the year.
- The tree removal could be important for any clearing that drillers must do to install wells/collect soil borings.

Steve gave Aaron a list of other protected species at the Base. No plants are on the Federal of State list. They gave Aaron a copy of an endangered fish study that was conducted in 1987.

Cultural Resources

David Poynter would like to see the locations of any proposed soil borings to make sure that the drilling is not being conducted in a known or potential cultural resources site. There is more of a concern for any test pitting because of the larger area that is disturbed.

GIS

They can send us their GIS layers, however, we already have many of them in-house. **Action Item:** Aaron will determine the layers that we have in house and when they were last updated. Crane has the following layers that might be of interest to us:

- National Wetland Inventory wetlands – they do not have any field verified wetland data
- Forest coverage including tree species – they do not have the same information for shrubs
- Buffered stream zone (50' for intermittent streams, 100' for perennial streams)
- Archaeological sites
- Bat buffer zones
- Timber management compartments
- Forest coverage
- Old house sites-ruins
- Natural preserves (lank Greenwood)
- Monitoring sites for neotropical migratory birds
- Old growth management areas (trees)
- Natural areas
- Clear cut openings
- Rock outcrops
- Springs
- Lakes/ Streams
- Birds
- Topo info – they have 2 foot contours in some places
- Drainage areas/Watersheds
- Fault lines

- Surficial geology
- Boring logs

Misc. Information

The Natural Resources personnel do not have any data on benthic macroinvertebrates in their streams. Steve gave me a copy of the Forest Management Section and the Fish and Wildlife Management Section of the Natural Resources Management Plan (1991). **Action Item:** David Poynter is having their forest stand information copied and it will be sent to Aaron (through Tom Brent) when it is completed.

FOLLOW-UP CONVERSATION WITH TOM BRENT (APPROXIMATELY 3:00 PM):

Land use is not likely to be residential in foreseeable future but it is possible. The RFI will address residential, recreational and industrial use scenarios.

Tom Johnston asked Tom Brent whether he was familiar with the MARSSIM document that is a multi-agency guidance document for radiological surveys to demonstrate compliance with regulations. Tom Johnston indicated that TtNUS was planning to use the MARSSIM document as a resource unless Tom Brent disagreed with that approach. **Action Item:** Johnston committed to sending web site address for MARSSIM document to Tom Brent so he can provide opinion on use of MARSSIM document for this investigation. The web site address is: http://www.epa.gov/radiation/marssim/

ATTACHMENT 1

MUSTARD GAS BURIAL GROUND, NSWC CRANE, SITE DESCRIPTION AND HISTORY

REGULATORY CONTEXT:

- MGBG is a Resource Conservation and Recovery Act (RCRA) Solid Waste Management Unit (SWMU) regulated under the Naval Surface Warfare Center (NSWC) Crane Final RCRA Storage Permit.
- Investigation is in compliance with the Corrective Actions Requirements (CAR) of the permit.

PHYSICAL DESCRIPTION:

- Approximately 2-acre, rolling terrain, almost rectangular area in the southwest quadrant of NSWC Crane. Located on NW trending ridge.
- Soils should be 2 to 15 feet deep.
- Water table in open communication with shallow bedrock aquifer system.
- Depth to GW ranges from 5 ft to 40 ft bgs.
- Relatively uniform depth to water table.
- GW recharge area.
- Contaminants moving in GW from MGBG are likely to be present at greater depths.
- Vegetation has been known to cover portions of the site, with trees along one edge.
- Site was used between 1945 and 1967 for disposal of mustard munitions and other items.
- Four documented Mustard Gas (HD) burial areas within the site.
- HD, thorium nitrate and other chemicals disposed (i.e., buried or dumped) at the site.
- Past efforts to remove those contaminants have been undertaken.
- Residual HD or $Th(NO_3)_2$ is not expected but is possible in primary burial area.

MARCH, 1973 CHEMICAL SAFETY SURVEY:

- Unknowns identified regarding chemical agent and explosives content of munitions disposed at site.

- Recommendation was to recover the chemical munitions and render the area safe. Was recommended that the plan should include SOPs governing:
  - personal protection,
  - authorized equipment,

- personnel and explosives limits,
- the use of "hot lines" to prevent agent land contamination,
- documentation of the quantity of agent present during operations,
- disposition of recovered munitions,
- demilitarization certification, and
- the handling, detoxification and agent detection.

- Recommendation suggested that SOPs should be reviewed and approved at the appropriate levels within the Navy to assure adequacy of the various safety factors.

1974 EXHUMATION AND FOLLOWING:

- Seven, 55-gal drums filled with thorium/illuminant materials and other hardware. All radioactive waste thought to have been removed and sent to NRC-licensed burial ground in 1975.

- Ten HD bombs exhumed. Seven bombs cleaned of HD. One more contained HD. Two others suspected to contain HD. Detected HD was about 40% pure, evidently undergoing chemical decomposition. Operation was terminated and transferred to Army personnel. In 1976, hardware from seven bombs was transferred to Magazine 1403; the three remaining bombs were wrapped in plastic and overpacked in 8" propellant charge shipping containers, then also stored in Magazine 1403.

- Exhumation personnel recommended resuming exhumation of four other areas in Autumn when temperatures are lower and the chance of HD overpressure in the bombs is limited.

1977 MAGNETOMETER SURVEY (PARTIAL COVERAGE ONLY):

- New metal contacts identified and plotted.
- Metal contacts both inside and outside the MGBG.

1980 EXHUMATION:

- Metal contacts plotted in 1977 as being outside of MGBG were innocuous (barbed wire and "junk").

- Most metal contacts within the MGBG detected during the 1977 survey were junk or barbed wire.

- Six items removed from plots marked "mustard" of various poundages were empty M70A1 aerial bombs with no connection between the pounds of material recorded and live agent found. Only mud (no live agent) was found inside the six aerial bombs.

- No trace of agent was found in soils surrounding the empty bombs.

- The three bombs suspected in 1974 of containing mustard gas contained approximately three, 1.5 and 0 gallons of agent, respectively. None were found to be full of agent, indicating that they were partially overlooked during burial. Some agent spilled on the ground was decontaminated with HTH chlorine solution.

- Most of material found was illuminating device hardware/composition remaining from a research and development project.

- One HD identification kit containing 6 oz of HD was exhumed

- An unidentified quantity of radioactive waste was located apart from the other buried material in a configuration illustrating a simple "stack type" burial.

- Three additional thorium nitrate burial areas were located.

- Three 55-gal drums were filled with radioactive thorium nitrate containers.

- Site declared not to pose environmental insult.

- Thorium nitrate disposal sites located at the NSWC Crane were considered to have been decontaminated and were approved for release for radiologically unrestricted use.

1991 DRAFT PHASE II WORK PLAN DEVELOPED:

- Work plan never implemented.

1995 GEOPHYSICAL SURVEY (COMPLETE MGBG AREA):

- Objective: Detect and delineate anomalies indicating buried structures, objects or disturbed zones with past hazardous waste burial.
- EM and magnetic surveys were used.
- Two anomalies identified that are unexplained.

ATTACHMENT 2
HEALTH AND SAFETY QUESTIONS

INFORMATION REQUEST

The following questions, provided by Tom Dickson (TtNUS, H&S) were asked in paraphrased form at the interview meeting on 1-18-2000. Some questions were significantly modified or not asked because the site visit prior to the meeting provided enough information to resolve the questions. The answers to the questions in the body of this report

Comprehensive Site Map illustrating sensitive receptors (Homes, farms, businesses, etc.) in the area. This map should be to scale or have distance provided to the sensitive receptors. Addition information requested include

- Existing fences and other security measures which are currently in place (i.e., Gates at the entrance of Hwy.251 or along Hwy.161)

- Closest Meteorological Station; typical wind patterns across the site (i.e., wind is out of the south/southwest 90% of the time); Average rainfall and ambient temperature ranges for the four seasons or for the anticipated project schedule dates.

- Site Preparations – Based topographical considerations – Existing roadways or roadways which will have to be constructed

  - Roadway approaches to the anomalies to be investigated. Access will be necessary for drill and direct push rigs. In addition, foot paths for personnel movement from the investigation area to decontamination and support areas. These approach routes will be structured to permit movement in and out of the investigation area preferably in a cross or upwind pattern.

  - Roadways to support areas of the site including delivery of potable water and/or services (toilets, supplies) to specified areas of the site.

  - Roadways to staging areas from the investigative areas to dispatch IDW and drums/Containers which may be uncovered in the investigation.

- Which roadways supporting the site currently that we can take control over by placing gates or other control mechanisms? Where would the facility allow us to place gates? (Theoretical modeling may determine a sufficient distance is required from the source, however the facility may not want to relinquish these right-of-ways. I am referring to Hwy. 251 and Hwy. 161.

- Additional site preparation considerations – Electrical power? Do power poles currently run along Hwy. 251 or Hwy. 161 that we can tap? Do any other supported utilities run near the site?

- Site preparation efforts (trailer placement, decontamination unit placement or construction, staging areas for IDW and Drum/Container Mgmt., staging areas for resource deployment).

- As this is a remote location are there other gates for us to access the site for resource acquisition/deployment?

➢ Topographical Map – This map (along with pictures preferably) is requested to ascertain potential dispersion routes (Over land and gas dispersion routes). Gas collection points surrounding the site, especially downwind.

➢ Emergency Action Items requested (Besides the information requested for Site Control)

- Identification of on-base services who would respond in the event of an emergency (NBC Teams?) Estimated response time to this location?

- Emergency medical teams versed in nuclear, biological, and chemical agents? Estimated response time to this location?

- Chemical WarFare Agent Experts available? Explosive Ordnance Support? Will these people be available to instruct our personnel (possibly as part of site-specific training) above our current knowledge level?

- Have the Base made any liaisons with local medical support facilities to handle chemical contamination of this sort (Mustard Gas)? Who is recommended?

- Hazard Monitoring issues

  - Are rare/CWA-specific monitoring instruments available at the site? Can TtNUS use them for this project?

- Spill Containment

  - Are special CWA spill containment kits/procedures available for use by TtNUS?

APPENDIX A, PART 2

MEMORANDA SUMMARIZING MUSTARD GAS AND ORDNANCE STATUS OF THE MUSTARD GAS BURIAL GROUND

PART 2.

MEMORANDUM FROM MR. THOMAS J. BRENT TO MR. TOM JOHNSTON

January 21, 2000

Tetra Tech NUS
Attn: Mr. Tom Johnston
661 Andersen Drive
Pittsburgh, PA 15220-2745

Mr. Johnston:

Enclosed are two memorandums from Mr. Dale Groh of the Safety office and Timber Inventory information from the NSWC Crane Natural Resources Office. If I can be of any further assistance please feel free to ask.

Thomas J. Brent
Environmental Protection Specialist
NSWC Crane

cc:
Bill Gates

encl

OPTIONAL FORM 99 (7-90)

FAX TRANSMITTAL # of pages ▶ 5

To Tom Johnston	From Bill Gates
Dept./Agency TTNUS	Phone # 843-820-7360
Fax # 412-921-4040	Fax # 7465

NSN 7540-01-317-7368 5099-101 GENERAL SERVICES ADMINISTRATION

DEPARTMENT OF THE NAVY
CRANE DIVISION
NAVAL SURFACE WARFARE CENTER
300 HIGHWAY 361
CRANE, INDIANA 47522-5000

IN REPLY REFER TO:
8020
Ser ESO/0008
19 January 2000

MEMORANDUM

From: Explosives Safety Officer
To: Director, Environmental Protection Department (Code 095)

Subj: MUSTARD GAS BURIAL GROUND

Ref: (a) After Action Report, Chemical Burial Ground Exhumation Project, October 1980

Encl: (1) Technical Report GL-97-7, June 1997, Geophysical Investigation at Mustard Gas Burial Ground, Naval Surface Warfare Center, Crane Division, Crane Indiana

1. Responding to a request made during a meeting conducted 19 January, the following is intended to provide background information pertaining to the subject Burial Ground. In addition, the safety position of Crane, regarding further investigations of the area is provided.

2. The subject of a mustard gas burial ground at Crane has been the focus of attention for over twenty five years. In 1974, using sketchy historical records, an aborted attempt was made at clearing the burial ground of any ordnance materials. In 1980, a better organized effort was conducted, as described by reference (a), to clear the area approximately 350 ft. by 250 ft. of all materials that could conceivably be considered ordnance. Using Explosive Ordnance Disposal (EOD) personnel and the latest magnetometers, all metallic items, including those containing residual mustard agent, were believed to be removed from the area. In addition, an amount of low level radioactive material was removed.

3. For purposes of further site related investigative efforts, complete assurance that all ordnance has been removed from the site is provided. Any potential for exposure to live mustard agent would be extremely small since all of the soil adjacent to where aerial bomb casings were located, was decontaminated using approved chemical methods.

4. With regard to the anomalies found and reported by enclosure (1), the magnetometer results of previous investigations made prior to the 1980 exhumation effort were overlaid on the results of the latest work conducted and reported by figure 8 of enclosure (1). The ten foot diameter item is located at the edge of what once was the primary burial ground. It was in this burial area that all of the aerial bomb casings were found and decontaminated in the fall of 1980. At that time, the excavations were down to bedrock with sand and gravel backfilled to establish a filter as directed by environmental offices at that time. The size of the item matches that of a steel horse tank that was used for decontaminant soaking of the ordnance hardware after being processed in the primary decontamination vat. The location of the anomaly is also in concert with the last

Subj: MUSTARD GAS BURIAL GROUND

location of the horse tank on site. At this time the exact cause of either of the anomalies cannot be stated. However, because so many different checks were made of the entire Burial Ground Area (both primary and surrounding areas) for metallic objects and all contacts were investigated, there is no reason to believe that the current anomalies are ordnance related. Additional investigative effort into the circumstances surrounding the final disposition of the horse tank will continue.

5. For planning purposes, any future excavations should follow the same policy as those for bio-remediation of explosive contaminated soil. That is to excavate cautiously and stop when there is reason to believe an unknown hazard exists. Should this occur, the appropriate Navy support effort would then be summoned.

6. Point of contact is D. L. Groh, Explosives Safety Officer, Building 12, Ext 3601.

D. L. Groh

D. L. GROH

DEPARTMENT OF THE NAVY
CRANE DIVISION
NAVAL SURFACE WARFARE CENTER
300 HIGHWAY 361
CRANE, INDIANA 47522-5000

IN REPLY REFER TO:
8020
Ser ESO/0009
20 January 2000

MEMORANDUM

From: Explosives Safety Officer
To: Director, Environmental Protection Department (Code 095)

Subj: MUSTARD GAS BURIAL GROUND

Ref: (a) ESO memo 8020 Ser ESO/0008 of 19 January 2000

Encl: (1) Overlay Drawing of Burial Ground Illustrating an Anomaly and the Overlay of the Metal Contacts Charted Prior to 1980 Exhumation Project

1. To officially follow-up on the issues raised by reference (a), contact was made this date with Mr. Robert Foster, former Explosive Ordnance Disposal, Detachment Crane member. Mr. Foster was an EOD team member for the exhumation project that was conducted in September 1980.

2. Paragraph 4 of reference (a) mentioned the possibility that some of the equipment used for the project could have been left on the site rather than be removed as was believed by the project manager (myself). Mr. Foster confirmed the suspicion that the ten foot diameter horse tank was buried in the hole excavated for the removal of the aerial bombs. It was decontaminated using HTH liquid, rinsed with water and then placed in the hole before backfilling took place. In addition, he remembers that steel fence posts, removed from around the site, were also buried with the tank. Mr. Foster identified the approximate location of the burial from memory and his recollections match the layout shown by enclosure (1).

3. As an aside, Mr. Foster stated that an area outside of the large fenced zone, located on the southwest (roadside) and northwest (near Magazine 1407) sides, was scanned for any metal contacts. The additional area is approximately ten feet outside of the original fenced line and is shown on enclosure (1).

4. All conclusions stated by reference (a) appear now to be supportable No metal exists at the site except for some equipment and fence posts buried after the project had been concluded.

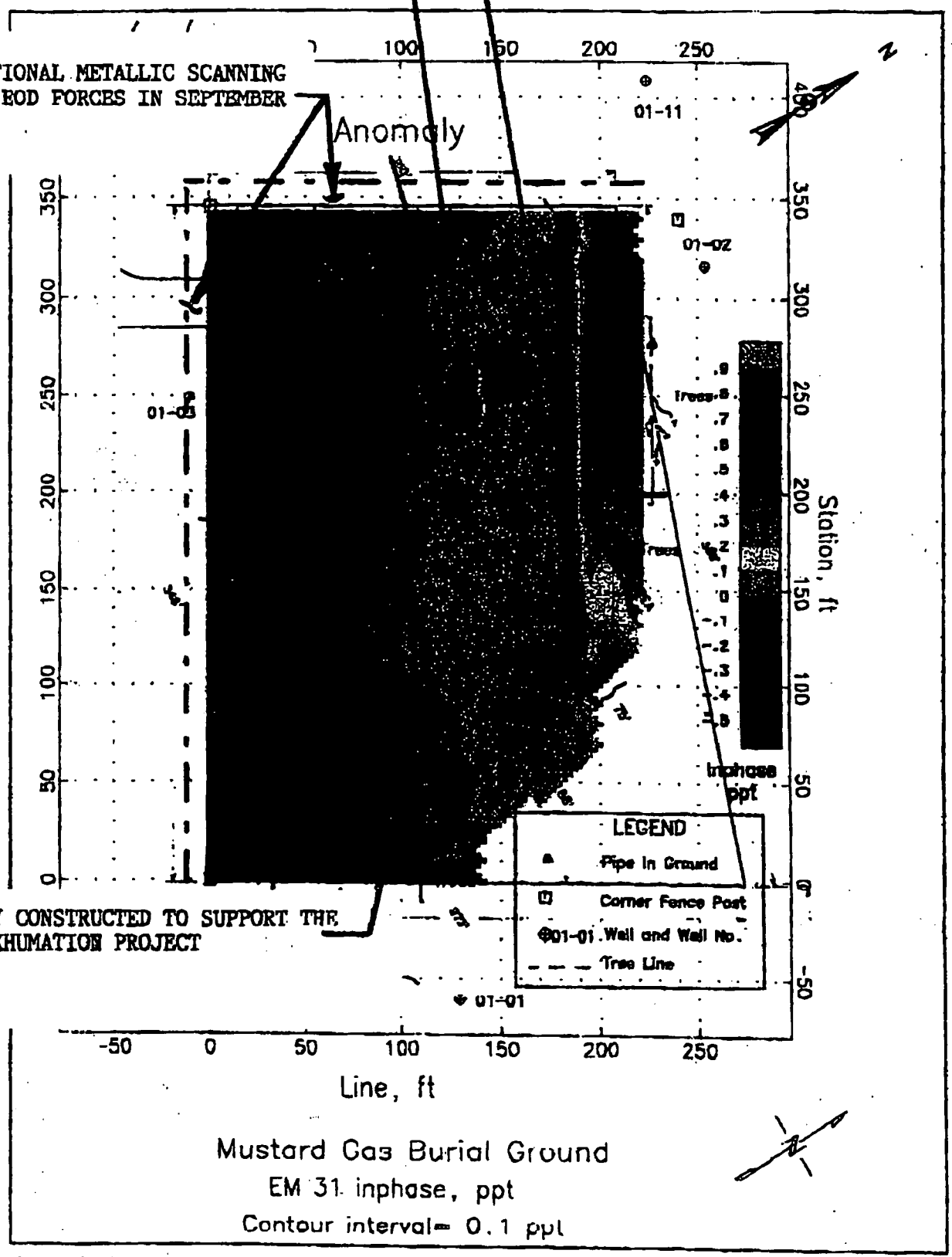
D. L. Groh

D. L. GROH

LOCATION OF THE HORSE TANK AND OTHER METALLIC DEBRIS BURIAL AS DESCRIBED BY MR. ROBERT FOSTER 1/20/2000

PRIMARY BURIAL GROUND WHERE ALL ORDNANCE HARDWARE WAS FOUND 1980

ZONE OF ADDITIONAL METALLIC SCANNING CONDUCTED BY EOD FORCES IN SEPTEMBER 1980



ROADWAY CONSTRUCTED TO SUPPORT THE 1980 EXHUMATION PROJECT

Figure 8. MGBG inphase results

ENCLOSURE (1)
OVERLAY DRAWING OF BURIAL GROUND
ILLUSTRATING AN ANOMALY AND THE OVER

APPENDIX B

PART 1. GROUND WATER DATA FROM 1981 THROUGH 1986

AND

PART 2. WELL BORING LOGS

APPENDIX B - PART 1

GROUND WATER DATA FROM 1981 THROUGH 1986

TABLE B-1

HISTORICAL GROUND WATER DATA SUMMARY
NSWC CRANE, CRANE, INDIANA

cas	parameter	fraction	frequency	min_nd	max_nd	min_c	max_c	min_qual	max_qual	range	range_nd	samp_max	avg_pos	avg_all
VOLATILES (ug/L)														
71-55-6	1,1,1-Trichloroethane	OV	11/22	1	1	1	29			1 - 29	1	01-14-[01/31/83]	9.090909	4.795455
79-34-5	1,1,2,2-Tetrachloroethane	OV	29/39	0	1	7	589000			7 - 589000	0 - 1	01-02-[11/18/82]	24478.24	18201.87
79-00-5	1,1,2-Trichloroethane	OV	12/21	1	5.2	2.2	341			2.2 - 341	1 - 5.2	01-12-[01/25/83]	44.34167	25.65238
75-35-4	1,1-Dichloroethene	OV	4/24	1	1	1	65			1 - 65	1	01-02-[10/05/82]	18.5	3.5
107-06-2	1,2-Dichloroethane	OV	11/30	1	1	3	4070			3 - 4070	1	01-02-[11/18/82]	573.4545	210.5833
	1,3-Dichloropropene	OV	1/7	1	1	1000	1000			1000	1	01-16-[02/15/83]	1000	143.2857
71-43-2	Benzene	OV	4/25	0	1	1	5			1 - 5	0 - 1	01-26-[01/28/86]	2.75	0.8
75-25-2	Bromoform	OV	1/25	0	2	8600	8600			8600	0 - 2	01-02-[10/05/82]	8600	344.66
56-23-5	Carbon Tetrachloride	OV	1/22	0	1	34	34			34	0 - 1	01-02-[10/05/82]	34	2
108-90-7	Chlorobenzene	OV	1/22	1	1	6	6			6	1	01-02-[10/05/82]	6	0.75
124-48-1	Chlorodibromomethane	OV	2/15	1	1	61	3040			61 - 3040	1	01-02-[11/18/82]	1550.5	207.1667
67-66-3	Chloroform	OV	21/39	0	5	2	2000			2 - 2000	0 - 5	01-02-[10/05/82]	109.3571	59.25641
100-41-4	Ethylbenzene	OV	1/16	1	1	10.5	10.5			10.5	1	01-22-[01/08/85]	10.5	1.125
75-09-2	Methylene Chloride	OV	16/31	1	10	1	47			1 - 47	1 - 10	01-02-[10/05/82]	9.5	5.290323
79-34-5	Tetrachloroethane	OV	1/1	0	0	7.1	7.1			7.1	0	01-19-[01/08/85]	7.1	7.1
127-18-4	Tetrachloroethene	OV	11/24	0	3.8	0.1	4200			0.1 - 4200	0 - 3.8	01-02-[11/18/82]	652.9273	299.5667
108-88-3	Toluene	OV	2/19	1	1	5	5.1			5 - 5.1	1	01-22-[01/08/85]	5.05	0.978947
156-60-5	Trans-1,2-dichloroethene	OV	16/28	0	1	3	2650			3 - 2650	0 - 1	01-02-[11/18/82]	320.4438	183.2893
79-01-6	Trichloroethene	OV	37/45	0	644	1	133000			1 - 133000	0 - 644	01-02-[11/18/82]	5867.759	4831.824
75-69-4	Trichlorofluoromethane	OV	4/20	0.1	1	2	19			2 - 19	0.1 - 1	01-14-[01/31/83]	7.25	1.8275
DIOXONS (ug/L)														
	Tetrahydrofuran	DIO	3/3	0	0	11	93			11 - 93	0	01-15-[01/28/86]	51	51
INORGANICS (ug/L)														
7440-38-2	Arsenic	M	1/20	10	10	10	10			10	10	01-05-[10/05/82]	10	5.25
7439-89-6	Iron	M	33/46	20	1000	30	7280			30 - 7280	20 - 1000	01-21-[01/08/85]	795.1515	584.8913
	Iron, Total	M	17/23	10	20	10	18000			10 - 18000	10 - 20	01-15-[01/28/86]	2930.588	2168.261
7439-96-5	Manganese	M	76/82	5	30	10	7000			10 - 7000	5 - 30	01-04-[03/23/82], 01-04-[07/18/82]	1889.474	1751.86
7439-97-6	Mercury	M	4/20	0.2	0.7	0.2	1.1			0.2 - 1.1	0.2 - 0.7	01-05-[10/05/82]	0.6	0.2125
7440-22-4	Silver	M	1/20	10	10	10	10			10	10	01-03-[03/23/82]	10	5.25
7440-23-5	Sodium	M	66/66	0	0	3800	210000			3800 - 210000	0	01-05-[03/23/82]	60869.7	60869.7
RADIONUCLIDES (PCi/L)														
	Gross Alpha	RAD	1/20	2.89	10.8	4.59	4.59			4.59	2.89 - 10.8	01-02-[11/30/81]	4.59	2.988
	Gross Beta	RAD	15/20	1.55	2.12	1.51	6.27			1.51 - 6.27	1.55 - 2.12	01-05-[11/30/81]	3.092	2.54675
	Radium-226	RAD	11/15	0.23	0.34	0.17	0.48			0.17 - 0.48	0.23 - 0.34	01-05-[03/23/82]	0.29	0.247
MISCELLANEOUS PARAMETERS (mg/L)														
	Chloride	MIS	54/66	1	1	1	110			1 - 110	1	01-02-[10/05/82]	33.98889	27.9
	Conductance, Field (uS/cm	MIS	41/41	0	0	145	6400			145 - 6400	0	01-27-[06/10/85]	1128.927	1128.927
	Fluoride	MIS	17/20	0.1	0.1	0.1	0.26			0.1 - 0.26	0.1	01-04-[07/20/82], 01-04-[10/05/82]	0.181765	0.162
	Nitrate/nitrite, As N	MIS	15/20	0.05	0.05	0.05	0.18			0.05 - 0.18	0.05	01-04-[10/05/82]	0.107333	0.08675
	Organic Bromine	MIS	6/65	0.002	0.01	0.005	0.016			0.005 - 0.016	0.002 - 0.01	01-03-[01/31/84]	0.0095	0.0042
	Organic Chlorine	MIS	52/68	0.01	0.01	0.01	48			0.01 - 48	0.01	01-02-[06/03/86]	2.414654	1.847676
	Organic Iodine	MIS	33/68	0.002	0.5	0.002	0.15			0.002 - 0.15	0.002 - 0.5	01-02-[06/07/84]	0.01997	0.015691

TABLE B-1

HISTORICAL GROUND WATER DATA SUMMARY
NSWC CRANE, CRANE, INDIANA

cas	parameter	fraction	frequency	min_nd	max_nd	min_c	max_c	min_qual	max_qual	range	range_nd	samp_max	avg_pos	avg_all
	pH (unitless)	MIS	41/41	0	0	6.1	7			6.1 - 7	0	01-03-[01/28/86], 01-09-[01/29/86], 01-10-[01/30/86], 01-10-[06/04/86]	6.585366	6.585366
	pH, Field (unitless)	MIS	88/88	0	0	5.7	7.7			5.7 - 7.7	0	01-11-[01/07/85]	6.622727	6.622727
	Phenols	MIS	22/66	0.004	0.05	0.01	0.17			0.01 - 0.17	0.004 - 0.05	01-02-[07/20/82]	0.030455	0.018712
	Specific Conductivity uS/cn	MIS	81/81	0	0	-1300	2520			-1300 - 2520	0	01-05-[02/22/83]	1160.889	1160.889
	Sulfate	MIS	82/82	0	0	15	990			15 - 990	0	01-23-[01/07/85]	358.1622	358.1622
	Total Coliform (PHM)	MIS	6/8	1	1	2	9			2 - 9	1	01-04-[03/05/82], 01-04-[11/30/81]	5.333333	4.125
	Total Organic Carbon	MIS	99/123	0.5	2	0.8	72			0.8 - 72	0.5 - 2	01-05-[07/27/83], 01-05-[10/05/82]	12.9697	10.55081
	Total Organic Halogens	MIS	64/71	0	0.01	0.0063	104			0.0063 - 104	0 - 0.01	01-02-[07/20/82]	2.89598	2.610742

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-01 GW 01-01-[11/30/81]	01-01 GW 01-01-[03/05/82]	01-01 GW 01-01-[03/23/82]	01-01 GW 01-01-[07/18/82]	01-01 GW 01-01-[07/20/82]	01-01 GW 01-01-[08/21/82]	01-01 GW 01-01-[10/05/82]	01-01 GW 01-01-[11/08/82]	01-01 GW 01-01-[01/14/83]	01-01 GW 01-01-[02/22/83]	01-01 GW 01-01-[07/26/83]	01-01 GW 01-01-[01/31/84]	01-01 GW 01-01-[06/08/84]	01-01 GW 01-01-[06/10/85]	01-01 GW 01-01-[01/28/86]	01-01 GW 01-01-[06/03/86]	01-02 GW 01-02-[11/30/81]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE																	
1,1,2,2-TETRACHLOROETHANE							1 U										
1,1,2-TRICHLOROETHANE																	
1,1-DICHLOROETHANE																	
1,1-DICHLOROETHENE							1 U										
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE							1 U										
1,2-DICHLOROPROPANE																	
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER																	
ACROLEIN																	
ACRYLONITRILE																	
BENZENE																	
BROMODICHLOROMETHANE																	
BROMOFORM							2 U										
BROMOMETHANE																	
CARBON TETRACHLORIDE							0 U										
CHLOROBENZENE							1 U										
CHLORODIBROMOMETHANE																	
CHLOROETHANE																	
CHLOROFORM							1 U										
CHLOROMETHANE																	
CIS-1,3-DICHLOROPROPENE																	
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE																	
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE																	
ETHYLBENZENE																	
METHYLENE CHLORIDE							8										
TETRACHLOROETHANE																	
TETRACHLOROETHENE							0.1										
TETRAHYDROFURAN																	
TOLUENE																	
TRANS-1,2-DICHLOROETHENE							1 U										
TRANS-1,3-DICHLOROPROPENE																	
TRICHLOROETHENE							1 U										
TRICHLOROFLUOROMETHANE																	
VINYL CHLORIDE																	
PESTICIDES/PCBs (ug/L)																	
ENDRIN	0.04 U		0.04 U		0.04 U		0.04 U										0.04 U
GAMMA-BHC (LINDANE)	0.08 U		0.08 U		0.08 U		0.08 U										0.08 U
METHOXYCHLOR	1.6 U		1.6 U		1.6 U		1.6 U										1.6 U
SILVEX (2,4,5-TP)	0.5 U		0.5 U		0.5 U		0.5 U										0.5 U
TOXAPHENE	1.6 U		1.6 U		1.6 U		1.6 U										1.6 U
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA	4.08 U		5.72 U		5.63 U		6.1 U										4.59
GROSS BETA	3.17		2.13		2.04		2.51										3.03
RADIUM-226			0.31		0.34	0.34	0.34 U										
HERBICIDES (ug/L)																	
2,4-D	3.8 U		3.8 U		3.8 U		3.8 U										3.8 U
INORGANICS (ug/L)																	
ARSENIC	10 U		10 U		10 U		10 U										10 U
BARIUM	100 U		100 U		100 U		100 U										100 U
CADMIUM	5 U		5 U		5 U		5 U										5 U
CHROMIUM	10 U		10 U		10 U		10 U										10 U
IRON	120		70		30 U		30 U			30 U							500
IRON, TOTAL												590			680		
LEAD	10 U		10 U		10 U		10 U										10 U
MANGANESE	2150	2150	2060	2060	2150		1780	2150	1780	1860		2700			2400		170
MERCURY	0.2 U		0.2 U		0.2 U		0.2										0.2 U
SELENIUM	5 U		5 U		5 U		5 U										5 U
SILVER	10 U		10 U		10 U		10 U										10 U
SODIUM	56000		55000		53000		49000			45000		43000			45000		180000
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L	43.1		40.4		46		37			43		46			45		13.7
CONDUCTANCE, FIELD UMHO/CM														620			
FLUORIDE MG/L	0.2		0.21		0.2		0.2										0.12
NITRATE/NITRITE, AS N MG/L	0.06		0.05 U		0.05 U		0.06										0.08
ORGANIC BROMINE MG/L												0.002 U	0.002 U		0.01 U		
ORGANIC CHLORINE MG/L												0.022	0.07		0.04	0.01 U	
ORGANIC IODINE MG/L												0.002 U	0.003		0.01 U	0.01 U	
PH															6.6	6.2	
PH, FIELD	6.6		6.4	6.4	6.5		6.4		6.4	6.3	6.1	6.5	6.4	6.2			7.4
PHENOLS MG/L	0.01 U		0.01 U		0.03		0.01			0.01 U		0.004 U			0.02		0.01
SPECIFIC CONDUCTIVITY UMHO/CM	1300		1220		1150		1300			1065	1400	1200	1200		1000	960	1930
SULFATE MG/L	331	331	340	340	310		270	310	270	280		340			330		544
TOTAL COLIFORPHM	1 U																1 U
TOTAL ORGANIC CARBON MG/L	10.9		6		62		6			44	56	2 U	2 U	4.4	1 U	3	19.4
TOTAL ORGANIC HALOGENS MG/L	0.012		0.012		0.034		0.014			0.018	0.084 C			0.0131			0.121
VOLATILES SCAN MG/L																	

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-02 GW 01-02-[03/05/82]	01-02 GW 01-02-[03/23/82]	01-02 GW 01-02-[07/18/82]	01-02 GW 01-02-[07/20/82]	01-02 GW 01-02-[08/21/82]	01-02 GW 01-02-[10/05/82]	01-02 GW 01-02-[11/08/82]	01-02 GW 01-02-[11/18/82]	01-02 GW 01-02-[01/14/83]	01-02 GW 01-02-[02/22/83]	01-02 GW 01-02-[07/26/83]	01-02 GW 01-02-[01/31/84]	01-02 GW 01-02-[06/07/84]	01-02 GW 01-02-[01/08/85]	01-02 GW 01-02-[06/10/85]	01-02 GW 01-02-[01/29/86]	01-02 GW 01-02-[06/03/86]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE								1 U						1 U			
1,1,2,2-TETRACHLOROETHANE						38000		589000						525		66000	
1,1,2-TRICHLOROETHANE								1 U						2.2			
1,1-DICHLOROETHANE								1 U						1 U			
1,1-DICHLOROETHENE						65		1 U									
1,2-DICHLOROBENZENE								1 U									
1,2-DICHLOROETHANE						2100		4070						1 U			
1,2-DICHLOROPROPANE								1 U						1 U			
1,3-DICHLOROBENZENE								1 U									
1,3-DICHLOROPROPENE								1 U									
1,4-DICHLOROBENZENE								1 U									
2-CHLOROETHYL VINYL ETHER								2 U						1 U			
ACROLEIN														100 U			
ACRYLONITRILE														100 U			
BENZENE								1 U						1 U			
BROMODICHLOROMETHANE								1 U						1 U			
BROMOFORM						8600		2 U						1 U			
BROMOMETHANE								2 U						10 U			
CARBON TETRACHLORIDE						34		1 U						1 U			
CHLOROBENZENE						6		1 U						1 U			
CHLORODIBROMOMETHANE								3040						1 U			
CHLOROETHANE								2 U						10 U			
CHLOROFORM						2000		1 U						1 U			
CHLOROMETHANE								1 U						1 U			
CIS-1,3-DICHLOROPROPENE														1 U			
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE														10 U			
DICHLOROFLUOROMETHANE								2 U									
DICHLOROPROPANE																	
ETHYLBENZENE								1 U						1 U			
METHYLENE CHLORIDE						47		1 U						1 U			
TETRACHLOROETHANE																	
TETRACHLOROETHENE						2700		4200						187			
TETRAHYDROFURAN																	
TOLUENE								1 U						1 U			
TRANS-1,2-DICHLOROETHENE						2300		2650						24.3			
TRANS-1,3-DICHLOROPROPENE														1 U			
TRICHLOROETHENE						42000		133000						1180		30000	
TRICHLOROFLUOROMETHANE								1 U						1 U			
VINYL CHLORIDE								1 U						10 U			
PESTICIDES/PCBs (ug/L)																	
ENDRIN		0.04 U		0.04 U		0.04 U											
GAMMA-BHC (LINDANE)		0.08 U		0.08 U		0.08 U											
METHOXYCHLOR		1.6 U		1.6 U		1.6 U											
SILVEX (2,4,5-TP)		0.5 U		0.5 U		0.5 U											
TOXAPHENE		1.6 U		1.6 U		1.6 U											
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA		2.89 U		6.41 U		8.05 U											
GROSS BETA		1.55 U		2.12 U		1.51											
RADIUM-226				0.23 U	0.23 U	0.23 U											
HERBICIDES (ug/L)																	
2,4-D		3.8 U		3.8 U		3.8 U											
INORGANICS (ug/L)																	
ARSENIC		10 U		10 U		10 U											
BARIUM		100 U		100 U		100 U											
CADMIUM		5 U		5 U		5 U											
CHROMIUM		10 U		10 U		10 U											
IRON	500	30		190		120				30 U							
IRON, TOTAL												10					
LEAD		10 U		10 U		0 U											
MANGANESE	170	30		490		960	490		960	710		630					
MERCURY		0.2 U		0.2 U		0.2											
SELENIUM		5 U		5 U		5 U											
SILVER		10 U		10 U		10 U											
SODIUM		35000		126000		128000				87000		110000					
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L		29.9		95		110				82		96					
CONDUCTANCE, FIELD UMHO/CM															707		
FLUORIDE MG/L		0.1 U		0.1		0.1 U											
NITRATE/NITRITE, AS N MG/L		0.16		0.05		0.07											
ORGANIC BROMINE MG/L												0.004 U	0.002 U				0.01 U
ORGANIC CHLORINE MG/L												30	34				48
ORGANIC IODINE MG/L												0.036	0.15				0.5 U
PH								i									6.4
PH, FIELD		6.1	6.1	6.6		6.7				6.9	6.6	6.6	6.9		7		
PHENOLS MG/L		0.01 U		0.17		0.03				0.01 U		0.004 U					
SPECIFIC CONDUCTIVITY UMHO/CM		420		1420		1700				1220	1950	1400	1000				960
SULFATE MG/L	544	44		330		440	330		440	190		440					
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L		3		61		65				42	42	5	3		6.1		5
TOTAL ORGANIC HALOGENS MG/L		8.9		104		15.35				17.32	15.28 C				7.76		
VOLATILES SCAN MG/L																	

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-03 GW 01-03-[11/30/81]	01-03 GW 01-03-[03/05/82]	01-03 GW 01-03-[03/23/82]	01-03 GW 01-03-[07/16/82]	01-03 GW 01-03-[07/20/82]	01-03 GW 01-03-[10/05/82]	01-03 GW 01-03-[11/08/82]	01-03 GW 01-03-[01/14/83]	01-03 GW 01-03-[02/22/83]	01-03 GW 01-03-[07/27/83]	01-03 GW 01-03-[01/31/84]	01-03 GW 01-03-[06/07/84]	01-03 GW 01-03-[06/10/85]	01-03 GW 01-03-[01/28/86]	01-03 GW 01-03-[06/03/86]	01-04 GW 01-04-[11/30/81]	01-04 GW 01-04-[03/05/82]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE																	
1,1,2,2-TETRACHLOROETHANE						20											
1,1,2-TRICHLOROETHANE																	
1,1-DICHLOROETHANE																	
1,1-DICHLOROETHENE						1 U											
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE						1 U											
1,2-DICHLOROPROPANE																	
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER																	
ACROLEIN																	
ACRYLONITRILE																	
BENZENE																	
BROMODICHLOROMETHANE																	
BROMOFORM						2 U											
BROMOMETHANE																	
CARBON TETRACHLORIDE						1 U											
CHLOROBENZENE						1 U											
CHLORODIBROMOMETHANE																	
CHLOROETHANE																	
CHLOROFORM						1 U											
CHLOROMETHANE																	
CIS-1,3-DICHLOROPROPENE																	
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE																	
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE																	
ETHYLBENZENE																	
METHYLENE CHLORIDE						1 U											
TETRACHLOROETHANE																	
TETRACHLOROETHENE						1 U											
TETRAHYDROFURAN																	
TOLUENE																	
TRANS-1,2-DICHLOROETHENE						1 U											
TRANS-1,3-DICHLOROPROPENE																	
TRICHLOROETHENE						3											
TRICHLOROFLUOROMETHANE																	
VINYL CHLORIDE																	
PESTICIDES/PCBs (ug/L)																	
ENDRIN	0.04 U		0.04 U		0.04 U	0.04 U										0.04 U	
GAMMA-BHC (LINDANE)	0.08 U		0.08 U		0.08 U	0.08 U										0.08 U	
METHOXYCHLOR	1.6 U		1.6 U		1.6 U	1.6 U										1.6 U	
SILVEX (2,4,5-TP)	0.5 U		0.5 U		0.5 U	0.5 U										0.5 U	
TOXAPHENE	1.6 U		1.6 U		1.6 U	1.6 U										1.6 U	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA	4.08 U		3.22 U		3.11 U	3.04 U										4.08 U	
GROSS BETA	2.07		4.49		2.12 U	1.66 U										3.36	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D	3.8 U		3.8 U		3.8 U	3.8 U										3.8 U	
INORGANICS (ug/L)																	
ARSENIC	10 U		10 U		10 U	10 U										10 U	
BARIUM	100 U		100 U		100 U	100 U										100 U	
CADMIUM	5 U		5 U		5 U	5 U										5 U	
CHROMIUM	10 U		10 U		10 U	10 U										10 U	
IRON	650	650	100		710	30 U	710		110							30 U	
IRON, TOTAL											10 U			20 U			
LEAD	10 U		10 U		10 U	10 U										10 U	
MANGANESE	30		10 U		30 U	290		290	10		5 U			20 U		6200	6200
MERCURY	0.2 U		0.2 U		0.2 U	0.9										0.2 U	
SELENIUM	5 U		10 U		5 U	5 U										5 U	
SILVER	10 U		10		10 U	10 U										10 U	
SODIUM	16000		17000		13000	10000			17000		12000			12000		90000	
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L	4.5		7		7	1 U			6		5			4		28.6	
CONDUCTANCE, FIELD UMHO/CM													350				
FLUORIDE MG/L	0.11		0.1 U		0.1	0.2										0.24	
NITRATE/NITRITE, AS N MG/L	0.17		0.13		0.06	0.11										0.06	
ORGANIC BROMINE MG/L											0.016	0.002 U		0.01 U			
ORGANIC CHLORINE MG/L											1.3	0.06		0.01 U	0.1		
ORGANIC IODINE MG/L											0.006	0.007		0.01 U	0.01		
PH														7	6.7		
PH, FIELD	7.3		6.4	6.4	6.7	7			7.2	6.5	6.9	7.2	7.3			6.8	
PHENOLS MG/L	0.01 U		0.01 U		0.06	0.03			0.01 U		0.004 U			0.01 U		0.01 U	
SPECIFIC CONDUCTIVITY UMHO/CM	540		422		465	500			590	650	360	400		320	415	1300	
SULFATE MG/L	36.5		29.8		31	15		15	33		26			27		372	372
TOTAL COLIFORPHM	5	5														9	9
TOTAL ORGANIC CARBON MG/L	3.6		2.5		38	34			25	32	2 U	2 U	2.8	1 U	3	12.7	
TOTAL ORGANIC HALOGENS MG/L	0.05		0.019		0.058	0.01 U			0.01 U	0.087 C			0.2			0.102	
VOLATILES SCAN MG/L														5 U			

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-04	01-05	01-05	01-05
matrix	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
nsample	01-04-[03/23/82]	01-04-[07/18/82]	01-04-[07/20/82]	01-04-[08/21/82]	01-04-[10/05/82]	01-04-[11/08/82]	01-04-[01/14/83]	01-04-[02/22/83]	01-04-[07/26/83]	01-04-[01/31/84]	01-04-[06/07/84]	01-04-[06/10/85]	01-04-[01/29/86]	01-04-[06/03/86]	01-05-[11/30/81]	01-05-[03/05/82]	01-05-[03/23/82]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE																	
1,1,2,2-TETRACHLOROETHANE					1 U												
1,1,2-TRICHLOROETHANE																	
1,1-DICHLOROETHANE																	
1,1-DICHLOROETHENE					1 U												
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE					1 U												
1,2-DICHLOROPROPANE																	
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER																	
ACROLEIN																	
ACRYLONITRILE																	
BENZENE																	
BROMODICHLOROMETHANE																	
BROMOFORM					2 U												
BROMOMETHANE																	
CARBON TETRACHLORIDE					1 U												
CHLOROBENZENE					1 U												
CHLORODIBROMOMETHANE																	
CHLOROETHANE																	
CHLOROFORM					1 U												
CHLOROMETHANE																	
CIS-1,3-DICHLOROPROPENE																	
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE																	
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE																	
ETHYLBENZENE																	
METHYLENE CHLORIDE					1												
TETRACHLOROETHANE																	
TETRACHLOROETHENE					1 U												
TETRAHYDROFURAN																	
TOLUENE																	
TRANS-1,2-DICHLOROETHENE					1 U												
TRANS-1,3-DICHLOROPROPENE																	
TRICHLOROETHENE					1 U												
TRICHLOROFLUOROMETHANE																	
VINYL CHLORIDE																	
PESTICIDES/PCBs (ug/L)																	
ENDRIN	0.04 U		0.04 U		0.04 U										0.04 U		0.04 U
GAMMA-BHC (LINDANE)	0.08 U		0.08 U		0.08 U										0.08 U		0.08 U
METHOXYCHLOR	1.6 U		1.6 U		1.6 U										1.6 U		1.6 U
SILVEX (2,4,5-TP)	0.5 U		0.5 U		0.5 U										0.5 U		0.5 U
TOXAPHENE	1.6 U		1.6 U		1.6 U										1.6 U		1.6 U
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA	6.73 U		6.54 U		6.33 U										4.08 U		10.1 U
GROSS BETA	2.88		1.55		1.66 U										6.27		4.16
RADIUM-226	0.19		0.17	0.17	0.21												0.48
HERBICIDES (ug/L)																	
2,4-D	3.8 U		3.8 U		3.8 U										3.8 U		3.8 U
INORGANICS (ug/L)																	
ARSENIC	10 U		10 U		10 U										10 U		10 U
BARIUM	100 U		100 U		100 U										100 U		100 U
CADMIUM	5 U		5 U		5 U										5 U		5 U
CHROMIUM	10 U		10 U		10 U										10 U		10 U
IRON	80		120		1000 U			30 U							200		90
IRON, TOTAL										10 U			40				
LEAD	10 U		10 U		10 U										10 U		10 U
MANGANESE	7000	7000	150		500	150	500	1090		130			70		5700	5700	6400
MERCURY	0.2 U		0.2 U		0.7 U										0.2 U		0.2 U
SELENIUM	5 U		5 U		5 U										5 U		5 U
SILVER	10 U		10 U		10 U										10 U		10 U
SODIUM	80000		130000		109000			132000		120000			100000		136000		210000
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L	62.4		30		22			21		19			20		98.9		82.9
CONDUCTANCE, FIELD UMHO/CM												1204					
FLUORIDE MG/L	0.19		0.26		0.26										0.17		0.15
NITRATE/NITRITE, AS N MG/L	0.05 U		0.05 U		0.18										0.05 U		0.12
ORGANIC BROMINE MG/L										0.002 U	0.008		0.01 U	0.01 U			
ORGANIC CHLORINE MG/L										0.39	0.02		0.31	0.01 U			
ORGANIC IODINE MG/L										0.003	0.008		0.01 U	0.01			
PH													6.6	6.6			
PH, FIELD	6.4	6.4	6.8		6.7			7.1	6.7	6.7	6.9	7			7.1		6.4
PHENOLS MG/L	0.01 U		0.02		0.01			0.01 U		0.004 U			0.01		0.01		0.01 U
SPECIFIC CONDUCTIVITY UMHO/CM	1500		1350		1480			1375	1850	1400	1800		-1300	1680	2100		2250
SULFATE MG/L	460	460	510		420	510	420	430		470			340		711	711	760
TOTAL COLIFORPHM															2	2	
TOTAL ORGANIC CARBON MG/L	11		48		58			22	25	2 U	2	2.4	3	1 U	12.7		6
TOTAL ORGANIC HALOGENS MG/L	0.023		0.02		0.038			0.014	0.011 C			0.0235			0.049		0.125
VOLATILES SCAN MG/L																	

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-05 GW 01-05-[07/18/82]	01-05 GW 01-05-[07/20/82]	01-05 GW 01-05-[08/21/82]	01-05 GW 01-05-[10/05/82]	01-05 GW 01-05-[11/08/82]	01-05 GW 01-05-[01/14/83]	01-05 GW 01-05-[02/22/83]	01-05 GW 01-05-[07/27/83]	01-05 GW 01-05-[01/31/84]	01-05 GW 01-05-[06/07/84]	01-05 GW 01-05-[01/07/85]	01-05 GW 01-05-[06/10/85]	01-05 GW 01-05-[01/29/86]	01-05 GW 01-05-[06/03/86]	01-06 GW 01-06-[10/05/82]	01-06 GW 01-06-[01/30/86]	01-06 GW 01-06-[06/15/86]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE											1 U						
1,1,2,2-TETRACHLOROETHANE				58							85.9		7		1 U		
1,1,2-TRICHLOROETHANE											4.6		5				
1,1-DICHLOROETHANE											1 U						
1,1-DICHLOROETHENE				1 U							1 U				1 U		
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE				1 U							1 U				1 U		
1,2-DICHLOROPROPANE											1 U						
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER											1 U						
ACROLEIN											100 U						
ACRYLONITRILE											100 U						
BENZENE											1 U						
BROMODICHLOROMETHANE											1 U						
BROMOFORM				2 U							1 U				2 U		
BROMOMETHANE											10 U						
CARBON TETRACHLORIDE				1 U							1 U				1 U		
CHLOROBENZENE				1 U							1 U				1 U		
CHLORODIBROMOMETHANE											1 U						
CHLOROETHANE											10 U						
CHLOROFORM				1 U							1 U				1 U		
CHLOROMETHANE											10 U						
CIS-1,3-DICHLOROPROPENE											1 U						
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE											10 U						
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE																	
ETHYLBENZENE											1 U						
METHYLENE CHLORIDE				1 U							1 U				3		
TETRACHLOROETHANE																	
TETRACHLOROETHENE				1 U							3.8 U				1 U		
TETRAHYDROFURAN													11				
TOLUENE											1 U						
TRANS-1,2-DICHLOROETHENE				1 U							1 U				1 U		
TRANS-1,3-DICHLOROPROPENE											1 U						
TRICHLOROETHENE				2900							1010		380		1 U		
TRICHLOROFLUOROMETHANE											1 U						
VINYL CHLORIDE											10 U						
PESTICIDES/PCBs (ug/L)																	
ENDRIN		0.04 U		0.04 U													
GAMMA-BHC (LINDANE)		0.08 U		0.08 U													
METHOXYCHLOR		1.6 U		1.6 U													
SILVEX (2,4,5-TP)		0.5 U		0.5 U													
TOXAPHENE		1.6 U		1.6 U													
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA		10.8 U		9.35 U													
GROSS BETA		3.91		3.3													
RADIUM-226		0.33	0.33	0.32													
HERBICIDES (ug/L)																	
2,4-D		3.8 U		3.8 U													
INORGANICS (ug/L)																	
ARSENIC		10 U		10													
BARIUM		100 U		100 U													
CADMIUM		5 U		5 U													
CHROMIUM		10 U		10 U													
IRON		120		30 U			30 U										
IRON, TOTAL									550				5800			20 U	
LEAD		10 U		10 U													
MANGANESE	6400	2820		4800	2820	4800	4500		6600				5700			20	
MERCURY		0.2 U		1.1													
SELENIUM		5 U		5 U													
SILVER		10 U		10 U													
SODIUM		208000		144000			182000		140000				14000			14000	
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L		90		95			88		94				83			4	
CONDUCTANCE, FIELD UMHO/CM												1564					
FLUORIDE MG/L		0.19		0.19													
NITRATE/NITRITE, AS N MG/L		0.16		0.14													
ORGANIC BROMINE MG/L									0.005	0.01			0.01 U			0.01 U	0.01 U
ORGANIC CHLORINE MG/L									0.14	0.45			0.25	0.39		0.01 U	0.01
ORGANIC IODINE MG/L									0.006	0.01			0.01 U	0.01		0.01 U	0.01 U
PH													6.6	6.6		6.7	6.6
PH, FIELD	6.4	6.7		6.8			6.8	6.8	6.7	7.3		7					
PHENOLS MG/L		0.05		0.01			0.01 U		0.004 U				0.01 U			0.01 U	
SPECIFIC CONDUCTIVITY UMHO/CM		2380		2200			2520	2460	2100	2300				2430		1400	1670
SULFATE MG/L	760	680		800	880	800	940		900				710			420	
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L		66		72			44	72	7	2		3.6	5	3		1 U	2
TOTAL ORGANIC HALOGENS MG/L		1.6		0.4			0.75	0.39 C				2.19					
VOLATILES SCAN MG/L													0 SR				

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location	01-07	01-07	01-07	01-07	01-07	01-07	01-07	01-08	01-08	01-08	01-08	01-08	01-09	01-09	01-09	01-09	01-09
matrix	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
nsample	01-07-[11/18/82]	01-07-[04/20/83]	01-07-[06/07/84]	01-07-[01/07/85]	01-07-[06/10/85]	01-07-[01/29/86]	01-07-[06/15/86]	01-08-[11/18/82]	01-08-[01/07/85]	01-08-[06/10/85]	01-08-[01/29/86]	01-08-[06/15/86]	01-09-[11/18/82]	01-09-[01/07/85]	01-09-[06/10/85]	01-09-[01/29/86]	01-09-[06/15/86]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE																	
1,1,2,2-TETRACHLOROETHANE		0 U															
1,1,2-TRICHLOROETHANE																	
1,1-DICHLOROETHANE																	
1,1-DICHLOROETHENE																	
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE																	
1,2-DICHLOROPROPANE																	
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER																	
ACROLEIN																	
ACRYLONITRILE																	
BENZENE		0 U															
BROMODICHLOROMETHANE		0 U															
BROMOFORM		0 U															
BROMOMETHANE																	
CARBON TETRACHLORIDE																	
CHLOROBENZENE																	
CHLORODIBROMOMETHANE																	
CHLOROETHANE																	
CHLOROFORM		0 U															
CHLOROMETHANE																	
CIS-1,3-DICHLOROPROPENE																	
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE																	
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE																	
ETHYLBENZENE																	
METHYLENE CHLORIDE	40							2					5				
TETRACHLOROETHANE																	
TETRACHLOROETHENE		0 U															
TETRAHYDROFURAN																	
TOLUENE																	
TRANS-1,2-DICHLOROETHENE		0 U															
TRANS-1,3-DICHLOROPROPENE																	
TRICHLOROETHENE	3	0 U						1					5				
TRICHLOROFLUOROMETHANE																	
VINYL CHLORIDE																	
PESTICIDES/PCBs (ug/L)																	
ENDRIN																	
GAMMA-BHC (LINDANE)																	
METHOXYCHLOR																	
SILVEX (2,4,5-TP)																	
TOXAPHENE																	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA																	
GROSS BETA																	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D																	
INORGANICS (ug/L)																	
ARSENIC																	
BARIUM																	
CADMIUM																	
CHROMIUM																	
IRON				270					2990					30			
IRON, TOTAL						1300					3700					20	
LEAD																	
MANGANESE				1400		1500			670		670			10		20 U	
MERCURY																	
SELENIUM																	
SILVER																	
SODIUM				26000		22000			9100		7100			4900		3800	
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L				2		16			1 U		7			1 U		1	
CONDUCTANCE, FIELD UMHO/CM				1200	940				500	410				290	265		
FLUORIDE MG/L																	
NITRATE/NITRITE, AS N MG/L																	
ORGANIC BROMINE MG/L			0.002 U			0.01 U	0.01 U				0.01 U	0.01 U				0.01 U	0.01 U
ORGANIC CHLORINE MG/L			0.02			0.03	0.01 U				0.1	0.01 U				0.01 U	0.01 U
ORGANIC IODINE MG/L			0.002 U			0.01 U	0.01 U				0.01 U	0.01 U				0.01 U	0.01 U
PH						6.5	6.3				6.4	6.1				7	6.7
PH, FIELD				6.4	6.2				6.4	6.1				5.7	7.1		
PHENOLS MG/L				0.05 U		0.01 U			0.05 U		0.01 U			0.05 U		0.01 U	
SPECIFIC CONDUCTIVITY UMHO/CM						1100	1240				400	470				390	330
SULFATE MG/L				290		380			120		62			63		38	
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L				3.9	3.3	1 U	1 U		3.9	9.7	1 U	3		5.4	2.2	3	7
TOTAL ORGANIC HALOGENS MG/L				0.0067	0.005 U				0.018	0 U				0.091	0.18		
VOLATILES SCAN MG/L																	

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-10 GW 01-10-[01/25/83]	01-10 GW 01-10-[06/07/84]	01-10 GW 01-10-[01/07/85]	01-10 GW 01-10-[06/10/85]	01-10 GW 01-10-[01/30/86]	01-10 GW 01-10-[06/04/86]	01-11 GW 01-11-[01/11/83]	01-11 GW 01-11-[06/07/84]	01-11 GW 01-11-[01/07/85]	01-11 GW 01-11-[06/10/85]	01-11 GW 01-11-[01/29/86]	01-11 GW 01-11-[06/03/86]	01-12 GW 01-12-[01/25/83]	01-12 GW 01-12-[06/07/84]	01-12 GW 01-12-[01/07/85]	01-12 GW 01-12-[06/10/85]	01-12 GW 01-12-[01/29/86]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE	5								1 U				6		1 U		
1,1,2,2-TETRACHLOROETHANE	1 U								138		760		6000		518		280
1,1,2-TRICHLOROETHANE	1 U								101		12		341		5.2 U		7
1,1-DICHLOROETHANE	1 U								1 U				1 U		1 U		
1,1-DICHLOROETHENE	1 U								1 U				1 U		1 U		
1,2-DICHLOROBENZENE	1 U												1 U				
1,2-DICHLOROETHANE	1 U								1 U				28		1 U		
1,2-DICHLOROPROPANE	1 U								1 U				1 U				
1,3-DICHLOROBENZENE	1 U												1 U				
1,3-DICHLOROPROPENE	1 U												1 U				
1,4-DICHLOROBENZENE	1 U												1 U				
2-CHLOROETHYL VINYL ETHER	2 U								1 U				2 U		1 U		
ACROLEIN									100 U						100 U		
ACRYLONITRILE									100 U						100 U		
BENZENE	1								1 U				1 U		1 U		
BROMODICHLOROMETHANE	1 U								1 U				1 U		1 U		
BROMOFORM	2 U								1 U				2 U		1 U		
BROMOMETHANE	2 U								10 U				2 U		10 U		
CARBON TETRACHLORIDE	1 U								1 U				1 U		1 U		
CHLOROBENZENE	1 U								1 U				1 U		1 U		
CHLORODIBROMOMETHANE	1 U								1 U				1 U		61		
CHLOROETHANE	2 U								10 U				2 U		10 U		
CHLOROFORM	1 U								1 U		20		53		13		5
CHLOROMETHANE	2 U								10 U				2 U		1 U		
CIS-1,3-DICHLOROPROPENE									1 U						1 U		
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE									10 U						10 U		
DICHLOROFLUOROMETHANE	1 U												2 U				
DICHLOROPROPANE																	
ETHYLBENZENE	1 U								1 U				1 U		1 U		
METHYLENE CHLORIDE	6								10 U				5		1 U		
TETRACHLOROETHANE																	
TETRACHLOROETHENE	1								5.2		10		1 U		1.4		
TETRAHYDROFURAN																	
TOLUENE	1 U						1 U		1 U				1 U		1 U		
TRANS-1,2-DICHLOROETHENE	1 U						4		1 U		17		24		19.3		6
TRANS-1,3-DICHLOROPROPENE									1 U						1 U		
TRICHLOROETHENE	8						150				500		2300		644 U		180
TRICHLOROFLUOROMETHANE	1 U						4		1 U				1 U		1 U		
VINYL CHLORIDE	1 U						1 U		10 U				1 U		10 U		
PESTICIDES/PCBs (ug/L)																	
ENDRIN																	
GAMMA-BHC (LINDANE)																	
METHOXYCHLOR																	
SILVEX (2,4,5-TP)																	
TOXAPHENE																	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA																	
GROSS BETA																	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D																	
INORGANICS (ug/L)																	
ARSENIC																	
BARIUM																	
CADMIUM																	
CHROMIUM																	
IRON			340						20 U						370		
IRON, TOTAL					130						20						140
LEAD																	
MANGANESE			870		530				40		20 U				340		240
MERCURY																	
SELENIUM																	
SILVER																	
SODIUM			21000		12000				4700		5800				17000		13000
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L			1 U		6				1 U		8				1 U		14
CONDUCTANCE, FIELD UMHO/CM			850	572					300	932					730	510	
FLUORIDE MG/L																	
NITRATE/NITRITE, AS N MG/L																	
ORGANIC BROMINE MG/L		0.002 U			0.01 U	0.01 U		0.01			0.01 U	0.01 U		0.002 U			0.01 U
ORGANIC CHLORINE MG/L		0.03			0.01 U	0.06		1.5			0.87	1.2		0.56			0.22
ORGANIC IODINE MG/L		0.002			0.01 U	0.01 U		0.017			0.01 U	0.02		0.004			0.01 U
PH					7	7					6.9	6.4					6.6
PH, FIELD			7	6.8					7.7	6.7					7.2	6.8	
PHENOLS MG/L			0.05 U		0.01 U				0.05 U		0.02				0.05 U		0.03
SPECIFIC CONDUCTIVITY UMHO/CM					620	760					400	410					470
SULFATE MG/L			140		54				15		46				120		120
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L			0.5 U	0.8	1 U	1 U			2.4	1.1	2	2			1.4	1.3	2
TOTAL ORGANIC HALOGENS MG/L			0.0065	0.005 U					0.386	0.204					1.53	0.71	
VOLATILES SCAN MG/L											0 SR						0 SR

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-12 GW 01-12-[06/15/86]	01-14 GW 01-14-[01/31/83]	01-14 GW 01-14-[06/07/84]	01-14 GW 01-14-[01/07/85]	01-14 GW 01-14-[06/10/85]	01-14 GW 01-14-[01/29/86]	01-14 GW 01-14-[06/04/86]	01-15 GW 01-15-[02/15/83]	01-15 GW 01-15-[04/20/83]	01-15 GW 01-15-[06/06/84]	01-15 GW 01-15-[01/07/85]	01-15 GW 01-15-[06/10/85]	01-15 GW 01-15-[01/28/86]	01-15 GW 01-15-[06/04/86]	01-16 GW 01-16-[02/15/83]	01-16 GW 01-16-[01/07/85]	01-16 GW 01-16-[06/10/85]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE		29		1 U				7			1 U				23		
1,1,2,2-TETRACHLOROETHANE		320		64.8		570		1500	1450		230		27		5400		
1,1,2-TRICHLOROETHANE		1 U		1 U		15		17			12.6				1 U		
1,1-DICHLOROETHANE		1 U		1 U				1 U			1 U				1 U		
1,1-DICHLOROETHENE		1 U		1 U				2			1 U				1		
1,2-DICHLOROBENZENE		1 U						1 U							1 U		
1,2-DICHLOROETHANE		4		1 U		14		32			1 U				23		
1,2-DICHLOROPROPANE		1 U		1 U				1 U			1 U				1 U		
1,3-DICHLOROBENZENE		1 U						1 U							1 U		
1,3-DICHLOROPROPENE		1 U						1 U							1000		
1,4-DICHLOROBENZENE		1 U						1 U							1 U		
2-CHLOROETHYL VINYL ETHER		2 U		1 U				2 U			1 U				2 U		
ACROLEIN				10 U							100 U						
ACRYLONITRILE				10 U							100 U						
BENZENE		1 U		1 U				1 U	0 U		1 U				1 U		
BROMODICHLOROMETHANE		1 U		1 U				1 U	0 U		1 U				1 U		
BROMOFORM		2 U		1 U				2 U	0 U		1 U				2 U		
BROMOMETHANE		2 U		10 U				2 U			10 U				2 U		
CARBON TETRACHLORIDE		1 U		1 U				1 U			1 U				1 U		
CHLOROBENZENE		1 U		1 U				1 U			1 U				1 U		
CHLORODIBROMOMETHANE		1 U		1 U				1 U			1 U				1 U		
CHLOROETHANE		2 U		10 U				2 U			10 U				2 U		
CHLOROFORM		7		3.3		24		39	8		13.8				43		
CHLOROMETHANE		2 U		10 U				2 U			10 U				2 U		
CIS-1,3-DICHLOROPROPENE				1 U							1 U						
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE				10 U							10 U						
DICHLOROFLUOROMETHANE		2 U						2 U							2 U		
DICHLOROPROPANE																	
ETHYLBENZENE		1 U		1 U				1 U			1 U				1 U		
METHYLENE CHLORIDE		7		1 U				3			1 U				7		
TETRACHLOROETHANE																	
TETRACHLOROETHENE		1 U		1 U				1 U			3.5				1 U		
TETRAHYDROFURAN													93				
TOLUENE		1 U		1 U				1 U			1 U						
TRANS-1,2-DICHLOROETHENE		3		3.6		16		18			14.8						
TRANS-1,3-DICHLOROPROPENE				1 U							1 U					1 U	
TRICHLOROETHENE		92		53.1		320		330	145		301		12			513	
TRICHLOROFLUOROMETHANE		19		1 U				0.1 U			1 U					1 U	
VINYL CHLORIDE		1 U		10 U				1 U			10 U					10 U	
PESTICIDES/PCBs (ug/L)																	
ENDRIN																	
GAMMA-BHC (LINDANE)																	
METHOXYCHLOR																	
SILVEX (2,4,5-TP)																	
TOXAPHENE																	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA																	
GROSS BETA																	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D																	
INORGANICS (ug/L)																	
ARSENIC																	
BARIUM																	
CADMIUM																	
CHROMIUM																	
IRON				210							5210						
IRON, TOTAL						6900							18000				
LEAD																	
MANGANESE				4300		2800					2600		4600				
MERCURY																	
SELENIUM																	
SILVER																	
SODIUM				51000		44000					36000		27000				
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L				3		43					3		63				
CONDUCTANCE, FIELD UMHO/CM				1520	145						1500	980					639
FLUORIDE MG/L																	
NITRATE/NITRITE, AS N MG/L																	
ORGANIC BROMINE MG/L	0.01 U		0.002 U			0.01 U	0.01 U			0.002 U			0.01 U	0.01 U			
ORGANIC CHLORINE MG/L	0.34		0.25			0.7	1.1			0.24			0.02	0.31			
ORGANIC IODINE MG/L	0.01 U		0.044			0.01 U	0.12			0.024			0.01 U	0.03			
PH	6.6					6.7	6.6						6.5	6.6			
PH, FIELD				6.2	6.2						6.1	6.4				7.1	6.4
PHENOLS MG/L				0.05 U		0.01					0.05 U		0.03				
SPECIFIC CONDUCTIVITY UMHO/CM	660					980	870						1200	1105			
SULFATE MG/L				360		230					290		400				
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L	5			9.6	4.8	2	5				0.5 U	8	1 U	3			3.4
TOTAL ORGANIC HALOGENS MG/L				0.159	0.334						0.59	1.62					1.33
VOLATILES SCAN MG/L						0 SR							0 SR				

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-17 GW 01-17-[02/15/83]	01-17 GW 01-17-[04/20/83]	01-17 GW 01-17-[06/07/84]	01-17 GW 01-17-[01/07/85]	01-17 GW 01-17-[06/10/85]	01-17 GW 01-17-[01/29/86]	01-17 GW 01-17-[06/04/86]	01-19 GW 01-19-[06/27/83]	01-19 GW 01-19-[06/06/84]	01-19 GW 01-19-[01/08/85]	01-19 GW 01-19-[06/10/85]	01-19 GW 01-19-[01/28/86]	01-19 GW 01-19-[06/04/86]	01-20 GW 01-20-[06/27/83]	01-20 GW 01-20-[06/06/84]	01-20 GW 01-20-[01/08/85]	01-20 GW 01-20-[06/10/85]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE	23			1 U				1 U		1 U				1			
1,1,2,2-TETRACHLOROETHANE	1 U	0 U		1 U		32				146		300					
1,1,2-TRICHLOROETHANE	1 U			1 U						5.7		9					
1,1-DICHLOROETHANE	1 U			1 U						1 U							
1,1-DICHLOROETHENE	1 U			1 U				1 U		1 U				6			
1,2-DICHLOROBENZENE	1 U																
1,2-DICHLOROETHANE	5			1 U				19		1 U		10		1 U			
1,2-DICHLOROPROPANE	1 U			1 U						1 U							
1,3-DICHLOROBENZENE	1 U																
1,3-DICHLOROPROPENE	1 U																
1,4-DICHLOROBENZENE	1 U																
2-CHLOROETHYL VINYL ETHER	2 U			1 U						1 U							
ACROLEIN				100 U						100 U							
ACRYLONITRILE				100 U						100 U							
BENZENE	1 U	0 U		1 U				1 U		1 U				1 U			
BROMODICHLOROMETHANE	1 U	0 U		1 U						1 U							
BROMOFORM	2 U	0 U		1 U						1 U							
BROMOMETHANE	2 U			10 U						10 U							
CARBON TETRACHLORIDE	1 U			1 U						1 U							
CHLOROBENZENE	1 U			1 U						1 U							
CHLORODIBROMOMETHANE	1 U									1 U							
CHLOROETHANE	2 U			10 U						10 U							
CHLOROFORM	8	2		1 U		5 U		15		10		14		1 U			
CHLOROMETHANE	2 U			10 U						10 U							
CIS-1,3-DICHLOROPROPENE				1 U						1 U							
DICHLORODIBROMOMETHANE				1 U													
DICHLORODIFLUOROMETHANE				1 U						10 U							
DICHLOROFLUOROMETHANE	1 U																
DICHLOROPROPANE																	
ETHYLBENZENE	1 U			1 U						1 U							
METHYLENE CHLORIDE	7			1 U				1 U		1 U				1 U			
TETRACHLOROETHANE										7.1							
TETRACHLOROETHENE	68	6		1 U													
TETRAHYDROFURAN																	
TOLUENE	1 U			1 U				1 U		5				1 U			
TRANS-1,2-DICHLOROETHENE	1 U	0 U		1 U						12		8					
TRANS-1,3-DICHLOROPROPENE				1 U						1 U							
TRICHLOROETHENE	67	58		1 U		52		180		221		240		430			
TRICHLOROFLUOROMETHANE	4			1 U				2		1 U				1 U			
VINYL CHLORIDE	1 U			10 U						10 U							
PESTICIDES/PCBs (ug/L)																	
ENDRIN																	
GAMMA-BHC (LINDANE)																	
METHOXYCHLOR																	
SILVEX (2,4,5-TP)																	
TOXAPHENE																	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA																	
GROSS BETA																	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D																	
INORGANICS (ug/L)																	
ARSENIC																	
BARIUM																	
CADMIUM																	
CHROMIUM										50						1600	
IRON				20 U													
IRON, TOTAL						50											
LEAD																	
MANGANESE				160		30				70						640	
MERCURY																	
SELENIUM																	
SILVER																	
SODIUM				64000		53000				83000						29000	
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L				3		20				2						1 U	
CONDUCTANCE, FIELD UMHO/CM				1200	600					1800	720					1500	1060
FLUORIDE MG/L																	
NITRATE/NITRITE, AS N MG/L																	
ORGANIC BROMINE MG/L			0.002 U			0.01 U	0.01 U		0.002 U				0.01 U		0.002 U		
ORGANIC CHLORINE MG/L			0.02			0.05	0.03		0.26				0.32		0.04		
ORGANIC IODINE MG/L			0.017			0.01 U	0.01		0.014				0.02		0.002 U		
PH						6.7	6.6						6.8				
PH, FIELD				6.3	6.8					6.8	6.7					7.4	5.8
PHENOLS MG/L				0.05 U		0.07				0.05 U						0.05 U	
SPECIFIC CONDUCTIVITY UMHO/CM						910	940						1140				
SULFATE MG/L				280		200				340						670	
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L				0.5 U	5.4	1 U	1 U			5.1	8.9		4			1.8	2.4
TOTAL ORGANIC HALOGENS MG/L				0.181	0.177					0.99	0.504					0.015	0.136
VOLATILES SCAN MG/L						0 SR											

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location	01-20	01-20	01-21	01-21	01-21	01-21	01-21	01-21	01-22	01-22	01-22	01-22	01-22	01-23	01-23	01-23	01-23
matrix	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW	GW
nsample	01-20-[01/29/86]	01-20-[06/04/86]	01-21-[06/27/83]	01-21-[06/06/84]	01-21-[01/08/85]	01-21-[06/10/85]	01-21-[01/30/86]	01-21-[06/15/86]	01-22-[07/14/83]	01-22-[06/06/84]	01-22-[01/08/85]	01-22-[01/28/86]	01-22-[06/04/86]	01-23-[07/14/83]	01-23-[06/07/84]	01-23-[01/07/85]	01-23-[06/10/85]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE			1						2		1 U			2			
1,1,2,2-TETRACHLOROETHANE	160								50		65.3	120		1 U			
1,1,2-TRICHLOROETHANE											1 U						
1,1-DICHLOROETHANE											1 U						
1,1-DICHLOROETHENE			1 U								1 U						
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE			1 U						3		1 U			1 U			
1,2-DICHLOROPROPANE																	
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER											1 U						
ACROLEIN											100 U						
ACRYLONITRILE											100 U						
BENZENE			2						3		1 U						
BROMODICHLOROMETHANE											1 U						
BROMOFORM											1 U						
BROMOMETHANE											10 U						
CARBON TETRACHLORIDE											1 U						
CHLOROBENZENE											1 U						
CHLORODIBROMOMETHANE											1 U						
CHLOROETHANE											10 U						
CHLOROFORM	5 U		1 U						4		4.4	8		2			
CHLOROMETHANE											1 U						
CIS-1,3-DICHLOROPROPENE											1 U						
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE											10 U						
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE											1 U						
ETHYLBENZENE											10.5						
METHYLENE CHLORIDE			3						1 U		1 U			6			
TETRACHLOROETHANE																	
TETRACHLOROETHENE											1 U						
TETRAHYDROFURAN																	
TOLUENE			1 U								5.1						
TRANS-1,2-DICHLOROETHENE											7.1						
TRANS-1,3-DICHLOROPROPENE											1 U						
TRICHLOROETHENE	75		1 U						80		117	140		2			
TRICHLOROFLUOROMETHANE			1 U								1 U						
VINYL CHLORIDE											10 U						
PESTICIDES/PCBs (ug/L)																	
ENDRIN																	
GAMMA-BHC (LINDANE)																	
METHOXYCHLOR																	
SILVEX (2,4,5-TP)																	
TOXAPHENE																	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA																	
GROSS BETA																	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D																	
INORGANICS (ug/L)																	
ARSENIC																	
BARIUM																	
CADMIUM																	
CHROMIUM																	
IRON					7280						160					500	
IRON, TOTAL	20 U						11000										
LEAD																	
MANGANESE	200				690		1100				240					450	
MERCURY																	
SELENIUM																	
SILVER																	
SODIUM	30000				16000		14000				113000					50000	
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L	9				1 U		8				1					1 U	
CONDUCTANCE, FIELD UMHO/CM					1500	565					1900					2340	1823
FLUORIDE MG/L																	
NITRATE/NITRITE, AS N MG/L																	
ORGANIC BROMINE MG/L	0.01 U	0.01 U		0.002 U			0.01 U	0.01 U		0.002 U			0.01 U		0.008		
ORGANIC CHLORINE MG/L	0.07	0.1		0.29			0.02	0.01 U		0.26			0.18		0.42		
ORGANIC IODINE MG/L	0.01 U	0.01 U		0.004			0.01 U	0.01 U		0.005			0.02		0.014		
PH	6.3	6.2						6.2					6.6				
PH, FIELD					6.2	5.8					6.5					6.7	6.4
PHENOLS MG/L	0.01				0.05 U		0.01				0.05 U					0.05 U	
SPECIFIC CONDUCTIVITY UMHO/CM	1400	1860					770	700					1420				
SULFATE MG/L	760				210		220				370					990	
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L	1 U	4			5.4	2	1 U	3			4.4		2			4.5	1.5
TOTAL ORGANIC HALOGENS MG/L					0.138	0.18					0.257					0.0063	0.0099
VOLATILES SCAN MG/L	0 SR						5 U										

TABLE B-2

HISTORICAL GROUNWATER ANALYSIS DATA DETAIL FOR THE MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA

location matrix nsample	01-23 GW 01-23-[01/30/86]	01-23 GW 01-23-[06/15/86]	01-24 GW 01-24-[07/14/83]	01-24 GW 01-24-[06/06/84]	01-24 GW 01-24-[01/07/85]	01-24 GW 01-24-[06/10/85]	01-24 GW 01-24-[01/30/86]	01-24 GW 01-24-[06/04/86]	01-25 GW 01-25-[06/06/84]	01-25 GW 01-25-[01/08/85]	01-25 GW 01-25-[06/10/85]	01-25 GW 01-25-[01/28/86]	01-25 GW 01-25-[06/04/86]	01-26 GW 01-26-[06/08/84]	01-26 GW 01-26-[01/08/85]	01-26 GW 01-26-[06/10/85]	01-26 GW 01-26-[01/28/86]
VOLATILE ORGANICS (ug/L)																	
1,1,1-TRICHLOROETHANE			1									42					
1,1,2,2-TETRACHLOROETHANE			1 U														
1,1,2-TRICHLOROETHANE																	
1,1-DICHLOROETHANE																	
1,1-DICHLOROETHENE																	
1,2-DICHLOROBENZENE																	
1,2-DICHLOROETHANE			1 U														
1,2-DICHLOROPROPANE																	
1,3-DICHLOROBENZENE																	
1,3-DICHLOROPROPENE																	
1,4-DICHLOROBENZENE																	
2-CHLOROETHYL VINYL ETHER																	
ACROLEIN																	
ACRYLONITRILE																	5
BENZENE			1 U														
BROMODICHLOROMETHANE																	
BROMOFORM																	
BROMOMETHANE																	
CARBON TETRACHLORIDE																	
CHLOROBENZENE																	
CHLORODIBROMOMETHANE																	
CHLOROETHANE												5 U					
CHLOROFORM			1 U														
CHLOROMETHANE																	
CIS-1,3-DICHLOROPROPENE																	
DICHLORODIBROMOMETHANE																	
DICHLORODIFLUOROMETHANE																	
DICHLOROFLUOROMETHANE																	
DICHLOROPROPANE																	
ETHYLBENZENE																	
METHYLENE CHLORIDE			2														
TETRACHLOROETHANE																	
TETRACHLOROETHENE																	
TETRAHYDROFURAN																	
TOLUENE																	
TRANS-1,2-DICHLOROETHENE																	
TRANS-1,3-DICHLOROPROPENE												59					
TRICHLOROETHENE			1 U														
TRICHLOROFLUOROMETHANE																	
VINYL CHLORIDE																	
PESTICIDES/PCBs (ug/L)																	
ENDRIN																	
GAMMA-BHC (LINDANE)																	
METHOXYCHLOR																	
SILVEX (2,4,5-TP)																	
TOXAPHENE																	
RADIONUCLIDES (PCU/L)																	
GROSS ALPHA																	
GROSS BETA																	
RADIUM-226																	
HERBICIDES (ug/L)																	
2,4-D																	
INORGANICS (ug/L)																	
ARSENIC																	
BARIUM																	
CADMIUM																	
CHROMIUM																	
IRON					70					20 U					2060		
IRON, TOTAL	20 U						890										
LEAD																	
MANGANESE	410				690		780			320					2440		
MERCURY																	
SELENIUM																	
SILVER																	
SODIUM	35000				21000		14000			127000					87000		
MISCELLANEOUS PARAMETERS																	
CHLORIDE MG/L	20				1 U		3			1 U					1 U		
CONDUCTANCE, FIELD UMHO/CM					445	285				2000	910				1900	1080	
FLUORIDE MG/L																	
NITRATE/NITRITE, AS N MG/L																	
ORGANIC BROMINE MG/L	0.01 U	0.01 U		0.002 U			0.01 U	0.01 U	0.002 U				0.01 U	0.002 U			
ORGANIC CHLORINE MG/L	0.01 U	0.01 U		0.23			0.01 U	0.01 U	0.08				0.05	0.02			
ORGANIC IODINE MG/L	0.01 U	0.01 U		0.002			0.01 U	0.01 U	0.007				0.01	0.011			
PH	6.7	6.4					6.9	6.5					6.8				
PH, FIELD					6.6	6.6				6	6.4				5.9	6.3	
PHENOLS MG/L	0.02				0.05 U		0.01 U			0.05 U					0.05 U		
SPECIFIC CONDUCTIVITY UMHO/CM	2000	1860					430	370					1500				
SULFATE MG/L	800				42		26			400					360		
TOTAL COLIFORPHM																	
TOTAL ORGANIC CARBON MG/L	1 U	3			2.7	1.1	1 U	2		10	9.4		3		9.5	3.3	
TOTAL ORGANIC HALOGENS MG/L					0.005 U	0.005 U				0.102	0.246				0.017	0.055	
VOLATILES SCAN MG/L	5 U						5 U										

APPENDIX B, PART 2

PART 2-1: BORING LOGS (WES-1-6-82 TO WES-1-27-83)

PART 2-2: WELL COMPLETION FORMS (ALL WELLS)

PART 2-3: GRAPHIC FIELD LOGS (WES-1-1-81 TO WES-1-5-81 AND WES-1-18-83 TO WES-1-27-83)

PART 2-4: HISTORICAL GROUND WATER MEASUREMENTS (ALL WELLS)

PART 2-1: BORING LOGS (WES-1-6-82 TO WES-1-27-83)

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 10 November 82
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 596.02 Boring No. WES-1-6-82

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	10 Nov			0.0	1.5			6-3/4"Rock Bit			6" Casing-Stickup 0.5'
		0.0	11.7	0.0	26.0			5-5/8"Rock Bit			Siltstone: reddish brown, grey, soft, weathered, dry
		11.7	23.5								Shale: grey, soft-medium, dry
		23.5	26.0								Shale: dark grey, black, dry
	10 Nov			0.0	50.0			5-5/8"Rock Bit			Air compressor filter went out and pumped large quantity of oil into hole. Traded air compressors and moved drilling rig 10 ft west to drill another boring. Grouted up contaminated hole.
		26.0	27.2								Coal: black, soft
		27.2	35.2								Shale: grey, soft
		35.2	36.0								Coal: black, soft
	11 Nov	36.0	54.5	50.0	90.0			5-5/8"Rock Bit			Sandstone: brown, red, fine-grained, 75% quartz sand, hard

WORKING DRAFT

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 1 of 2 Sheets

BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-6-82

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
											Damp spot at 42 and 49 ft
											No water overnight
		54.5	82.5								Limestone: grey, white, hard
		82.5	88.5								Shale: grey, soft
		88.5	89.5								Limestone: grey, hard
		89.5	90.0								Shale: grey, soft
											Water at 79.5 ft - Blew water
											from hole several times and will
											monitor depth in morning before
											installing screen.
	12 Nov										Water level at 69.87 ft -
											installed well screen

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 2 of 2 Sheets

BORING LOG
FIELD DATA

Project: NWSC Groundwater Study Site: Crane, IN Date: 14 November 82
Location: Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig: Failing Inspector: J. Dunbar Operator: D. Taylor Surface El: 604.20 Boring No. WES-1-7-82

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	14 Nov			0.0	0.8			6-3/4"Rock Bit			6" Casing to 0.8-Stickup at 1.2 ft
		0.0	3.5	0.8	20.0			5-5/8"Rock Bit			Siltstone: brown, white, soft
				20.0	28.5			5-5/8"Rock Bit			weathered, dry
		3.5	28.5								Shale: grey, dark grey, soft
											Water between 15-20 ft -
											Water level at 16.8 ft after 60
											minutes. Installed well

Sheet 1 of 1 Sheets

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WORKING DRAFT

Project NWSC Groundwater Study Site Crane, IN Date 15 November 82

Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22

Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 601.99 Boring No. WES-1-8-82

SAMPLE NUMBER	DATE TAKEN 1982	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	15 Nov			0.0	0.8			6-3/4"Rock Bit			6"Casing to 0.8 ft-Stickup 1.2 ft
				0.0	4.0			5-5/8"Rock Bit			Cleanout for core barrel
				4.0	6.5			Pitcher Sampler			Run 1-Cleanout to 6.5 with rock bit
				6.5	11.3			4x5½"Core Barrel			Run 2
				11.3	16.4			" "	"		Run 3
				16.4	21.1			" "	"		Run 4-Water starts at 18.0 ft
				21.1	25.5			" "	"		Run 5
				25.5	28.0			" "	"		Run 6
				28.0	31.1			" "	"		Run 7
		0.0	3.8								Siltstone
		3.8	12.0								Clay Shale
		12.0	28.8								Shale
		28.8	31.1								Limestone
											See boring log starting on
											page 2 for details

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Hole No. WES-1-8-82

DRILLING LOG	DIVISION US Navy	INSTALLATION NWSC, Crane, IN	SHEET 2 OF 5 SHEETS

1. PROJECT NWSC Groundwater Study	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Mustard Gas Burial Grounds	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
4. HOLE NO. (As shown on drawing title and file number) WES-1-8-82	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED Zero; UNDISTURBED Zero
5. NAME OF DRILLER D. Taylor	14. TOTAL NUMBER CORE BOXES Zero
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED 15 Nov 82; COMPLETED 15 Nov 82
7. THICKNESS OF OVERBURDEN 0.0	17. ELEVATION TOP OF HOLE 601.99
8. DEPTH DRILLED INTO ROCK 31.1 ft	18. TOTAL CORE RECOVERY FOR BORING 91.5% %
9. TOTAL DEPTH OF HOLE 31.1 ft	19. SIGNATURE OF INSPECTOR [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
601.99	0.0					
600.99	1.0		Siltstone: brown, white, weathered, soft-brittle, dry			
599.99	2.0			0%		
598.99	3.0					
597.99	4.0					
596.99	5.0		Clay shale: brownish grey, grey, weathered, soft, oxidized in regions, recovered 1 ft with Pitcher Sampler	40%		
595.99	6.0		Run 1			
594.99	7.0		No recovery			2 11:45 3.7' 11.52 1.1' 7 Min 7 Min 200-300PSI
593.99	8.0		Clay shale: brownish grey, grey, dark grey, soft, dry oxidized in regions, weathered, thinly bedded to thickly bedded, attitude of bedding is horizontal, sandy	77.1%		70 ± Smooth Grey Carbaloid Drill Bit
592.99	9.0					
591.99	10.0					

WORKING DRAFT

Hole No. WES-1-8-82

DRILLING LOG	DIVISION US Navy	INSTALLATION NWSC, Crane, IN	SHEET 3 OF 5 SHEETS

1. PROJECT NWSC Groundwater Study	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Mustard Gas Burial Grounds	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
4. HOLE NO. (As shown on drawing title and file number) WES-1-8-82	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER D. Taylor	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED / COMPLETED
	17. ELEVATION TOP OF HOLE
7. THICKNESS OF OVERBURDEN	18. TOTAL CORE RECOVERY FOR BORING %
8. DEPTH DRILLED INTO ROCK	19. SIGNATURE OF INSPECTOR
9. TOTAL DEPTH OF HOLE	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
591.99	10.0		Clay shale: same			
590.99	11.0		Run 2 RQD=64.7%			
589.99	12.0		No recovery			WL - Run 3 Began 12:45 Rec 3.7' End 1:05 Los 1.4' Time 20 Min Gai - Drl time 20 Min Hyd press 200-300 PSI Water press - RPM 70 + Drl Action Smo[illegible] [illegible] Grey, dark g[illegible]
588.99	13.0		closed - limonitic			
				72.5%		
587.99	14.0		Shale: grey, dark grey, soft, thinly bedded, horizontal, dry, sandy, oxidized, contains 2-5% thinly bedded (1/8") limestone			
586.99	15.0					
585.99	16.0		Run 3 RQD=64.9%			
584.99	17.0					WL - Run 4 Began 1:25 Rec 4.[illegible] End 1:40 Loss - Time 15 Min Gair - Drl time 15 Min Hyd press 200-300 P[illegible] Water press - RPM 70+ Drl Action Smooth [illegible] rot Grey [illegible]marks Water start at 18 ft - [illegible] quantity pr[illegible]d
583.99	18.0		Shale: dark grey, black, soft, uniform, highly fractured, thinly bedded, horizontal. Water starts at 18 ft-	100%		
582.99	19.0		20.15 ft - 1/2" grey sandstone, fine-grained, hard			
581.99	20.0					

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE

Hole No. WES-1-8-82

DRILLING LOG	DIVISION US Navy	INSTALLATION NWSC, Crane, IN	SHEET 4 OF 5 SHEETS

1. PROJECT: NWSC Groundwater Srudy
2. LOCATION (Coordinates or Station): Mustard Gas Burial Grounds
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): WES -1-8-82
5. NAME OF DRILLER: D. Taylor
6. DIRECTION OF HOLE: ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing 1500
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
581.99	20.0		Shale: same			
580.99	21.0		Run 4 RQD=46.8%			WL - Run 5 Began 2:00 Rec 4.4 End 2:15 Loss - Time 15 Min Gain - Drl time 15 Min Hyd press 200-300 PSI Water press - RPM 70± Drl Action ~~Water~~ ret Water-grey Remarks -
579.99	22.0					
578.99	23.0		Shale: same	100%		
577.99	24.0		fractured			
576.99	25.0		Run 5 RQD=54.5%			
575.99	26.0		fractured			WL - Run 6 Began 2:35 Rec 2.6' End 3:00 Loss - Time 25 Min Gain - Drl time 25 Min Hyd press 200 PSI Water press - RPM 70± Drl Action ~~Water~~ ret Water-dark grey Remarks
574.99	27.0		Shale: same	100%		
573.99	28.0		Run 6 RQD=0.0%			WL - Run 7 Began 3:50 Rec 3.0' End 4:15 Loss - Time 25 Min Gain - Drl time 25 Min Hyd press 200-300 PSI Water press - RPM 70± Drl Action ~~Water~~ ret Wet Brown Remarks Diamond Bit
572.99	29.0		Shale: same Limestone: brown, grey, fossilized, cherty(2-3%), fine grained	100%		
571.99	30.0		fractured			

WORKING DRAFT

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

Hole No. WES-1-8-82

DRILLING LOG	DIVISION US Navy	INSTALLATION NWSC, Crane, IN	SHEET 5 OF 5 SHEETS

1. PROJECT NWSC Groundwater Study	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Mustard Gas Burial Grounds	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL Failing 1500
4. HOLE NO. (As shown on drawing title and file number) WES-1-8-82	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER D. Taylor	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
571.99	30.0					
			Limestone	100%		
570.99	31.0		Run 7 RQD=96.7%			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 16 November 82
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Inspector J. Dunbar Operator D. Taylor Surface El 610.18 Boring No. WES-1-9-82

SAMPLE NUMBER	DATE TAKEN 1982	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	16Nov			0.0	1.0			6-3/4"Rock Bit			6" Casing to 1 ft-Stickup 1 ft
		0.0	1.5	0.0	29.5			5-5/8"Rock Bit			Clay(CL): brown, soft, sandy
		1.5	2.3								Sandstone: brown, fine-grained, weathered
											Clay shale: brownish grey, soft
		2.3	5.3								Clay shale: grey, soft
		5.3	9.0								Clay shale: brownish grey, soft
		9.0	11.3								Shale: grey, soft-slightly damp
		11.3	14.2								Shale: grey, soft
		14.2	17.0								Shale: light grey-grey, soft, wet
		17.0	24.0								Shale: dark grey, hard
		24.0	32.0								Water overnight at 22.2 ft -
	17Nov			29.5	32.0			5-5/8"Rock Bit			drilled to 32 ft and installed well

WORKING DRAFT

Sheet 1 of 1 Sheets

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 30 November 82
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 636.77 Boring No. WES-1-10-83

SAMPLE NUMBER	DATE TAKEN 1982	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	30Nov			0.0	1.0			6 3/4"Rock Bit			6" Casing to 1 ft-Stickup 1 ft
		0.0	2.0	0.0	120.0			5 5/8"Rock Bit			Clay(CL): brown, soft, damp,
											sandy
		2.0	6.5								Clay shale: brown, grey, soft
		6.5	8.0								Clay shale and sandstone interbedded:
											brown, soft
		8.0	20.0								Sandstone with interbedded shale:
											sandstone is brown, grey, fine-
											grained and shale is dark grey, soft
		20.0	21.0								Coal: black, soft
											dry
		21.0	35.0								Sandstone: white, light grey, soft
											uniform
		35.0	65.3								Shale: dark grey, soft, damp at
											around 40 ft - very little water
											after 75 min.

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-10-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		65.3	65.8								Coal/shale: black, soft
		65.8	73.2								Shale: light grey, dark grey, soft
		73.2	73.5								Shale/coal: black, soft
		73.5	83.0								Sandstone: grey, dark grey, very
											fine-grained, soft
		83.0	83.2								Limestone: grey, hard
		83.2	103.0								Sandstone: light brown, brown, grey
											very fine-grained, soft
		103.0	120.0								Limestone: grey, hard
	22Jan										Boring is to deep for any
											practical use. Filled boring with
											cement mix and grout. Moved
											approximately 10 ft from this
											location and drilled to 40 ft.
											Borings WES-1-12 and 13-83 on same

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 2 of 3 Sheets

WORKING DRAFT

BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-10-83

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
											shelf, encountered water between
											20 to 30 ft. Fractures are not
											present or not as intense at this
											location as in WES-1-12 and
											1-13-83. Believe there is a damp
											spot at 30.0 ft. Will construct
											a longer gravel filter around
											well screen.

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 3 of 3 Sheets

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 8 January 83
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 656.34 Boring No. WES-1-11-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	8 Jan			0.0	1.7			6" Casing			Stickup 0.3 ft
	8 Jan	0.0	4.6	0.0	19.6			5-5/8"Rock Bit			Clay(CL): brown, soft, moist, organic matter(roots)
		4.6	11.1								Sandstone: brown, very fine-grained, friable, water at 9.1 ft
		11.1	14.4								Sandstone: grey, very fine-grained, clayey
		14.4	18.8								Shale: dark grey, soft, interbedded with sandstone
		18.8	19.6								Limestone(?): very hard, no return
											Installed well

WORKING DRAFT

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 1 of 1 Sheets

BORING LOG
FIELD DATA

Project NWSC Groundwater Study
Location Mustard Gas Burial Grounds
Site Crane, IN
Date 19 January 83
Drill Rig Failing
Inspector J. Dunbar
Operator D. Taylor
Surface El 634.05
Job No. 441-G150.13GR21/22
Boring No. WES-1-12-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	19 Jan			0.0	1.0			6-3/4"Rock Bit			6" Casing - 1.0 ft stickup
		0.0	1.5	0.0	38.0			5-5/8"Rock Bit			Clay(CL): brown, soft, damp
		1.5	3.0								silty sand(SM): reddish brown, soft, damp, fine-grained
		3.0	7.5								Clay shale: brown, soft
		7.5	10.0								Shale: dark grey, soft
		10.0	13.5								Shale: dark grey, medium
		13.5	17.5								Shale: dark grey, medium, sandstone lenses-very fine-grained
		17.5	18.8								Shale: grey, soft
		18.8	19.5								Sandstone: grey, hard, fine-grained
		19.5	22.0								Coal: black, soft
		22.0	23.5								Shale: dark grey, soft
		23.5	28.0								Shale and sandstone: dark grey, soft, fine-grained sandstone, water at 27 ft
		28.0	38.0								Shale: light grey, soft, uniform

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 1 of 2 Sheets

BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-12-83

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
											Installed well

WORKING DRAFT

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 2 of 2 Sheets

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 19 January 83

Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22

Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 634.98 Boring No WES-1-13-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	19 Jan			0.0	1.0			6-3/4"Rock Bit			6"Casing - Stickup 1.0 ft
	21 Jan			0.0	4.0			5-5/8"Rock Bit			Cleanout for 4"x5½" Core Barrel
				4.0	7.2			4"x5½"Core Barrel			Run 1
				7.2	11.5			" " "			Run 2
				11.5	12.6			" " "			Run 3
				12.6	15.9			" " "			Run 4
				15.9	20.3			" " "			Run 5
				20.3	25.6			" " "			Run 6
				25.6	30.35			" " "			Run 7
				30.35	34.7			" " "			Run 8
	22 Jan			0.0	35.0			5-5/8"Rock Bit			Cleanout
		0.0	10.5								
		10.5	18.6								Clay Shale
		18.6	21.4								Shale(60%) and Sandstone(40%)
		21.4	22.9								Shale
		22.9	30.35								Coal (Bituminous)
											Sandstone

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-13-83

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		30.35	35.0								Sandstone(80-90%) and Shale (10-20%)
											See boring log starting on page 3 for details. Installed monitoring well on 22 January 83. Flow is estimated to be approximately 10-20 GPM

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 2 of 6 Sheets

WORKING DRAFT

Hole No. WES-1-

DRILLING LOG	DIVISION US Navy	INSTALLATION Crane, IN	SHEET OF 6

1. PROJECT: NWSC Groundwater Study
2. LOCATION (Coordinates or Station): Mustard Gas Burial Grounds
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): WES-1-13-83
5. NAME OF DRILLER: D. Taylor
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 0.0
8. DEPTH DRILLED INTO ROCK: 35.0
9. TOTAL DEPTH OF HOLE: 35.0
10. SIZE AND TYPE OF BIT: 4"x5½" Diamond
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED Zero; UNDIST Zero
14. TOTAL NUMBER CORE BOXES: Zero
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 20 Jan 83; COMPLETED 22 Jan
17. ELEVATION TOP OF HOLE: 634.98
18. TOTAL CORE RECOVERY FOR BORING: 92.6%
19. SIGNATURE OF INSPECTOR: [signature]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, dri... weathering, etc., if significant) g
634.98	0.0					
633.98	1.0		Clay Shale: brown, dark grey, weathered, brittle, oxidized, limonitic, soft			5-5/8" Rock Bit to ft to make room for 4"x5½" Core Barrel
632.98	2.0					
631.98	3.0					
630.98	4.0		MB = Machine break			21 January 83
629.98	5.0		MB; closed fracture; MB; MB			WL - Sec 1; Began 9:50 Rec 3; End 10:10 Loss -; Time 20 Min Gain -; Drl time 20 Min; Hyd press 200 PSI; Water press -; RPM 70+; Drl Action Smooth; ~~Water~~ ret brown, gr; Remarks Carbaloid dr bit
			fractured-weathered			
628.98	6.0		Clay shale: brown, dark grey, weathered, brittle, oxidized, limonitic, soft.			
			fractured - v. brittle, broke on removal from barrel			
627.98	7.0		Run 1 RQD=15.6%	100%		
			fractured - partial recovery			WL - Sec 2; Began 10:20 Rec 3.; End 10:35 Loss 0.; Time 15 Min Gain -; Drl time 15 Min; Hyd press 200 PSI; Water press -; RPM 70+; Drl Action Smooth; ~~Water~~ ret brown, grey orange; Remarks Carbaloid dr bit
626.98	8.0		fractured - larger rock pieces (1" to 4" fragments)			
625.98	9.0		Clay shale: same	88.4%		
			closed			
624.98	10.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

Hole No. WES-1-13-83

DRILLING LOG	DIVISION US Navy	INSTALLATION Crane, IN	SHEET 4 OF 6 SHEETS

1. PROJECT NWSC Groundwater Study	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Mustard Gas Burial Grounds	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL Failing
4. HOLE NO. (As shown on drawing title and file number) WES-1-13-83	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER D. Taylor	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED / COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
624.98	10.0		∠= 45° Clay shale: same			
			Shale(60%) and Sandstone(40%): ultra fine horizontal lamina and lenses of interbedded dark grey shale and light grey, very fine-grained sandstone, soft to medium			
623.98	11.0		Run 2 RQD=48.8%			WL - Run 3 Began 10:46 Rec 1.1' End 11:03 Loss - Time 17 Min Gain - Drl time 17 Min Hyd press 200 PSI Water press - RPM 70± Drl Action Smooth ~~Water~~ ret lt to dark grey Remarks Carbaloid drill bit
622.98	12.0		MB Shale(60%) and Sandstone(40%) MB same as above	100%		
			Run 3 RQD=45.5%			
621.98	13.0		oxidized from 13.25 to 13.35 ft Spin			
620.98	14.0		Shale(60%) and Sandstone(40%) same as above	72.7%		WL - Run 4 Began 11:13 Rec 2.4' End 11:20 Loss 0.9' Time 7 Min Gain - Drl time 7 Min Hyd press 200 PSI Water press - RPM 70± Drl Action Smooth ~~Water~~ ret light-dark grey Remarks Diamond drill bit
619.98	15.0		Run 4 RQD=72.7%			
618.98	16.0		Shale(50%) and Sandstone(50%) same as above			
617.98	17.0					WL - Run 5 Began 11:40 Rec 4.4' End 12:00 Loss - Time 20 Min Gain - Drl time 20 Min Hyd press 200 PSI Water press - RPM 70± Drl Action Smooth ~~Water~~ ret light-dark grey Remarks same
616.98	18.0		MB	100%		
615.98	19.0		fractured Shale: dark grey, soft, uniform, possibly damp			
614.98	20.0					

WORKING DRAFT

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

Hole No. WES-1-13-83

DRILLING LOG	DIVISION US Navy	INSTALLATION Crane IN	SHEET 5 OF 6 SHEETS

1. PROJECT: NWSC Groundwater Study
2. LOCATION (Coordinates or Station): Mustard Gas Burial Grounds
3. DRILLING AGENCY: CEWES
4. HOLE NO. (As shown on drawing title and file number): WES-1-13-83
5. NAME OF DRILLER: D. Taylor
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED _____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE
10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: Failing
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED / COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
614.98	20.0		Run 5 ROD=79.5%			
613.98	21.0		Shale: same - no recovery			WL - Run 6 Began 12:35 Rec 4.2' End 1:10 Loss 1.2' Time 35 Min Gain - Drl time 35 Min Hyd press 200 PSI Water press - RPM 70± Drl Action Smooth ~~Water~~ ret dark grey, black, white Remarks wet at coal seam
612.98	22.0		Coal (Bituminous): black, blocky, brittle, fractured, weathered-sulfides with gossan			
611.98	23.0		45°			
610.98	24.0		Sandstone: light grey, white, fine-grained, quartz sandstone, thinly bedded to massive with cross bedding visible, fractures are weathered, oxidized, with partial solution filling.	79.2%		WL - Run 7 Began 2:05 Rec 3.75' End 2:25 Loss - Time 20 Min Gain - Drl time 20 Min Hyd press 200 PSI Water press - RPM 70± Drl Action Smooth ~~Water~~ ret lt. grey, white Remarks Blocked off, More water
609.98	25.0		MB MB MB Run 6 ROD=40%			
608.98	26.0		orange brown from 26.7 ft to 27.1 ft			
607.98	27.0					
606.98	28.0		Sandstone: same as above	100%		
605.98	29.0		orange brown from 29.3 ft to 29.6 ft closed			
604.98	30.0					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

Hole No. WES-1-13-83

DRILLING LOG	DIVISION US Navy	INSTALLATION Crane, IN	SHEET 6 OF 6 SHEETS

1. PROJECT NWSC Groundwater Study	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station) Mustard Gas Burial Grounds	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY CEWES	12. MANUFACTURER'S DESIGNATION OF DRILL Failing
4. HOLE NO. (As shown on drawing title and file number) WES-1-13-83	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED / UNDISTURBED
5. NAME OF DRILLER D. Taylor	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE: STARTED / COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
604.98	30.0		Run 7 RQD=100%			
			Sandstone: same			
			fracture-weathered and oxidized			
603.98	31.0		Shale content in this interval at 5-10%			WL - Run 8 Began 3:00 Rec 4.35 End 3:35 Loss - Time 35 Min Gain - Drl time 35 Min Hyd press 200 PSI Water press - RPM 70 ± Drl Action Smooth ~~Water~~ ret lt-dark grey
602.98	32.0		Sandstone (see above) with 10-20% thinly bedded, soft, dark grey shale seams, coal lamina are also present			
601.98	33.0					Remarks Stuck core barrel and removed on 22 January 83 Estimate quantity of flow to be 10 to 20 GPM
600.98	34.0			100%		
			Run 8 RQD=54%			
599.98	35.0		Reamed hole with 5-5/8" Rock Bit and set well			

WORKING DRAFT

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 25 January 83
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 656.14 Boring No. WES-1-14-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	26 Jan			0.0	1.0			6-3/4"Rock Bit			6" Casing - 1.0 ft stickup
		0.0	3.0					5-5/8"Rock Bit			Clay(CL): brown, soft, damp, sandy
		3.0	6.0								Gravelly clay(GC): same as above, gravel is fine to coarse at 30%
		6.0	7.5								Clay(CL): brown, soft, damp
		7.5	14.5								Sandstone: brown, fine-grained, soft, weathered
		14.5	15.5								Shale: brown, dark brown, soft
		15.5	20.0								Sandstone: brown, light grey, fine-grained, soft
		20.0	24.0								Shale(60%) and sandstone(40%): light grey, dark grey, medium fine-grained sandstone
		24.0	36.0								Shale: dark grey, uniform, water at 25.5 ft
											Installed well

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 1 of 1 Sheets

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 10 February 83
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 663.01 Boring No. WES-1-15-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	10 Feb			0.0	1.0			6-3/4"Rock Bit			6" Casing - 1 ft stickup
		0.0	5.0	1.0	37.8			5-5/8"Rock Bit			Clay(CL): brown, soft, damp, sandy
		5.0	10.0								Limestone: grey, hard, fine-grained
		10.0	11.5								Clay: brown, soft
		11.5	13.2								Sandstone: reddish brown, fine-
											grained, soft
		13.2	15.8								Clay: brown, soft
		15.8	21.7								Sandstone: light brown, grey, fine-
											grained, soft
		21.7	32.0								Sandstone: grey, fine-grained, soft
											water between 25-26 ft
		32.0	33.0								Shale: grey, soft
		33.0	37.8								Sandstone: light grey, fine-grained,
											soft
											Installed well

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Sheet 1 of 1 Sheets

WORKING DRAFT

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 11 February 83
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 641.94 Boring No. WES-1-16-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	11 Feb			0.0	1.0			6-3/4"Rock Bit			6" Casing - 1 ft stickup
		0.0	9.5	1.0	38.5			5-5/8"Rock Bit			Sandstone: reddish brown, fine-
											grained, soft, weathered
		9.5	10.6								Clay: brown, soft
		10.6	16.5								Sandstone: brownish grey, soft,
											fine-grained
		16.5	26.0								Sandstone: grey, fine-grained, soft
		26.0	29.4								Sandstone: reddish brown, grey,
											soft, fine-grained, water at 27.5 ft
		29.4	35.2								Shale: blueish grey, soft, uniform
		35.2	36.0								Coal: black, soft
		36.0	38.5								Sandstone: grey, soft, fine-grained
											Installed well

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Sheet 1 of 1 Sheets

BORING LOG
FIELD DATA

Project NWSC Groundwater Study Site Crane, IN Date 12 February 83
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator D. Taylor Surface El 662.54 Boring No. WES-1-17-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	12 Feb			0.0	1.5			6-3/4"Rock Bit			6" Casing - 0.5 ft stickup
		0.0	2.8	1.5	39.0			5-5/8"Rock Bit			Clay(CL): brown, soft, damp, sandy
		2.8	10.0								Clay(CL) and sandstone gravel:
											brown, reddish brown, soft,damp, fin
											to coarse gravel, weathered
		10.0	18.0								Sandstone: tan, light brown, soft,
											fine-grained, uniform
		18.0	34.0								Sandstone: light brown, reddish
											brown, weathered, soft, water
											at 28 ft
		34.0	39.0								Shale: grey, soft, possibly oily
											Blew well several times. Appearance
											of oil film which did not come from
											compressor or rig. Installed well
											and gravel and rinsed with water to

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WORKING DRAFT

BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-17-83

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
											clear up. Poured bentonite pellets
											and grouted up.

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Sheet 2 of 2 Sheets

BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 17 June 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 658.40 Boring No. WES-1-18-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	17 Jun	0.0	3.0	0.0	30.5			5-5/8" Rock	Bit		Clay (CL): brown, sandy, damp, slight to moderate cohesion, organic matter.
		3.0	11.0								Sandstone: light brown, soft weathered, very fine-grained, quartz sand.
		11.0	12.5								Sandstone: dark brown, weathered, soft, very fine-grained, quartz sand.
		12.5	13.5								Sandstone: light brown, weathered, soft, very fine-grained, quartz sand.
		13.5	13.7								Shale: light grey, soft.

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-18-83

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		13.7	14.0								Sandstone: light brown, soft, very fine-grained, quartz sand.
		14.0	16.5								Shale: light grey, soft.
		16.5	18.0								Sandstone: dark brown, very fine-grained, soft, wet at 18 ft.
		18.0	19.5								Sandstone and shale: brown, light grey, soft, thinly bedded.
		19.5	19.7								Sandstone: brown, weathered, very fine-grained.
		19.7	21.5								Sandy shale: dark grey, soft, sandy - very fine-grained.

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-18-83

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
		21.5	24.0								Sandstone and shale: sandstone grades from dark brown to brown, shale ranges from light grey to dark grey, soft, thinly bedded.
		24.5	30.5								Sandstone: brown, tan, dark brown, soft, very fine-grained, quartz sand.
	18 Jun										Open hole overnight - water level at 14.04 ft. Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 17 June 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 656.79 Boring No. WES-1-19-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	17 Jun	0.0	6.5	0.0	30.2			5-5/8" Rock	Bit		Clay (CL): brown, soft, sandy, organic matter, slight to moderate cohesion.
		6.5	11.5								Sandstone: brown, very fine-grained, soft.
		11.5	12.5								Shale: grey, very soft.
		12.5	15.0								Sandstone: light brown, very fine-grained, soft.
		15.0	16.0								Sandstone: light grey - same.
		16.0	16.5								Sandstone: brown - same.
		16.5	17.0								Clay/Shale: grey, very soft, damp.

Sheet 1 of 2 Sheets

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____

Location _____ Job No. _____

Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-19-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		17.0	30.2								Sandstone: brown, grey, dark brown, very fine-grained, quartz sand, soft, thinly bedded with trace of shale.
	18 Jun										Open hole overnight - water level at 19.2 ft. Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 20 June 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 631.35 Boring No. WES-1-20-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	20 Jun	0.0	6.0	0.0	36.1			5-5/8" Rock	Bit		Clay (CL): brown soft, gravelly, damp.
		6.0	7.0								Sandstone: brown, very fine-grained, soft, weathered.
		7.0	36.1								Shale: grey, light grey, dark grey, soft, uniform, water at 20 ft.
	21 Jun										Hole open overnight - water level at 24.55. Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 20 June 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 603.82 Boring No. WES-1-21-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	20 Jun	0.0	6.5	0.0	40.5			5-5/8" Rock	Bit		Clay (CL): brown, soft, gravelly, damp.
		6.5	9.5								Clay (CL): grey, soft, uniform.
		9.5	16.5								Clay (CL): brown, soft, uniform.
		16.5	24.5								Shale: grey, soft, uniform.
		24.5	40.5								Shale: light grey, grey, dark grey, soft, water at 28 ft.
	21 Jun										Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 8 July 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 653.55 Boring No. WES-1-22-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	8 Jul	0.0	13.0	0.0	35.0			6" Rock Bit			Clay (CL): brown and grey, sandy, soft to stiff.
		13.0	21.5								Sandstone: brown, weathered, very fine-grained, soft, damp at 17.5 (no water).
		21.5	22.0								Siltstone: brown, soft, weathered, damp at 22 ft.
		22.0	32.0								Sandstone: brown, light grey, soft, weathered, very fine-grained, water at 25 ft.
		32.0	35.0								Shaley Sandstone: brown, grey, dark grey, soft, weathered, very fine-grained.

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____

Location _____ Job No. _____

Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-22-83

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	1983	FROM	TO	FROM	TO	FROM	TO				
	9 Jul										Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 9 July 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 625.81 Boring No. WES-1-23-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	9 Jul	0.0	3.0	0.0	40.4			6" Rock Bit			Clay (CL): brown, soft to stiff, sandy.
		3.0	6.5								Sandstone: brown very fine-grained, soft.
		6.5	9.0								Sandstone and clay: very fine-grained, brown sandstone and soft, brown clay, damp.
		9.0	17.5								Siltstone: grey, very soft.
		17.5	19.0								Sandstone: brown, very fine-grained, soft, weathered.
		19.0	38.5								Shale: grey, dark grey, soft, damp spot at 30 ft with slight water.

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-23-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		38.5	39.5								Coal: black, soft.
		39.5	45.0								Siltstone: light grey, soft.
											Water level overnight: 34 ft.
	11 Jul			40.4	45.0			6" Rock Bit			Drilled 10 ft below water depth. Rinsed mud from hole several times. Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 9 July 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 600.57 Boring No. WES-1-24-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	9 Jul	0.0	3.5	0.0	30.4			6" Rock Bit			Clay (CL): brown, soft to stiff, sandy.
		3.5	9.0								Sandstone: brown, very fine-grained, soft.
		9.0	17.0								Clay and sandstone: brown, soft, sandy clay with interbedded very fine-grained, soft sandstone.
		17.0	26.5								Shale: grey, dark grey, soft, water at 20 ft.
		26.5	28.0								Siltstone: light grey, soft.
		28.0	30.4								Shale: dark grey, soft.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 6 August 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 654.16 Boring No. WES-1-25-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	6 Aug	0.0	1.0	0.0	32.0			6" Rock Bit			Clay (CL): brown, soft, sandy, dry.
		1.0	7.0								Sandstone and clay: brown, grey, very weathered, thinly bedded, very fine-grained.
		7.0	16.5								Shale: brown, grey (15.5-16.5) soft, weathered, thinly bedded.
		16.5	19.0								Sandstone: brown, light grey, thinly bedded, soft, very fine-grained.
		19.0	21.8								Shale: brown and grey, soft.
		21.8	32.0								Sandstone and shale: brown, grey,

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-25-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
											dark grey, thinly bedded, very fine-
											grained, soft, water at 22 ft.
	6 Aug										Installed monitoring well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 6 August 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 670.21 Boring No. WES-1-26-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	6 Aug	0.0	4.0	0.0	55.0			6" Rock Bit			Sandy clay (CL): brown, soft, dry.
		4.0	15.3								Sandstone: tan, brown, very fine-grained, weathered, thinly bedded with siltstone and clay shale.
		15.3	17.3								Clay shale: brown, soft.
		17.3	21.6								Sandstone and clay shale: brown, grey, thinly bedded, soft, very fine-grained.
		21.6	30.1								Shale: brown, grey, soft, thinly bedded.
		30.1	41.2								Sandstone and shale: light to dark grey, thinly bedded, very

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-26-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
											fine-grained.
		41.2	45.0								Sandstone: brown, reddish brown, soft, very fine-grained. Water at 45 ft.
		45.0	49.5								Sandstone and shale: brown, light to dark grey, thinly bedded, very fine-grained, soft.
		49.5	52.0								Shale: grey, dark grey, soft.
		52.0	55.0								Sandstone: dark brown, soft, very fine-grained.
	6 Aug										Installed well.

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BORING LOG
FIELD DATA

Project NWSC Ground-Water Study Site Crane, IN Date 6 August 1983
Location Mustard Gas Burial Grounds Job No. 441-G150.13GR21/22
Drill Rig Failing Inspector J. Dunbar Operator C. Drake Surface El 659.75 Boring No. WES-1-27-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	6 Aug	0.0	2.3	0.0	25.0			6" Rock Bit			Clay (CL): brown, dark brown, dry, soft, sandy.
		2.3	29.3								Sandstone: brown, tan, very fine-grained, thinly bedded with siltstone and shale, weathered, soft, hard at 23 ft.
	6 Aug			--	30.0			6" Rock Bit			Crooked hole - used guide to straighten and sheared drill rod with bit - moved over 6 in. and drilled alongside existing hole to intersect drill tools.
	9 Aug										Recovered rod and bit except for approximately 2 ft section of rod. Unable to recover small piece.

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BORING LOG
FIELD DATA

Project _____ Site _____ Date _____
Location _____ Job No. _____
Drill Rig _____ Inspector _____ Operator _____ Surface El _____ Boring No. WES-1-27-83

SAMPLE NUMBER	DATE TAKEN 1983	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	10 Aug			0.0	40.0			6" Rock Bit			Moved 10 ft east and drilled another boring. Grouted boring with rod.
		29.3	40.3								Shale: grey, dark grey, thinly bedded with approx 5-10% very fine-grained sandstone, soft to medium, water at 30 ft.
	10 Aug										Installed monitoring well.

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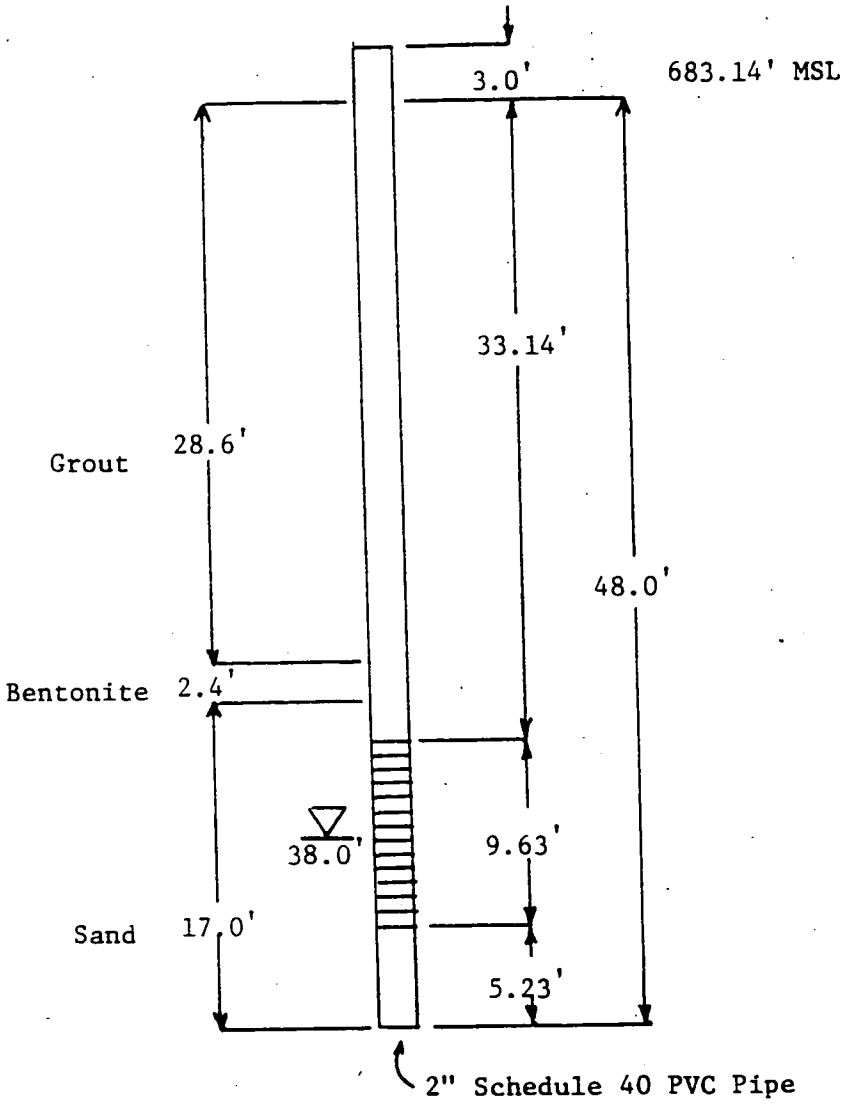
WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

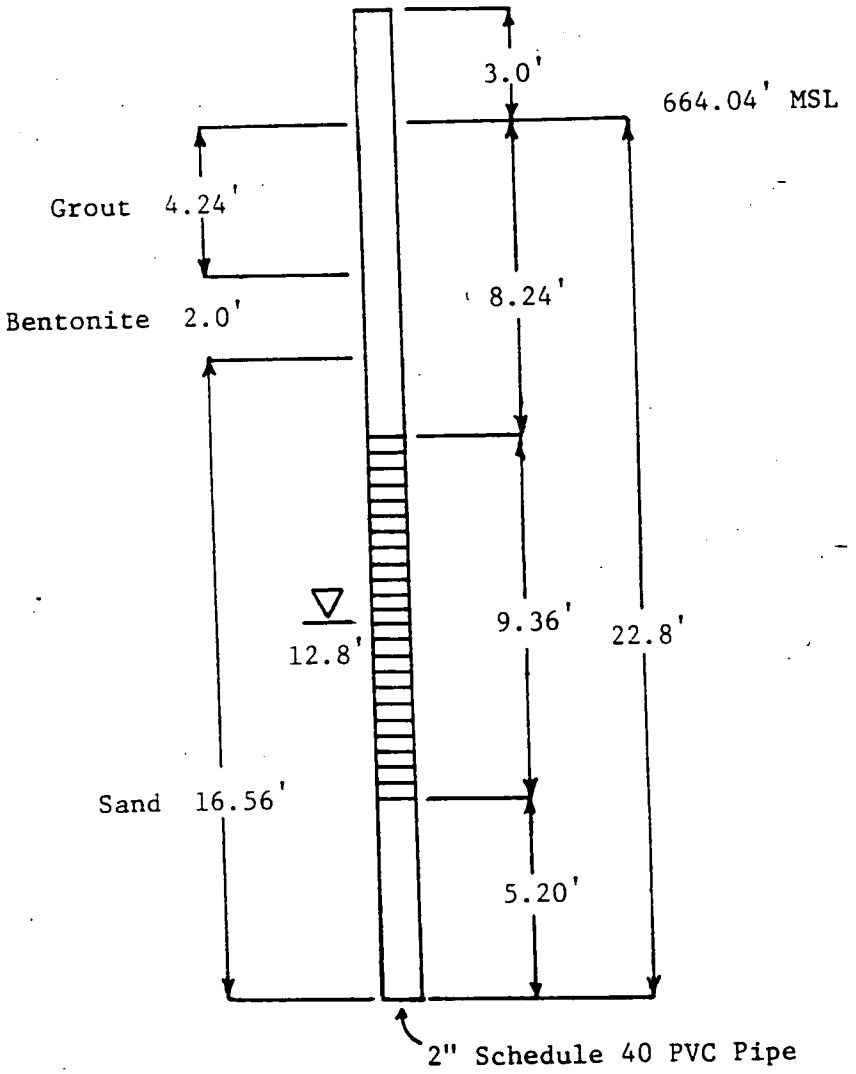
PART 2-2: WELL COMPLETION FORMS (ALL WELLS)



Water depth at time of drilling

Well screen

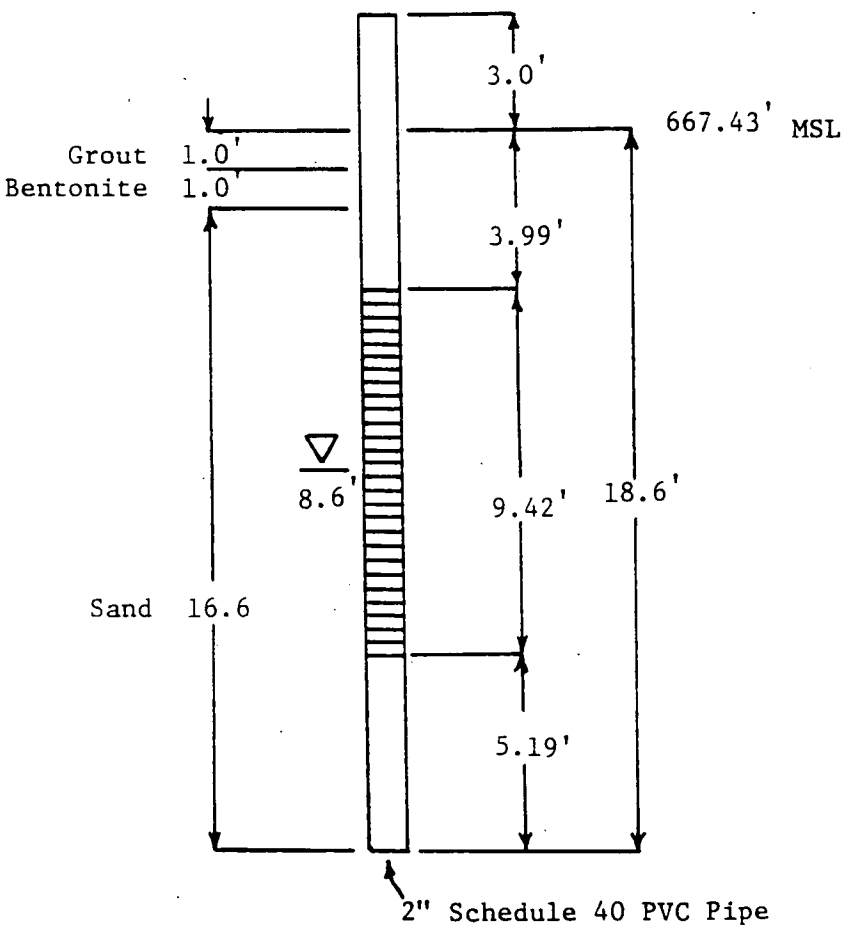
NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-1-81



▽ -Water depth at time of drilling

Well screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-2-81



Water depth at time of drilling

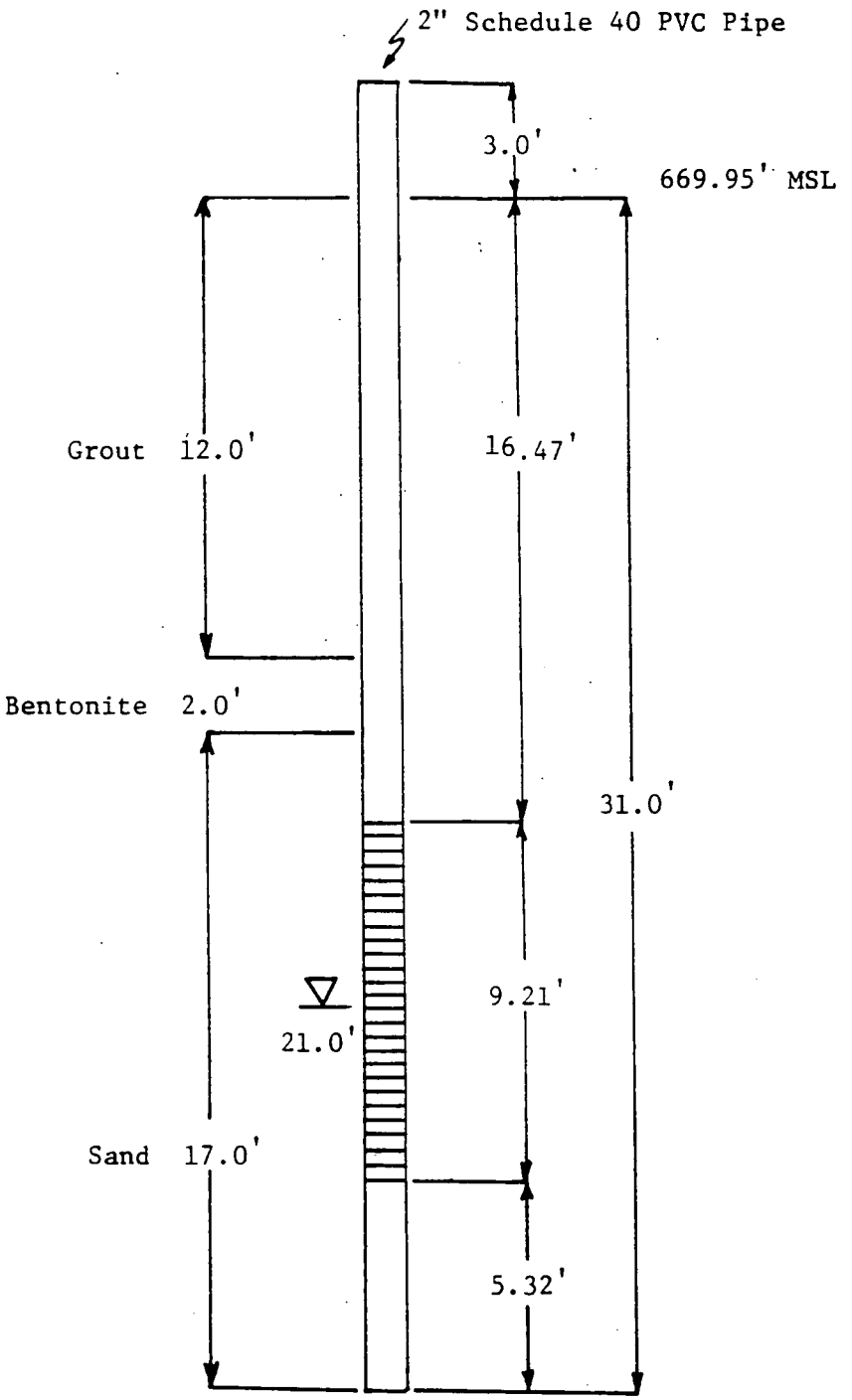
Well screen

NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Well Completion

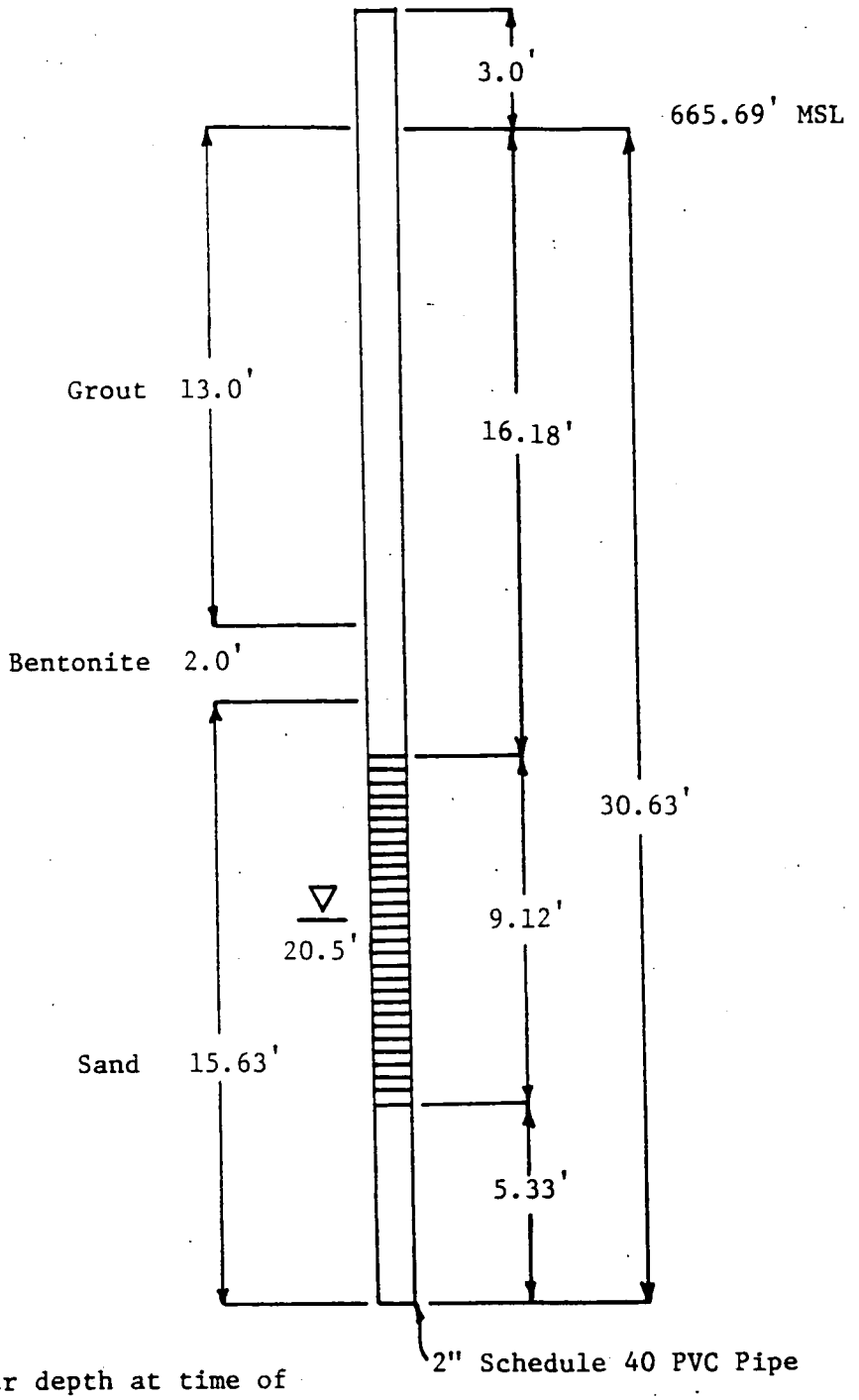
Boring Number: WES-1-3-81



▽ Water depth at time of drilling

Well screen

NWSC , Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-4-8



▽ Water depth at time of drilling

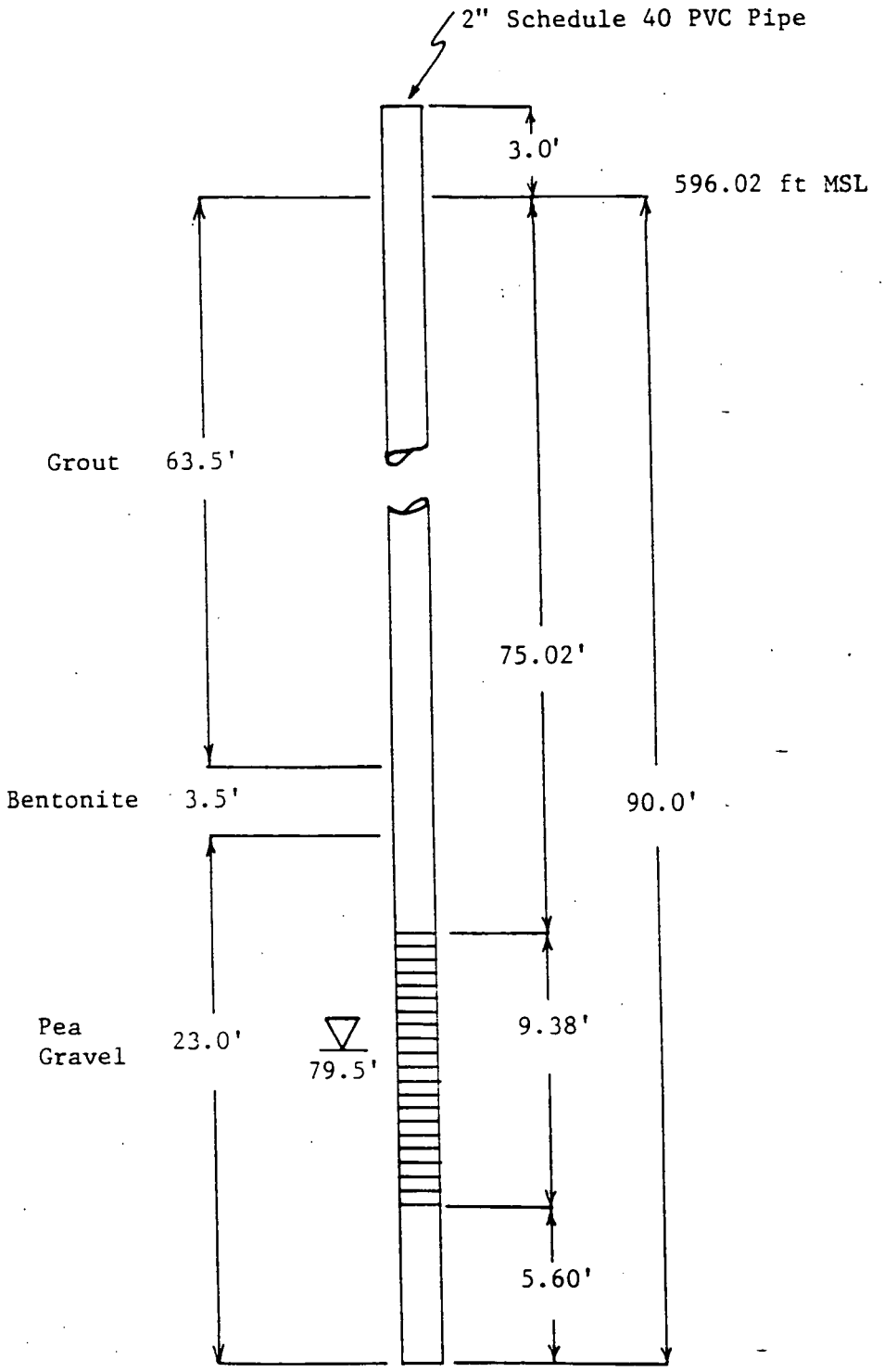
Well screen

NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Well Completion

Boring Number: WES-1-5-81

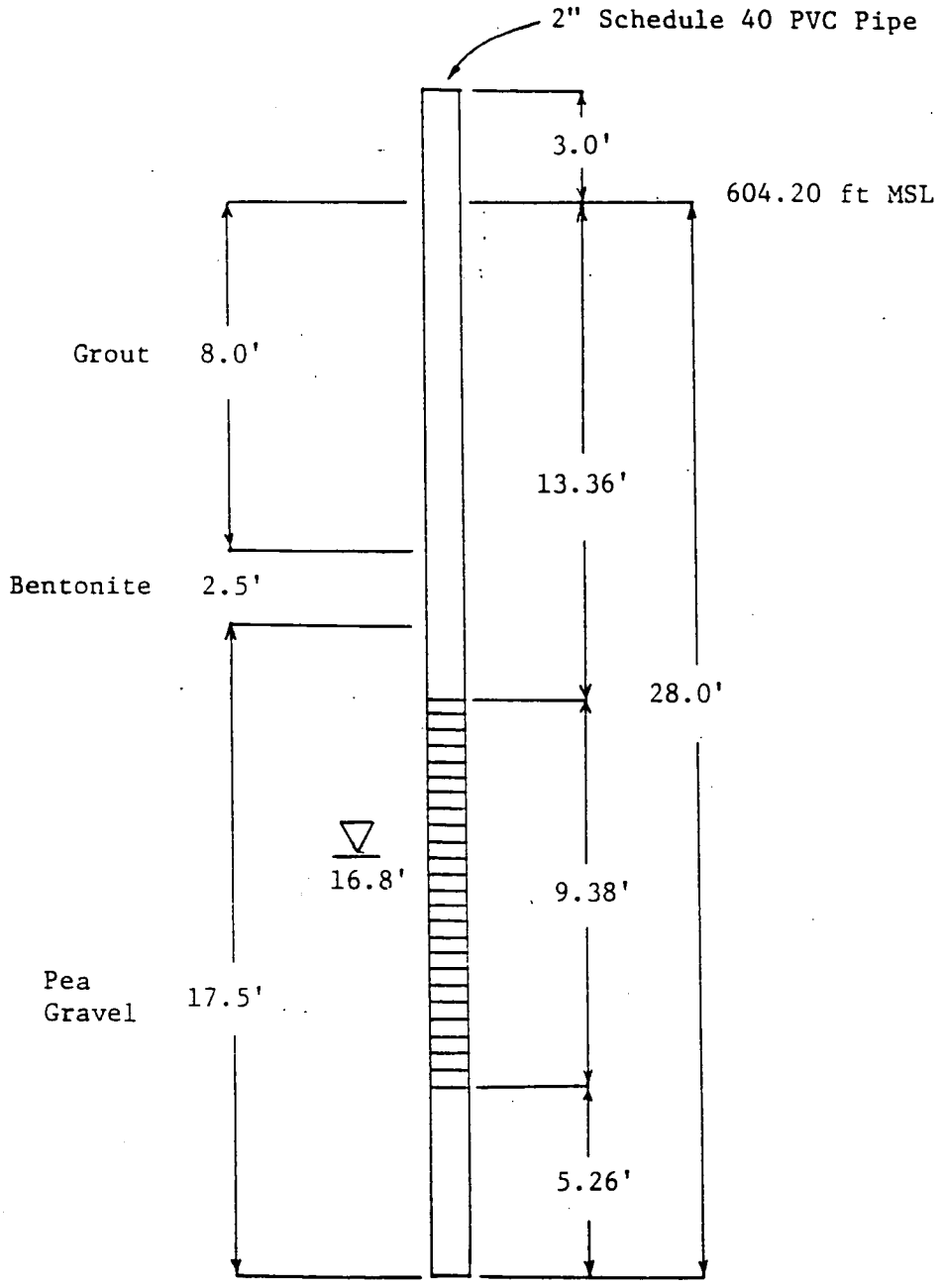


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-6-82

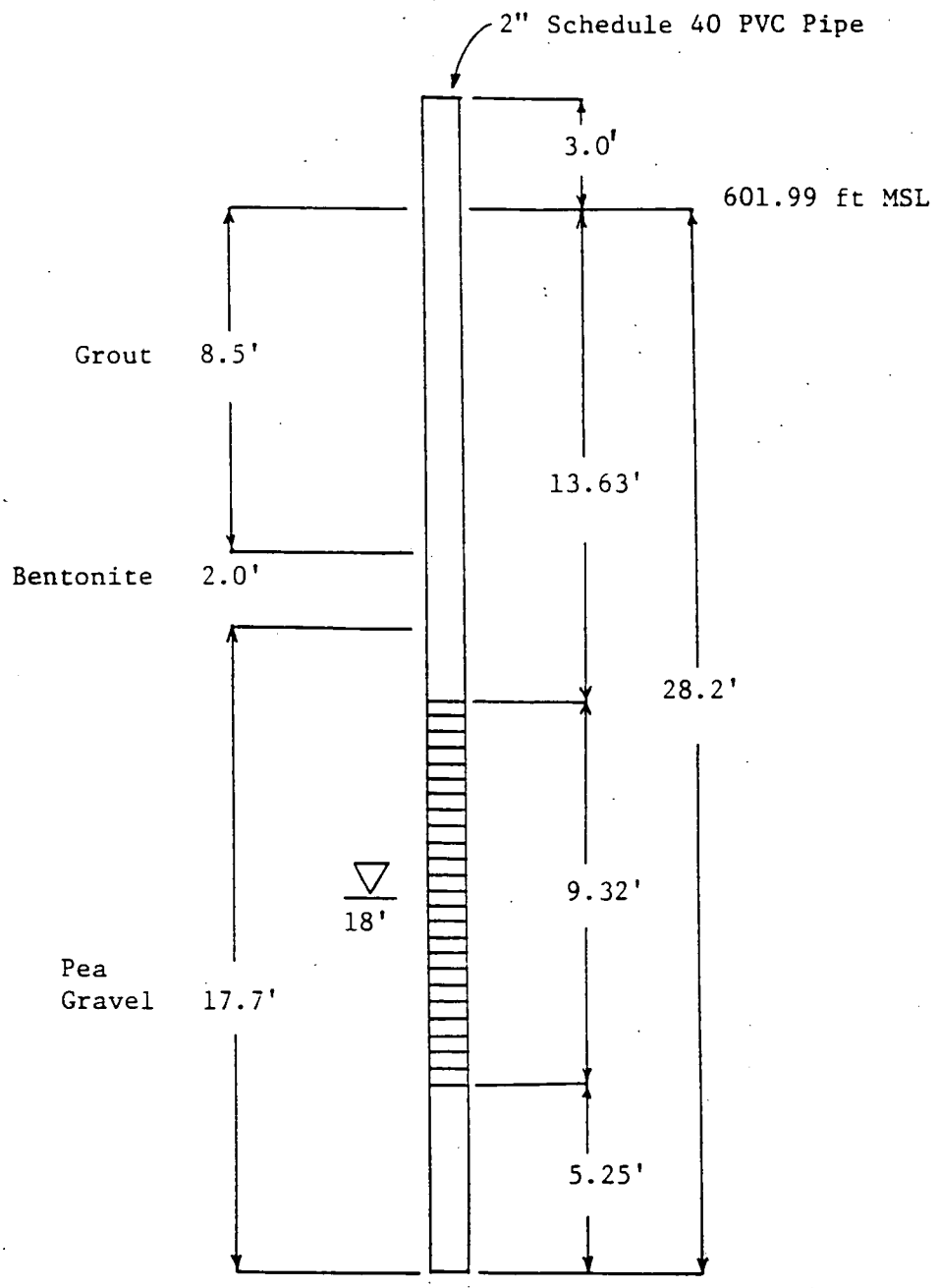
WORKING DRAFT



Water level at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number WES-1-7-82

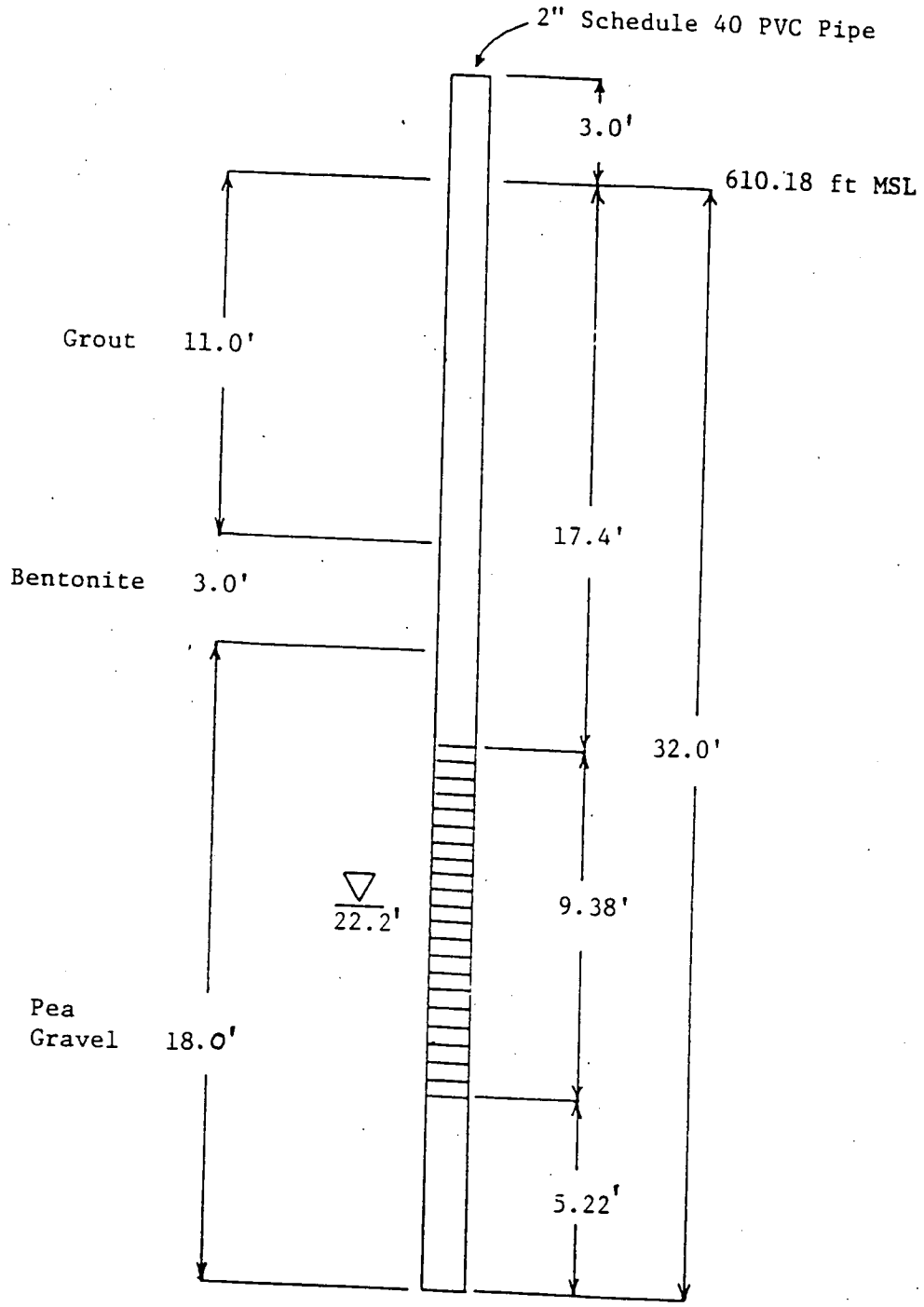


▽ Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-8-82

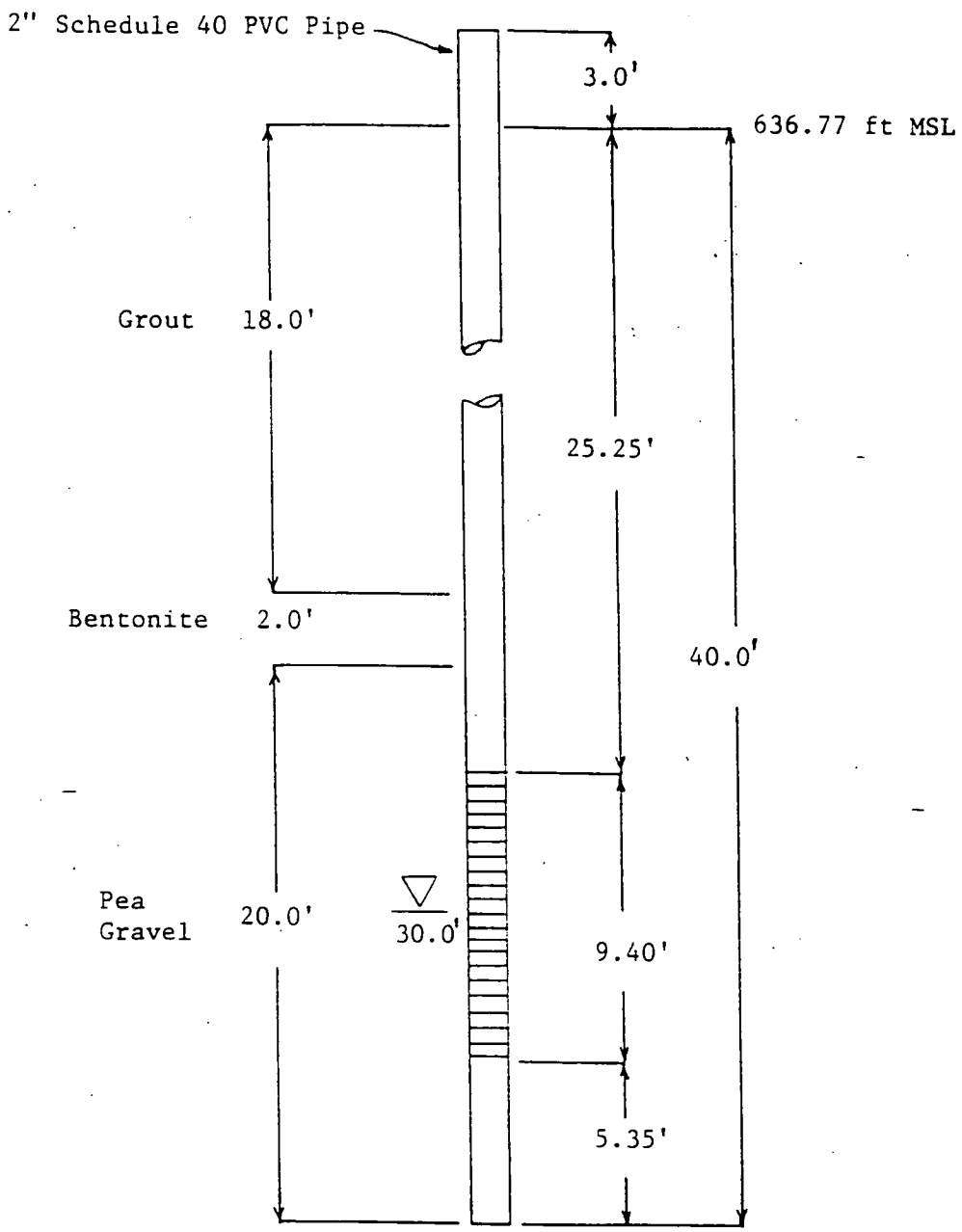
WORKING DRAFT



Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-9-82

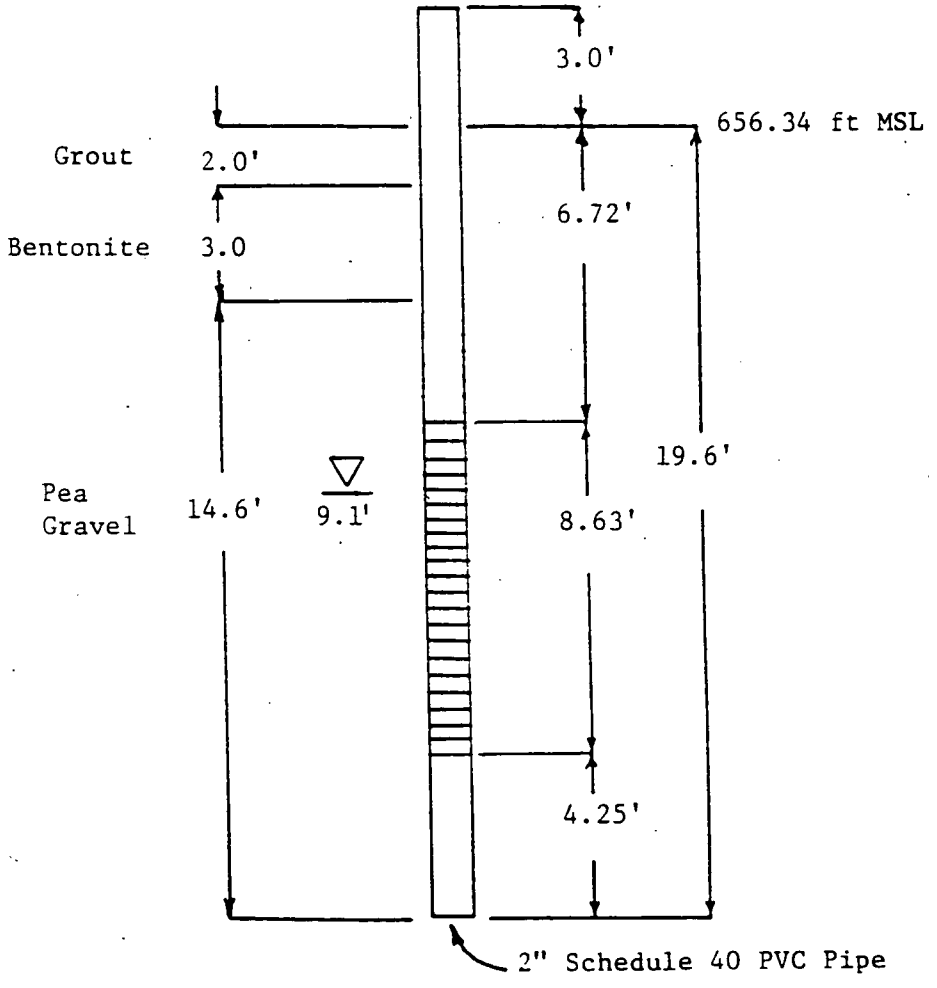


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-10-83

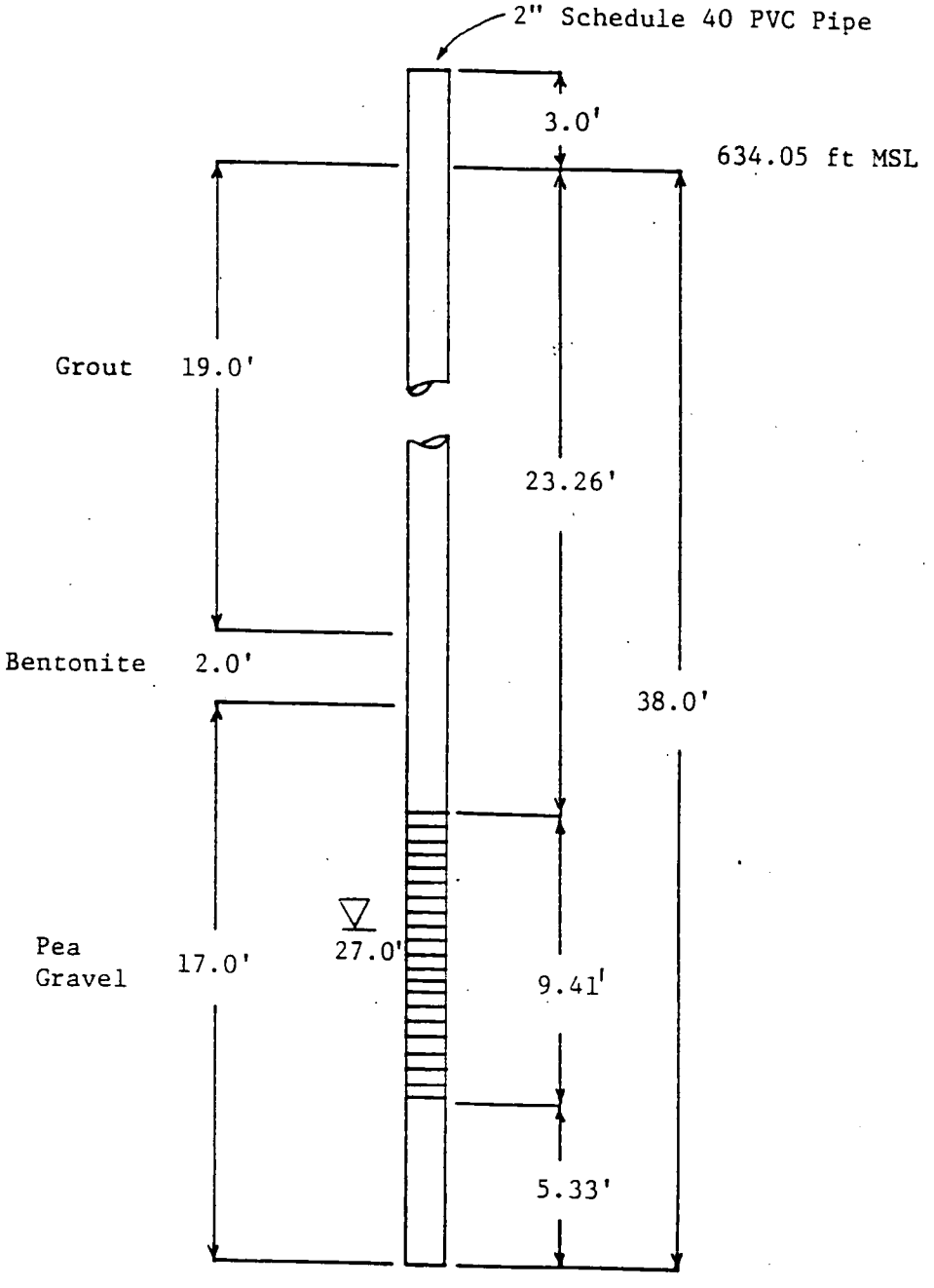
WORKING DRAFT



Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Ground
Well Completion
Boring Number: WES-1-11-

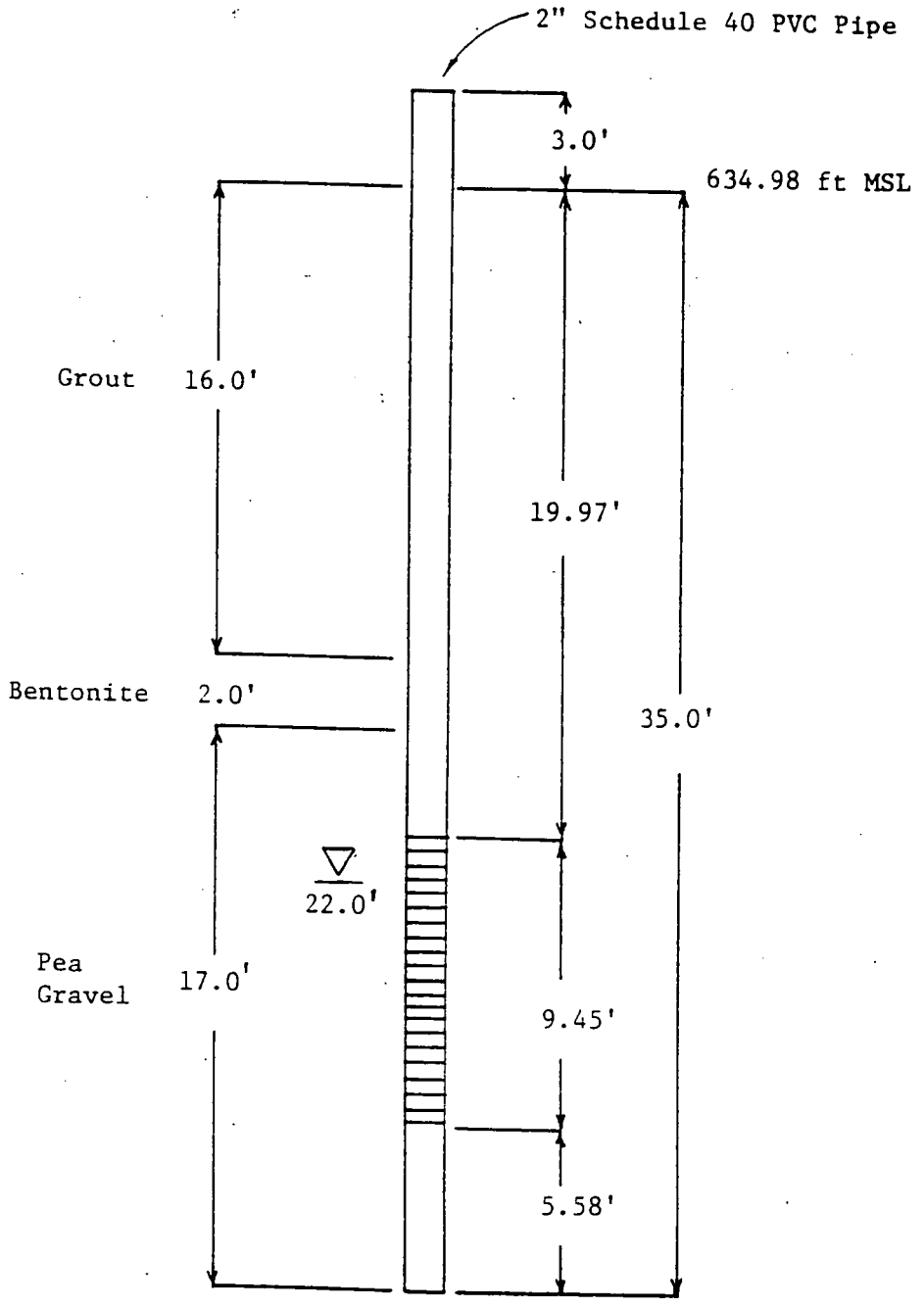


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-12-83

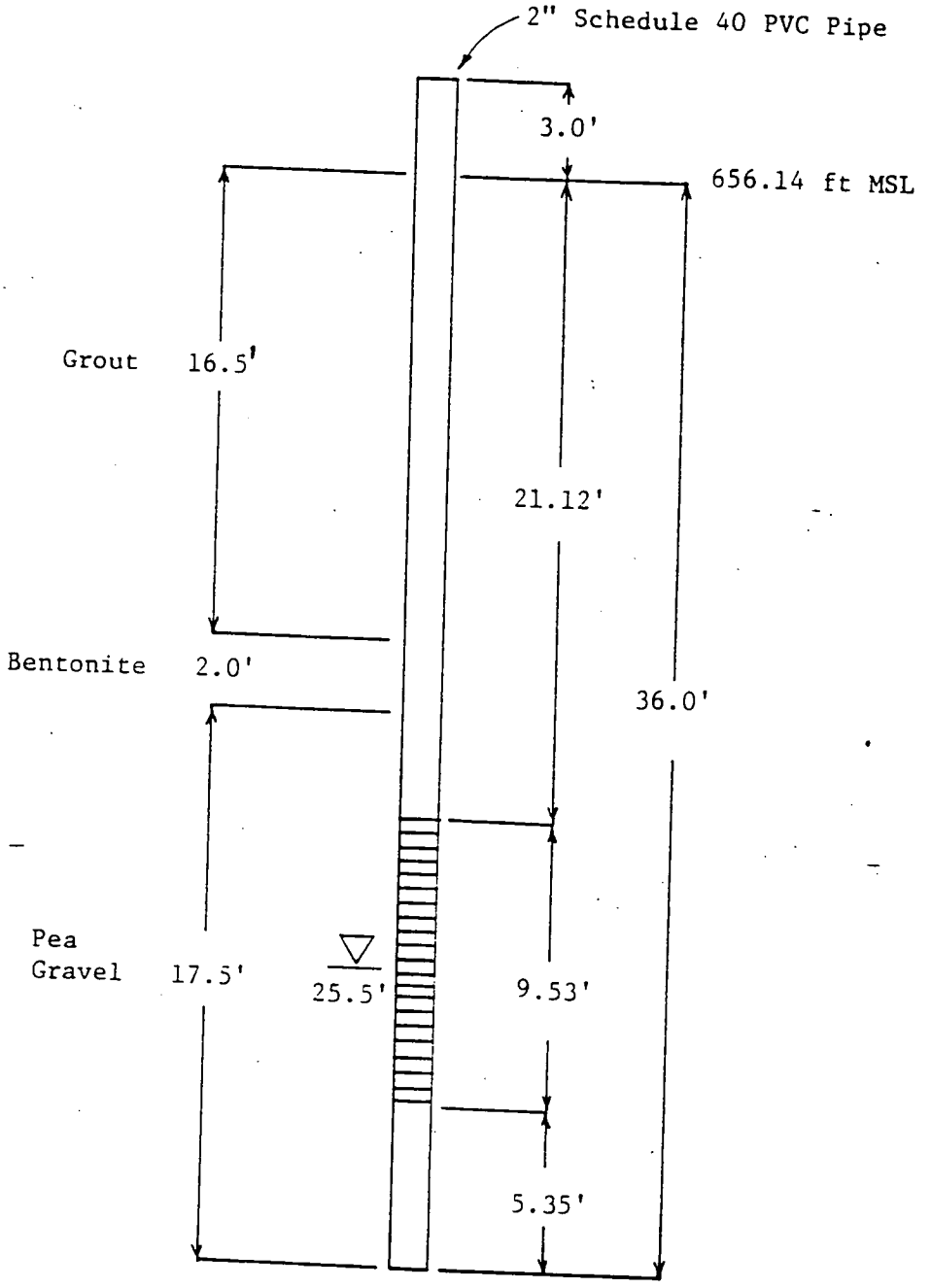
WORKING DRAFT



Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Ground
Well Completion
Boring Number: WES-1-13-

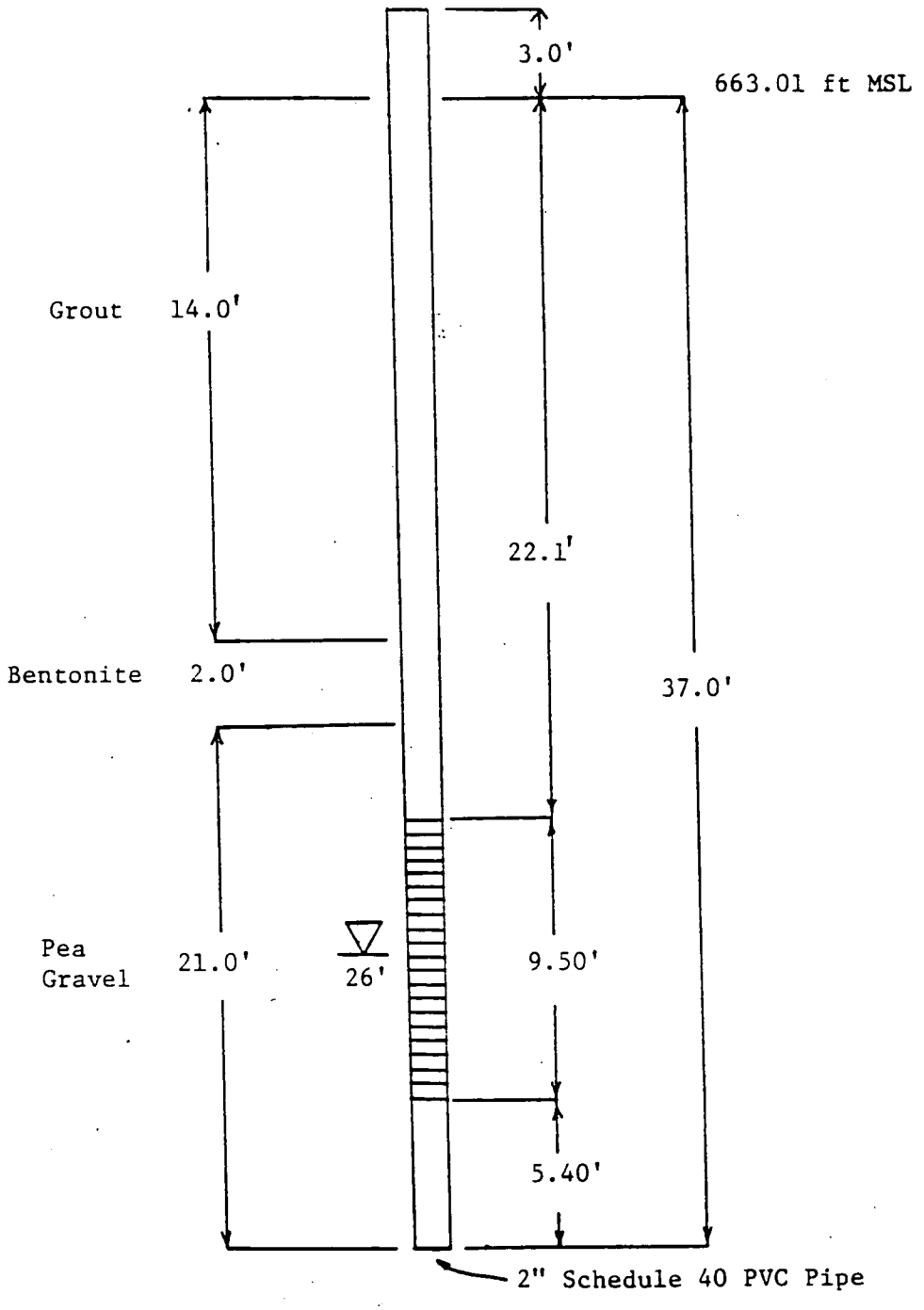


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-14-83

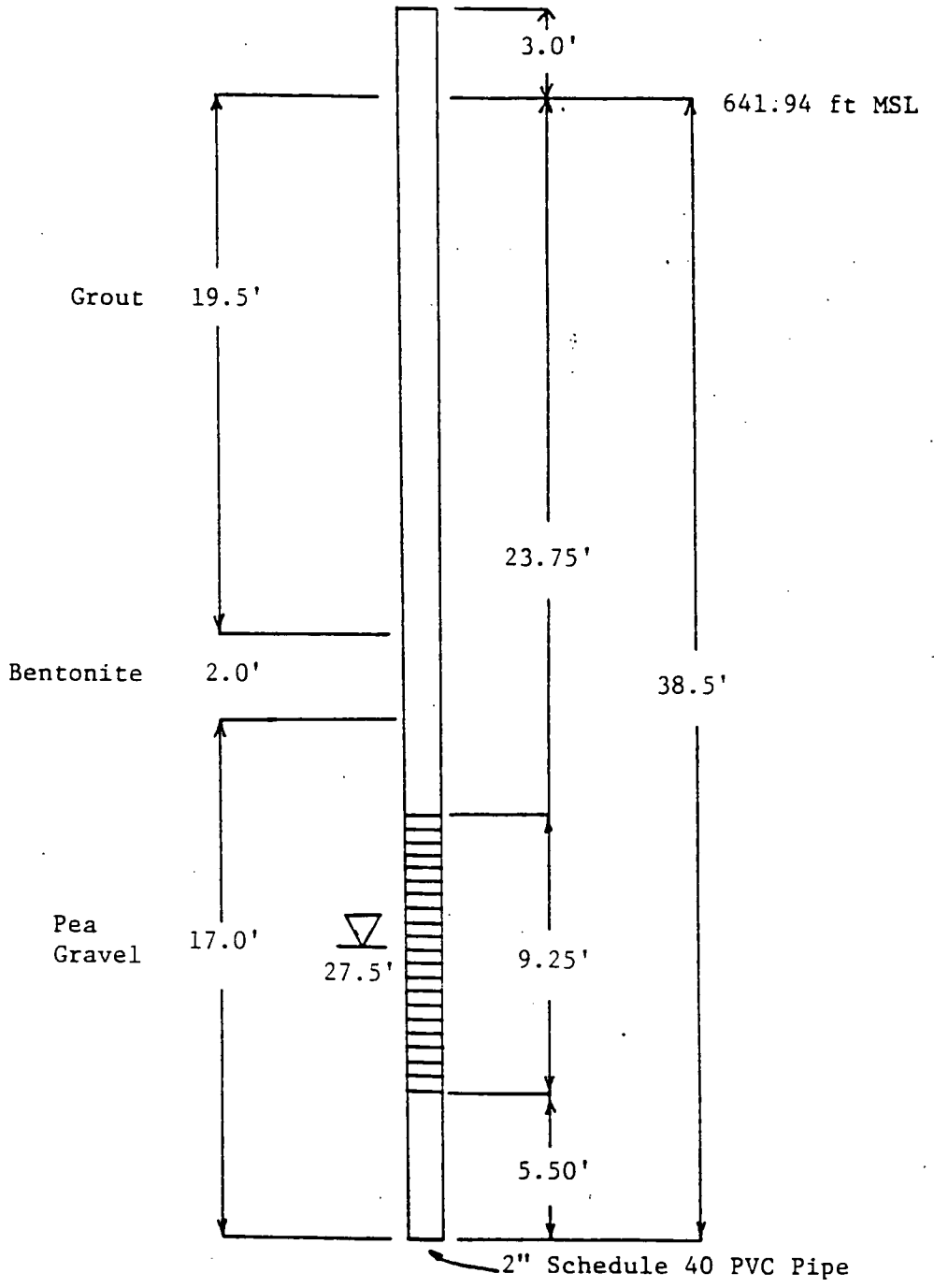
WORKING DRAFT



Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-15-8

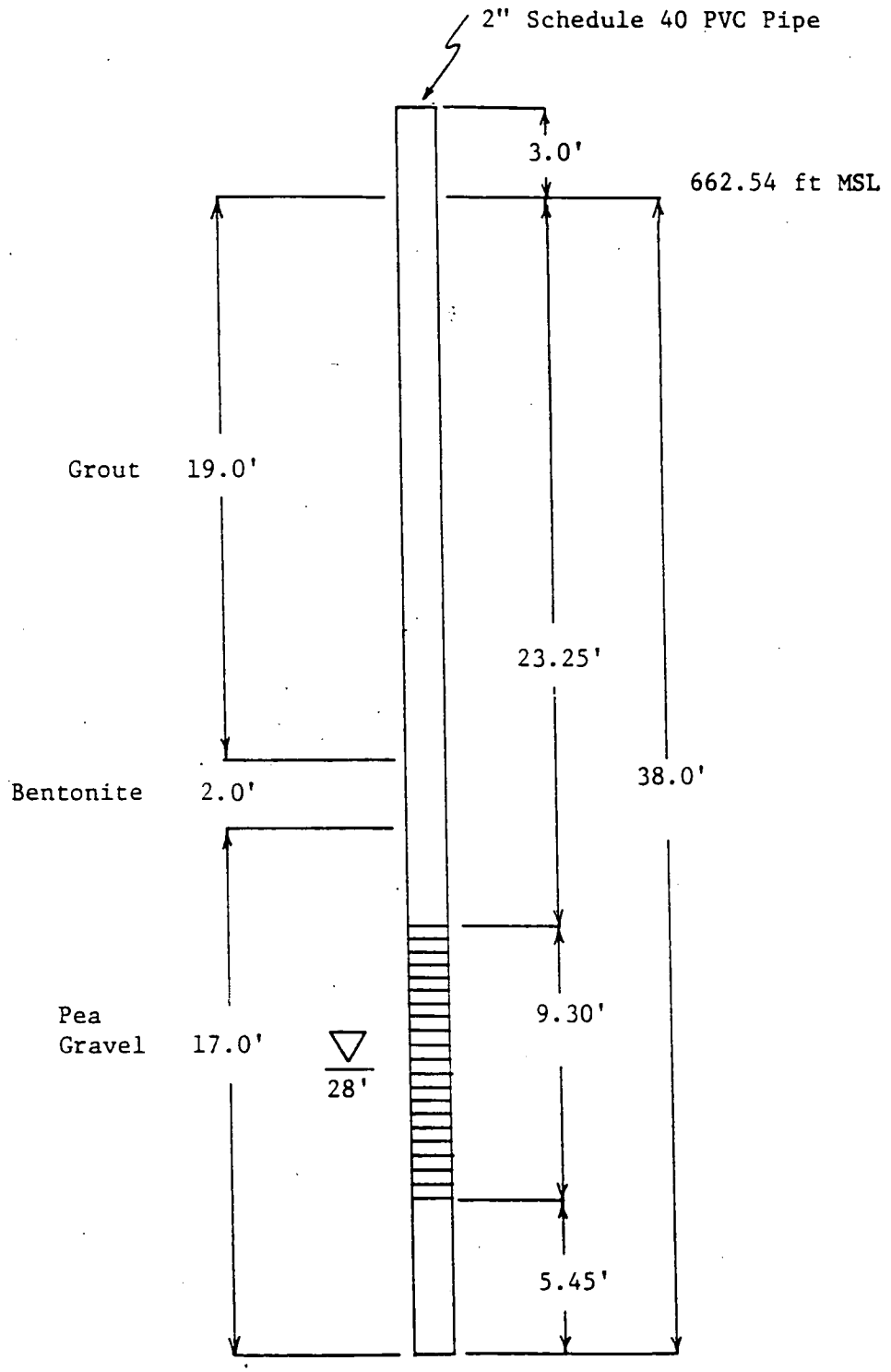


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-16-83

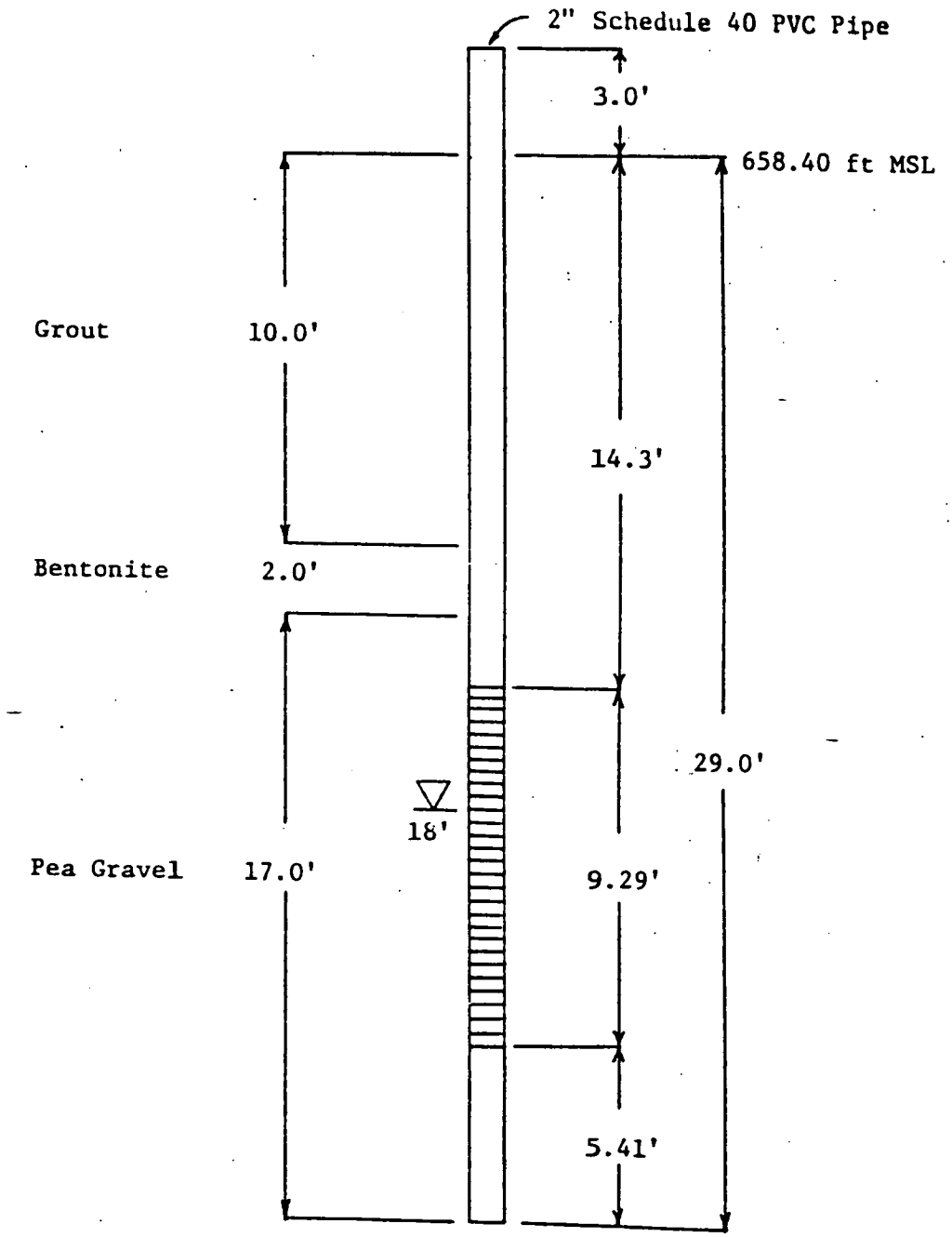
WORKING DRAFT



Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-17-83

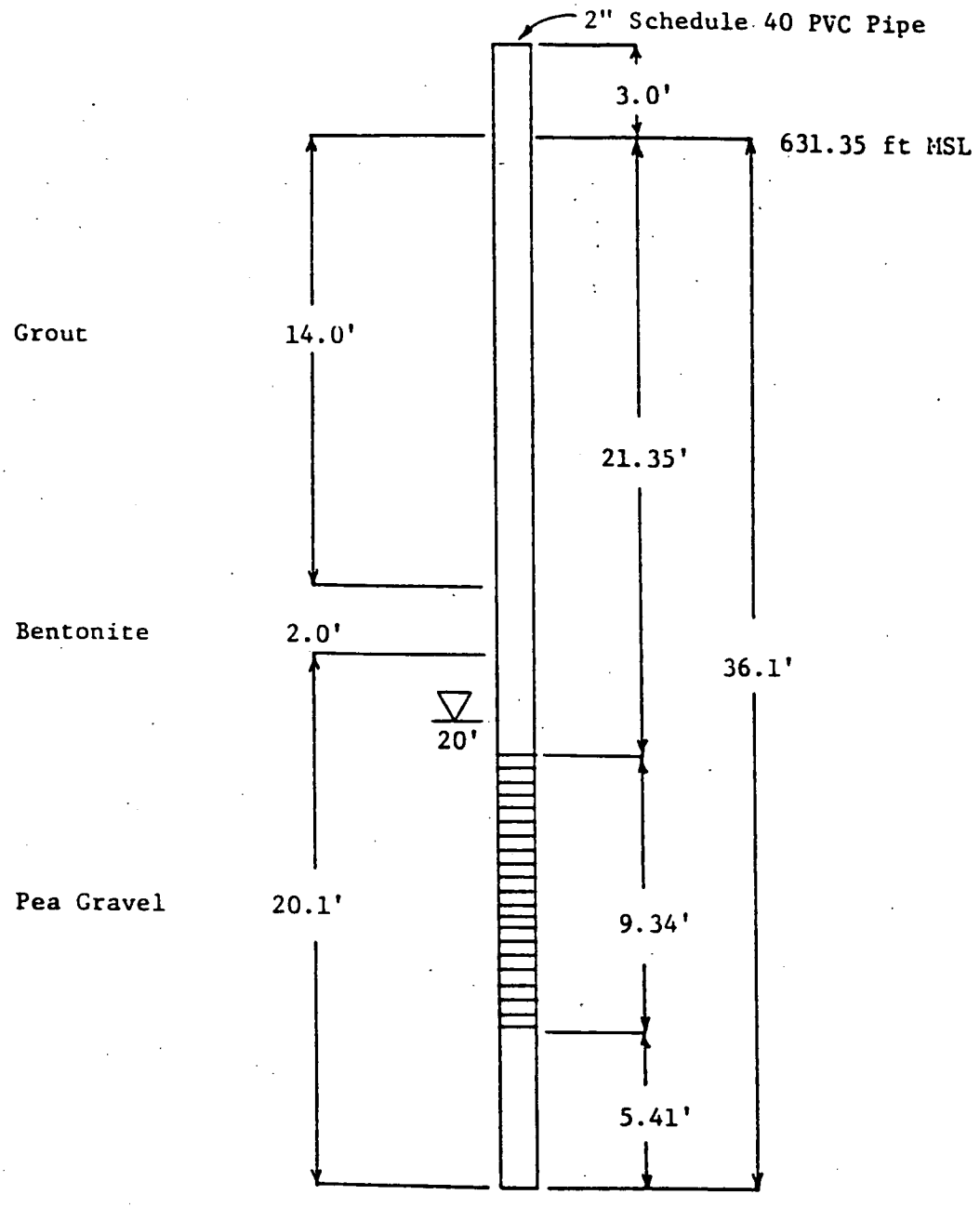


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Groun
Well Completion
Boring Number: WES-1-18-

WORKING DRAFT

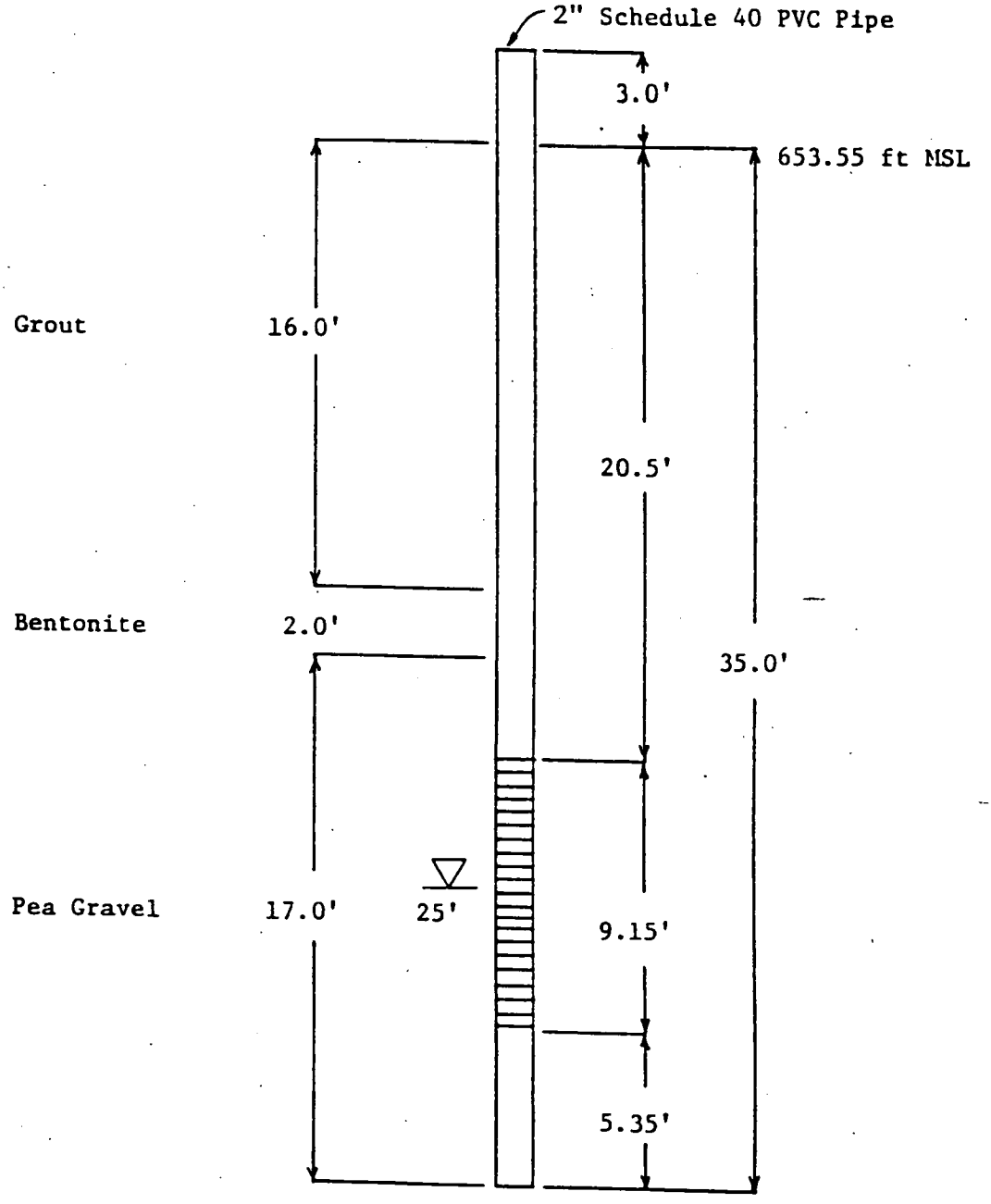


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-20-83

WORKING DRAFT

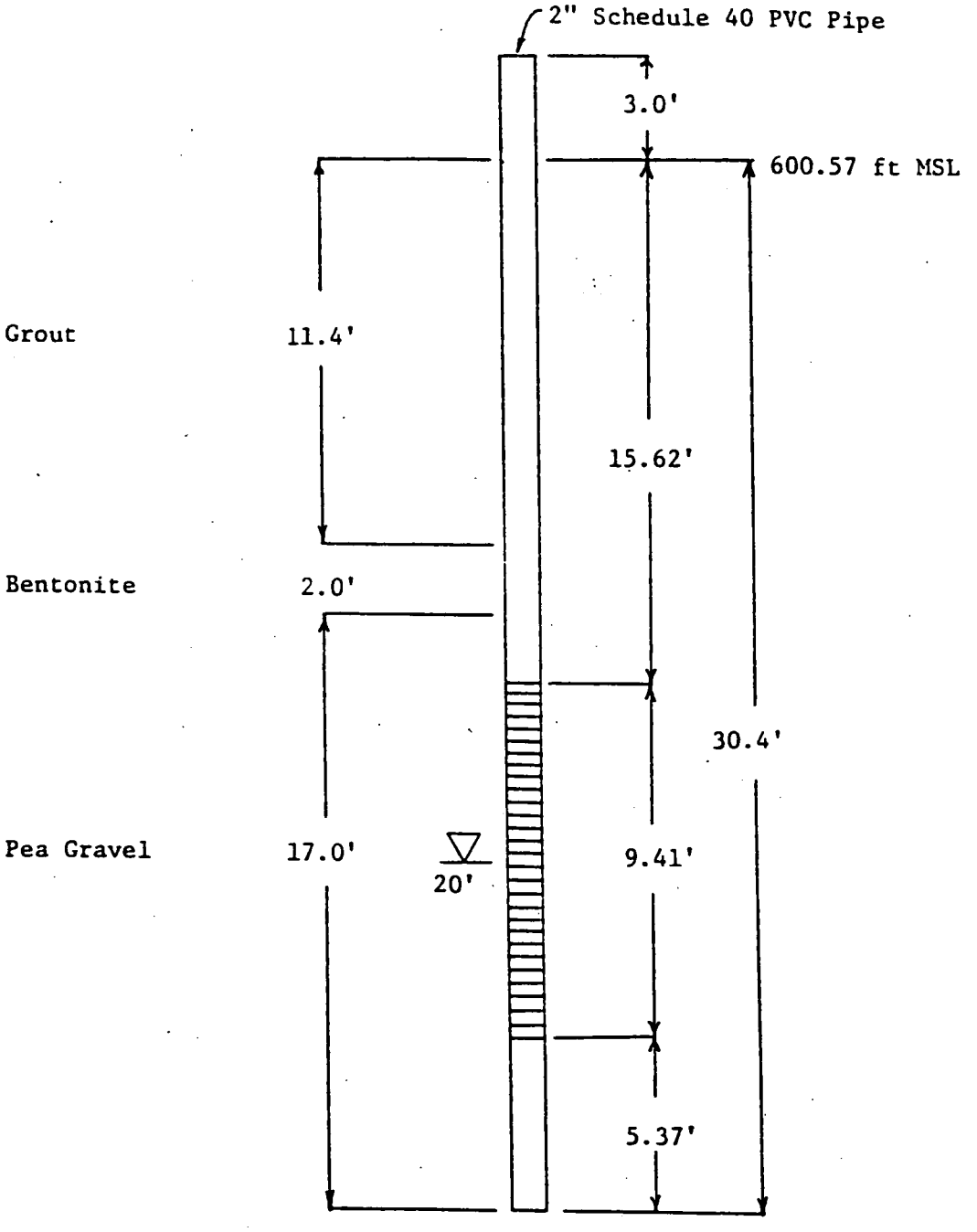


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-22-83

WORKING DRAFT

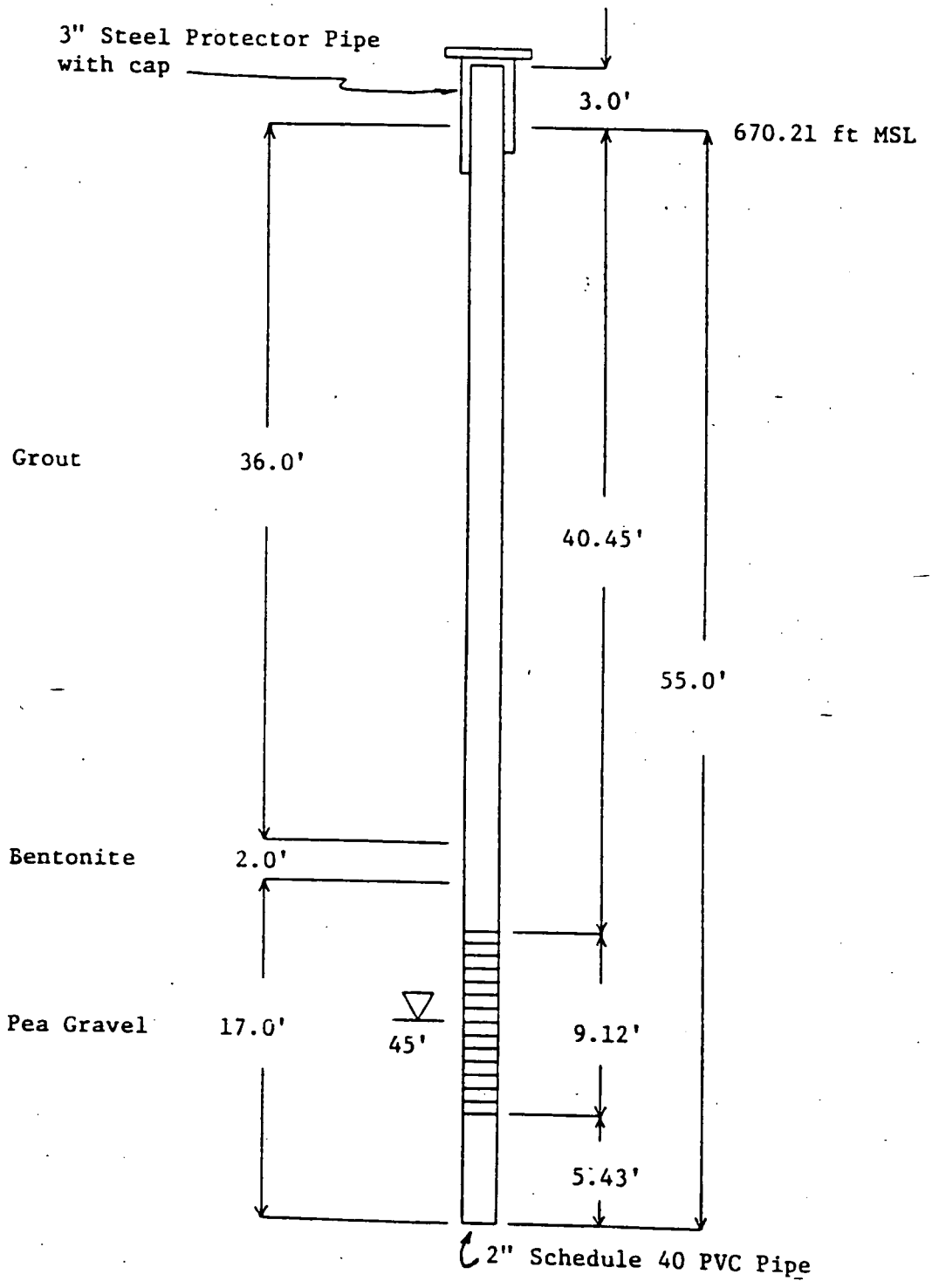


Water depth at time of drilling

Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-24-83

WORKING DRAFT



Water depth at time of drilling

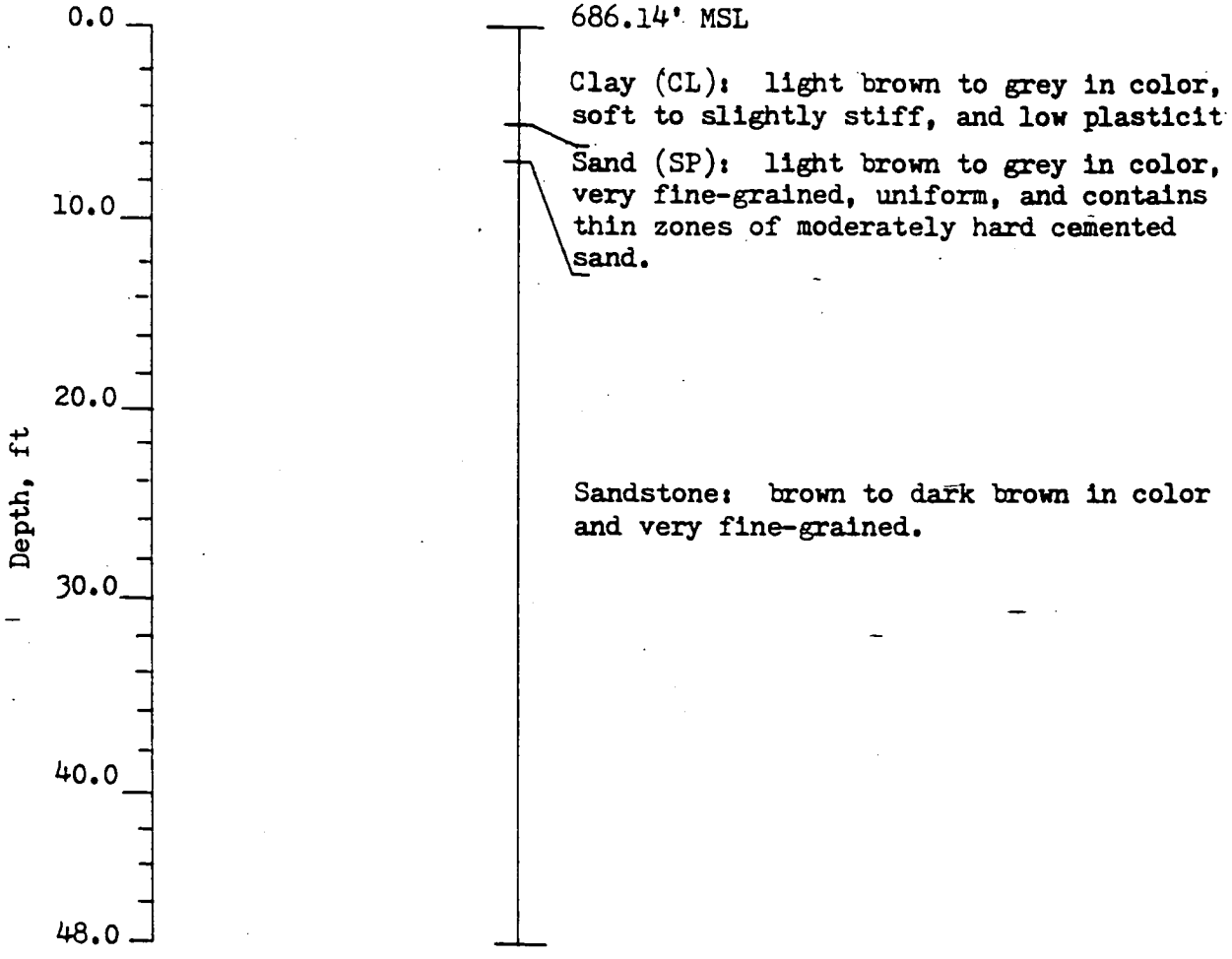
Well Screen

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Well Completion
Boring Number: WES-1-26-83

WORKING DRAFT

PART 2-3: GRAPHIC FIELD LOGS

(WES-1-1-81 TO WES-1-5-81 AND WEST-1-18-83 TO WES-1-27-83)

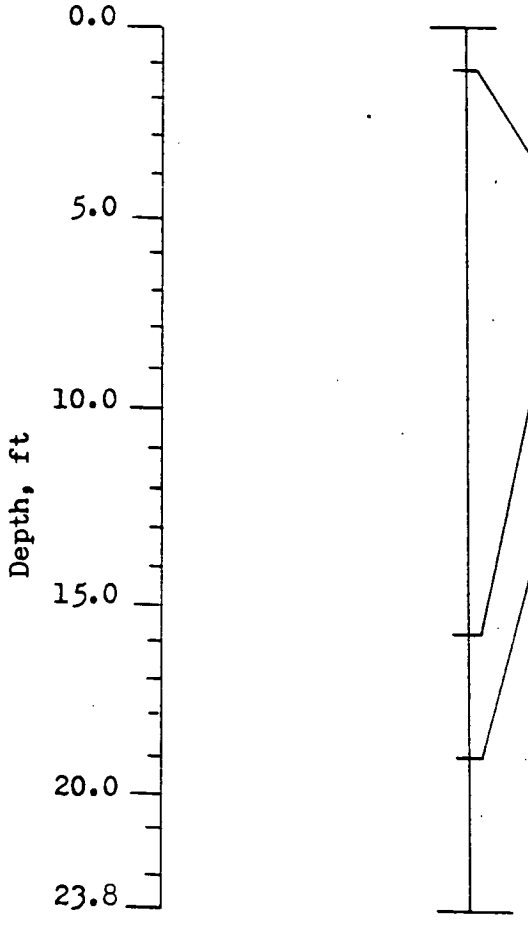


NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Lithology

Boring Number: WES-1-1-81



664.04' MSL

Silty sand (SM): light brown in color, dry, weathered, very fine-grained sand, and contains fragments of weathered sandstone.

Sandstone: light brown in color, very friable to moderately friable, weathered, uniform, and very fine to fine-grained quartz sand.

Sandstone and interbedded shale: sandstone is grey in color, uniform, and very fine-grained quartz sand. Shale is dark grey in color, soft, and ranges in thickness from 1/16 to 1/2 in.

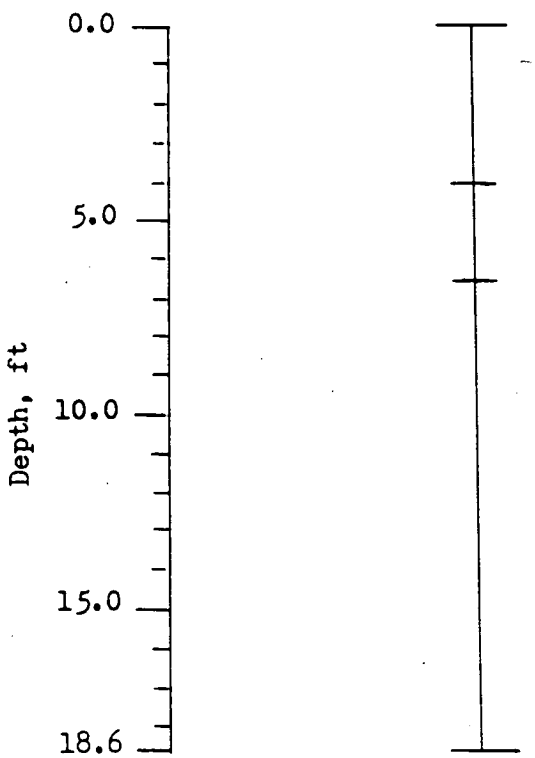
Sandy shale: black in color, soft, and interbedded with fine-grained, grey sandstone lenses which range in thickness from 1/16 to 2 in.

NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Lithology

Boring Number: WES-1-2-81



667.43' MSL

Silt(ML): brown in color, soft, organic matter, and low plasticity.

Clayey sand(SC): reddish brown in color, dry, uniform, and fine-grained sand and sandstone fragments.

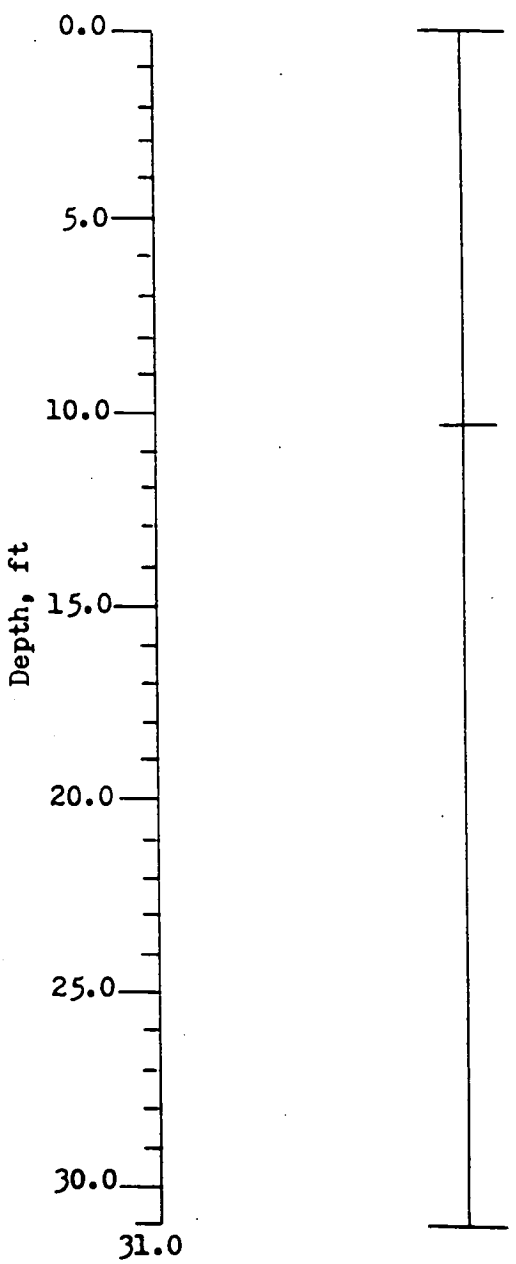
Sandstone: light brown to reddish brown and light grey in color, very friable to slightly friable, weathered, and very fine to fine-grained.

NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Lithology

Boring Number: WES-1-3-81



669.95' MSL

Sandy silt(ML): brown to grey in color, moderate cohesion, dry, stiff, and contains 20 to 30% fine-grained sand.

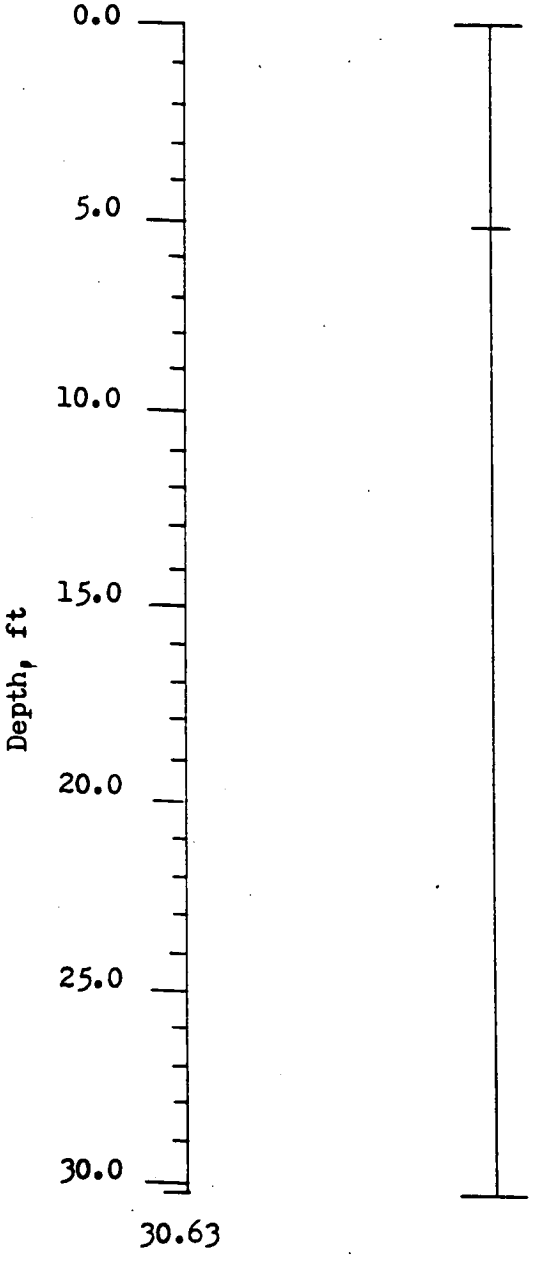
Sandstone: reddish brown in color, fine-grained, and weathered.

NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Lithology

Boring Number: WES-1-4-81



665.69' MSL

Clay (CL): brown in color, dry, little cohesion, uniform, and contains 5% sand and gravel.

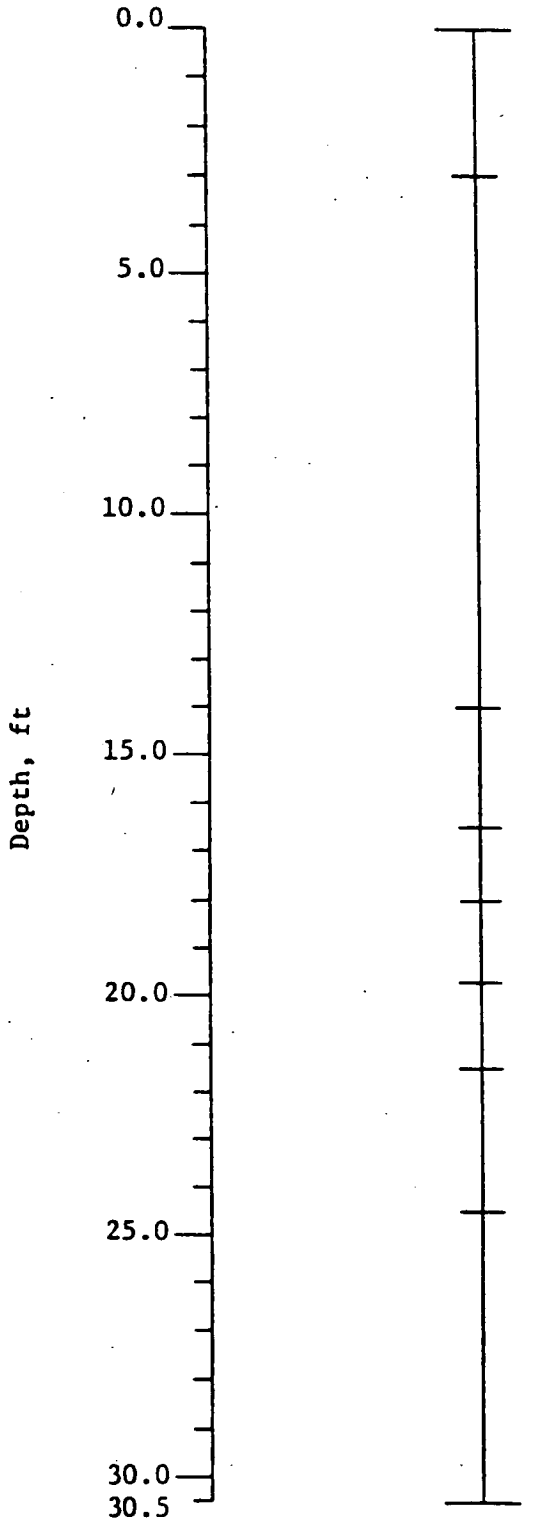
Brown sandstone and interbedded grey shale

NWSC, Crane, Indiana

Mustard Gas Burial Grounds

Lithology

Boring Number: WES-1-5-81



658.40 ft MSL

Clay (CL): brown, sandy, damp, slight to moderate cohesion, organic matter.

Sandstone: light brown, dark brown, very fine-grained, quartz, weathered, soft. From 13.5 to 13.7 ft, grey shale.

Shale: light grey, soft.

Sandstone: dark brown, weathered, soft, very fine-grained, quartz sand.

Sandstone and shale: brown, light grey, soft, thinly bedded.

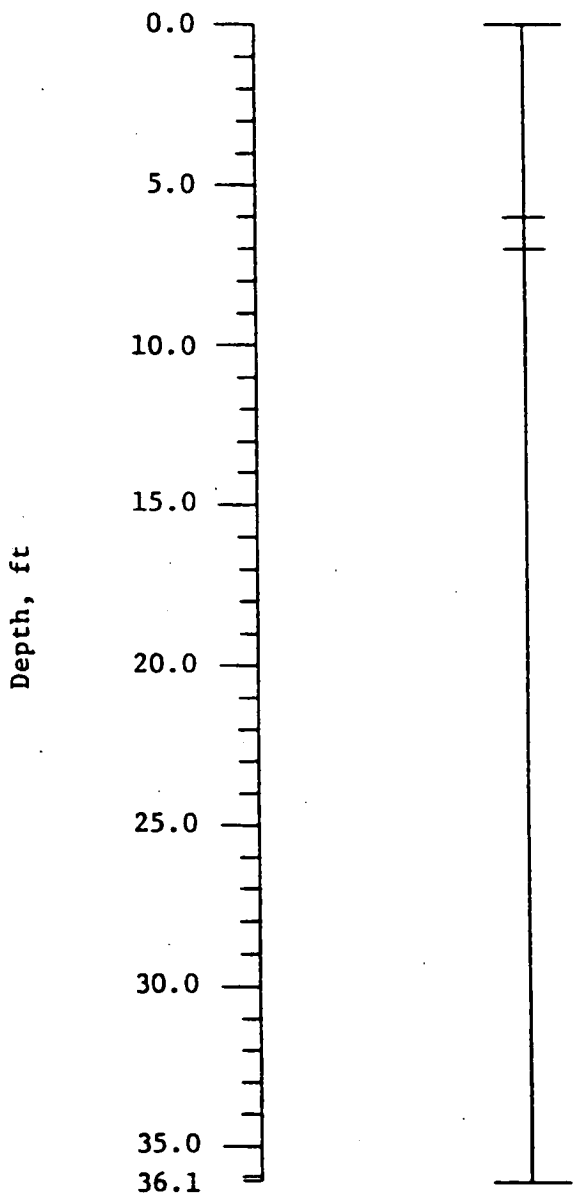
Sandy shale: dark grey, soft very fine-grained, white quartz sand.

Sandstone and shale: various shades of brown and grey, thinly bedded.

Sandstone: brown, tan, dark brown, soft, very fine-grained, quartz sand.

NWSC, Crane, Indiana
Mustard Gas Burial Grunds
Lithology
Boring Number: WES-1-18-83

WORKING DRAFT



631.35 ft MSL

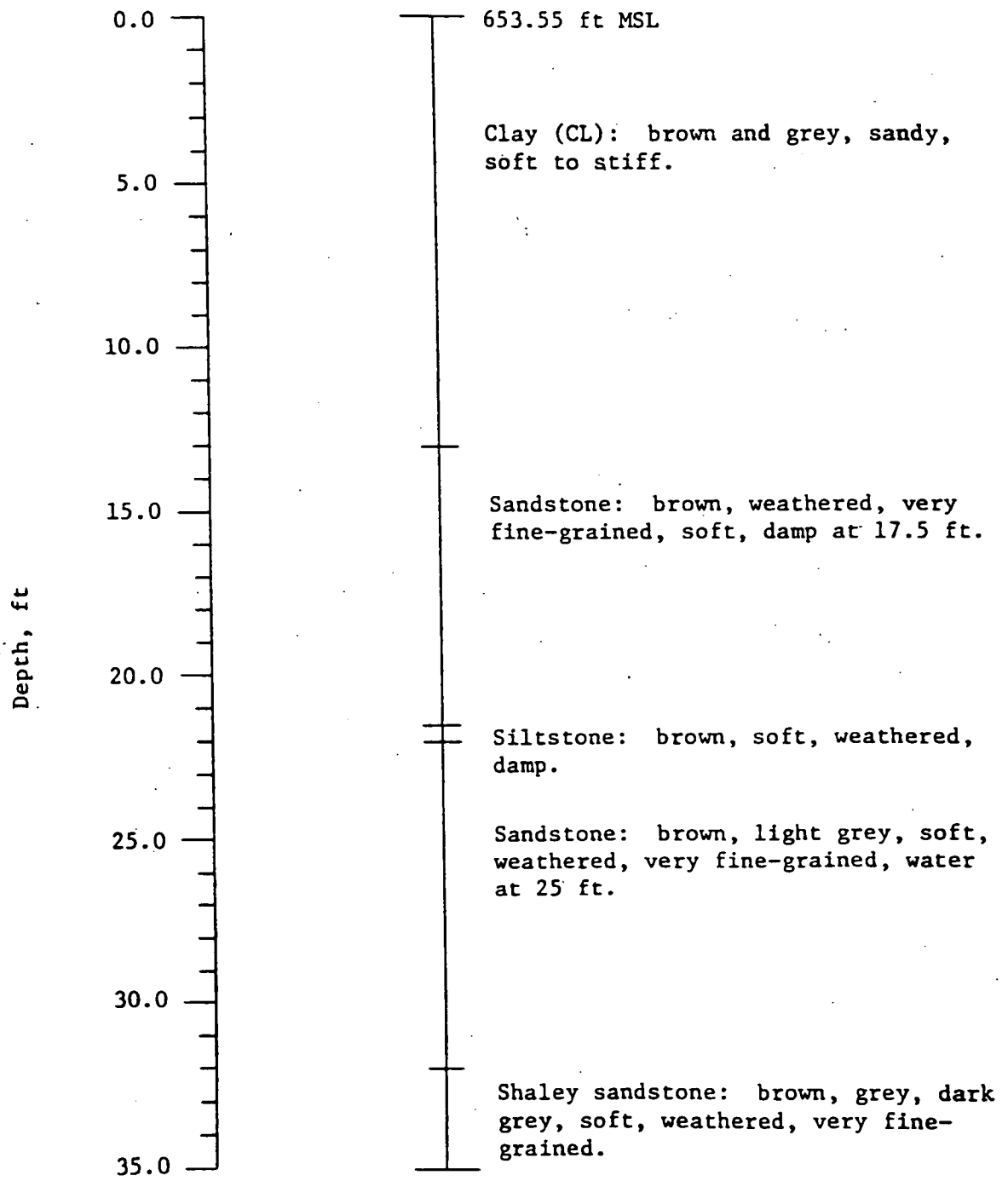
Clay (CL): brown, soft, gravelly, damp.

Sandstone: brown, very fine-grained, soft, weathered.

Shale: light grey to dark grey, soft, uniform.

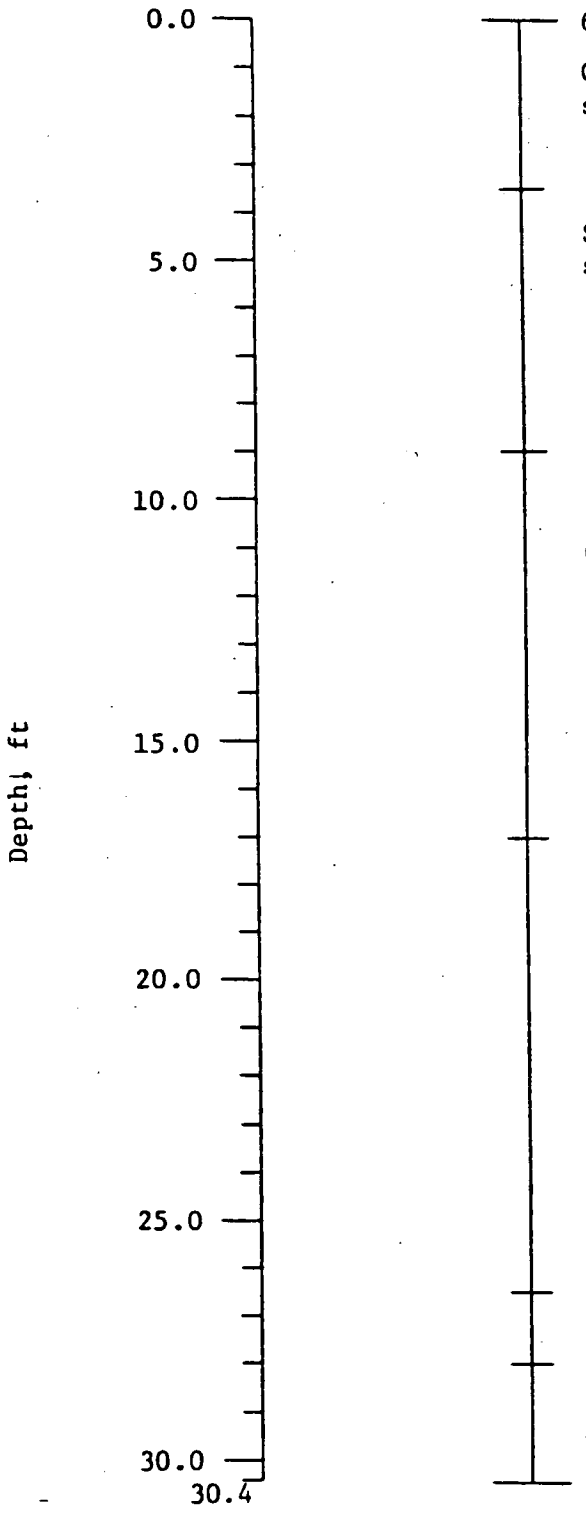
NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Lithology
Boring Number: WES-1-20-83

WORKING DRAFT



NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Lithology
Boring Number: WES-1-22-83

WORKING DRAFT



600.57 ft MSL

Clay (CL): brown, soft to stiff, sandy.

Sandstone: brown, very fine-grained, soft.

Clay and sandstone: brown, soft, sandy clay with interbedded, very fine-grained, soft sandstone.

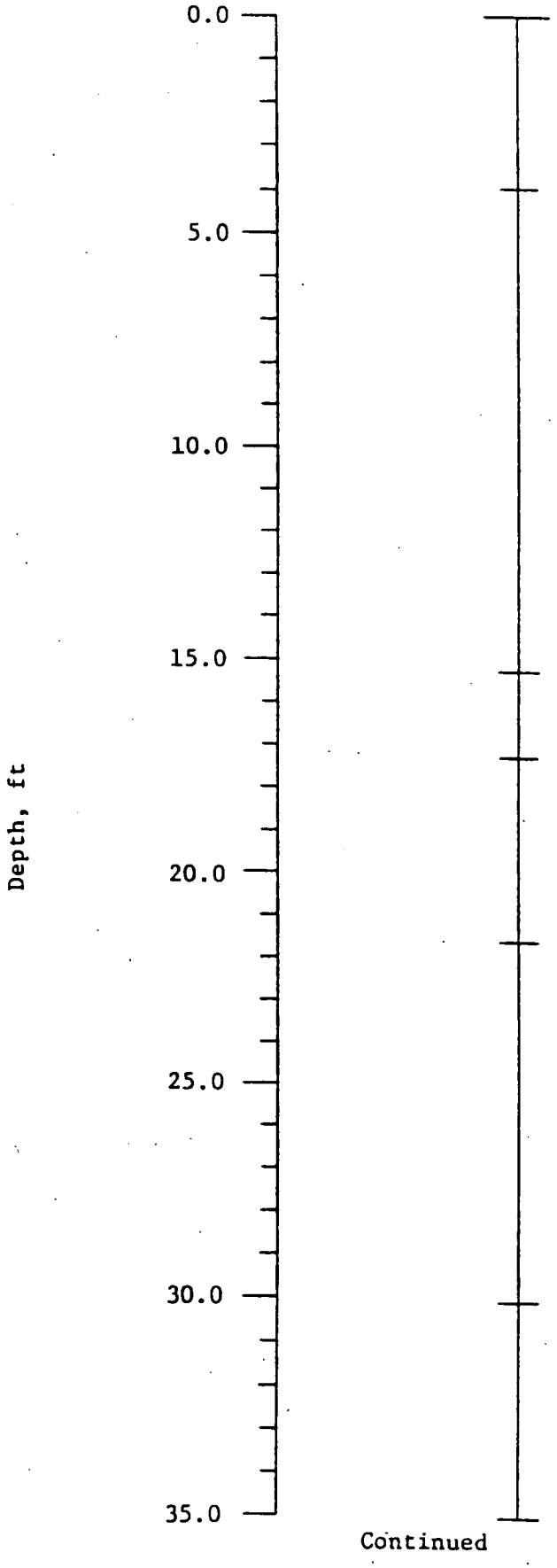
Shale: grey, dark grey, soft, water at 20 ft.

Siltstone: light grey, soft.

Shale: dark grey, soft.

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Lithology
Boring Number: WES-1-24-83

WORKING DRAFT



670.21 ft MSL

Sandy clay (CL): brown, soft, dry.

Sandstone: tan, brown, very fine-grained, weathered, thinly bedded with siltstone and clay shale.

Clay shale: brown, soft.

Sandstone and clay shale: brown, grey, thinly bedded, soft, very, fine-grained.

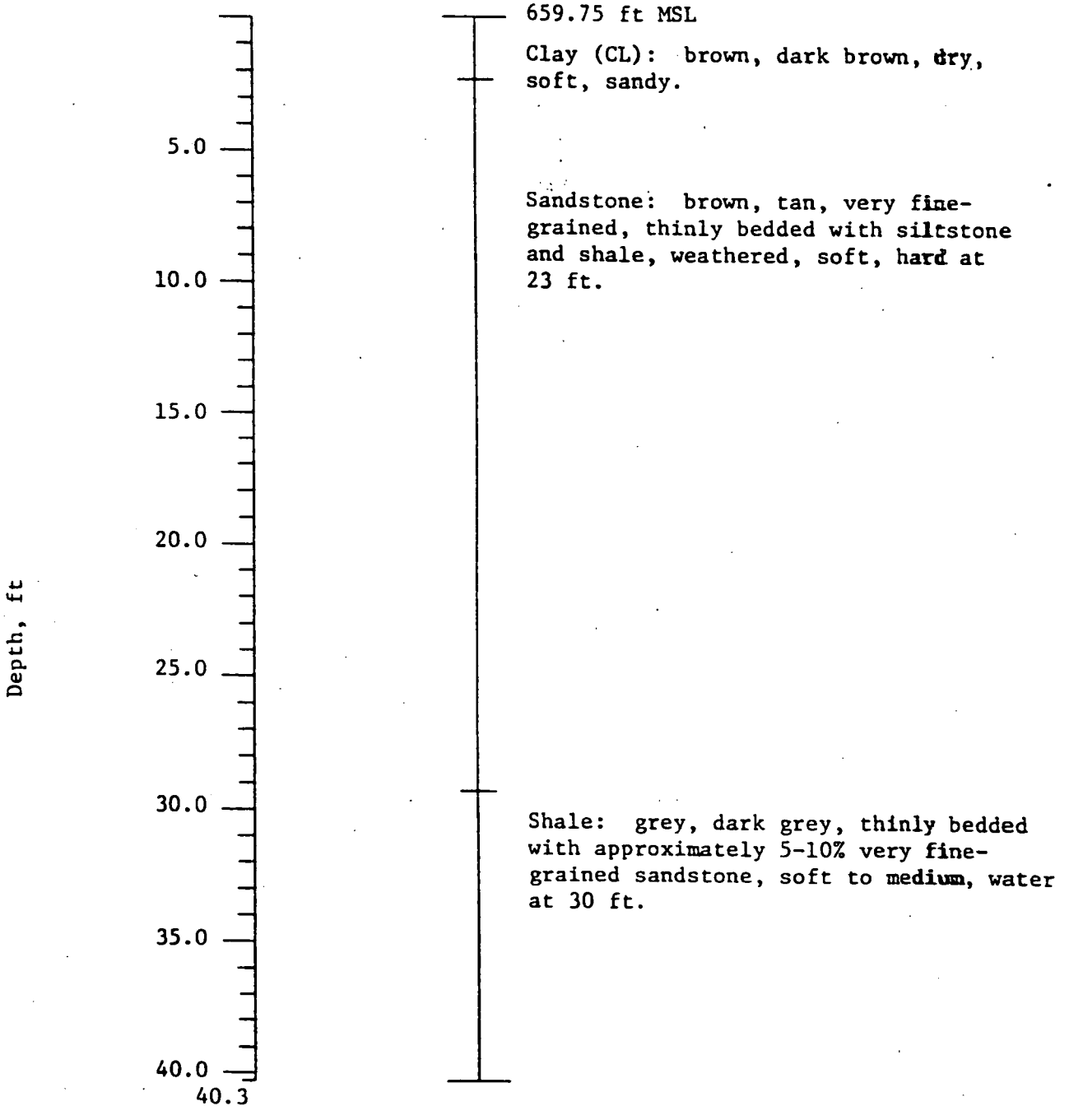
Shale: brown, grey, soft, thinly bedded.

Sandstone and shale: light to dark grey, thinly bedded, very fine-grained.

Continued

NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Lithology
Boring Number: WES-1-26-83

WORKING DRAFT



NWSC, Crane, Indiana
Mustard Gas Burial Grounds
Lithology
Boring Number: WES-1-27-83

WORKING DRAFT

PART 2-4: HISTORICAL GROUND WATER MEASUREMENTS (ALL WELLS)

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-1-81

Top of Pipe Elevation: 686.14 ft MSL

Screen Interval Elevation: from 650.00 to 640.37 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:51	24.90	661.24	
6 Jul 83	12:08	25.32	660.82	
13 Jul 83	1:45	25.18	660.96	
20 Jul 83	8:13	25.29	660.85	
27 Jul 83	3:15	25.63	660.51	
3 Aug 83	8:51	25.60	660.54	
10 Aug 83	11:17	25.59	660.55	
17 Aug 83	9:11	25.59	660.55	
24 Aug 83	10:43	25.79	660.35	
14 Sep 83	3:52	26.05	660.09	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-2-81

Top of Pipe Elevation: 667.04 ft MSL

Screen Interval Elevation: from 655.80 to 646.44 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:46	11.40	655.64	
6 Jul 83	12:15	12.05	654.99	
13 Jul 83	1:51	12.09	654.95	
20 Jul 83	8:23	12.21	654.83	
27 Jul 83	3:52	12.40	654.64	
3 Aug 83	9:25	12.65	654.39	
10 Aug 83	11:23	12.79	654.25	
17 Aug 83	10:07	12.77	654.27	
24 Aug 83	11:32	13.20	653.84	
14 Sep 83	4:01	13.50	653.54	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-3-81

Top of Pipe Elevation: 670.43 ft MSL

Screen Interval Elevation: from 663.44 to 654.02 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:54	9.37	661.06	
6 Jul 83	12:05	10.25	660.18	
13 Jul 83	1:42	10.62	659.81	
20 Jul 83	8:16	10.68	659.75	
27 Jul 83	3:18	11.25	659.18	
3 Aug 83	8:53	11.22	659.21	
10 Aug 83	11:12	11.55	658.88	
17 Aug 83	9:13	11.48	658.95	
24 Aug 83	10:47	12.00	658.43	
14 Sep 83	3:55	12.53	657.90	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-4-81

Top of Pipe Elevation: 672.95 ft MSL

Screen Interval Elevation: from 653.48 to 644.27 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:49	14.18	658.77	
6 Jul 83	12:11	14.55	658.40	
13 Jul 83	1:47	14.70	658.25	
20 Jul 83	8:20	14.85	658.10	
27 Jul 83	3:48	16.05	656.90	
3 Aug 83	9:23	15.37	657.58	
10 Aug 83	11:20	15.45	657.50	
17 Aug 83	10:04	15.49	657.46	
24 Aug 83	11:28	15.87	657.08	
14 Sep 83	3:58	16.28	656.67	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-5-81

Top of Pipe Elevation: 668.69 ft MSL

Screen Interval Elevation: from 649.51 to 640.39 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:47	13.0	655.69	
6 Jul 83	12:17	13.73	654.96	
13 Jul 83	1:49	13.85	654.84	
20 Jul 83	8:21	14.03	654.66	
27 Jul 83	3:50	15.20	653.49	
3 Aug 83	9:25	14.45	654.24	
10 Aug 83	11:22	14.52	654.17	
17 Aug 83	10:05	14.62	654.07	
24 Aug 83	11:30	15.04	653.65	
14 Sep 83	3:59	15.35	653.34	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-6-82

Top of Pipe Elevation: 599.02 ft MSL

Screen Interval Elevation: from 521.00 to 511.62 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:34	70.45	528.57	
6 Jul 83	12:22	69.58	529.44	
20 Jul 83	8:49	69.70	529.32	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-7-82

Top of Pipe Elevation: 606.45 ft MSL*

Screen Interval Elevation: from 590.84 to 581.46 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
22 Jun 83	11:16	15.85	590.60	
28 Jun 83	3:30	15.98	590.47	
6 Jul 83	12:25	16.53	589.92	
13 Jul 83	1:58	16.24	590.21	
20 Jul 83	8:52	17.10	589.35	
27 Jul 83	3:40	17.18	589.27	
3 Aug 83	9:05	17.46	588.99	
10 Aug 83	10:50	17.51	588.94	
17 Aug 83	9:45	17.77	588.68	
24 Aug 83	11:21	17.80	588.65	
14 Sep 83	4:37	17.94	588.51	

* Change in top of pipe elevation

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-8-82

Top of Pipe Elevation: 604.99 ft MSL

Screen Interval Elevation: from 588.36 to 579.04 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:32	14.33	590.66	
6 Jul 83	12:23	14.72	590.27	
13 Jul 83	1:56	14.90	590.09	
20 Jul 83	8:50	14.91	590.08	
27 Jul 83	3:42	15.15	589.84	
3 Aug 83	9:07	15.08	589.91	
10 Aug 83	10:48	15.17	589.82	
17 Aug 83	9:43	15.37	589.62	
24 Aug 83	11:19	16.31	588.68	
14 Sep 83	4:34	15.67	589.32	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-9-82

Top of Pipe Elevation: 613.18 ft MSL

Screen Interval Elevation: from 592.78 to 583.40 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:36	19.27	593.93	
6 Jul 83	12:19	20.22	592.96	
13 Jul 83	1:55	20.87	592.31	
20 Jul 83	8:47	21.50	591.68	
27 Jul 83	3:44	22.00	591.18	
3 Aug 83	9:09	21.87	591.37	
10 Aug 83	10:46	21.40	591.78	
17 Aug 83	9:41	21.73	591.45	
24 Aug 83	11:17	22.09	591.09	
14 Sep 83	4:32	22.38	590.80	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-10-83

Top of Pipe Elevation: 639.77 ft MSL

Screen Interval Elevation: from 611.52 to 602.12 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:38	23.78	615.99	
6 Jul 83	12:17	24.57	615.20	
13 Jul 83	1:53	24.68	615.09	
20 Jul 83	8:45	25.18	614.59	
27 Jul 83	3:58	25.34	614.43	
3 Aug 83	9:09	25.75	614.02	
10 Aug 83	10:28	25.72	614.05	
17 Aug 83	10:10	25.94	613.83	
24 Aug 83	11:34	26.14	613.63	
14 Sep 83	4:30	26.45	613.32	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-11-83

Top of Pipe Elevation: 659.34 ft MSL

Screen Interval Elevation: from 649.62 to 640.99 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:39	10.00	649.34	
6 Jul 83	12:40	7.57	651.77	
13 Jul 83	2:16	7.97	651.37	
20 Jul 83	8:26	8.00	651.34	
27 Jul 83	3:53	8:23	651.11	
3 Aug 83	9:26	8.33	651.01	
10 Aug 83	11:24	8.28	651.06	
17 Aug 83	10:21	8.44	650.90	
24 Aug 83	11:44	8.56	650.78	
14 Sep 83	4:03	9.04	650.30	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-12-83

Top of Pipe Elevation: 637.05 ft MSL

Screen Interval Elevation: from 610.79 to 601.38 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:41	23.76	613.29	
6 Jul 83	12:32	24.39	612.66	
13 Jul 83	3:12	24.82	612.23	
20 Jul 83	8:42	24.91	612.14	
27 Jul 83	3:55	25.25	611.80	
3 Aug 83	9:11	25.47	611.58	
10 Aug 83	10:32	25.52	611.53	
17 Aug 83	10:14	25.62	611.43	
24 Aug 83	11:37	26.19	610.86	
14 Sep 83	4:27	25.85	611.20	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-13-83

Top of Pipe Elevation: 637.98 ft MSL

Screen Interval Elevation: from 615.01 to 605.56 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:39	22.78	615.20	
6 Jul 83	12:38	23.44	614.54	
13 Jul 83	2:14	23.75	614.23	
20 Jul 83	8:43	24.15	613.83	
27 Jul 83	3:57	24.13	613.85	
3 Aug 83	9:10	24.40	613.58	
10 Aug 83	10:30	24.48	613.50	
17 Aug 83	10:12	24.72	613.26	
24 Aug 83	11:36	24.94	613.04	
14 Sep 83	4:29	25.08	612.90	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-14-83

Top of Pipe Elevation: 659.14 ft MSL

Screen Interval Elevation: from 635.02 to 625.49 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:42	15.15	643.99	
6 Jul 83	12:42	15.83	643.31	
13 Jul 83	2:18	15.73	643.41	
20 Jul 83	8:30	15.93	643.21	
27 Jul 83	3:21	15.88	643.26	
3 Aug 83	9:20	16.14	643.00	
10 Aug 83	11:32	16.14	643.00	
17 Aug 83	10:16	16.38	642.76	
24 Aug 83	11:39	16.59	642.55	
14 Sep 83	4:07	16.84	642.30	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-15-83

Top of Pipe Elevation: 666.01 ft MSL

Screen Interval Elevation: from 640.91 to 631.41 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:22	26.40	639.61	
6 Jul 83	12:45	26.69	639.32	
13 Jul 83	2:23	26.53	639.48	
20 Jul 83	8:32	26.75	639.26	
27 Jul 83	3:25	26.62	639.39	
3 Aug 83	3:18	26.85	639.16	
10 Aug 83	10:56	26.84	639.17	
17 Aug 83	9:28	26.74	639.27	
24 Aug 83	11:03	26.91	639.10	
14 Sep 83	4:20	27.03	638.98	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-16-83

Top of Pipe Elevation: 644.94 ft MSL

Screen Interval Elevation: from 618.19 to 608.94 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:26	35.18	609.76	
6 Jul 83	12:30	35.10	609.84	
13 Jul 83	2:10	35.03	609.91	
20 Jul 83	8:40	35.10	609.84	
27 Jul 83	3:33	35.25	609.69	
3 Aug 83	9:13	35.10	609.84	
10 Aug 83	10:35	35.37	609.57	
17 Aug 83	9:31	35.12	609.82	
24 Aug 83	11:12	35.39	609.55	
14 Sep 83	4:26	35.25	609.69	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-17-83

Top of Pipe Elevation: 665.54 ft MSL

Screen Interval Elevation: from 639.29 to 629.99 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
28 Jun 83	3:44	18.44	647.10	
6 Jul 83	12:44	18.73	646.81	
13 Jul 83	2:21	18.75	646.79	
20 Jul 83	8:28	18.72	646.82	
27 Jul 83	3:22	18.88	646.66	
3 Aug 83	9:21	19.24	646.30	
10 Aug 83	11:35	18.96	646.58	
17 Aug 83	10:19	19.10	646.44	
24 Aug 83	11:41	19.50	646.04	
14 Sep 83	4:09	19.70	645.84	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-18-83

Top of Pipe Elevation: 661.40 ft MSL

Screen Interval Elevation: from 644.10 to 634.81 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
20 Jun 83	10:40	14.04	644.36	
21 Jun 83	8:58	13.18	648.20	
22 Jun 83	10:58	13.10	648.30	
23 Jun 83	8:29	13.10	648.30	
24 Jun 83	4:25	13.02	648.38	
25 Jun 83	9:16	12.95	648.45	
27 Jun 83	10:30	13.34	648.06	Sampled well
28 Jun 83	3:19	13.32	648.08	
6 Jul 83	12:50	13.62	647.78	
13 Jul 83	2:30	13.55	647.85	
20 Jul 83	8:18	13.74	647.66	
27 Jul 83	3:20	13.85	647.55	
3 Aug 83	8:55	14.14	647.26	
10 Aug 83	11:10	14.08	647.32	
17 Aug 83	9:15	14.00	647.40	
24 Aug 83	10:48	14.37	647.03	
14 Sep 83	4:05	14.58	646.82	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-19-83

Top of Pipe Elevation: 659.79 ft MSL

Screen Interval Elevation: from 641.09 to 632.09 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
20 Jun 83	1:17	19.20	637.59	
21 Jun 83	9:01	20.10	639.69	
22 Jun 83	11:04	20.10	639.69	
23 Jun 83	8:32	20.10	639.69	
24 Jun 83	4:27	19.95	639.84	
25 Jun 83	9:28	19.95	639.84	
27 Jun 83	11:44	19.95	639.84	Sampled well
28 Jun 83	3:23	19.87	639.92	
6 Jul 83	12:47	20.20	639.59	
13 Jul 83	2:24	20.00	639.79	
20 Jul 83	8:33	20.00	639.79	
27 Jul 83	3:28	20.15	639.64	
3 Aug 83	9:15	20.15	639.64	
10 Aug 83	10:53	20.14	639.65	
17 Aug 83	9:25	20.00	639.77	
24 Aug 83	11:01	20.26	639.53	
14 Sep 83	4:17	20.35	639.44	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-20-83

Top of Pipe Elevation: 634.35 ft MSL

Screen Interval Elevation: from 610.00 to 600.66 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
22 Jun 83	11:10	24.55	609.80	
23 Jun 83	8:44	24.50	609.85	
24 Jun 83	4:30	24.50	609.85	
25 Jun 83	9:55	24.52	609.83	
27 Jun 83	11:26	24.55	609.80	Sampled well
28 Jun 83	3:25	24.65	609.70	
6 Jul 83	12:29	25.04	609.31	
13 Jul 83	2:08	25.42	608.93	
20 Jul 83	8:39	25.78	608.57	
27 Jul 83	3:34	26.20	608.15	
3 Aug 83	8:58	26.57	607.78	
10 Aug 83	10:37	26.72	607.63	
17 Aug 83	9:34	27.14	607.21	
24 Aug 83	11:08	27.40	606.95	
14 Sep 83	4:24	28.00	606.35	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-21-83

Top of Pipe Elevation: 606.82 ft MSL

Screen Interval Elevation: from 580.08 to 571.07 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
22 Jun 83	11:14	10.52	596.30	
23 Jun 83	8:50	10.55	596.27	
24 Jun 83	4:33	15.43	591.39	
25 Jun 83	10:20	15.61	591.21	
27 Jun 83	11:05	15.10	591.72	Sampled well
28 Jun 83	3:28	16.10	590.72	
6 Jul 83	12:27	16.53	590.29	
13 Jul 83	2:00	16.95	589.87	
20 Jul 83	8:53	17.05	589.77	
27 Jul 83	3:38	17.28	589.54	
3 Aug 83	9:04	17.59	589.23	
10 Aug 83	10:53	17.57	589.25	
17 Aug 83	9:47	17.63	589.19	
24 Aug 83	11:25	17.98	588.84	
14 Sep 83	4:38	18.24	588.58	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-22-83

Top of Pipe Elevation: 656.55 ft MSL

Screen Interval Elevation: from 633.05 to 623.90 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
9 Jul 83	8:28	16.75	639.80	
11 Jul 83	11:52	17.25	639.30	
12 Jul 83	3:50	17.25	639.30	
13 Jul 83	2:26	17.30	639.25	
14 Jul 83	8:49	17.30	639.25	Sampled well
15 Jul 83	10:05	17.25	639.30	
16 Jul 83	4:18	17.20	639.35	
18 Jul 83	11:08	17.15	639.40	
19 Jul 83	2:53	17.18	639.37	
20 Jul 83	8:35	17.25	639.30	
27 Jul 83	3:29	17.20	639.35	
3 Aug 83	9:16	17.43	639.12	
10 Aug 83	11:00	17.31	639.24	
17 Aug 83	9:24	17.32	639.23	
24 Aug 83	10:59	17.43	639.12	
14 Sep 83	4:16	17.55	639.00	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-23-83

Top of Pipe Elevation: 628.81 ft MSL

Screen Interval Elevation: from 595.30 to 586.23 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
11 Jul 83	8:00	34.00	591.81	Open hole
12 Jul 83	3:55	39.00	589.81	
13 Jul 83	2:07	39.23	589.58	
14 Jul 83	8:30	39.75	589.06	Sampled well
15 Jul 83	10:07	39.87	588.94	
16 Jul 83	4:17	39.75	589.06	
18 Jul 83	11:05	39.90	588.91	
19 Jul 83	2:49	39.90	588.91	
20 Jul 83	8:37	39.95	588.86	
27 Jul 83	3:32	39.90	588.91	
3 Aug 83	8:59	39.95	588.86	
10 Aug 83	10:40	40.00	588.81	
17 Aug 83	9:36	40.03	588.78	
24 Aug 83	11:09	40.00	588.81	
14 Sep 83	4:22	40.05	588.76	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-24-83

Top of Pipe Elevation: 603.57 ft MSL

Screen Interval Elevation: from 584.95 to 575.54 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
11 Jul 83	12:04	13.57	590.00	
12 Jul 83	4:00	13.65	589.92	
13 Jul 83	2:03	13.78	589.79	
14 Jul 83	8:17	13.71	589.86	Sampled well
15 Jul 83	10:10	13.80	589.77	
16 Jul 83	4:15	13.75	589.82	
18 Jul 83	11:00	13.90	589.67	
19 Jul 83	2:50	14.00	589.57	
20 Jul 83	8:55	14.05	589.52	
27 Jul 83	3:37	14.22	589.35	
3 Aug 83	9:01	14.45	589.12	
10 Aug 83	10:43	14.56	589.01	
17 Aug 83	9:38	14.63	588.94	
24 Aug 83	11:14	14.84	588.73	
14 Sep 83	4:40	15.18	588.39	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-25-83

Top of Pipe Elevation: 657.16 ft MSL

Screen Interval Elevation: from 636.74 to 628.37 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
3 Aug 83	3:07	19.86	637.30	
9 Aug 83	3:50	19.91	637.25	
10 Aug 83	11:02	19.90	637.26	
11 Aug 83	1:14	19.68	637.48	
12 Aug 83	8:35	19.92	637.24	
13 Aug 83	9:29	20.00	637.16	
15 Aug 83	3:19	19.59	637.57	
17 Aug 83	9:22	19.88	637.28	
24 Aug 83	10:57	20.13	637.03	
14 Sep 83	4:14	20.10	637.06	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-26-83

Top of Pipe Elevation: 673.21 ft MSL

Screen Interval Elevation: from 629.76 to 620.64 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
8 Aug 83	3:13	34.80	638.41	
9 Aug 83	3:52	34.85	638.36	
10 Aug 83	11:08	34.45	638.76	
11 Aug 83	1:17	34.72	638.49	
12 Aug 83	8:40	34.88	638.33	
13 Aug 83	9:32	35.05	638.16	
15 Aug 83	3:21	34.91	638.30	
17 Aug 83	9:19	34.92	638.29	
24 Aug 83	10:55	35.30	637.91	
14 Sep 83	4:13	35.25	637.96	

WORKING DRAFT

Ground-Water Elevations

Mustard Gas Burial Grounds

Boring Number: WES-1-27-83

Top of Pipe Elevation: 662.75 ft MSL

Screen Interval Elevation: from 634.20 to 625.20 ft MSL

Grid Coordinates:

Date	Time	Depth to Water, ft	Water Elevation, ft MSL	Remarks
11 Aug 83	1:20	23.60	639.15	
12 Aug 83	8:43	23.47	639.28	
13 Aug 83	9:35	23.45	639.30	
15 Aug 83	3:23	23.38	639.37	
17 Aug 83	9:17	23.40	639.35	
24 Aug 83	10:52	23.71	639.04	
14 Sep 83	4:11	23.86	638.89	

WORKING DRAFT

APPENDIX C

TABULAR PRESENTATION OF RBSLs

TABLE C-1

TABULAR PRESENTATION OF RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE, INDIANA

PARAMETER	CAS	REGION 5 ECO DQLs SURFACE WATER (ug/L)	Footnote	FEDERAL MCLs (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER ACUTE (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER CHRONIC (ug/L)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL GW CLOSURE LEVELS (ug/L)	IDEM TIER 1 DEFAULT INDUSTRIAL GW CLOSURE LEVELS (ug/L)	Footnote	Footnote	REGION 9 TAP WATER PRGs (ug/L)	Footnote	MINIMUM CRITERIA VALUE	Footnote
EXPLOSIVES (SW-846 METHOD 8330)																	
1,3,5-Trinitrobenzene	99-35-4											N	N	1100	N	1100	
1,3-Dinitrobenzene	99-65-0	2.36										N	N	3.6	N	2.36	
2,4,6-Trinitrotoluene (TNT)	118-96-7											C	C	2.2	C	2.2	
2,4-Dinitrotoluene	121-14-2	230								1.2 C (15)	4.2 C (15)	N	N	73	N	1.2	
2,6-Dinitrotoluene	606-20-2	42								1.2 C (15)	4.2 C (15)	N	N	36	N	1.2	
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0											N	N	1800	N	1800	
2-Nitrotoluene	88-72-2													61		61	
3-Nitrotoluene	99-08-1											N	sat	61	N	61	
4-Nitrotoluene	99-99-0											N	sat	61	N	61	
4-Amino-2,6-dinitrotoluene	19406-51-0																
2-Amino-4,6-dinitrotoluene	35572-78-2																
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	479-45-8											N	N	360	N	360	
Nitrobenzene	98-95-3	740								4.3	51	N	N	3.4	N	3.4	
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4											C	C	0.61	C	0.61	
MUSTARD GAS AND DEGRADATION PRODUCTS																	
Bis(2-chloroethyl)sulfide (HD)	505-60-2															2	
1,4-Thioxane	15980-15-1															370	
1,4-Dithiane	505-29-3											N	N	360	N	360	
Thiodiglycol	111-48-8															370	
APPENDIX IX METALS (ANALYTICAL METHODS TO BE DETERMINED BASED ON LABORATORY CAPABILITIES)																	
Antimony	7440-36-0	31		6						6	41	N	N	15	N	6	
Arsenic	7440-38-2	53		50		340		150		50 C	50 C	C	C	0.045	C	0.045	
Barium	7440-39-3	5000		2000						2000 C	7200	N	max	2600	N	2000	
Beryllium	7440-41-7	7.6		4						4 C	4 C	N	C	73	N	4	
Cadmium	7440-43-9	0.66		5		4.3	1	2.2	1	5	51	N	N	18	N	0.66	
Chromium (total)	7440-47-3	42		100		16	10	11	10	100	510	C	C	110 (10)	N	11	
Cobalt	7440-48-4	5										N	max	2200	N	5	
Copper	7440-50-8	5		1300	2,3	13	1	9	1	1300	3800	N	N	1400	N	5	
Lead	7439-92-1	1.3		15	2	65	1	2.5	1	15	42	N	N			1.3	
Mercury (SW-846 Method 7470A/7471A)	7439-97-6	0.0013		2		1.4		0.77		2	31			11	N	0.0013	
Nickel	7440-02-0	29		100	4	470	1	52	1	100	2000	N	N	730	N	29	
Selenium	7782-49-2	5		50				5		50	510	N	N	180	N	5	
Silver	7440-22-4	1		100	7	3.4	1			180	510	N	N	180	N	1	
Thallium	7440-28-0	0.56		2						2	9			2.9 (11)		0.56	
Tin	7440-31-5	73										N	max	22000	N	73	
Vanadium	7440-62-2	19										N	N	260	N	19	
Zinc	7440-66-6	58.9		5000	7	120	1	120	1	11000	31000	N	max	11000	N	58.9	
MISCELLANEOUS METALS (SW-846 METHOD 6010B)																	
Aluminum	7429-90-5			50-200	1	750		87				N	max	36000	N	87	
Calcium	7440-70-2																
Iron	7439-89-6			300	1			1000				N	max	11000	N	300	
Magnesium	7439-95-4																
Manganese	7439-96-5			50	1							N	N	880	N	50	
Potassium	7440-09-7																
Sodium	7440-23-5																
Strontium	7440-24-6											N	max	22000	N	22000	
RADIONUCLIDES																	
Thorium-228 (resdiential screening scenario)	14274-82-9															0.087 pCi/L	24
Thorium-230 (resdiential screening scenario)	14269-63-7															0.37 pCi/L	24
Thorium-232 (resdiential screening scenario)	7440-29-1															0.028 pCi/L	24
APPENDIX IX VOLATILE ORGANIC COMPOUNDS (SW-846 METHOD 8260B WITH 25 ML PURGE FOR WATER, 5 GM PURGE FOR SOIL)																	
1,1,1,2-Tetrachloroethane	630-20-6	90.25								6.9 C	110 C	C	C	0.43	C	0.43	
1,1,1-Trichloroethane	71-55-6	88		200						200	9200	N	sat	790	N	88	
1,1,2,2-Tetrachloroethane	79-34-5	13								0.9 C	14 C	C	C	0.055	C	0.055	

TABLE C-1

TABULAR PRESENTATION OF RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE, INDIANA

PARAMETER	CAS	REGION 5 ECO DQLs SURFACE WATER (ug/L)	Footnote	FEDERAL MCLs (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER ACUTE (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER CHRONIC (ug/L)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL GW CLOSURE LEVELS (ug/L)	IDEM TIER 1 DEFAULT INDUSTRIAL GW CLOSURE LEVELS (ug/L)	Footnote	Footnote	REGION 9 TAP WATER PRGs (ug/L)	Footnote	MINIMUM CRITERIA VALUE	Footnote
1,1,2-Trichloroethane	79-00-5	650		5						5 C	50 C	C	C	0.2	C	0.2	
1,1-Dichloroethane	75-34-3	47								990	10000	N	N	810	N	47	
1,1-Dichloroethene	75-35-4	78		7						7 C	7 C	C	C	0.046	C	0.046	
1,2,3-Trichloropropane	96-18-4	12.11										C	C	0.0016	C	0.0016	
1,2-Dibromo-3-chloropropane	96-12-8	11.2		0.2								C	C	0.048	C	0.048	
1,2-Dibromoethane	106-93-4	22.5		0.05								C	C	0.00076	C	0.00076	
1,2-Dichloroethane	107-06-2	190		5						5 C	31 C	C	C	0.12	C	0.12	
1,2-Dichloropropane	78-87-5	380		5						5 C	42 C	C	C	0.16	C	0.16	
1,4-Dioxane	123-91-1													6.1	C	6.1	
2-Butanone	78-93-3	7100								2500	61000	N	N	1900	N	1900	
2-Chloro-1,3-butadiene (chloroprene)	126-99-8											N	N	14	N	14	
2-Hexanone	591-78-6	1710												1500 (13)		1500	
4-Methyl-2-pentanone	108-10-1	3680										N	N	160	N	160	
Acetone	67-64-1	78000								770	10000	N	N	610	N	610	
Acetonitrile	75-05-8													79	N	79	
Acrolein	107-02-8	0.205								0.056	2000	N	N	0.042	N	0.042	
Acrylonitrile	107-13-1	0.89										C	C	0.039	C	0.039	
Allyl chloride (3-chloro-1-propene)	107-05-1											N	N	1800	N	1800	
Benzene	71-43-2	114		5						5 C	99 C	C	C	0.41	C	0.41	
Bromodichloromethane	75-27-4			80	9					100 C	100 C	C	C	0.18	C	0.18	
Bromoform	75-25-2	466		80	9					100 C	360 C	C	C	8.5	C	8.5	
Bromomethane	74-83-9									11	140	N	N	8.7	N	8.7	
Carbon disulfide	75-15-0	84.1								1300	10000	N	sat	1000	N	84.1	
Carbon tetrachloride	56-23-5	5.9		5						5 C	22 C	C	C	0.17	C	0.17	
Chlorobenzene	108-90-7	10		100						100	2000	N	N	110	N	10	
Chloroethane	75-00-3	230000										C	C	4.6	C	4.6	
Chloroform	67-66-3	79		80	9					100 C	470 C	C	C	0.16	C	0.16	
Chloromethane	74-87-3											C	C	1.5	C	1.5	
cis-1,2-Dichloroethene	156-59-2	310	5	70						70	1000	N	N	61	N	61	
cis-1,3-Dichloropropene	10061-01-5	7.9								1.3 C (12)	16 C (12)	C	C	0.081 (12)	C	0.081	
Dibromochloromethane	124-48-1	6400		80	9							C	C	0.13	C	0.13	
Dibromomethane	74-95-3											N	N	61	N	61	
Dichlorodifluoromethane	75-71-8											N	N	390	N	390	
Ethyl methacrylate	97-63-2											sat	sat	550	N	550	
Ethylbenzene	100-41-4	17.2		700						700	10000	sat	sat	1300	N	17.2	
Isobutyl alcohol	78-83-1													1800	N	1800	
Methacrylonitrile	126-98-7											N	N	1	N	1	
Methyl iodide	74-88-4																
Methyl methacrylate	80-62-6	2800										N	sat	1400	N	1400	
Methylene chloride	75-09-2	430		5						5 C	380 C	C	C	4.3	C	4.3	
Proprionitrile	107-12-0	6080														6080	
Styrene	100-42-5	56		100						100	20000	sat	sat	1600	N	56	
Tetrachloroethene	127-18-4	8.9		5						5 C	55 C	C	C	1.1	C	1.1	
Toluene	108-88-3	253		1000						1000	20000	sat	sat	720	N	253	
Total Xylenes	1330-20-7	117		10000						10000	180000	sat	sat	1400	N	117	
trans-1,2-Dichloroethene	156-60-5	310		100						100	2000	N	N	120	N	100	
trans-1,3-Dichloropropene	10061-02-6	7.9								1.3 C (12)	16 C (12)	C	C	0.081 (12)	C	0.081	
trans-1,4-Dichloro-2-butene	110-57-6													0.0012 (2)		0.0012	
Trichloroethene	79-01-6	75		5						5 C	260 C	C	C	1.6	C	1.6	
Trichlorofluoromethane	75-69-4											N	sat	1300	N	1300	
Vinyl acetate	108-05-4	248.03								550	100000	N	N	410	N	248.03	
Vinyl chloride	75-01-4	9.2		2						2 C	2 C	C	C	0.02	C	0.02	

TABLE C-1

TABULAR PRESENTATION OF RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE, INDIANA

PARAMETER	CAS	REGION 5 ECO DQLs SURFACE WATER (ug/L)	Footnote	FEDERAL MCLs (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER ACUTE (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER CHRONIC (ug/L)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL GW CLOSURE LEVELS (ug/L)	IDEM TIER 1 DEFAULT INDUSTRIAL GW CLOSURE LEVELS (ug/L)	Footnote	Footnote	REGION 9 TAP WATER PRGs (ug/L)	Footnote	MINIMUM CRITERIA VALUE	Footnote
APPENDIX IX SEMIVOLATILE ORGANIC COMPOUNDS (SW-846 METHOD 8270C; 8270C SIM OR 8310, BASED ON LABORATORY CAPABILITIES, WHERE NOTED)												0	0				
1,2,4,5-Tetrachlorobenzene	95-94-3	26.24										N	N	11	N	11	
1,2,4-Trichlorobenzene	120-82-1	69.2		70						70	1000	N	sat	190	N	69.2	
1,2-Dichlorobenzene	95-50-1	11		600						600	9200	sat	sat	370	N	11	
1,3-Dichlorobenzene	541-73-1	87								22	3100	N	N	5.5	N	5.5	
1,4-Dichlorobenzene	106-46-7	43		75						75 C	120 C	C	C	0.5	C	0.5	
1,4-Naphthoquinone	130-15-4																
1,4-Phenylenediamine	106-50-3											N	max	6900	N	6900	
1-Naphthylamine	134-32-7	0.67														0.67	
2,3,4,6-Tetrachlorophenol	58-90-2	14.06										N	N	1100	N	14.06	
2,4,5-Trichlorophenol	95-95-4									3600	10000	N	N	3600	N	3600	
2,4,6-Trichlorophenol	88-06-2	2								77 C	26 C	C	C	6.1	C	2	
2,4-Dichlorophenol	120-83-2	18								110	310	N	N	110	N	18	
2,4-Dimethylphenol	105-67-9	100.17								730	2000	N	N	730	N	100.17	
2,4-Dinitrophenol	51-28-5	4.07								73	200	N	N	73	N	4.07	
2,6-Dichlorophenol	87-65-0																
2-Acetylaminofluorene	53-96-3	534.97														534.97	
2-Chloronaphthalene	91-58-7	0.396										N	N	490	N	0.396	
2-Chlorophenol	95-57-8	8.8								38	510	N	N	30	N	8.8	
2-Methylnaphthalene (by SIM)	91-57-6	329.55														329.55	
2-Methylphenol	95-48-7									1800	5100	N	N	1800	N	1800	
2-Naphthylamine	91-59-8																
2-Nitroaniline	88-74-4											N	N	2.1	N	2.1	
2-Nitrophenol	88-75-5	13.5												290 (14)	N	13.5	
2-Picoline	109-06-8	3790														3790	
3,3'-Dichlorobenzidine	91-94-1	99.75								1.9 C	6.4 C	C	C	0.15	C	0.15	
3,3'-Dimethylbenzidine	119-93-7											C	C	0.0073	C	0.0073	
3-Methylcholanthrene	56-49-5	0.0891														0.0891	
3-Methylphenol	108-39-4											N	N	1800	N	1800	
3-Nitroaniline	99-09-2																
4,6-Dinitro-2-methylphenol	534-52-1	2.3														2.3	
4-Aminobiphenyl	92-67-1																
4-Bromophenyl phenyl ether	101-55-3	1.5														1.5	
4-Chloro-3-methylphenol	59-50-7	20														20	
4-Chloroaniline	106-47-8	231.97								150	410	N	N	150	N	150	
4-Chlorophenyl phenyl ether	7005-72-3																
4-Methylphenol	106-44-5											N	N	180	N	180	
4-Nitroaniline	100-01-6																
4-Nitrophenol	100-02-7	35										N	N	290	N	35	
4-Nitroquinoline-1-oxide	56-57-5																
5-Nitro-o-toluidine	99-55-8											C	C	2	C	2	
7,12-Dimethylbenz(a)anthracene	57-97-6																
a,a-Dimethylphenethylamine	122-09-8	300.16										N	N	37	N	37	
Acenaphthene (by SIM)	83-32-9	9.9								460	4200	N	N	370	N	9.9	
Acenaphthylene (by SIM)	208-96-8	4840								460 (19)	460 (19)			370 (19)	N	370	
Acetophenone	98-86-2	687.89										N	N	0.042	N	0.042	
Aniline	62-53-3	0.44										C	C	12	C	0.44	
Anthracene (by SIM)	120-12-7	0.029								43	43	N	max	1800	N	0.029	
Aramite	140-57-8	3.09										C	C	2.7	C	2.7	
Benzo(a)anthracene (by SIM)	56-55-3	0.839								1.2 C	3.9 C	C	C	0.092	C	0.092	
Benzo(a)pyrene (by SIM)	50-32-8	0.014		0.2						0.2 C	0.39 C	C	C	0.0092	C	0.0092	
Benzo(b)fluoranthene (by SIM)	205-99-2	9.07								1.2 C	1.5 C	C	C	0.092	C	0.092	
Benzo(g,h,i)perylene (by SIM)	191-24-2	7.64								8.3 (20)	8.3 (20)			6.2 (20)	N	6.2	
Benzo(k)fluoranthene (by SIM)	207-08-9	0.0056								0.8 C	0.8 C	C	C	0.92	C	0.0056	
Benzyl alcohol	100-51-6	281.24										N	max	11000	N	281.24	

TABLE C-1

TABULAR PRESENTATION OF RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE, INDIANA

PARAMETER	CAS	REGION 5 ECO DQLs SURFACE WATER (ug/L)	Footnote	FEDERAL MCLs (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER ACUTE (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER CHRONIC (ug/L)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL GW CLOSURE LEVELS (ug/L)	IDEM TIER 1 DEFAULT INDUSTRIAL GW CLOSURE LEVELS (ug/L)	Footnote	Footnote	REGION 9 TAP WATER PRGs (ug/L)	Footnote	MINIMUM CRITERIA VALUE	Footnote
Bis(2-chloroethoxy)methane	111-91-1	6400														6400	
Bis(2-chloroethyl)ether	111-44-4	1140								0.15 C	2.6 C	C	C	0.0098	C	0.0098	
Bis(2-chloroisopropyl)ether	39638-32-9											C	C	0.27	C	0.27	
Bis(2-ethylhexyl)phthalate	117-81-7	2.1		6						6 C	200 C	C	C	4.8	C	2.1	
Butyl benzyl phthalate	85-68-7	49								2700	2700	N	max	7300	N	49	
Chlorobenzilate	510-15-6	7.16										C	C	0.25	C	0.25	
Chrysene (by SIM)	218-01-9	0.033								1.6 C	1.6 C	C	C	9.2	C	0.033	
Diallate	2303-16-4	29										C	C	1.1	C	1.1	
Dibenzo(a,h)anthracene (by SIM)	53-70-3	0.0016								0.12 C	0.39 C	C	C	0.0092	C	0.0016	
Dibenzofuran	132-64-9	20										N	N	24	N	20	
Diethyl phthalate	84-66-2	3								29000	82000	N	max	29000	N	3	
Dimethyl phthalate	131-11-3	73										max	max	360000	N	73	
Di-n-butyl phthalate	84-74-2	3								3600	10000	N	N	3600	N	3	
Di-n-octyl phthalate	117-84-0	30								20	20	N	sat	730	N	20	
Diphenylamine	122-39-4	412.51										N	N	910	N	412.51	
Ethyl methane sulfonate	62-50-0																
Ethyl parathion	56-38-2	0.008				0.065		0.013				N	N	220	N	0.008	
Famphur	52-85-7																
Fluoranthene (by SIM)	206-44-0	8.1								210	210	N	N	1500	N	8.1	
Fluorene (by SIM)	86-73-7	3.9								310	2000	N	N	240	N	3.9	
Hexachlorobenzene	118-74-1	0.00024		1						1 C	1.8 C	C	C	0.042	C	0.00024	
Hexachlorobutadiene	87-68-3	0.223								7.3	20	C	C	0.86	C	0.223	
Hexachlorocyclopentadiene	77-47-4	77.04		50						50	720	N	N	260	N	50	
Hexachloroethane	67-72-1	30.5								36	100	C	C	4.8	C	4.8	
Hexachloropropene	1888-71-7	20														20	
Indeno(1,2,3-cd)pyrene (by SIM)	193-39-5	4.31								0.022 C	0.022 C	C	C	0.092	C	0.092	
Isodrin	465-73-6	0.0309														0.0309	
Isophorone	78-59-1	900								900 C	3000 C	C	C	71	C	71	
Isosafrole	120-58-1																
Kepone	143-50-0	0.132										C	C	0.0037	C	0.0037	
Methapyrilene	91-80-5																
Methyl methane sulfonate	66-27-3																
Methyl parathion	298-00-0											N	N	9.1	N	9.1	
Naphthalene (by SIM)	91-20-3	44								8.3	2000	N	N	6.2	N	6.2	
n-Nitrosodiethylamine	55-18-5	767.94										C	C	0.00045	C	0.00045	
n-Nitrosodimethylamine	62-75-9											C	C	0.0013	C	0.0013	
n-Nitrosodi-n-butylamine	924-16-3	1000										C	C	0.002	C	0.002	
n-Nitrosodi-n-propylamine	621-64-7									0.12 C	0.41 C	C	C	0.0096	C	0.0096	
n-Nitrosomethylethylamine	10595-95-6											C	C	0.0031	C	0.0031	
n-Nitrosomorpholine	59-89-2																
n-Nitrosopiperidine	100-75-4																
n-Nitrosopyrrolidine	930-55-2											C	C	0.032	C	0.032	
O,O,O-Triethyl phosphorothioate	126-68-1	58.25														58.25	
o-Toluidine	95-53-4											C	C	0.28	C	0.28	
p-(Dimethylamino)azobenzene	60-11-7																
Pentachlorobenzene	608-93-5	0.47										N	N	29	N	0.47	
Pentachloroethane	76-01-7	56.42														56.42	
Pentachloronitrobenzene	82-68-8	50										C	C	0.26	C	0.26	
Pentachlorophenol	87-86-5	5.23		1		19		15		1 C	24 C	C	C	0.56	C	0.56	
Phenacetin	62-44-2																
Phenanthrene (by SIM)	85-01-8	2.1								8.3 (20)	2000 (20)			6.2 (20)	N	2.1	
Phenol	108-95-2	100								22000	61000	N	max	22000	N	100	
Pronamide	23950-58-5	160										N	N	2700	N	160	
Pyrene (by SIM)	129-00-0	0.3								140	140	N	N	180	N	0.3	
Pyridine	110-86-1	2380										N	N	37	N	37	

TABLE C-1

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NSWC CRANE, CRANE, INDIANA

PARAMETER	CAS	REGION 5 ECO DQLs SURFACE WATER (ug/L)	Footnote	FEDERAL MCLs (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER ACUTE (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER CHRONIC (ug/L)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL GW CLOSURE LEVELS (ug/L)	IDEM TIER 1 DEFAULT INDUSTRIAL GW CLOSURE LEVELS (ug/L)	Footnote	Footnote	REGION 9 TAP WATER PRGs (ug/L)	Footnote	MINIMUM CRITERIA VALUE	Footnote
Safrole	94-59-7	40														40	
APPENDIX IX ORGANOCHLORINE PESTICIDES and PCBs (SW-846 METHOD 8081A and 8082)																	
4,4'-DDD	72-54-8	0.0011								3.6 C	12 C	C	C	0.28	C	0.0011	
4,4'-DDE	72-55-9	0.00000000451								2.5 C	8.4 C	C	C	0.2	C	0.00000000451	
4,4'-DDT	50-29-3	0.001				1.1		0.001		2.5 C	8.4 C	C	C	0.2	C	0.001	
Aldrin	309-00-2	0.0309				3				0.05 C	0.17 C	C	C	0.004	C	0.004	
Alpha-BHC	319-84-6	12.38								0.14 C	0.45 C	C	C	0.011	C	0.011	
Alpha-chlordane	5103-71-9	0.00029	6	2	6	2.4	6	0.0043	6	2 C (6)	8.2 C (6)	C	C	0.19 (6)	C	0.00029	
Aroclor-1016	12674-11-2	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	N	C	0.96	C	0.000029	
Aroclor-1221	11104-28-2	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	C	C	0.034	C	0.000029	
Aroclor-1232	11141-16-5	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	C	C	0.034	C	0.000029	
Aroclor-1242	53469-21-9	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	C	C	0.034	C	0.000029	
Aroclor-1248	12672-29-6	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	C	C	0.034	C	0.000029	
Aroclor-1254	11097-69-1	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	C	C	0.034	C	0.000029	
Aroclor-1260	11096-82-5	0.000029	8	0.5	8			0.014	8	0.5 C (8)	1.4 C (8)	C	C	0.034	C	0.000029	
Beta-BHC	319-85-7	0.495								0.47 C	1.6 C	C	C	0.037	C	0.037	
Delta-BHC	319-86-8	666.67								0.14 C (17)	0.45 C (17)			0.011 (17)		0.011	
Dieldrin	60-57-1	0.000026				0.24		0.056		0.053 C	0.18 C	C	C	0.0042	C	0.000026	
Endosulfan I	959-98-8	0.003				0.22		0.056		0.22 C (16)	0.51 C (16)			220	NC	0.003	
Endosulfan II	33213-65-9	0.003				0.22		0.056		0.22 C (16)	0.51 C (16)			220	NC	0.003	
Endosulfan sulfate	1031-07-8	2.22								0.22 C (16)	0.51 C (16)			220	NC	0.22	
Endrin	72-20-8	0.002		2		0.086		0.036		2	31	N	N	11	N	0.002	
Endrin aldehyde	7421-93-4	0.15								2 (18)	31 (18)			11	N	0.15	
Gamma-BHC (Lindane)	58-89-9	0.01		0.2		0.95				0.2 C	2.2 C	C	C	0.052	C	0.01	
Gamma-chlordane	12789-03-6	0.00029	6	2	6	2.4	6	0.0043	6	2 C (6)	8.2 C (6)	C	C	0.19 (6)	C	0.00029	
Heptachlor	76-44-8	0.00039		0.4		0.52		0.0038		0.4 C	0.64 C	C	C	0.015	C	0.00039	
Heptachlor epoxide	1024-57-3	0.00048		0.2		0.52		0.0038		0.2 C	3.2 C	C	C	0.0074	C	0.00048	
Methoxychlor	72-43-5	0.005		40				0.03		40	45	N	N	180	N	0.005	
Toxaphene	8001-35-2	0.0002		3		0.73		0.0002		3 C	3 C	C	C	0.061	C	0.0002	
APPENDIX IX HERBICIDES (SW-846 METHOD 8151A)																	
2,4-D	94-75-7			70								N	N	360	N	70	
2,4,5-T	93-76-5	686.33										N	N	360	N	360	
2,4,5-TP (Silvex)	93-72-1	326.64		50								N	N	290	N	50	
Dinoseb	88-85-7	0.39		7								N	N	37	N	0.39	
Hexachlorophene	70-30-4	0.228										N	N	11	N	0.228	
MISCELLANEOUS PARAMETERS (ANALYTICAL METHODS TO BE DETERMINED BASED ON LABORATORY CAPABILITIES)																	
Alkalinity	TTNUS001							20000								20000	
Carbon Dioxide	124-38-9																
CEC (SW-846 9081)	n/a																
Chloride	16887-00-6			250000	7	860000		230000								230000	
Dissolved Oxygen	TTNUS054																
Ethane	74-84-0																
Ethene	74-85-1																
Ferrous Iron	n/a																
Gross Alpha	14127-62-9			15	21											15	
Gross Beta	n/a			4	22											4	
Hardness (Standard Methods 2340B)	TTNUS044																
Hydrogen Sulfide	7783-06-4							2						110	N	2	
Methane	74-82-8																
Nitrate	14797-55-8			10000										10000	N	10000	
Nitrite	14797-65-0			1000										1000	N	1000	
Orthophosphate	n/a																
pH (SW-846 9045C)	n/a			6.5-8.5	7			6.5-9									
Specific Conductance	n/a																
Sulfate	14808-79-8			500000	23											500000	

TABLE C-1

TABULAR PRESENTATION OF RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE, INDIANA

PARAMETER	CAS	REGION 5 ECO DQLs SURFACE WATER (ug/L)	Footnote	FEDERAL MCLs (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER ACUTE (ug/L)	Footnote	FEDERAL AWQCs FRESHWATER CHRONIC (ug/L)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL GW CLOSURE LEVELS (ug/L)	IDEM TIER 1 DEFAULT INDUSTRIAL GW CLOSURE LEVELS (ug/L)	Footnote	Footnote	REGION 9 TAP WATER PRGs (ug/L)	Footnote	MINIMUM CRITERIA VALUE	Footnote
Sulfide	18496-25-8																
Temperature	TTNUS047																
Total Organic Carbon (TOC) (EPA 415.1)	7440-44-0																
Total Suspended Solids (EPA 160.1)	n/a																
Turbidity	n/a																

Footnotes:

1 Criteria are hardness dependent.
2 Action level.
3 Secondary MCL for copper is 1,000 ug/L.
4 Value is being remanded.
5 trans-1,2-Dichloroethene.
6 Chlordane.
7 Secondary MCL, based on aesthetic drinking water qualities (i.e., color, odor, taste, etc.).
8 Total for all Aroclor congeners.
9 1994 Proposed rule for Disinfectants and Disinfection By-Products: Total for all trihalomethanes combined cannot exceed 80 ug/L.
10 Hexavalent chromium.
11 Thallium carbonate.
12 1,3-Dichloropropene.
13 EPA Region 3 RBC presented.
14 Value for 4-nitrophenol presented.
15 Dinitrotoluene mixture.
16 Endosulfan.
17 Value for alpha-BHC presented.
18 Value for endrin presented.
19 Value for acenahpthene presented.
20 Value for naphthalene presented.
21 Gross alpha particle activity.
22 Beta particle and photon activity.
23 Secondary MCL for sulfate is 250,000 ug/L.
24 Value based on adult exposure scenario using inputs from RAGS Part 1B (U.S. EPA, 1991)

TABLE C-2A

TABULAR PRESENTATION OF SOIL AND SEDIMENT RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE,
INDIANA

PARAMETER	CAS	EPA GENERIC SSLs INGESTION (mg/kg)	Footnote	EPA GENERIC SSLs INHALATION (mg/kg)	Footnote	EPA GENERIC SSLs MIGRATION TO GW (mg/kg) DAF = 1	Footnote	REGION 5 ECO DQLs SOIL (mg/kg)	Footnote	REGION 5 ECO DQLs SEDIMENT (mg/kg)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	IDEM TIER 1 DEFAULT INDUSTRIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	REGION 9 SOIL PRGs FOR RESIDENTIAL LAND USE (mg/kg)	REGION 9 SOIL PRGs FOR INDUSTRIAL LAND USE (mg/kg)	MINIMUM CRITERIA VALUE (SOIL) (mg/kg)	MINIMUM CRITERIA VALUE (SED) (mg/kg)	Footnote	MINIMUM CRITERIA VALUE (SOIL AND SED) (mg/kg)
EXPLOSIVES (SW-846 METHOD 8330)																					
1,3,5-Trinitrobenzene	99-35-4															1800	26000	1800	1800		1800
1,3-Dinitrobenzene	99-65-0							0.6547		0.000924						6.1	88	0.6547	0.000924		0.000924
2,4,6-Trinitrotoluene (TNT)	118-96-7															16	82	16	16		16
2,4-Dinitrotoluene	121-14-2	0.9				0.00004		1.28		0.07513		0.0085 (1)	C	0.028 C (1)	C	120	1800	0.00004	0.00004		0.00004
2,6-Dinitrotoluene	606-20-2	0.9				0.00003		0.03283		0.02062						61	880	0.00003	0.00003		0.00003
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	2691-41-0															3100	44000	3100	3100		3100
2-Nitrotoluene	88-72-2															370	1000	370	370		370
3-Nitrotoluene	99-08-1															370	1000	370	370		370
4-Nitrotoluene	99-99-0															370	1000	370	370		370
4-Amino-2,6-dinitrotoluene	19406-51-0																				0
2-Amino-4,6-dinitrotoluene	35572-78-2																				0
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	479-45-8															610	8800	610	610		610
Nitrobenzene	98-95-3	39		92		0.007		1.31		0.4876		0.028		0.34		20	110	0.007	0.007		0.007
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	121-82-4															4.4	22	4.4	4.4		4.4
MUSTARD GAS AND DEGRADATION PRODUCTS																					0
Bis(2-chloroethyl)sulfide (HD)	505-60-2																	2.6	????		2.6
1,4-Thioxane	15980-15-1																	1700	????		1700
1,4-Dithiane	505-29-3															610	8800	610	610		610
Thiodiglycol	111-48-8																	1800	????		1800
APPENDIX IX METALS (ANALYTICAL METHODS TO BE DETERMINED BASED ON LABORATORY CAPABILITIES																					0
Antimony	7440-36-0	31				0.3		0.1423				5.4		37		31	820	0.1423	0.3		0.1423
Arsenic	7440-38-2	0.4		750		1		5.7		0.0059		3.9	C	20	C	0.39	2.7	0.39	0.0059		0.0059
Barium	7440-39-3	5500		690000		82		1.04				1600		5900		5400	100000	1.04	82		1.04
Beryllium	7440-41-7	0.1		1300		3		1.06				1.9	C	10	C	150	2200	0.1	0.1		0.1
Cadmium	7440-43-9	78		1800		0.4		0.00222		0.596		7.5		77		3	810	0.00222	0.4		0.00222
Chromium (total)	7440-47-3	390	4	270	4	2	4					38		196		210	450	2	2		2
Cobalt	7440-48-4							0.14033		50						4700	100000	0.14033	50		0.14033
Copper	7440-50-8							2.96		16		580		1700		2900	76000	2.96	16		2.96
Lead	7439-92-1	400	14					0.05373		31		81		227		400	1000	0.05373	31		0.05373
Mercury (SW-846 Method 7470A/7471A)	7439-97-6	23		10		0.1		0.073		0.174		2.1		32				0.073	0.1		0.073
Nickel	7440-02-0	1600		13000		7		13.6		16		130		2700		1600	41000	7	7		7
Selenium	7782-49-2	390				0.3		0.02765				5.2		53		390	10000	0.02765	0.3		0.02765
Silver	7440-22-4	390				2		4.04		0.5		31		87		390	10000	2	0.5		0.5
Thallium	7440-28-0					0.04		0.05692				2.9		13		6.3 (16)	160 (16)	0.04	0.04		0.04
Tin	7440-31-5							7.62								47000	100000	7.62	47000		7.62
Vanadium	7440-62-2	550				300		1.59								550	14000	1.59	300		1.59
Zinc	7440-66-6	23000				620		6.62		120		10000		10000		23000	100000	6.62	120		6.62
MISCELLANEOUS METALS (SW-846 METHOD 6010B)																					0
Aluminum	7429-90-5															76000	100000	76000	76000		76000
Calcium	7440-70-2																				0
Iron	7439-89-6															23000	100000	23000	23000		23000
Magnesium	7439-95-4																				0
Manganese	7439-96-5															1800	32000	1800	1800		1800
Potassium	7440-09-7																				0
Sodium	7440-23-5																				0
Strontium	7440-24-6															47000	100000	47000	47000		47000
RADIOLOGICAL PARAMETERS																					0
Gross Alpha	14127-62-9																				0
Gross Beta	n/a																				0
Thorium-228 (residential exposure scenario)	14274-82-9																	00074 (pCi/	0.00074 (pCi/g)	20	0.00074 (pCi/g)
Thorium-230 (residential exposure scenario)	14269-63-7																	5.7 (pCi/g)	5.7 (pCi/g)	20	5.7 (pCi/g)
Thorium-232 (residential exposure scenario)	7440-29-1																	00049 (pCi/	0.00049 (pCi/g)	20	0.00049 (pCi/g)
APPENDIX IX VOLATILE ORGANIC COMPOUNDS (SW-846 METHOD 8260B WITH 25 ML PURGE FOR WATER, 5 GM PURGE FOR SOIL																					0
1,1,1,2-Tetrachloroethane	630-20-6							225		0.01089		0.050	C	0.79	C	3	7	0.05	0.01089		0.01089
1,1,1-Trichloroethane	71-55-6			1200		0.1		29.8		0.24685		1.9		89		770	1400	0.1	0.1		0.1
1,1,2,2-Tetrachloroethane	79-34-5	3		0.6		0.0002		0.12722		0.02908		0.007	C	0.11	C	0.38	0.9	0.0002	0.0002		0.0002
1,1,2-Trichloroethane	79-00-5	11		1		0.0009		28.6		0.67351		0.03	C	0.30	C	0.84	1.9	0.0009	0.0009		0.0009
1,1-Dichloroethane	75-34-3	7800		1300		1		20.1		0.000575		5.6		58		590	2100	1	0.000575		0.000575
1,1-Dichloroethene	75-35-4	1		0.07		0.003		8.27		0.02327		0.058	C	0.058	C	0.054	0.12	0.003	0.003		0.003
1,2,3-Trichloropropane	96-18-4							3.36		0.00835						0.0014	0.0031	0.0014	0.0014		0.0014
1,2-Dibromo-3-chloropropane	96-12-8							0.03518		0.01998						0.45	4	0.03518	0.01998		0.01998
1,2-Dibromoethane	106-93-4							1.23		0.01237						0.0069	0.048	0.0069	0.0069		0.0069
1,2-Dichloroethane	107-06-2	7		0.4		0.001		21.2		0.05418		0.024	C	0.15	C	0.35	0.76	0.001	0.001		0.001

TABLE C-2A

TABULAR PRESENTATION OF SOIL AND SEDIMENT RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE,
INDIANA

PARAMETER	CAS	EPA GENERIC SSLs INGESTION (mg/kg)	Footnote	EPA GENERIC SSLs INHALATION (mg/kg)	Footnote	EPA GENERIC SSLs MIGRATION TO GW (mg/kg) DAF = 1	Footnote	REGION 5 ECO DQLs SOIL (mg/kg)	Footnote	REGION 5 ECO DQLs SEDIMENT (mg/kg)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	IDEM TIER 1 DEFAULT INDUSTRIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	REGION 9 SOIL PRGs FOR RESIDENTIAL LAND USE (mg/kg)	REGION 9 SOIL PRGs FOR INDUSTRIAL LAND USE (mg/kg)	MINIMUM CRITERIA VALUE (SOIL) (mg/kg)	MINIMUM CRITERIA VALUE (SED) (mg/kg)	Footnote	MINIMUM CRITERIA VALUE (SOIL AND SED) (mg/kg)
1,2-Dichloropropane	78-87-5	9		15		0.001		32.7		0.35161		0.03	C	0.25	C	0.35	0.77	0.001	0.001		0.001
1,4-Dioxane	123-91-1							2.05		0.00000543						44	220	2.05	0.00000543		0.00000543
2-Butanone	78-93-3							89.6		0.13696		10		260		7300	28000	10	0.13696		0.13696
2-Chloro-1,3-butadiene (chloroprene)	126-99-8							0.0029		0.00106						3.6	12	0.0029	0.00106		0.00106
2-Hexanone	591-78-6							12.6		1.01						3100 (6)	82,000 (6)	12.6	1.01		1.01
4-Methyl-2-pentanone	108-10-1							443		0.54437						790	2900	443	0.54437		0.54437
Acetone	67-64-1	7800		100000		0.8		2.5		0.45337		3.1		41		1600	6200	0.8	0.45337		0.45337
Acetonitrile	75-05-8							1.37		0.13905						270	1700	1.37	0.13905		0.13905
Acrolein	107-02-8							5.27		0.0000144		0.00027		0.32		0.1	0.34	0.00027	0.0000144		0.0000144
Acrylonitrile	107-13-1							0.02393		0.0000157						0.21	0.51	0.02393	0.0000157		0.0000157
Allyl chloride (3-chloro-1-propene)	107-05-1							0.01338		0.000266						3000	43000	0.01338	0.000266		0.000266
Benzene	71-43-2	22		0.8		0.002		0.25462		0.14157		0.34	C	0.67	C	0.67	1.5	0.002	0.002		0.002
Bromodichloromethane	75-27-4	10		3000		0.03		0.53978		0.00113		0.63	C	0.63	C	1	2.4	0.03	0.00113		0.00113
Bromoform	75-25-2	81		53		0.04		15.9		0.99627		0.75	C	2.7	C	62	310	0.04	0.04		0.04
Bromomethane	74-83-9	110		10		0.01		0.23516		0.94674		0.052		0.7		3.9	13	0.01	0.01		0.01
Carbon disulfide	75-15-0	7800		720		2		0.09412		0.13397		10		82		360	720	0.09412	0.13397		0.09412
Carbon tetrachloride	56-23-5	5		0.3		0.003		2.98		0.03573		0.068	C	0.29	C	0.24	0.53	0.003	0.003		0.003
Chlorobenzene	108-90-7	1600		130		0.07		13.1		0.06194		1.3		27		1	540	0.07	0.06194		0.06194
Chloroethane	75-00-3									58.6						3	6.5	3	3		3
Chloroform	67-66-3	100		0.3		0.03		1.19		0.027		0.59	C	2.7	C	0.24	0.52	0.03	0.027		0.027
Chloromethane	74-87-3							10.4		0.0000785						1.2	2.7	1.2	0.0000785		0.0000785
cis-1,2-Dichloroethene	156-59-2	780		1200		0.02		0.78373	5	0.20894	5	0.4		5.8		43	150	0.02	0.02		0.02
cis-1,3-Dichloropropene	10061-01-5	4	11	0.1	11	0.0002	11	0.39786		0.00296		0.0091 (11)	C	0.11 (11)	C	0.082 (11)	0.18 (11)	0.0002	0.0002		0.0002
Dibromochloromethane	124-48-1	8		1300		0.02		2.05		0.26761						1.1	2.7	0.02	0.02		0.02
Dibromomethane	74-95-3							65		0.0000859						67	240	65	0.0000859		0.0000859
Dichlorodifluoromethane	75-71-8							39.5		0.00133						94	310	39.5	0.00133		0.00133
Ethyl methacrylate	97-63-2							30		0.000602						140	140	30	0.000602		0.000602
Ethylbenzene	100-41-4	7800		400		0.7		5.16		0.0001		13		200		230	230	0.7	0.0001		0.0001
Isobutyl alcohol	78-83-1							20.8		3.35						13000	40000	20.8	3.35		3.35
Methacrylonitrile	126-98-7							0.05705		0.0000297						2.1	8.8	0.05705	0.0000297		0.0000297
Methyl iodide	74-88-4																				0
Methyl methacrylate	80-62-6							984		0.16756						2200	2700	984	0.16756		0.16756
Methylene chloride	75-09-2	85		13		0.001		4.05		1.26		0.023	C	1.8	C	8.9	21	0.001	0.001		0.001
Proprionitrile	107-12-0							0.04983		0.11466								0.04983	0.11466		0.04983
Styrene	100-42-5	16000		1500		0.2		4.69		0.44496		3.5		720		1	1700	0.2	0.2		0.2
Tetrachloroethene	127-18-4	12		11		0.003		9.92		0.19583		0.058	C	0.64	C	5.7	19	0.003	0.003		0.003
Toluene	108-88-3	16000		650		0.6		5.45		52.5		12		240		520	520	0.6	0.6		0.6
Total Xylenes	1330-20-7	160000		410	17	9	17	10		1.88		190		410		210	210	9	1.88		1.88
trans-1,2-Dichloroethene	156-60-5	1600		3100		0.03		0.78373		0.20894		0.68		14		63	210	0.03	0.03		0.03
trans-1,3-Dichloropropene	10061-02-6	4	11	0.1	11	0.0002	11	0.39786		0.00296		0.0091 (11)	C	0.11 (11)	C	0.082 (11)	0.18 (11)	0.0002	0.0002		0.0002
trans-1,4-Dichloro-2-butene	110-57-6									0.00182						0.0079 (9)	0.018 (9)	0.0079 (9)	0.00182		0.00182
Trichloroethene	79-01-6	58		5		0.003		12.4		0.17956		0.057	C	3.0	C	2.8	6.1	0.003	0.003		0.003
Trichlorofluoromethane	75-69-4							16.4		0.00307						390	2000	16.4	0.00307		0.00307
Vinyl acetate	108-05-4	78000		1000		8		12.7		0.01295		2.3		430		430	1400	2.3	0.01295		0.01295
Vinyl chloride	75-01-4	0.3		0.03		0.0007		0.64614		0.002		0.013	C	0.013	C	0.022	0.049	0.0007	0.0007		0.0007
APPENDIX IX SEMIVOLATILE ORGANIC COMPOUNDS (SW-846 METHOD 8270C; 8270C SIM OR 8310, BASED ON LABORATORY CAPABILITIES, WHERE NOTED																					0
1,2,4,5-Tetrachlorobenzene	95-94-3							2.02		20.9						18	260	2.02	18		2.02
1,2,4-Trichlorobenzene	120-82-1	780		3200		0.3		11.1		11.7		5.3		77		6	3000	0.3	0.3		0.3
1,2-Dichlorobenzene	95-50-1	7000		560		0.9		2.96		0.23132		17		260		370	370	0.9	0.23132		0.23132
1,3-Dichlorobenzene	541-73-1							37.7		3.01		0.42		59		13	52	0.42	0.42		0.42
1,4-Dichlorobenzene	106-46-7	27				0.1		0.54559		1.45		2.2	C	3.4	C	3	8.1	0.1	0.1		0.1
1,4-Naphthoquinone	130-15-4																				0
1,4-Phenylenediamine	106-50-3							6.16		0.00000568						12000	100000	6.16	0.00000568		0.00000568
1-Naphthylamine	134-32-7																				0
2,3,4,6-Tetrachlorophenol	58-90-2							0.19878		1.51						1800	26000	0.19878	1.51		0.19878
2,4,5-Trichlorophenol	95-95-4	7800				14		14.1		0.08556		250		700		6100	88000	14	0.08556		0.08556
2,4,6-Trichlorophenol	88-06-2	58		200		0.008		9.94		0.08484		1.5	C	5.0	C	44	220	0.008	0.008		0.008
2,4-Dichlorophenol	120-83-2	230				0.05		87.5		0.13363		1.1		3		1	2600	0.05	0.05		0.05
2,4-Dimethylphenol	105-67-9	1600				0.4		0.01		0.30453		9		25		1	18000	0.01	0.30453		0.01
2,4-Dinitrophenol	51-28-5	160				0.01		0.06086		0.00133		0.29		0.82		120	1800	0.01	0.00133		0.00133
2,6-Dichlorophenol	87-65-0							1.17		0.00394								1.17	0.00394		0.00394
2-Acetylaminofluorene	53-96-3							0.59634		0.01532								0.59634	0.01532		0.01532
2-Chloronaphthalene	91-58-7							0.01218		0.41723						4900	27000	0.01218	0.41723		0.01218
2-Chlorophenol	95-57-8	390		53000		0.2		0.24266		0.0117		0.75		10		6	240	0.2	0.0117		0.0117

TABLE C-2A

TABULAR PRESENTATION OF SOIL AND SEDIMENT RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE,
INDIANA

PARAMETER	CAS	EPA GENERIC SSLs INGESTION (mg/kg)	Footnote	EPA GENERIC SSLs INHALATION (mg/kg)	Footnote	EPA GENERIC SSLs MIGRATION TO GW (mg/kg) DAF = 1	Footnote	REGION 5 ECO DQLs SOIL (mg/kg)	Footnote	REGION 5 ECO DQLs SEDIMENT (mg/kg)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	IDEM TIER 1 DEFAULT INDUSTRIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	REGION 9 SOIL PRGs FOR RESIDENTIAL LAND USE (mg/kg)	REGION 9 SOIL PRGs FOR INDUSTRIAL LAND USE (mg/kg)	MINIMUM CRITERIA VALUE (SOIL) (mg/kg)	MINIMUM CRITERIA VALUE (SED) (mg/kg)	Footnote	MINIMUM CRITERIA VALUE (SOIL AND SED) (mg/kg)
2-Methylnaphthalene (by SIM)	91-57-6							3.24		0.0202								3.24	0.0202		0.0202
2-Methylphenol	95-48-7	3900				0.8		40.4		0.000826		14		39		3100	44000	0.8	0.000826		0.000826
2-Naphthylamine	91-59-8							3.03		0.00174								3.03	0.00174		0.00174
2-Nitroaniline	88-74-4							74.1		0.000222						3.5	50	3.5	0.000222		0.000222
2-Nitrophenol	88-75-5							1.6		0.00777						490 (10)	7000 (10)	1.6	0.00777		0.00777
2-Picoline	109-06-8							9.9		0.75305								9.9	0.75305		0.75305
3,3'-Dichlorobenzidine	91-94-1	1				0.0003		0.64636		0.02822		0.062	C	0.21	C	1.1	5.5	0.0003	0.0003		0.0003
3,3'-Dimethylbenzidine	119-93-7							0.1042		0.002						0.053	0.27	0.053	0.002		0.002
3-Methylcholanthrene	56-49-5							0.07794		8190								0.07794	8190		0.07794
3-Methylphenol	108-39-4							163		0.000808						3100	44000	163	0.000808		0.000808
3-Nitroaniline	99-09-2							3.16		0.000222								3.16	0.000222		0.000222
4,6-Dinitro-2-methylphenol	534-52-1							0.14408		0.01038								0.14408	0.01038		0.01038
4-Aminobiphenyl	92-67-1							0.00305		0.00566								0.00305	0.00566		0.00305
4-Bromophenyl phenyl ether	101-55-3									1.68									1.68		1.68
4-Chloro-3-methylphenol	59-50-7							7.95		0.38818								7.95	0.38818		0.38818
4-Chloroaniline	106-47-8	310				0.03		1.1		0.14608		0.97		2.7		240	3500	0.03	0.03		0.03
4-Chlorophenyl phenyl ether	7005-72-3									0.656112									0.656112		0.65611
4-Methylphenol	106-44-5							3.49		0.000845						310	4400	3.49	0.000845		0.000845
4-Nitroaniline	100-01-6							21.9		0.000222								21.9	0.000222		0.000222
4-Nitrophenol	100-02-7							5.12		0.00778						490	7000	5.12	0.00778		0.00778
4-Nitroquinoline-1-oxide	56-57-5							0.12222		0.00124								0.12222	0.00124		0.00124
5-Nitro-o-toluidine	99-55-8							8.73		0.000845						15	75	8.73	0.000845		0.000845
7,12-Dimethylbenz(a)anthracene	57-97-6																				0
a,a-Dimethylphenethylamine	122-09-8															61	880	61	61		61
Acenaphthene (by SIM)	83-32-9	4700				29		682		0.00671		130		1200		3700	38000	29	0.00671		0.00671
Acenaphthylene (by SIM)	208-96-8							682		0.00587		130 (12)		1200 (12)		3700 (12)	38000 (12)	682	0.00587		0.00587
Acetophenone	98-86-2							300		0.246						0.49	1.6	0.49	0.246		0.246
Aniline	62-53-3							0.05678		0.0000338						85	430	0.05678	0.0000338		0.0000338
Anthracene (by SIM)	120-12-7	23000				590		1480		0.0469		51		51		22000	100000	51	0.0469		0.0469
Aramite	140-57-8							166		0.00000111						19	99	19	0.00000111		0.00000111
Benzo(a)anthracene (by SIM)	56-55-3	0.9				0.08		5.21		0.0317		5.0	C	15	C	0.62	2.9	0.08	0.0317		0.0317
Benzo(a)pyrene (by SIM)	50-32-8	0.09				0.4		1.52		0.0319		0.50	C	1.5	C	0.062	0.29	0.062	0.0319		0.0319
Benzo(b)fluoranthene (by SIM)	205-99-2	0.9				0.2		59.8		10.4		5.0	C	15	C	0.62	2.9	0.2	0.2		0.2
Benzo(g,h,i)perylene (by SIM)	191-24-2							119		0.17		0.7 (15)		170 (15)		56 (15)	190 (15)	119	0.17		0.17
Benzo(k)fluoranthene (by SIM)	207-08-9	9				2		1480		0.24		39	C	39	C	6.2	29	2	0.24		0.24
Benzyl alcohol	100-51-6							65.8		0.03394						18000	100000	65.8	0.03394		0.03394
Bis(2-chloroethoxy)methane	111-91-1							0.30209		0.34971								0.30209	0.34971		0.30209
Bis(2-chloroethyl)ether	111-44-4	0.6		0.2		0.00002		23.7		0.21196		0.0007	C	0.012	C	0.21	0.62	0.00002	0.00002		0.00002
Bis(2-chloroisopropyl)ether	39638-32-9											0.027	C			2.5	7.4	0.027	0.027		0.027
Bis(2-ethylhexyl)phthalate	117-81-7	46		31000		180		0.92594		0.182		300	C	980	C	35	180	0.92594	0.182		0.182
Butyl benzyl phthalate	85-68-7	16000		930		810		0.23889		4.19		930		930		12000	100000	0.23889	4.19		0.23889
Chlorobenzilate	510-15-6							5.05		0.86029						1.8	9.1	1.8	0.86029		0.86029
Chrysene (by SIM)	218-01-9	88				8		4.73		0.0571		26	C	26	C	62	290	4.73	0.0571		0.0571
Diallate	2303-16-4							0.45214		0.00151						8	40	0.45214	0.00151		0.00151
Dibenzo(a,h)anthracene (by SIM)	53-70-3	0.09				0.08		18.4		0.00622		0.5	C	1.5	C	0.062	0.29	0.062	0.00622		0.00622
Dibenzofuran	132-64-9									1.52						290	5100	290	1.52		1.52
Diethyl phthalate	84-66-2	63000		2000		23		24.8		0.00804		450		1300		49000	100000	23	0.00804		0.00804
Dimethoate	60-51-5							0.21802		0.19015						12	180	0.21802	0.19015		0.19015
Dimethyl phthalate	131-11-3							734		0.02495						100000	100000	734	0.02495		0.02495
Di-n-butyl phthalate	84-74-2	7800		2300		270		0.14979		0.1105		2300		2000		6100	88000	0.14979	0.1105		0.1105
Di-n-octyl phthalate	117-84-0	1600		10000		10000		709		40.6		2000		2000		1200	10000	709	40.6		40.6
Diphenylamine	122-39-4							1.01		0.0346						1500	22000	1.01	0.0346		0.0346
Ethyl methane sulfonate	62-50-0																				0
Ethyl parathion	56-38-2							0.00034		0.00034						370	5300	0.00034	0.00034		0.00034
Fluoranthene (by SIM)	206-44-0	3100				210		122		0.1113		880		880		2300	30000	122	0.1113		0.1113
Fluorene (by SIM)	86-73-7	3100				28		122		0.0212		170		1100		2600	33000	28	0.0212		0.0212
Hexachlorobenzene	118-74-1	0.4		1		0.1		0.19878		0.02		2.2	C	3.9	C	3	1.5	0.1	0.02		0.02
Hexachlorobutadiene	87-68-3	8		8		0.1		0.03976		1.38		16	C	44	C	6	32	0.03976	0.1		0.03976
Hexachlorocyclopentadiene	77-47-4	550		10		20		0.75537		0.90074		400		2000		420	5900	0.75537	0.90074		0.75537
Hexachloroethane	67-72-1	46		55		0.02		0.59634		2.23		2.8	C	7.7	C	35	180	0.02	0.02		0.02
Hexachloropropene	1888-71-7									0.0002									0.0002		0.0002
Indeno(1,2,3-cd)pyrene (by SIM)	193-39-5	0.9				0.7		109		0.2		3.0	C	3.0	C	0.62	2.9	0.62	0.2		0.2
Isodrin	465-73-6							0.00332		0.05516								0.00332	0.05516		0.00332
Isophorone	78-59-1	670		4600		0.03		139		0.4223		5.3	C	18	C	510	2600	0.03	0.03		0.03

TABLE C-2A

TABULAR PRESENTATION OF SOIL AND SEDIMENT RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE,
INDIANA

PARAMETER	CAS	EPA GENERIC SSLs INGESTION (mg/kg)	Footnote	EPA GENERIC SSLs INHALATION (mg/kg)	Footnote	EPA GENERIC SSLs MIGRATION TO GW (mg/kg) DAF = 1	Footnote	REGION 5 ECO DQLs SOIL (mg/kg)	Footnote	REGION 5 ECO DQLs SEDIMENT (mg/kg)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	IDEM TIER 1 DEFAULT INDUSTRIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	REGION 9 SOIL PRGs FOR RESIDENTIAL LAND USE (mg/kg)	REGION 9 SOIL PRGs FOR INDUSTRIAL LAND USE (mg/kg)	MINIMUM CRITERIA VALUE (SOIL) (mg/kg)	MINIMUM CRITERIA VALUE (SED) (mg/kg)	Footnote	MINIMUM CRITERIA VALUE (SOIL AND SED) (mg/kg)
Isosafrole	120-58-1							9.94		0.00412								9.94	0.00412		0.00412
Kepone	143-50-0							0.03272		0.00331						0.027	0.14	0.027	0.00331		0.00331
Methapyrilene	91-80-5							2.78		0.0000144								2.78	0.0000144		0.0000144
Methyl methane sulfonate	66-27-3																				0
Methyl parathion	298-00-0							0.000292		0.000755						15	220	0.000292	0.000755		0.000292
Naphthalene (by SIM)	91-20-3	3100				4		0.09939		0.0346		0.7		170		56	190	0.09939	0.0346		0.0346
n-Nitrosodiethylamine	55-18-5							0.06933		0.02277						0.0032	0.016	0.0032	0.0032		0.0032
n-Nitrosodimethylamine	62-75-9							0.0000321		0.00000275						0.0095	0.048	0.0000321	0.00000275		0.00000275
n-Nitrosodi-n-butylamine	924-16-3							0.26707		0.77204						0.024	0.061	0.024	0.024		0.024
n-Nitrosodi-n-propylamine	621-64-7	0.09				0.000002		0.54368		0.000217		0.0006	C	0.002	C	0.069	0.35	0.000002	0.000002		0.000002
n-Nitrosomethylethylamine	10595-95-6							0.00166		0.00000485						0.022	0.11	0.00166	0.00000485		0.00000485
n-Nitrosomorpholine	59-89-2							0.07057		0.0000037								0.07057	0.0000037		0.0000037
n-Nitrosopiperidine	100-75-4							0.00665		0.0000226								0.00665	0.0000226		0.0000226
n-Nitrosopyrrolidine	930-55-2							0.01258		0.000000908						0.23	1.2	0.01258	0.000000908		0.000000908
O,O,O-Triethyl phosphorothioate	126-68-1																				0
o-Toluidine	95-53-4							2.97		0.000199						2	10	2	0.000199		0.000199
p-(Dimethylamino)azobenzene	60-11-7																				0
Pentachlorobenzene	608-93-5							0.49695		1.26						49	700	0.49695	1.26		0.49695
Pentachloroethane	76-01-7							10.7		0.68918								10.7	0.68918		0.68918
Pentachloronitrobenzene	82-68-8							7.09		18.2						1.9	9.5	1.9	1.9		1.9
Pentachlorophenol	87-86-5	3				0.001		0.11927		30.1		0.028	C	0.66	C	3	11	0.001	0.001		0.001
Phenacetin	62-44-2							11.7		0.00225								11.7	0.00225		0.00225
Phenanthrene (by SIM)	85-01-8							45.7		0.0419		0.7 (15)		170 (15)		56 (15)	190 (15)	45.7	0.0419		0.0419
Phenol	108-95-2	47000				5		120		0.02726		110		320		37000	100000	5	0.02726		0.02726
Pronamide	23950-58-5							0.0136		0.0016						4600	66000	0.0136	0.0016		0.0016
Pyrene (by SIM)	129-00-0	2300				210		78.5		0.053		570		570		2300	54000	78.5	0.053		0.053
Pyridine	110-86-1							1.03		0.10617						61	880	1.03	0.10617		0.10617
Safrole	94-59-7							0.40398		0.16486								0.40398	0.16486		0.16486
APPENDIX IX ORGANOCHLORINE PESTICIDES and PCBs (SW-846 METHOD 8081A and 8082)																					0
4,4'-DDD	72-54-8	3				0.8		0.75815		0.00553		28	C	121	C	2.4	17	0.75815	0.00553		0.00553
4,4'-DDE	72-55-9	2				3		0.59587		0.00142		20	C	86	C	1.7	12	0.59587	0.00142		0.00142
4,4'-DDT	50-29-3	2				2		0.0175		0.00119		20	C	86	C	1.7	12	0.0175	0.00119		0.00119
Aldrin	309-00-2	0.04		3		0.02		0.00332		0.002		0.25	C	0.80	C	0.029	0.15	0.00332	0.002		0.002
Alpha-BHC	319-84-6	0.1		0.8		0.00003		0.09939		0.006		0.0072	C	0.024	C	0.09	0.59	0.00003	0.00003		0.00003
Alpha-chlordane	5103-71-9	0.5	7	20	7	0.5	7	0.224	7	0.0045	7	9.6 (7)		39 (7)		1.6 (7)	11 (7)	0.224	0.0045		0.0045
Aroclor-1016	12674-11-2	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	3.9	29	0.67971	0.0341		0.0341
Aroclor-1221	11104-28-2	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	0.22	1	0.22	0.0341		0.0341
Aroclor-1232	11141-16-5	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	0.22	1	0.22	0.0341		0.0341
Aroclor-1242	53469-21-9	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	0.22	1	0.22	0.0341		0.0341
Aroclor-1248	12672-29-6	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	0.22	1	0.22	0.0341		0.0341
Aroclor-1254	11097-69-1	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	0.22	1	0.22	0.0341		0.0341
Aroclor-1260	11096-82-5	1	8					0.67971	8	0.0341	8	1.8 (8)	C	5.3 (18)	C	0.22	1	0.22	0.0341		0.0341
Beta-BHC	319-85-7	0.4				0.0001		0.00398		0.005		0.026	C	0.086	C	0.32	2.1	0.0001	0.0001		0.0001
Delta-BHC	319-86-8							9.94		71.5		0.0072 (18)	C	0.024 (18)	C	0.09 (18)	0.59 (18)	0.0072	71.5		0.0072
Dieldrin	60-57-1	0.04		1		0.0002		0.00238		0.002		0.046	C	0.15	C	0.03	0.15	0.0002	0.0002		0.0002
Endosulfan I	959-98-8	470	13			0.9	13	0.11927		0.000175		20 (13)		46 (13)		370 (13)	5300 (13)	0.11927	0.000175		0.000175
Endosulfan II	33213-65-9	470	13			0.9	13	0.11927		0.000104		20 (13)		46 (13)		370 (13)	5300 (13)	0.11927	0.000104		0.000104
Endosulfan sulfate	1031-07-8							0.03578		0.0346		20 (13)		46 (13)		370 (13)	5300 (13)	0.03578	0.0346		0.0346
Endrin	72-20-8	23				0.05		0.0101		0.00267		0.99		15		18	260	0.0101	0.00267		0.00267
Endrin aldehyde	7421-93-4							0.0105		3.2		0.99 (19)		15 (19)		18 (19)	260 (19)	0.0105	3.2		0.0105
Gamma-BHC (Lindane)	58-89-9	0.5				0.0005		0.005		0.00094		0.0094	C	0.10	C	0.44	2.9	0.0005	0.0005		0.0005
Gamma-chlordane	12789-03-6	0.5	7	20	7	0.5	7	0.224	7	0.0045	7	9.6 (7)		39 (7)		1.6 (7)	11 (7)	0.224	0.0045		0.0045
Heptachlor	76-44-8	0.1		0.1		1		0.00598		0.0006		0.56	C	1.2	C	0.11	0.55	0.00598	0.0006		0.0006
Heptachlor epoxide	1024-57-3	0.07		5		0.03		0.15188		0.0006		0.46	C	1.0	C	0.053	0.27	0.03	0.0006		0.0006
Methoxychlor	72-43-5	390				8		0.01988		0.00359		160		180		310	4400	0.01988	0.00359		0.00359
Toxaphene	8001-35-2	0.6		89		2		0.11927		0.000109		3.9	C	12	C	0.44	2.2	0.11927	0.000109		0.000109
APPENDIX IX HERBICIDES (SW-846 METHOD 8151A)																					0
2,4-D	94-75-7							0.02725		0.00579						690	12000	0.02725	0.00579		0.00579
2,4,5-T	93-76-5							0.59634		58.7						610	8800	0.59634	58.7		0.59634
2,4,5-TP (Silvex)	93-72-1							0.1088		7.35						490	7000	0.1088	7.35		0.1088
Dinoseb	88-85-7							0.0218		0.01178						61	880	0.0218	0.01178		0.01178
Hexachlorophene	70-30-4							0.19878		231						18	260	0.19878	18		0.19878

TABLE C-2A

TABULAR PRESENTATION OF SOIL AND SEDIMENT RBSLs FOR RBTL SELECTION
NSWC CRANE, CRANE,
INDIANA

PARAMETER	CAS	EPA GENERIC SSLs INGESTION (mg/kg)	Footnote	EPA GENERIC SSLs INHALATION (mg/kg)	Footnote	EPA GENERIC SSLs MIGRATION TO GW (mg/kg) DAF = 1	Footnote	REGION 5 ECO DQLs SOIL (mg/kg)	Footnote	REGION 5 ECO DQLs SEDIMENT (mg/kg)	Footnote	IDEM TIER 1 DEFAULT RESIDENTIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	IDEM TIER 1 DEFAULT INDUSTRIAL SOIL CLOSURE LEVELS (mg/kg)	Footnote	REGION 9 SOIL PRGs FOR RESIDENTIAL LAND USE (mg/kg)	REGION 9 SOIL PRGs FOR INDUSTRIAL LAND USE (mg/kg)	MINIMUM CRITERIA VALUE (SOIL) (mg/kg)	MINIMUM CRITERIA VALUE (SED) (mg/kg)	Footnote	MINIMUM CRITERIA VALUE (SOIL AND SED) (mg/kg)
MISCELLANEOUS PARAMETERS																					0
CEC (SW-846 9081)	n/a																				0
Gross Alpha	14127-62-9																				0
Gross Beta	n/a																				0
Total Organic Carbon (TOC) (EPA 415.1)	7440-44-0																				0

Footnotes:
1 Dinitrotoluene mixture.
2 Interim value based on TLV.
3 Interim value based on LD50
4 Assume hexavalent chromium.
5 trans-1,2-Dichloroethene.
6 EPA Region 3 risk-based concentration.
7 Chlordane.
8 Total for all Aroclor congeners.
9 Value for 1,4-dichloro-2-butene presented.
10 Value for 4-nitrophenol presented
11 1,3-Dichloropropene.
12 Value for acenphthene presented
13 Endosulfan.
14 OSWER soil screening level for residential land use (USEPA, July 1994).
15 Value for naphthalene presented.
16 Thallium carbonate.
17 o-Xylene.
18 Val;ue for alpha-BHC presented.
19 Value for endrin presented.
20 Value based on adult exposure scenario using inputs from RAGS Part 1B (U.S. EPA 1991)

TABLE C - 2B

TABULAR PRESENTATION OF SOIL AND SEDIMENT
RBSLs FOR RBTL SELECTION (GAMMA EMITTERS)
NSWC CRANE
CRANE, INDIANA

Chemical	Gamma Energy (keV)	Ingestion of Soil (1)	Ingestion of Produce (1)	Particulate Emission Factor (1)	External Exposure (1)	Soil to Groundwater (1)
Radionuclide (pCi/g)						
Ac-228	338	4.20E+06	5.80E+06	1.10E+10	7.30E+02	NA
Bi-212	609	8.00E+07	2.50E+06	4.20E+10	2.30E+04	NA
Bi-214	727	1.00E+09	2.90E+07	3.40E+11	8.20E+03	NA
Co-60	NA	7.90E+01	3.2	2.00E+06	3.60E-02	2.4
Cs-137 + D	NA	2.50E+01	1.3	2.10E+06	6.10E-02	5.70E+01
Eu-154	NA	7.30E+01	9.90E+01	4.10E+05	5.00E-02	NA
Eu-155	NA	6.30E+02	8.70E+02	5.20E+06	3.8	NA
K-40	1460	1.30E+01	1.40E-01	1.80E+06	0.14	NA
Pb-210 + D	238	4.60E-01	6.30E-02	2.00E+03	4.10E+01	1.10E-02
Pb-214	295	3.80E+08	1.20E+08	2.00E+11	4.60E+04	2.90E+12
Ra-226 + D	186	1.1	6.90E-02	1.60E+03	1.30E-02	0.32
Pa-234m	1001	NA	NA	NA	1.50E+07	NA
Th-234	63	3.70E+03	1.30E+04	1.90E+08	2.20E+03	8.30E+04
Tl-208	860	NA	NA	NA	2.30E+04	NA
U-235 + D	143	4.9	5.8	1.80E+03	2.10E-01	0.78
Th-228 + D	NA	1.10E-01	3.60E+01	1.40E+03	1.60E-01	6.60E+01
Th-230	NA	3.9	1.20E+01	6.40E+02	1.40E+02	6.1
Th-232	NA	3.4	1.10E+01	4.20E+02	3.30E+02	6.1

pCi/g picocurie per gram
NA Not Available
1 Soil Screening Levels for Radionuclides are presented at http://risk.lsd.ornl.gov/cgi-bin/epa/radssl2.cgi

APPENDIX D

DETAILED HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

This section of the QAPP outlines the general methodologies and procedures that will be used to conduct the Baseline Human Health Risk Assessment for SWMU 01/12, the Mustard Gas Burial Ground (MGBG) at NSWC Crane. The objective of the risk assessment is to determine whether detected concentrations of chemicals at the sites pose a significant threat to potential human receptors under current and/or future land use. The potential risks to human receptors will be estimated based on the assumption that no actions are taken to control contaminant releases.

The following current United States Environmental Protection Agency (U.S. EPA) and the State of Indiana Department of Environmental Management (IDEM) risk assessment guidance were used to develop the framework for the Baseline Human Health Risk Assessment:

- Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part A). (U.S. EPA ,1989).

- Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Washington, D.C. OSWER Directive 9285.6-03 (U.S. EPA, 1991a)

- Dermal Exposure Assessment: Principles and Applications. Interim Report. Office of Research and Development, Washington, D.C. EPA/600/8-91/011B (U.S. EPA 1992a).

- Supplemental Guidance to RAGS: Calculating the Concentration Term. OSWER Publication No. 9285.7-081 (U.S. EPA, 1992c)

- Distribution of Preliminary Review Draft: Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure. Office of Solid Waste and Emergency Response, Washington, D.C. (U.S. EPA 1993a).

- Soil Screening Guidance: Technical Background Document. Office of Solid Waste and Emergency Response, Washington, D.C. EPA/540/R-95/128 (U.S. EPA 1996a).

- Exposure Factors Handbook. Office of Health and Environmental Assessment, Washington, D.C. EPA/600/P-95/002Fa (U.S. EPA 1997a).

- Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Supplemental Guidance, Dermal Risk Assessment, Interim Guidance (Peer Consultation Workshop Draft) (U.S. EPA 1998b).

- RISC (Risk-Integrated System of Cleanups). Indiana Department of Environmental Management, Office of Environmental Response (IDEM 1997).

- 1998 Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments) (U.S. EPA 1998a).

A Baseline Human Health Risk Assessment consists of five components: (1) Data Evaluation; (2) Exposure Assessment; (3) Toxicity Assessment; (4) Risk Characterization; and (5) Uncertainty Analysis. Section 1 of this QAPP contains discussions of the methodologies to be followed for the five components of the risk assessment. A schematic diagram of the general risk assessment process is provided as Figure D-1 in this appendix.

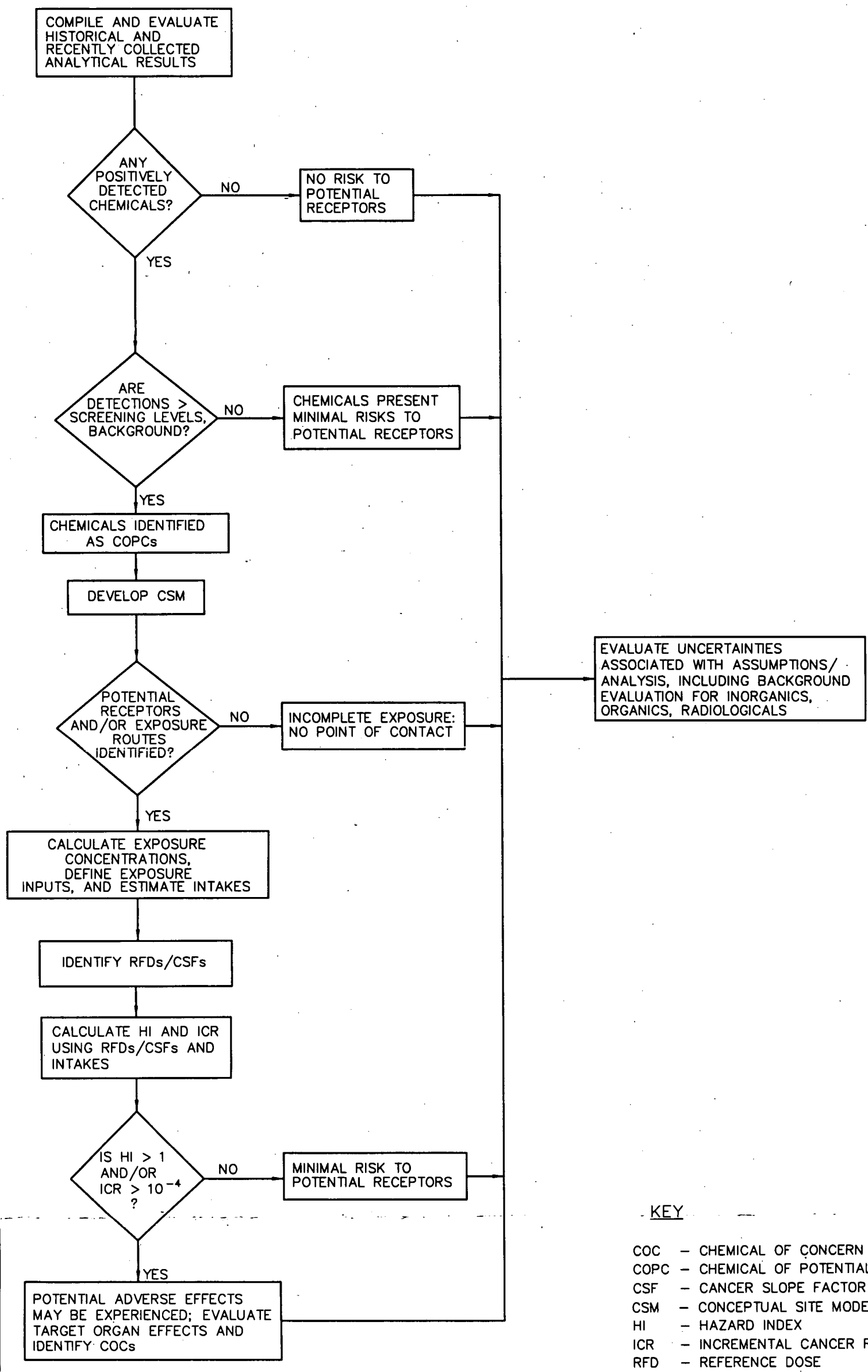
Three major aspects of chemical contamination and environmental fate and transport must be considered to evaluate potential risks: (1) contaminants with toxic characteristics must be found in environmental media and must be released by either natural processes or by human action; (2) potential exposure points must exist; and (3) human receptors must be present at the point of exposure. Risk is a function of both toxicity and exposure. If any one of the factors listed above is absent for a site, the exposure route is regarded as incomplete, and no potential risks will be considered to exist for human receptors.

D.1 DATA EVALUATION

Data evaluation, the first component of a Baseline Human Health Risk Assessment, is a media-specific task involving the compilation and evaluation of analytical data. The main objective of the data evaluation is to develop a media-specific list of Chemicals of Potential Concern (COPCs), which will be used to quantitatively determine potential human health risks for site media.

D.1.1 Data Usability

Data from samples collected for the proposed field investigations, which are described in Section 4 of this QAPP, will be used to assess risks to potential human receptors. All analytical data used in the quantitative estimation of potential risks will be subjected to data validation. A discussion of data



KEY

COC – CHEMICAL OF CONCERN
COPC – CHEMICAL OF POTENTIAL CONCERN
CSF – CANCER SLOPE FACTOR
CSM – CONCEPTUAL SITE MODEL
HI – HAZARD INDEX
ICR – INCREMENTAL CANCER RISK
RFD – REFERENCE DOSE

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CHECKED BY DATE	SUMMARY OF HUMAN HEALTH RISK ASSESSMENT PROCESS NSWC CRANE, INDIANA	APPROVED BY DATE 5-6-01	
COST/SCHED-AREA		APPROVED BY DATE	
SCALE NOT TO SCALE		DRAWING NO. FIGURE D-1	REV. 0

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validation protocol to be followed is provided in the *Section 9* of this QAPP. A *Data Evaluation (see QAPP Sections 9 and 12)* will be generated for the proposed field investigation data. Precision, accuracy, representativeness, completeness, and comparability will be evaluated and a brief summary of the results of the data validation will be documented. Additionally, the "data useability" evaluation worksheet suggested by USEPA RAGS Part D will be completed as a part of the data evaluation.

Fixed-based analytical results only from the target analyte lists for the proposed field investigations will be used in the quantitative risk evaluation. Typically, unfiltered results for ground water and surface water are used to assess risks associated with these media. Filtered groundwater results will be used for the risk assessment if the associated unfiltered groundwater samples are found to be turbid. Field measurements, data regarded as unreliable (i.e., qualified as "R" during the data validation process), and results of Tentatively Identified Compound (TIC) analyses will not be used in the quantitative risk assessment. However, these data may be used to substantiate the conclusions of the quantitative risk analysis.

Because of uncertainties associated with data quality, historical data collected during the 1981 to 1986 ground water monitoring, exhumations and geophysical surveys will not be used to quantitatively assess potential risks at the MGBG. The quality associated with the historical data has not been adequately documented, and the data do not seem to have been validated. The data packages (including the raw data) cannot be obtained to ascertain the level of quality associated with the data or to independently validate the data. However, these data may be used in a qualitative fashion to support the conclusions of the quantitative risk analysis. The proposed field investigations were developed to be comprehensive (i.e., locations sampled historically, as well as data gap locations, were included), thus, the uncertainty associated with the elimination of the historical data from the quantitative risk assessment will not be significant.

D.1.2 Selection of Chemicals of Potential Concern

The selection of COPCs is a qualitative screening process used to limit the number of chemicals and exposure routes quantitatively evaluated in the Baseline Human Health Risk Assessment to those site-related constituents that dominate overall potential risks. Screening by risk-based concentrations and Basewide background levels will be used to focus the risk assessment on meaningful chemicals and exposure routes.

In general, a chemical will be selected as a COPC and retained for further quantitative risk evaluation if: 1) the maximum detection in a sampled medium exceeds the lowest risk-based concentration and 2) the

chemical is determined to be present at concentrations exceeding background. (only naturally occurring inorganics or chemicals and radiologicals are eliminated as COPCs based on background comparisons.) Chemicals eliminated from further evaluation at this time are assumed to present minimal risks to potential human receptors.

D.1.2.1 COPC Screening Levels

Several types of screening levels will be used to identify COPCs for the MGBG. Risk-based screening concentrations based on U.S. EPA Region IX (referred to as Preliminary Remediation Goals [PRGs]) (U.S. EPA, Region IX, 1999) will be used, as well as other IDEM and U.S. EPA criteria (U.S. EPA 1991b). The risk-based U.S. EPA Region IX screening concentrations will correspond to a systemic hazard quotient of 0.1 (for noncarcinogens) or a lifetime cancer risk of 1E-6 (for carcinogens). It should be noted that the EPA Region IX PRGs for noncarcinogens are set at a hazard index of 1.0. These values will be multiplied by 0.1 so that the screening concentrations will be set at an HI = 0.1. The screening levels to be used for each media in the risk assessment are briefly discussed below.

Soil/Sediment

The following criteria will be used to select COPC for soil (surface and subsurface soil):

- U.S. EPA Region IX PRGs for Residential Soil (U.S. EPA Region IX, 1999);
- U.S. EPA Generic SSLs for Migration to Ground Water (U.S. EPA, 1996a);
- U.S. EPA Generic SSLs for Transfers from Soil to Air (U.S. EPA, 1996a);
- IDEM Tier I Cleanup Levels for Surface Soil (IDEM, 1999); and
- IDEM Tier I Cleanup Levels for Subsurface Soil (IDEM, 1999).

If the maximum concentration of a constituent exceeds any of these criteria (and the constituent is considered to be present at concentrations greater than Basewide background levels), the chemical will be selected as a COPC for soil and carried through to the quantitative risk assessment. Given the anticipated size of the background and site-specific data-sets, it is anticipated that background comparisons will be accomplished by statistical analyses that compare background and site-specific soil data sets. The background comparisons for purposes of COPC selection will be limited to naturally occurring inorganics and radiologicals only.

Because of the different exposure scenarios for potential human receptors, COPCs will be identified for surface and subsurface soil. Surface soil will be defined as soil collected from 0 to 2 feet bgs. Subsurface soil will be defined as soil collected from depths greater than 2 feet bgs.

The comparison of site soil data to U.S. EPA Generic SSLs for transfers from soil to air will be used to identify whether a quantitative analysis of this exposure pathway is warranted. If the maximum soil concentration of a chemical exceeds the SSL, a quantitative evaluation of potential risks from inhalation will be performed, as described in Section D.2.4. Otherwise, the risks associated with the inhalation pathway will be considered insignificant, and the exposure pathway will be eliminated from further evaluation.

No specific screening levels exist for human exposure to sediment. COPCs will be selected for sediment by comparing detected site concentrations to the following:

- U.S. EPA Region IX PRGs for Residential Soil (U.S. EPA Region IX, 1999) and
- IDEM Tier I Cleanup Levels for Surface Soil (IDEM, 1999).

A chemical detected in sediments will be selected as a COPC for sediments if the maximum detected concentration exceeds the preceding screening values and upstream/background concentrations. The background comparisons for purposes of COPC selection will be limited to naturally occurring inorganics and radiologicals only. U.S. EPA Generic SSLs for transfers from soil to air and for migration to ground water are not considered to be appropriate for sediment screening because of high moisture content associated with sediment matrices. The use of soil screening levels for sediment COPC identification is regarded as a conservative approach because anticipated exposure to sediment is less than anticipated exposure to soil.

Ground Water/Surface Water

The same screening levels will be used to select COPCs for ground water and surface water. The following criteria will be used:

- U.S. EPA Region IX PRGs for Tap Water (U.S. EPA, Region IX, 1999);
- IDEM Tier I Cleanup Levels for Residential Ground Water (IDEM, 1999); and
- U.S. EPA Maximum Contaminant Levels (MCLs) (U.S. EPA, 1996b).

If the maximum concentration of a constituent exceeds any of these criteria (and the constituent is considered to be present at concentrations greater than Basewide background levels), the chemical will be selected as a COPC and carried through to the quantitative risk assessment. Given the anticipated size of the background and site-specific data-sets, it is anticipated that background comparisons will be accomplished by statistical analyses that compare background and site-specific groundwater data sets. The background comparisons for purposes of COPC selection will be limited to naturally occurring inorganics and radiologicals only.

Risk-based COPC screening levels for tap water ingestion, which are based on daily, residential exposure assumptions, will be used to select COPCs for ground water and surface water. In general, the use of tap water screening levels is regarded as a highly conservative approach to COPC selection at the MGBG because ground water at the site is not used as a potable drinking water source. (The nearest private domestic water supply well is located outside the NSWC Crane boundary, which is more than one half mile from the MGBG.) In addition, potential human exposure to surface water at the MGBG is expected to be limited to incidental exposures (such as that which occurs during trespassing [i.e., exposure to seeps] or shallow subsurface soil excavations by construction workers), which is significantly less than the daily exposure assumed during the development of the aforementioned ground water screening criteria.

Federal Ambient Water Quality Criteria (AWQC) will not be used to select COPCs for surface water. AWQC applicable to the protection of human health will not be used since surface water present at the MGBG is not currently used and will not be used in the future as a potable drinking water source. In addition, the surface water bodies present at the sites do not support game fish populations because of their size and intermittent nature. Lake Greenwood is used as a drinking water supply for the Facility. Ground water at the MGBG does discharge to nearby surface water bodies. However, none of the surface water bodies (streams, creeks, tributaries, etc.) at the sites affect Lake Greenwood.

D.1.2.2 Lead as a COPC

Limited criteria are available to evaluate the potential risks associated with lead. There are no risk-based concentrations for this chemical since the U.S. EPA has not derived toxicity values for lead. However, recommended screening levels are available for lead in soil which are used to indicate the need for response activities.

Guidance from both the Office of Prevention, Pesticides, and Toxic Substances (OPPTS) and the Office of Solid Waste and Emergency Response (OSWER) recommend 400 mg/kg as the lowest screening level for lead-contaminated soil in a residential setting, where children are frequently present (U.S. EPA,

1994a). OPPTS identifies 2,000 to 5,000 mg/kg as an appropriate range for areas where contact with soil by children in a residential setting is less frequent. A value of 400 mg/kg will be used as the screening level for soil and sediment.

Guidance for the USEPA Technical Review Workgroup for Lead (TRW) indicates that "a reasonable screening level for soil lead at commercial/industrial (i.e., non-residential) sites is 750 mg/kg" for a typical non-contact intensive worker (U.S. EPA, 1999a/b). This value will not be used for COPC selection; but, may be used in the qualitative evaluation of lead.

The Safe Drinking Water Act Action Level of 15 µg/L will used as the screening level for lead in ground water and surface water.

D.1.2.3 Essential Nutrients and Chemicals without Toxicity Criteria

The essential nutrients calcium, magnesium, potassium, and sodium will not be identified as COPCs for the MGBG. These inorganic chemicals are naturally abundant in environmental matrices and are only toxic at high doses. In addition, because of the lack of toxicity criteria, risk-based COPC screening levels are not available for some chemicals (i.e., hexanone, benzo(g,h,i)perylene, phenanthrene). These chemicals will not be selected as COPCs as they can not be addressed during the quantitative risk assessment. However, these chemicals will be mentioned in the data evaluation section, after the identification of COPCs, and qualitatively addressed in the uncertainty section of the risk assessment.

D.1.2.4 Determination of Site-Related Chemicals

Chemicals found at concentrations indicative of background levels are not considered to be site-related contaminants and will not be retained as COPCs for the quantitative risk assessment. The use of Basewide background soil data will determine if detected chemicals are present at naturally occurring levels. To the extent possible, conventional statistical methods (e.g., Bartlett's T-test, etc.) will be employed to compare site concentrations for THE MGBG to background concentrations. If conventional statistical methods are not possible due to limited sample size or other constraints, the background comparison will be conducted as a simple maximum site concentration to maximum background concentration comparison.

The elimination of detected chemicals based on background data for soil will be limited to inorganics and naturally occurring radiologicals only. Although some organic compounds (primarily PAHs, pesticides, and PCBs) are found at low-level concentrations in background samples, the concentrations detected are

most likely reflective of non-site related, anthropogenic sources of contamination (e.g., automobile exhausts). All detected organic compounds will be regarded as site-related for purposes of COPC selection. However, historical information for a site and the results of the analysis of background samples will be reviewed in the baseline risk assessment to determine if the organics present in the site samples are attributable to site-related activities or anthropogenic sources.

D.1.3 COPC Summary Screening Tables

Media-specific tables summarizing the selection of COPCs will be included in the SWMU-specific risk assessments. The tables will be prepared according to the guidelines established for preparation of Standard Table 2 of the RAGS Part D guidance. An example format of a typical COPC selection table is provided as Table D-1.

D.2 EXPOSURE ASSESSMENT

This portion of the risk assessment defines and evaluates, quantitatively or qualitatively, the type and magnitude of human exposure to the chemicals present at or migrating from a site. The exposure assessment is designed to depict the physical setting of the site, identify potentially exposed populations and applicable exposure pathways, calculate concentrations of COPCs to which receptors might be exposed, and estimate chemical/radiological intakes under the identified exposure scenarios.

Actual or potential exposures at THE MGBG at NSWC Crane will be determined based on the most likely pathways of contaminant release and transport, as well as human activity patterns. A complete exposure pathway has three components: (1) a source of chemicals that can be released to the environment; (2) a route of contaminant transport through an environmental medium; and (3) an exposure or contact point for a human receptor.

D.2.1 Conceptual Site Model

The development of a CSM is an essential component of the exposure assessment. The CSM will integrate information regarding the physical characteristics of the site, exposed populations, sources of contamination, and contaminant mobility (fate and transport) to identify potential exposure routes and receptors to be evaluated in the risk assessment. A well-defined CSM will allow for a better understanding of the risks at a site and will aid the risk managers in the identification of the potential need for remediation. The site-specific CSM for the MGBG is presented in this section and illustrated in Figure D-2. The model was used to develop the proposed field investigations to ensure that the data collected meet the needs of the risk assessment. Sources of contamination, contaminant release mechanisms,

TABLE D-1

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
MUSTARD GAS BURIAL GROUND
NSWS CRANE, CRANE, INDIANA

Scenario Timeframe:
Medium:
Exposure Medium:
Exposure Point:

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening	Background Value (2)	Screening Toxicity Value (3)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection (4)

1 Minimum/maximum defected concentration.

2 N/A - Refer to supporting information for background discussion.
Background values derived from statistical analysis. Follow Regional guidance and provide supporting information.

3 Provide reference for screening toxicity value.

4 Rationale Codes Selection Reason: Infrequent Detection but Associated Historically (HIST).
Frequent Detection (FD)
Toxicity Information Available (TX0
Above Screening Levels (ASL)
Deletion Reason: Infrequent Detection (IFD)
Background Levels (BKG)
No Toxicity Information (NTX)
Essential Nutrient (NUT)
Below Screening Level (BSL)

Definitions: N/A = Not Applicable
SQL = Sample Quantitation Limit
COPC = Chemical of Potential Concern
ARAC/TBC = Applicable or Relevant and Appropriate Requirement/To Be Considered
MCL = Federal Maximum Contaminant Level
SMCL = Secondary Maximum Contaminant Level
J = Estimated Value
C = Carcinogenic
N = Non-Carcinogenic

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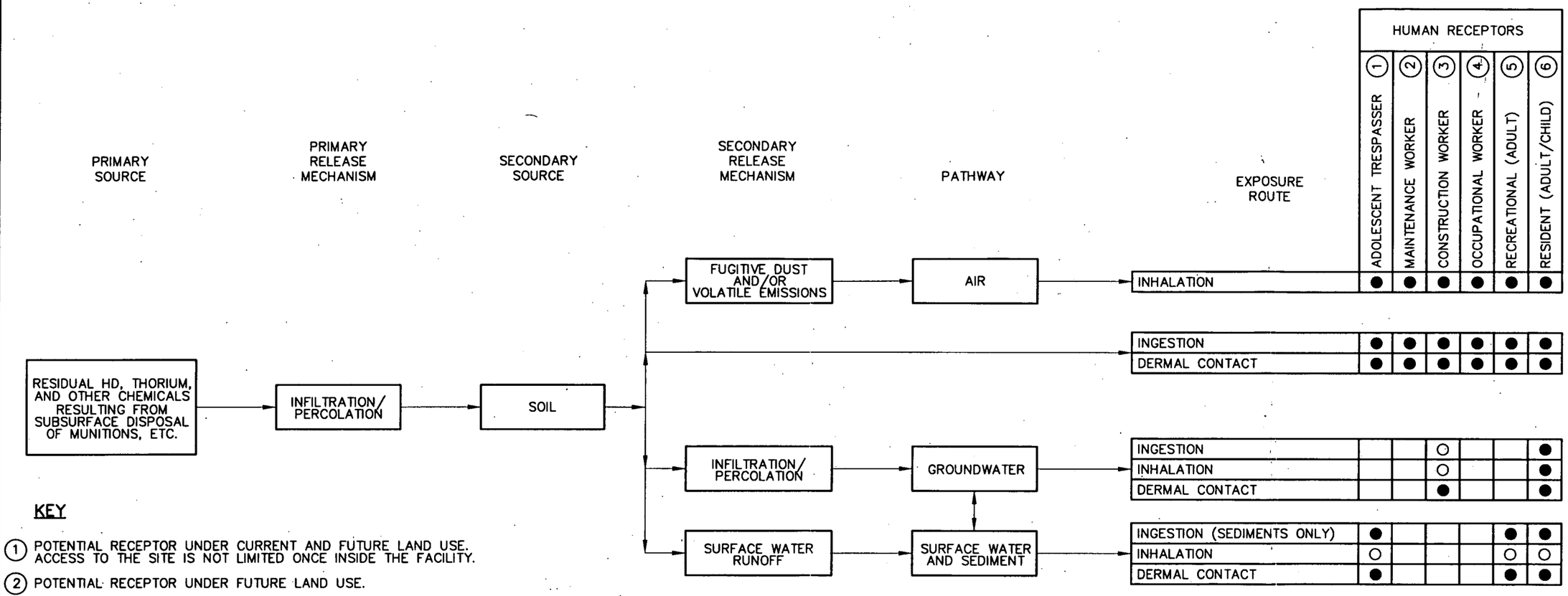

KEY

1. POTENTIAL RECEPTOR UNDER CURRENT AND FUTURE LAND USE. ACCESS TO THE SITE IS NOT LIMITED ONCE INSIDE THE FACILITY.
2. POTENTIAL RECEPTOR UNDER FUTURE LAND USE.
3. POTENTIAL RECEPTOR UNDER FUTURE LAND USE. A SHORT-TERM PROJECT (I.E. UTILITY INSTALLATION) MAY OCCUR.
4. PLAUSIBLE FUTURE RECEPTOR. HOWEVER, SITE IS NOT LIKELY TO BE DEVELOPED.
5. POTENTIAL RECEPTOR UNDER FUTURE LAND USE. BASE COULD CLOSE AND BE TURNED INTO A STATE PARK.
6. POTENTIAL RECEPTOR UNDER FUTURE LAND USE. EVALUATED FOR DECISION-MAKING PURPOSES.

● EXPOSURE PATHWAY TO BE EVALUATED IN RISK ASSESSMENT.

○ RELATIVELY INSIGNIFICANT POTENTIAL EXPOSURE PATHWAY COMPARED TO OTHER PATHWAYS EVALUATED IN THE RISK ASSESSMENT. RISKS NOT EVALUATED QUANTITATIVELY.

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY HJP DATE 5/7/01
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COST/SCHED-AREA
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CONCEPTUAL SITE MODEL
SWMU 01/12, MUSTARD GAS (HD)
BURIAL GROUND
NSWC CRANE, INDIANA

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APPROVED BY DATE
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transport/migration pathways, exposure routes, and potential receptors are defined. The CSM will be refined during the risk assessment process using the data and information collected as part of the proposed field investigations. *Table D-2* provides a site-specific summary of the potential receptors to be evaluated for THE MGBG. A summary of the exposure routes that will be addressed quantitatively for each human receptor is also provided in *Table D-2*. A summary discussion of the CSMs for the MGBG is provided in Section 1 of this QAPP.

Site Sources of Environmental Contamination

Based on historical site data and sampling, the following parameters are among the site-related chemical/ radiological contaminants known to be present or potentially present in environmental media within the study area:

- Mustard gas (HD) and its degradation products (1,4-thioxane; 1,4-dithiane; and thiodiglycol)
- Thorium nitrate, other metal salts, and laboratory metals
- Volatile organic chemicals (VOCs) such as 1,1,2,2-Trichloroethane, 1,2-Dichloroethane, Bromoform, Chlorodibromomethane, Trichloroethene

Potential Contaminant Release Mechanisms and Transport/Migration Pathways

Based on historical information available for the study area and a review of the existing (but limited) ground water data for the site, a release of hazardous constituents to environmental media has occurred as a result of historical site operations. For example, the existing historical ground water data indicates the presence of several halogenated volatile organic chemicals at concentrations exceeding 1000 ug/L. These data indicate that volatile organic chemicals may have been disposed at (or upgradient of) the study area and have migrated to the ground water via infiltration/percolation. Because the shallow water table aquifer is in communication with the shallow bedrock aquifer system, transport of contaminants is possible along this pathway. Depth to ground water ranges from 5 feet to 40 feet below ground surface across the MGBG. The shallower water depths may facilitates transport of chemicals from soils to ground water. The study area is a ground water recharge area. Based on the elevation of the study area versus the surrounding area, ground water may flow radially from the study area.

Assuming surface and sub-surface soil contamination has occurred as a result of waste disposal at the MGBG and that contaminant migration to ground water has occurred, additional plausible contaminant release and migration mechanisms are as follow:

TABLE D-2

EXPOSURE ROUTES FOR QUANTITATIVE EVALUATION
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE INDIANA

Receptors	Exposure Routes
Adolescent Trespassers (6 to 17 Years) (current/future land use)	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface) • Surface Water/Sediment Dermal Contact • Sediment Ingestion
Maintenance/Occupational Workers (future land use)	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface)
Construction Workers (future land use)	• Soil Dermal Contact (surface and subsurface) • Soil Ingestion (surface and subsurface) • Inhalation of Air/Dust/Emissions (surface and subsurface) • Ground Water Dermal Contact (during excavation)
Adult Recreational Users (future land use)	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface) • Surface Water/Sediment Dermal Contact • Sediment Ingestion
Residents (Adult/Children) (future land use)	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface) • Direct Ingestion of Ground Water • Ground Water Dermal Contact (showering/bathing) • Inhalation of Volatiles in Ground Water (showering/bathing) • Surface Water/Sediment Dermal Contact • Sediment Ingestion

- Discharge of ground water to surface water and sediments, such as the intermittent drainage channels to the north and south of the MGBG.

- Surface water/sediment run-off to the drainage culverts and intermittent drainage channels to the north and south of the MGBG. (Migration of on-site surface soil contaminants to off-site soils as a result of overland flow of surface waters is also possible.).

- Migration of contaminants in ground water (i.e., lateral migration) to potential receptor locations beyond the MGBG boundary and the NSWC Crane boundary.

- Migration of fugitive dusts and volatile organic chemicals from surface soils (and subsurface soils if construction/excavation activities occur).

Potential Current and Future Receptors of Concern and Exposure Pathways

NSWC Crane is currently an active naval base and will remain an active base for the foreseeable future. There are currently no plans to disestablish NSWC Crane. The MGBG is no longer used as a disposal area and is likely to be used for military or recreational purposes in the future. However, for purposes of completeness, the baseline risk assessment will consider receptor exposure under residential, industrial, or recreational land use scenarios. Based on current and potential future land use, the following potential receptors may be exposed to contaminated environmental media at the site:

- Trespassers – A plausible receptor under current and future land use. Although access to the Base is controlled, once inside the Base access to the site is not limited by any physical constraints (the fence at the MGBG has been removed). In addition, hunting activities are permitted at the Base. Since the site is remote and surrounded by forested areas, hunters (particularly adolescents) may trespass onto the site. This receptor may be exposed to potentially contaminated surface soil (0 to 2 feet below ground surface) (incidental ingestion; dermal contact), air (inhalation), and surface water (dermal contact) and sediments (incidental ingestion; dermal contact) in the intermittent streams. However, because of the intermittent nature of the streams, exposure to surface waters is likely to be very limited. Direct contact with ground water or sub-surface soils is not anticipated for this receptor.

- Maintenance Workers – A likely receptor under future land use. This includes adult military or civilian personnel assigned duties within the MGBG (e.g., groundskeeping activities). This receptor could be exposed to surface soils (incidental ingestion; dermal contact) and air (inhalation). Direct contact with

ground water or sub-surface soils or exposure to surface water or sediments is not anticipated for this receptor.

- Construction Workers – A plausible receptor under future land use. No construction activities are currently planned at the site. Additionally, the shallow depth to ground water in some sections of the MGBG area would likely preclude excavation/construction. However, excavation/construction is plausible in other sections of the MGBG area. Consequently, this receptor would potentially be exposed to surface and subsurface soils (to an estimated maximum depth of 10 feet bgs) (incidental ingestion; dermal contact), ground water (dermal contact), and air (inhalation). Exposure to surface water and sediments is not expected for the construction worker.

- Occupational Worker – A plausible receptor under future land use. Includes adult military or civilian personnel assigned to work at the former MGBG. This receptor could potentially exposed to surface soil (incidental ingestion; dermal contact) and air (inhalation). It is anticipated that this receptor would not be exposed to subsurface soils, ground water, surface waters or sediments. This receptor is expected to be exposed on a more frequent basis than the maintenance worker.

- Recreational Users – A plausible receptor under future land use. If the NSWC Crane were to close, the most likely scenario is that the property would be converted to a state park. A recreational user may be exposed to potentially contaminated surface soil (0 to 2 feet below ground surface) (incidental ingestion; dermal contact), air (inhalation), and surface water (dermal contact) and sediments (incidental ingestion; dermal contact) in the intermittent streams. However, because of the intermittent nature of the streams, exposure to surface waters is likely to be very limited. Direct contact with ground water or sub-surface soils is not anticipated for this receptor. It should be noted that it is unlikely that Crane would close because principal Base operations, the demilitarization of munitions, are critical to the support of the U.S. Naval fleet.

- Residents – Although this scenario is highly unlikely, a future residential scenario is typically evaluated in a risk assessment for decision making purposes. For example, the need for deed restrictions at a site may be eliminated, prior to site closure, if minimal risks are estimated for residential receptors. It is assumed that a hypothetical resident may be exposed to surface soils (incidental ingestion; dermal contract), ground water (ingestion, dermal contact), surface waters (dermal contact), air (inhalation), and sediment (incidental ingestion; dermal contact).

In addition to the preceding exposure pathways, the baseline risk assessment will evaluate, as necessary, direct radiation exposure to radiological COPCs in surface and subsurface soils. Details regarding the

assumed receptor characteristics (e.g., intake rate, frequency, duration of exposure) are defined in this section which presents the methodologies for human health risk assessment.

D.2.2 Central Tendency Exposure vs. Reasonable Maximum Exposure

Traditionally, exposures evaluated in the human health risk assessment were based on the concept of a Reasonable Maximum Exposure (RME) only, which is defined as "the maximum exposure that is reasonably expected to occur at a site" (U.S. EPA, December 1989). However, recent risk assessment guidance (U.S. EPA, 1992b) indicates the need to address an average case or Central Tendency Exposure (CTE).

To provide a full characterization of potential exposure, both RME and CTE will be evaluated in the site-specific risk assessment for THE MGBG at NSWC Crane. The available guidance (U.S. EPA, 1993a) concerning the evaluation of CTE is limited and at times vague. Therefore, professional judgment may be exercised when defining CTE conditions for a particular receptor at a site.

D.2.3 Exposure Point Concentrations

The exposure point concentration (EPC), which is calculated for COPCs only, is an estimate of the chemical/radionuclide concentration within an exposure unit that is likely to be contacted over time by a receptor and is used to estimate exposure intakes. The 95 percent upper confidence limit (UCL), which is based on the distribution of a data set, is often considered to be the best estimate of the exposure point concentration for data sets with 10 or more samples (U.S. EPA, 1992c). The 95 percent UCL will be used as the exposure concentration to assess RME and CTE risks (U.S. EPA, 1993a). For data sets with less than 10 samples, the UCL is considered to be a poor estimate of the mean, and the exposure point concentration is usually defined using an alternative descriptive statistic (e.g., the maximum detected concentration).

Conventional statistical methods (i.e., the Shapiro-Wilk W-Test) will be used to determine the distribution and UCL of a particular data set (Gilbert, 1987; U.S. EPA, 1992c). Detailed sample calculations, as well as general methodology for the statistical evaluation, will be presented in the site-specific risk assessment. Sample and duplicate analytical results will be averaged for statistical use. Nondetected data points will be utilized; in general, one-half the sample-specific detection limit will be employed for these analytical results.

The following paragraphs discuss the exposure units to be evaluated and the guidelines used to calculate the media-specific exposure point concentration.

The entire MGBG extended 20 feet in all directions (approximately 2 acres) will be considered the exposure unit for soils. For purposes of risk assessment, surface soils will extend to a depth of two feet; subsurface soil will be all soil from a depth of two foot to 10 feet or bedrock, whichever is shallower. A 2-acre exposure unit area is considered a reasonable exposure unit size based on the current/anticipated land use for the study area (i.e., military/industrial) and the rural nature of the area surrounding the Base (i.e., farmland). The 20-ft extension of the MGBG area facilitates assessing contamination that extends beyond the former MGBG fence line, but does not extend so far into expected uncontaminated regions that the exposure unit concentrations are artificially reduced. Additional exposure units may be defined if, based on the first soils sampling event, significant soil contamination is noted beyond the MGBG study area or if a significant "hot spot" exists within the MGBG.

As detailed below, the EPC for a receptor hypothetically using/exposed to the ground water underlying the MGBG study area will be the arithmetic average of wells in the highly contaminated area of the plume potentially underlying the study area. EPCs for ground water at receptor locations beyond the study area may be determined using modeling techniques if it is determined that a ground water contaminant plume is/may be moving beyond the study area boundaries. These ground water receptor locations may include the study area boundary and the facility boundary. The locations will be selected, if necessary, based on the concentrations detected within the MGBG area (i.e., the observed or potential contaminant loading to/within the ground water aquifer), the aquifer characteristics (e.g., flow, direction), and the chemical/physical nature of the contaminants detected in the ground water.

The exposure unit for receptors potentially exposed to surface waters and sediments will include all sampled locations in the drainage ditches and streams downstream of the MGBG. The exposure unit for surface waters and sediments is likely to include the two or three depositional areas proximal but downstream of the study area. It is assumed that the depositional areas will be separated by at least 100 feet). Additional exposure units may be defined if, based on the first surface water/sediment sampling event, significant sediment contamination is noted beyond the MGBG study area.

The following guidelines will be used to calculate the exposure point concentrations:

- If a soil, surface water, or sediment dataset for an exposure unit contains less than 10 samples, the exposure point concentration for the RME and CTE case will be defined as the maximum detected concentration.

- If a soil, surface water or sediment dataset for an exposure unit contains 10 or more samples, the 95 % upper confidence limit (UCL) on the arithmetic mean, which will be based on the distribution of the dataset, will be selected as the exposure point concentration for the RME and CTE case. As noted previously, conventional statistical methods (e.g., the Shapiro-Wilk W-Test the T and H-statistic based UCL calculation) will be used to determine the distribution and UCL. (The "best fit" distribution [normal or lognormal] will be assumed if the dataset distribution is undefined.) However, the EPCs calculated assuming a log-normal distribution will be reviewed and may be re-calculated (if necessary) as recommended in a recent EPA reference to assure that the H-statitistic based UCL is not an over-prediction of the EPC (EPA, 1997b [Attachment D.A-1]). If the calculated 95 percent UCL exceeds the maximum detected concentration, the maximum will be used as the EPC.

- Assuming that multiple rounds of ground water samples will be collected from site monitoring wells, and that no temporal concentration trend is obvious, the EPC for a ground water receptor will be the arithmetic average of wells in the highly concentrated area of the plume. If a temporal trend is noted, the EPC will be based on the most recent ground water sampling event only.

D.2.4 Chemical Intake Estimation

The methodologies and techniques used to estimate exposure intakes are presented in this section of this QAPP. Intakes for the identified potential receptor groups will be calculated using current U.S. EPA risk assessment guidance (e.g., U.S. EPA, 1998b, 1998a, and 1991b) and presented in the risk assessment spreadsheets. Risk assessment spreadsheets will be appended to the site-specific risk assessments as support documentation. All quantitative risk assessment results will be presented in RAGS Part D format tables.

Noncarcinogenic intakes will be estimated using the concept of an average annual exposure. Carcinogenic intakes will be calculated as an incremental lifetime exposure, which will assume a life expectancy of 70 years. The equations used to calculate radiological intakes will be based on the equations presented in RAGS Part B. Assumptions regarding exposure are presented in Table D-3.

TABLE D-3

SUMMARY OF EXPOSURE ASSUMPTIONS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 1 OF 4

Receptor	Exposure Assumptions			Rationale/Reference
	Input Parameter	RME	CTE	
Adolescent Trespasser (6 to 17 Years)	EF (days/yr)	26	13	Professional judgement; 1 day/week in warm weather months for the RME and 1 day/every other week in warm weather months for the CTE.
	ED (yrs)	11	11	Adolescents from age 6 to 17 evaluated.
	ET (hours/day) and t_{event} (hr/event)	4	2	Professional judgment.
	BW (kg)	43	43	Average age-specific value (USEPA, May 1989).
	SA (cm^2/day) and A (cm^2)	3,820	3,100	25 percent of the total body surface area will be assumed to be available for soil, sediment, and surface water contact. CTE and RME areas represent the mean of 50th and 95th percentile values for ages 6 to 17, respectively, as provided in Table 6-6 of the Exposure Factors Handbook (USEPA, August 1997).
	IR_S (mg/day)	100	50	Assumed similar to adult exposure (USEPA, May 1993).
	IR_a (m^3/hour)	1.9	1.9	Recommended short-term heavy activities rate for children (USEPA, August 1997; Table 5-23).
Maintenance/ Occupational Worker	EF (days/yr)	24 (maintenance) 250 (occupational)	12 (maintenance) 219 (occupational)	Professional judgement for maintenance worker; 2 days/month for the RME and 1 day/month for the CTE. Convention for the occupational worker (USEPA, May 1993).
	ED (yrs)	25	9	Convention for RME (USEPA, March 1991) and CTE (USEPA, May 1993).
	ET (hours)	8 (air) (occupational worker) 4 (air) (maintenance worker)	8 (air) (occupational worker) 4 (air) (maintenance worker)	Standard default for occupational worker. (USEPA, March 1991). Professional judgement for maintenance worker.
	BW (kg)	70	70	USEPA, May 1993.

TABLE D-3

SUMMARY OF EXPOSURE ASSUMPTIONS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 2 OF 4

Receptor	Exposure Assumptions			Rationale/Reference
	Input Parameter	RME	CTE	
Maintenance/ Occupational Worker (Continued)	SA (cm^2/day)	2,830	2,300	Surface area of the hands and forearms measured in men assumed to be available for soil contact . The RME and CTE values represent the 95th and 50th percentile areas of the hands and forearms (USEPA, August 1997, Table 6-2).
	IR_S (mg/day)	100	50	USEPA, May 1993.
	IR_a (m^3/hour)	2.5 (maintenance) 0.6 (occupational)	2.5 (maintenance) 0.6 (occupational)	For maintenance workers, recommended short-term heavy activities rate for outdoor workers (USEPA, August 1997; Table 5-23). For occupational workers, adult daily inhalation rate (USEPA, December 1989).
Construction Worker	EF (days/yr)	150	150	Professional judgement. Ground assumed to be frozen or snow covered for 22 weeks/yr.
	ED (yrs)	1	1	Estimated length of construction project (professional judgement).
	ET (hours)	8 (air) 2 (ground water)	8 (air) 1.5 (ground water)	For air, standard default (USEPA, March 1991). Professional judgement for dermal exposure to ground water.
	BW (kg)	70	70	USEPA, May 1993.
	SA (cm^2/day)	5,800	5,000	Recommended values for adult skin surface area assumed to be available for soil contact (USEPA, August 1997; Table 6-16).
	IR_S (mg/day)	480	240	Convention for the RME (USEPA, March 1991). CTE is assumed to be one-half the RME value.
	IR_a (m^3/hour)	2.5	2.5	Recommended short-term heavy activities rate for outdoor workers (USEPA, August 1997; Table 5-23).
	EV (events/day)	1	1	Professional judgement.

TABLE D-3

SUMMARY OF EXPOSURE ASSUMPTIONS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 3 OF 4

Receptor	Exposure Assumptions			Rationale/Reference
	Input Parameter	RME	CTE	
Adult Recreational User	EF (days/yr)	52	26	Professional judgement; 2 day/week for the RME in warm weather months and 1 day/every other week in warm weather months for the CTE.
	ED (yrs)	30	9	USEPA, May 1993. Assumed length of residence for an adult living near the facility.
	ET (hours/day) and t_{event} (hr/event)	4	2	Professional judgement.
	BW (kg)	70	70	USEPA, May 1993.
	SA (cm^2/day)	9,190	7,770	Feet, lower legs, hands, and arms of adult male assumed to be available for sediment contact. The RME and CTE values represent the 95th and 50th percentile areas of the feet, lower legs, hands and arms (USEPA, August 1997, Table 6-2).
	IR_S (mg/day)	100	50	Based on USEPA, May 1993.
	IR_a (m^3/hour)	1.6	1.6	Recommended short-term moderate activities rate for adults (USEPA, August 1997; Table 5-23).

TABLE D-3

SUMMARY OF EXPOSURE ASSUMPTIONS
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA
PAGE 4 OF 4

Receptor	Exposure Assumptions			Rationale/Reference
	Input Parameter	RME	CTE	
Resident (Adult/Child)	EF (days/yr or showers/yr)	350	234	USEPA, May 1993. One shower assumed to be taken per day.
	ED (yrs)	24(1) 6(3)	7(1) 2(3)	USEPA, May 1993.
	t_{event} (hr/event)	0.25	0.167	15 min/event for RME and 10 min/event for CTE (USEPA, January 1992).
	BW (kg)	70(1) 15(3)	70(1) 15(3)	USEPA, May 1993.
	SA (cm^2/day)	5,800(1) 2,000(3)	5,000(1) 1,745(3)	Recommended values for adult skin surface area assumed to be available for soil contact (USEPA, August 1997). Child CTE and RME areas represent 25% of the total body area, as provided in Table 6-6 of the Exposure Factors Handbook (USEPA, August 1997).
	IR_S (mg/day)	100(1) 200(3)	50(1) 100(3)	USEPA, May 1993.
	IR_a (m^3/day) (transfers from soil to air)	20(1) 8.3(3)	20(1) 8.3(3)	Adult daily inhalation rate (USEPA, December 1989) Child daily inhalation rate – Recommended long-term rate for children, 3-5 years of age (USEPA, August 1997; Table 5-23).
	IR_a (m^3/hr) (showering)	0.6	0.6	For all age groups while showering (USEPA, December 1989).
	IR_W (L/day)	2(1) 1.5(2)	1.4(1) 0.66(2)	USEPA, May 1993 for adult exposure. USEPA, August 1997, Table 3-30 for child exposure.
	EV (events/day)	1	1	Professional judgement

EF = Exposure Frequency
ED = Exposure Duration
ET = Exposure Time
BW = Body Weight
SA = Body Surface Area Exposed
IRs = Ingestion Rate - Soil
IRa = Inhalation Rate
EV = Exposure Events
CR = Contact Rate - Surface Water
Irw = Ingestion Rate - Groundwater

1 Exposure assumption for adult receptor.
2 Exposure assumption for adolescent receptor.
3 Exposure assumption for small children (0 to 6 years of age).

D.2.4.1 Inhalation of Air and Fugitive Dust/Volatile Emissions

The amount of a chemical a receptor takes in as a result of respiration is determined using the concentration of the contaminant in air. Intakes of both particulates and vapors/gases from soil will be calculated using the same equation, as follows (U.S. EPA, 1998b):

(chemical) $Intake_{ai} = (C_{ai})(IR_a)(ET)(EF)(ED) / (BW)(AT)$

(radiological) $Intake_{(ai)} = (C_{ai}) \times (IR_a)(ET)(EF)(ED)$

where:

$Intake_{ai}$	=	intake of chemical "i" from air via inhalation (mg/kg/day, chem) (pCi, rad)
C_{ai}	=	concentration of chemical "i" in air (mg/m^3, chem) (pCi/m^3, rad)
IR_a	=	inhalation rate (m^3/hr)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED x 365 days/yr;
		for carcinogens, AT = 70 yrs x 365 days/yr

The concentration of a chemical in air will be developed using modeling techniques, measured soil concentrations, and additional site-specific information.

As mentioned previously in Section D.1.2.1, a qualitative evaluation of exposure (i.e., comparison of maximum site soil concentrations to U.S. EPA Generic SSLs for transfers from soil to air) will be used to identify whether a quantitative analysis of this exposure pathway is warranted. If it is determined that a quantitative evaluation is not required, the potential risks associated with the inhalation pathway will be regarded as minimal and no further evaluation will be performed.

D.2.4.2 Dermal Contact with Soil/Sediment

Direct physical contact with soil (and sediment) may result in the dermal absorption of chemicals. Exposures associated with the dermal route are estimated in the following manner (U.S. EPA, 1998b; 1992a; and 1998b):

where: $Intake_{si}$ = amount of chemical "i" absorbed during contact with soil/sediment (mg/kg/day)

C_{si} = concentration of chemical "i" in soil/sediment (mg/kg)

SA = skin surface area available for contact (cm^2/day)

AF = skin adherence factor (mg/cm^2)

ABS = absorption factor (dimensionless)

CF = conversion factor (1E-6 kg/mg)

EF = exposure frequency (days/yr)

ED = exposure duration (yr)

BW = body weight (kg)

AT = averaging time (days);
for noncarcinogens, AT = ED x 365 days/yr;
for carcinogens, AT = 70 yrs x 365 days/yr

Exposed surface areas of body available for dermal contact are determined on a receptor-specific basis since they correspond with assumed human activities and clothing worn during exposure events. Current guidance (U.S. EPA, 1992a; U.S. EPA, 1997a; U.S. EPA, 1998b) were used to develop the default assumptions concerning the amount of skin surface area available for contact for a receptor. To maintain consistency from project to project, input parameters previously used for other NSWC Crane risk assessments (B&R Environmental, 1997) were also reviewed when developing the exposed surface areas. The rationales used to select the skin areas are as follows:

- For maintenance and occupational workers exposed to surface soil, the surface area available for soil contact is assumed to be the hands and forearms of an adult male. The skin surface area is 2,300 cm^2 for the CTE and is 2,830 cm^2 for the RME. These values represent the 50th and 95th percentile areas for the hands and forearms, respectively (U.S. EPA, 1997a).

- For construction workers exposed to surface and subsurface soil, the surface areas for the RME (5,800 cm^2) and CTE (5,000 cm^2) are the values recommended for soil contact by the U.S. EPA in the Exposure Factors Handbook (U.S. EPA, 1997a). These values represent 25 percent of the total body surface area of an adult male.

- For adolescent trespassers, 25 percent of the total body surface area for an adolescent (aged 6 to 16) will be assumed to be available for surface soil and/or sediment contact. The RME value (3,820 cm^2) is derived from the 95th percentile surface area data and the CTE value (3,100 cm^2) is derived from the 50th percentile data, as provided in Table 6-6 of the Exposure Factors Handbook (U.S. EPA, 1997a).

- For adult recreational users assumed to be exposed to surface soil and sediment, the exposed surface area available for contact will be the sum of the feet, lower, legs, hands, and arms of an adult male. This skin surface area is 7,770 cm^2 for the CTE and is 9,190 cm^2 for the RME. These values represent the 50th and 95th percentile areas for the feet, lower legs, hands and forearms, respectively (U.S. EPA, 1997a).

- For adult residents exposed to surface soil, the exposed surface areas available for contact will be the U.S. EPA recommended values for adult skin surface area for exposure to soil (Table 6-14, U.S. EPA, 1997a). For child residents assumed to be exposed to surface soil, the CTE and RME areas will represent 25 percent of the 50th and 95th percentile total body area of children ages 2 to 6, respectively, as provided in Table 6-6 of the Exposure Factors Handbook (U.S. EPA, 1997a).

The published range for the recommended soil adherence factors for the typical residential and industrial land use scenarios in the November 1998 Peer Consultation Workshop Draft RAGS Volume 1: Human Health Evaluation Manual Supplemental Guidance for Dermal Risk Assessment are as follows:

	Central Tendency Case		**Reasonable Maximum Case**	
	Residential (mg/cm^2)	**Industrial (mg/cm^2)**	**Residential (mg/cm^2)**	**Industrial (mg/cm^2)**
Adult Receptor	0.01	0.02	0.07	0.2
Child Receptor	0.06	NA	0.2	NA

NA – Not applicable

It should be noted that the adherence factors suggested for the residential land use scenario will be used to evaluate recreational and trespass exposure scenarios.

Current U.S. EPA guidance (U.S. EPA, 1998b) will be used to determine chemical-specific dermal absorption factors. It is assumed that dermal absorption of radiologicals is not a significant pathway because penetration through the skin is anticipated to be minimal.

D.2.4.3 Incidental Ingestion of Soil/Sediment

Incidental ingestion of soil (and sediment) by potential receptors coincides with dermal exposure. Exposures associated with incidental ingestion are estimated in the following manner (U.S. EPA, 1989):

(chemicals) $Intake_{Si} = (C_{Si})(IR_S)(FI)(EF)(ED)(CF)/(BW)(AT)$

(radiologicals) $Intake_{Si} = (C_{Si})(IR)(ED)(EF)(FI)$

where: $Intake_{si}$ = intake of contaminant "i" from soil or sediment (mg/kg/day, chem) (pCi, rad)

C_{si}	=	concentration of contaminant "i" in soil or sediment (mg/kg, chem) (pCi/g, rad)
IR_s	=	ingestion rate (mg/day)
FI	=	fraction ingested from contaminated source (dimensionless)
EF	=	exposure frequency (days/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (1E-6 kg/mg)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED x 365 days/yr;
		for carcinogens, AT = 70 yrs x 365 days/yr

The same exposure frequencies and durations used in the estimation of dermal intakes will be used to estimate exposure via incidental ingestion. Default values of 1.0 (RME) and 0.5 (CTE) will be used for the fraction of soil ingested from the source.

D.2.2.4.4 Direct Radiation Exposure from Soil/Sediment

The estimation of direct radiation exposure from soil or sediment is determined using the concentration in the soil or sediment at the locations evaluated. The following equation used to estimate intake:

$$D = (C_{Si})(ED)(EF)(CF)[ET_{in}(1-S_i) + ET_{out} \times (1-S_o)]$$

where:

D	=	dose from exposure (pCi-yr/g)
C_{si}	=	concentration of ith constituent in surface soil or sediment (pCi/g)

D	=	exposure duration (y) years
EF	=	exposure frequency (d/y)
CF	=	1.142×10^{-4} y/h
ET_{in}	=	exposure time indoors on-site (h/d)
ET_{out}	=	exposure time outdoors on-site (h/d)
S_i	=	indoor shielding factor (0.5)
S_o	=	outdoor shielding factor outdoors (0, assumes no shielding)

D.2.4.5 Dermal Contact with Ground Water/Surface Water

The same equation is used to estimate intakes for dermal contact with ground water and surface water. Direct contact with ground water at THE MGBG is limited to exposure that would occur under a residential, recreational, trespasser, and construction scenarios. Residential receptors are assumed to use ground water for domestic purposes (i.e., bathing, showering, washing dishes), that can result in a dermal exposure. Short-term dermal exposure is assumed to occur for the construction worker. Dermal contact with surface water may also occur while receptors are involved in certain activities, such as trespassing or recreational sport (hiking, biking, etc.).

The following equation will be used to assess exposures resulting from dermal contact with water (U.S. EPA, 1992a; U.S. EPA, 1998b):

$$DAD_{wi} = (DA_{event})(EV)(ED)(EF)(A) / (BW)(AT)$$

where:	DAD_{wi}	=	dermally absorbed dose of chemical "i" from water (mg/kg/day)
	DA_{event}	=	absorbed dose per event (mg/cm^2-event)
	EV	=	event frequency (events/day)
	ED	=	exposure duration (yr)
	EF	=	exposure frequency (days/yr)
	A	=	skin surface area available for contact (cm^2)
	BW	=	body weight (kg)
	AT	=	averaging time (days);
			for noncarcinogens, AT = ED x 365 days/yr;
			for carcinogens, AT = 70 yrs x 365 days/yr

Ground water exposure for residential receptors is assumed to occur on a daily basis. Exposure to ground water for construction workers and exposure to surface water for residents, trespassers, and

recreational users will be limited to infrequent exposure events. Dermal intakes for residents will assume total body exposure. For construction workers, trespassers, and recreational users, the exposed surface area of the body available for contact will be determined based on assumed activities and will be similar to the assumptions outlined for dermal contact with soil and sediment. Table D-3 summarizes recommendations for exposure parameters that will be evaluated in the Baseline risk assessment.

The absorbed dose per event (DA_{event}) will be estimated using a nonsteady-state approach for organic compounds and a traditional steady-state approach for inorganics. For organics, the following equations apply:

$$\text{If } t_{event} < t^*, \text{then: } DA_{event} = (2K_p)(C_{wi})(CF)\left[\frac{\sqrt{6\,T\,t_{event}}}{\pi}\right]$$

$$\text{If } t_{event} > t^*, \text{then: } DA_{event} = (K_p)(C_{wi})(CF)\left[\frac{t_{event}}{1+B} + 2T\left[\frac{1+3B+3B^2}{(1+B)^2}\right]\right]$$

where:

t_{event}	=	duration of event (hr/event)
t^*	=	time it takes to reach steady-state conditions (hr)
K_p	=	permeability coefficient from water through skin (cm/hr)
C_{wi}	=	concentration of chemical "i" in water (mg/L)
T	=	lag time (hr)
π	=	constant (dimensionless; equal to 3.141592654)
CF	=	conversion factor (1E-3 L/cm^3)
B	=	Dimensionless ratio of the permeability of the stratum corneum relative to the permeability across the viable epidermis.

Values for the chemical-specific parameters (t_{event}, t^*, K_p, T, and B) will be obtained from the current dermal guidance (U.S. EPA, 1998b and updates). If no published values are available for a particular compound, they will be calculated using equations provided in the cited guidance.

The following nonsteady-state equation will be used to estimate DA_{event} for inorganics:

$$DA_{event} = (K_p)\,(C_{wi})\,(t_{event})$$

In general, the recommended default value of 1E-3 will be used for the dermal permeability of inorganic constituents. For most metals and, hence, most radiologicals, dermal absorption is not a significant pathway because penetration through the skin is minimal.

D.2.4.6 Incidental/Direct Ingestion of Ground Water/Surface Water

Residents may be exposed to ground water via direct ingestion. Intakes associated with ingestion of water will be evaluated using the following equations (U.S. EPA, 1989):

(chemicals) $Intake_{wi} = (C_{wi})(IR_w)(EF)(ED) /(BW)(AT)$ *for groundwater*

(radionuclides) $Intake_{wi} = (C_{wi})(IR_w) \times (EF) \times (ED)$

where:	$Intake_{wi}$	=	intake of chemical "i" from water (mg/kg/day, chem) (pCi, rad)
	C_{wi}	=	concentration of chemical "i" in water (mg/L, chem) (pCi/L, rad)
	IR_w	=	ingestion rate for ground water (L/day)
	CR	=	contact rate for surface water (L/hr)
	ET	=	exposure time for surface water (hr/day)
	EF	=	exposure frequency (days/yr)
	ED	=	exposure duration (yr)
	BW	=	body weight (kg)
	AT	=	averaging time (days);
			for noncarcinogens, AT = ED x 365 days/yr;
			for carcinogens, AT = 70 yrs x 365 days/yr

The same exposure times, frequencies, and durations used to assess dermal exposure to water will be used to estimate intakes for ingestion of water.

D.2.4.7 Inhalation of Volatiles in Ground Water

Ground water exposure may also result in an inhalation exposure. This exposure route will be evaluated for residential receptors only who may be exposed while showering, bathing, washing dishes, etc. Inhalation exposures will be estimated using a mass transfer model, developed specifically for this exposure route, in combination with an air intake estimation model. The mass transfer model accounts for inhalation that occurs during a shower and after a shower while the receptor remains in the closed bathroom. The method employed is as follows (U.S. EPA, 1989; Foster and Chrostowski, 1987):

$$Intake_{si} = (S)(IR_{sh})(K)(EF)(ED) / (BW)(AT)(R_a)(CF)$$

$$K = D_s + \frac{\exp(R_a \times D_t)}{R_a} - \frac{\exp R_a \times (D_s - D_t)}{R_a}$$

where: $Intake_{wi}$ = intake of chemical "i" from water via inhalation (mg/kg/day)

S = volatile chemical generation rate (µg/m^3-min-shower)

IR_{sh} = inhalation rate (L/min)

K = mass transfer coefficient (min)

EF = exposure frequency (showers/yr)

ED = exposure duration (yrs)

BW = body weight (kg)

AT = averaging time or period of exposure (days)

R_a = air exchange rate (min^{-1})

CF = conversion factor (1E+6 µg-L/mg-m^3)

D_s = shower duration (min)

D_t = total time in bathroom (min)

The volatile chemical generation rate will be estimated using the Foster and Chrostowski mass transfer model, which is based on two-phase film theory. The model employs contaminant-specific mass transfer coefficients, Henry's Law constants, droplet diameter, drop time, viscosity, temperature, etc. Calculations of the shower model will be provided in the appendices to the site-specific risk assessments. For most metals and, hence, most radionuclides anticipated at THE MGBG, volatilization is not a significant pathway because these substances do not vaporize at room temperature

D.2.4.8 Summary of Exposure Parameters

A summary of the exposure input parameters for all exposure pathways are presented in Table D-3 for the identified potential receptor groups at THE MGBG. In general, standard default parameters (e.g., U.S. EPA, 1991a; Exposure Factors Handbook, U.S. EPA 1997a), which combine mid-range and upper-end exposure factors, will be used to assess RME conditions. CTE will be assessed primarily by the use of mid-range exposure factors presented in current risk assessment guidance (U.S. EPA, 1989 and 1993a). These input parameters may be updated according to new risk assessment guidance, as it becomes available.

D.2.5 Exposure to Lead

The equations and methodology presented in the previous section cannot be used to evaluate exposure to lead because of the absence of published dose-response parameters. Exposure to lead will be assessed using the following models:

- The latest version of the U.S. EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead (U.S. EPA, 1994a). This model is typically used to evaluate lead exposure assuming a residential land use scenario.

- The U.S. EPA's Technical Review Workgroup Model for Lead (U.S. EPA, 1996c). This model is typically used to evaluate lead exposure assuming a non-residential land use scenario.

The U.S. EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead (U.S. EPA, 1994a) is designed to estimate blood levels of lead in children (under 7 years of age) based on either default or site-specific input values for air, drinking water, diet, dust, and soil exposure. Studies indicate that infants and young children are extremely susceptible to adverse effects from exposure to lead. Considerable behavioral and developmental impairments have been noted in children with elevated blood lead levels. The threshold for toxic effects from this chemical is believed to be in the range of 10 µg/dL to 15 µg/dL. Blood lead levels greater than 10 µg/dL are considered to be a "concern".

For THE MGBG, the IEUBK Model for lead will be used to address exposure to lead in children when detected ground water and surface water concentrations exceed the 15 µg/L Federal Action Level promulgated under the Safe Drinking Water Act and when detected soil and sediment concentrations exceed the OSWER soil screening level of 400 mg/kg for residential land use (U.S. EPA, 1994b). Average chemical concentrations, as well as default parameters for some input parameters, will be employed. Estimated blood lead levels and probability density histograms will be presented as support documentation for this analysis and appended to the site-specific risk assessment.

Non-residential adult exposure to lead in soil will be evaluated using the U.S. EPA's Technical Review Workgroup for Model Lead (U.S. EPA, 1996c). In this model, adult exposure to lead in soil is addressed by an evaluation of the relationship between the site soil lead concentration and the blood lead concentration in the developing fetuses of adult women. The adult lead model will generate a spreadsheet for each exposure scenario evaluated (i.e., industrial, recreational). The spreadsheets will estimate the 95th percentile blood lead concentrations in fetuses born to women exposed to lead in soil

and will also estimate the probability that blood lead concentration in a fetus will exceed the EPA goal (i.e., the 10 ug/dL blood lead concentration).

No models are currently available to evaluate the periodic exposure of adolescent trespassers to lead. Therefore, the results of the IEUBK Model for children will be used to qualitatively assess exposure of this receptor. Essentially, the qualitative discussion will cite that potential adverse effects from exposure to lead are expected to be of a lesser magnitude for adolescent trespassers than for children.

D.2.6 Exposure to Total Petroleum Hydrocarbons

Total petroleum hydrocarbons (TPH) will be qualitatively evaluated by comparing maximum concentrations in soil and sediment to the 100 mg/kg soil notification level specified in the State of Indiana's Underground Storage Tank (UST) program (http://www.state.in.us/idem/oer/ustclosure.html). The notification level is typically used to signify potential releases to soil from fuel tanks and is used to identify the need for contaminant-specific analyses, which will be performed for the site.

D.3 TOXICITY ASSESSMENT

The objective of the toxicity assessment is to identify the potential health hazards and adverse effects in exposed populations. Quantitative estimates of the relationship between the magnitude and type of exposures and the severity or probability of human health effects will be defined for the identified COPCs. Quantitative toxicity values determined during this component of the risk assessment will be integrated with outputs of the exposure assessment to characterize the potential for the occurrence of adverse health effects for each receptor group.

The toxicity value used to evaluate noncarcinogenic health effects is the Reference Dose (RfD). Carcinogenic effects are quantified using the Cancer Slope Factor (CSF).

D.3.1 Toxicity Criteria

Oral and inhalation RfDs and CSFs to be used in the site-specific risk assessments for THE MGBG will be obtained from the following primary literature sources:

- Integrated Risk Information System (IRIS)
- Annual Health Effects Assessment Summary Tables (HEAST)
- NCEA Superfund Health Risk Technical Support Center

Although RfDs and CSFs can be found in several toxicological sources, U.S. EPA's IRIS on-line database is the preferred source of toxicity values. This database is continuously updated and values presented have been verified by U.S. EPA RfD and Carcinogenic Risk Assessment Verification Endeavor (CRAVE) work groups. The U.S. EPA Region IX PRG Tables and Region III RBC Tables will also be used as a source of toxicity criteria when toxicity criteria are not available from the aforementioned references. It should be noted that toxicity criteria for radiological parameters are not currently provided on IRIS; the HEAST tables will be the primary source for toxicity criteria for radiological parameters.

D.3.1.1 Toxicity Criteria for Dermal Exposure

RfDs and CSFs found in literature may be expressed as administered doses; therefore, these values are considered to be inappropriate for estimating the risks associated with dermal routes of exposure. Oral dose-response parameters based on administered doses must be adjusted to absorbed doses before the comparison to estimated dermal exposure intakes is made.

The adjustment from administered to absorbed dose will be made using chemical-specific absorption efficiencies published in available guidance (i.e., U.S. EPA 1998b [the primary reference]; IRIS; Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles, etc.) and the following equations:

$$RfD_{dermal} = (RfD_{oral})(ABS_{GI})$$

$$CSF_{dermal} = (CSF_{oral}) / (ABS_{GI})$$

where: ABS_{GI} = absorption efficiency in the gastrointestinal tract

Absorption efficiencies used in the risk assessments will reflect the U.S. EPA's current dermal assessment guidance (U.S. EPA, 1998b).

D.3.1.2 Toxicity Criteria for Carcinogenic Effects of PAHs

Limited toxicity values are available to evaluate the carcinogenic effects from exposure to PAHs. The most extensively studied PAH is benzo(a)pyrene, which is classified by the U.S. EPA as a known human carcinogen. Although CSFs are available for benzo(a)pyrene, insufficient data are available to calculate CSFs for other carcinogenic PAHs. Toxic effects for these chemicals will be evaluated using the concept of estimated orders of potential potency, as presented in current U.S. EPA guidance (U.S. EPA, 1993b). These parameters are based on the carcinogenicity of benzo(a)pyrene and are available for select

carcinogenic PAHs. The equivalent oral and inhalation CSF for these chemicals is derived by multiplying the CSF for benzo(a)pyrene by the order of potential potency.

D.3.1.3 Toxicity Criteria for Carcinogenic Effects of Dioxins/Furans

Similar to the concept of estimated orders of potential potency for PAHs, chlorinated dibenzo-p-dioxins (CDDs) and -dibenzofurans (CDFs) will be evaluated using Toxicity Equivalence Factors (TEFs) relative to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) (Environmental Health Perspectives, December 1998; U.S. EPA, March 1989). Based on a variety of approaches that generate toxicities relative to 2,3,7,8-TCDD, the U.S. EPA and others have developed TEFs for other dioxins/furans from structure-activity relationships and the available toxicological information. An equivalent oral CSF for these chemicals may be derived by multiplying the CSF for 2,3,7,8-TCDD by the TEF. However, the TEFs are more typically used to derive a toxicity equivalent concentration (TEQ) representing all of the significant dioxin/furans in a sample (Attachment D.A-2). An EPC based on the TEQs for a dataset is then evaluated using the CSF for 2,3,7,8-TCDD.

D.3.1.4 Toxicity Criteria for Chromium

Toxicity criteria are available for different forms of chromium, which is considered to be more toxic in the hexavalent state. Because there is no evidence to support the conclusion that hexavalent chromium is present at the sites, speciation analyses will not be completed for THE MGBG. Risks associated with this chemical will be assessed by assuming that 10 percent of the reported total chromium result is attributable to hexavalent chromium, while 90 percent of the total chromium result is comprised of trivalent chromium. This assumption is based on published toxicological information (ATSDR, 1991).

D.3.1.5 Toxicity Criteria for Mustard Gas

A ***provisional*** reference dose provided courtesy EPA Region 5 (8E-5 mg/kg/day) will be used to quantitatively evaluate mustard gas concentrations in environmental media. This reference dose was developed by the U.S. EPA Office of Environmental Criteria and Assessment.

D.3.2 <u>Toxicity Profiles</u>

Toxicological profiles for each COPC will be presented as an appendix to the risk assessment. These brief profiles present a summary of the current available literature on the carcinogenic and noncarcinogenic health effects associated with human exposure to COPCs.

D.4 RISK CHARACTERIZATION

Potential risks (noncarcinogenic and carcinogenic) for human receptors resulting from the exposures outlined in the exposure assessment are quantitatively determined during the risk characterization component of the Baseline Human Health Risk Assessment.

A summary and interpretive discussion of the quantitative risk estimates will be provided in the text of the site-specific risk assessments. During the interpretive risk discussion, COPCs which contribute significantly to elevated risks will be identified as "risk drivers" or Chemicals of Concern (COCs). All the numeric estimates of risk will be contained in the risk assessment spreadsheets, which will appended to the assessment as support documentation.

D.4.1 Quantitative Analysis

Quantitative estimates of risk will be calculated according to risk assessment methods outlined in U.S. EPA guidance (U.S. EPA, 1989). Lifetime cancer risks will be expressed in the form of dimensionless probabilities, referred to as incremental cancer risks (ICRs), based on CSFs. Noncarcinogenic risk estimates will be presented in the form of Hazard Quotients (HQs) that are determined through a comparison of intakes with published RfDs.

ICR estimates are generated for each COPC using estimated exposure intakes and published CSFs, as follows:

$$ICR = (\text{Estimated Exposure Intake})(CSF)$$

If the above equation results in an ICR greater than 0.01, the following equation will be used:

$$ICR = 1\text{-}[\exp(\text{-Estimated Exposure Intake})(CSF)]$$

An ICR of 1E-6 indicates that the exposed receptor has a one-in-one-million chance of developing cancer under the defined exposure scenario. Alternatively, such a risk may be interpreted as representing one additional case of cancer in an exposed population of one million persons.

As mentioned previously, noncarcinogenic risks will be assessed using the concept of HQs and Hazard Indices (HIs). The HQ for a COPC is the ratio of the estimated intake to the RfD, as follows:

HQ = (Estimated Exposure Intake) /(RfD)

An HI will be generated by summing the individual HQs for all COPCs. The HI is not a mathematical prediction of the severity of toxic effects and therefore is not a true "risk"; it is simply a numerical indicator of the possibility of the occurrence of noncarcinogenic (threshold) effects.

D.4.1.1 Comparison of Quantitative Risk Estimates to Benchmarks

To interpret the quantitative risks and to aid risk managers in determining the need for remediation at a site, quantitative risk estimates will be compared to typical benchmarks. Calculated ICRs will be interpreted using the U.S. EPA's "target range" (1E-4 to 1E-6), while HIs will be evaluated using a value of 1.0.

The U.S. EPA has defined the range of 1E-4 to 1E-6 as the ICR "target range" for most hazardous waste facilities addressed under CERCLA and RCRA. Individual or cumulative ICRs greater than 1E-4 will typically not be considered as protective of human health, while ICRs less than 1E-6 will typically be regarded as protective. (Risk management decisions are necessary when the ICR is within the 1E-4 to 1E-6 cancer risk range.)

An HI exceeding unity (1.0) indicates that there may be potential noncarcinogenic health risks associated with exposure. If an HI exceeds unity, a segregation of target organs effects associated with exposure to COPCs will be performed. Only those chemicals which affect the same target organ(s) or exhibit similar critical effect(s) will be regarded as truly additive. Consequently, it may be possible for a cumulative HI to exceed 1.0, but no adverse health effects are anticipated if the COPCs do not affect the same target organ or exhibit the same critical effect.

As a *general* guideline, a "no further action" recommendation will be forwarded to the Navy, the State of Indiana, and the EPA, if the cancer risk estimates and total HIs (developed on a target organ/target effect basis) for receptors of concern do not exceed $1x10^{-4}$ and 1, respectively. Otherwise the need for remedial action (including institutional controls) will be evaluated in the Corrective Measures Study (CMS). However, as indicated in EPA RAGS Part D, the upper boundary of the acceptable risk range is not a discrete line at $1x\ 10^{-4}$. "Risks slightly greater than $1x10^{-4}$ may be considered to be acceptable (i.e., protective) if justified based on site-specific conditions, including any uncertainties about the nature and extent of contamination and associated risks." Consequently, a "no further action" recommendation may forwarded even when the $1x\ 10^{-4}$ risk benchmark is exceeded. The following factors will be considered in this determination:

- The magnitude of the *media-specific* risk estimates.

- Significant uncertainties in the baseline human health risk assessment that would tend to overestimate baseline risk assessment results. Uncertainties in the baseline human health risk assessment intake estimates (and their impact on the risk estimates) could be evaluated using "probabilistic risk assessment" techniques. Uncertainties associated with the toxicity criteria would be evaluated qualitatively.

- Significant uncertainties in the EPC estimates that would tend to overestimate baseline risk assessment results.

D.4.2 Qualitative Analysis

As mentioned previously, a qualitative evaluation of risk will be made for several exposure situations.

- The soil inhalation pathway (Section D.2.4) will be initially evaluated by a comparison of maximum site soil concentrations to U.S. EPA Generic SSLs for transfers from soil to air. If the maximum site concentration exceeds the SSL for a chemical, a quantitative analysis of this exposure pathway will be performed.

- Total petroleum hydrocarbons (Section D.2.6) will be qualitatively evaluated by comparing maximum concentrations in soil and sediment to the 100 mg/kg soil notification level specified in the State of Indiana's UST program.

- The potential for the migration of soil contaminants to groundwater will be assessed by a comparison on maximum and average soil concentrations to U.S. EPA Generic SSLs for transfers from soils to groundwater. SSLs based on a dilution and attenuation factors (DAFs) of 1 and 20 will be used in the evaluation.

D.5 UNCERTAINTY ANALYSIS

The goal of the uncertainty analysis is to identify important uncertainties and limitations associated with the Baseline Human Health Risk Assessment. Uncertainties related to each component of the assessment (i.e., data evaluation, exposure assessment, toxicity assessment, and risk characterization) will be presented. In addition, the effect of a particular uncertainty on the outcome of the assessment (i.e.,

risk estimates) will also be indicated, where possible. The following subsections present an overview of uncertainties which may be addressed in the risk assessment uncertainty section.

D.5.1 Uncertainty in Data Evaluation

This section may discuss uncertainties in the risk assessment associated with the analytical data and data quality. This may also involve a discussion of uncertainty in the COPC selection process, the inclusion or exclusion of COPCs in the risk assessment on the basis of background concentrations, the uncertainty in COPC screening levels, and the omission of constituents for which health criteria are not available. The discussion presented will be based, in part, on the evaluation presented in the "Data Useability Worksheet" as suggested U.S. EPA RAGS Part D.

D.5.2 Uncertainty in the Exposure Assessment

This section will include a discussion of the following: assumptions related to current and future land use; the uncertainty in exposure point concentrations, for example, the use of maximum concentrations to estimate risks; uncertainty in the selection of potential receptors and exposure scenarios; and uncertainty in the selection of exposure parameters (RME vs. CTE). If predictive models are used in the risk estimation, the uncertainty associated with the model and modeling parameters will be evaluated.

D.5.3 Uncertainty in the Toxicity Assessment

The uncertainties inherent in RfDs and CSFs and use of available criteria will be discussed. A discussion of the uncertainty in hazard assessment, which deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will also induce adverse effects in humans, will be provided. This section will also discuss uncertainty in the dose-response evaluations for the COPCs which relates to the determination of a CSF for the carcinogenic assessment and derivation of an RfD or RfC for the noncarcinogenic assessment. In addition, a discussion of the uncertainty in the toxicity of specific constituents, such as mustard gas, any of the radiological parameters selected as COPCs, PAHs, arsenic, chromium, aluminum, iron, and copper, will be presented, if applicable.

D.5.4 Uncertainty in the Risk Characterization

This section will discuss the uncertainty in risk characterization which results primarily from assumptions made regarding additivity/synergism of effects from exposure to multiple COPCs affecting different target organs across various exposure routes. The risk assessment will discuss the uncertainty inherent in

summing risks for several substances across different exposure pathways. It should be noted that probabilistic risk assessment techniques may also be used to further define the uncertainty attached to the risk characterization results. However, the exposure assumptions (e.g., probability distributions) used to prepare the probabilistic risk assessment will be reviewed with the regulatory reviewers before they are incorporated into the uncertainty section of the baseline risk assessment.

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ATTACHMENT D.A-1

THE LOG-NORMAL DISTRIBUTION IN ENVIRONMENTAL APPLICATIONS

United States Environmental Protection Agency | Office of Research and Development | Office of Solid Waste and Emergency Response | EPA/600/R-97/006 December 1997

EPA Technology Support Center Issue

THE LOGNORMAL DISTRIBUTION IN ENVIRONMENTAL APPLICATIONS

Ashok K. Singh[1], Anita Singh[2], and Max Engelhardt[3]

The Technology Support Projects, Technology Support Center (TSC) for Monitoring and Site Characterization was established in 1987 as a result of an agreement between the Office of Research and Development (ORD), the Office of Solid Waste and Emergency Response (OSWER) and all ten Regional Offices. The objectives of the Technology Support Project and the TSC were to make available and provide ORD's state-of-the-science contaminant characterization technologies and expertise to Regional staff, facilitate the evaluation and application of site characterization technologies at Superfund and RCRA sites, and to improve communications between Regions and ORD Laboratories. The TSC identified a need to provide federal, state, and private environmental scientists working on hazardous waste sites with a technical issue paper that identifies data assessment applications that can be implemented to better define and identify the distribution of hazardous waste site contaminants. The examples given in this Issue paper and the recommendations provided were the result of numerous data assessment approaches performed by the TSC at hazardous waste sites. Mr. John Nocerino provided guidance and suggestions that greatly enhanced the quality of this Issue Paper.

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PURPOSE AND SCOPE

The purpose of this issue paper is to provide guidance to environmental scientists regarding the interpretation and statistical assessment of data collected from sites contaminated with inorganic and organic contaminants. Contaminant concentration data from sites quite often appear to follow a skewed probability distribution. The lognormal distribution is frequently used to model positively skewed contaminant concentration distributions. The H-statistic based Upper Confidence Limit (UCL) for the mean of a lognormal

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population is recommended by U.S. EPA guidance documents (see, for example, EPA (1992)) and is widely used to make remediation decisions at Superfund sites. However, recent work in environmental statistics has cast some doubts on the performance of the formula based on the H-statistic for computing an upper confidence limit of the mean of a lognormal population. This issue paper is mainly concerned with the problem of computing an upper confidence limit when the contaminant concentration distribution appears to be highly skewed.

Several approaches to computing upper confidence limits for the mean of a lognormal population are considered. The approaches discussed include those based on the H-statistic, the jackknife method, the bootstrap method, and a method based on the Chebychev inequality. Simulated examples show that for values of the coefficient of variation larger than 1, the upper confidence limits for the mean contaminant concentration based on the H-statistic are much higher than the upper confidence limits obtained by the other estimation methods. This may result in an unnecessary cleanup. In other words, the use of the jackknife method, the bootstrap method, or the Chebychev inequality method provides better input to the risk assessors and may result in a significant reduction in remediation costs. This is especially true when the number of samples is thirty or less. When the value of the coefficient of variation exceeds 1, upper confidence limits based on any of the other estimation procedures appear to be more stable and reliable than those based on the H-statistic. Values of the coefficient of variation computed from observed contaminant concentrations are typically used by environmental scientists to assess the normality of the population distribution. In this issue paper, the issue of using the coefficient of variation in environmental data analysis is addressed and the problem of estimating the coefficient of variation, when sampling from lognormal populations, is also discussed.

This issue paper is divided into the following major sections: (1) Introduction, (2) the Lognormal Distribution, (3) Methods of Computing a UCL of the Mean, (4) Examples, and (5) Summary and Recommendations.

1. INTRODUCTION

Most of the procedures available in the literature of environmental statistics for computing UCL of the mean of a population assume that contaminant concentration data is approximately normally distributed. However, the distributions of contaminant concentration data from Superfund sites typically are positively skewed and are usually modeled by the lognormal distribution. This apparent skewness, however, may be due to biased sampling, multiple populations, or outliers, and not necessarily due to lognormally distributed data.

Biased sampling is often used in sampling for site characterization (Power, 1992). Another common situation often present with environmental data is a mixed distribution of several subpopulations (see Figure 1). Also, the presence of one or more outliers, spurious observations, or anomalies can result in a data set which appears to come from a highly skewed distribution. When dealing with a skewed distribution, statisticians sometimes recommend using the population median (instead of the population mean) as a measure of central tendency. However, remediation decisions at a

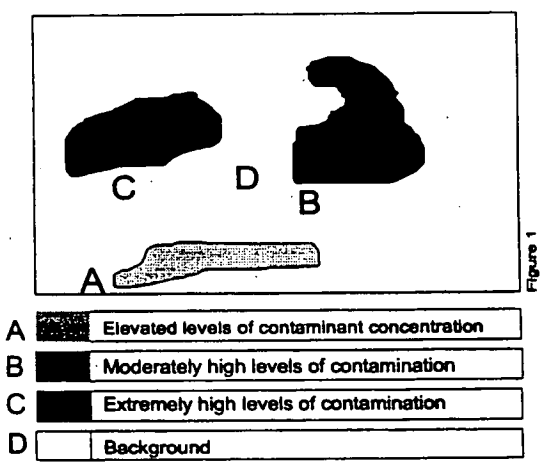

Figure 1 A site with several sources of contamination.

polluted site typically are made on the basis of the population mean, and therefore UCL of the mean of the concentration-distribution is needed. For positively skewed distributions, the median is smaller than the mean: therefore a UCL for the median provides an inappropriate basis for a decisión about the mean.

U.S. EPA guidance documents recommend the use of H-statistics to compute the UCL of the mean of a lognormal distribution (EPA, 1992). A detailed discussion of H-statistics is given in Gilbert (1987). For data sets with nondetects, estimation methods developed for censored data from a lognormal distribution are discussed by Lecher (1991). The use of the lognormal distribution has been controversial because it can lead to incorrect decisions. For example, recent work of Gilbert (1993) indicates that statistical tests of hypotheses based on H-statistics can yield unusually high false positives, which would result in an unnecessary cleanup. The situation may be reversed when dealing with estimation of the mean background level. If the H-statistic based method is used to compute a UCL of the mean for the observed background concentrations, then the mean of the background level may be over-estimated, which may result in not remediating a contaminated area of the site. Stewart (1994) also showed that the incorrect usage of a lognormal distribution may lead to erroneous results.

Most of the "classical" statistical methods based on the normal distribution were developed between 1920 and 1950 and have been well investigated in the statistical literature. On the other hand, lognormal-based methods have not received the same level of scrutiny. Furthermore, the classical methods became popular due to their computational convenience. The 1980s have produced a new breed of statistical methods based on the power and availability of computers (see, for example, Efron and Gong, 1983). Both the jackknife and bootstrap methods require a great deal of computer power, and, therefore, have not been widely adopted by environmental statisticians. However, with the recent advances in computer equipment and software, computationally intensive statistical procedures have become more practical and accessible.

The authors of this article have critically reviewed several estimation procedures which can be used to compute UCL values via monte carlo simulation. These include the simple arithmetic mean, the Minimum Variance Unbiased Estimate (MVUE), and nonparametric procedures such as the jackknife and the bootstrap procedures. Computer simulation experiments (not included in this paper) have been performed for various values of the population standard deviation, or equivalently the Coefficient of Variation (CV), and sample sizes ranging from 10 to 101. It has been demonstrated that for samples of size 30 or less, the H-statistic based UCL results in unacceptably high estimates of the threshold levels such as the background level contamination. This is especially true for data sets from populations with CV values exceeding 1. For samples of larger sizes, the use of H-statistics can be replaced by UCLs based on nonparametric methods such as the jackknife or the bootstrap. Other well-known results such as the central limit (CLT) and Chebychev theorems may also be used to obtain UCLs. To illustrate problems associated with methods based on lognormal theory, results for some simulated examples and some from Superfund work done by the authors have been included in this paper.

2. THE LOGNORMAL DISTRIBUTION

The authors briefly describe the lognormal distribution. By definition, contaminant concentration is lognormally distributed if the log-transformed concentrations are normally distributed. This can be mathematically described as follows:

If $Y = \ln(X)$ is normally distributed with mean, μ, and variance, σ^2, then X is said to be lognormally distributed with parameters μ and σ^2. It should be noted that μ and σ^2 are not the mean and variance of the lognormal random variable, X, but they are the mean and variance of the log-transformed random variable, Y. However, it is common practice to use the same parameters to specify either, and it is convenient to refer to the

normal distribution with the abbreviated notation $Y \sim N(\mu, \sigma^2)$ and the log-normal distribution with the abbreviation $X \sim LN(\mu, \sigma^2)$. Figure 2, which shows plots of a normal and a lognormal density function with $\mu = 0$ and $\sigma^2 = 0.5$, illustrates the difference between normal and lognormal distributions.

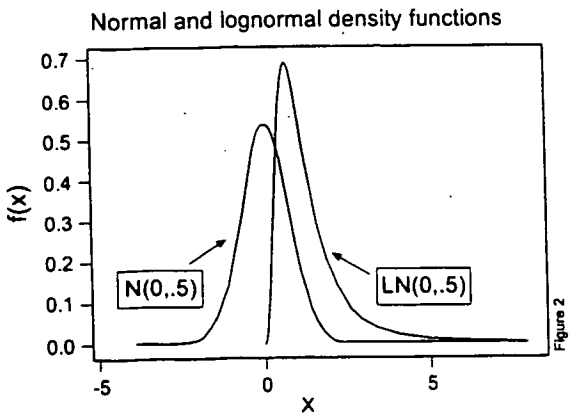

Figure 1 Graphs of normal $N(\mu = 0, \sigma^2 = 0.5)$ and lognormal $LN(\mu = 0, \sigma^2 = 0.5)$ density functions.

Figure 3, which shows plots of several lognormal distributions, each with $\mu = 0$, illustrates how varying the parameter σ^2 can change the amount of skewness.

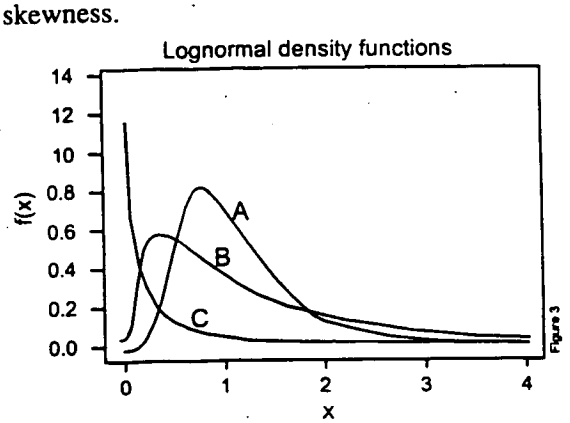

Figure 2 Graphs of A: $LN(\mu = 0, \sigma^2 = 0.25)$, B: $LN(\mu = 0, \sigma^2 = 1.0)$ and C: $LN(\mu = 0, \sigma^2 = 25.0)$ density functions.

The parameters of interest of a lognormal distribution, $LN(\mu, \sigma^2)$, are given as follows:

$$\text{Mean} = \mu_1 = \exp(\mu + 0.5\sigma^2) \quad (1)$$

$$\text{Median} = \exp(\mu) \quad (2)$$

$$\text{Variance} = \sigma_1^2 = [\exp(2\mu + \sigma^2)][\exp(\sigma^2) - 1] \quad (3)$$

$$\text{Coefficient of Variation} = CV = \sigma_1/\mu_1 = \sqrt{\exp(\sigma^2) - 1} \quad (4)$$

$$\text{Skewness} = (CV)^3 + 3(CV). \quad (5)$$

Throughout this paper, irrespective of the underlying distribution, μ_1, and σ_1^2 represent the mean and variance of the random variable X (in original units), whereas μ and σ^2 are the mean and variance of its logarithm given by Y=ln(X). The pth quantile (or 100pth percentile), x_p, of the distribution of a random variable, X, is defined by the probability statement $P(X \le x_p) = p$. If z_p is the pth quantile of the distribution of the standard normal random variable, Z, with $P(Z \le z_p) = p$, then the pth quantile of a lognormal distribution is given by $x_p = \exp(\mu + z_p\sigma)$. For example, on the average, 95% of the observations from a lognormal $LN(\mu, \sigma^2)$ distribution would lie below $\exp(\mu + 1.65\sigma)$. Because the 0.5th quantile of the standard normal distribution is $z_{0.5} = 0$, the 0.5th quantile (or median) of a lognormal distribution is $\exp(\mu)$, which is obviously smaller than the mean, μ_1, which is given by Equation (1). In this paper, several procedures to estimate the UCL of the mean have been considered. Ordinarily, one would expect the spread of an estimate of the mean to be smaller than the spread of the population itself (see Figure 4). Thus, intuitively, the 95% UCL of the mean should be smaller than the 95th percentile of the corresponding lognormal distribution. In many instances with lognormal-based methods, this statement is violated even on lognormal data, especially for smaller sample sizes. The quantiles discussed above are used later to shed some light on the behavior of the UCL of the mean which are based on the H-statistic.

One of the inherent assumptions required to compute the UCL of the mean is that the data set under consideration comes from a single statistical population (e.g., background only). Violation ofthis assumption can lead to invalid applications of a statistical technique. The consequences of

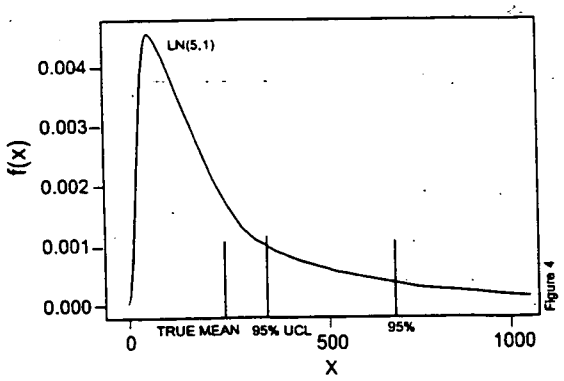

Figure 3 Graphs showing the relative positions of the TRUE MEAN, the 95% UCL, and the 95-th percentile..

this assumption being violated are discussed as follows. A data set can be put into a statistical procedure (e.g., the Shapiro-Wilks test of normality) or a computer program whether or not the required assumptions are met. It is the user's responsibility to ensure the underlying assumptions required to conduct the statistical procedure are met. The decisions and conclusions derived from incorrectly used statistics can be expensive. For example, incorrect use of a statistic may lead to wrong conclusions such as: 1) remediation of a clean part of the site, or 2) no remediation at a contaminated part of the site. The first wrong conclusion will result in an unnecessary cleanup whereas the second incorrect conclusion may cause a threat to human health and the environment. It is likely that the availability of new and improved statistical software has also increased the misuse of statistical techniques. This is illustrated in the following discussion of the application to some simulated and real data sets. It should be reiterated that it is the analyst's (user's) responsibility to verify that none of the required assumptions are violated before using a statistical test and deriving inferences based upon the resulting analysis. In many cases, this may warrant expert advice from a statistician.

Often, the central portion of a data set will behave as if it came from a normal distribution. However, in practice, a normally distributed data set with a few extreme (high) observations can be incorrectly modeled by the lognormal distribution with the lognormal assumption hiding the outliers. Also, the mixture of two or more normally distributed data sets with significantly different mean concentrations such as one coming from the clean background part and the other taken from a contaminated part of the site can also be modeled (incorrectly) by a lognormal distribution. The following example illustrates this point.

Example 2.1. Simulated data set from two populations

A simulated data set of size fifteen (15) has been obtained from a mixture of two normal populations. Ten observations (representing background) were generated from a normal distribution with mean, 100, and standard deviation, 50, and five observations (representing contamination) were generated from a normal distribution with mean, 1000, and standard deviation, 100. The mean of this mixture distribution is 400. The generated data are as follows: 180.5071, 2.3345, 48.6651, 187.0732, 120.2125, 87.9587, 136.7528, 24.4667, 82.2324, 128.3839, 850.9105, 1041.7277, 901.9182, 1027.1841, and 1229.9384.

Discussion of Example 2.1

The data set in Example 2.1 failed the normality test based on several goodness-of-fit tests such as the Shapiro-Wilks, W-test (W=0.7572), and Kolmogorov-Smirnov (K-S = 0.35) tests (see Figures 5 and 6). However, when these tests were carried out on the log-transformed

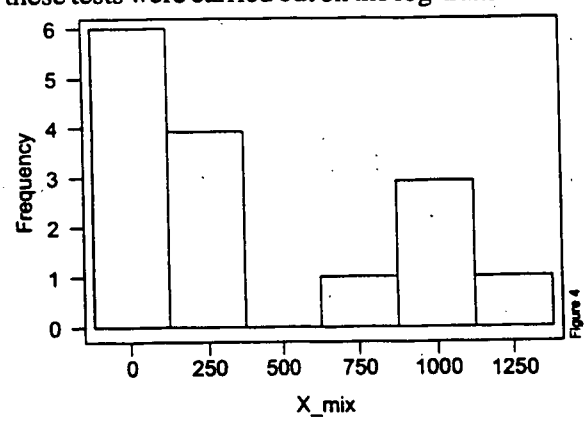

Figure 4 Histogram of the 15 observations from the mixture population of Example 2.1.

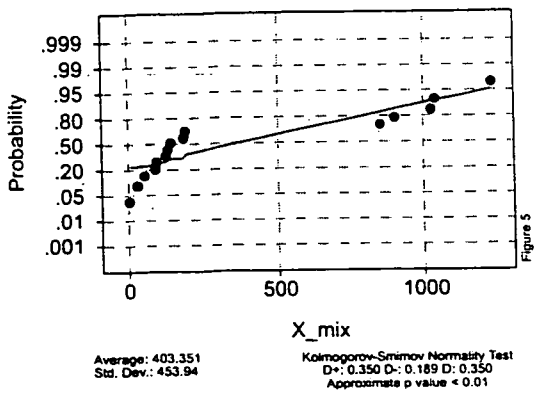

Figure 5 K-S test of normality for the data of Example 2.1.

data, the test statistics are insignificant at the α = 0.05 level of significance with W=0.8957, and K-S = 0.168, suggesting that a lognormal distribution (see Figures 7 and 8) provides a reasonable fit to the data. Based upon this test, one might incorrectly conclude that the observed concentrations come from a single background lognormal population. This incorrect conclusion is made quite frequently. This data set is used later to illustrate how modeling the mixture data set by a lognormal distribution will result in incorrect estimates of mean contamination levels at various parts of the site.

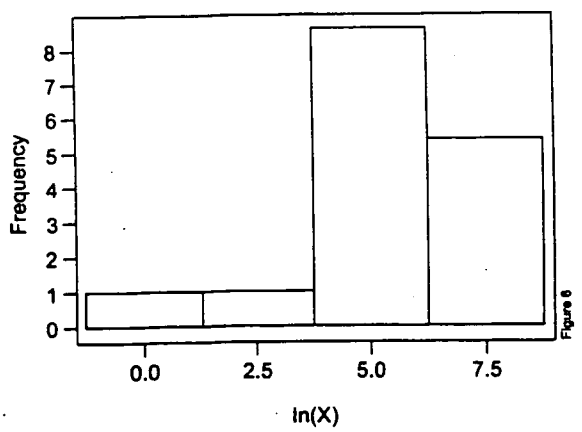

Figure 6 Histogram of the log-transformed 15 observations from the mixture population of Example 2.1.

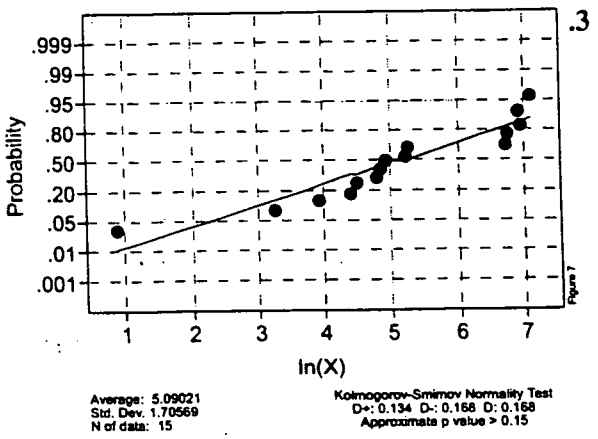

Figure 7 K-S test of lognormality for the data of Example 2.1.

METHODS OF COMPUTING A UCL OF THE MEAN

The main objective of this study is to assess the performances of the various methods of estimating the UCL for the mean, μ_1, of positively skewed populations. The assumption of a lognormal distribution to model such populations has become quite popular among environmental scientists (Ott, 1990). As noted in Section 2, for positively skewed data sets, there are potential problems in using standard methods based on the lognormal theory. Therefore, we will compare the lognormal-based methods often used with cleanup standards with some other available methods. The alternate methods considered here have the advantage that they do not require assumptions about the specific form of the population distribution. In other words, they do not assume normality or lognormality of the data set under consideration. In Section 4, the UCL of the mean has been computed for several examples using the following methods:

- The H-statistic
- The Jackknife procedure
- The Bootstrap procedure
- The Central Limit Theorem
- The Chebychev Theorem

A brief description of the computation of the various estimates and the associated confidence limits obtained using the above-mentioned procedures follows:

Parametric Lognormal Procedures

Let $x_1, x_2, \ldots, x_n$ be a random sample from a lognormal distribution with mean, μ_l, and variance, σ_l^2, and denote by μ and σ the population mean and population standard deviation (sd), and $\bar{y}$, and s_y the sample mean and sample sd, respectively, of the log-transformed data $y_i = \ln(x_i)$; $i = 1, 2, \ldots, n$. . Specifically,

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{6}$$

and

$$s_y^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2. \tag{7}$$

In a more general setting, consider a population with an unknown parameter, θ. The minimum variance unbiased estimate (MVUE) of θ is the one that is not only an unbiased estimate of θ (i.e., the expected value of the estimate is equal to the true value of the parameter), but it also has a smaller variance than any other unbiased estimate of θ. When the parameter of interest is the mean, μ_1, of a lognormally distributed population, Bradu and Mundlak (1970) derive its MVUE, which is given by

$$\hat{\mu}_1 = \exp(\bar{y})g_n\left(s_y^2/2\right) \tag{8}$$

where $g_n(u)$ is a function whose form is rather complicated, but an infinite series solution is given by Aitchison and Brown (1976). Tabulations of this function are provided by Gilbert (1987, Table A9). Note that Gilbert uses ψ_n in place of g_n. This function is also used in computing the MVUE of the variance, σ_1^2, of a lognormal population, as given by Finney (1941),

$$\hat{\sigma}_1^2 = \exp(2\bar{y})\left[g_n\left(2s_y^2\right) - g_n\left((n-2)s_y^2/(n-1)\right)\right]. \tag{9}$$

Bradu and Mundlak (1970) give the MVUE of the variance of the estimate $\hat{\mu}_1$,

$$\hat{\sigma}^2(\hat{\mu}_1) = \exp(2\bar{y})\left[\left(g_n\left(s_y^2/2\right)\right)^2 - g_n\left((n-2)s_y^2/(n-1)\right)\right]. \tag{10}$$

Another estimate which is also sometimes used is known as the Maximum Likelihood Estimate (MLE). When the data set is a random sample from a lognormal distribution, the MLE of the parameter, μ, is simply the sample mean of the log-transformed data, $\hat{\mu} = \bar{y}$, and the MLE of σ^2 is a multiple of the sample variance of the log-transformed data, namely, $\hat{\sigma}^2 = [(n-1)/n]s_y^2$. The MLE of any function of the parameters μ and σ^2 is obtained by simply substituting these MLEs in place of the parameters. For example, the MLE of the mean of a lognormal population is $\exp(\hat{\mu} + 0.5\hat{\sigma}^2)$, and the MLE of the 95th percentile is $\exp(\hat{\mu} + 1.65\hat{\sigma})$. One disadvantage of the MLEs for the lognormal mean and percentiles is that they are biased estimates. Another slight modification uses s_y in place of the MLE, $\hat{\sigma}$. Although the result is not identical to the MLE, there is only a small difference numerically, and for convenience the use of the term MLE will also include this modified version.

Finally, the one-sided $(1-\alpha)100\%$ UCL for the mean, μ_1, of the lognormal distribution derived by Land (1971, 1975) is given as follows:

$$UCL = \exp\left[\bar{y} + 0.5s_y^2 + s_y H_{1-\alpha}/\sqrt{n-1}\right]. \tag{11}$$

Tables of H-statistic values can be found in Land (1975) and also in Gilbert (1987, Table A10).

Use of the UCL for a population mean based on the H-statistic is widely recommended in environmental guidance documents. Theoretically, the UCL based on the H-statistic has optimal properties when the population is truly lognormal. However, in practice the results can be quite disappointing and misleading if the data set includes outliers, or is a mixture of data from two or more distributions. Monte carlo investigations performed by the authors confirm that, for small sample sizes, the use of the H-statistic approach can result in unacceptably high values of UCL when the CV is larger than 1.0.

Consequently, other methods for computing a UCL of the mean, μ_1, of a distribution of unspecified form will be considered and the results compared with UCLs obtained by the H-statistic approach.

The methods considered in this paper can be viewed as variations of a basic approach to constructing confidence intervals known as the pivotal quantity method. In general, a pivotal quantity is a function of both the parameter θ and an estimate $\hat{\theta}$ such that probability distribution of the pivotal quantity does not depend on θ. Perhaps the best-known example of a pivotal quantity is the well-known t statistic,

$$t = \frac{\bar{x} - \mu_1}{s_x/\sqrt{n}} \tag{12}$$

where $\bar{x}$ and s_x are, respectively, the sample mean and sample standard deviation. If the data is a random sample from a normal population with mean, μ_1, and standard deviation, σ_1, then the distribution of this pivotal quantity is the familiar Student's t distribution with $n-1$ degrees of freedom. Because the Student's t distribution does not depend on either unknown parameter, quantiles are available. Denote by $t_{\alpha,n-1}$ the upper αth quantile of the Student's t distribution with $n-1$ degrees of freedom. Based on equation (12), it is possible to derive a $(1-2\alpha)100\%$ confidence interval of the form

$$\left(\bar{x} - t_{\alpha,n-1}s_x/\sqrt{n},\ \bar{x} + t_{\alpha,n-1}s_x/\sqrt{n}\right). \tag{13}$$

The confidence interval is given in the familiar form of a two-sided confidence interval for the mean. If the lower limit of this interval is disregarded, the upper limit provides a $(1-\alpha)100\%$ UCL for the mean, μ_1.

For a population which is normally distributed, equation (13) provides the best way of constructing confidence intervals for the population mean. However, as noted previously, the distribution of contaminant concentration data is typically positively skewed and frequently involves outliers. It is well known that the sample mean and sample standard deviation get severely distorted in the presence of outliers, (Singh and Nocerino 1995), and consequently any function, such as the Student's t, given by equation (12) above of these statistics also gets severely influenced by the presence of outliers. Robust methods for estimating the population mean and sd are available in the software package, SCOUT, as identified in Singh and Nocerino (1995). In practice, statistical procedures based on the pivotal quantity (equation 12) are usually thought to be "robust" relative to violation of the normality assumption. As noted by Staudte and Sheather (1990), tests based on the Student's t are nonrobust in the presence of outliers. Consequently, other procedures which do not rely on a specific parametric assumption for the population distribution are also considered in the following discussion.

The approach of constructing confidence intervals from pivotal quantities (or approximate pivotal quantities) permits a unified treatment of these alternate procedures. In particular, each procedure involves an approximate pivotal quantity with the difference between the unknown population mean, μ_1, and a point estimate of the mean in the numerator, and an estimate of the standard error of the point estimate in the denominator. Thus, each procedure involves two parts: 1) finding some reasonably robust estimate of the mean, (Singh and Nocerino 1995), and 2) providing a convenient way to obtain quantiles of the pivotal quantity. A general discussion of the pivotal quantity approach to constructing confidence intervals is given by Bain and Engelhardt (1992).

As noted above, in order to apply the pivotal quantity method, it is necessary to have quantiles of the distribution of the pivotal quantity. For example, in order to compute equation (13), it is necessary to have quantiles of the Student's t distribution. These quantiles can be found in tables or computed with the appropriate software. However, for nonnormal populations the required quantiles are not, in general, readily available. In some cases, even though the exact distribution of a pivotal quantity is not known, an approximate distribution can be used. Thus, except for the H-

statistic approach, which is exact if the population is truly lognormal, all of the other methods discussed below give only approximate UCL values for the population mean. The true confidence level of UCLs will vary from one method to the next, and without some additional study, it will not be clear whether the comparisons are fair. In other words, it is possible to have a smaller UCL at the expense of a true confidence level which is below the nominal level, and below the true confidence level of another competing method.

In environmental applications, the objectives typically are: 1) the identification of hot spots, which are typically represented by the high extreme concentrations, or 2) the separation of clean part(s) of a site from the dirty contaminated part(s) of the site. However, from the examples discussed in the following, it can be seen that the practical use of the lognormal distribution in those environmental applications is questionable as a lognormal distribution often accommodates extreme outlying observations and mixture populations as part of one lognormal distribution.

Jackknife and Bootstrap Procedures

General methods for deriving estimates, such as the method of maximum likelihood, often result in estimates which are biased. Bootstrap and jackknife procedures as discussed by Efron (1982) and Miller (1974) are nonparametric statistical techniques which can be used to reduce the bias of point estimates and construct approximate confidence intervals for parameters such as the population mean. These two procedures require no assumptions regarding the statistical distribution (e.g., normal or lognormal) for the underlying population, and can be applied to a variety of situations no matter how complicated. However, it should be pointed out that a use of a parametric statistical method (depending upon distributional assumptions), when appropriate, is more efficient than its nonparametric counterpart. In practice, parametric assumptions are often difficult to justify, especially in environmental applications. In these cases, nonparametric methods are valuable tools for obtaining reliable estimates of the parameters of interest. Although bootstrap and jackknife procedures are conceptually simple, they are based on resampling techniques requiring considerable computing power and time.

Let $x_1, x_2, \ldots, x_n$ be a random sample of size n from a population with an unknown parameter θ ($e.g., \theta = \mu_l$), and let $\hat{\theta}$ be an estimate of θ which is a function of all n observations. For example, the parameter θ could be the mean, and a reasonable choice for the estimate $\hat{\theta}$ might be the sample mean, $\bar{x}$. Another choice is the MVUE of a lognormal mean. Of course, if the population is not lognormal then this estimate may not perform well: but, because it is frequently used with skewed data sets, it is of interest to see how it performs relative to the other methods.

Jackknife Estimation

In the jackknife approach, n estimates of θ are computed by deleting one observation at a time. Specifically, for each index, i, denote by $\hat{\theta}_{(i)}$ the estimate of θ (computed similarly as $\hat{\theta}$ given above) when the ith observation is omitted from the original sample of size n, and denote the arithmetic mean of these estimates by

$$\bar{\theta} = \frac{1}{n}\sum_{i=1}^{n} \hat{\theta}_{(i)}. \tag{14}$$

A quantity known as the ith "pseudo-value" is defined by

$$J_i = n\hat{\theta} - (n-1)\hat{\theta}_{(i)}. \tag{15}$$

The jackknife estimator of θ is given by

$$J(\hat{\theta}) = \frac{1}{n}\sum_{i=1}^{n} J_i = n\hat{\theta} - (n-1)\bar{\theta}. \tag{16}$$

If the original estimate $\hat{\theta}$ is biased, then, under certain conditions, part of the bias is removed by the jackknife procedure, and an estimate of the standard error of the jackknife estimate, $J(\hat{\theta})$, is given by

$$\hat{\sigma}_{J(\hat{\theta})} = \sqrt{\frac{1}{n(n-1)}\sum_{i=1}^{n}\left(J_i - J(\hat{\theta})\right)^2}. \tag{17}$$

Another application of the pseudo-values, suggested by J. Tukey (see Miller, 1974), is to use the pseudo-values to obtain confidence intervals for the parameter, θ, based on the following pivotal quantity:

$$t = \frac{J(\hat{\theta}) - \theta}{\hat{\sigma}_{J(\hat{\theta})}}. \tag{18}$$

The statistic, t, given by equation (18) has an approximate Student's t distribution with $n-1$ degrees of freedom, which can be used to derive the following approximately two-sided $(1-2\alpha)100\%$ confidence interval for θ:

$$\left(J(\hat{\theta}) - t_{\alpha,n-1}\hat{\sigma}_{J(\hat{\theta})},\ J(\hat{\theta}) + t_{\alpha,n-1}\hat{\sigma}_{J(\hat{\theta})}\right). \tag{19}$$

The upper limit of equation (19) is an approximate $(1-\alpha)100\%$ UCL for θ. If the sample size, n, is large, then the upper αth t-quantile can be replaced with the corresponding upper αth standard normal quantile, z_α. Observe also that when $\hat{\theta}$ is the sample mean, then the jackknife estimate is the sample mean, that is $J(\bar{x}) = \bar{x}$; the estimate of the standard error in equation (17) simplifies to $s_x/n^{1/2}$, and the confidence interval in equation (19) reduces to the familiar t-statistic based confidence interval given by equation (13).

Bootstrap Estimation

In the bootstrap procedure, repeated samples of size n are drawn with replacement from the given set of observations. The process is repeated a large number of times, and each time an estimate of θ is computed. The estimates thus obtained are used to compute an estimate of the standard error of $\hat{\theta}$. There exists in the literature of statistics an extensive array of different bootstrap methods for constructing confidence intervals. In this article two of these methods are considered: 1) the standard bootstrap, and 2) the pivotal (or Studentized) bootstrap method as discussed by Hall (1988). A general description of bootstrap methods, illustrated by application to the sample mean, follows:

Step 1. Let $(x_{i1}, x_{i2}, \ldots, x_{in})$ represent the ith sample of size n **with replacement** from the original data set $(x_1, x_2, \ldots, x_n)$. Then compute the sample mean and denote it by $\bar{x}_i$.

Step 2. Perform Step 1 independently N times (e.g., 500-1000), each time calculating a new estimate. Denote those estimates by $\bar{x}_1, \bar{x}_2, \bar{x}_3, \ldots, \bar{x}_N$. The bootstrap estimate of the population mean is the arithmetic mean, $\bar{x}_B$, of the N estimates $\bar{x}_i$. The bootstrap estimate of the standard error is given by

$$\hat{\sigma}_B = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(\bar{x}_i - \bar{x}_B\right)^2}. \tag{20}$$

If some parameter, θ (say, a population median), other than the mean is of concern, with an associated estimate (e.g., the sample median), then the same steps previously described could be applied with the parameter and its estimate used in place of μ_1 and $\bar{x}$. Specifically, the estimate, $\hat{\theta}_i$, would be computed, instead of $\bar{x}_i$, for each of the N bootstrap samples. The general bootstrap estimate, denoted by $\bar{\theta}_B$, is the arithmetic mean of the N estimates. The difference, $\bar{\theta}_B - \hat{\theta}$, provides an estimate of the bias of the estimate, $\hat{\theta}$, and the bootstrap estimate of the standard error of $\hat{\theta}$ is given by

$$\hat{\sigma}_B = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(\hat{\theta}_i - \bar{\theta}_B\right)^2}. \tag{21}$$

The standard bootstrap confidence interval is derived from the following pivotal quantity:

$$z = \frac{\hat{\theta} - \theta}{\hat{\sigma}_B}. \tag{22}$$

Finally, the $(1-2\alpha)100\%$ standard bootstrap confidence interval for θ, which assumes that equation (22) is approximately normal, is

$$\left(\hat{\theta} - z_\alpha\hat{\sigma}_B,\ \hat{\theta} + z_\alpha\hat{\sigma}_B\right). \tag{23}$$

In this case, the bootstrap approach gives a convenient way to estimate the standard error of $\hat{\theta}$. Depending on the type of estimate $\hat{\theta}$, the

standard error may be quite difficult to derive, and consequently difficult to estimate. However, the bootstrap approach always yields an estimate of the standard error directly from the data, even when the mathematical form of the standard error is not known.

Another variation of the bootstrap method, called the "bootstrap t" by Efron (1982), is a nonparametric procedure which uses the bootstrap methodology to estimate quantiles of the pivotal quantity in equation (12). As previously noted, for nonnormal populations the required quantiles may not be easily obtained, or it may be impossible to compute exactly. However, with a variation of the bootstrap procedure, as proposed by Hall (1988), the required quantiles can be estimated directly from the data. Specifically, in Steps 1 and 2 described above, if $\bar{x}$ is the sample mean computed from the original data, and $\bar{x}_i$ and $s_{x,i}$ are the sample mean and sample standard deviation computed from the ith resampling of the original data, the N quantities, $t_i = (\bar{x}_i - \bar{x})/s_{x,i}$, are computed and sorted, yielding ordered quantities $t_{(1)} \le t_{(2)} \le \cdots \le t_{(N)}$. The estimate of the upper αth quantile of the pivotal quantity in equation (12) is $t_{\alpha,B} = t_{((1-\alpha)N)}$. For example, if $N = 1000$ bootstrap samples are generated, then the 950th ordered value, $t(950)$, would be the bootstrap estimate of the upper .05th quantile of the pivotal quantity in equation (12). This estimated quantile can be used in place of the upper αth Student's t quantile in an interval of the form given in equation (13). In the next section, this method of construction will be called the "pivotal bootstrap". This approach has the advantage that it does not rely on the assumption of a special parametric form for the distribution of the population, and it does not require an assumption of approximate normality for the pivotal quantity as does the standard bootstrap interval of equation (23).

In the examples to follow, the jackknife, the standard bootstrap method, and the pivotal bootstrap methods are applied using the sample mean, $\bar{x}$, and also the estimate given by equation (8), which is the MVUE of the mean when the population is lognormal.

The Central Limit Theorem

Given a random sample, $x_1, x_2, \ldots, x_n$, of size n from a population with a finite variance, σ_1^2, where $\theta = \mu_1$ is the unknown population mean, the Central Limit Theorem (CLT) states that the asymptotic distribution, as n approaches infinity, of the sample mean, $\bar{x}_n$, is normally distributed with mean, μ_1, and variance, σ_1^2/n. More precisely, the sequence of random variables

$$z_n = \frac{\bar{x}_n - \mu_1}{\sigma_1/\sqrt{n}} \tag{24}$$

has a standard normal limiting distribution. In practice, this means that for large sample sizes n, the sample mean, $\bar{x}$, has an approximate normal distribution irrespective of the underlying distribution function. Consequently, equation (24) is an approximate pivotal quantity for large n. This powerful result can be used to obtain approximate $(1-2\alpha)100\%$ confidence intervals for the mean for any distribution with a finite variance, although, strictly speaking, it requires one to know the population standard deviation, σ_1. However, as noted by Hogg and Craig (1978), if σ_1 is replaced by the sample standard deviation, s_x, the normal approximation for large n is still valid. This leads to the following confidence interval:

$$\left(\bar{x} - z_\alpha s_x/\sqrt{n},\ \bar{x} + z_\alpha s_x/\sqrt{n}\right). \tag{25}$$

Note that the confidence interval in equation (25) has the same general form as equation (13), but with the t quantiles replaced with approximate standard normal quantiles. As noted previously, if the lower limit is disregarded, the upper limit of the interval provides a one-sided UCL for the population mean.

An often cited rule of thumb for a sample size with the CLT is $n \ge 30$. However, this may not be adequate if the population is highly skewed. A refinement of the CLT approach, which makes an adjustment for skewness, is discussed by Chen (1995). Specifically, the "adjusted CLT" UCL is obtained if the standard normal quantile, z_α, in the upper limit of equation (25) is replaced by

$$z_{a,adj} = z_a + \frac{\hat{\kappa}_3}{6\sqrt{n}}\left(1 + 2z_a^2\right) \tag{26}$$

where $\hat{\kappa}_3$ is the sample coefficient of skewness,

$$\hat{\kappa}_3 = \frac{1}{n s_x^3}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^3. \tag{27}$$

Notice that this adjustment results in a UCL which is larger than that of equation (25) when the sample skewness is positive.

The Chebychev Theorem

This theorem is given here to obtain a reasonably conservative estimate of the UCL of the mean. The two-sided Chebychev theorem states that given a random variable, X, with finite mean and standard deviation, μ_1 and σ_1, one has

$$P\left(-k\sigma_1 \le X - \mu_1 \le k\sigma_1\right) \ge 1 - 1/k^2. \tag{28}$$

This result can be applied with the sample mean, $\bar{x}$, to obtain a conservative UCL for the population mean. Specifically, if the right side of equation (28) is equated to 0.95, then $k = 4.47$, and $UCL = \bar{x} + 4.47\sigma_1/n^{1/2}$ is a conservative 95% upper confidence limit for the population mean. Of course, this would require the user to know the value of σ_1. The obvious modification would be to replace σ_1 with the sample standard deviation, s_x, but, since this is estimated from the data, the result is no longer guaranteed to be conservative. In general, if μ_1 is an unknown mean, $\hat{\mu}_1$ is an estimate and $\hat{\sigma}(\hat{\mu}_1)$ is an estimate of the standard error of $\hat{\mu}_1$, then the quantity $UCL = \hat{\mu}_1 + 4.47\hat{\sigma}(\hat{\mu}_1)$ will give 95% UCLs for μ_1, which should tend to be conservative, but this is not assured. This could be used, for example, with the mean of a lognormal population, using equation (8), as the estimate of the population mean and the square root of equation (10) as the estimate of the standard error. This has been used in the following examples.

4. EXAMPLES

Monte carlo simulation experiments were performed to compare various methods of computing the UCL of the lognormal mean. Based on these experiments, the methods of jackknife, bootstrap, or even the conservative method based on the Chebychev inequality appear to be superior to the H-statistic-based UCL for small sample sizes. When the number of samples is large ($n \ge 100$), all of these methods give similar results. In this section, a few simulated examples are provided to compare the various methods of computing values of the UCL. A few examples from Superfund sites have also been included.

Example 4.1. Simulated sample from a mixture of two normal populations, N(100, 50) and N(1000, 100).

This example uses the sample of size n = 15 which was discussed previously in Example 2.1. Recall, that this is a simulated sample from a mixture of two normal populations. The mean of the mixed normal population is μ_1 = 400. The values of the mean, standard deviation, and coefficient of variation computed for the log-transformed data are:

$\bar{y}$ = 5.090, s_y = 1.705, and CV_y = 0.34.

The values of the mean, standard deviation, and CV computed for the raw data are:

$\bar{x}$ = 403.35, s_x = 453.94, and CV_x = 1.125.

If it is assumed (incorrectly) that the population is lognormal, point estimates based on MVUE theory of the mean, μ_1, standard deviation, σ_1, and standard error of the mean are 572.98, 1334.56 and 290.14, respectively. Estimates of the 80th, 90th, and 95th percentiles of a lognormal distribution are 686.33, 1453.48, and 2685.56, respectively.

Discussion of Example 4.1

The 95% UCL values obtained from the methods discussed above, without using lognormal theory, are:

Jackknife	609.75
Standard Bootstrap	584.32
Pivotal Bootstrap	651.52
CLT	596.16
Adjusted CLT	618.51
Chebychev	927.27

The values of the 95% UCL obtained from the methods discussed above, calculated using the lognormal theory, are:

Jackknife	1085.17
Standard Bootstrap	994.40
Chebychev	1869.90
H-UCL	4150.96

Notice that the 95% UCL computed from the H-statistic (4150.96) exceeds the estimated 95th percentile (2685.56) of an assumed lognormal distribution. The H-UCL is also an order of magnitude larger than the true mean, 400, of the mixture of two normal populations.

It is also of interest to see how the methods compare when applied to simulated lognormal data with different sample sizes and various combinations of parameter values.

Example 4.2. Simulated sample of size n = 15 from a lognormal distribution, LN(5, 1).

In this example, n = 15 data were generated from the lognormal distribution LN(5,1), with following (true) values of population parameters: μ_1 = 244.69, σ_1 = 320.75, and CV = 1.31. The generated data are:

139.2056, 259.9746, 138.7997, 48.8109, 166.1733, 54.1241, 120.3665, 60.9887, 551.2073, 66.3336, 16.0695, 364.5569, 153.2404, 271.5436, 473.6461.

The values of the sample mean, standard deviation, and CV of the log-transformed data are:

$\bar{y}$ = 4.887, s_y = 0.966, CV_y = 0.20.

The sample mean, standard deviation, and CV for the raw data are:

$\bar{x}$ = 192.34, s_x = 161.56, CV_x = 0.84.

For a lognormal distribution, the estimates of μ_1, σ_1, and the standard error of the mean, based on MVUE theory, are 202.58, 219.21, and 54.00, respectively. The MLEs of μ_1, σ_1, and CV are 211.33, 262.47, and 1.24, respectively. Estimates of the 80th, 90th, and 95th percentiles of the lognormal distribution are 299.79, 458.58, and 649.31, respectively.

Discussion of Example 4.2

The values of the 95% UCL obtained from the methods discussed above, without using lognormal theory, are:

Jackknife	265.79
Standard Bootstrap	258.21
Pivotal Bootstrap	292.17
CLT	260.96
Adjusted CLT	271.57
Chebychev	378.80

The values of the 95% UCL obtained from the methods discussed above, calculated from lognormal theory, are:

Jackknife	289.30
Standard Bootstrap	281.22
Chebychev	448.41
H-UCL	427.62

The differences in UCLs for the various methods are not as extreme as they were in the previous example, but a similar pattern with the Chebychev (as expected) and H-UCL limits being the largest is still present. However, unlike the previous example, the 95% UCL is below the estimated 95th percentile of a lognormal distribution, as one would intuitively expect. It is also interesting to note that the CV estimated as the ratio of the sample standard deviation to the sample mean from raw data is less than 1 (0.84), while the CV computed from the MLEs is slightly greater than 1 (1.24). According to the CV test, which says that if CV <1.0, then the population is normally distributed, the former CV of 0.84 might lead one to incorrectly assume that the population is normally distributed.

In the next example, the variance of the log-transformed variable is increased slightly with a corresponding increase in CV and skewness.

Example 4.3. Simulated sample of size n = 15 from a lognormal distribution, LN(5, 1.5).

In this example, n = 15 observations were generated from the lognormal distribution, LN(5,1.5), with the following true values of population parameters: μ_1 = 457.14, σ_1 = 1331.83, CV = 2.91. The generated data are:

440.8517, 1013.4986, 1857.7698, 500.9632, 397.9905, 110.7144, 196.2847, 128.2843, 1529.9753, 5.7978, 940.8903, 597.5925, 1519.5159, 181.6512, 52.8952.

The sample mean, standard deviation, and CV of the log-transformed data are:

$\bar{y}$ = 5.761, s_y = 1.536, and CV_y = 0.27.

The sample mean, standard deviation, and CV for the raw data are:

$\bar{x}$ = 631.65, s_x = 603.13, and CV_x = 0.96.

For a lognormal distribution, the estimates of μ_1, σ_1, and standard error of the mean, based on MVUE theory, are 894.76, 1784.95, and 405.79, respectively. The MLEs of μ_1, σ_1, and CV are 1033.63, 3202.28 and 3.10, respectively. Estimates of the 80th, 90th, and 95th percentiles of the lognormal distribution are 1163.05, 2286.63, and 3975.71, respectively.

Discussion of Example 4.3

The values of the 95% UCL obtained from the methods discussed above, without using lognormal theory, are:

Jackknife	905.88
Standard Bootstrap	882.82
Pivotal Bootstrap	977.18
CLT	887.82
Adjusted CLT	919.81
Chebychev	1327.75

The values of the 95% UCL obtained from the methods discussed above, calculated from lognormal theory, are:

Jackknife	1534.94
Standard Bootstrap	1363.26
Chebychev	2708.63
H-UCL	4570.27

As in the case of Example 4.1, the 95% H-UCL (4570.27) again exceeds the estimated 95th percentile of the lognormal distribution. The situation with the CV is similar to that of Example 4.2. That is, the CV computed from raw data (0.96) is less than 1, which by application of the CV-test could lead one to adopt (incorrectly) the normal distribution. Notice that the true CV and the estimate based on the MLEs are both close to three. The next example involves the same population but with a larger sample size.

Example 4.4. Simulated sample of size n = 31 from a lognormal distribution, LN(5, 1.5).

In this simulated example, n = 31 observations were generated from a lognormal distribution, LN(5,1.5). This is the same distribution use in the previous example, and thus true mean, standard deviation, and CV are the same. The generated data are:

49.0524, 806.8449, 122.2339, 697.7315, 2888.1238, 37.7998, 7.2799, 292.5909, 433.4413, 639.7468, 3876.8206, 1376.8859, 197.8634, 93.0379, 180.9311, 1817.9912, 284.3526, 344.6761, 44.8680, 297.3899, 11.9195, 100.5519, 264.7574, 41.3961, 43.4202, 1053.3770, 2067.0361, 132.2938, 75.9661, 53.2236, 83.5585.

The sample mean, standard deviation, and CV of log-transformed data are:

$\bar{y} = 5.326$, s_y=1.577, and $CV_y = 0.30$

The sample mean, standard deviation, and CV for raw data are:

$\bar{x} = 594.10$, $s_x = 919.05$, and $CV_x = 1.55$.

For a lognormal distribution, the estimates of μ_1, σ_1, and the standard error of the mean are 657.45, 1632.25, and 238.86, respectively. The MLEs of μ_1, σ_1, and CV are 713.34, 2369.11, and 3.32. Estimates of the 80th, 90th, and 95th percentiles of a lognormal distribution are 779.73, 1560.71, and 2753.62, respectively.

Discussion of Example 4.4

The values of the 95% UCL obtained from the methods discussed above, without using lognormal theory, are:

Jackknife	874.22
Standard Bootstrap	854.51
Pivotal Bootstrap	1003.00
CLT	865.64
Adjusted CLT	932.36
Chebychev	1331.95

The values of the 95% UCL obtained from the methods discussed above, calculated from lognormal theory, are:

Jackknife	1062.35
Standard Bootstrap	1088.94
Chebychev	1725.15
H-UCL	1792.54

As one might expect with a larger sample size (n = 31), the point estimates tend to be closer to the true parameter values they are intended to estimate. Also, there is not as much variation among the UCLs computed from the different methods. Furthermore, the H-UCL is below the estimated 95th percentile of the lognormal distribution.

In the next example, a sample of size $n = 15$ is considered again, but with the variance of the log-transformed variable slightly larger than that of Examples 4.2-4.4.

Example 4.5. Simulated sample of size $n = 15$ from a lognormal distribution, LN(5, 1.7).

This last simulated data set of size n = 15 is obtained from LN(5, 1.7), with the following true values of population parameters: $\mu_1 = 629.55$, $\sigma_1 = 2595.18$, CV = 4.12.

The generated data are:

16.5197, 235.4977, 1860.4443, 74.5825, 3.9684, 325.2712, 167.7949, 189.0130, 1307.6180, 878.8519, 35.4675, 96.2498, 229.2540, 182.0494, 1498.6146.

The sample mean, standard deviation, and CV of the log-transformed data are:

$\bar{y} = 5.178$, $s_y = 1.710$, $CV_y = 0.33$.

The sample mean, standard deviation, and CV for raw data are:

$\bar{x} = 473.41$, $s_x = 606.79$, $CV_x = 1.28$.

For a lognormal distribution, the estimates of μ_1, σ_1, and the standard error of the mean, based on MVUE theory, are 629.82, 1473.12, and 319.0, respectively. The MLEs of μ_1, σ_1, and CV are 765.52, 3213.52, and 4.20, respectively. Estimates of the 80th, 90th, and 95th percentiles for a lognormal distribution are 752.50, 1596.91, and 2955.58, respectively.

Discussion of Example 4.5

The values of the 95% UCL obtained from the four methods discussed above, without using lognormal theory, are:

Jackknife	749.31
Standard Bootstrap	721.07
Pivotal Bootstrap	862.51
CLT	731.14
Chebychev	1173.74

The values of the 95% UCL obtained from the four methods discussed above, calculated from lognormal theory, are:

Jackknife	1176.39
Standard Bootstrap	1141.95
Chebychev	2059.47
H-UCL	4613.32

Notice that in this example (as with Examples 4.1 and 4.3), the 95% H-UCL (4613.32) exceeds the estimated 95th percentile (2955.58) of the lognormal distribution.

The sample size and the mean of the log-transformed variable in examples 4.2, 4.3, and 4.5 are held constant at 15 and 5, respectively, whereas the standard deviation (sd) of the log-transformed variable are 1.0, 1.5, and 1.7, respectively. From these examples alone, it can be seen that as soon as the sd of the log-transformed variable becomes greater than 1.0, the H-statistic-based UCL becomes orders of magnitude higher than the largest concentrations observed, even when the data were obtained from a lognormal population. Thus, even though the H-UCL is theoretically sound and possesses optimal properties for truly lognormal populations such as being MVUE, the practical merit of the use of H-UCL in environmental applications is questionable when the sd of the log-transformed variable starts exceeding 1.0. This is especially true for small sample sizes (e.g., n <30). As seen in the examples discussed here, the use of the lognormal distribution and the H-UCL in some circumstances tends to hide contamination rather than find it, which is contrary to one of the main objectives in many environmental applications. Actually, under the assumption of lognormal distribution, one can get away with very little or no cleanup, (Bowers, Neil, and Murphy 1994), at a polluted site.

Example 4.6. Data from the Naval Construction Battalion Center (NCBC) Superfund Site in Rhode Island.

Inorganic analyses were performed on the groundwater samples from seventeen (17) wells from the NCBC Site. The main objective was to provide reliable estimates of the mean background threshold levels for the various inorganic contaminants at the site. The UCLs have been computed using the procedures described above. The results for two of the contaminants, aluminum and manganese, are summarized below.

Aluminum: 290, 113, 264, 2660, 586, 71, 527, 163, 107, 71, 5920, 979, 2640, 164, 3560, 13200, 125.

The sample mean, standard deviation, and CV of log-transformed data are:

$\bar{y} = 6.226$, $s_y = 1.659$, $CV_y = 0.27$.

The sample mean, standard deviation, and CV for the raw data are:

$\bar{x} = 1849.41$, $s_x = 3351.27$, $CV_x = 1.81$.

With the lognormal assumption, the estimates of μ_1, σ_1, and the standard error of the mean, based on MVUE theory, for aluminum are 1704.84, 3959.87, and 807.64, respectively. The MLEs of μ_1, σ_1, and CV are 2002.71, 7676.37, and 3.83, respectively. Estimates of the 80th, 90th and 95th percentiles for a lognormal distribution are 2054.44, 4263.44, and 7747.81, respectively.

Manganese: 15.8, 28.2, 90.6, 1490, 85.6, 281, 4300, 199, 838, 777, 824, 1010, 1350, 390, 150, 3250, 259.

The sample mean, standard deviation, and CV of log-transformed data are:

$\bar{y} = 5.91$, $s_y = 1.568$, $CV_y = 0.27$.

The sample mean, standard deviation, and CV for the raw data are:

$\bar{x} = 902.25$, $s_x = 1189.49$, $CV_x = 1.32$.

With the lognormal assumption, the estimates of μ_1, σ_1, and the standard error of the mean, based on MVUE theory, for manganese are 1100.92, 2340.72, and 490.16, respectively. The MLEs of μ_1, σ_1, and CV are 1262.59, 4125.5, and 3.27, respectively. Estimates of the 80th, 90th, and 95th percentiles for a lognormal distribution are 1389.65, 2769.95, and 4870.45, respectively.

The calculated Shapiro Wilks statistics for the raw data are 0.594 (aluminum) and 0.725 (manganese), and for the log-transformed data, the corresponding values are 0.913 and 0.969. The tabulated critical value for 0.10 level of significance is 0.91. Thus, for both aluminum and manganese, the data failed the normality test and passed the lognormality test at significance level 0.10 (Note: Shapiro-Wilks is a lower tail test).

Discussion of Example 4.6

The values of the 95% UCL obtained from the methods discussed above, without using lognormal theory, are:

	Aluminum	Manganese
Jackknife	3268.22	1405.83
Standard Bootstrap	3125.56	1354.15
Pivotal Bootstrap	5286.63	1968.03
CLT	3186.47	1376.82
Adjusted CLT	3675.94	1503.84
Chebychev	5482.64	2191.81

Observe that for both of the contaminants, the 95% UCLs calculated from the jackknife, both bootstrap methods, the CLT, the adjusted CLT, and the Chebychev limit are well below their respective estimates of the 95th percentile (Aluminum: 7747.81 and Manganese: 4870.45) of assumed (based on Shapiro-Wilks' test) lognormal distributions.

The values of the 95% UCL obtained from the methods discussed above, calculated from lognormal theory, are:

	Aluminum	Manganese
Jackknife	3283.34	1889.52
Standard Bootstrap	3663.20	1821.55
Chebychev	5314.99	3291.95
H-UCL	9102.73	5176.16

Observe that the 95% UCLs calculated using lognormal theory from the jackknife, the bootstrap, and the Chebychev inequality are similar to the respective values obtained without using lognormal theory, and that these are well below their respective estimated 95th percentiles for a lognormal distribution. The 95% UCLs calculated from the H-statistic, however, exceed their respective estimated 95th percentiles for a lognormal distribution.

Example 4.7. Data from the Elrama School Superfund site in Washington County, PA.

The data were compiled from two waste piles for risk evaluations of the contaminants found at the Elrama School Superfund Site, Washington County, PA. Twenty-six (26) contaminants (10 inorganics, 12 semi-volatile compounds, and 4 volatile compounds) were detected in both of the waste piles. Using the nonparametric Kolmogorov-Smirnov two-sample test on the two waste piles, it was concluded that there is no statistically significant difference between distributions of the contaminants from the two waste piles. Thus, the data from these two waste piles were combined to compute all of the relevant statistics such as the mean, the standard deviation, and the UCLs. This resulted in data sets consisting of 23 observations (15 from Waste Pile 1 and 8 from Waste Pile 2). The results are provided for two of the contaminants of concern: aluminum and toluene.

Aluminum: 31900.0, 8030.0, 12200.0, 11300.0, 4770.0, 5730.0, 5410.0, 8420.0, 8200.0, 9010.0, 8600.0, 9490.0, 9530.0, 7460.0, 7700.0, 13700.0, 30100.0, 7030.0, 2730.0, 5820.0, 8780.0, 360.0, 7050.0.

The sample mean, standard deviation, and CV of the log-transform data are:

$\bar{y} = 8.927$, $s_y = 0.845$, $CV_y = 0.095$

The sample mean, standard deviation, and CV for the raw data are:

$\bar{x} = 9709.57$, $s_x = 7310.02$, $CV_x = 0.75$.

With the lognormal assumption, the estimates of μ_1, σ_1, and the standard error of the mean, based on MVUE theory, for aluminum are 10552.68, 10031.60, and 2044.90, respectively. The MLEs of μ_1, σ_1, and CV are 10768.22, 10993.32, and 1.02, respectively. Estimates of the 80th, 90th, and 95th percentiles for a lognormal distribution are 15323.48, 22224.45, and 30381.95, respectively.

Toluene: 7300.0, 6.0, 6.0, 5.5, 29000.0, 46000.0, 12000.0, 2500.0, 1300.0, 3.0, 510.0, 230.0, 63.0, 6.0, 5.5, 6.0, 6.0, 5.5, 280000.0, 8.0, 28.0, 6.0, 7.0.

The sample mean, standard deviation and CV of log-transform data are:

$\bar{y} = 4.652$, $s_y = 3.660$, $CV_y = 0.79$

The sample mean, standard deviation, and CV for the raw data are:

$\bar{x} = 16478.33$, $s_x = 58510.78$, $CV_x = 3.55$.

With the lognormal assumption, the estimates of μ_1, σ_1, and the standard error of the mean, based on MVUE theory, for toluene are 21328.39, 362471.55, and 18788.05, respectively. The MLEs of μ_1, σ_1, and CV are 84702.17, 68530556.56, and 809.08, respectively. Estimates of the 80th, 90th, and 95th percentiles for a lognormal distribution are 2264.17, 11329.16, and 43876.88, respectively.

The Shapiro-Wilks statistics for the raw data are 0.707 (aluminum) and 0.313 (toluene), and for the log-transformed data, the corresponding values are 0.781 and 0.818. The tabulated critical value for a 0.10 level of significance with n = 23 is 0.928. Thus, neither a normal nor a lognormal distribution gives a good fit.

Discussion of Example 4.7

The values of the 95% UCL obtained from the methods discussed above, without using lognormal theory, are:

	Aluminum	Toluene
Jackknife	12327.40	37431.95
Standard Bootstrap	12246.67	33494.25
Pivotal Bootstrap	15161.90	152221.00
CLT	12216.95	36547.89
Adjusted CLT	12895.10	47316.80
Chebychev	16522.94	71013.85

The values of the 95% UCL obtained from the four methods discussed above, calculated from lognormal theory, are:

	Aluminum	Toluene
Jackknife	13542.11	62263.37
Standard Bootstrap	13579.18	278888.51
Chebychev	19693.40	105757.50
H-UCL	16503.51	18444955.15

Observe that the 95% UCL for toluene, calculated from the H-statistic, is orders of magnitude higher than those calculated from the other methods, and is also orders of magnitude higher than the maximum observed toluene concentration at the site. Also with the toluene data, the pivotal bootstrap method results in a UCL which is two to five times larger than the others computed from the non-lognormal theory methods. It is even larger than the Chebychev limit. As noted earlier, this is possible when the standard error of the point estimate is also estimated from the data. In most environmental applications, the true population standard deviation of the point estimate is unknown, and therefore, it needs to be estimated from the available data. Note, however, it is two orders of magnitude smaller than the H-UCL.

Note, also, that the CV (0.75) computed from the raw data for aluminum is less than 1. The use of the CV-test for normality could lead one to assume normality, even though the Shapiro-Wilks test strongly rejects the normal distribution (p-value = 0.00002).

5. SUMMARY AND RECOMMENDATIONS

It is seen from the simulated examples that, even when the underlying distribution is lognormal, the performance (in terms of a lower UCL) of the jackknife, bootstrap, and CLT procedures is more accurate than that of the H-UCL. In each of the four simulation experiments, the 95% UCLs computed from all of the above methods exceeds the true respective population means, but the 95% H-UCL is consistently larger, except in some cases where it is comparable to the conservatiave Chebychev result, than the 95% UCLs obtained from other methods. It is also seen from the simulation examples that the estimate of the CV based on the MLEs is closer to the true CV than the usual (moment) estimate of CV. Furthermore, the usual estimate of the CV

appears to underestimate the true CV. In some of the examples, the usual estimate of the CV is less than 1, while the true population CV is somewhat greater than 1. That is, the rule of thumb (CV-test) which declares the distribution to be normal when the moment estimate of the CV is less than 1, can frequently lead to an incorrect assumption about the underlying distribution of the data.

Moreover, from the examples discussed in this paper, it is observed that the H-UCL becomes order of magnitures higher even when the data were obtained from a lognormal population and can lead to incorrect conclusions. This is especially true for samples of smaller sizes (e.g., <30). It appears that the lognormal distribution and the H-UCL tend to hide contamination rather than revealing it. Under the assumption of the lognormal distribution, one can get away with very little or no cleanup at a polluted site. Thus, although the H-UCL is theoretically sound and possesses optimal properties, the practical merit of the H-UCL in environmental applications is questionable, as it becomes order of magnitude higher than the largest concentration observed high when the sd of the log-transformed data starts exceeding 1.0. It is therefore, recommended that in environmental applications, the use of the H-UCL to obtain an estimate of the upper confidence limit of the mean should be avoided.

Based on the monte carlo simulation results, and the authors' experience with Superfund site work, the following steps for computing a UCL of the mean of the contaminant(s) of concern are recommended:

1) Plot histograms of the observed contaminant concentrations and perform a statistical test of normal or lognormal distribution (e.g., the Shapiro-Wilks test). *Do not use the rule of thumb that declares the data distribution to be normal if CV is less than 1.*
2) If a normal distribution provides an adequate fit to the data, then use the Student's *t* approach (equivalent to the jackknife) for calculating the UCL of the population mean.
3) If a lognormal distribution provides an adequate fit to the data, then a) use the lognormal theory based formulas for computing the MVUE of the population mean and the standard deviation, b) either use these MVUEs with the jackknife or bootstrap methods to calculate a UCL of the mean, or use the Chebychev approach for calculating a UCL. *Do not use the UCL based on the H-statistic, especially if the number of samples is less than 30.*
4) If the data distribution turns out to be neither normal nor lognormal, then use the nonparametric versions of the jackknife or bootstrap to calculate a UCL. Even if the lognormal distribution seems to provide a reasonable fit to the data, and if there is evidence of a mixture of two or more subpopulations, or if outliers are suspected, then using one of the nonparametric methods discussed above is recommended.

NOTICE

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ATTACHMENT D.A-2

TOXICITY EQUIVALENCY FACTORS (TEFS) FOR PCBS, PCDDS, PCDFS FOR HUMANS AND WILDLIFE

Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife

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An expert meeting was organized by the World Health Organization (WHO) and held in Stockholm on 15–18 June 1997. The objective of this meeting was to derive consensus toxic equivalency factors (TEFs) for polychlorinated dibenzo-*p*-dioxins (PCDDs) and dibenzofurans (PCDFs) and dioxinlike polychlorinated biphenyls (PCBs) for both human, fish, and wildlife risk assessment. Based on existing literature data, TEFs were (re)evaluated and either revised (mammals) or established (fish and birds). A few mammalian WHO-TEFs were revised, including 1,2,3,7,8-pentachlorinated DD, octachlorinated DD, octachlorinated DF, and PCB 77. These mammalian TEFs are also considered applicable for humans and wild mammalian species. Furthermore, it was concluded that there was insufficient *in vivo* evidence to continue the use of TEFs for some di-*ortho* PCBs, as suggested earlier by Ahlborg et al. [Chemosphere 28:1049–1067 (1994)]. In addition, TEFs for fish and birds were determined. The WHO working group attempted to harmonize TEFs across different taxa to the extent possible. However, total synchronization of TEFs was not feasible, as there were orders of a magnitude difference in TEFs between taxa for some compounds. In this respect, the absent or very low response of fish to mono-*ortho* PCBs is most noticeable compared to mammals and birds. Uncertainties that could compromise the TEF concept were also reviewed, including nonadditive interactions, differences in shape of the dose–response curve, and species responsiveness. In spite of these uncertainties, it was concluded that the TEF concept is still the most plausible and feasible approach for risk assessment of halogenated aromatic hydrocarbons with dioxinlike properties. *Key words:* dioxins, humans, PCBs, polychlorinated biphenyls, TEFs, toxic equivalency, uncertainties, wildlife. *Environ Health Perspect* 106:775–792 (1998). [Online 10 November 1998]

http://ehpnet1.niehs.nih.gov/docs/1998/106p775-792vandenberg/abstract.html

Polychlorinated dibenzo-*p*-dioxins (PCDDs), dibenzofurans (PCDFs), and biphenyls (PCBs) constitute a group of persistent environmental chemicals. Due to their hydrophobic nature and resistance towards metabolism, these chemicals have been found in fatty tissues of animals and humans. Several PCDDs, PCDFs, and PCBs have been shown to cause toxic responses similar to those caused by 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), the most potent congener within these groups of compounds. These toxic responses include dermal toxicity, immunotoxicity, carcinogenicity, and adverse effects on reproduction, development, and endocrine functions.

PCDDs, PCDFs, and PCBs exist in environmental and biological samples as complex mixtures of various congeners whose relative concentrations differ across trophic levels. These differences are caused by environmental degradation, which refers to the different environmental fates of congeners with different solubilities, volatilities, and rates of degradation/metabolism. As a result, these mixtures change spatially and temporally into the environment and are very different from the technical mixtures originally released into the environment.

The complex nature of PCDD, PCDF, and PCB mixtures complicates the risk evaluation for humans, fish, and wildlife. For this purpose, the concept of toxic equivalency factors (TEFs) has been developed and introduced to facilitate risk assessment and regulatory control of exposure to these mixtures. To apply this TEF concept, a fundamental understanding of the mechanism of action is a prerequisite. At present, there is sufficient evidence available that there is a common mechanism for these compounds, involving binding to the aryl hydrocarbon (Ah) receptor as an initial step. When applying the TEF concept, the toxicity of these compounds relative to that of 2,3,7,8-TCDD is determined on the basis of available *in vivo* and *in vitro* data. However, it should also be understood that the TEF concept is based on a number of

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assumptions and has limitations. In this respect, the most basic assumption is that the combined effects of the different congeners are dose or concentration additive, and results of many studies support this assumption.

In the last decade, several different TEF schemes have been developed for PCDDs, PCDFs, and dioxinlike PCBs. Recognizing the need for a harmonized approach in setting internationally agreed upon TEFs, the European Centre of Environmental Health of the World Health Organization (ECEH-WHO) and the International Programme on Chemical Safety (IPCS) have initiated a program to derive TEFs for these compounds for assessing the impact of these compounds on human and environmental health.

At an initial WHO consultation on the derivation of TEFs for wildlife for dioxinlike compounds, held on 9–10 August 1996 in Bilthoven, The Netherlands, the question was addressed whether it is appropriate to use TEFs derived for the purpose of human risk assessment to estimate the risk for fish and wildlife species. The meeting concluded that there was a need to derive separate sets of TEFs for fish and wildlife, and recommended to combine this effort with a reevaluation and possible update of existing TEFs for human health risk assessment. In addition, it was recommended that the same TEFs for human health and wildlife should be used as much as possible.

For the (re)evaluation process, experimental data on the relative potencies (REPs) of PCDDs, PCDFs, and dioxinlike PCBs for mammalian, avian, and fish species have been collected by the Institute of Environmental Medicine, Karolinska Institute, Stockholm, Sweden, and inserted into a database. Following collection of all available information, an ECEH-WHO/IPCS meeting was held at the Karolinska Institute on 15–18 June 1997. The objective of the meeting was to assess the REP values in the database and to derive consensus TEFs for PCDDs, PCDFs, and dioxinlike PCBs for both human, fish, and wildlife risk assessment. The results of this process are presented in this paper.

TEF Concept and Data Requirements

Toxic Equivalency Factors, Relative Potencies, and Toxic Equivalents

In the literature, there is some confusion regarding the definition of the term toxic equivalency factor (TEF). One reason for confusion is the fact that the term TEF has been used in two different ways: 1) as a relative potency value that is based on the results of several *in vivo* and *in vitro* studies; or 2) as the relative potency of a compound relative to TCDD to cause a particular toxic or biological effect in a single study. Furthermore, TEF is frequently used to refer to an end point that is not a toxic response per se, such as binding affinity to the aryl hydrocarbon (Ah) receptor or induction of cytochrome P4501A1, although these biochemical effects may in some way be associated with subsequent toxic responses.

It is important to realize that in this paper and associated WHO publications TEF indicates an order of magnitude estimate of the toxicity of a compound relative to TCDD. This consensus TEF value has been derived using careful scientific judgment after considering all available scientific data. However, when the potency of a compound relative to TCDD has been obtained in a single *in vivo* or *in vitro* study, it will be referred to as a REP value.

TEF values, in combination with chemical residue data, can be used to calculate toxic equivalent (TEQ) concentrations in various environmental samples, including animal tissues, soil, sediment, and water. TEQ concentrations in samples are calculated using the following equation:

$$TEQ = \Sigma_{n1}[PCDD_i \times TEF_i] + \Sigma_{n2}[PCDF_i \times TEF_i] + \Sigma_{n3}[PCB_i \times TEF_i]. \quad (1)$$

TEFs and TEQs are used for risk characterization and management purposes, e.g., to help prioritize areas of concern for cleanup. However, in relation to the use of TEFs for abiotic compartments, the biological meaning of these values is obscure. This is caused by the fact that the assumed biological or toxicological effect is influenced by many physicochemical factors before the actual uptake of the compounds by the organism takes place. Nevertheless, TEQ values can be used as relative measures between different abiotic samples, e.g., sediment and soil, to prioritize remedial actions. In relation to the initial transport of these compounds from the abiotic to biotic compartment, it was recognized that congener-specific biota-sediment accumulation factors (BSAFs) can be used to predict the concentrations in fish tissue, after which these can be converted to TEQs using TEFs.

The TEFs presented in this paper apply only to AhR-mediated responses, and this concept assumes a model of dose additivity. In relation to this prerequisite, we decided that for PCDDs, PCDFs, and some planar PCBs there is sufficient evidence from both *in vivo* and *in vitro* studies supporting the dose or concentration-additivity model for Ah receptor-mediated responses. In addition, it should be emphasized that the TEF concept cannot be applied to effects that are not Ah receptor-mediated, and it does not consider modulating effects of [illegible] pounds that are not Ah receptor ligan[illegible]

TEF values were determined for the following classes of vertebrates: mammals, fish, and birds. TEFs that were determined for mammalian species were also considered to be applicable for human risk assessment purposes. It was concluded that, to date, not enough information was available to determine REP values in amphibians and reptiles, such that TEFs could not be proposed for these classes of vertebrates. At this time, development of TEFs for invertebrates is not recommended because there is limited evidence for ligand activation of AhR or for TCDD-like toxicity in invertebrates.

The criteria for including a compound in a fish and wildlife TEF scheme are the same criteria as those used for the derivation human TEFs (*1*). These are 1) a co[illegible]pound must show a structural relationship to the PCDDs and PCDFs; 2) a compound must bind to the Ah receptor; 3) a compound must elicit Ah receptor-mediated biochemical and toxic responses; and 4) a compound must be persistent and accumulate in the food chain.

Compilation of the Database

Since 1993, the data of all available m[illegible]malian, bird, and fish studies on relativ[illegible]icity of dioxinlike compounds that meet the criteria of inclusion in a TEF scheme (*1*) have been collected, and this information has been stored in a database at the Karolinska Institute in Stockholm (Sweden). These publications were analyzed and the data to be included i.. the database were selected using the following criteria:

1. At least one PCDD, PCDF, or PCB congener and a reference compound must be included in the study.
2. Either TCDD or PCB 126 must be included as a reference compound in the same experiment or studied with the same experimental design by the same authors in another experiment.
3. The relevant end point should be affected by the congener studied as well as the reference compound.

PCB 126 was used as reference in some cases, with an assigned REP of 0.1 for mammals and birds or 0.005 for fish, based on a variety of *in vivo* studies covering various end points. The use of PCB 77 and PCB 169 as reference compounds was no longer included in this evaluation due to the limited comparative information [illegible]able for these two compounds. Only [illegible]in-specific end points were included in the database (see criteria 3).

However, it is recognized that some end points such as liver enlargement and tumor promotion are affected by both dioxinlike and nondioxinlike halogenated aryl hydrocarbons (HAHs; e.g., mono- or di-*ortho* PCBs). In addition, several biological or toxic effects have been described for PCBs, for example, which are probably not related to an Ah receptor-mediated mechanism of action. Among others, these effects include a decrease in dopamine levels (*2,3*), alterations in retinoid and thyroid hormone levels (*4,5*), and binding to the estrogen receptor (*6*). These effects show distinctly different structure–activity relationships for PCBs than those observed for Ah receptor binding involving multiple *ortho* chlorine substitution or hydroxylated metabolites. Based on the four criteria mentioned earlier, these effects, how biologically relevant they might be, are not covered in this TEF concept. For these compounds and their associated effects, a different approach for risk assessment is needed, which might possibly involve the development of an alternative toxic equivalency concept.

Compounds included in the database are the 2,3,7,8-substituted PCDDs and PCDFs and those PCBs with established dioxinlike activity, especially the non- and mono-*ortho* PCBs. We agreed that there are a large number of other halogenated compounds that meet the criteria for inclusion in the TEF concept and could contribute to the total concentration of TEQs in environmental samples. These include any or all of the following classes of polychlorinated compounds: naphthalenes, diphenyl ethers, diphenyl toluenes, phenoxy anisoles, biphenyl anisoles, xanthenes, xanthones, anthracenes, fluorenes, dihydroanthracenes, biphenyl methanes, phenylxylylethanes, dibenzothiophenes, quaterphenyls, quaterphenyl ethers, and biphenylenes. In addition to the chlorinated compounds, brominated and chloro/bromo-substituted analogues of PCDDs (PBDDs) and PCDFs (PBDFs) have been found in the environment (*7–10*) and are known to induce CYP1A1 activity *in vivo* and *in vitro* (*11*). PBDDs and PBDFs have also been shown to cause developmental toxicity, and REPs have been determined in mammals and fish (*12–14*). However, it was decided that, at present, insufficient environmental and toxicological data are available to establish a TEF value for any of the above compounds.

Calculation of REPs

The following methods were used to derive REPs from the available data:

- REPs were used as reported in each publication; if experimental data were also reported, these were used to calculate the REPs using one of the methods below.
- REPs were calculated by comparing dose–response curves or by using linear interpolation of log-doses, comparing the same effect level; if necessary, corrections were made for different control levels.
- REPs were determined from ratios of medium effective dose (ED_{50}), median lethal dose (LD_{50}), and median effective concentration (EC_{50}) values, tumor promotion indexes, dissociation constant (K_d) values for Ah receptor binding, or directly estimated from the graphs presented.

All the data were compiled into a spreadsheet format using Quattro Pro (version 6.0) for Windows (Corel Corporation Limited). The database used for the derivation of TEF values is available from The European Centre for Environment and Health, World Health Organization, Bilthoven, The Netherlands.

Basis for the Review Process

TEFs for Mammalian Wildlife

The TEF values, which are mainly based on rodent studies, should be suitable for both human risk assessment and for estimating the risk for species of mammalian wildlife.

Based on two semichronic studies with mink and TCDD and PCB 169, the REP of PCB 169 was evaluated. In the first study with adult male mink, a 28-day oral LD_{50} value (single dose) of 4.2 µg TCDD/kg body weight (bw) was reported (*15,16*), and a 28-day dietary median lethal concentration (LC_{50}) of 4.3 ppb was calculated for female mink. In the second study, PCB 169 was given to mink via the diet (*17*). Exposure of adult females to dietary concentrations of 0.05 mg PCB 169/kg bw for 131 days resulted in 50% mortality. Assuming a daily feed consumption of 150 g and a body weight of 1 kg, the total intake of PCB 169 was about 1,000 µg/kg bw. By using the LD_{50} values of 4.2 for TCDD and 1,000 for PCB 169, a value of 0.0042 can be calculated as a first estimate for the relative potency of PCB 169 in mink. Based on these calculations, the previous assigned TEF value of 0.01 for PCB 169 for human risk assessment seems fairly reasonable for mink and gives some support to the use of similar TEF values for humans and wild mammals.

The TEF concept is further supported in mink by comparison of the no observed adverse effect level (NOAEL) derived from a meta-analysis of mink reproductive toxicity data (*18*) with the NOAEL calculated from a mink laboratory reproductive study in which the diets were subject to complete chemical characterization (*19*). These two independent analyses of the TEF approach, utilizing different effects data sets and the same set of international TEFs (*1,20*) for the assessment of mink reproductive toxicity, confirmed one another. Overall these results suggest that the relative potencies of the PCBs, PCDDs, and PCDFs toward mink reproductive toxicity are not different from those of the rodent models from which most of the data were derived.

One argument that might be considered to refine future risk assessment of mammalian wildlife is the substance-specific biotransformation capacity of different mammalian species. Certain marine mammals might have a higher capacity to metabolize dioxins and dioxinlike congeners than certain terrestrial mammals, but due to their position in the foodchain and strictly aquatic diet, body burdens can still be high. Due to these differences in metabolic CYP1A1 capacities, it has been suggested that terrestrial mammals, when compared to highly exposed marine mammals, may experience a greater threat from dioxinlike compounds, e.g., PCB 126, than mammalian top predators in the aquatic food webs (*21–25*).

Furthermore, pharmacokinetic differences will undoubtedly contribute to the interspecies variability observed with different congeners. At present, the mammalian TEF scheme is based on administered dose. Although it has been discussed whether mammalian TEFs should be derived based on target tissue concentrations, this is at present considered not feasible due to the limited amount of scientific information available.

TEFs for Ah Receptor-mediated Toxicity for Fish

Fish, including all salmonids that have been studied, express CYP4501A activity (*26,27*), which is an Ah receptor-mediated process and can be induced by many (halogenated) aromatic hydrocarbons (*28–31*). This mechanism indicates that fish should be sensitive to the effects of Ah receptor-active compounds; but compared to mammals, fish are less responsive to mono-*ortho* PCBs. The hepatic cytochrome P450-dependent enzymes in fish are considered to be functionally similar to those of mammals (*32*). In those instances where adequate data are available, it appears that fish enzymes are influenced by some of the same factors that affect these enzymes in mammals: species (*32*), strain (*33*), size and/or age (*34*), developmental stage (*35*), sex (*36*), reproductive state (*37*), nutrition (*38*), and exposure to certain types of organic xenobiotic inducers as well as environmental conditions (*39*).

The inclusion of fish in the TEF concept is justified by the common Ah receptor-mediated mechanism of response; this was confirmed by many toxicological and

biochemical studies during the last decades. Fish-specific REPs have been derived from mortality in early life stages in rainbow trout (*40–42*) and from *in vivo* CYP1A induction in adult rainbow trout (*43*) and *in vitro* in rainbow trout liver (RTL-W1) (*44–46*) and gonadal cell lines (*47*). These have been developed for ecological risk assessments involving fish exposed to complex mixtures of dioxinlike PCBs, PCDDs, and PCDFs. Generally, the REPs derived from CYP1A induction either *in vivo* or *in vitro* are higher than those derived from early life stage mortality (*48*). Injection of trout eggs with TCDD has been shown to result in the same effects and LD_{50} as with maternal transfer of the chemical (*41*) and has confirmed the application of the TEF concept in fish.

In addition, it has been established that REPs determined for mortality in rainbow trout sac fry following waterborne exposure are nearly identical to those determined for the same end point after egg injection (*40,42,49*). Thus, the REPs based on sac fry mortality were not influenced by the route of exposure. Zabel et al. (*50*) also showed that the REP for PCB 126 in producing lake

Table 1. Toxic equivalency factors (TEFs) for human risk assessment and mammals

Congener	Description	Old TEF	WHO TEF
Dioxins			
1,2,3,7,8-PentaCDD	Based on new *in vivo* tumor promotion data and CYP1A1/A2 induction potencies from subchronic studies (*79–81*); a value closer to 1.0 is recommended.	0.5	1
1,2,3,4,7,8-HexaCDD	Limited *in vivo* data are available, but more recent LD_{50} values continue to support the current value (*82,83*); no revision is recommended.	0.1	0.1
1,2,3,6,7,8-HexaCDD	No new *in vivo* data. Recent *in vitro* data support the current value (*84*); no revision is recommended.	0.1	0.1
1,2,3,7,8,9-HexaCDD	No new *in vivo* information; no revision is recommended.	0.1	0.1
1,2,3,4,6,7,8-HeptaCDD	Two recent semichronic studies indicate values between 0.02 and 0.03 for various end points (*85,86*); no revision is recommended.	0.01	0.01
OctaCDD	A recalculation of the old data in which exposure versus tissue concentrations were compared suggests that a lower value is more appropriate (*87*).	0.001	0.0001
Furans			
2,3,7,8-TetraCDF	Recent semichronic studies generally support a value of 0.1 (*88,89*); less emphasis was put on LD_{50} values; no revision is recommended.	0.1	0.1
1,2,3,7,8-PentaCDF	Although new semichronic data suggest that mice are more responsive (*81,90*), the combined potency values indicate the current value is adequately protective; no revision is recommended.	0.05	0.05
2,3,4,7,8-PentaCDF	Most REPs dealing with relevant toxic end points [e.g., (*79*)] support the continued use of a value of 0.5. Due to the fact that this congener is a major contributor to total TEQs in biological samples, confirmation of recent immunotoxicity data indicating a higher value is strongly recommended (*91*); at present, no revision is recommended.	0.5	0.5
1,2,3,4,7,8-HexaCDF	Additional *in vivo* potency values on nonspecific biological end points (liver, thymus, body weight alterations) are in the range of the current TEF (*92*); no revision is recommended.	0.1	0.1
1,2,3,6,7,8-HexaCDF	No new information; no revision is recommended.	0.1	0.1
1,2,3,7,8,9-HexaCDF	Very limited data (*93*) and no new *in vitro* and QSAR data that suggest a change in value is warranted; no revision is recommended.	0.1	0.1
2,3,4,6,7,8-HexaCDF	Limited new *in vitro* and QSAR information indicate a change of value is not warranted (*93*); no revision is recommended.	0.1	0.1
1,2,3,4,6,7,8-HeptaCDF	Recent values greater than 0.01 are under discussion due to possible impurity of test compound and the fact that no reference (TCDD/PCB126) was included at the time of studies (*94*). In addition, the same study reports approximately the same response with 1,2,3,4,7,8,9-heptaCDF, whereas this congener is known to be less persistent *in vivo* (*95*). Confirmation of REPs >0.01 is required; no revision is recommended.	0.01	0.01
1,2,3,4,7,8,9-HeptaCDF	A very limited data set is available and the same comment holds as for 1,2,3,4,6,7,8-heptaCDF; no revision is recommended.	0.01	0.01
OctaCDF	New *in vivo* EROD induction potency values (*81*) and an expected structural similarity with octaCDD for the *in vivo* situation support a change in analogy with octaCDD.	0.001	0.0001
Non-*ortho* PCBs			
3,3′,4,4′-TetraCB (77)[a]	Recent subchronic studies with EROD induction and hepatic retinol decreases suggest a value around or below 0.0001 (*96–98*), which is lower than the previous value based on tumor promotion (*99*); however, impurity and background contamination (e.g, PCB 126) is an identified problem with this congener. A change in value to 0.0001 is recommended.	0.0005	0.0001
3,4,4′,5-TetraCB (81)	Based on Ah receptor binding, *in vitro* CYP1A induction, and QSAR calculations, a value similar to PCB 77 was suggested (*100–102*). It should be noted that *in vitro* REPs possibly overestimate the potency of this compound, as in analogy with PCB 77, it is likely to be metabolized efficiently by higher organisms; however, this congener is detectable in certain wildlife species and human samples. A value of 0.0001 is recommended.	–	0.0001
3,3′,4,4′,5-PentaCB (126)	Multiple *in vivo* end points in semichronic studies with rats, including CYP1A1/A2 induction, tumor promotion, and hepatic retinol decreases, support the current value (*89,103,104*); no revision is recommended.	0.1	0.1
3,3′,4,4′,5,5′-HexaCB (169)	Recent *in vivo* EROD induction and thymic atrophy values support a conservative value of 0.01 for this congener. Confirmation of recent immunotoxicity data possibly indicating a higher REP is strongly recommended (*91,105*); no revision is recommended.	0.01	0

continued, next page

trout early life stage mortality is similar to the REP for the same response in rainbow trout. These results are significant because they suggest that TCDD-like congeners show similar REPs in rainbow trout and lake trout and support both the use of rainbow trout REPs in assessments of risks to lake trout and, perhaps, other fish species. While this agreement in REPs for PCB 126 between trout species is encouraging, further comparisons of REPs for other potent congeners and more disparate fish species are needed. In relation to environmental risk assessment, the use of early life stage mortality-specific TEFs and the egg toxicity equivalent additivity model predicted that PCDDs, PCDFs, and PCBs in Great Lakes lake trout are currently below levels that cause early life stage mortality (*51*). This information is in agreement with recent observations of juvenile lake trout survival in this area of the Great Lakes and gives further support for the use of the TEF concept in fish.

One of the major differences between the TEFs determined for mammals and fish is the lack or low response to mono-*ortho* PCBs in the latter taxa. Even with an extremely sensitive Ah receptor-mediated effect, the induction of CYP1A1, it was found that fish are very insensitive, if sensitive at all, to mono-*ortho*-substituted PCBs (*45,48,52–55*). Similar lack of responses toward mono-*ortho* PCBs have been observed for early life stage mortality in rainbow trout (*40,42*). Based on the above considerations, we decided that fish should be included in the TEF concept, but due to the deviations found for PCBs, fish should be treated as a separate taxa in this TEF evaluation.

TEFs for Birds

Although many studies with young or adult birds have shown dioxinlike toxic and biochemical effects of TCDD and PCBs, these studies were not designed for REPs of compounds to be reliably derived (*56–63*). At present, TEFs for birds can only be derived from egg injection studies, studies with cultured avian hepatocytes, and studies with cultured thymus cells.

The end points mentioned above have been studied in a number of avian species. These species include domestic chicken, duck, domestic goose, turkey, pheasant, gull, common tern, double-crested cormorant, and American kestrel (*64–68*). As with fish and mammals, Ah receptor-mediated CYP1A1 induction has been found in a large number of avian species, clearly indicating an Ah receptor responsiveness in this taxa. This justifies the inclusion of birds in the TEF concept. The induction of CYP1A1 in avian systems has been studied for most of the environmentally relevant PCDDs, PCDFs, and dioxinlike PCBs. However, the number of studies that could be used for this evaluation was limited. REPs for Tier 1 studies were not available for PCDDs and PCDFs, but for some PCBs, Tier 1 studies (*in ovo* lethality) were available. In general, REPs for ethoxyresorufin-*O*-deethylase (EROD) induction for dioxins, furans, and non-*ortho*-PCBs in birds are in the same range as those reported from mammalian systems. The major exception is TCDF, which can be more potent than TCDD in hepatocyte cultures from several species of birds (*65,66,69*).

Based on studies with chicken embryos, it has been concluded that birds can be highly responsive toward non-*ortho* PCBs, although much of the information available concerns induction of CYP1A1 and not distinct toxic

Table 1. (*continued*)

Congener	Description	Old TEF	WHO TEF
Mono-*ortho* PCBs	For this group of congeners, more than one mechanism of action (not only Ah receptor specific) is involved. A variety of *in vivo* mammalian experiments have demonstrated distinct Ah receptor-mediated biochemical and toxic effects. Among these are CYP1A1/1A2 induction and reproductive and teratogenic effects similar to TCDD.		
2,3,3′,4,4′-PentaCB (105)	The majority of potency values from subchronic bioassays support a value of less than 0.0002, including those for tumor promotion and thymus atrophy (*97,106*). The immunotoxicity data suggest a TEF between 10^{-5} and 10^{-7} while acute *in vivo* values for nonspecific end points, e.g., liver weight gain and body weight decrease, are in the range of 10^{-3} and 10^{-4}; no revision is recommended.	0.0001	0.0001
2,3,4,4′,5-PentaCB (114)	There are no new data which suggest that the current value is not appropriate. Older Ah receptor binding and enzyme induction data need confirmation regarding the present value (*100,101,107*); at present no revision is recommended.	0.0005	0.0005
2,3′,4,4′,5-PentaCB (118)	New data support the original value (*91,96,108*); no revision is recommended.	0.0001	0.0001
2′,3,4,4′,5-PentaCB (123)	No new data are available; no revision is recommended.	0.0001	0.0001
2,3,3′,4,4′,5-HexaCB (156)	Recent data from semichronic studies suggest that the old value is appropriate (*109*). Higher REPs measuring nonspecific end points, e.g., effects on thyroid hormones and body and thymus weight, were not included in the evaluation. Some concern was raised about identity and purity of test compounds in some studies; no revision is recommended.	0.0005	0.0005
2,3,3′,4,4′,5′-HexaCB (157)	No new relevant *in vivo* data available; no revision is recommended.	0.0005	0.0005
2,3′,4,4′,5,5′-HexaCB (167)	No new data are available; no revision is recommended.	0.00001	0.00001
2,3,3′,4,4′,5,5′-HeptaCB (189)	New data for immunotoxicity (*91*) are within the range of the current value; no revision is recommended.	0.0001	0.0001
Di-*ortho* PCBs	The limited data set as recognized in 1993 still exists. *In vivo* subchronic assay results with relevant end points, including CYP1A1/A2 induction and reproductive toxicity, with the structurally similar congener PCB 153 (*98,104,110–112*) do not confirm the weak Ah receptor agonist properties reported from *in vitro* experiments (*11,113,114*); as a result, the previous TEF values for di-*ortho* PCBs have been withdrawn.		
2,2′,3,3′4,4′,5 HeptaCB (170)	Withdrawn.	0.0001	–
2,2′,3,4,4′,5,5′-OCB (180)	Withdrawn.	0.00001	–

Abbreviations: WHO, World Health Organization; CDD, chlorinated dibenzodioxin; CDF, chlorinated dibenzofurans; CB, chlorinated biphenyls, LD_{50}, median lethal dose; REPs, relative potencies; QSAR, quantitative structure–activity relationship; EROD, ethoxyresorufin-*O*-deethylase; Ah, aryl hydrocarbon; PCBs, polychlorinated biphenyls.

[a]International Union of Pure and Applied Chemistry numbers are shown in parentheses.

end points (70–72). Birds, in contrast with fish, show a more pronounced response to mono-*ortho* PCBs, and REPs resemble those found in mammalian systems. In addition, studies with cultured chicken embryo hepatocytes indicate that some di-*ortho* PCBs, e.g., PCBs 128, 138, 170, and 180, are also EROD inducers (69,73,74). However, *in vivo* studies with either biochemical or toxic end points have not been done with these di-*ortho* PCBs, which could confirm an Ah receptor-mediated response by these congeners.

When REPs for CYP1A1 induction and embryo mortality in avian systems are compared, it can be concluded that no significant

Table 2. Toxic equivalency factors (TEFs) for fish

Congener	Description	WHO TEF
Dioxins		
1,2,3,7,8-PentaCDD	In a rainbow trout egg injection study, this compound was found to be 0.7 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 1.0 is recommended.	1
1,2,3,4,7,8-HexaCDD	In a rainbow trout egg injection study, this compound was found to be 0.3 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 0.5 is recommended.	0.5
1,2,3,6,7,8-HexaCDD	In a rainbow trout egg injection study, this compound was found to be 0.02 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*42*); a value of 0.01 is recommended.	0.01
1,2,3,7,8,9-HexaCDD	No *in vivo* studies have been carried out with this compound. It was determined to be 0.02 times as potent as 2,3,7,8-TCDD at inducing EROD in PLHC-1 cells (*115*); a value of 0.01 is recommended.	0.01
1,2,3,4,6,7,8-HeptaCDD	In a rainbow trout egg injection study, this compound was found to be 0.002 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*42*); a value of 0.001 is recommended.	0.001
OctaCDD	A two week study in carp using a single ip dose of this compound failed to detect any dose or hepatic concentration relationship with CYP1A induction (*53*). Based on structure homology with OCDF, a value <0.0001 is recommended.[a]	<0.0001
Furans		
2,3,7,8-TetraCDF	In a rainbow trout egg injection study, this compound was found to be 0.03 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 0.05 is recommended.	0.05
1,2,3,7,8-PentaCDF	In a rainbow trout egg injection study, this compound was found to be 0.03 times as potent as 2,3,7,8-TCDD at causing early life stage mortality revision (*40*); a value of 0.05 is recommended.	0.05
2,3,4,7,8-PentaCDF	In a rainbow trout egg injection study this compound was found to be 0.3 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 0.5 is recommended.	0.5
1,2,3,4,7,8-HexaCDF	In a rainbow trout egg injection study, this compound was found to be 0.2 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 0.1 is recommended.	0.1
1,2,3,6,7,8-HexaCDF	At present, available data are only from QSAR studies (*93,116*). Also based on structural similarity between the hexaCDF isomers generally observed in experiments, a value of 0.1 is recommended.	0.1
1,2,3,7,8,9-HexaCDF	Data from EROD induction in PLHC-1 cells and QSAR studies indicate an REP between 0.04 and 0.09 (*116*); a value of 0.1 is recommended.	0.1
2,3,4,6,7,8-HexaCDF	Based on the structural similarity of this compound with other hexaCDFs and supported by QSAR modeling (*93,116*); a value of 0.1 is recommended.	0.1
1,2,3,4,6,7,8-HepaCDF	At present, no *in vivo* or *in vitro* data are available from fish studies, but based on structure homology with 1,2,3,4,7,8,9-heptaCDF, a value of 0.01 is recommended.	0.01
1,2,3,4,7,8,9-HeptaCDF	Data from EROD induction in PLHC-1 cells indicate an REP of 0.01 (*116*); a value of 0.01 is recommended.	0.01
OctaCDF	A two week study in carp using a single ip dose of this compound failed to detect any dose or hepatic concentration relationship with CYP1A induction (*53*). In the PLHC-1 cell line, this compound was 0.0008 times as potent as 2,3,7,8-TCDD at inducing EROD activity (*115*). However, both studies do not accurately reflect the environmental *in vivo* situation in which extreme low solubility and large molecular size limiting transport over the gill membranes (*117*) should reduce the octaCDF potency for fish significantly. A value <0.0001 is recommended.[a]	<0.0001
Non-*ortho* PCBs		
3,4,4′,5-TetraCB (81)[b]	In a rainbow trout egg injection study, this compound was found to be 0.0006 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*42*); a value of 0.0005 is recommended.	0.0005
3,3′,4,4′-TetraCB (77)	In a rainbow trout egg injection study, this compound was found to be 0.0002 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 0.0001 is recommended.	0.0001
3,3′,4,4′,5-PentaCB (126)	In a rainbow trout egg injection study this compound was found to be 0.005 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*40*); a value of 0.005 is recommended.	0.005
3,3′,4,4′,5,5′-HexaCB (169)	In a rainbow trout egg injection study, this compound was found to be 0.00004 times as potent as 2,3,7,8-TCDD at causing early life stage mortality (*42*); a value of 0.00005 is recommended.	0.00005
Mono-*ortho* PCBs		
2,3,3′,4,4′-PentaCB (105)	In a rainbow trout egg injection study, this compound did not cause early life stage mortality at the highest dose administered (*40*); a value of <0.000005 is recommended.	<0.000005
2,3,4,4′,5-PentaCB (114)	A value of <0.000005 was assigned based on the similarity of the structure of this compound with other mono-*ortho* pentaCBs.	<0.000005
2,3′,4,4′,5-PentaCB (118)	In a rainbow trout egg injection study, this compound did not cause early life stage mortality at the highest dose administered (*40*); a value of <0.000005 is recommended.	<0.000005
2′,3,4,4′,5-PentaCB (123)	A value of <0.000005 was assigned based on structural similarity of this compound with other mono-*ortho* pentaCBs.	<0.000005
2,3,3′,4,4′,5-HexaCB (156)	An *in vitro* study with the rainbow trout RTG-2 cell line supports the earlier assigned value of <0.000005 for the other mono-*ortho* PCBs (*47*). In another *in vitro* study with the rainbow trout cell line RTL-2, this compound was 0.00003 times as potent as TCDD in inducing EROD activity (*45*); a value of <0.000005 is recommended.	<0.000005
2,3,3′,4,4′,5′-HexaCB (157)	A value of <0.000005 was assigned based on structural similarity of this compound with other mono-*ortho* pentaCBs; this value is also supported by QSAR modeling (*118*).	<0.000005
2,3′,4,4′,5,5′-HexaCB (167)	A value of <0.000005 was assigned based on structural similarity of this compound with other mono-*ortho* pentaCBs.	<0.000005
2,3,3′,4,4′,5,5′-HeptaCB (189)	A value of <0.000005 was assigned based on structural similarity of this compound with other mono-*ortho* pentaCBs.	<0.000005

Abbreviations: WHO, World Health Organization; CDD, chlorinated dibenzodioxins; ip, intraperitoneal; EROD, ethoxyresorufin-*O*-deethylase; CDF, chlorinated dibenzofurans; QSAR, quantitative structure–activity relationship; REP, relative potency; CB, chlorinated biphenyl.

[a]After a postmeeting consultation in February 1998, we agreed upon a revision of the TEF values for octaCDD and octaCDF in fish and birds, which were presented at the 17th International Symposium on Chlorinated Dioxins and Related Compounds on 25–29 August 1997 in Indianapolis, Indiana.

[b]International Union of Pure and Applied Chemistry numbers are shown in parentheses.

differences have been found between these values. Thus, the relative potencies of these compounds, as determined by CYP1A1 induction in cultured avian hepatocytes, appear to be predictive for the relative toxicity in the developing embryo (66).

However, some toxic end points, such as porphyrin accumulation in cultured avian hepatocytes, should be approached with caution because structure–activity relationships differ significantly from those of CYP1A induction (74–76). Based on this information, it is unclear if porphyrin accumulation in birds is uniquely an Ah receptor-mediated effect. Therefore, it is unclear whether it should be included in the TEF concept. This case again stresses the importance to include only those end points in which the Ah receptor-mediated mechanism is shown to be involved and is the major determining factor.

Review of TEFs

Approach for Deriving TEFs

For reevaluation of the existing mammalian TEFs for PCDDs, PCDFs, and PCBs, both previously reviewed and new data were examined. These included all congeners that have been selected before and also published data of multiple *ortho*-substituted PCBs (1,11,77,78). For prioritization, a rank order was followed as was suggested at an earlier WHO/IPCS TEF meeting (1). The TEFs for humans and mammals were primarily derived from *in vivo* toxicity data, which were given more weight than *in vitro* and/or quantitative structure–activity relationship (QSAR) data. *In vivo* toxicity data were prioritized according to the following ranking scheme: chronic > subchronic > subacute > acute. In the final TEF selection, different Ah receptor-specific end points were also ranked according to toxic > biochemical (e.g., enzyme induction) response. For revision of the existing mammalian TEFs, we agreed that if the available information was considered insufficient to warrant a change, the existing value would remain. The suggested TEFs for humans and mammals, including a short description, are given in Table 1.

A tiered approach was followed in deriving TEFs for fish and birds. Following this approach, we noted that the number of bird and fish studies, which could be used for the derivation of a TEF, was often very limited when compared with mammalian data. For all congeners, the studies that were given the most weight were tier 1 studies, followed by tiers 2, 3, and 4. The tiers were as follows:

- Tier 1: Overt toxicity observed in developing embryos; the only end point used was the LD_{50}
- Tier 2: Biochemical effects observed in developing embryos; the only end point used was the relative potency to induce CYP1A
- Tier 3: Biochemical effects observed in *in vitro* systems; the only endpoint used was the REP to induce CYP1A in cultured cells
- Tier 4: Estimates from QSAR studies.

Fish studies that determined early life stage mortality were considered to be most useful for determining TEF values (40,42). In addition, there was a preference to use results from egg injection studies in which the dose to the egg was known, rather than results from waterborne studies in which this was not determined. Furthermore, TEF values for octaCDD, octaCDF, and the mono-*ortho* PCBs for fish were given a "lower than" value. This approach was chosen because fish appear to be very insensitive, if sensitive at all, toward an Ah receptor-mediated response of octaCDD, octaCDF, or these types of PCBs. Nevertheless, we recognized that some regulatory agencies would like to have some directions for possible TEF values of these compounds in fish. Therefore, based on the present state of the science, a "smaller than" TEF value was given for these compounds, which should be considered to be the expected upper limit of such a compound in fish. The suggested TEFs for fish, including a short description, are given in Table 2.

Few studies have been carried out to determine the overt toxic effects of PCBs in bird embryos after injection of compounds into eggs. Where data from tier 1 studies were available, they were used to derive TEFs, but TEF values of PCDDs and PCDFs for birds were mainly derived from tier 2, 3, or 4 studies. These data include mainly studies that measured EROD induction in cultured hepatocytes or derived QSAR. The suggested avian TEFs, including a short motivation, are given in Table 3.

In line with the already existing TEF values, new TEFs were rounded to a value of either 1 or 5, irrespective of the order of magnitude difference with the reference compound, TCDD.

Discussion

Molecular Basis for TEFs across Species

A strict criterion for application of the TEF concept is that a compound must be demonstrated to bind to the Ah receptor since most (if not all) biological effects of these compounds appear to be mediated by the Ah receptor (128,129). Studies of biological effects of 2,3,7,8-TCDD and related polyhalogenated polyaromatic hydrocarbons have made it apparent that there are extensive and important species differences in the functional responses elicited by these compounds (130). However, for a number of common biological effects, many species can respond at dose levels that are within one order of magnitude (131).

With regard to the ligand binding properties of the Ah receptor, most data on receptor interaction with PCDDs, PCDFs, and PCBs have been generated using rodent experimental model systems. In addition, there are data on the ligand binding specificity of the human Ah receptor (129,132–134). The mouse has been studied in most detail with regard to determinants in Ah receptor structure of ligand binding activity. Four differently sized allelic variants of the receptor have been described, which show extended C-terminal parts as well as point mutations that affect binding of 2,3,7,8-TCDD and other polyhalogenated aromatic hydrocarbons (135,136).

With regard to humans, the Ah receptor is detected in a wide variety of tissues (e.g., placenta, liver, lung) and primary/established human-derived cell lines. Moreover, the Ah receptor can be activated both *in vivo* and *in vitro* into a DNA binding state by a variety of halogenated aromatic hydrocarbons (134,137,138). As in mice, a similar situation with several different allelic variants of the receptor might be present in humans. Although the mean 2,3,7,8-TCDD binding affinity (K_d) for the human Ah receptor may be lower than that observed in responsive mouse strains (C57BL/6J), there exisits a range of K_d values similar in magnitude to the range observed between responsive and nonresponsive mouse strains (135).

The extension of the TEF concept to other classes of vertebrates such as fish and birds is supported by data on ligand binding properties of the Ah receptor in these species. In this respect it should be noted that the Ah receptor has been detected in both bony and cartilagenous fish (139–141). Thus, it appears that the Ah receptor is phylogenetically very old, which is supported by the fact that development of these fish groups diverged from one another about 450–550 million years ago. Moreover, there exist homologs of both the receptor gene and the gene encoding the dimerization partner of the receptor, Arnt, in the nearly entirely sequenced genome of the nematode worm *Caenorhabditis elegans*. Studies using species-specific recombinant cells and primary cultures from birds also suggest that the ligand binding specificity of the Ah receptor may not be identical between species (66,142). Furthermore, one study determined the specific binding characteristics of TCDD to the Ah receptor in four different avian species and found differences in binding affinity of over an order of magnitude (67). Consequently, some caution in

the absolute homology of ligand binding properties of the Ah receptor between species may be justified.

In conclusion, the Ah receptor and Arnt have been very well conserved during evolution, indicating that they may have important physiological functions, possibly in development (27). This evolutionary conservation, in combination with the ligand binding properties of the Ah receptor, support the use of the TEF concept across taxa.

The Role of Pharmacokinetics and Food Chain Transport in the TEF Concept

The pharmacokinetic behavior of dioxinlike compounds and PCBs is largely governed by three major factors: 1) lipophilicity, 2) binding to CYP1A2 leading to hepatic sequestration, and 3) relative rates of metab[illegible] Lipophilicity controls the rate and exte[illegible] of absorption, tissue distribution, and passive elimination. In addition, the chlorine substitution pattern determines hepatic sequestration and rate of metabolism. Pharmacokinetic properties have been shown to play a role in the determination of TEF values for a number

Table 3. Toxic equivalency factors (TEFs) for birds

Congener	Description	WHO TEF
Dioxins		
1,2,3,7,8-PentaCDD	In a chicken embryo egg injection study, this compound was found to be approximately equipotent to 2,3,7,8-TCDD as an inducer of EROD (*119*). In addition, a study with chick embryo hepatocytes from several bird species determined that the potency of this compound to induce EROD is similar or even higher than that of TCDD (*68,69*): a value of 1 is recommended.	1.0
1,2,3,4,7,8-HexaCDD	In a chicken embryo egg injection study this compound was found to be approximately 0.05 times less potent than 2,3,7,8-TCDD as an inducer of EROD (*119*); a value of 0.05 is recommended.	0.05
1,2,3,6,7,8-HexaCDD	In a chicken embryo egg injection study, this compound was found to be approximately 0.01 times less potent than 2,3,7,8-TCDD as an inducer of EROD (*119*); a value of 0.01 is recommended.	0.01
1,2,3,7,8,9-HexaCDD	In two chicken embryo egg injection studies, this compound was found to be approximately 0.1–0.4 times less potent than 2,3,7,8-TCDD as an inducer of EROD (*119,120*); a value of 0.1 is recommended.	0.1
1,2,3,4,6,7,8-HeptaCDD	In a chicken embryo egg injection study, this compound was found to be a poor inducer of EROD (*119*); a lower than value of 0.001 is recommended.	<0.001
OctaCDD	At present, no *in vivo* or *in vitro* data are available for this compound in birds; a value of 0.0001 was recommended based on data from mammalian studies.[a]	0.0001
Furans		
2,3,7,8-TetraCDF	Chicken embryo egg injection studies and one study with chicken embryo hepatocytes of several species of birds found this compound to be approximately equipotent or even more potent than 2,3,7,8-TCDD as an inducer of EROD (*66,119,121*); a value of 1 is recommended.	1.0
1,2,3,7,8-PentaCDF	In a chicken embryo egg injection study, this compound was found to be approximately 0.3 times less potent than 2,3,7,8-TCDD as an inducer of EROD (*119*); a value of 0.1 is recommended.	0.1
2,3,4,7,8-PentaCDF	Studies with chicken embryo egg injections and chick embryo hepatocytes from several bird species indicated that this compound is approximately equipotent to 2,3,7,8-TCDD as an inducer of EROD (*68,119*); a value of 1.0 is recommended.	1.0
1,2,3,4,7,8-HexaCDF	This compound was reported to be 0.01 times as potent as 2,3,7,8-TCDD as an inducer of EROD in chicken embryos after egg injection (*119*). However, examination of the dose–response curves indicates problems with rigorous comparison to that of 2,3,7,8-TCDD. Based on QSAR calculations with other existing bird data (M. Tysklind and P.L. Anderson, University of Umea, Sweden), a value of 0.1 is recommended.	0.1
1,2,3,6,7,8-HexaCDF	In a chicken embryo egg injection study, this compound was found to be approximately 0.4 times less potent than 2,3,7,8-TCDD as an inducer of EROD (*119*). In combination with QSAR calculations with other existing bird data (M. Tysklind and P.L. Anderson, University of Umea, Sweden), a value of 0.1 is recommended.	0.1
1,2,3,7,8,9-HexaCDF	No *in vivo* or *in vitro* data are available. Based on QSAR calculations with other existing bird data (M. Tysklind and P.L. Anderson, University of Umea, Sweden), a value of 0.1 is recommended.	0.1
2,3,4,6,7,8-HexaCDF	No *in vivo* or *in vitro* data are available. Based on QSAR calculations with other existing bird data (M. Tysklind and P.L. Anderson, University of Umea, Sweden); a value of 0.1 is recommended.	0.1
1,2,3,4,6,7,8-HeptaCDF	At present no data are available for this compound in birds; a value of 0.01 is recommended based on similar homolog class REPs across taxa for the hexaCDFs and heptaCDFs.	0.01
1,2,3,4,7,8,9-HeptaCDF	At present, no data are available for this compound in birds; a value of 0.01 is recommended based on similar homolog class REPs across taxa for the hexaCDFs and heptaCDFs.	0.01
OctaCDF	At present, no *in vivo* or *in vitro* data are available for this compound in birds; a value of 0.0001 was recommended based on data from mammalian studies.[a]	0.0001
Non-*ortho* PCBs		
3,3′,4,4′-TetraCB (77)	Studies with chickens and wild avian species reported *in vitro* and *in ovo* effects, with REPs ranging from <0.0003 to 0.15 depending on the species (*66,68,69,122,123*). A value of 0.05 is recommended.	0.05
3,4,4′,5-TetraCB (81)	Egg injection studies have not been carried out with this compound. Two studies with chick embryo hepatocytes from several bird species indicate a wide range of REPs (0.001–0.5) of this compound to induce EROD relative to TCDD (*66,68*). As for most species, REPs were close to a value of 0.1, which is the recommended value.	0.1
3,3′,4,4′,5-PentaCB (126)	A 24-hr study with chickens determined a REP of 0.07 (*124*); a value of 0.1 is recommended.	0.1
3,3′,4,4′,5,5′-HexaCB (169)	One study determined the LD_{50} in chicken embryos after injection of the compound into the egg, and a REP of 0.002 was reported (*125,126*). A value of 0.001 is recommended.	0.001

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of dioxinlike chemicals. These factors can include alterations in absorption, tissue distribution, and metabolism between individual congeners.

The importance of pharmacokinetic factors has been illustrated with studies using octaCDD in rodents. This compound initiated dioxinlike responses following subchronic exposure to rats, with an estimated relative potency of 0.01 based on hepatic levels correlated with the induction of CYP1A1 (*87*). However, earlier acute toxicity studies had suggested that octaCDD was essentially nontoxic, with a TEF value less than 0.000001. These subchronic studies also showed that octaCDD is extremely poorly absorbed and absorption from the gastro-intestinal tract decreased with increasing dose (*143*). Consequently, very little is stored from a (single) high dose of octaCDD in tissues of animals. In contrast, repeated exposure to relatively low doses can lead to significant tissue accumulation and hence a biological response. Based on these findings, it can be discussed whether future TEF values should be based on intake or tissue level values to bridge differences between species.

Differences in tissue distribution can also significantly influence TEF values based on tissue concentrations. The liver/adipose tissue distribution can vary significantly between the species and dose levels used (*95*). A number of highly toxic congeners such as 2,3,4,7,8-pentaCDF, 2,3,7,8-TCDD, and PCB 126 bind very tightly to CYP1A2 and subsequently concentrate in the liver in many rodent species, even at very low dose levels (*88,131,144–148*). In this respect, it should be noted that the structure–activity relationship for binding to the Ah receptor and to CYP1A2 are not identical (*149*). As the level of CYP1A2 is increased, dioxinlike compounds redistribute from the adipose tissue back to the liver. Thus, depending on the species and dose level, the binding of an Ah receptor agonist to CYP1A2 can alter tissue distribution. As a result of this CYP1A2 binding, hepatic REPs for these compounds are lower than those based on intake because of disproportionately high liver concentrations. However, if other tissues are considered, e.g., skin and lung, the REP values would be higher because the tissue concentrations are lower than expected based on administered dose (*81*).

The distribution of PCBs in laboratory animals differs significantly from that of the 2,3,7,8-substituted PCDFs and PCDDs with respect to liver distribution. Highly biopersistent PCBs, e.g, PCB 153, are predominantly stored in adipose tissue and skin and not in the liver (*150*). Nevertheless, PCB congeners that are isostereomers of TCDD, such as PCB 126, attain a high liver concentration. With the addition of one *ortho* chlorine, the hepatic accumulation decreases dramatically, as was shown in comparative semichronic studies with rats and PCBs 126 and 156 (*103,109*). These differences again appear to be related to induction of and binding to CYP1A2. It has also been shown that coadministration of PCDDs, PCDFs, or dioxinlike PCBs with the nondioxinlike congener PCB 153 can result in modulation of the hepatic disposition and elimination (*151–153*). These toxicokinetic interactions are quantitatively limited, compound and dose dependent, and probably the result of multiple mechanisms involving, among others, *de novo* synthesis of both the Ah receptor and CYP1A2 (*151*). To some extent, these toxicokinetic interactions could explain the nonadditive effects that were observed when combinations of dioxins and PCB 153 were used in rodent studies (*95*). To what extent these toxicokinetic interactions are also relevant at low-level environmental exposure is still unknown.

The position and degree of halogenation determines the rate and extent of metabolism, which is the key determinant of excretion or bioaccumulation of these compounds (*95,154*). Full lateral halogenation at the 2,3,7,8-positions produces PCDDs and PCDFs that lack two adjacent unsubstituted carbon atoms. These congeners tend to be very resistant to metabolism, as these positions are also preferentially oxidized by the cytochrome P450 system, most likely by the CYP1A enzymes. Because of the stress on the furan ring, PCDFs are more susceptible to biochemical degradation than PCDDs. In addition, the positions adjacent to the oxygen bridge in the PCDF molecule (positions 4 and 6) are more sensitive to metabolic attack than those in the PCDD molecule (*95*).

For PCBs the presence of two adjacent unsubstituted carbon atoms also facilitates the metabolic conversion to more polar metabolites. As with PCDFs and PCDDs, the cytochrome P450 1A enzyme(s) seems to play an important role in metabolism of

Table 3. (*continued*)

Congener	Description	WHO TEF
Mono-*ortho* PCBs		
2,3,3′,4,4′-PentaCB (105)	One study determined the LD_{50} in chicken embryos after injection of the compound into the egg, and a REP value of 0.00014 was reported (*125,126*). A value of 0.0001 is recommended.	0.0001
2,3,4,4′,5-PentaCB (114)	At present, available data are only from QSAR studies (*74,102,127*); based on these calculations, a value of 0.0001 is recommended.	0.0001
2,3′,4,4′,5-PentaCB (118)	One study was carried out to determine the LD_{50} in chicken embryos after injection of the compound into the egg; at the highest doses, no lethality was observed (*126*). This compound is also a poor inducer of EROD in avian hepatocyte cultures (*66*); a value of 0.00001 is recommended.	0.00001
2′,3,4,4′,5-PentaCB (123)	At present, available data are only from QSAR studies (*74,102*); based on these calculations, a value of 0.00001 is recommended.	0.00001
2,3,3′,4,4′,5-HexaCB (156)	One study determined the LD_{50} in chicken embryos after injection of the compound into the egg and reported a REP of 0.0002 (*126*). A value of 0.0001 is recommended.	0.0001
2,3,3′,4,4′,5′-HexaCB (157)	One study determined the LD_{50} in chicken embryos after injection of the compound into the egg, and reported a REP of 0.0001 (*126*). A value of 0.0001 is recommended.	0.0001
2,3′,4,4′,5,5′-HexaCB (167)	One study determined the LD_{50} in chicken embryos after egg injection and reported a REP <0.00008 (*126*). A value of 0.00001 is recommended.	0.00001
2,3,3′,4,4′,5,5′-HeptaCB (189)	No *in vivo* or *in vitro* data are available. Based on QSAR calculations with other existing bird data (M. Tysklind and P.L. Anderson, University of Umea, Sweden), a value of 0.00001 is recommended.	0.00001

Abbreviations: WHO, World Health Organization; CDD, chlorinated dibenzodioxins; EROD, ethoxyresorufin-*O*-deethylse; CDF, chlorinated dibenzofurans; QSAR, quantitative structure–activity relationship; REPs, relative potencies; CB, chlorinated biphenyl, LD_{50}, median lethal dose.

[a]After a postmeeting consultation in February 1998, we agreed upon a revision of the TEF values for octaCDD and octaCDF in fish and birds, which were presented at the 17th International Symposium on Chlorinated Dioxins and Related Compounds on 25–29 August 1997 in Indianapolis, Indiana.

those PCB congeners that are more or less isosteric with 2,3,7,8-TCDD (*155*). This is based on a study with rats, marine mammals, and wild bird species in which it was observed that the metabolic degradation of PCB 77 correlated well with EROD activity. However, the same study indicated that for fish species this isoenzyme might be less effective in metabolizing these PCBs (*156*). In addition, several other P450 isoenzymes, e.g., P450 2B and 3A, might be involved in the metabolism of PCBs that have an *ortho*-substitution pattern. With an increasing *ortho* chlorine substitution pattern, the induction of P450 2B1 and 2B2 isoenzymes increases significantly (*155,157*). Studies with PCB patterns and enzyme activities in wild mammals indicate that, at least in seals and polar bears, the involvement of CYP2B isoenzymes in metabolism of PCBs cannot be excluded (*158,159*).

The role of metabolism can also be important when comparing acute and subchronic studies. In rodent studies using both 2,3,7,8-TCDF and TCDD, it was demonstrated that the REP of 2,3,7,8-TCDF for enzyme induction was almost equal to that of TCDD after acute exposure. However, when subchronic studies were done, 2,3,7,8-TCDF was much less potent than TCDD due to its rapid metabolism and lack of bioaccumulation (*88*). A similar explanation was suggested when comparing the relative potencies for the induction of cleft palate in mice by 1,2,3,7,8-pentaCDF versus 2,3,4,7,8-pentaCDF (*160*). When comparing the brominated dioxins and dibenzofurans with the chorinated ones, it appears that at least some brominated compounds can be more resistant to metabolism than their corresponding chlorinated analogs (*12*). Species differences in metabolism might also be one of the causes for the observed differential TEFs between fish, birds, and laboratory mammals. For example, some fish and birds may have limited ability to metabolize PCB 77 and 2,3,7,8-TCDF. However, both lay eggs and embryos have little depuration capability compared to adults. The respective avian and mammalian PCB 77 and 2,3,7,8-TCDF TEFs demonstrate more potency *in ovo* than *in vivo*. The PCB 77 and 2,3,7,8-TCDF TEFs are higher in bird eggs/embryos without a postconception maternal influence than in mammalian embryos with maternal metabolic protection. Conversely, a similar fish and mammalian comparison shows almost identical fish egg/embryo and mammalian TEFs. The role of metabolism, subsequent elimination, and reproductive strategy differences, especially through maternal egg deposition for most nonmammalian vertebrate species, points to the need to focus future REP/TEF determinations on *in vivo* or *in ovo* studies with comparisons between target organ or tissue exposure measurements and toxicity end points. In addition, it points to the need to base future TEF values on *in vivo* studies in which steady-state conditions are obtained or at least have been approached. Utilizing this approach will greatly increase the value of laboratory-determined exposure measurements for data interpretation in similar environmental samples regardless of taxonomic group.

As illustrated above, many PCBs, PCDFs, and PCDDs are relatively resistant to metabolism and can therefore accumulate in different trophic levels, causing biomagnification and toxicity higher in the foodchain (*161*). For PCDDs and PCDFs, the structure–activity relationships for bioaccumulation are relatively simple and involve primarily the 2,3,7,8-substituted congeners for most vertebrate species. Only in some invertebrates and the guinea pig has the accumulation of non-2,3,7,8-substituted PCDDs and PCDFs been found to be significant, but the guinea pig has been found to have low metabolic capacities for these compounds (*95*). Thus, from a pharmacokinetic point of view, only the 2,3,7,8-substituted congeners should be considered when TEFs must be determined for ecotoxicological risk assessment of vertebrates.

For PCBs the situation is more complex, as structure–activity relationships are less well defined for metabolism and associated bioaccumulation. The degree of accumulation is strongly determined by the capability of the organism to metabolize the various PCB congeners (*22,162*). This can differ qualitatively as well as quantitatively between species. In general, it can be stated that fish are less capable of metabolizing PCBs than most birds and mammals. In spite of the complexity of the above processes, the lack of chlorine substitution on both the *meta* and *para* positions in the PCB molecule appears to facilitate the metabolism of these compounds in most higher vertebrate species (*21,156,158,163*). As a result of this "biofiltering" by metabolism at different levels in the foodchain, the qualitative PCB pattern in top predators shows some resemblance, which allows selection of PCB congeners of major concern for risk assessment (*164*).

Qualitative and quantitative changes occur in PCDD, PCDF, and PCB patterns among different trophic levels and between the abiotic and biotic components of different ecosystems. This is especially confounded when attempts are made to perform risk and exposure assessments from a contaminated soil or sediment. It is preferable and indeed desirable to model Ah receptor-active congeners from abiotic to biotic components of ecosystems because of differential partitioning across these matrices, which are influenced by physicochemical properties, physiological differences, food chain position, and different reproductive strategies.

Depending on the assessment and toxicity end points identified in a particular ecological risk assessment, application of the appropriate TEFs for fish, birds, or mammals, as well as resulting TEQs, should only be determined in biotic matrices after the quantitative estimates of congener concentrations are made in a particular target species or generic food chains. Conversely, TEQs in abiotic matrices could be misused and have obscure value. For example, calculating TEQs in sediment or soil does not harm or place any risk on these abiotic matrices, regardless of TEF scheme. The application of the TEF concept for foodchain transport out of the abiotic compartments is clearly an area for future research.

Application of *in Vitro* Assays in the Derivation of TEFs

A number of *in vitro* assays, either in primary cultures or immortalized cells, have been used to establish REPs for mammals, birds, and fish. These include assays for Ah receptor competitive ligand binding, CYP1A1 gene induction, cell differentiation, plaque-forming cell (PFC) response, and porphyrin accumulation.

The most extensively used biological *in vitro* response studied so far is the induction of the *CYP1A1* gene. *CYP1A1* gene induction has been measured by monitoring changes in mRNA (*165,166*), protein levels (*66,167*), and/or enzyme activity [i.e., EROD or aryl hydrocarbon hydroxylase (AHH)] (*168,169*).

In addition, permanently transfected cells have also been established that contain CYP1A-regulated reporter genes. These cell lines contain a permanently incorporated reporter gene that is regulated by the mouse CYP1A1 regulatory region (*55,142,170,171*). These cell lines have a number of advantages over conventional enzyme induction assays such as 1) a sensitive and more easily measurable enzyme activity; 2) chemical inducers do not act as competitive inhibitors of the reporter gene; and 3) a larger number of available species- and tissue-specific assays.

Only two studies have compared endogenous EROD induction to reporter gene induction (*55,172*). The structure–activity relationship of the tested chemicals was comparable between wild-type and recombinant H4IIE cells. Dose–response relationships exhibited comparable dynamic ranges, and binary mixtures of TCDD, PCB 126, and PCB 77 did not depart from additivity in either cell line. In addition, PCB 153 significantly antagonized induction by

TCDD and PCB 126 in both cell lines. The recombinant cell line was found to be generally more sensitive to PCDDs, PCDFs, and PCBs when compared to the wild-type cells (*172*). Additionally, Richter et al. (*55*) recently reported that a recombinant trout cell line (RLT 2.0) could be used as an approximate predictor of responses in fish. However, the use of this assay was not advocated to develop REPs for ecological risk assessment since it was still plagued by the same drawbacks that limit the utility of other *in vitro* assays.

In vitro CYP1A induction has also been used to assess the level of dioxin equivalents (TEQs) in a number of environmental samples (*69,173–177*). In general, the TEF/TEQ approach using CYP1A induction accurately predicted dioxin equivalents within a complex mixture when compared to gas chromatography-mass spectrometry analysis or *in vivo* assessments, but may overestimate the TEQs when using other responses such as PFC (*91*). The accuracy of this *in vitro* approach also depends on the composition of the sample. The presence of high amounts of Ah receptor agonists that are not covered by the TEF concept (e.g, polycyclic aromatic hydrocarbons) can result in a considerable overestimation of TEQs in environmental samples. Furthermore, these *in vitro* studies have shown that some responses (i.e., PFC, reporter gene, and AHH/EROD induction) and cell lines (H4IIE, recombinant reporter cells) are susceptible to nonadditive interactions. This is especially true if the complex mixture contains PCB congeners that are partial Ah receptor agonists (*91,142,178,179*).

In summary, a single *in vitro* assay based on a single surrogate species may not accurately predict the toxicity of a chemical or complex mixture following exposure to other species. Nevertheless, the use of *in vitro* assays provides a general tool as a prescreening method of TEQs in environmental samples. However, it does not replace *in vivo* experiments when determining TEFs for dioxinlike compounds.

The Use of QSARs for Identification and Screening of Dioxinlike Compounds

PCDDs, PCDFs, and PCBs consist of a large number of possible congeners with varying degrees of chlorination and substitution patterns. Thus, from a practical point of view, it does not seem feasible to test extensive numbers of congeners for their biological or toxic properties. The determination of QSARs could facilitate future risk assessment procedures significantly. Based on a limited number of compounds, structure–activity relationships have been developed for Ah receptor-mediated effects, e.g., induction of CYP1A1 and binding to this protein (*11,129,180*). In addition, structure–activity relationships have also been determined for effects that are not directly related to the Ah receptor and involve both parent compounds and their hydroxylated metabolites. These non-Ah receptor-mediated structure–activity relationships include binding to transthyretin and thyroxin-binding globulin (*6,181,182*), binding to the estrogen receptor (*183,184*), and decrease in dopamine levels (*2,3*). Based on these studies it can be concluded that the structure–activity relationships of the latter effects deviate significantly from those observed for the Ah receptor-mediated effects. As only Ah receptor-mediated effects are considered in the present TEF concept, these structure–activity relationships will not further be considered in this evaluation (see criteria above).

Most biological systems are complex, and it is unlikely that only one or a few chemical properties will suffice to describe them. Thus, it is necessary to characterize these compounds with a multitude of physicochemical descriptors. Such a broad chemical characterization may capture the underlying, hidden factors that correlate with the response of interest. This information can then be used as the future base for the selection of congeners for biological testing (*185*).

Within the TEF concept, the critical question is how to identify the physicochemical properties that determine if a compound can be expected to be dioxinlike or not. The planar structure of the PCDDs and the PCDFs is characteristic for high Ah receptor binding affinity. Furthermore, the 2,3,7,8-chlorine substitution pattern is of great importance as well. PCBs show a larger chemical variation due to the possible rotation of the two phenyl rings. The number of chlorine atoms in the *ortho*-position will, in this case, define the degree of dioxinlike properties. However, from a chemical point of view, it is difficult to define the point at which the compounds lose their dioxinlike properties. As a consequence of this, no single PCB congener can be identified as being structurally representative for the whole class of compounds. Hence, a number of congeners must be investigated in order to include the many facets of chemical structure within the PCB class of chemicals.

The use of multivariate chemical characterization (*118*) in combination with factorial design provides a tool by which small sets of structurally representative congeners can be selected. This tool can be used in the design of *in vitro* and *in vivo* experiments in order to introduce systematic structural variation in the congeners to be tested. In studies of complex environmental mixtures, indicator congeners can be selected from the structural variation found in such matrices as flue gases from incineration plants or Aroclor mixtures. The use of these systematic and balanced sets of congeners in the experimental protocol will provide increased knowledge of the biological behavior of the compounds studied.

Small sets of congeners, representative for the PCDDs, PCDFs, and PCBs, have been suggested (*186,187*). Twenty congeners were selected based only on their physicochemical properties and not on expected biological activity. As a first screening of possible dioxinlike effects, PCDFs and PCBs were tested in different *in vitro* systems using primary hepatocytes from different species as well as rat and fish hepatoma cell lines. Based on these results, QSARs have been established to define the correlation between chemical properties and a dioxinlike biochemical response. As can be seen in Table 4, these studies predict that a large number of PCBs, and also PCDFs, exhibit dioxinlike activity measured as *in vitro* induction of CYP1A(1) activity.

The systematic selection approach makes it possible to make interpolations and predictions of not yet tested congeners. In this way, all congeners within the chemical range in which the selection of test congeners were made can be ranked according to expected dioxinlike activity and the congeners of special interest can be identified and investigated further. This method has so far mainly focused on CYP1A1 induction, but could also be used in the screening of other dioxin-linked effects or other groups of halogenated aromatics, e.g., polychlorinated naphthalenes and polybrominated diphenylethers.

Based on the information presented in Table 4 about the predicted dioxinlike activity of PCBs, it should be noted that experimental data were used from *in vitro* experiments. Therefore, the structure–activity relationships determined with this multivariate characterization await further confirmation from *in vivo* experiments, including the role of pharmacokinetics, before these dioxinlike PCBs can be included in the TEF concept. Nevertheless these QSAR data indicate that more PCBs might be considered in the future for inclusion in the TEF concept. In relation to the large number of PCDFs that are predicted to induce CYP1A 1 *in vitro* activity, it should be noted that in *in vivo* situations only the 2,3,7,8-substituted PCDFs exhibit a significant tissue retention. In this case, a pharmacokinetic factor (metabolism) seems to dominate the toxicodynamic aspects of these non-2,3,7,8-PCDFs (*in vitro* Ah receptor binding and CYP1A1 induction).

Uncertainties Associated with the TEF Concept

Toxic equivalency factors were initially developed for calculating the TEQs in mixtures of PCDDs and PCDFs. The TEF

approach for hazard assessment of reconstituted PCDD/PCDF mixtures has been validated using standardized TEF or response-specific TEF values. In a limited number of validation studies using mixtures, a good correlation was found between the observed *in vivo* or *in vitro* response and TEQ values calculated from the relative concentrations of individual congeners in the mixture (*84,188–190*). The non-*ortho* and mono-*ortho* PCBs also elicit Ah receptor-mediated responses. As a consequence, TEFs have been assigned to these PCBs (*1,11,77*). From a risk assessment point of view this was a logical decision, as most environmental matrices contain PCDDs, PCDFs, and PCBs. In fact, in some environmental samples, the overall contributions of PCBs to TEQs exceed that of the PCDDs and PCDFs (*191*). When concentrations of TEQs in complex mixtures from environmental matrices were determined *in vitro* and compared to TEQs by using REPs from the same *in vitro* system, the results were generally within a factor of 2 (*192*).

However, the inclusion of PCBs in the TEF concept also poses a problem due to the nonadditive effects, which have been observed in laboratory studies with mixtures containing PCDDs, PCDFs, and PCBs. Ah receptor antagonist activities of certain PCB congeners, including the major environmental contaminant PCB 153, have been reported in several experimental systems. Recently, these nonadditive interactions of PCB on dioxinlike effects have been reviewed (*193*). In summary, the following antagonistic effects of nondioxinlike PCBs were described: induction of EROD activity in chick embryo hepatocytes (*194*), splenic PFC response to sheep erythrocytes in mice (*195*), splenic PFC response to trinitrophenyl-lipopolysaccharide in mice (*196*), serum IgM units in mice (*91*), mouse fetal cleft palate (*110,195*), and chick embryo malformations and edema and liver lesions (*197*). The apparent antagonism by PCB 153 of the TCDD-induced immunosupression is due to the enhanced immune response induced by PCB 153 (*198*). In addition, synergistic interactions have also been reported between PCBs and dioxins in the development of porphyria in rats (*199*) and mice (*89*), the induction of CYP1A1 (*152,178*) and thyroid hormone levels and associated enzyme activities (*200,201*). These multiple nonadditive interactions between dioxinlike and nondioxinlike HAHs require further investigation to establish the extent to which they compromise the TEF concept.

Several reports have also questioned the relative contributions of TEQs associated with dioxinlike compounds versus the substantial daily intakes of natural nonchlorinated

Table 4. Screening of compounds with a relative potency (REP) for PCDFs of at least 10^{-3} TCDD [illegible] PCBs of 10^{-5} of PCB 126 in different *in vitro* systems

Compounds and assay	Number of dioxinlike congeners	Reference
PCDFs in H4IIE rat hepatoma bioassay	40 out of 87 tetra- through octaCDFs	(*93*)
PCDFs in PLHC-1 fish hepatoma bioassay	47 out of 87 tetra- through octaCDFs	(*127*)
PCBs in primary hepatocytes from chicken	56 out of 154 tetra- through heptaCBs	(*102*)
PCBs in primary hepatocytes from monkey	79 out of 154 tetra- through hepta CBs	(*102*)
PCBs in primary hepatocytes from pig	101 out of 154 tetra- through heptaCBs	(*102*)

Abbreviations: PCDFs, chlorinated dibenzofurans; PCBs, chlorinated biphenyls. Congeners tested and creating the quantitative structure–activity relationship models were selected based on multivariate chemical characterization in combination with experimental design.

Ah receptor agonists in cooked foods and vegetables (*193,202,203*). The Ah receptor agonist and antagonist activities of indole-3-carbinol have been reported (*204–206*). Perinatal exposure of pregnant rats to indole-3-carbinol resulted in reproductive abnormalities in male rat offspring, which were also elicited by TCDD in the same study. However, when comparing the effects caused by indole-3-carbinol or TCDD, both similar and different responses were observed (*205*). In contrast, a recent study with TCDD or indole-3-carbizole in rats did not find characteristic TCDD-like responses, e.g., hypophagia, body weight loss, and CYP1A1 induction (*207*). These results suggest that at least in some animal and cell models, the potential effects of the natural Ah receptor agonists could be significant. However, it has been suggested that the difference in pharmacokinetics between natural and halogenated Ah receptor agonists may decrease the potential impact of the natural agonists in *in vivo* situations. These possible differences between halogenated and natural Ah receptor agonists, such as indole-3-carbinol, in pharmacokinetics and toxicodynamics should be examined in more detail in *in vivo* experiments.

In view of the nonadditive effects mentioned above, a question has been raised as to which effect would compromise the TEF concept more: antagonism or synergism. From the available experimental data, it appears that antagonism is the most commonly reported nonadditive effect between individual dioxinlike compounds and complex mixtures (*195,208–212*). However, it should be noted that the occurrence of either antagonism or synergism is ratio and dose dependent. With respect to nonadditive effects between TCDD and PCB 153 on CYP1A1 induction in rodents, it was observed that synergism prevailed at the lower dose levels, while antagonism dominated at higher dose levels (*95*). Mechanistically, this antagonism can be explained by the fact that less potent congeners still have Ah receptor binding affinities and therefore are effective competitors for binding the site (*195,209*). This reduces the probability of the more toxic dioxinlike compounds to bind to the Ah receptor. However, the less active congeners do not bind with such a high affinity that they would effectively induce EROD activity or cause other Ah receptor-mediated adverse effects (*11*). In this respect, some results of interactive studies with these compounds are equivocal. For instance, 3,3′,4,4′-tetraCB and TCDD caused greater than additive induction of AHH activity in the liver of rainbow trout at doses calculated to produce 50% or less of the maximum response. However, in rainbow trout at greater doses, the same mixture was found less than additive (*213*). In addition, PCB 153 had an antagonistic effect on the induction of EROD activity by TCDD (*214*), but was found to be synergistic in another study (*215*).

In conclusion, there has been much discussion about the possible interactions between and among individual congeners, complex technical mixtures and extracts of environmental matrices (*216*). Based on receptor theory and the proposed mechanism of action of Ah receptor-active compounds, an additive model for the prediction of TCDD TEQs still seems most plausible in spite of the also observed nonadditive interactions. It is unlikely that the use of additivity in the TEF concept will result in a great deal of error in predicting the concentrations of TEQs due to synergism or antagonism.

Validation of the TEF Concept for Environmental Risk Assessments

A range of validation studies with fish and birds have examined the suitability of an additive model of toxicity for these compounds. These span from isobolographic studies of several pairs of Ah receptor agonists (and/or antagonists) to the testing of complex environmental mixtures found in the environment.

In rainbow trout and lake trout embryos, binary mixtures of Ah receptor agonists were tested following the isobolographic method (*14,50,217*). These interactions on embryo lethality between congener pairs were, in general, found to be additive. However, for the combinations of TCDD and some non-*ortho* PCBs, deviations from additivity were dependent on the ratio of the congeners were also reported (*49,213,218*). With respect to these nonadditive interactions,

Table 5. World Health Organization toxic equivalency factors (TEFs) for humans, mammals, fish, and birds

Congener	TEF		
	Humans/mammals	Fish[d]	Birds[d]
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PentaCDD	1	1	1[c]
1,2,3,4,7,8-HexaCDD	0.1[a]	0.5	0.05[c]
1,2,3,6,7,8-HexaCDD	0.1[a]	0.01	0.01[b]
1,2,3,7,8,9-HexaCDD	0.1[a]	0.01[c]	0.1[b]
1,2,3,4,6,7,8-HeptaCDD	0.01	0.001	<0.001[b]
OctaCDD	0.0001[a]	<0.0001	0.0001
2,3,7,8-TetraCDF	0.1	0.05	1[b]
1,2,3,7,8-PentaCDF	0.05	0.05	0.1[b]
2,3,4,7,8-PentaCDF	0.5	0.5	1[b]
1,2,3,4,7,8-HexaCDF	0.1	0.1	0.1[b,d]
1,2,3,6,7,8-HexaCDF	0.1	0.1[d]	0.1[b,d]
1,2,3,7,8,9-HexaCDF	0.1[a]	0.1[c,d]	0.1[d]
2,3,4,6,7,8-HexaCDF	0.1[a]	0.1[d,e]	0.1[d]
1,2,3,4,6,7,8-HeptaCDF	0.01[a]	0.01[e]	0.01[e]
1,2,3,4,7,8,9-HeptaCDF	0.01[a]	0.01[c,e]	0.01[e]
OctaCDF	0.0001[a]	<0.0001[c,e]	0.0001[e]
3,4,4′,5-TetraCB (81)	0.0001[a,c,d,e]	0.0005	0.1[c]
3,3′,4,4′-TetraCB (77)	0.0001	0.0001	0.05
3,3′,4,4′,5-PentaCB (126)	0.1	0.005	0.1
3,3′,4,4′,5,5′-HexaCB (169)	0.01	0.00005	0.001
2,3,3′,4,4′-PentaCB (105)	0.0001	<0.000005	0.0001
2,3,4,4′,5-PentaCB (114)	0.0005[a,d,e,f]	<0.000005[e]	0.0001[g]
2,3′,4,4′,5-PentaCB (118)	0.0001	<0.000005	0.00001
2′,3,4,4′5-PentaCB (123)	0.0001[a,d,f]	<0.000005[e]	0.00001[g]
2,3,3′,4,4′,5-HexaCB (156)	0.0005[d,e]	<0.000005	0.0001
2,3,3′,4,4′,5′-HexaCB (157)	0.0005[d,e,f]	<0.000005[d,e]	0.0001
2,3′,4,4′,5,5′-HexaxCB (167)	0.00001[a,f]	<0.000005[e]	0.00001[g]
2,3,3′,4,4′,5,5′-HeptaCB (189)	0.0001[a,d]	<0.000005	0.00001[g]

Abbreviations: CDD, chlorinated dibenzodioxins; CDF, chlorinated denzofurans; CB, chlorinated biphenyls; QSAR, quantitative structure–activity relationship.

[a]Limited data set.

[b]*In vivo* CYP1A induction after *in ovo* exposure.

[c]*In vitro* CYP1A induction.

[d]QSAR modeling prediction from CYP1A induction (monkey, pig, chicken, or fish).

[e]Structural similarity.

[f]No new data from 1993 review (*1*).

[g]QSAR modeling prediction from class specific TEFs.

deviations from strict additivity were less than a factor of two in the LD_{50} values (*50,217*). In addition, brominated analogs of 2,3,7,8-TCDD and other dioxin, furan, and biphenyl congeners also showed additive interactions (*14*).

When testing synthetic or complex environmental mixtures of chemicals in fish, additivity also appears to be the general case (*219*). This was shown with a synthetic mixture of Ah agonists and non-Ah receptor compounds in rainbow trout early life stage mortality tests in which results simply followed an additive model (*40*). The additivity model has also been investigated in fish through the use of environmentally derived mixtures. One study used the organic extract made from lake trout, which was injected into eggs of hatchery-reared rainbow trout (*220*) and lake trout (*221*). Additive toxicity of PCDDs, PCDFs, and planar PCBs to developing trout embryos was also evaluated through the direct injection of environmentally derived mixtures into newly fertilized eggs (*220*). The good agreement between $TEQs_{egg}$ calculated with the trout early life stage mortality TEFs for concentrations of PCDDs, PCDFs, and PCBs measured in Lake Michigan lake trout and $TEQs_{egg}$ measured on the basis of toxicity of the lake trout extract to rainbow trout sac fry following egg injection again suggests that $TEQs_{egg}$ are strictly additive and TEFs for all significant Ah receptor agonists present were included (*220*).

The results from these studies showed again that the mixture of these compounds present in lake trout acted in an additive fashion when compared with experiments using single congeners (*40*). The additive model of toxicity is also supported by studies of embryotoxicity in birds. The toxicity of an environmentally derived mixture of chemicals, including dioxinlike chemicals, was tested in chicken and found to be additive (*222*).

Additionally, the TEF approach could also be validated by using TEF factors derived from experiments in chickens that were successfully used to predict the embryo lethality for double crested cormorant eggs (*175,223*). The TEF and TEQ approaches were also successfully applied in a biological monitoring study with great blue herons and double crested cormorants (*224,225*). Thus, as with fish, the additivity in the TEF concept is also supported by studies with (wild) birds. Based on the use of more environmentally relevant species, it can be concluded that the type of interaction that is most prevalent among Ah receptor agonists and non-Ah receptor compounds is additivity. However, more studies to validate the additivity in fish and wildlife are required to better understand the limitations of the TEF and TEQ approachs. Yet, evidence from fish and bird studies indicates that the hazards of not using such an approach are greater than the uncertainties currently observed with the TEF/TEQ approaches.

Conclusions

Based on an extension of the existing database (*1*), TEFs for PCDDs, PCDFs, and PCBs were reevaluated and either revised (mammals) or established (fish and birds). A limited number of existing mammalian TEFs for HAHs were revised based on new scientific information or reevaluation of existing data. These HAHs included 1,2,3,7,8-pentaCDD, octaCDD, octaCDF, and PCB 77. In addition, we decided that there was insufficient *in vivo* evidence to support Ah receptor agonist activity and thus determine TEF values for some di-*ortho* PCBs. Therefore, we recommended the withdrawal of the TEF values for PCB 170 and 180 that were assigned earlier (see Table 1) (*1*).

The mammalian TEFs established by this WHO expert meeting and presented here are considered to be applicable for the human situation as well as for wild mammalian species. In addition, TEFs for fish and birds were determined, which could be used in ecotoxicological risk assessments of these vertebrate classes.

When deriving TEFs for humans/mammals, fish, and birds, we attempted to harmonize the TEFs across different taxa to the extent possible, as this would have a clear advantage from a risk assessment and management perspective. However, total synchronization of TEFs between mammals, birds, and fish was not feasible, as there were obvious indications of orders of a magnitude difference in TEFs between the taxa for some compounds. In this respect the absent or very low response of fish to mono-*ortho* PCBs compared to mammals and birds is most noticeable. It is also important to note that mammalian TEFs are based on intake (administered dose) while fish and bird TEFs are based on residue analysis (tissue concentration and administered dose in egg injection studies).

We also reviewed a number of uncertainties that could compromise the TEF concept when used for risk assessment purposes. These uncertainties include nonadditive interactions, differences in shape of the dose–response curve, and species responsiveness. This was based on the proposed Ah receptor mechanism of action for PCDDs, PCDFs, and dioxinlike PCBs, but was also based on a number of combination studies with mammals, birds, and fish that predicted the measured TEQ adequately according to the dose additive model.

Therefore, the prediction of TEQs according to the TEF model is considered to be plausible and to be the most feasible approach for risk assessment of HAHs with dioxinlike properties. In view of the available scientific evidence from studies with mixtures, it was concluded that it is unlikely for the use of this additive model to result in a great deal of error in predicting the concentrations of TCDD TEQs or responses at environmentally relevant levels due to nonadditive interactions.

A summary of the suggested WHO TEFs for PCDDs, PCDFs, and dioxinlike PCBs is shown in Table 5.

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Big Ideas

Future

- An enviro[illegible] disease-susceptibility genes vary from person to person in a represen[illegible], to help us see why you might get a nerve disorder from an exposure [illegible] friend Lee might not . . . information to protect you *and* Lee, without gu[illegible]
- A survey o[illegible]od—a look at what we, as a population, have been exposed to.
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APPENDIX E

SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT

ECOLOGICAL RISK ASSESSMENT

E.1 INTRODUCTION

The goal of the Screening-Level Ecological Risk Assessment (SERA) will be to identify the chemicals detected at concentrations that exceed the COPC screening levels, the locations of these exceedances, and the need for further investigation and/or remedial action at the Mustard Gas Burial Ground, at NSWC Crane. This SERA will provide information to scientists and managers that will enable them to conclude either that ecological risks at the site are most likely negligible, or that further information is necessary to evaluate potential ecological risks at the site. A phased approach to the SERA will be used that relies first on environmental chemistry data and field observations for the preliminary assessments. Biological sampling or testing may be conducted if further work is needed. The SERA methodology used at NSWC Crane will follow the guidance presented in the Final Guidelines for Ecological Risk Assessment (U.S. EPA, 1998a) and the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (U.S. EPA, June 1997).

This SERA will consist of the first two of eight steps required by the Environmental Protection Agency (EPA) guidance (EPA, 1997 and 1998) and the Navy Policy for Conducting Ecological Risk Assessments. Figure E-1 presents the Navy's Ecological Risk Assessment Tiered Approach. The first two steps are the screening-level assessment. Step 3a is the final step of the BERA and consists of refining the list of COPCs that were retained following the SERA. Steps 3b through 7 are conducted if additional evaluations or investigations are necessary. Finally, Step 8, Risk Management, is incorporated throughout the ERA process, in cooperation with the Region 5 Biological Technical Assistance Group (BTAG).

The first phase in the ERA process is the screening-level risk assessment. In this phase, conservative exposure estimates are made for grouped or individual ecological receptors, and these exposures are compared to screening-levels and threshold toxicity values. The SERA includes the following considerations:

- Screening-level problem formulation
- Screening-level ecological effects evaluation
- Screening-level exposure estimate
- Screening-level risk calculation

These sections are discussed in detail throughout the QAPP and this appendix.

E.2 SCREENING-LEVEL PROBLEM FORMULATION

The screening-level problem formulation includes identification of potential receptor groups, contaminants of potential concern (COPCs), and the mechanisms for fate/transport and toxicity. Determination of the complete exposure pathways that exist on a site is accomplished at this point to facilitate receptor selection. As part of receptor identification, site habitats and potential ecological receptors are described.

E.2.1 Environmental Setting

E.2.1.1 Site Specific Environmental Setting

The MGBG lies on a northwest-southeast trending ridge crest. A deeply-incised drainage channel lies about 450 ft north of the MGBG. The elevation along this channel is approximately 530 to 580 Above Mean Seal Level (AMSL). Another deeply-incised channel lies about 1200 feet south-southwest of the MGBG and its elevation is about 510 to 560 ft AMSL as it passes south of the MGBG. Total relief in the immediate vicinity of the MGBG is approximately 150 feet. The steepest slopes near the MGBG occur on the north side and are about 30%.

Runoff from the MGBG drains into the two drainage channels/unnamed tributaries (see above) of Goldsberry Hollow, which drains west-southwest about 1.2 miles before they enter Boggs Creek (Figure 1-8 in Section 1 of the QAPP). Boggs Creek then flows southward into a large reservoir located at the southern boundary of NWSC Crane. From the reservoir, Boggs Creek continues to flow south about 6 miles where it joins the East Fork of the White River. The Boggs Creek basin drains roughly 70% of NWSC Crane.

During a 18 January, 2000 site reconnaissance the site was observed to be heavily vegetated with grasses/shrubs ranging from 1 to 5 feet high at the time of the site visit. Attachment E.A-1 contains the Checklist for Ecological Assessment/Sampling" from EPA (1997). The MGBG crowns at approximately 5 to 10 feet above the elevation of HWY-251. Some small saplings were scattered over the site, but they did not exceed about 7 feet in height, except at the tree lines on the northern, eastern and southern edges of the site. The areas to the east and west of the site are vegetated with a very dense layer of shrubs and grasses. The land rolls off on the NE edge of the site and toward the SW of HWY 251. At the NE end of the MGBG northern edge was a mound of earth with some scrap material.

The area to the north (including the northeast corner of the site) is heavily wooded with mature deciduous trees including oaks, maples, sycamore, and American beech. The understory in the forest consisted of sparse patches of ground vegetation (i.e., ferns, grasses, moss). The drainage channel to the north was dry at the time of the site visit (with the exception of some small pools of standing water). Based on the scoured nature of the channel, it appears to experience heavy flows during rain events. The stream bed was approximately 10 feet wide, and the substrate was sand/exposed rocks. There were two primary drainage ditches (both were dry) leading from the site area down to this intermittent drainage channel.

On the SE side of the MGBG, between the MGBG and HWY-251, were a few scrap piles with asphalt, concrete and earth visible among the trees. The piles were approximately two to five feet high. There is a drainage ditch immediately north of, and parallel to, HWY-251 that lies between the road and the southern border of the MGBG. At least one culvert transports site runoff via the drainage ditch, under the road, and into the intermittent drainage channel located about 400 feet south-southwest of the MGBG. The ditch was dry at the time of the site visit. The stream bed was not observed during the site visit because the heavy vegetation and ice on the ground made the footing treacherous.

The area to the south of HWY-251 is heavily wooded with mature deciduous trees including oaks, maples, sycamore, and American beech. The understory in the forest consisted of vegetation including vines with thorns.

Based on the habitat at the site, and the observation of one potential burrow, it is likely that small mammals and birds are present at the site.

E.2.1.2 Basewide Environmental Setting

A biological characterization of NSWC Crane, including a listing of plants and animals found at the facility, is presented in the Installation Assessment (IA; Army, 1978) and the Initial Assessment Study (IAS; NEESA, 1983), and is summarized in the Environmental Monitoring Reports (EMR; Halliburton NUS August and November, 1992). A list of the species which may inhabit NSWC Crane and are protected under the U.S. Endangered Species Act, Indiana Department of Natural Resources Heritage Data Center, or the U.S. Fish and Wildlife Service is summarized in the RCRA Facility Permit (U.S. EPA, July 1995). The following paragraphs briefly summarize the environmental setting at the Base.

Eighty percent of NSWC Crane's 63,000 acres is classified as Central Hardwoods Forest of the United States (NEESA, 1983). In addition, some agricultural fields are in various stages of succession. Openings on dry upland sites contain almost pure stands of grasses with some clumps of woody plants

such as persimmon, sassafras, and sumac. Wetter sites have river birch, willow, sycamore, and cottonwood. Hillside communities have mostly hickory, white and black oak, red maple, sugar maple, tulip poplar, ash, and beech (NEESA, 1983).

The great variety of habitats at NSWC Crane (i.e., many stages of forest succession, streams, ponds, Lake Greenwood, grassy open spaces) lead to a high diversity of animal species (NEESA, 1983). Some of these species include (but are not limited to) mammals such as white-tailed deer, beaver, coyote, hawks, red fox, rabbits, raccoons, mice; birds such as ducks, geese, wild turkey, bobwhite quail, red-tailed hawks, and American robins; and various amphibians, reptiles, fish, and invertebrates.

The bird population includes a number of State or Federal Threatened, Endangered, or Species of Special Concern that use the site as their home range. These species include the bald eagle, osprey, sharp-shinned hawk, red-shouldered hawk, broad-winged hawk, black and white warbler, hooded warbler, and the worm-eating warbler (B&R Environmental, 1997). Also, the Indiana bat is the only Federal endangered species known to inhabit the site, although it is unlikely to forage at the MGBG. Because of the bat and their potential habitat, the cutting of trees is restricted to certain times during the year, and no shagbark hickory trees can be cut down at all.

There are six main creeks that receive drainage in five separate drainage basins at NSWC Crane: Furst Creek, Sulphur Creek, Little Sulphur Creek, Boggs Creek, Turkey Creek, and Seed Tick Creek. There also are many smaller streams/creeks and drainage ditches located at the facility, along with several small man-made ponds and one large lake (Lake Greenwood). Lake Greenwood is the source of potable water for NSWC Crane. Surface water from the facility eventually discharges to the east fork of the White River, which is located south of the facility.

E.2.2 Contaminants Ecotoxicity and Fate and Transport

Because all of the constituents that may have been disposed of at the site are not known, several classes of contaminants have the possibility to be present at the Base. These include mustard gas and its degradation products, thorium nitrate, metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, herbicides, polychlorinated biphenyls (PCBs), and/or explosives. The following sections present a brief discussion regarding the toxicity, potential food chain and trophic transfer, and fate and transport properties of each class of contaminants.

E.2.2.1 Physical and Chemical Characteristics

Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include bioconcentration factors (BAFs), organic carbon partition coefficients, and octanol water partition coefficients. The following paragraphs discuss the significance of each factor.

The SERA will use plant and invertebrate bioaccumulation factors to predict contaminant loading in plants and invertebrates. The following list presents the source of the bioaccumulation factors that will be used in the SERA.

- Plant Bioaccumulation Factors - Organics: Toxicity and Chemical-Specific Factors Database (ORNL, 1998a)

- Plant Bioaccumulation Factors - Inorganics: Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants (ORNL, 1998b)

- Soil Invertebrate Bioaccumulation Factors - PCBs and Inorganics: Development and Validation of Bioaccumulation Models for Earthworms (Sample et al., 1998a)

Some of the BAFs presented in the documents listed previously estimate the tissue concentrations in dry weight. These values must be converted to wet weight for use in exposure estimation in the foodchain models by multiplying the BAF by the proportion of dry matter content of the organism (Sample, et al., 1997). The following table presents the proportion of dry matter that will be used to adjust the BAFs, if necessary (Sample et al., 1997).

Food Type	Percent Water Content	Percent Dry Weight
Terrestrial Invertebrates (earthworms)	84	16
Terrestrial Plants (monocots-young grass)	70	30

Other plant, invertebrate, and small mammal bioaccumulation factors obtained from the literature also may be used for contaminants that are not listed in the above reference sources. Contaminants that do not have bioaccumulation factors will be assigned a default value of 1.

The organic carbon partition coefficient (K_{oc}) measures the tendency for a chemical to partition between soil or sediment particles containing organic carbon and water. This coefficient is important in the ecological environment because it determines how strongly an organic chemical will bind to the organic carbon in the sediment.

The octanol/water partition coefficient (K_{ow}) is the ratio of a chemical concentration in octanol divided by the concentration in water. The octanol/water partition coefficient has been shown to correlate well with bioconcentration factors in aquatic organisms and with adsorption to soil or sediment.

The BAFs, K_{oc}s, and K_{ow}s for all of the contaminants detected in the soil will be included in the SERA.

E.2.2.2 Metals

Many metals are found naturally in the surface water, sediment, and/or soil at various concentrations due primarily to chemical weathering and fallout from volcanoes. Most metals are toxic to aquatic (i.e., fish, invertebrates) and terrestrial (i.e., plants, invertebrates, vertebrates) ecological receptors at certain concentrations, with some metals being more toxic at lower concentrations than others. Also, different chemical forms of the metals may be more toxic than other forms. For example, hexavalent chromium is typically more toxic than trivalent chromium, and methylmercury is more toxic than inorganic mercury. In addition, the toxicity of several metals (cadmium, chromium, copper, lead, nickel, silver, and zinc) to aquatic receptors in freshwater systems decreases with increasing water hardness.

Only a portion of the total bulk concentration of metals in soils is bioavailable to ecological receptors. The uptake and accumulation of trace elements by plants are affected by several soil factors such as pH, Eh, clay content, organic matter content, cation exchange capacity, nutrient balance, concentration of other trace elements in soil, soil moisture, and temperature (Tarradellas et al., 1996). The bioavailability of the metals, however, is not known because there are other soil factors that influence uptake.

Many of these same factors also will influence the bioavailability of metals to invertebrates in sediment. One way to estimate the bioavailable portion of certain divalent metals (cadmium, copper, lead, nickel, and zinc) in sediment is to measure the amount of acid volatile sulfides (AVS) and simultaneously extracted metals (SEM) in a sediment sample. If the molar concentration of AVS is higher than the molar concentration of SEM, than all the SEM metals are expected to be unavailable to aquatic invertebrates and, therefore, nontoxic. AVS plays little or no role in determining interstitial water concentrations of metals in aerobic systems or those with low productivity (i.e., where the absence of organic carbon limits

sulfate reduction) (Ankley et al., 1996), or when ingestion of sediments is the primary exposure route (Lee at al., 2000).

Of the 29 elements essential for plant growth, seven are micronutrients, including copper, iron, manganese, and zinc (Tarradellas et al., 1996). Also, the following metals may stimulate plant growth but are only essential for some plant species: aluminum, cobalt, nickel, sodium, selenium, and vanadium (Tarradellas et al., 1996). Finally, some elements such as lead, cadmium, and mercury are toxic elements with no known function in plant metabolism (Tarradellas et al., 1996).

ORNL (1998b) has calculated soil-to-plant uptake factors for several metals based on a compilation of various studies. Cadmium, mercury, selenium, and zinc were the only metals (except for calcium and potassium) with mean uptake factors greater than one (1.02 to 2.25). None of the metals (except for calcium and potassium) have median uptake factors greater than one. Arsenic, cadmium, mercury, nickel, selenium, and zinc were the only metals (except for calcium, magnesium, and potassium) with upper 90th percentile uptake factors greater than one (1.1 to 5) (ORNL, 1998b). This indicates that most metals will not biomagnify in plants. Finally, it is reported that, for arsenic, copper, nickel, and zinc, the plant-based food chain may be protected because the toxic concentrations of these metals in plants are higher than those for animals, while cadmium and selenium are not toxic to plants at high concentrations and may be accumulated in plants at levels that may be toxic to animals (Cockerham and Shane, 1994). Other metals such as lead, cobalt and mercury can enter the food chain via plant uptake, but to a lesser extent (Cockerham and Shane, 1994).

Cadmium appears to accumulate in most species of earthworms at greater levels than any other metal (Satchell, 1983). This is supported by the high mean soil-to-plant uptake factor of 17 for cadmium, compared to mean uptake factors of 5.7 (zinc), 5.2 (mercury), 4.5 (silver), and 3.3 (lead) (Sample et al., 1998). The remaining metals (except potassium, sodium, and some radionuclides) had mean uptake factors of 1.8 or less (Sample et al., 1998). Cadmium, mercury, nickel, silver, and zinc are the only metals with median uptake factors greater than one (Sample et al., 1998). The upper 90th percentile uptake factors were 40.7, 20.6, 15.3, and 12.9 for cadmium, mercury, silver, and zinc (Sample et al., 1998). The remaining metals had upper 90th percentile uptake factors of 4.7 or less (Sample et al., 1998).

E.2.2.3 Semivolatile Organic Compounds

The most common semivolatile organic compounds that are found at naval facilities include polyaromatic hydocarbons (PAHs) and phthalates. PAHs are a diverse group of compounds consisting of two or more substituted and unsubstituted polycyclic aromatic rings formed by the incomplete combustion of

carbonaceous materials. PAHs are ubiquitous in the modern environment and commonly are constituents of coal tar, soot, vehicle exhaust, cigarette smoke, certain petroleum products, road tar, mineral oils, creosote, and many cooked foods. PAHs also are released to the environment through natural sources such as volcano and forest fire emissions. However, most of the emissions result from anthropogenic sources, largely wood burning for homes. Vehicular emissions are another primary source of PAHs. Hazardous waste sites can be a concentrated source on a local scale. Examples of such sites include former manufactured gas sites (i.e., sources of coal tar) and abandoned wood treatment plants (i.e., sources of creosote) [Agency for Toxic Substances and Disease Registry (ATSDR), 1989a].

PAHs are transferred from surface water by volatilization and sorption to settling particles. The compounds are transformed in surface water by photooxidation, chemical oxidation, and microbial metabolism (ATSDR, 1989a). In soil and sediments, microbial metabolism is the major process for degradation of PAHs (ATSDR, 1989a). Although PAHs accumulate in terrestrial and aquatic plants, many organisms are able to metabolize and eliminate these compounds. Vertebrates can readily metabolize PAHs, but lower forms (insects and worms) cannot metabolize PAHs as quickly. Food chain uptake does not appear to be a major exposure source to PAHs for aquatic animals (ATSDR, 1989a).

Plants and vegetables can absorb PAHs from soils through their roots and translocate them to other plant parts such as developing shoots (Eisler, 1987). In general, however, PAHs are not readily taken up by plants because these compounds are strongly adsorbed onto soil organic particles and root uptake is very inefficient (Donker, et al., 1994). As such, lower molecular weight PAHs (which would be more water soluble) are absorbed by plants more readily than higher molecular weight PAHs. This is indicated by the low soil-to-plant uptake factors, which were calculated using the K_{ow} for the contaminants. Finally, many higher plants can catabolize benzo(a)pyrene and possibly other PAHs (Eisler, 1987).

PAHs vary substantially in their toxicity to aquatic organisms. In general, toxicity increases as molecular weight increases, with the exception of some high molecular weight PAHs that have low acute toxicity. Most species of aquatic organisms rapidly accumulate PAHs from low concentrations in the ambient medium. However, uptake of PAHs is highly species specifics, it is higher in algae, mollusks, and other species that are incapable of metabolizing PAHs (Eisler, 1987). The ability of fish to metabolize PAHs may explain why benzo(a)pyrene is frequently not detected or is found at only very low levels in fish from environments heavily contaminated with PAHs (ATSDR, 1989a).

Phthalates are compounds that are used in production of plastics (ATSDR, 1993). Most phthalates are expected to sorb to soil or sediment particles after their release because of their high Log K_{oc} values

(Howard, 1989). Some phthalates may bioconcentrate in aquatic organisms [Spectrum Laboratories, 1999; Howard, 1989; ATSDR, 1989a].

E.2.2.4 Pesticides

Pesticides are used to control pestiferous invertebrates and, therefore, they are toxic to many soil and aquatic invertebrates. In addition, many pesticides are toxic to higher trophic level ecological receptors such as mammals and birds. For example, DDT compounds have been linked to eggshell thinning and subsequent decreased survival of several birds of prey (such as eagles and falcons). Other pesticides such as chlordanes, dieldrin, aldrin, endrin, and heptachlor also are very toxic to mammals and birds (Newell et al., 1987).

Organochlorine insecticides such as DDT, chlordane, aldrin, dieldrin, heptachlor, endosulfan, and endrin and their associated breakdown products generally degrade very slowly and tend to be soluble in lipids, which results in bioaccumulation and possible increases in concentrations through food webs (Newman, 1998). Pesticides have high Log K_{oc} values so they are expected to sorb strongly to soil and sediment particles when released to the environment. Consequently, these compounds are not easily displaced from their site of application, whether by runoff or leaching to groundwater. As a result, these compounds typically will not be taken up by plants.

DDT, DDE and DDD are highly lipid soluble, which, combined with an extremely long half-life, results in bioaccumulation (ATSDR, 1989b). When present in ambient water, DDT and its metabolites are concentrated in freshwater and marine plankton, insects, mollusks, and other invertebrates and fish (ATSDR, 1989b). As these organisms are part of the food chain, a progressive accumulation of residues may result in high levels of residues in organisms at the top of the food chain (ATSDR, 1989b). Moderate to significant bioconcentration in aquatic species has been reported for dieldrin, with bioconcentration factors (BCFs) ranging from 100 to 10,000 (Howard, 1991). Heptachlor also has been reported to bioconcentrate in aquatic species, with bioconcentration factors in fish up to about 20,000 (Howard, 1991).

Chlordane will bioconcentrate in both marine and freshwater species (ATSDR, 1989c). In living organisms, chlordane concentrations are usually highest in samples collected near areas where chlordane was used to control termites or other pests, in predatory species, and in tissues with high lipid content (Eisler, 1990). Food chain biomagnification is low except in certain marine mammals (Eisler, 1990).

E.2.2.5 PCBs

The term polychlorinated biphenyls (PCBs) commonly refers to a variety of mixtures of individual biphenyl isomers, each consisting of two joined benzene rings and up to 10 chlorine atoms. Mixtures of these isomers are known by their commercial designation of Aroclor. This trade name is followed by a four-digit number; the first two numbers indicate the type of isomer mixture and the last two numbers indicate the approximate weight percent of chlorine in the mixture (EPA, 1985).

PCBs released into water adsorb to sediments and other organic matter. Typically, PCB concentrations are greater in the sediment and suspended material than in the water column. Substantial quantities of PCBs in aquatic sediments can act as an environmental reservoir from which PCBs may be released slowly over a long period of time (ATSDR, 1989d). For PCBs that exist in the dissolved state in water, volatilization becomes the primary fate process. PCBs have the capability to bioaccumulate and biomagnify (EPA, 1985).

Degradation of PCBs in the environment is dependent upon the degree of chlorination. Generally, the more chlorinated the PCB molecule, the more persistent it will be in the environment. Factors that determine biodegradability include the amount of chlorination, concentration, type of microbial population, available nutrients, and the temperature (ATSDR, 1989d).

PCBs are expected to be highly immobile in the soil due to rapid and strong sorption (ATSDR, 1989d). Some data indicate that plants are capable of taking up PCBs and transferring them into polar metabolites or insoluble molecules (Donker et al., 1994). However, it is not very probable that uptake and transformation of these compounds occur to any great extent, because a large part (greater than 95 percent) will adsorb to the root surface (Donker et al., 1994). The transfer of vapor-phase PCBs from air to aerial plant parts may be the main source of vegetation contamination (ATSDR, 1989d).

Because PCBs are highly lipophilic, they can bioaccumulate in the lipid portions of animals. Bioconcentration factors in the thousands have been reported for various aquatic species (Eisler, 1986a). PCBs also can accumulate in upper trophic level animals such as piscivorous birds and mammals that feed on contaminated prey items (Eisler, 1986a). Finally, Sample et al. (1998) calculated mean, median, and 90th percentile reported soil-to-earthworm bioaccumulation factors (BAF) of 8.9, 6.7 and 15.9, respectively, indicating the PCBs can accumulate in soil invertebrates.

Adverse effects of PCBs on terrestrial wildlife include increased mortality, reproductive effects, and behavioral effects (USEPA, 1985). As a group, birds are more resistant to acutely toxic effects of PCBs

than mammals (Eisler, 1986a). Among sensitive avian species, PCBs disrupt the normal pattern of growth, reproduction, metabolism, and behavior (Eisler, 1986a). Of the mammals, the mink is the most sensitive wildlife species tested for which data are available (Eisler, 1986a). Impacts to mink include anorexia, weight loss, lethargy, reproductive effects, and death (Eisler, 1986a).

E.2.2.6 Volatile Organic Compounds

VOCs are usually very mobile in the environment because they are poorly adsorbed to soil and sediment particles. Also, because they are very volatile, they typically are only detected in surface waters and surface soils at low concentrations.

Most VOCs have very little potential to bioaccumulate in ecological receptors; therefore, biomagnification through the food chain does not appear to be significant. VOCs are not expected to biomagnify in plants and are typically only toxic to ecological receptors only at relatively high concentrations.

E.2.2.7 Explosives

Some of the more common explosives include nitroaromatic compounds such as 2,4,6-trinitrotoluene, hexahydro-1,3,5-trinitro-1,3,5-triazine, octahydro-1,3,5,7-tetranitro-1,3,5-tetrazocine, N-methyl-N,2,4,6-tetranitroaniline, and associated by-products and degradation products that may have been released to the environment during manufacturing and load, assembly, and pack processes at military facilities (Talmage et al., 1999). These explosives are moderately to highly toxic to freshwater organisms, with chronic screening values less than 1 mg/L, although some of the screening values are low because of the conservative methods used to develop them based on an absence of data (Talmage et al., 1999). Available data indicate that none of the compounds are expected to bioconcentrate (Talmage et al., 1999). Most of the explosives do not appear to be highly toxic to mammals. Terrestrial reference values (TRVs) are greater than 1 mg/kg-day.

Explosives have little to moderate potential to adsorb to soil and sediment (Talmage et al., 1999). Therefore, explosives will have moderate to high mobility in soils and sediment, and most of the explosives will be found in the water column (Talmage et al., 1999).

E.2.2.8 Mustard Gas

Mustard gas is a liquid that is not likely to change into a gas immediately if it is released at ordinary temperatures (ATSDR, 1995). It is not very water soluble and is not expected to migrate from soil to

groundwater. Mustard gas breaks down into the following three primary chemicals: thiodiglycol, thioxane, and 1,4-dithiane (Mitretek, 2000).

The log K_{ow} for mustard gas ranged from 1.37 to 2.41, which is below the 3.5 threshold that is usually cited as the threshold for bioaccumulation in food chains (Mitretek, 2000). This is also supported by ASDTR (1995) which states that mustard gas does not build up in the tissues of animals because it breaks down so quickly.

E.2.2.9 Thorium Nitrate/Radionuclides

Thorium nitrate is a radioactive chemical with a half life of 1.41×10^{10} years. It has a specific activity of 0.11 picoCuries/gm (alpha).

The 1977 International Commission on Radiological Protection (ICRP) report states that chronic radiation dose rates below 1 mGy/d (0.1 rad/d) will not harm plant and animal populations and that radiation standards for human protection will also protect populations of nonhuman biota (Barnthouse, 1995). A 1992 International Atomic Energy Agency report endorsed the findings of the of ICRP (1977) report (Barnthouse, 1995).

E.2.3 Potential Exposure Pathways

Based on the historical site operations, the primary source of contaminants is the soil. From the soil, the contaminants may migrate to ground water after the contaminants leach from the soil. In addition, contaminants from the site can enter surface water bodies via overland runoff/erosion, or through ground water discharge. Finally, contaminants can enter the air via the emission of volatile organic compounds or through wind erosion/dust. The following paragraphs discuss each of these exposure pathways in more detail. Figure E-2 presents the conceptual site model.

E.2.3.1 Ground Water

Currently, no discharge points of the ground water potentially contaminated with site-related contaminants have been identified. No seeps were observed during the January 18, 2000 site visit, and the intermittent stream to the north of the site was dry. In addition, the two large drainage ditches from the site to the northern intermittent stream, and one drainage ditch from the site to the southern intermittent stream, were dry during the site visit. Because the intermittent stream to the south of the MGBG has not been inspected, it is not known whether ground water was discharging to this stream. However, ecological receptors are not directly exposed to ground water (prior to it discharging from a seep or as surface

water), so this pathway will not be evaluated in this SERA. Ground water discharge to a seep or to the intermittent streams is discussed below.

E.2.3.2 Seep/Surface Water

Contaminants in the ground water may discharge as a seep or to a surface water body. Contaminants in the soil may also enter the intermittent streams via overland flow. Based on the surrounding habitat, and the presence of small mammals and birds, it is possible that these species could use seeps (if present) as a source of drinking water. However, unless the seep represents a potential source of drinking water (i.e., pooled water), a complete exposure pathway will not occur.

It is unlikely that the northern stream would support a healthy benthic macroinvertebrate or fish population because of the intermittent nature of the stream. However, contaminants from the site could migrate to locations further downstream that do support benthic macroinvertebrates and fish. These receptors could be exposed to the water by direct contact and incidental ingestion of water. Potential receptors in the southern stream are not known but are expected to be similar to those associated with the northern stream.

E.2.3.3 Surface Soil

Several groups of terrestrial ecological receptors can be exposed to contaminants in the surface soil. Invertebrates, such as earthworms, are exposed to the contaminants as they move through the soil, and ingest soil particles while searching for food. Plants are exposed to the contaminants via direct contact as contaminants are absorbed through the roots, which may then translocate to different parts of the plants (i.e., leaves, seeds).

Small mammals may be exposed to contaminants in the soil via several exposure routes. They may be exposed by direct contact as they search for food or burrow into the soil. However, exposure of terrestrial wildlife to contaminants in the soil via dermal contact is unlikely to represent a major exposure pathway because fur, feathers, and chitinous exoskeletons are expected to minimize transfer of contaminants across dermal tissue. Therefore, the dermal pathway will not be evaluated in the SERA. Small mammals also may be exposed to contaminants in the soil via incidental ingestion of soil, and ingestion of plants and/or invertebrates that have accumulated contaminants from the soil. These pathways will be evaluated in the SERA.

Larger, predatory species, such as the red fox and red-tailed hawk, can be exposed (indirectly) to site contaminants in the soil by ingesting small mammals that have accumulated contaminants from the soil. However, because of the relatively small size of the site (approximately 2 acres), the site would only occupy 1 or 2 percent of the predators' home range. Therefore, these receptors will not be evaluated in the SERA.

E.2.3.4 Air

The inhalation pathway will not be evaluated because air concentrations are expected to be minimal because the majority of the site is grass covered. Also, inhalation pathways typically are not evaluated in SERAs because of the uncertainty in exposures and effects concentrations.

E.2.4 Endpoints

E.2.4.1 Assessment Endpoints

Assessment endpoints are an explicit expression of the environmental value that is to be protected (EPA 1997a). The selection of these endpoints is based on the habitats present, the migration pathways of probable contaminants, and the routes that contaminants may take to enter receptors.

As already discussed in E.2.1.1, the habitat at and adjacent to the site consists of forested areas, open fields with grasses, and potential aquatic habitats. For this SERA the assessment endpoints are protection of the following groups of receptors from adverse effects of contaminants on their growth, survival, and reproduction:

- Soil invertebrates
- Terrestrial Vegetation
- Herbivorous mammals
- Herbivorous birds
- Carnivorous birds
- Carnivorous mammals
- Omnivorous mammals
- Omnivorous birds
- Benthic invertebrates
- Fish
- Amphibians and Reptiles

The following paragraphs discuss why the above assessment endpoints were selected for this SERA.

Soil Invertebrates: soil invertebrates are expected to be present in the soil at the site. They aid in the formation of soil, redistribution and decomposition of organic matter in the soil and serve as a food source for higher trophic level organisms. They also can accumulate some contaminants which can then be transferred to the higher trophic level organisms that consume invertebrates.

Terrestrial Vegetation: Terrestrial vegetation at site consists of grasses, shrubs, and trees. They serve as a food source and provide shade and cover for many organisms, and help prevent soil erosion, among other important functions. They also can accumulate some contaminants which can then be transferred to the higher trophic level organisms that consume plants.

Herbivorous Birds and Mammals: Herbivorous birds and mammals (animals that consume only plant tissue) may be present at the site because of the vegetative habitats (i.e., forested, open field). Their role in the community is essential because without them, higher trophic level could not exist (Smith, 1966). They may be exposed to, and accumulate contaminants that are present in the plants they consume.

Carnivorous Birds and Mammals: Carnivorous birds and mammals consist of birds and mammals that consume, invertebrates, fish, and other mammals and birds. Soil invertebrate-eating birds and mammals may be present at the site based on the habitat. These animals are considered first-level carnivores and they serve as a food source for higher trophic level carnivores. Carnivorous birds and mammals that feed on other birds and mammals are at the top of the food chain. The top carnivores typically are less densely distributed than the herbivores and first-level carnivores because they require a larger area to hunt for their food. All of the carnivores may be exposed to and accumulate contaminants that are present in the food items they consume. As discussed in Section E.2.3.3, top predators (i.e., red fox, red-tailed hawks) will not be evaluated in this SERA because of their large home range in comparison to the size of the site.

Omnivorous Birds and Mammals: Omnivorous birds and mammals (that consume both plant and animal tissue) are present throughout the Base in the different terrestrial habitats (i.e., forested, open field). They may be exposed to, and accumulate contaminants (such as) that are present in the plants and animals they consume.

Benthic Macroinvertebrates: Benthic macroinvertebrates are similar to the soil invertebrates in that they serve as a food source for higher trophic level organisms (i.e., fish, amphibians, birds, mammals). They also can accumulate some contaminants which can then be transferred to the higher trophic level

organisms that consume invertebrates. Their presence in the intermittent water body to the north will be ephemeral because of a lack of suitable habitat and water flow. It is not known if there is sufficient water flow to support a perennial benthic macroinvertebrate population in the intermittent tributary to the south because it could not be observed during the site visit. This information will be collected during the sampling investigation.

Fish: It is unlikely that fish are present in the intermittent tributary to the north, as it is probably dry most of the year. Fish are exposed to and can accumulate contaminants from the food items they consume, or from the surface water in which they live. It is not known if there is sufficient water flow to support a fish population in the intermittent tributary to the south because it could not be observed during the site visit. This information will be collected during the sampling investigation.

Amphibians and Reptiles: Amphibians are expected to inhabit the intermittent tributaries to the north and south, as well as the surrounding areas; reptiles can inhabit both aquatic environments and surrounding terrestrial habitats. Amphibians and reptiles feed primarily on invertebrates, plants, fish, and/or small mammals. They are exposed to, and can accumulate, contaminants from the food items they consume, or from the surface water/sediment/surface soil in which they live.

E.2.4.2 Measurement Endpoints

Measurement endpoints are estimates of biological impacts (i.e., mortality, growth and reproduction) that are used to evaluate the assessment endpoints. The following measures of effects will be used to evaluate the assessment endpoints in this ERA, where applicable.

- Soil screening values – Mortality, growth, and reproduction of plants and soil invertebrates will be evaluated by comparing the measured concentrations (maximum) of chemicals in the surface soil to screening values designed to be protective of ecological receptors.

- No observed adverse effects levels (NOAELs) for surrogate wildlife species - Mortality, reproductive, and/or developmental effects of birds and mammals will be evaluated by comparing the estimated ingested dose (based on conservative and average assumptions) from contaminants in the surface water, surface soil, plants, and/or invertebrates to these levels.

- Sediment screening values – Mortality and other adverse effects (e.g., growth, feeding rates, behavioral changes) of benthic macroinvertebrates will be evaluated by comparing the measured

concentrations (maxima and averages) of chemicals in the sediment to screening values designed to be protective of ecological receptors.

- Surface water screening values – Mortality and other adverse effects (i.e., growth, feeding rates, behavioral changes) of aquatic organisms will be evaluated by comparing the measured concentrations (maxima and averages) of chemicals in the surface water to screening values designed to be protective of ecological receptors.

E.2.4.3 Selection of Receptor Species

Many receptors in the soil and aquatic environments are adequately described in general categories such as soil invertebrates, vegetation, and sediment-dwelling (benthic) invertebrates. This is due to the nature of the threshold values, effects values, or water quality criteria that are typically used to characterize risk for such organisms. For vertebrate receptors, selection of particular species may be required so that intake through eating, drinking, and other routes can be estimated.

Receptor identification is influenced by the contaminants, their likely mode of transport, ultimate fate, and toxicity. For example, most metals (with notable exceptions of cadmium and mercury) typically do not bioaccumulate. For contaminants that bioaccumulate, such as mercury compounds and chlorinated pesticides, effects on upper trophic level receptors need to be assessed. For contaminants that do not bioaccumulate, organisms that are in direct contact with soil/sediment (i.e., sediment- and soil-dwelling organisms and plants) and animals that may incidentally ingest soil particles are selected as receptors for metals if exposure pathways are complete. Sensitivity to particular contaminants is also considered. For example, birds and mammals may have different sensitivities to organic compounds, so each group, or the most sensitive group for a particular contaminant, is assessed.

As previously mentioned, for most receptor species, ingestion is the primary route of exposure. Indicator species are selected for their preferred habitat, body size, sensitivity, home range, abundance, commercial or sport utilization, legal status, and functional role (e.g., predators). For conservativeness, indicator species may be small and have small home ranges. Species known to be sensitive to particular contaminants may be selected or toxicity values for those species may be used. For example, mink are sensitive to PCBs for reproductive endpoints and therefore mink TRVs would be selected for a scenario involving exposure to PCBs from an aquatic or sedimentary source. The availability of exposure parameters such as body mass, feeding rate, and drinking rate may also be a factor in selecting indicator species. The following indicator species will be used for the food chain modeling (discussed later), if necessary:

- Herbivorous mammal: Meadow Vole
- Herbivorous birds: Bobwhite Quail
- Carnivorous birds: American Woodcock
- Carnivorous mammals: Short-Tail Shrew

Receptor profiles for each of these species are presented in Attachment E.A-2.

E.3 ECOLOGICAL EFFECTS EVALUATION

The preliminary ecological effects evaluation is an investigation of the relationship between the magnitude of exposure to a chemical and the nature and magnitude of adverse effects resulting from exposure. In addition to being a toxicity study, it may also include descriptions of apparent effects seen during the site visit. Toxicity thresholds are usually expressed in units of concentration when the medium of concern is in intimate contact with the receptor, such as surface water for pelagic organisms or soil for soil invertebrates. For other receptors, such as terrestrial vertebrates, toxicity data are typically available as doses, with units equal to mass of contaminant per unit of body mass per unit of time (usually mg/kg/day).

As the first step in the ecological effects evaluation, Contaminants of Potential Concern (COPCs) will be selected by comparing the contaminant concentrations in the surface water, sediment, and surface soil samples to Region 5 Ecological Data Quality Levels (EDQLs) (U.S. EPA, Region 5, October 1999). The following bullets summarize the procedures that will be used in each of the SWMU-specific SERAs to select COPCs. Calcium, magnesium, potassium, and sodium will not be retained as COPCs in any medium because of their relatively low toxicity to ecological receptors, and their high natural variability in concentrations. Contaminants without EDQLs will be retained as COPCs but they may only be evaluated qualitatively.

Seep, Surface Water and Sediment for Benthic Macroinvertebrates, Fish, and Terrestrial Wildlife

1. Inorganic and organic contaminants whose maximum concentrations do not exceed EDQLs will not be retained as COPCs.
2. Inorganic contaminants whose maximum concentrations do not exceed the maximum upstream/upgradient concentrations will not be retained as COPCs.

It is recognized that the EDQLs were not established for the protection of wildlife ingesting water. However, based on the very low and conservative EDQLs for surface water, contaminants that do not exceed the EDQL are not expected to be toxic to terrestrial wildlife.

Surface Soil for Invertebrates, Plants, and Terrestrial Wildlife

1. Inorganic and organic contaminants whose maximum concentrations do not exceed EDQLs will not be retained as COPCs.
2. Inorganic contaminants whose maximum concentrations do not exceed the site-specific background concentrations will not be retained as COPCs.

Contaminants that are retained as COPCs will be further evaluated as part of Step 3a of the eight-step ERA process. The next section presents the additional data sources that will be used to evaluate the COPCs.

E.4 STEP 3A – REFINEMENT OF COPCS

Step 3a consists of refining the list of COPCs from the SERA using less conservative screening values and more site-specific exposure assumptions (where available) to more realistically estimate potential risks to ecological receptors (i.e., plants, invertebrates, and aquatic receptors). Note that the Step 3a evaluation will be included as an attachment to the SERA. For example, for all the media, both maximum and average concentrations will be compared to the benchmark values because most receptors (other than immobile plants) will have an average exposure to contaminants as they move across the surface water, sediment, or soil. This evaluation may include (but is not necessarily limited to) a consideration of the following topics:

- Magnitude of criterion exceedence: Although risks may not relate directly to the magnitude of a criterion exceedence, the magnitude may be one item used in a weight-of-evidence approach to determine the need for further site evaluation.

- Frequency of chemical detection: A chemical that is detected at a low frequency typically will be of less concern than a chemical detected at higher frequency provided that toxicity and concentrations of the constituents are similar. All else being equal, chemicals detected frequently will be given greater consideration than those detected relatively infrequently.

- Contaminant bioavailability: Many contaminants (especially metals) are present in the environment in forms that are typically not bioavailable and the limited bioavailability will be considered when evaluating the exposures of receptors to site contaminants.

- Habitat: Although exceedences of criteria may occur, potential risks to ecological receptors may be minimal if there is little habitat for those receptors. Therefore, the extent of habitat will be used qualitatively when considering the site for additional evaluation.

E.4.1 Alternate Benchmarks

The following sections present some of the alternate benchmarks and evaluations that will be conducted as part of Step 3a.

E.4.1.1 Terrestrial Plants and Invertebrates

Risks to terrestrial plants and invertebrates resulting from exposure to the COPCs will be evaluated by comparing the contaminant concentrations in the surface soil to alternate soil benchmark values. These alternate benchmarks will be designated as Surface Soil Screening Levels (SSSLs). Currently, neither Indiana nor U.S. EPA has developed ecological SSSLs. The following list presents the SSSLs that have been developed by a few groups/agencies. Additional details explaining the origin and basis for the alternate benchmarks are provided below the list.

- Dutch Intervention Values and Target Values – Soil Quality Standards (MHSPE, 1994)

- Canadian Soil Quality Guidelines (CCME, 1997)

- Oak Ridge National Laboratory Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision (Efroymson R.A. et al., 1997a)

- Oak Ridge National Laboratory Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision (Efroymson R.A. et al., 1997b)

The Intervention Values and Target Values – Soil Quality Standards were developed by the Netherlands Ministry of Housing, Spatial Planning, and Environment, Department of Soil Protection and will be referred to as the Dutch Screening Values (MHSPE, 1994).. The Dutch Screening Values for surface soil

consist of Target Values and Intervention Values. The Target Values are the soil quality levels that are ultimately desired (MHSPE, 1994). The values for heavy metals, arsenic, and fluoride were derived from analysis of field data from relatively pollution-free rural areas. The Intervention Values indicate the "concentration levels of the contaminants in the soil above which the functionality of the soil for human, plant, or animal life is seriously impaired or threatened" (MHSPE, 1994). The "ecotoxicological effects are quantified in terms of the concentrations in the soil at which 50% of the species actually (or potentially) occurring may undergo adverse effects" (MHSPE, 1994). The following equation is used to determine the criteria that indicate the need for further investigation (MHSPE, 1994):

$$\text{Criteria} = (\text{Intervention Value} + \text{Target Value})/2$$

The Canadian Soil Quality Guidelines were developed by the Canadian Council of Ministers of the Environment (CCME, 1997). They are derived using toxicological data to determine the threshold level for key receptors (CCME, 1997). The values are calculated for four land uses: agricultural, residential/parkland, commercial, and industrial. Exposure from direct soil contact is used to derive guidelines for the residential/parkland, commercial, and industrial land uses (CCME, 1997). However, the soil guidelines for the agricultural land use incorporates direct soil contact as well as soil and food ingestion (CCME, 1997). A more detailed discussion of the derivation of the soil quality guidelines is presented in A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME, 1996).

The Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision (Efroymson R.A., et al., 1997a) and the Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision (Efroymson R.A. et al., 1997b) were developed by the Oak Ridge National Laboratory (ORNL). These benchmarks were intended to be used as screening values, and as such, may be overly conservative. They are based on a 20 percent reduction in growth, reproduction, or activity (for invertebrates) or growth and yield (for plants) as the threshold for significant effects (Efroymson R.A. et al., 1997a, b).

Additional sources of toxicity data from the literature may be used to evaluate potential risks to soil flora and invertebrates from contaminants in the surface soil for contaminants that are not evaluated in the above documents.

E.4.1.2 Seeps/Surface Water

Water Quality Standards (WQS) for surface water have been developed for Indiana (IDEM, 1998). These are the primary enforceable surface water standards for the MGBG. In addition, the U.S. EPA has established Ambient Water Quality Criteria (AWQC) for a few contaminants. Other, non-regulatory surface water screening values will be used to evaluate the surface water data that do not have WQS or AWQC. All values will be collectively referred to as surface water screening levels (SWSLs) in this SERA QAPP. The following presents the SWSLs that will be used in this evaluation.

- Indiana Water Quality Standards (IDEM, 1998)
- Ambient Water Quality Criteria (U.S. EPA, 1999)
- Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota, 1996 Revision (Suter and Tsao, 1996)
- "Eco Update-Ecotox Thresholds" (U.S. EPA, 1996)

The Indiana WQS are the concentrations of toxic substances that will not result in acute or chronic toxicity to aquatic life. All of the WQS used in this SERA will be based on total recoverable metals in accordance with the Indiana WQS (IDEM, 1998).

The Ambient Water Quality Criteria were developed by U.S. EPA to provide states with guidance for developing their own criteria. These values are set to protect the majority of aquatic organisms from adverse impacts from contaminants in the surface water.

The publication "ECO Update-Ecotox Thresholds" was prepared by U.S. EPA for use as benchmark screening values in the first step of a baseline risk assessment (U.S. EPA, 1996). Most of the surface water thresholds for the contaminants that are evaluated in this SERA are based on Suter and Mabrey, (1994) in the Ecotox Thresholds. Because Suter and Mabrey (1994) has been updated, Suter and Tsao (1996) values will be used when the Ecotox Thresholds were based on the Suter and Mabrey (1994) data. The Suter and Tsao (1996) benchmarks were calculated using Tier II methodology as described in the U.S. EPA's Proposed Water Quality Guidance for the Great Lakes System (U.S. EPA, 1993b). Tier II values are developed so that aquatic benchmarks could be established with fewer data than are required for the U.S. EPA AWQC.

Both the acute and chronic SWSLs will be used to evaluate the COPCs to determine potential impacts in a weight-of-evidence approach.

E.4.1.3 Sediment

Indiana has not established sediment-screening levels (SSLs) for any contaminants, and the U.S. EPA has established SSLs for only a few contaminants. Therefore, other, non-regulatory alternate benchmarks will be used to evaluate the sediment data. SSLs based on freshwater studies will be used where available. The following list presents the SSLs that will be used in this evaluation. The paragraphs following this list discuss the SSLs in more detail:

- "Eco Update-Ecotox Thresholds" (U.S. EPA, 1996)
- "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (OMOE, 1993)
- "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments" (Long et al., 1995)

The sediment Ecotox Thresholds include draft U.S. EPA Sediment Quality Criteria (SQC) that have been established for five contaminants (acenaphthene, dieldrin, endrin, fluoranthene, and phenanthrene), Sediment Quality Benchmarks (SQB) that have been established using equilibrium partitioning, and Effects Range-Low values from Long et al., (1995). The SQC and SQBs Ecotox Thresholds are based on an assumption of 1 percent organic carbon [10,000 mg/kg total organic carbon (TOC)]. It is the understanding of TtNUS (based on personal communication with Ms. Mary Riley from U.S. EPA) that the three PAH SQC documents (acenaphthene, fluoranthene, and phenanthrene) will be withdrawn in favor of a total PAH SQC document due out in the summer of 1999. In addition, a SQC document for metals also is due out in the summer of 1999. These documents will be utilized if they are available when the SERA is prepared.

The "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario" (OMOE, 1993) are based on freshwater studies. The OMOE guidelines establish three effects levels, as follows:

- ***No Effect Level:*** Sediment will not affect fish or sediment-dwelling organisms. In addition, no transfer through the foodchain and no effect on water quality is expected.

- ***Lowest Effect Level:*** Sediment is considered marginally polluted but will not affect the majority of sediment-dwelling organisms.

- ***Severe Effect Level:*** Sediment is considered highly polluted and likely to affect the health of sediment-dwelling organisms.

The "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments" (Long et al., 1995) will be used if no freshwater data are available because they are generally accepted by many state agencies and U.S. EPA regions, even though they are based primarily on estuarine and marine studies. Long et al. (1995) establishes three effects levels, as follows:

- ***Below Effects Range-Low (ER-L):*** (Effects Range-Low) Minimal-effects range (adverse effects would be rarely observed);

- ***Between ER-L and Effects Range-Median (ER-M):*** Possible-effects range (adverse effects would occasionally occur); and

- ***Above the ER-M:*** Probable-effects range (adverse effects would probably occur).

Additional sources of toxicity data from the literature may be used to evaluate potential risks to aquatic receptors from contaminants in the sediment for contaminants that are not evaluated in the above documents.

Contaminants that exceed the SSLs also will be compared to background contaminant levels developed in the Sediment Background Concentration Distributions of 172 Potential Pollutants in Indiana (Wente, 1994) document. The term "background" was interpreted in that document as "the concentration that would be present in the absence of any particular pollutant source." Background values will be used as another piece of information in the weight-of-evidence approach for evaluating the sediments.

E.4.2 Terrestrial Food Chain Modeling

Most of the above-mentioned additional surface soil standards/benchmark values are not designed to screen out risks to terrestrial wildlife ingestion of the soil, plants, invertebrates, and small mammals. Therefore, in addition to comparing the soil concentrations to toxicity values for terrestrial invertebrates and plants, a terrestrial intake model will used to estimate the exposure of the COPCs to terrestrial receptors.

Risk to terrestrial receptors to the COPCs in the soil will be determined by estimating the Chronic Daily Intake (CDI) (see Section E.4.3) and comparing the CDI to Terrestrial Reference Values (TRVs) representing acceptable daily doses in mg/kg/day. The TRVs will be developed from No-Observed-Adverse-Effect-Levels (NOAELs) and Lowest-Observed-Adverse-Effect-Levels (LOAELs) obtained from

wildlife studies, if available. The majority of the TRVs will come from the ORNL Toxicological Benchmarks for Wildlife: 1996 Revision (Sample et al., 1996). Toxicity data in the Agency for Toxic Substances and Disease Registry toxicity profiles and Integrated Risk Information System printouts will be utilized, when necessary.

For avian species, the NOAEL (or LOAEL) for the test species will be used as the NOAEL (or LOAEL) for the surrogate species in accordance with Sample et al. (1996). For mammalian species, the NOAEL (or LOAEL) from one species will be adjusted to a NOAEL (or LOAEL) for the surrogate species using the following body weight scaling equation from Sample et al., 1996):

$$NOAEL_w = NOAEL_t * (bw_t/bw_w)^{1/4}$$

Where: $NOAEL_w$ = No Observed Adverse Effect Level for the surrogate wildlife species
$NOAEL_t$ = No Observed Adverse Effect Level for the test species
bw_t = body weight of the test species
bw_w = body weight of the surrogate test species

The body weight scaling is done because studies have shown that for mammals, numerous physiological functions such as metabolic rate, as well as responses to toxic chemicals, are a function of body size (Sample et al., 1996). However, Sample et al., (1996) indicated that physiological scaling factors may not be appropriate for birds. Therefore, scaling factor of 1.0 will be used for this SERA.

Table E-1 presents the body weights that will be used for the surrogate and potential test species. If a subchronic study is used to develop the TRV, the final value will be multiplied by a factor of 0.1 to account for uncertainty between subchronic and chronic effects. Also, if a LOAEL study is used to develop the NOAEL TRV, then the LOAEL will be multiplied by a factor of 0.1 to obtain the NOAEL. Finally, the estimated doses will incorporate literature-based soil to plant and soil to earthworm bioaccumulation factors.

E.4.3 Characterization of Exposure

This section describes the potential or actual contact or co-occurrence of the contaminants with the receptors to determine their exposure dose.

Terrestrial soil invertebrates and plants are exposed to contaminants in the surface soil through direct contact and/or ingestion. Aquatic organisms are exposed to contaminants in the surface water and

sediment through direct contact and/or ingestion. 95 percent Upper Confidence Levels (UCLs) and average soil, surface water, and/or sediment concentrations will be compared to the applicable soil screening values to determine potential risk to these ecological receptors to obtain a range of exposures. The 95 percent upper confidence limit (UCL), which is based on the distribution of a data set, is often considered to be the best estimate of the exposure point concentration for data sets with 10 or more samples (U.S. EPA, 1992). For data sets with less than 10 samples, the UCL is considered to be a poor estimate of the mean, and the exposure point concentration will be defined using the maximum detected concentration.

Exposure of the terrestrial receptors to the COPCs in the soil will be determined by estimating the daily doses in mg/kg/day using exposure equations. The contaminant concentrations in the surface soil will be used to calculate the chronic daily intake (CDI) doses. The following equation presents a generic food chain model that will be used for the surrogate species that are selected for modeling:

$$CDI = \frac{[(Cc * BAF * IR) + (Cc * Is)] * H}{BW}$$

Where:

CDI	=	Chronic Daily Intake (mg/kg-day)
Cc	=	Contaminant concentration in surface soil (mg/kg)
BAF	=	Bioaccumulation factor (unitless)
IR	=	Ingestion Rate (kg/day)
Is	=	Rate of Incidental surface soil ingestion (kg/day)
H	=	Contaminated area/Home area range area ratio (unitless)
BW	=	Body Weight (kg)

The lower bound of the threshold effects is based on consistently conservative assumptions and NOAEL toxicity values (U.S. EPA, 1997). This bound will present the highest potential risks. The upper bound is based on observed impacts or predictions that ecological effects could occur and is developed using consistent assumptions, site-specific data, LOAEL toxicity values, or an impact evaluation (U.S. EPA, 1997). This bound will present the average potential risk. Both the upper and lower bounds will be evaluated in this SERA to provide the overall range of potential risks as presented in the following table:

Conservative Scenario	Average Scenario
95% UCL soil, surface water, or sediment concentration	Average soil, surface water, or sediment concentration
90% BAF value from the literature (when available)	Median BAF value from the literature (when available)
Highest receptor body weight for NOAEL calculation	Average receptor body weight for LOAEL calculation
Lowest receptor body weight for CDI equation	Average receptor body weight for CDI equation
Conservative receptor ingestion rate	Average receptor ingestion rate
Use NOAELS	Use LOAELs
Receptors spend 100% of their time at the site	Receptor's home range taken into account

The exposure assumptions (i.e., ingestion rate, body weight) will be obtained from the Wildlife Exposure Factors Handbook (U.S. EPA, 1993), or other literature sources, if necessary. Table E-1 presents the exposure parameter that will be used in the SERA. Table E.A-2-1 in Attachment E.A-2 presents the values that were used to calculate the exposure parameters, and a discussion of how they were calculated.

E.5 ECOLOGICAL RISK CHARACTERIZATION

The risk characterization is the final phase of a risk assessment that compares the exposure to the ecological effects. It is at this phase that the likelihood of adverse effects occurring as a result of exposure to a stressor will be evaluated. An Ecological Effects Quotient (EEQ) approach will be used to characterize the risk to terrestrial receptors. This approach characterizes the potential effects by comparing exposure concentration with the effects data. An EEQ of greater than "1.0" is considered to indicate a potential risk. The EEQ is not an expression of probability, and the meaning of values greater than 1.0 must be interpreted in light of attendant uncertainties in risk management.

An EEQ for the aquatic receptors will be calculated as follows:

$$EEQ = \frac{C_{sw}}{SWSL} \text{ or } \frac{C_{sd}}{SSL}$$

Where: EEQ = Hazard Quotient, (unitless)

C_{sw} = Contaminant concentration in surface water, (µg/L)

C_{sd} = Contaminant concentration in sediment, (µg/kg or mg/kg)

SWSL = Surface Water Screening Level, (µg/L)

SSL = Sediment Screening Level, (µg/kg or mg/kg)

An EEQ for terrestrial plants and invertebrates will be calculated as follows:

$$EEQ = \frac{C_{ss}}{SSSL}$$

Where: EEQ = Ecological Effects Quotient, (unitless)

C_{ss} = Contaminant concentration in surface soil, (µg/kg or mg/kg)

SSSL = Plant or Invertebrate Screening Level in Soil, (µg/kg or mg/kg)

The EEQ for the terrestrial wildlife model will be calculated as follows:

$$EEQ = \frac{Dose}{TRV}$$

Where: EEQ = Hazard Quotient, (unitless)

Dose = Daily Intake Dose, (mg/kg-day)

TRV = Terrestrial Reference Value (NOAEL or LOAEL), (mg/kg-day)

E.6 ECOLOGICAL RISK UNCERTAINTY ANALYSIS

This section presents some of the uncertainties associated with ecological risk assessments.

E.6.1 Measurement and Assessment Endpoints

Measurement endpoints are used to evaluate the assessment endpoints that are selected for the SERA. For this SERA, the measures of effects are not the same as the assessment endpoints. Therefore, the measures are used to predict effects to the assessment endpoints by selecting surrogate species that will be evaluated. For example, a decrease in reproduction of a shrew is used to assess a decrease in reproduction of the small mammal population. However, predicting a decrease in reproduction to a shrew may either under- or overprotect the small mammal population, resulting from differences in ingestion rates, toxicity, food preferences, etc. between different species.

Risks to reptiles and amphibians will not be quantitatively evaluated because exposure factors are not established for most species, and toxicity data are very limited. However, risks to reptiles and amphibians will be qualitatively evaluated as part of the SERA.

E.6.2 Exposure Characterization

The contaminant dose to terrestrial wildlife is calculated using an equation that incorporates ingestion rates, body weights, bioaccumulation factors, and other exposure factors. These exposure factors are obtained from literature studies or predicted using various equations. Ingestion rates and body weights vary between species, especially between species inhabiting different areas. For example, the food ingestion rate for the robin was calculated as 0.89 g/g-day in California and 1.52 g/g-day in Kansas (EPA, 1993a).

Bioaccumulation of contaminants into various biological media (i.e., plants, invertebrates, small mammals) depend on characteristics of the media such as pH, organic carbon, etc. Therefore, actual bioaccumulation factors at the site may be different than those used in the ERA that were obtained from the literature. Also, the bioavailability of the chemicals is not taken into account in this SERA. All the chemicals are assumed to be 100 percent bioavailable at the detected concentrations, which is unlikely to occur for contaminants in the environment.

There is uncertainty in the chemical data that are collected at the site. Measured levels of chemicals are only estimates of the true site chemical concentrations. For samples that are deliberately biased toward known or suspected high concentrations, predicted doses probably will be higher than actual doses.

Finally, under the conservative exposure scenario, terrestrial wildlife are assumed to live and feed only at the site. These assumptions will tend to overpredict risk because it is unlikely that most receptors will obtain all their food from within the site boundaries and from the most contaminated areas.

E.6.3 Ecological Effects Data

There is uncertainty in the ecological toxicity value comparison. The water quality criteria developed by EPA in theory protects 95 percent of the exposed species. Therefore, some sensitive species may be present at the site that are not protected by the use of these criteria. There also may be situations where the surface water screening levels (SWSLs) are over-predictive of risk if the sensitive species used to develop the criteria do not inhabit the site. Finally, with the exception of hardness for a few metals, the SWSLs do not account for site-specific factors, such as TOC or pH, that may affect toxicity.

Potential adverse impacts to aquatic receptors from constituents in the sediment are evaluated by comparing the COPC concentration to sediment screening levels (SSLs). The SSLs have more uncertainty associated with them than do the SWSLs for the following reasons: The procedures for developing them are not as well established so screening levels have been developed using different methodologies and there are fewer sediment toxicity data than surface water toxicity data. Sediment characteristics (i.e., pH, acid volatile sulfides, total organic carbon) also will have a large impact on the bioavailability and toxicity of constituents.

Potentially adverse impacts to terrestrial plants and invertebrates from constituents in the surface soil are evaluated by comparing the COPC concentration to surface soil screening levels (SSSLs). The SSSLs are similar to the sediment screening levels in that they are less established than the SWSLs. Fewer studies and fewer data are available for establishing SSSLs than SSLs and many of the SSSLs are based on the results of only a few studies. In addition, the SSSLs are based on different endpoints, depending on the preference of the agency that developed them. Therefore, they have more uncertainty than surface water and sediment screening values.

The NOAELS that were selected for the wildlife endpoint species were based on species other than the endpoint species (i.e., rats, mice, ducks). There is uncertainty in the application of toxicity data across species because the contaminant may be more or less toxic to the endpoint species than it was to the test study species.

The toxicity of chemical mixtures is not well understood. All the toxicity information used in the ERA for evaluating risk to the ecological receptors is for individual chemicals. Chemical mixtures can affect the organisms very differently than the individual chemicals because of synergistic or antagonistic effects.

Finally, toxicological data for a few of the COPCs are limited or do not exist. Therefore, there is uncertainty in any conclusions involving the potential impacts to ecological receptors from these constituents.

E.6.4 Risk Characterization

Risks are possible if an EEQ is greater than or equal to unity regardless of the magnitude of the EEQ. However, the magnitude of effects to ecological receptors cannot be inferred based on the magnitude of the EEQ. Rather, an EEQ greater than 1.0 simply indicates that the dose used to derive the toxicity reference value was exceeded. Finally, there is uncertainty in how the predicted risks to a species at the site translate into risk to the population in the area as a whole.

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TABLE E-1

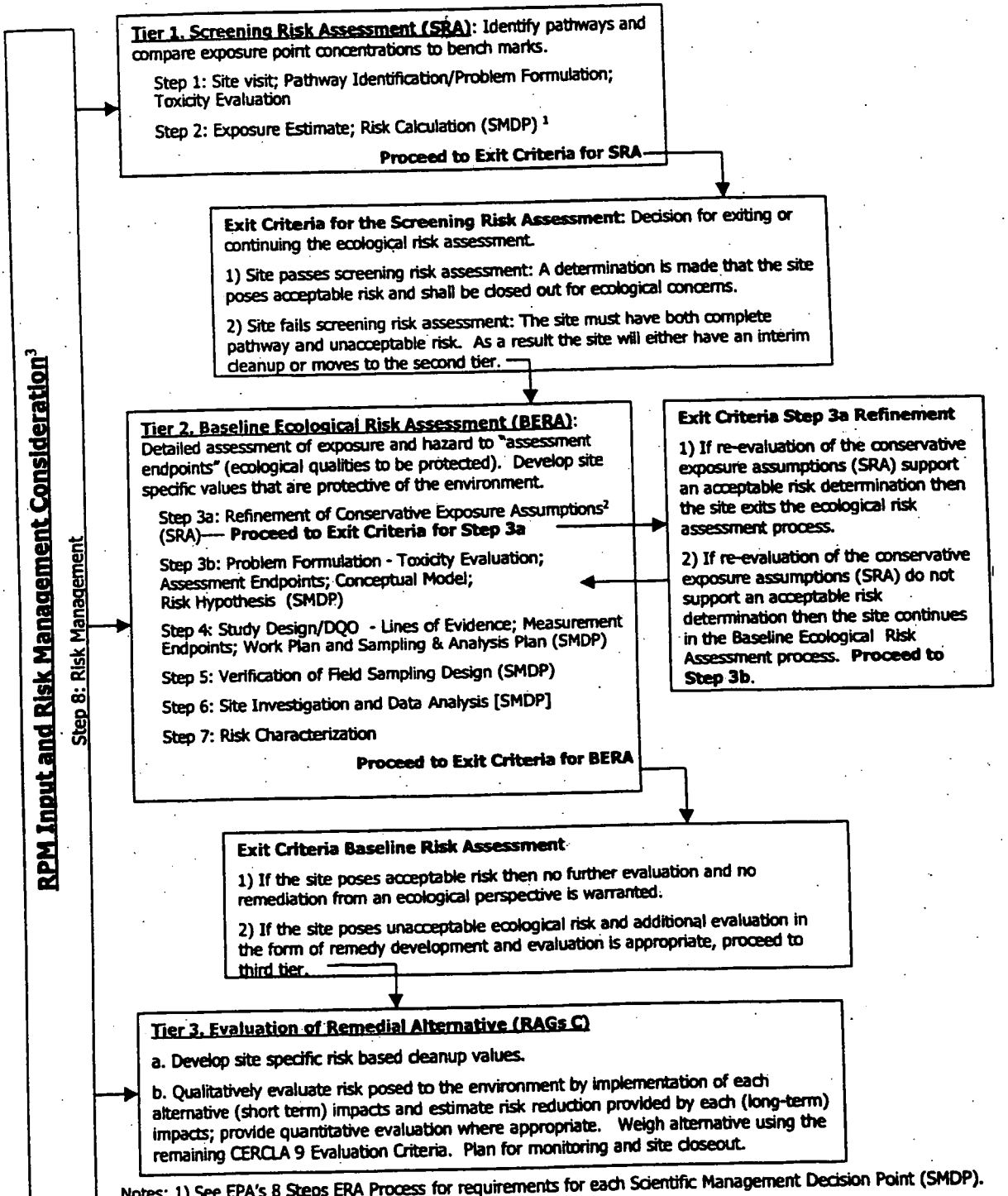
EXPOSURE PARAMETERS FOR TEST SPECIES AND SURROGATE WILDLIFE SPECIES
MUSTARD GAS BURIAL GROUNDS
NAVAL SURFACE WARFARE CENTER, CRANE, INDIANA

Species	Body Weight (kg)			Food Ingestion Rate (kg/day)		Water Ingestion Rate (L/day)		Soil Ingestion Rate (kg/day)		Home Range (acres)		
	Avg.	Min.	Max.	Avg.	Conserv.	Avg.	Conserv.	Avg.	Conserv.	Avg.	Min.	Max.
Potential Test Species (1)												
Rat	0.35	NA	NA	NA		NA		NA		NA		
Mouse	0.03	NA	NA	NA		NA		NA		NA		
Rabbit	3.8	NA	NA	NA		NA		NA		NA		
Mink	1	NA	NA	NA		NA		NA		NA		
Surrogate Wildlife Species (2)												
Bobwhite Quail	0.177	0.162	0.1855	0.0144	0.0164	0.0184	0.0231	0.001181	0.001345	28.6	15.8	41.3
American Robin	0.081	0.0773	0.0862	0.0976	0.1231	0.0113	0.0121	0.01015	0.012802	1.19	0.37	2
Short-Tailed Shrew	0.01687	0.01525	0.01921	0.0103	0.0162	0.0038	0.0043	0.001339	0.002106	0.97	0.97	0.97
Meadow Vole	0.03663	0.0329	0.0391	0.0119	0.0128	0.0064	0.0077	0.000286	0.000307	0.03	0.164	1.06

Notes:
See Attachment E.A-2 for the source of calculation of the exposure factors
NA - Not Applicable
1 - Sample et al., 1996 (only one value was provided so it was plaved in the average column)
2 - EPA, 1993 for all factors except soil ingestion; Beyer (1993) or Talmage and Walton (in press) for soil ingestion rates

FIGURE E-1

NAVY'S ECOLOGICAL RISK ASSESSMENT TIERED APPROACH



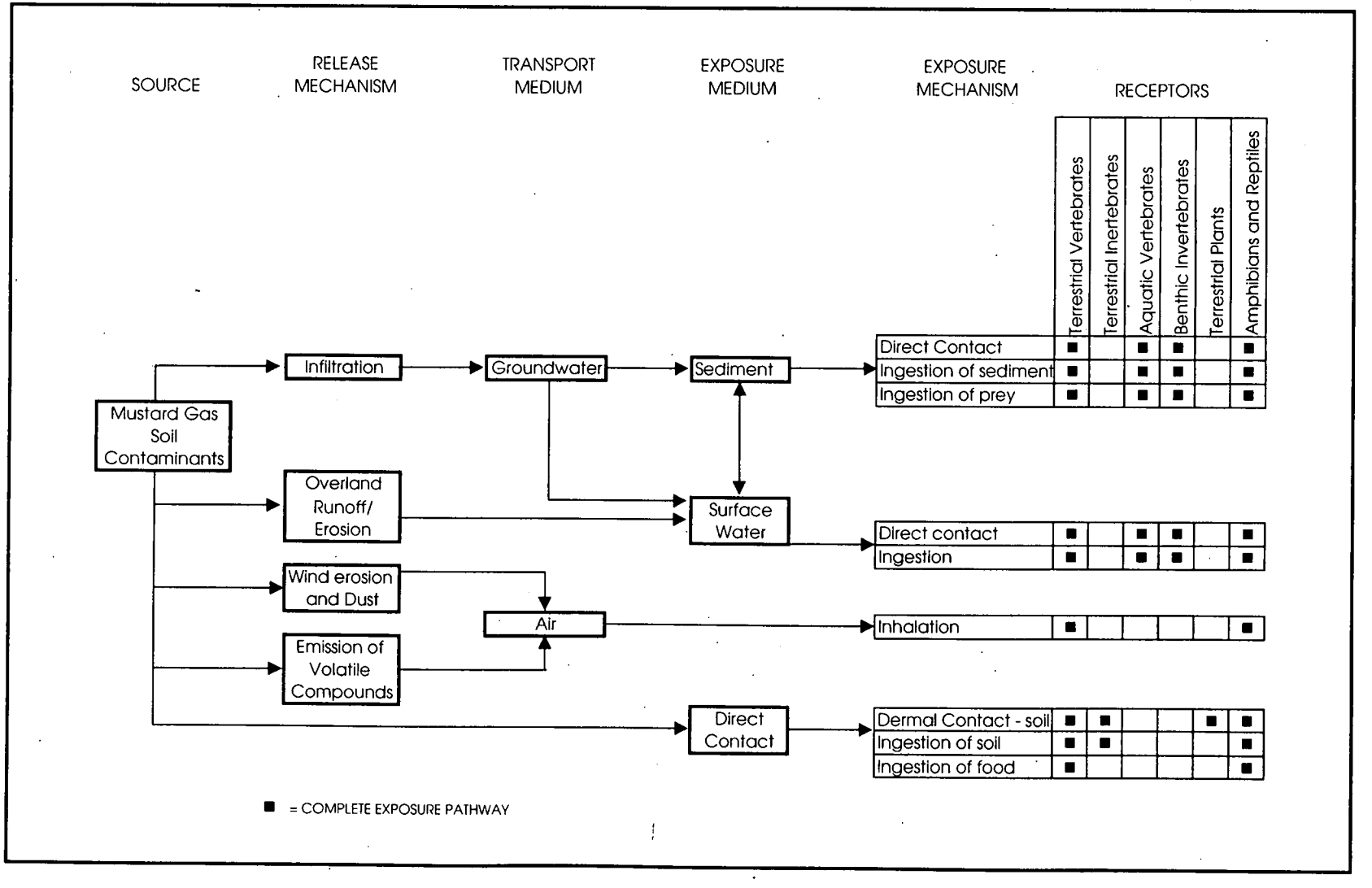
Notes: 1) See EPA's 8 Steps ERA Process for requirements for each Scientific Management Decision Point (SMDP).

2) Refinement includes but is not limited to background, bioavailability, detection frequency. Etc.

3) Risk Management is incorporated throughout the tiered approach.

FIGURE E-2

ECOLOGICAL CONCEPTUAL SITE MODEL
MUSTARD GAS BURIAL GROUND
NSWC CRANE, CRANE, INDIANA



ATTACHMENT E-1

ECOLOGICAL RISK ASSESSMENT SCOPING CHECKLIST

ATTACHMENT E-1

CHECKLIST FOR ECOLOGICAL ASSESSMENT/SAMPLING

INTRODUCTION

The checklist that follows provides guidance in making observations for an ecological assessment. It is not intended for limited or emergency response actions (e.g., removal of a few drums) or for purely industrial settings with no discharges. The checklist is a screening tool for preliminary site evaluation and may also be useful in planning more extensive site investigations. It must be completed as thoroughly as time allows. The results of the checklist will serve as a starting point for the collection of appropriate biological data to be sued in developing a response action. It is recognized that certain questions in this checklist are not universally applicable and that site-specific conditions will influence interpretation. Therefore, a site synopsis is requested to facilitate final review of the checklist by a trained ecologist.

CHECKLIST

The checklist has been divided into sections that correspond to data collection methods and ecosystem types. These sections are:

I. Site Description
   - IA. Summary of Observations and Site Setting

II. Terrestrial Habitat Checklist
   - IIA. Wooded
   - IIB. Shrub/Scrub
   - IIC. Open Field
   - IID. Miscellaneous

III. Aquatic Habitat Checklist - Non-Flowing Systems

IV. Aquatic Habitat Checklist - Flowing Systems

V. Wetlands Habitat Checklist

Checklist for Ecological Assessment/Sampling

I. SITE DESCRIPTION

1. Site Name: NSWC Crane Mustard Gas Burial Ground

   Location: Crane, Indiana

   County: Martin, Green, Davies Lawrence City: Crane State: Indiana

2. Latitude: _____ Longitude: _____

3. What is the approximate area of the site? 2 acres

4. Is this the first site visit? ☒ yes ☐ no If no, attach trip report of previous site visit(s), if available.

   Date(s) of previous site visit(s): _____.

5. Please attach to the checklist USGS topographic map(s) of the site, if available.

6. Are aerial or other site photographs available? ☐ yes ☒ no If yes, please attach any available photo(s) to the site map at the conclusion of this section.

APPENDIX A - CHECKLIST FOR ECOLOGICAL ASSESSMENT/SAMPLING

Introduction

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Checklist

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I. Site Description

   IA. Summary of Observations and Site Setting

II. Terrestrial Habitat Checklist

   IIA. Wooded
   IIB. Shrub/Scrub
   IIC. Open Field
   IID. Miscellaneous

III. Aquatic Habitat Checklist -- Non-Flowing Systems

IV. Aquatic Habitat Checklist -- Flowing Systems

V. Wetlands Habitat Checklist

TEJ 5-4-00

7. The land use on the site is:

_____% Urban

100 % Rural

_____% Residential

_____% Industrial (☐ light ☐ heavy)

_____% Agricultural

(Crops:_____)

_____% Recreational

(Describe; note if it is a park, etc.)

Site is located in rural area of the Base

_____% Undisturbed

_____% Other

The area surrounding the site is:
_____ mile radius

_____% Urban

100 % Rural

_____% Residential

_____% Industrial (☐ light ☐ heavy)

_____% Agricultural

(Crops:_____)

_____% Recreational

(Describe; note if it is a park, etc.)

_____

_____

_____% Undisturbed

_____% Other

8. Has any movement of soil taken place at the site? ☒ yes ☐ no. If yes, please identify the most likely cause of this disturbance:

_____ Agricultural Use X Heavy Equipment _____ Mining

_____ Natural Events _____ Erosion _____ Other

Please describe:

Mustard gas bombs, thorium nitrate, and research and development chemicals were buried at the site. The items were exhumed in 1974 and 1980.

9. Do any potentially sensitive environmental areas exist adjacent to or in proximity to the site, e.g., Federal and State parks, National and State monuments, wetlands, prairie potholes? *Remember, flood plains and wetlands are not always obvious; do not answer "no" without confirming information.*

No. Site is on a topographic high. No signs of wetlands were observed during the site visit.

Please provide the source(s) of information used to identify these sensitive areas, and indicate their general location on the site map.

10. What type of facility is located at the site?

☐ Chemical ☐ Manufacturing ☐ Mixing ☒ Waste disposal

☐ Other (specify)_____

11. What are the suspected contaminants of concern at the site? If known, what are the maximum concentration levels?

Mustard Gas
Thorium nitrate
VOCs
Research and Development Chemicals

12. Check any potential routes of off-site migration of contaminants observed at the site:

☐ Swales ☐ Depressions ☒ Drainage ditches

☐ Runoff ☐ Windblown particulates ☐ Vehicular traffic

☐ Other (specify)_____

13. If known, what is the approximate depth to the water table?_____

14. Is the direction of surface runoff apparent from site observations? ☒ yes ☐ no If yes, to which of the following does the surface runoff discharge? Indicate all that apply.

☐ Surface water ☐ Groundwater ☐ Sewer ☐ Collection impoundment

15. Is there a navigable waterbody or tributary to a navigable waterbody? ☐ yes ☒ no

16. Is there a waterbody anywhere on or in the vicinity of the site? If yes, also complete Section III: Aquatic Habitat Checklist -- Non-Flowing Systems and/or Section IV: Aquatic Habitat Checklist -- Flowing Systems.

☒ yes (approx. distance ~~48~~ 450') ☐ no

17. Is there evidence of flooding? ☐ yes ☒ no *Wetlands and flood plains are not always obvious; do not answer "no" without confirming information.* If yes, complete Section V: Wetland Habitat Checklist.

18. If a field guide was used to aid any of the identifications, please provide a reference. Also, estimate the time spent identifying fauna. [Use a blank sheet if additional space is needed for text.]

19. Are any threatened and/or endangered species (plant or animal) known to inhabit the area of the site? ☐ yes ☐ no *If yes, you are required to verify this information with the U.S. Fish and Wildlife Service.* If species' identities are known, please list them next.

Several state and or Federal T&E species inhabit the Base. It is not known if any of them frequent the site. The list of T&E species is maintained the the Base Fish and wildlife department.

20. Record weather conditions at the time this checklist was prepared:

DATE: January 18, 2000

~ 35°F Temperature (°C/°F)

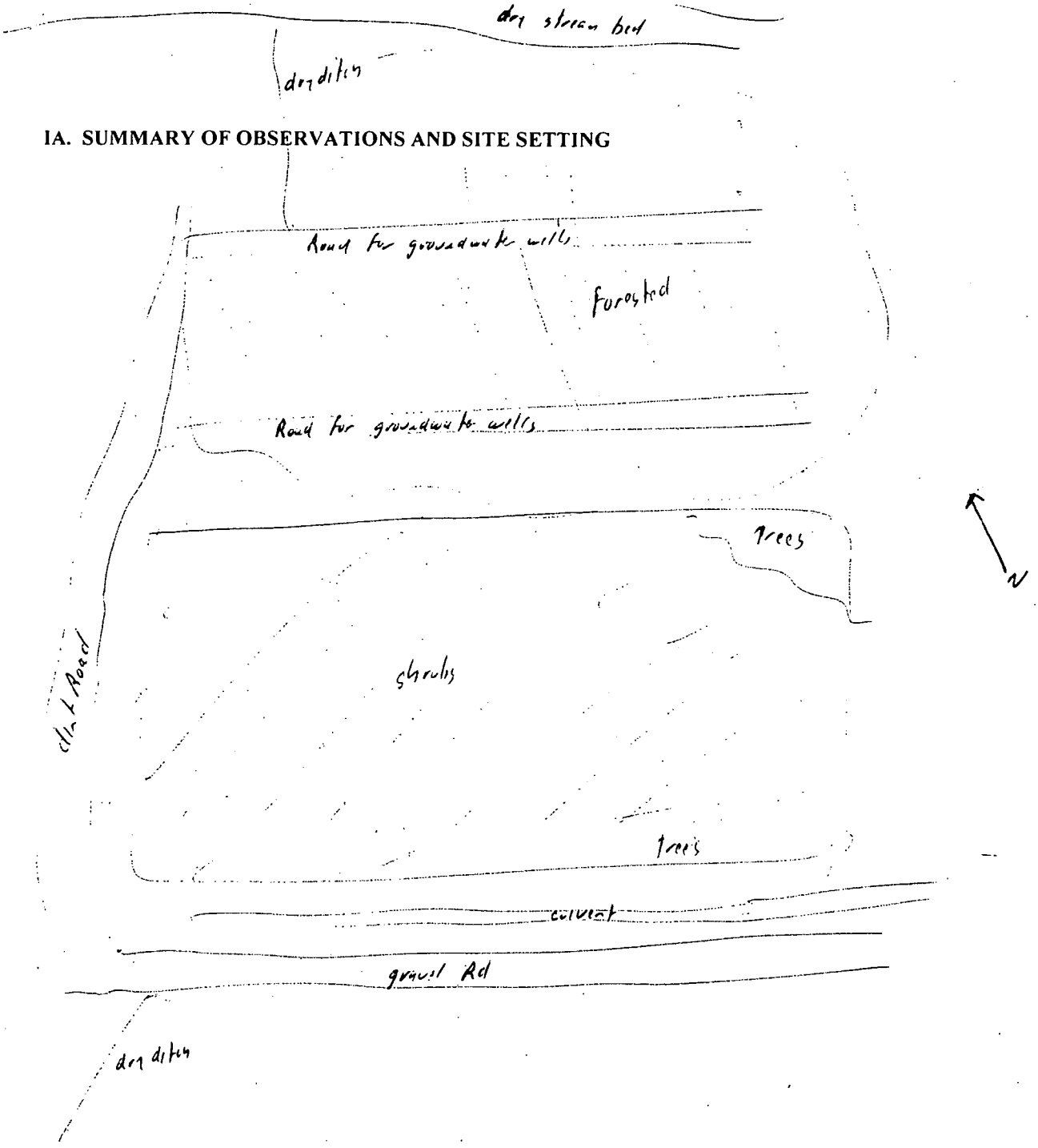
calm Wind (direction/speed)

_____ Cloud cover

_____ Normal daily high temperature

Ice storm the night before Precipitation (rain, snow)

IA. SUMMARY OF OBSERVATIONS AND SITE SETTING



Completed by Aaron Bernhardt Affiliation Tetra Tech NUS

Additional Preparers

Site Manager Tom Johnston (Tetra Tech NUS), Tom Brent (Crane)

Date

II. TERRESTRIAL HABITAT CHECKLIST

IIA. WOODED

1. Are there any wooded areas at the site? ☒ yes ☐ no If no, go to Section IIB: Shrub/Scrub.

2. What percentage or area of the site is wooded? (5 % _____ acres). Indicate the wooded area on the site map which is attached to a copy of this checklist. Please identify what information was used to determine the wooded area of the site.

3. What is the dominant type of vegetation in the wooded area? (Circle one: Evergreen/Deciduous/Mixed) Provide a photograph, if available.

   Dominant plant, if known: Oaks

4. What is the predominant size of the trees at the site? Use diameter at breast height.

   ☐ 0-6 in. ☒ 6-12 in. ☒ > 12 in.

5. Specify type of understory present, if known. Provide a photograph, if available.

IIB. SHRUB/SCRUB

1. Is shrub/scrub vegetation present at the site? ☒ yes ☐ no If no, go to Section IIC: Open Field.

2. What percentage of the site is covered by scrub/shrub vegetation? (95 % _____ acres). Indicate the areas of shrub/scrub on the site map. Please identify what information was used to determine this area.

3. What is the dominant type of scrub/shrub vegetation, if known? Provide a photograph, if available.

4. What is the approximate average height of the scrub/shrub vegetation?

   ☐ 0-2 ft. ☒ 2-5 ft. ☐ > 5 ft.

Note: Area gets mowed periodically.

5. Based on site observations, how dense is the scrub/shrub vegetation?

☒ Dense ☐ Patchy ☐ Sparse

IIC. OPEN FIELD

1. Are there open (bare, barren) field areas present at the site? ☐ yes ☒ no If yes, please indicate the type below:

   ☐ Prairie/plains ☐ Savannah ☐ Old field ☐ Other (specify)_____

2. What percentage of the site is open field? (_____% _____ acres). Indicate the open fields on the site map.

3. What is/are the dominant plant(s)? Provide a photograph, if available.

4. What is the approximate average height of the dominant plant?_____

5. Describe the vegetation cover: ☐ Dense ☐ Sparse ☐ Patchy

IID. MISCELLANEOUS

1. Are other types of terrestrial habitats present at the site, other than woods, scrub/shrub, and open field? ☐ yes ☒ no If yes, identify and describe them below.

2. Describe the terrestrial miscellaneous habitat(s) and identify these area(s) on the site map.

3. What observations, if any, were made at the site regarding the presence and/or absence of insects, fish, birds, mammals, etc.? One burrow observed. deer tracks.

4. Review the questions in Section I to determine if any additional habitat checklists should be completed for this site.

III. AQUATIC HABITAT CHECKLIST -- NON-FLOWING SYSTEMS

Note: Aquatic systems are often associated with wetland habitats. Please refer to Section V, Wetland Habitat Checklist.

1. What type of open-water, non-flowing system is present at the site?

   ☐ Natural (pond, lake)
   ☐ Artificially created (lagoon, reservoir, canal, impoundment)

2. If known, what is the name(s) of the waterbody(ies) on or adjacent to the site?

   _____

3. If a waterbody is present, what are its known uses (e.g.: recreation, navigation, etc.)?

4. What is the approximate size of the waterbody(ies)? _____ acre(s).

5. Is any aquatic vegetation present? ☐ yes ☐ no If yes, please identify the type of vegetation present if known.

   ☐ Emergent ☐ Submergent ☐ Floating

6. If known, what is the depth of the water? _____

7. What is the general composition of the substrate? Check all that apply.

   ☐ Bedrock ☐ Sand (coarse) ☐ Muck (fine/black)
   ☐ Boulder (>10 in.) ☐ Silt (fine) ☐ Debris
   ☐ Cobble (2.5-10 in.) ☐ Marl (shells) ☐ Detritus
   ☐ Gravel (0.1-2.5 in.) ☐ Clay (slick) ☐ Concrete
   ☐ Other (specify) _____

8. What is the source of water in the waterbody?

   ☐ River/Stream/Creek ☐ Groundwater ☐ Other (specify) _____
   ☐ Industrial discharge ☐ Surface runoff

NA
AMB 4/25/00

9. Is there a discharge from the site to the waterbody? ☐ yes ☐ no If yes, please describe this discharge and its path.

10. Is there a discharge from the waterbody? ☐ yes ☐ no If yes, and the information is available, identify from the list below the environment into which the waterbody discharges.

☐ River/Stream/Creek	☐ onsite	☐ offsite	Distance_____
☐ Groundwater	☐ onsite	☐ offsite	
☐ Wetland	☐ onsite	☐ offsite	Distance_____
☐ Impoundment	☐ onsite	☐ offsite	

11. Identify any field measurements and observations of water quality that were made. For those parameters for which data were collected provide the measurement and the units of measure below:

_____ Area

_____ Depth (average)

_____ Temperature (depth of the water at which the reading was taken) _____

_____ pH

_____ Dissolved oxygen

_____ Salinity

_____ Turbidity (clear, slightly turbid, turbid, opaque) (Secchi disk depth _____)

_____ Other (specify)

12. Describe observed color and area of coloration.

13. Mark the open-water, non-flowing system on the site map attached to this checklist.

NA
MB 4.18.00

14. What observations, if any, were made at the waterbody regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc.?

NA - HMB 4-25-00

IV. AQUATIC HABITAT CHECKLIST -- FLOWING SYSTEMS

Note: Aquatic systems are often associated with wetland habitats. Please refer to Section V, Wetland Habitat Checklist.

1. What type(s) of flowing water system(s) is (are) present at the site?

☐ River	☐ Stream	☐ Creek
☒ Dry wash	☐ Arroyo	☐ Brook
☐ Artificially created (ditch, etc.)	☐ Intermittent Stream	☐ Channeling
	☐ Other (specify)_____	

2. If known, what is the name of the waterbody?_____

3. For natural systems, are there any indicators of physical alteration (e.g., channeling, debris, etc.)?
☐ yes ☒ no If yes, please describe indicators that were observed.

Note: There are two intermittent streams. One to the north and one to the south. The one to the north was viewed during the site visit but the one to the south was not because the hill was heavily vegetated w/ ~~the~~ thorny vines and the ground was ice. Therefore, the notes in this section refer to the north waterbody

4. What is the general composition of the substrate? Check all that apply.

☒ Bedrock	☒ Sand (coarse)	☐ Muck (fine/black)
☒ Boulder (>10 in.)	☐ Silt (fine)	☐ Debris
☒ Cobble (2.5-10 in.)	☐ Marl (shells)	☐ Detritus
☒ Gravel (0.1-2.5 in.)	☐ Clay (slick)	☐ Concrete
☐ Other (specify)_____		

5. What is the condition of the bank (e.g., height, slope, extent of vegetative cover)?

The banks are heavily forested with steep slopes.

6. Is the system influenced by tides? ☐ yes ☒ no What information was used to make this determination?

7. Is the flow intermittent? ☒ yes ☐ no If yes, please note the information that was used in making this determination.

(N) It was dry during the investigation, Based on the scouring, it appears to have heavy flows during rain events.

(S) unknown, but probably similar to north waterbody

8. Is there a discharge from the site to the waterbody? ☒ yes ☐ no If yes, please describe the discharge and its path.

There are drainage ditches leading down to both waterbodies

9. Is there a discharge from the waterbody? ☐ yes ☒ no If yes, and the information is available, please identify what the waterbody discharges to and whether the discharge is on site or off site.

10. Identify any field measurements and observations of water quality that were made. For those parameters for which data were collected, provide the measurement and the units of measure in the appropriate space below:

10	Width (ft.)
No water	Depth (ft.)
—	Velocity (specify units):_____
—	Temperature (depth of the water at which the reading was taken_____)
—	pH
—	Dissolved oxygen
—	Salinity
—	Turbidity (clear, slightly turbid, turbid, opaque) (Secchi disk depth _____)
—	Other (specify)_____

11. Describe observed color and area of coloration.

None

12. Is any aquatic vegetation present? ☐ yes ☒ no If yes, please identify the type of vegetation present, if known.

☐ Emergent ☐ Submergent ☐ Floating

13. Mark the flowing water system on the attached site map.

14. What observations were made at the waterbody regarding the presence and/or absence of benthic macroinvertebrates, fish, birds, mammals, etc.?

None - No water present

V. WETLAND HABITAT CHECKLIST

1. Based on observations and/or available information, are designated or known wetlands definitely present at the site?
   ☐ yes ☒ no

   Please note the sources of observations and information used (e.g., USGS Topographic Maps, National Wetland Inventory, Federal or State Agency, etc.) to make this determination.

   Site visit

2. Based on the location of the site (e.g., along a waterbody, in a floodplain) and site conditions (e.g., standing water; dark, wet soils; mud cracks; debris line; water marks), are wetland habitats suspected?
   ☐ yes ☐ no If yes, proceed with the remainder of the wetland habitat identification checklist.

3. What type(s) of vegetation are present in the wetland?

   ☐ Submergent ☐ Emergent
   ☐ Scrub/Shrub ☐ Wooded

   ☐ Other (specify)_____

4. Provide a general description of the vegetation present in and around the wetland (height, color, etc.). Provide a photograph of the known or suspected wetlands, if available.

5. Is standing water present? ☐ yes ☐ no If yes, is this water: ☐ Fresh ☐ Brackish
   What is the approximate area of the water (sq. ft.)?_____
   Please complete questions 4, 11, 12 in Checklist III - Aquatic Habitat -- Non-Flowing Systems.

6. Is there evidence of flooding at the site? What observations were noted?

   ☐ Buttressing ☐ Water marks ☐ Mud cracks

   ☐ Debris line ☐ Other (describe below)

7. If known, what is the source of the water in the wetland?

☐ Stream/River/Creek/Lake/Pond ☐ Groundwater

☐ Flooding ☐ Surface Runoff

8. Is there a discharge from the site to a known or suspected wetland? ☐ yes ☐ no If yes, please describe.

9. Is there a discharge from the wetland? ☐ yes ☐ no. If yes, to what waterbody is discharge released?

☐ Surface Stream/River ☐ Groundwater ☐ Lake/Pond ☐ Marine

10. If a soil sample was collected, describe the appearance of the soil in the wetland area. Circle or write in the best response.

Color (blue/gray, brown, black, mottled) _____

Water content (dry, wet, saturated/unsaturated) _____

11. Mark the observed wetland area(s) on the attached site map.

ATTACHMENT E-2

RECEPTOR PROFILES

ATTACHMENT E-2

RECEPTOR PROFILES
MUSTARD BURIAL GROUND
NSWC CRANE, INDIANA

The following sections present the receptor profiles for the meadow vole, American robin, northern bobwhite quail, and short-tailed shrew. The majority of the information for the profiles was obtained from the Wildlife Exposure Factors Handbook (EPA, 1993). The data for the incidental soil ingestion rates were obtained from the Estimates of Soil Ingestion by Wildlife (Beyer, 1993) except for the shrew which was in Talmage and Walton (undated). The exposure parameters that were selected for this SERA are based on animals collected in or near southern Indiana, when available.

The food and water ingestion rates are presented in g/g (of body weight)-day on a wet weight basis. The home ranges are presented in hectares in EPA (1993) but were converted to acres in this workplan by multiplying the number of hectares by 2.471. Also note that the estimated percent of soil in the diets are listed in dry weight, while the other exposure factors are in wet weight. The soil dry weight was not converted to a wet weight in this workplan because the percent moisture of the soils is not known. Also, incidental soil ingestion is only a small portion of the overall diet (2.4 to 13 percent).

The attached table presents the calculation of the exposure parameters. Note that in this table the ingestion rates in kg/day (or L/day) for the conservative scenario was calculated by multiplying the maximum ingestion rate in g/g-day by the average body weight, while the ingestion rates in kg/day (or L/day) for the average scenario was calculated by multiplying the average ingestion rate in g/g-day by the average body weight. Typically, a minimum body weight is used in the conservative models. However, using the minimum body weight to calculate the maximum ingestion rate sometimes causes the conservative ingestion rate to be lower that the average ingestion rate. Therefore, the average body weight was selected to ensure that the ingestion rate for the conservative scenario was higher than the ingestion rate for the average scenario. The minimum body weight will be used in the dose equation for the conservative scenario. The only exception to this was for the water ingestion rates for the shrew and robin. Because only one ingestion rate was available, the maximum body weights were used to calculate the conservative ingestion rates and the average body weights were used to calculate the average ingestion rates.

Meadow Vole (*Microtus pennsylvanicus*)

Meadow voles inhabit grassy fields, marshes, and bogs; however, they prefer fields with more grass, more cover, and fewer woody plants. They typically consume green succulent vegetation, sedges, seeds, roots, bark, fungi, insects, and animal matter. Green succulent vegetation makes up the majority of their diet.

The adult body weight for the vole in southern Indiana ranged from 0.0329 to 0.039 kg with an average of 0.0366 kg. The only listed food ingestion rates was for voles in Russia which ranged from 0.30 to 0.35 g/g-day, with an average of 0.325 g/g-day. The water ingestion rates are 0.14 (estimated) and 0.21 g/g-day, with an average of 0.175 g/g-day. Finally, the incidental soil ingestion rate was calculated by multiplying the ingestion rate by the percentage of soil that is incidentally ingested (2.4 percent) from Beyer, (1993).

The home range for the meadow vole was calculated using data from a Michigan old field. The values ranged from 0.0297 to 1.06 acres with an average home range of 0.164 acres.

American Robin (*Turdus migratorius*)

American robins habitats include parks, lawns, moist forests, swamps, open woodlands, and orchards. Robins forage on the ground in open areas, along habitat edges, or the edges of streams. They also may forage above ground in shrubs and within the lower branches of trees. In the months preceding and during the breeding season, robins feed primarily on invertebrates and on some fruits. During the rest of the year their diet consists primarily of fruits.

The adult body weight for the American robin in New York woodlands and forests, and in Pennsylvania ranged from 0.0773 to 0.0862 kg with an average of 0.081 kg. The only listed food ingestion rates were for robins in Kansas (1.52 g/g-day) and California (0.89 g/g-day), with an average of 0.1205 g/g-day. The water ingestion rate was estimated as 0.14 g/g-day. The incidental soil ingestion rate was calculated by multiplying the ingestion rate by the percentage of soil that is incidentally ingested (10.4 percent for an woodcock) from Beyer, (1993).

The home range for the robin was calculated using data from an Ontario forest. The values ranged from 0.37 to 2 acres with an average home range of 1.19 acres.

Northern Bobwhite Quail (*Colinus virginianus*)

Quails inhabit grasslands, idle fields, pastures, and large clumps of grasses. Bobwhites forage in areas with open vegetation, some bare ground, and light litter. Seeds from weeds, woody plants, and grasses comprise the majority of an adults diet, although green vegetation has been found to dominate their diet in winter in the south.

The adult body weight for the bobwhite quail in southern Illinois agricultural areas ranged from 0.162 to 0.1855 kg with an average of 0.177 kg. The listed food ingestion rates are for quails in Kansas and Texas lab studies, and in a captive study from Massachusetts. The values ranged from 0.067 to 0.093 g/g-day, with an average of 0.082 g/g-day. The water ingestion rate was estimated as 0.10 and 0.11 g/g-day, and measured in a Texas lab (0.86 to 0.131 g/g-day), for an average water ingestion rate of 0.104 g/g-day. The incidental soil ingestion rate is calculated by multiplying the food ingestion rate by the percentage of soil that is incidentally ingested (0.082 percent for a Canada goose) from Beyer (1993).

The home range for the quail was calculated using data from southern Illinois idle farms, woods, brush, and cornfields. The values for individuals ranged from 15.8 to 41.3 acres with an average home range of 28.6 acres.

Short-Tailed Shrew (*Blarina brevicauda*)

Shrews inhabit a wide variety of habitats and are common in areas with abundant vegetative cover. They need cool, moist habitats because of their high metabolic and water-loss rates. The short-tailed shrew is primarily carnivorous, eating insects such as earthworms, slugs, and snails.

The adult body weight for the short-tailed shrew in various Pennsylvania habitats ranged from 0.01525 to 0.01921kg with an average of 0.01687 kg. The listed food ingestion rates are for shrews in labs on Ohio (0.49 g/g-day), Wisconsin (0.43 to 0.96 g/g-day), and Virginia (0.541 g/g-day), with an average of 0.61 g/g-day. The water ingestion rate was determined as 0.223 g/g-day in an Illinois laboratory. The incidental soil ingestion rate was calculated by multiplying the ingestion rate by the percentage of soil that is incidentally ingested (13 percent) from Talmage and Walton (undated).

The home range for the shrew was calculated using data from a tamarak bog in Manitoba (only value available). The values was 0.9699 acres.

REFERENCES

Beyer, N., E. Connor, and S. Gerould. 1993. Estimates of Soil Ingestion by Wildlife. Patuxent Wildlife Research Center, Laurel, MD.

Talmage, Sylvia S, and Barbara T. Walton. In Press. "Food Chain Transfer and Potential Renal Toxicity of Mercury to Small Mammals at a Contaminated Terrestrial Field Site." Health and Safety Research Division and Environmental Science Division, Oak Ridge National Laboratory.

U.S. EPA, 1993. Wildlife Exposure Factors Handbook. U.S. Environmental Protection Agency. Office of Research and Development. Washington, D.C. December 1993. EPA/600/R-93/187a.

TABLE E.A-2-1

CALCULATION OF EXPOSURE PARAMETERS FOR WILDLIFE RECEPTORS
MUSTARD GAS BURIAL
GROUNDS
NSWC CRANE, CRANE, INDIANA

Exposure Parameters	Meadow Vole		Short-Tailed Shrew		American Robin	Bobwhite Quail	
Body Weights (g)	32.9	35.5	17.61	16.87	77.3	180	181
	39.1	39	17.33	15.58	80.8	168	183
			19.21	15.7	86.2	162	179
			17.4	15.25	83.6	175	175
					77.4	178	183.2
					80.6	179	185.5
						180	173
						162.8	180.4
Minimum	***32.9***		***15.25***		***77.3***	***162***	
Maximum	***39.1***		***19.21***		***86.2***	***185.5***	
Average	***36.63***		***16.87***		***81.0***	***177***	
Food Ingestion Rate (g/g-day)	0.3	0.35	0.49	0.77	0.89	0.067	0.079
			0.62	0.55	1.52	0.072	0.093
			0.43	0.96		0.09	0.089
			0.52	0.54			
Minimum	***0.3***		***0.43***		***0.89***	***0.067***	
Maximum	***0.35***		***0.96***		***1.52***	***0.093***	
Average	***0.325***		***0.61***		***1.205***	***0.082***	
Food Ingestion rate (kg/day)							
Conservative	***0.0128***		***0.0162***		***0.1231***	***0.0164***	
Average	***0.0119***		***0.0103***		***0.0976***	***0.0144***	
Water Ingestion Rate (g/g-day)	0.14	0.21	0.223		0.14	0.115	0.1
						0.106	0.131
						0.093	0.101
						0.086	0.102
						0.11	0.1
Minimum	***0.14***		***0.223***		***0.14***	***0.086***	
Maximum	***0.21***		***0.223***		***0.14***	***0.131***	
Average	***0.175***		***0.223***		***0.14***	***0.104***	
Water Ingestion rate (L/day)							
Conservative	***0.0077***		***0.0043***		***0.0121***	***0.0231***	
Average	***0.0064***		***0.0038***		***0.0113***	***0.0184***	
Home Range (Ha)	0.43	0.097	0.3925		0.15	7.6	6.4
	0.019	0.041			0.81	16.7	15.6
	0.013	0.033					
	0.012	0.013					
	0.043	0.057					
	0.023	0.032					
	0.051	0.078					
	0.058	0.061					
Minimum (acres)	0.0297		0.9699		0.37	15.8	
Maximum (acres)	1.06		0.97		2.00	41.3	
Average (acres)	0.164		0.970		1.19	28.6	

Notes:
Source of data is EPA, 1993
Ingestion Rates (kg/day or L/day) (if more than 1 ingestion rate is available)
- Conservative value = Max Ingestion Rate (g/g-day)* Avg. Body Weight
- Average value = Avg. Ingestion Rate (g/g-day)*Avg. Body Weight

Ingestion Rates (L/day) (if only 1 ingestion rate is available)
- Conservative value = Ingestion Rate (g/g-day)* Max. Body Weight
- Average value = Ingestion Rate (g/g-day)*Avg. Body Weight

APPENDIX F

DATA MANAGEMENT PLAN

1.0 PROJECT PLANNING

A large amount of environmental and physical data has been collected in support of the Installation Restoration (IR) program. TtNUS has the responsibility of managing this data in a basewide relational database and geographical information system GIS. The contents of the database shall be outlined in the Sitewide Data Catalog (which at a minimum, contains the data fields identified in Attachment F1 of this appendix). The Data Catalog shall outline what data is contained within the database (by investigation, media, etc.), the generator of the data (TtNUS, Corps of Engineers, etc.), and the level of quality of the data where applicable. It should be noted whether or not the analytical data were validated and to what level. It is the responsibility of the TtNUS data manager to coordinate with the NSWC Crane project team in order to keep the Data Catalog current and make available the most recent version to all team members. A copy of the Data Catalog shall be maintained in the project central file at the office of TtNUS. It is the responsibility of the all team members to ensure that the Data Catalog is correct and current and shall notify the TtNUS data manager of any newly generated data that will support the needs of the project.

Prior to every data collection event, the TOM shall call a kick-off meeting to outline the data needs of the task order and to review the data flow process (Attachment F2). Attendees of the kick-off meeting should include the TOM, the Human Health Risk Assessment (HHRA) lead, the ecological Risk Assessment (ERA) Lead, the Field Operations Leader (FOL), the project chemist, the data management lead and the Geographic Information System (GIS) lead. The data management lead shall distribute a copy of the database checklist (Attachment F3) and shall lead the project team through its contents. The database checklist will allow the project team to determine how the data will be managed and manipulated in order to achieve the project needs and objectives. A completed copy of the database checklist shall be maintained in the project central file and distributed to all members of the project team within seven days of the kick-off meeting.

2.0 NEWLY GENERATED DATA

Upon directive from SOUTHDIV to collect additional site data, the TOM shall coordinate with the designated data management lead and GIS lead for the project. It is the responsibility of the FOL to comply with the sample and location nomenclature outlined in the QAPP. It is also the responsibility of the FOL to coordinate with the GIS lead to ensure that all survey technical specifications require the proper coordinate system, which is Indiana State Planar - North American Datum 1983 for the horizontal coordinates and National Geodetic Vertical Datum 1988 for the vertical coordinates.

Prior to field mobilization, the FOL shall coordinate with the Sample Management Coordinator (SMC) to initiate a sample tracking process. It is the responsibility of the TOM to ensure that a sampling tracking procedure is implemented. Sample Tracking Request Forms, a sample tracking database example, and example jar labels are included as Attachments F4, F5 and F6, respectively. In the event that a field change has taken place, the FOL is required to complete the Field Task Modification Request (FTMR) that will be forwarded to all members of the project team.

According to all laboratory technical specifications for NSWC Crane, the analytical laboratories will be contractually required to deliver the analytical data in NSWC Crane standard Electronic Data Deliverable (EDD) format (Attachment F7). Particular attention should be paid to the EDD requirements for validated vs. non-valididated data. Once all samples and analyses have been accounted for, the SMC shall forward the analytical data to TtNUS for incorporation into the NSWC Crane database which is located on the Local Area Network (LAN) in Pittsburgh, PA. The NSWC Crane database structure is presented in Attachment F8.

3.0 HISTORICAL DATA

In the event that the NSWC Crane project team decides that existing hardcopy data not outlined in the Data Catalog (Attachment F1) needs to be incorporated into the project database, SOUTHDIV shall provide directive to the appropriate consultant to incorporate the data into the project database. The data management lead shall review the hardcopy data and prepare a summary of the samples and analyses that need to be entered. The format of the summary table should be similar to the sample tracking database provided in Attachment F5. It is the responsibility of the TOM to review the sample summary table and verify that the entry of this data will satisfy the project requirements. The data management lead shall physically edit the hardcopy analytical data to clearly designate which information on the hardcopy needs to be entered into the database. Copies of the marked-up data must be distributed to two separate parties for entry into an Excel spreadsheet. Upon completion of the dual-key entry, the data management lead shall electronically compare the two data files to identify discrepancies and correct the data appropriately. The database should then be queried against the sample summary table to ensure that all pertinent data has been entered and checked for accuracy.

The data management lead shall coordinate with the GIS lead to acquire the sample location data (Attachment F8) for those samples that need to be entered. Sample location maps should be used to digitize the sample locations using the base mapping layer in the GIS. To the extent possible, the GIS lead shall capture, as metadata, the accuracy of the sample location maps used to digitize the location

coordinates. If no sample location maps or other positional information exist for the historical data, the project team should evaluate the utility of this data in the NSWC Crane database.

4.0 MAPPING AND GRAPHICS

CADD mapping is generally provided by the activity. We currently do not use metadata to track changes to the mapping. In addition, Tri-Service Spatial Data Standards (TSSDS) are not utilized unless the mapping from the base already incorporates them. TSSDS is not used in the final GIS, based on the view that limited utility is gained from the substantial time required to incorporate the standards.

In addition to CADD mapping, Digital Ortho Quarter (DOQ) Quads, Aerial Photography, and USGS 7.5 minute Quads are obtained. The Quads are obtained from either the USGS or other suppliers, while the aerial photography is provided by the activity. As necessary, the images are warped to the predetermined coordinate system using Microstation. Again, metadata are not used to track the changes. From survey data, sampling locations are organized, and then a sample-vs-location table is built so that the data can be loaded into the sample_data.dbf table (Attachment F8).

5.0 THE ENVIRONMENTAL GEOGRAPHIC INFORMATION SYSTEM (EGIS)

All environmental data collected in support of the NSWC Crane project shall be incorporated into the GIS. The themes, layers and database information contained in the GIS is outlined in the Data Catalog (Attachment F1). The NSWC Crane GIS shall be made available to all members of the project team. CD-ROM EGIS deliverables shall be made available upon request from SOUTHDIV.

6.0 ASSIMILATION OF DATA FROM OUTSIDE SOURCES

When environmental data is collected by a contractor other than TtNUS, it is the responsibility of the SOUTHDIV Remedial Project Manager (RPM) to notify the TtNUS TOM. The RPM should forward a scope of work directing TtNUS to coordinate with the contractor and incorporate their data into the basewide GIS. To the extent possible, the RPM should direct the Navy Contractor to supply the data to TtNUS in the format outlined in Attachment F8. Once TtNUS has incorporated the data into the GIS, a hardcopy report shall be sent to the contractor for verification that all pertinent data have been incorporated in a complete and accurate fashion.

7.0 SOFTWARE

TtNUS will standardize on the following software packages when managing and manipulating data for the NSWC Crane project:

- Data Management - Microsoft Visual FoxPro 6.0
- GIS - ArcView 3.1 (see Attachment F9 for instructions)
- Geostatistics (2-D Kriging) - Geosoft 3.1b
- 3-D Visualization - EVS Pro 3.0
- Ground Water Modeling - GMS
- Statistical Analysis - Statistica 5.1
- Terrain Analysis - TerraModel 9.4.1

8.0 STORAGE OF DATA

TtNUS utilizes Microsoft NT for Networks as its Information Management System (IMS). The NT IMS has a storage capacity of 2 Gigabytes and currently serves over 110 desktop computers. The NT IMS automatically backs-up the system on a daily basis, thereby disallowing more than one day of work being lost should the network crash or malfunction. The database management and GIS groups have been allocated distinct drives on the Local Area Network (LAN). All environmental data for the NSWC Crane Project shall be stored in the \\nusrpitbdc1\sdiv\NSWC_Crane subdirectory of this drive on the NT Server. All tables, queries, programs and reports shall be saved in the NSWC_Crane.pjx file in Microsoft Visual FoxPro. The NSWC Crane EGIS shall be stored in the \\nusrpitbdc1\gis\NSWC_Crane directory on the NT Server. All ArcView project files (*.apr) shall be documented in a text file called readme_project.txt. This text file shall also be stored in the \\nusrpitbdc1\gis\NSWC_Crane directory.

ATTACHMENT F1

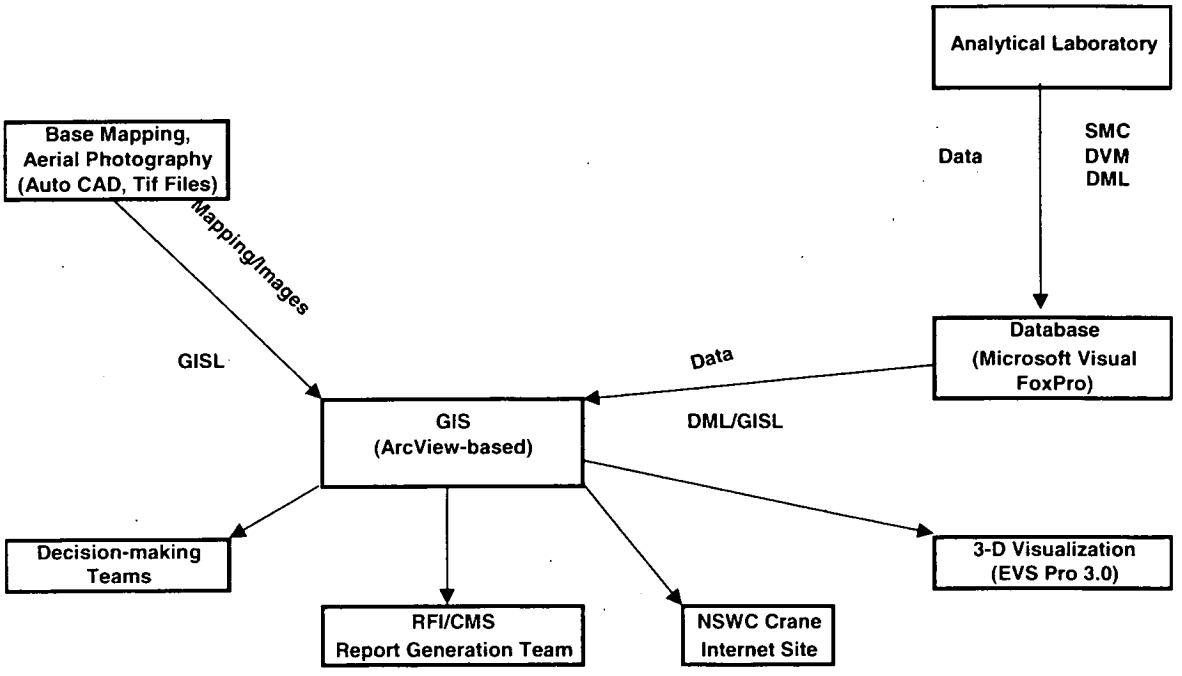
DATA CATALOG

(Minimum Requirements)

Category	RFI Phase	Medium Sampled	Sample Type	No. of Samples	Fraction Analyzed

ATTACHMENT F2

THE DATA FLOW PROCESS



Notes:

SMC = Sample Management Coordinator
DVM = Data Validation Manager
DML = Data Management Leader
GISL = GIS Leader

ATTACHMENT F3

DATABASE CHECKLIST

DATABASE PLANNING CHECKLIST

PROJECT NAME NSWC Crane MGBG **PROJECT NUMBER** 0504

PROJECT MANAGER Tom Johnston **PLANNING DATE** 1/10/00 to 5/31/00

1. Provide a general description of the project (regulatory authority, media to be sampled, approximate number of samples by media, analyses by media, data evaluation tasks required):

RCRA
All media
Approximately 80 soil, 8 sediment, 6 surface water, 80 ground water

2. Provide a general description of the sample nomenclature that will be used for samples collected by Tetra Tech NUS:

See SOP CTO131-7

3. Will historical data be entered in the database? (Yes) No

4. Will historical data be used to define the nature and extent of contamination?
Yes (No)

5. Will historical data be used for risk assessment purposes?
Yes (No)

6. How much historical data exists (i.e., number of samples by matrix, analysis by matrix)?

<27 wells sampled once per year (or more frequently) for 5 yrs ≈140

7. In what format will the historical data be provided? (Hardcopy) Electronic

8. If historical data are in electronic form, what software was used and what is the format? NA

9. If historical data are in hardcopy form, will Form I's, summary tables, or reports be provided? Copies of historical data will be necessary to generate a budget estimate.

No raw data just summary data sheets with results only
Data already in database
Non-detects simply identified as non-detect

10. Will Quality Assurance review of historical data be necessary?
Yes (No) No QC data available

11. If Quality Assurance review of historical data is necessary, describe the scope of the Quality Assurance review:
NA

12. Will a GIS database be necessary for the project.
(Yes) No
If so, the GIS Group should be consulted for a budget estimate.

13. What nomenclature has been (will be) used to identify field duplicate samples?
See SOP CTO131-7

14. Will field duplicate results be averaged and presented as one result in the database? Will they be presented as distinct results, or will both the average and the distinct results be presented?
Use average for freq. of detect computation

15. How will the average value for duplicate samples be determined on a matrix-specific basis?
~~Two detects: (A+B)/2~~ Sample results will not be averaged T.G. 4-30-01
~~Two Nondetects: $(DL_A/2 + DL_B/2)/2$~~
~~One detect (D) + one non-detect (N) with N<D~~ $(D + DL_N/2)/2$
~~One detect (D) + one non-detect (N) with N>D~~ D

16. Are any unvalidated data to be included in the database? Historical data only (Yes) No

17. Will unvalidated data be used for defining the nature and extent of contamination? Yes (No)

18. Will unvalidated data be used for risk assessment purposes? Yes (No)

19. Are any field screening (e.g., no-fixed base laboratory) data to be included in the database? (Yes) No

20. Will field screening data be used for defining the nature and extent of contamination? Yes (No)

21. Will field screening data be used for risk assessment purposes? Yes (No)

22. Will statistical correlation of laboratory and field screening data be necessary? Possibly Yes No

23. If a correlation exists between field screening and laboratory data, will the results of regression analysis be used to define nature and extent? Yes (No)

24. If a correlation exists between field screening and laboratory data, will the results of regression analysis be used to support the risk assessment? Yes No

25. Will fixed base laboratory field parameters be included in the database (e.g., pH, conductance, temperature)? Yes No

26. Will statistical correlations be necessary for TCLP versus total analysis data? Yes No

27. Will statistical correlations be necessary for filtered versus unfiltered samples? Possibly Yes No

28. Will any other statistical correlations be necessary? Possibly, e.g., Th-232 vs Th-total Yes No

29. Are there wells that have been screened in different aquifers? Different depths but not really different aquifers. Yes No

30. Will data for various aquifers be segregated by depth? Possibly Yes No

31. Can the sample nomenclature system be used to identify wells in different aquifers? Yes No

32. Will samples from other matrices (soil, sediment, or surface water) be segregated by depth? Yes No

33. Can the sample nomenclature system be used to identify depth-specificity? Yes No

34. Have any removal actions been performed at the site? Yes No

If removal actions have been performed, plan and cross-sectional views reflecting the extent of the removal action must be provided. Not available

35. Will any composite sample results be included in the database? Yes No

36. If composite samples are included, how will they be used for the nature and extent of contamination?

NA

37 If composite samples are included, how will they be used for the risk assessment?

NA

38. Will the site be segregated into Areas of Concern, Solid Waste Management Units, etc? Yes No

39. Is the sample nomenclature adequate for such segregation? Yes No

If the sample nomenclature is inadequate for assigning samples to an AOC or SWMU, the Project Manager or designee must provide a base map of tabular summary clearly delineating the relationship between each sample and each AOC/SWMU.

40. Were any temporal samples collected (e.g., quarterly sampling of wells)? Historical data only Yes No

41. If temporal samples were collected, how will they be used to define the nature and extent of contamination?

NA

42. If temporal samples were collected, how will they be used to support the risk assessment?

NA

43. Are State, Federal, or Regional criteria to be included in data summary tables? (Yes) No

44. Identify the criteria that must be presented in the summary tables.

RBSLs + RBTLs

45. Will State, Federal, or Regional criteria be used to select COPCs? (Yes) No

46. Identify the criteria to be used as COPC selection tools.

RBTLs, EBQLs and background concentrations

47. Are filtered and unfiltered surface water samples differentiated? (Yes) No

48. If such samples are differentiated, how?

Identified as filtered or unfiltered OR total or dissolved

49. Which of these samples will be used for the human health risk assessment?

Surface Water	Filtered (Unfiltered)
Groundwater	Filtered (Unfiltered)

50. Which of these samples will be used for the ecological assessment?

Surface Water	Filtered (Unfiltered)
Groundwater	Filtered (Unfiltered)

51 Will background data be included in the database? Soil and water (Yes) No

52. How are background samples identified?

Map location

53. Will background results be used to support selection of COPCs? (Yes) No

53. What statistical analyses will be required for the background data?

Maximum values and data set comparisons See QAPP Sections 1+12

54. Will background data be segregated by depth? (Yes) No

55. What background matrices must be segregated by depth?

Soil and GW

56. What format will be used for data presentation (e.g., appendices and summary tables, comprehensive text tables, tag maps, isoconcentration contours, etc.)?

All of above; correlation plots, as necessary

ATTACHMENT F4

SAMPLE TRACKING REQUEST FORM

SAMPLE TRACKING AND DATA MANAGEMENT AT PROJECT INCEPTION

PROJECT START-UP CHECKLIST

ATTACHED IS A PROJECT START-UP CHECKLIST (CAN BE FOUND IN DATA MANAGEMENT CENTRAL FILE). WHENEVER A NEW PROJECT IS STARTED THE TOP PART SHOULD BE FILLED IN. A COPY SHOULD BE RETURNED TO THE DATA MANAGEMENT CENTRAL FILE, KEEP ORIGINAL FOR YOUR RECORDS TO KEEP TRACK OF WHAT HAS BEEN PROVIDED. IMSG WILL CHECK OFF WHEN ALL INFORMATION IS RECEIVED

FOLLOWING THIS PROCESS WILL IMPROVE THE FOLLOWING:

- TURN-AROUND TIME FOR DELIVERABLES NEEDED WHEN ALL RESULTS HAVE BEEN RECEIVED.
- CONFIDENCE THAT ALL SAMPLE RESULTS HAVE BEEN RECEIVED
- CONSISTENCY OF SAMPLE NOMENCLATURE
- CORRECTNESS OF SAMPLE ATTRIBUTES
- REVIEW OF INVOICES
- ENABLE IMSG PERSONNEL TO BETTER TRACK UPCOMING WORKLOAD

PROJECT START-UP CHECKLIST

INFORMATION NEEDED TO CREATE NEW DATABASE

PROJECT NAME:_____

CTO #:_____ JOB #:_____ ETS Code:_____

PROJECT MANAGER/CONTACT:_____

LABELS: Y / N DUE DATE:_____

VALIDATE: Y / N / L DUE DATE:_____

COMBINE WITH HISTORICAL DATA: Y/N

SAMPLE DATA CHECKLIST:

_____ SAMPLE NUMBERS AND ANALYSES (LOCATIONS,DEPTHS)

_____ SECTION OF WORK PLAN PERTAINING TO SAMPLE NOMENCLATURE

_____ LABORATORY/BOTTLE REQUIREMENTS

_____ LAB SPECS

_____ COC'S

_____ SAMPLE LOG SHEETS

_____ DUPLICATE ID'S / ORIGINALS

_____ SURVEY DATA / SAMPLE LOCATION MAPS

_____ BREAKDOWN OF PROJECT BY SITE / MATRIX FOR FUTURE PRINTOUTS

_____ TABLE HEADERS (SEE EXAMPLE)

TO BE COMPLETED BY IMSG:

_____ FINAL RESULTS GIVEN TO _____ (PM/IMSG)

DATE:_____

_____ SAMPLE DATA LOADED INTO NEW/EXISTING PROJECT DATABASE

_____ RESULTS LOADED INTO NEW/EXISTING PROJECT DATABASE

PATHNAME OF PROJECT DATABASE:_____

_____ DATA LOADED INTO GIS

ATTACHMENT F5

SAMPLE TRACKING DATABASE EXAMPLE

CTO 020 SDG U06972

Sdg	Sample Number	Lab id	Fraction	Sort	Lab Rec	Rec Date	Turn-time	Laboratory
F5717	H10MW0501	F5717-2	M	M	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	MISC	CL	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	MISC	NTA	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	MISC	NTI	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	MISC	SO4	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	MISC	SUL	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	OS	OS	03-Feb-00	28-Feb-00	25	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	OV	ETHA	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	OV	ETHE	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	OV	METH	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	OV	OV	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ
F5717	H10MW0501	F5717-2	PAH	PAH	25-Jan-00	28-Feb-00	34	ACCUTEST, NJ

ATTACHMENT F6

EXAMPLE SAMPLE JAR LABELS

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: CTO 038 Location: NSWC CRANE	
Sample No: BGSBP0401		Tag # : A0001	
Date: (1)	Time: (2)	Preserve:	
Analysis: TAL Metals + Tin		Matrix: SOIL	
Sampled By: (3)		Laboratory: LAUCKS	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: Location:	
Sample No:		Tag # :	
Date: (1)	Time: (2)	Preserve:	
Analysis:		Matrix:	
Sampled By:		Laboratory:	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: CTO 038 Location: NSWC CRANE	
Sample No: BGSBP0401		Tag # : A0001	
Date: (1)	Time: (2)	Preserve:	
Analysis: TAL Metals + Tin		Matrix: SOIL	
Sampled By: (3)		Laboratory: LAUCKS	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: Location:	
Sample No:		Tag # :	
Date: (1)	Time: (2)	Preserve:	
Analysis:		Matrix:	
Sampled By:		Laboratory:	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: CTO 038 Location: NSWC CRANE	
Sample No: BGSBP0401		Tag # : A0001	
Date: (1)	Time: (2)	Preserve:	
Analysis: TAL Metals + Tin		Matrix: SOIL	
Sampled By: (3)		Laboratory: LAUCKS	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: Location:	
Sample No:		Tag # :	
Date: (1)	Time: (2)	Preserve:	
Analysis:		Matrix:	
Sampled By:		Laboratory:	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: Location:	
Sample No:		Tag # :	
Date: (1)	Time: (2)	Preserve:	
Analysis:		Matrix:	
Sampled By: (3)		Laboratory:	

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project: Location:	
Sample No:		Tag # :	
Date: (1)	Time: (2)	Preserve:	
Analysis:		Matrix:	
Sampled By: (3)		Laboratory:	

ATTACHMENT F7

ELECTRONIC DATA DELIVERABLE REQUIREMENTS FOR ANALYTICAL LABORATORIES

ELECTRONIC DATA FORMAT REQUIREMENTS

1.0 INTRODUCTION

The laboratory is to provide 3.5" high density diskette(s) containing separate database (DBF) files in the format specified in this Attachment. The electronic deliverable includes all environmental samples, sample dilutions, sample reanalyses, and laboratory quality control samples. **All entries in the electronic deliverable must agree exactly with the final entries reported on the hardcopy data package sample result summaries**. Any corrections made to the hardcopy data must also be made to the electronic file. Appropriate qualifiers as identified by the analytical protocol must also be designated; laboratory QC non-compliance codes are not to be depicted.

Each diskette is to be properly labeled with the laboratory name, project name, file name(s), and laboratory point of contact. Electronic files should be delivered in the same fashion as are the hard copy data packages. A separate .dbf file shall be made for each analytical fraction (by method) and each sample delivery group (SDG). The files shall be named with the first character being the analytical fraction designator, followed by an underscore, followed by the SDG name. For example, the file for the volatile fraction for SDG BR001 should be named V_BR001.DBF. Additionally, the laboratory must provide a hardcopy listing all electronic files saved to the diskette, indicating what analytical fraction and matrix the file data contained therein pertain to. All electronic data deliverables are due within the same time established for the associated hardcopy data packages.

In addition, the laboratory QC officer must read and sign a copy of the Quality Assurance Review Form displayed on the next page of this Attachment. Electronic deliverables are not considered to be complete without the accompanying Quality Assurance Review Form.

I _____, as the designated Quality Assurance Officer, hereby attest that all electronic deliverables have been thoroughly reviewed and are in agreement with the associated hardcopy data. The enclosed electronic files have been reviewed for accuracy (including significant figures), completeness and format. The laboratory will be responsible for any labor time necessary to correct enclosed electronic deliverables that have been found to be in error. I can be reached at (____)_____if there are any questions or problems with the enclosed electronic deliverables.

Signature:_____ Title: _____ Date: _____

The analytical data shall be delivered electronically in a Dbase III file format (filename.dbf). The exact structure of the database is described in the table below. It shall be the responsibility of the laboratory to ensure that all electronic entries are in strict accordance with the information provided on the Form I.

An example database shall be sent for review prior to the first electronic deliverable in Dbase III format. The example file will be examined for completeness and comments will be sent to the laboratory. Any questions regarding the electronic deliverable shall be directed to Patrick Hooper at Tetra Tech NUS (412) 921-8250.

DATA FIELD	DATA TYPE	FIELD WIDTH	DATA FIELD DESCRIPTION
SAMPLE_NO	C	25	Field sample ID as listed on the chain-of-custody. The sample number indicated in this field should never be truncated. The only exception for this field not matching the chain-of-custody is for reanalyses and matrix spike results in which a RE or MS suffix will be added to the sample number respectively.
TRUNCATE	C	15	If the field sample ID listed on the Chain of Custody is truncated by the laboratory for use with the laboratory software, the truncated sample ID should appear in this field.
LAB_ID	C	15	Laboratory number for the given sample.
LABORATORY	C	25	Laboratory name.
BATCH_NO	C	10	Laboratory code for batch of samples included in a given run.
ASSOC_BLNK	C	15	Laboratory name of the method blank associated with that particular batch of samples.
QC_TYPE	C	15	Normal Environmental Sample = "NORMAL", Laboratory Duplicate = "DUPLICATE", Matrix Spike = "MS", Matrix Spike Duplicate = "MSD", Laboratory Control Sample = "LCS", Laboratory Control Sample Duplicate = "LCSD", Method Blank = "M_BLANK", Preparation Blank = "P_BLANK".
SAMP_DATE	D	8	Date of sample collection as indicated on the Chain of Custody. Example: 11/07/93.
REC_DATE	D	8	Date sample was received by the laboratory.
EXTR_DATE	D	8	Date sample was extracted or prepared by the laboratory.
ANAL_DATE	D	8	Date sample was analyzed by the laboratory.
RUN_NUMBER	N	2 (0)	The number of the analytical run for a given sample in sequence. For example, if a sample is diluted and reanalyzed, the original run number would be 1 and the reanalysis would be 2.
SDG	C	15	Sample delivery group identifier assigned by the laboratory. This number should exactly match the SDG designated on the hardcopy data package.

DATA FIELD	DATA TYPE	FIELD WIDTH	DATA FIELD DESCRIPTION
PROJECT_NO	C	10	Identification of Project Number or CLEAN Task Order (CTO) number.
PROJ_MNGR	C	25	The Tetra Tech NUS Project Manager's last name, followed by a comma, followed by the first initial of the Project Manager (e.g. Hutson, D).
PARAMETER	C	45	Chemical or analyte name exactly as reported on Form I.
CAS_NO	C	10	Chemical Abstract Service number for the parameter listed. The CAS number should be reported exactly as it is listed in publications such as the Merck Index. This field should be left blank for those parameters not having CAS numbers (e.g. Total Organic Carbon).
FRACTION	C	5	Metals = 'M', Volatiles = 'OV', Semivolatiles/BNAs = 'OS', Pesticides = 'PEST', Herbicides = 'HERB', Polychlorinated Biphenyls = 'PCB', Explosives = 'EXP', Any petroleum hydrocarbon or fuel = 'TPH', Wet Chemistry = 'WET', Radionuclide = 'RAD', Miscellaneous = 'MISC'
METHOD	C	20	Analytical method used to quantitate parameter concentrations as listed in the laboratory technical specification (e.g. '8270A' for SW-846 Method 8270A.
LAB_RESULT	N	20 (6)	Reported value in units specified in the UNITS field containing the proper number of significant digits. The % Recovery shall be placed in this field for matrix spike and laboratory control sample results.
UNITS	C	5	The units of measure as reported on the Form I.
LAB_QUAL	C	2	The laboratory qualifier as reported on the Form I. For example, a 'U' qualifier should be used for all nondetected results.
IDL	N	15 (6)	Instrument detection limit in units specified in the UNITS field.
MDL	N	15 (6)	Method detection limit in units specified in the UNITS field and method specified in the METHOD field.
CRDL_CRQL	N	15 (6)	Contract Required Detection/Quantitation Limit in the units specified in the UNITS field. RDL for non-CLP parameters.
DIL_FACTOR	N	6 (1)	Dilution factor.
PCT_MOIST	N	5 (1)	Percent moisture for soil samples; blank for water samples.
COMMENTS	C	20	Analytical result qualifier or comment other than that listed in the LAB_QUAL field. Example: 'Reanalysis'.

C = Character string (everything shall be reported in capital letters)
N = Numeric string (decimal places are in parentheses in field width column)
D = Date (Ex: 05/25/97)

ATTACHMENT F8

DATABASE STRUCTURE

DATA DICTIONARY

TETRA TECH NUS DATABASE STANDARDS

January, 1999

DRAFT

TABLE: well
PRIMARY KEY: location

Table Structure

FIELD	DESCRIPTION
location	Unique location name.
post_id	Location name as derived from original source document.
instal_date	Date the monitoring well was installed. Null for other location types.
loc_type	Type of location (e.g., soil boring, GW well, drive point, wipe)
Northing	Northing coordinate in horizontal datum referenced in the HORIZ_DATUM field.
Easting	Easting coordinate in horizontal datum referenced in the HORIZ_DATUM field.
horiz_datum	Datum in which the horizontal coordinates were derived.
grnd_surf	Ground surface elevation with reference to mean sea level in vertical datum referenced in the VERT_DATUM field.
vert_datum	Datum in which the vertical coordinates were derived.
datum_state	State for which datum was developed.
surveyed	Logical field denoting whether positional data were surveyed or digitized.
Surveyor	Company who performed the survey.
survey_date	Date in which survey was performed.
surv_method	Surveying method used.
longitude	Longitude.
latitude	Latitude.

Table Indexes

INDEX	TYPE
location	Primary
hd	Regular
vd	Regular
loc_type	Regular

Table Relations:
Relation 1
*RelatedChild loc_type
*RelatedTable loc_type_vvl
*RelatedTag loc_type
Relation 2
*RelatedChild cd
*RelatedTable coord_datum_vvl
*RelatedTag cd

TABLE: loc_type_vvl - Valid value list for LOC_TYPE field in the well table.
PRIMARY KEY: loc_type

Table Structure

FIELD	DESCRIPTION
loc_type	Location type
description	Description of location type

Table Indexes

INDEX	TYPE
loc_type	Primary

TABLE: coord_datum_vvl - Valid value list for HORIZ_DATUM field in the well table.
PRIMARY KEY: cd (coord_datum)

Table Structure

FIELD	DESCRIPTION
coord_datum	Datum in which coordinates reflect.

Table Indexes

INDEX	TYPE
cd (coord_datum)	Primary

TABLE: sample_data - Sample data table
PRIMARY KEY: nsample

Table Structure

FIELD	DESCRIPTION
location	Unique location name.
Matrix	Sample matrix.
nsample	Unique sample identification.
sample	Sample identification as designated on Chain-of-Custody.
sacode	Sample code for reference to field duplicates.
top_depth	Depth in feet to the top of the sample interval. Applicable for soil and sediment samples.
Bottom_depth	Depth in feet to the bottom of the sample interval. Applicable for soil and sediment samples. *Rule Expression*: if(bottom_depth>0,top_depth<=bottom_depth)
qc_type	Quality control type.
status	Status of sample location - Normal or excavated.
sample_date	Date in which sample was collected.
validated	Logical field denoting whether or not data validation was performed on sample.
coll_method	Sample collection method.
cto_proj	Clean task order (Navy) or project number in which the sample was collected (e.g., "129").
proj_manager	Internal project manager for which the data were originally generated (e.g. "Hutson, D.").

Table Indexes

INDEX	TYPE
location	Regular
nsample	Primary
sacode	Regular
matrix	Regular
status	Regular
qc_type	Regular
coll_meth	Regular

Table Relations:

Relation 1
*RelatedChild sacode
*RelatedTable sacode_vvl
*RelatedTag sacode
Relation 2
*RelatedChild qc_type
*RelatedTable qc_type_vvl
*RelatedTag qc_type
Relation 3
*RelatedChild matrix
*RelatedTable matrix_vvl
*RelatedTag matrix
Relation 4
*RelatedChild location
*RelatedTable well
*RelatedTag location
Relation 5
*RelatedChild coll_meth
*RelatedTable coll_method_vvl
*RelatedTag coll_meth

TABLE: sacode_vvl - Sample code valid value list for SACODE field in sample_data.dbf
PRIMARY KEY: sacode

Table Structure

FIELD	DESCRIPTION
sacode	Sample code designating whether sample is a normal environmental sample, a field duplicate, or the average of field duplicate pairs.
description	Description of sacode entry.

Table Indexes

INDEX	TYPE
sacode	Primary

TABLE: qc_type_vvl - Quality control valid value list for QC_TYPE field in sample_data.dbf
PRIMARY KEY: qc_type

Table Structure

FIELD	DESCRIPTION
qc_type	Quality control type.
description	Description of quality control type.

Table Indexes

INDEX	TYPE
qc_type	Primary

TABLE: matrix_vvl - Matrix valid value list for MATRIX field in sample_data.dbf
PRIMARY KEY: matrix

Table Structure

FIELD	DESCRIPTION
matrix	Sample matrix.
description	Description of sample matrix code.

Table Indexes

INDEX	TYPE
matrix	Primary

TABLE: well_completion
PRIMARY KEY: None

Table Structure

FIELD	DESCRIPTION
location	Unique location name.
top_casing	Elevation of top of well casing in vertical datum found in VERT_DATUM in the well table.
hole_diameter	Diameter of the drilled hole in inches. *Rule Expression*: hole_diameter>casing_id.AND.hole_diameter>casing_od
scr_aquifer	Aquifer name in which the screen resides.
screen_material	Type of material from which the screen is constructed.
scrn_slot_size	Screen slot size in thousandths of an inch.
scrn_top_depth	Depth below ground surface to the top of the screen (in feet).
scrn_bot_depth	Depth below ground surface to the bottom of the screen. *Rule Expression*: if(scrn_bot_depth>0,scrn_top_depth<scrn_bot_depth)
scrn_top_elev	Elevation the top of the screen in vertical datum found in VERT_DATUM in the well table.
scrn_bot_elev	Elevation the top of the screen in vertical datum found in VERT_DATUM in the well table. *Rule Expression*: if(scrn_bot_elev>0,scrn_top_depth>scrn_bot_depth)
drill_method	Drilling method for well installation.
contractor	Drilling contractor.
casing_material	Type of material in which the casing is constructed from.
depth_to_seal	Depth below ground surface to seal (in feet).
seal_material	Type of material in which the seal is constructed from.
fill_top_depth	Depth below ground surface to the top of fill material (in feet).
fill_bot_depth	Depth below ground surface to the bottom of fill material (in feet). *Rule Expression*: if(fill_bot_depth>0,fill_top_depth<scrn_bot_depth)
fill_material	Type of material used for fill.
comments	Geologist's comments

Table Indexes

INDEX	TYPE
location	Regular

Table Relations:
Relation 1
*RelatedChild location
*RelatedTable well
*RelatedTag location
TABLE: lithology
PRIMARY KEY: None

FIELD	DESCRIPTION
location	Unique location name.
top_lithology	Depth in feet below ground surface to the top of lithologic unit.
bottom_lithology	Depth in feet below ground surface to the bottom of lithologic unit.
uscs_code	Unified Soil Classification System for lithology type.
blow_counts	Number of blow counts recorded on boring log.
description	Geologist's description of lithology.
comments	Geologist's comments.

Table Indexes

INDEX	TYPE
location	Regular
uscs_code	Regular

Table Relations:
Relation 1
*RelatedChild location
*RelatedTable well
*RelatedTag location
Relation 2
*RelatedChild uscs_code
*RelatedTable lithology_vvl
*RelatedTag uscs_code

TABLE: lithology_vvl - Lithology valid value list for USCS_CODE field in lithology.dbf
PRIMARY KEY: uscs_code

Table Structure

FIELD	DESCRIPTION
uscs_code	Unified Soil Classification System for lithology type.
descript	Description of lithology for given USCS code.

Table Indexes

INDEX	TYPE
uscs_code	Primary

TABLE: coll_method_vvl - Collection method valid value list for COLL_METHOD field in sample_data.dbf
PRIMARY KEY: coll_meth

Table Structure

FIELD	DESCRIPTION
coll_method	Sample collection method

Table Indexes

INDEX	TYPE
coll_method	Primary

TABLE: cas_vvl - CAS number valid value list for CAS field in analytical results.dbf
PRIMARY KEY: cas

Table Structure

FIELD	DESCRIPTION
parameter	Parameter or chemical name
cas	Chemical Abstracts Service Number

Table Indexes

INDEX	TYPE
parameter	Regular
cas	Primary

TABLE: analytic_results
PRIMARY KEY: nfp (nsample+fraction+parameter)

Table Structure

FIELD	DESCRIPTION
nsample	Unique sample identification.
lab_id	Laboratory sample identification.
laboratory	Laboratory name.
batch_no	Analytical batch number.
assoc_blnk	Associated blank.
extr_date	Extraction date.
anal_date	Analysis date.
run_number	Sequential analytical run number.
sdg	Sample delivery group.
parameter	Parameter or chemical name (using IUPAC nomenclature where appropriate).
cas	Chemical Abstracts Service Number.
fraction	Analtytical fraction.
method	Analytical method.
lab_result	Analytical result as reported by the laboratory.
lab_qual	Qualifier as reported by the laboratory.
val_res	Final result (via validation or otherwise).
result	Final analytical result with the correct number of significant figures.
val_qual	Validation qualifer (null if data were not validated).
qual	Final qualifer (validation or otherwise).
qual_code	Validation flag used to define the quality control noncompliance.
units	Units of measure for the RESULT field.
idl	Instrument detection limit (same units as UNITS field).
mdl	Method detection limit (same units as UNITS field).
crdl_crql	Contract required detection/quantitation limit (same units as UNITS field).
dil_factor	Dilution factor.
pct_moist	Percent moisture.
comments	Comments from laboratory analyst.

Table Indexes

INDEX	TYPE
nfp	Primary
units	Regular
qual	Regular
fraction	Regular
parameter	Regular
nsample	Regular
cas	Regular

Table Relations:
Relation 1
*RelatedChild cas
*RelatedTable cas_vvl
*RelatedTag cas

Relation 2
*RelatedChild units
*RelatedTable units_vvl
*RelatedTag units
Relation 3
*RelatedChild qual
*RelatedTable qual_vvl
*RelatedTag qual
Relation 4
*RelatedChild fraction
*RelatedTable fraction_vvl
*RelatedTag fraction
Relation 5
*RelatedChild parameter
*RelatedTable para_vvl
*RelatedTag para
Relation 6
*RelatedChild nsample
*RelatedTable sample_data
*RelatedTag nsample

TABLE: units_vvl - Units valid value list for UNITS field in analytical_results.dbf
PRIMARY KEY: Units

Table Structure

FIELD	DESCRIPTION
units	Units of measure for chemical analysis
description	Description of units

Table Indexes

INDEX	TYPE
units	Primary

TABLE: qual_vvl
PRIMARY KEY: qual - Qualifier valid value list for QUAL field in analtyic_results.dbf

Table Structure

FIELD	DESCRIPTION
qual	Final QA qualifier
description	Definition of qualifier

Table Indexes

INDEX	TYPE
qual	Primary

TABLE: fraction_vvl - Analytical fraction valid value list for FRACTION field in analytic_results.dbf
PRIMARY KEY: fraction

Table Structure

FIELD	DESCRIPTION
fraction	Analytical fraction
description	Description of fraction

Table Indexes

INDEX	TYPE
fraction	Primary

TABLE: para_vvl
PRIMARY KEY: parameter

Table Structure

FIELD	DESCRIPTION
para	Parameter or chemical name
frac_name	Analytical fraction for given parameter

Table Indexes

INDEX	TYPE
para	Primary

TABLE: fluid
PRIMARY KEY: None

Table Structure

FIELD	DESCRIPTION
location	Unique location name
meas_elev	Measuring point elevation
dep_to_water	Depth below ground surface to water table (in feet)
dep_to_fp	Depth below ground surface to free product (in feet)
elev_water	Elevation of water level
elev_fp	Elevation of free product
prod_thick	Product thickness in feet
meas_date	Date measurement was taken.

Table Indexes

INDEX	TYPE
location	Regular

Table Relations:
Relation 1
*RelatedChild location
*RelatedTable well
*RelatedTag location

ATTACHMENT F9

ARCVIEW GIS STRUCTURE

ARCVIEW GIS STRUCTURE

The project ArcView GIS shall have the following directory structure and database table structure.

PART ONE: DIRECTORY STRUCTURE

The following table defines the directory structure and major file names/types located within each directory.

Main subdirectory	First tier subdirectories	Second tier subdirectories	Files/Types
p:\gis\project name\	database\		coordinate.dbf cross_reference.dbf res_ gw.dbf res_so.dbf res_sd.dbf res_sw.dbf well_completion.dbf
		criteria\	crit_ gw.dbf crit_so.dbf crit_ sd.dbf crit_sw.dbf crit_des.dbf
	mapping\	aerial\	registered aerial photos
		drg\	USGS Digital Raster Graphic
		image\	GeoStatistic Layers, pictures of sites, equipment, EVS, and all other raster files.
		dwg\	AutoCAD files
		dgn\	Microstation files
		shp\	samp_gw.shp .dbf .shx samp_so.shp .dbf .shx samp_sd.shp .dbf .shx samp_sw.shp .dbf .shx and all other AV shape files
	working\	database\	files used to generate specific drawings will be put under the working subdirectory in subdirectories similar to database & mapping. These will not be included in CD deliverable.
		mapping\	same as above

PART TWO: DATABASE TABLE STRUCTURE

The project ArcView GIS will contain separate database tables to store analytical, criteria, and coordinate information. The structure of these tables is presented below.

Analytical Data Table

The following table lists all the fields contained in the analytic database table.

FIELD	VISIBLE	ALIAS*	DESCRIPTION
site	Yes	Site or SWMU	Site or SWMU.
location	Yes	Location	Unique location name.
nsample	Yes	Sample	Unique sample identification.
sample	No		Sample identification as designated on Chain-of-Custody.
sample_date	Yes	Sample Date	Date on which sample was collected.
matrix	Yes	Matrix	Sample matrix.
sacode	Yes	Sample Code	Sample code for reference to field duplicates.
depth	Yes	Depth	Depth in feet to the middle of the sample interval. Applicable for soil and sediment samples.
top_depth	Yes	Top Depth	Depth in feet to the top of the sample interval. Applicable for soil and sediment samples.
bottom_depth	Yes	Bottom Depth	Depth in feet to the bottom of the sample interval. Applicable for soil and sediment samples. Rule Expression: if(bottom_depth>0,top_depth<=bottom_depth)
parameter	Yes	Parameter	Parameter or chemical name (using IUPAC nomenclature where appropriate).
cas	Yes	CAS	Chemical Abstracts Service Number.
fraction	Yes	Fraction	Analytical fraction.
val_res	Yes	Numeric Result	Final result (via validation or otherwise).
qual	Yes	Qualifier	Final qualifier (validation or otherwise).
units	Yes	Units	Units of measure for the RESULT field.
method	Yes	Method	Analytical method.
status	Yes	Status	Status of sample location – Normal or excavated.
validated	Yes	Validated	Logical field denoting whether or not data validation was performed on sample.
coll_method	Yes	Collection Method	Sample collection method (e.g., grab/composite).
cto_proj	Yes	CTO	Clean task order (Navy) or project number for which the sample was collected (e.g. "129").

FIELD	VISIBLE	ALIAS*	DESCRIPTION
proj_manager	Yes	Project Manager	Internal project manager for which the data was originally generated (e.g. "Hooper, P.").
lab_id	No	Laboratory ID	Laboratory sample identification.
laboratory	No	Laboratory	Laboratory name.
batch_no	No	Batch Number	Analytical batch number.
assoc_blnk	No	Associated Blank	Associated blank.
extr_date	No	Extraction Date	Extraction date.
anal_date	No	Analysis date	Analysis date.
run_number	No	Run Number	Sequential analytical run number.
sdg	No	SDG	Sample delivery group.
lab_result	No	Result	Analytical result as reported by the laboratory.
lab_qual	No	Lab Qualifier	Qualifier as reported by the laboratory.
result	No	String Result	Final analytical result with the correct number of significant figures.
val_qual	No	Validation Qualifier	Validation qualifier (null if data were not validated).
idl	No	Detection Limit	Instrument detection limit (same units as UNITS field).
mdl	No	Detection Units	Method detection limit (same units as UNITS field).
crdl_crql	No		Contract required detection/quantitation limit (same units as UNITS field).
dil_factor	No	Dilution factor	Dilution factor.
pct_moist	No	Percent moisture	Percent moisture.
ourresult	No		
qc_type	No		Quality control type.
comments	No	Comments	Comments from laboratory analyst.

*A blank indicates that no alias exists.

Criteria Table

Each medium will have a criteria table to specify the applicable criteria for all parameters.

FIELD	ALIAS	DESCRIPTION
parameter	Parameter	Parameter or chemical name (using IUPAC nomenclature where appropriate)
epa_mcl	None	Federal MCL – groundwater

Note: usually there will be many criteria fields. This example table only shows the "epa_mcl" criteria field.

Criteria Description Table

This table stores the definition or description of all standards and criteria used in the project. For example, epa_mcl's media would be GW, description would be "Federal Maximum Contaminant Level".

FIELD	Visible	DESCRIPTION
Field	Yes	
Media	Yes	
Descript	Yes	

Coordinate Table

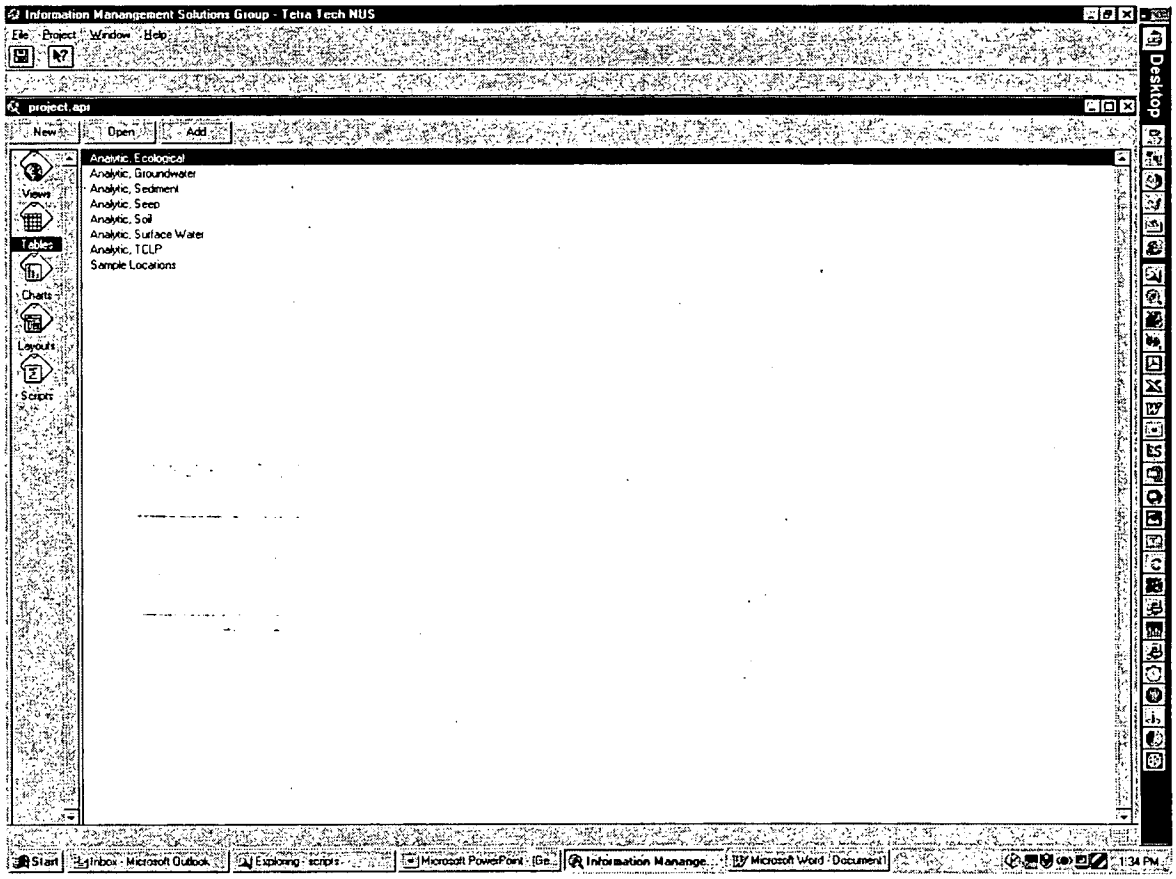
The coordinate table holds all the geographic position information of sampling locations

FIELD	Visible	ALIAS*	DESCRIPTION
location	Yes		Unique location name.
post_id	Yes	Location Designation	Location name as derived from original source document.
instal_date	No	Installation Date	Date the monitoring well was installed. Null for other location types.
loc_type	Yes	Location Type	Type of location. Example MW, HP, etc.
northing	Yes		Northing coordinate in horizontal datum referenced in the HORIZ_DATUM field.
easting	Yes		Easting coordinate in horizontal datum referenced in the HORIZ_DATUM field.
grnd_surf	Yes	Ground Surface Elevation	Ground surface elevation with reference to mean sea level in vertical datum referenced in the VERT_DATUM field
horiz_datum	Yes	Horizontal Datum	Datum in which the horizontal coordinates were derived.

FIELD	Visible	ALIAS*	DESCRIPTION
vert_datum	Yes	Vertical Datum	Datum in which the vertical coordinates were derived.
fatum_state	Yes	Coordinate System	State for which datum was developed.
durveyed	Yes		Logical field denoting whether positional data were surveyed or digitized.
durveyor	Yes		Company who performed the survey.
durvey_date	No	Survey Date	Date on which survey was performed.
durv_method	No	Survey Method	Surveying method used.
longitude	No		Longitude.
latitude	No		Latitude.
gw_code	Yes		This will be populated by database personnel. It will be used for event driven theme.
sd_code	Yes		This will be populated by database personnel. It will be used for event driven theme.
so_code	Yes		This will be populated by database personnel. It will be used for event driven theme.
sw_code	Yes		This will be populated by database personnel. It will be used for event driven theme.
_nullflags	No		Various fields are put in by database personnel starting here and followed by several fields. Make all of these invisible.

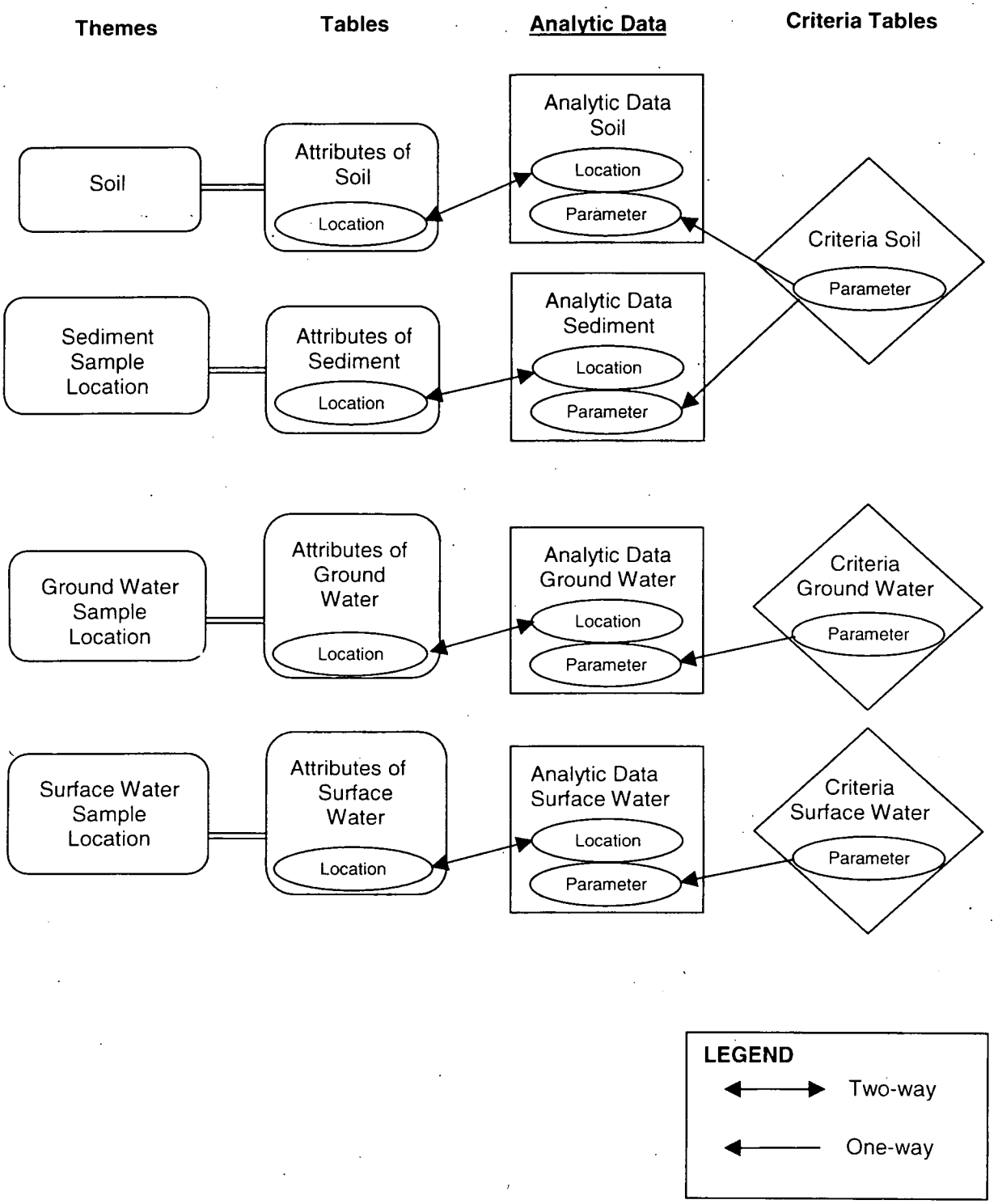
*A blank indicates that no alias exists.

TABLE LINKS



All sample location theme attribute tables are two-way linked to the corresponding analytical data table. In addition, the analytical data tables are joined to the criteria table. The following diagram illustrates the relationship.

Database Model:



APPENDIX G

FIELD AUDIT CHECKLIST (EXAMPLE)

Location: NSWC Crane, Crane, Indiana

Project: NSWC Crane Mustard Gas Burial Ground, CTO 131

Date of Audit: _____

Instructions: Record answers to questions below, providing comments as required for clarification.

QA/QC Procedures

1. Were any field observations, deficiencies, non-conformances, or complaints recorded by the site QA/QC Officer or other personnel?
   If so, summarize below.

   _____
   _____
   _____
   _____
   _____

2. Based on personnel interviews, did any variances from the project planning documents occur? If so, what were they?

   _____
   _____
   _____
   _____

3. Were field modification records pertinent to the above initiated in an appropriate manner?

   _____

4. If applicable, were corrective action plans implemented (according to proper procedure) regarding Question 2?

   _____
   _____
   _____

5. Were field QC samples obtained with the frequency specified in the QAPP?

   _____

6. For this site, were field duplicates submitted "blind" to the laboratory?

7. For this site, are sufficient replicate aliquots of samples designated for the laboratory for the matrix spike/duplicate analyses specified in the QAPP?

Boring/Drilling

8. Is the drilling method specified in the QAPP being used?

9. In accordance with TtNUS policies and field SOPs, the FOL has the authority to change drilling methods if site conditions so dictate. Did any change in drilling methods from that cited in the project planning documents occur? If so, discuss.

10. If a change in drilling methods was required, did the FOL properly document the change and the rationale for the change?

11. Were any field changes initiated by the drilling subcontractor? If so, was the FOL notified and were the changes documented?

12. Per TtNUS SOP CTO 131-14, was the auger plugged until the desired sampling depth was reached? (If the sample is to be taken at a relatively deep point, the auger may be advanced without a plug to within five feet of the sample depth. Beyond that point, the procedure outlined in the SOP must be observed.)

_____
_____
_____
_____

13. Have all abandoned borings been backfilled as specified in the QAPP or applicable SOP?

_____
_____

14. When applicable, was the casing cleaned before sampling? (In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches for cuttings are encountered, the borehole must be recleaned prior to attempting sampling.)

water wash (disturbed samples above and below water table) _____
clean-out auger (undisturbed samples below water table) _____
dry method (undisturbed samples above water table) _____

15. Were any drilling lubricants used? If so, were the procedures cited in TtNUS SOP CTO131-14 observed?

_____
_____
_____

16. Were detailed boring logs maintained by the site geologist for each borehole? (Logging is not required if explicitly stated so in the associated FSAP.)

_____
_____
_____
_____

17. Was the following information complete on the borehole logs:
description of materials _____
description of samples _____
sampling method _____
blow counts _____
final location for drilling _____

Soil Sampling

18. Are the sampling devices and boring methods designated in the QAPP or applicable project-specific SOP being used?

_____
_____
_____
_____

19. Was the following information recorded in the boring logs or the field notebook?

For soil classification:

Was the USCS classification and soil type (clay, silt, sand) indicated?

_____

Were the following characteristics identified per the relevant TtNUS SOP CTO131-6 sections?

color _____
soil type _____
relative density and consistency _____
stratification _____
texture/fabric/bedding _____

20. For surface soil samples obtained by hand auger or scoop or trowel, were the following activities performed?

area cleared of loose debris prior to sampling _____
location marked with numbered stake or pin flag _____
sketch of approximate locations of sample points in site notebook _____

21. Were VOC samples NOT collected from the top 6" soil interval? Yes/No

Groundwater Sampling

22. Were all monitoring wells properly developed, purged and recovered prior to sampling?

_____
_____

23. When applicable, were well volumes calculated as described in SOP CTO131-15?

_____

24. If a peristaltic pump was used to obtain Volatile Organic Compound (VOC) samples, was it verified that no degassing "bubbles" developed?

_____

25. If samples were acquired by a pump, was the pump lowered to midscreen (middle of open section of uncased wells) for sample acquisition?

_____

26. If samples were collected using bailers, were only bailers equipped with check balls used?

_____

27. For samples acquired by packer assembly, was the packer positioned just above the screen (or open section for uncased wells), prior to inflating?

_____

Surface Water and Sediment Sampling

28. In accordance with SOP 131-21, surface water samples taken from different depths or cross-sectional locations may be composited. However, samples collected along the length of the water course or a different times shall not be composited. If composited surface water samples were obtained, was the above rule observed?

_____
_____

29. Per SOP CTO131-21; it is preferable to sample larger streams (and rivers) by compositing a sample from (1) just below the surface, (2) at mid-depth, (3) just above the bottom. If applicable, was this practice observed?

_____
_____

30. SOP CTO131-21 states that it is preferable to obtain surface water samples from a stream area that is well mixed. If applicable, was this observed?

_____
_____
_____
_____

31. SOP CTO131-21 states that "For sampling running water, it is suggested that the farthest downstream sample be obtained first and that subsequent samples be taken as one works upstream." Furthermore, the SOP states that work should be directed from "zones suspected of low contamination to zones of high contamination". If applicable, were these practices observed?

_____

_____

32. In accordance with SOP CTO131-21, sampling at the surface should never be performed unless specifically sampling for a known constituent which is immersible and on top of the water. Sample containers should be inverted, lowered to the approximate sample depth, then positioned at an approximate 45-degree angle with the mouth of the bottle facing upstream in order to acquire the sample. If applicable, was this technique observed?

_____

_____

Equipment Decontamination Procedures

33. Has an adequate, pre-determined area for steam cleaning of equipment been established?

_____

_____

34. Is the decontamination (decon) area lined and/or bermed?

_____

_____

35. Are hand augers decontaminated as required?

_____

_____

36. Was steam cleaning conducted:

prior to commencement of field activities? _____
between boring/pit locations? _____
at the end of field activities? _____

37. Verify that all sampling equipment not subject to steam cleaning (e.g., trowels, mixing bowls, etc.) are subjected to decontamination per the sequence outlined in the QAPP and project-specific SOP

_____
_____

Calibration and Use of Field Monitoring Equipment

38. Were the following calibration criteria observed:

calibration according to manufacturer's instructions _____
calibration only by qualified individuals _____
calibrated and operationally checked prior to project assignment _____
use of certified/traceable standards _____
calibration documented _____
if applicable, maintenance documented _____

39. For Photoionization Detectors (PIDs), is the proper eV Lamp (e.g., 9.5, 10.2, 11.7) installed?

_____
_____
_____
_____

40. Confirm that proper PID Start-up and Shut-down procedures are performed as required.

_____
_____
_____
_____

41. Has PID UV light source window cleaning been conducted as required?

_____

42. Has the PID ionization chamber been cleaned as required?

_____

43. Has the PID unit been recharged after every use?

_____
_____

Waste Handling Procedures

44. Were cuttings or fluids disposed of in accordance with the QAPP Section 4 requirements (i.e., discharged to ground, drummed, or tanked)?

_____

45. Do the project planning documents provide for the disposal of Personal Protective Equipment (PPE) by double-bagging and discard?

_____

46. By what method are PPE disposed of?

_____

47. If applicable, were used spill-containment materials containerized or otherwise acceptably disposed of?

_____
_____

Sample Handling

48. Are the appropriate containers provided by the laboratory being used for each sample?

_____
_____
_____

49. Has the temperature blank been handled properly and one submitted with each cooler of samples?

_____
_____

50. Have equipment rinsate blanks of the proper type and frequency been obtained?

_____
_____

51. Have source water blanks been obtained from water sources applicable to the field effort?

_____
_____

52. Have the rinsate and source water blanks been designated for the same analyses as the associated samples?

53. Has sample custody been maintained with regard to the following criteria:

A sample is under an individual's custody if:

- it is in the individual's actual possession
- it is in the individual's view after possession
- it was locked up to prevent tampering
- it was placed in a designated and identified secure area

(The sample remains in the individual's custody until it is entrusted to a laboratory courier or commercial express carrier.)

Documentation

54. Are all sample logs complete (i.e., containing all information stipulated in SOPs CTO131-6, -19, -21, and -22)?

55. Have chain-of-custody (COC) forms been filled out for all samples, including field quality control samples?

56. Have the COC forms been signed by the appropriate individual at each step that the samples are relinquished?

57. Have the COC forms been filled-out using black waterproof ink?

58. If the COC form or other field document was corrected, was a line drawn through the information and was the change dated and initialed? (Use of white-out or erasure is not permitted.)

59. Have the appropriate analyses (per the QAPP) been properly designated for each sample on the COC form?

60. Have all sample labels been filled out appropriately and completely?

61. Have sample tags been properly completed and attached securely to samples?

62. Have all sample labels been filled out using indelible ink?

63. Do the sample identifications agree between the sample log, field notebook, sample label and COC form?

64. When applicable, have the name of the photographer, date, time, site location, and site description been entered sequentially into the site logbook as documentational photographs of the sampling have been taken?

65. Has the following information (at a minimum) been recorded in the site logbook:

- arrival/departure of site visitors
- arrival/departure of equipment
- sample pickup, COC form numbers, carrier company, time
- sampling activities/sample log sheet numbers
- start/completion of boreholes, trenches, monitoring wells
- health and safety issues

66. Is the site logbook a bound notebook with consecutively numbered pages that cannot be easily removed?

_____

_____

67. As required by SOP CTO131-25, does the cover of the site logbook contain the following information?

project name _____
project number _____
contractor (or Teaming firm) name _____
sequential book number _____
start date _____
end date _____

68. As required by SOP CTO131-25, has the following information been recorded at the beginning of each day?

date _____
start time _____
weather conditions _____
all field personnel present _____
any visitors present _____

69. Do the site logbook entries summarize the daily activities and refer to other site notebooks or log sheets where applicable?

_____

70. Have all site logbook entries been made in black indelible ink?

_____

_____

71. If a logbook entry was corrected, was a line drawn through the information and was the change dated and initialed? (Use of white-out or erasure is not permitted.)

_____

_____

72. Did the individual making the logbook entry sign it?

_____

73. Did the Field Operations Leader sign all logbook pages utilized that day at the end of each day?

_____

_____

Auditor Name:_____

Auditor Signature:_____

Date:_____

APPENDIX H

FIELD SOPs

FIELD SOP TABLE OF CONTENTS

CTO131-1	Unexploded Ordnance and Chemical Warfare Agents Activities
CTO131-2	Soil Sample Field Screening to Meet Radioactive Sample Shipping Requirements
CTO131-3	Screening of Soil Samples for Mustard Gas
CTO131-4	Calibration and Use of Photoionization Detector
CTO131-5	Borehole Advancement and Soil Coring Using Direct Push Technology
CTO131-6	Borehole and Soil Sample Logging
CTO131-7	Sample Identification Nomenclature
CTO131-8	Surface and Subsurface Soil Sampling
CTO131-9	Ground Water Sample Collection Using Geoprobe®
CTO131-11	Inspection and Rehabilitation of Existing Monitoring Wells
CTO131-12	Drilling and Geologic Logging of Boreholes in Rock
CTO131-13	Packer Testing of Uncased Boreholes
CTO131-14	Monitoring Well Installation
CTO131-15	Monitoring Well Development
CTO131-16	Measurement of Water Levels in Monitoring Wells
CTO131-17	Low-Flow Well Purging and Stabilization
CTO131-18	Calibration and Care of Water Quality Meter
CTO131-19	Monitoring Well Sampling
CTO131-20	Hydraulic Testing of Monitoring Wells
CTO131-21	Surface Water and Seep Sampling
CTO131-22	Sediment Sampling
CTO131-23	Estimating Flow of Small Streams
CTO131-24	Sample Preservation, Packaging and Shipping
CTO131-25	Sample Custody and Documentation of Field Activities
CTO131-26	Decontamination of Field Sampling Equipment
CTO131-27	Management of Investigation Derived Waste

STANDARD OPERATING PROCEDURE
NUMBER CTO131-1

UNEXPLODED ORDNANCE AND CHEMICAL WARFARE AGENTS ACTIVITIES

1.0 PURPOSE

This Standard Operating Procedure (SOP) governs field activities at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane where unexploded ordnance (UXO) and chemical warfare agent (CWA)-contaminated media might be present. All personnel conducting operations under this SOP must read and understand this SOP prior to commencing any work described within this SOP. The QAPP, health and safety plan, and other referenced SOPs submitted for the purpose of accomplishing work covered by this SOP are to be considered supporting documents to this SOP.

This SOP is site-specific in nature and applies to all anticipated operations involving UXO and/or CWA at the MGBG. It provides procedural requirements for anticipated activities involving UXO and CWA. It provides detailed procedures for the location, identification, documentation, and emergency actions on UXO/CWA activities.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Protective Equipment (see Section 6.0)

UXO Support Equipment

a. Magnetometer (G-856 AG)

b. Electromagnetic Terrain Conductivity Meter (EM-31)

c. GA-72CV/52CX Magnetic Locator (passive instrument) will be used for UXO surface survey during UXO activities. The GA-72CV detects the magnetic field of any ferromagnetic object.

d. MG-220 Magnetic Gradiometer (Down-Hole Magnetometer) will be used to conduct downhole UXO checks. The MG-220 detects the magnetic field of any ferromagnetic object as it is lowered into a borehole.

e. Marking tape, pin flags, stakes, indelible markers.

Decontamination Equipment (see MGBG Site Health and Safety Plan).

Hand Tools

3.0 APPLICABILITY

This SOP applies to all personnel performing activities associated with UXOs and CWAs. This includes personnel of the prime contractor as well as personnel of any subcontractor. This SOP also applies to persons who may visit the site during the conduct of UXO/CWA activities. Compliance with the provisions herein are mandatory for all Tetra Tech NUS, Inc. (TtNUS) personnel, subcontractors, and visitors to the site where UXO/CWA activities are in progress.

4.0 RESPONSIBILITIES

The TtNUS Task Order Manager (TOM) is directly responsible for seeing that all applicable rules and regulations are complied with, and that all necessary safety precautions are taken to conduct operations in accordance with this SOP.

It is the responsibility of the TOM to ensure that all personnel conducting field activities in accordance with this SOP have the proper training (including hazard control briefings) and if required the proper certifications for the job being performed. The onsite TtNUS Health and Safety Officer in conjunction with the UXO specialist will assume these responsibilities in the absence of the TOM.

5.0 PERSONNEL QUALIFICATIONS AND REQUIREMENTS

5.1 Personnel Qualifications: Qualifications for those personnel actively involved in UXO/CWA operations shall be as follows:

a. UXO personnel shall be graduates of the U.S. Naval Explosive Ordnance Disposal (EOD) School, Indian Head, Maryland.

b. The lead UXO Supervisor for the operation will have been awarded the Master EOD Badge and have served at least 15 years in military EOD assignments, of which more than 10 years were in a supervisory position.

c. UXO personnel must meet the requirements as stated in the Site Health and Safety Plan, consistent with OSHA 29 CFR 1910.120, paragraph (e).

5.2 Personnel Requirements: During any activity where the possibility that UXOs and/or CWAs may be encountered (no matter how remote), the following requirements will be met:

a. One EOD-qualified technician will be required to support each field team engaged in operations in areas that might contain UXOs/CWAs.

b. One EOD-qualified person will be present at the site during all activities to provide UXO/CWA support in the event their services are required.

5.3 The activities to be conducted under the CLEAN contract will not normally be conducted in areas requiring maximum personnel limitations. Work will not be permitted unless at least two persons are present in the work area. The provisions of 29 CFR 1910.120 concerning personnel qualifications and requirements will be followed while working on site. Any personnel limitation requirements that may be in force by the NSWC Crane Safety office will be adhered to at all times.

5.4 During all hazardous operations related to searching or screening for UXO or any hazardous UXO/explosive related service, the "buddy system" (29 CFR 1910.120, paragraph (d) (3)) must be used, with one of these persons being a qualified and approved TtNUS EOD technician.

6.0 SAFETY REQUIREMENTS

6.1 Reference Safety Requirements: The safety requirements that apply to the UXO/CWA operations covered under this SOP are:

a. NAVSWCINST 5100.6; Subj: Occupational Safety and Health Program.

b. NSWCDDINST 5104.1; Subj: Control of Emissions (EMCON) Causing Hazards of Electromagnetic Radiation to Ordnance (HERO).

c. OSHA 29 CFR 1910-120 and 1910.134.

d. NRC 10 CFR, Part 19, 20, and 40.

e. NAVSEA SO420-AA-RAD-010, dated 01 October 1991.

6.2 Specific Safety Requirements: The specific safety requirements for UXO/CWA operations are as follows:

a. All operations will be suspended if so ordered by the NSWC Crane UXO Control Officer.

b. If UXO/CWA or suspected UXO/CWA is encountered, all operations in the affected area will cease, the affected area will be evaluated, and notification will be made in accordance with Section 9.0 of this SOP.

c. TtNUS UXO technicians (EOD-qualified) will be present during UXO-related activities.

d. Installation approved communications equipment (two-way radios) will be onsite during any operation. HERO restrictions will comply with Reference 6.1 b. above.

e. Standard work practices as outlined in the site QAPP will apply.

7.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

The following PPE will be worn by personnel on site. Items marked with an asterisk (*) will be available and will be used, if necessary, as determined by the TtNUS Site Safety Officer.

a. Safety glasses
b. Safety shoes (and protective overboots/or steel-toe rubber boots*)
c. Cotton clothing (with protective coveralls*)
d. Gloves (type to be determined by TtNUS Site Safety Officer)
e. Respiratory protection equipment* (29 CFR 1910.134)
f. Hearing protection*
g. Hard hats*

Additional equipment may be required on a case-by-case basis. Equipment will be selected by the Site Safety Officer (SSO) and the TOM in accordance with the QAPP and appendices.

8.0 UXO/CWA PROCEDURES FOR FIELD OPERATIONS

8.1 General - field procedure for work can include any or all of the following tasks:

a. Initial entry into suspect areas for
b. Surface and subsurface sampling,
c. Monitoring well installation,
d. Exploratory trenching,
e. Geophysical surveys, and
f. Other miscellaneous operations.

8.2 Initial entry - initial entry into suspect areas at the MGBC will not require a survey by an EOD-qualified technician with a magnetometer (GA-72CV) to screen a path into the area.

8.3 Sampling - sampling will be conducted in accordance with established protocols and methodologies. MGBG sampling requirements are presented in the QAPP and in the fieldwork Standard Operating Procedures.

Sites potentially contaminated with UXO/CWA will be screened by EOD-qualified technicians prior to sampling. The immediate sampling area will be surface screened for the sampling team.

Prior to any subsurface intrusive sampling, a check with a magnetometer needs to be accomplished. The GA-72CV Magnetic Locator can be used for collecting subsurface samples not greater than 0.5 feet. If excavation of a bore hole or hand auguring hole is to exceed this depth, then the MG-220 Magnetic Gradiometer (downhole magnetometer) should be utilized and a reading taken at every two feet of depth.

If an anomaly is detected then the location will be marked and avoided and the sampling location relocated to a clean area. If the sampling location cannot be relocated, then the EOD-qualified technician may, at the discretion of the TOM and UXO specialist, hand excavate down to the anomaly to determine if it is hazardous. If it is not hazardous, the object will be set aside and the sampling event will continue. If the object has been determined to be hazardous or suspect, the sampling team will move out of the area and the emergency procedures listed in paragraph 9.0 will be implemented.

8.4 Monitoring Well Installation – Heavy equipment such as front-end loaders, backhoes, and bulldozers will not be used to develop or establish drill sites. The following action will be followed:

a. The GA-72CV magnetometer will be used directly over the borehole site to check for buried items down to 2 feet. After a surface check, a 2-foot core may be obtained using the Geoprobe.

b. Once the borehole site has been cleared, the drill rig will be positioned over the proposed borehole. Drilling will commence to a depth two feet, the Geoprobe will be removed from the borehole, and the drill crew chief and UXO personnel will make observations of the soil from the core barrel. The drilling log and lithologic log will be maintained in accordance with standard practices, noting any metal objects that may be found.

c. The drilling derrick will be secured and the drill rig moved to a position at least 20 feet from the borehole.

d. The borehole will be checked again with the MG-220 magnetometer.

e. If a UXO or magnetic anomaly is present, the borehole will be abandoned and another location selected. The new borehole should be at least six feet from the original borehole. If a UXO or anomaly is not detected and the clearance is given, the drill rig shall be positioned back over the borehole, and drilling will proceed to the next depth (4 feet).

f. Repeat above steps, at intervals of 2 feet, until a depth of 10 feet is reached. At the 10 foot interval, a magnetometer reading shall be taken with the MG-220 set on the maximum sensitivity. The instrument will detect larger objects, approximately 100 lbs., that would be expected at this depth depending on density from 4 to 8 feet.

g. After reaching the depth of 10 feet, the above steps will be repeated at intervals of 4 feet, until the desired depth is reached.

8.5 Exploratory Trenching and Excavation - at times, exploratory trenching may be used to determine the lateral extent of a landfill, burial pit, or subsurface geophysical anomaly. Trenching and excavation to uncover a subsurface area will be conducted using a backhoe, an excavator, or sometimes a front-end loader. The following procedures will be utilized to conduct these operations:

a. The surface of the area to be trenched or excavated will first be swept with the GA-72CV magnetometer. Anomalies will be hand excavated to determine if hazardous.

b. No more than 0.5 feet of surface soil will then be removed from the area of concern.

c. The heavy equipment will be removed at least 20 feet away from the area, and the area will be checked with the MG-220 magnetometer. If the area is a trench, the entire length of the trench will be checked with the MG-220 and the excavation may continue two feet at a time. If the area is a wide open area, it can once again be checked with the GA-72CV, but only 0.5 feet of soil removal can be excavated at a time.

d. Anomalies will continue to be uncovered by hand excavation until the desired results are obtained and the trench/area is abandoned and refilled.

e. Excavation will continue another 2 feet if using the MG-220 or 0.5 feet if using the GA-72CV magnetometer. Once again, after the proper depth of soil is excavated the heavy equipment is removed from the area (>20 feet) and the area is rechecked with the magnetometer.

f. The above procedures are followed until the desired depth is reached and/or the desired results are obtained.

Once the area or trench has been cleared, excavation may continue to the proper depth before the equipment is again moved away (at least 20 feet) and the area/trench is re-cleared.

8.6 Geophysical Surveys - two instruments will be used to conduct geophysical surveys for this MGBG project. The EG&G Geometrics magnetometer (G-856 AG) and a Geonics Terrain Conductivity Meter (EM-31). The magnetometer is a passive instrument, and the EM-31 is a active instrument and is commonly used to measure subsurface terrain conductivity. This information can be used for geophysical surveys, as well as for locating voids, discontinuities in soil structures such as boundaries of disposal pits and buried conducting objects. An Ordnance Safety Analysis of the Geonics Model EM-31-D, Non-Contacting Terrain Conductivity Meter was conducted by the Naval Surface Warfare Center at the request of TtNUS in April 1993. The analysis concluded, in summary, that the "Geonics EM-31-D poses no ordnance safety hazard

when operated in the normal survey mode, where the device is held at hip height." However, the Geonics EM-31-D should not be used with the boom on the ground if ordnance is "present".

When using the magnetometer or the EM-31-D, an EOD-qualified technician will conduct a surface sweep of the area to be surveyed to ensure that no surface ordnance or other hazards exist. The magnetometer is a passive instrument therefore, no special ordnance safety precautions are required.

The following procedure will be used to ensure the safe operation of the EM-31-D during the geophysical survey:

a. The instrument will be turned on and calibrated off site.

b. Background readings will be taken off site and recorded in the field logbook.

c. The instrument will be turned off and taken to the first survey point.

d. The instrument will be placed on a stand or held at waist height (at least 1 meter off ground), turned on, and readings taken and recorded.

e. After all readings have been taken at the survey point, the instrument will be turned off, removed from the stand, and taken to the next survey point.

f. Steps c. and d. above will be repeated until all points have been surveyed.

g. The instrument will be turned off and taken off site, turned on, and background readings again taken.

h. The geophysical survey is now complete.

8.7 Miscellaneous Operations – because of the potential of UXO/CWA material being encountered during field activities, UXO support will be provided at all site locations within the MGBG. UXO support will be provided for any and all field activities that are in areas suspected to contain UXO and/or CWA. These areas also include those areas covered with water and creeks, canals, etc..

9.0 EMERGENCY RESPONSE AND CONTINGENCY PLANS

9.1 Emergency Contacts: Telephone numbers for emergency contacts are provided in Table 2-1 of the CTO 131 HASP. In the event of an emergency, notification will be made to the following in the order presented or in the order dictated by NSWC Crane:

a. Emergency Fire and Medical Assistance
b. NSWC Crane Safety Office
c. NSWC Crane EOD Office
d. NSWC Crane Environmental Office (listed as the NSWC Crane Base Contact in HASP Table 2-1)
e. TtNUS Site Supervisor (Field Operations Leader)
f. TtNUS TOM

None of the activities to be performed during field work for this project will be conducted within buildings. In the event of an emergency, all site personnel will be evacuated to a predetermined location away from the work place in accordance with the HASP. Emergency Response Planning will follow in accordance with 29 CFR 1910.38(a). TtNUS will utilize the NSWC Crane Fire Protection and Emergency Services in emergencies or potential emergencies.

9.2 Contingency Plans: The following contingency plans will be implemented:

a. Pre-Planning - Upon arrival at NSWC Crane, the TtNUS Field Operations Leader and/or Site Safety Officer will meet with the NSWC Crane Fire Protection Department, NSWC Crane Security Personnel, and Emergency Services to notify them what activities are to be undertaken and where. All site personnel will be required to follow NSWC Crane emergency procedures and will rely on NSWC Crane services to handle emergency calls when needed. Medical services will be provided by the NSWC Crane if available or off site by local medical services.

   Hand-held radios will be available at the work site for communications between field teams and NSWC Crane EOD Control.

b. Emergency Escape Procedures and Assignments - Upon notification of a site emergency that requires evacuation, all site personnel will proceed to predetermined locations based on emergency location and wind directions (see the HASP). If personnel cannot reach

these locations without danger to their lives or health, and alternate meeting place will be designated during the daily hazard control briefing (see Section 11.0). Personnel will be trained to remain at the refuge location until directed to resume work, or leave the site.

c. Procedure to Account for Site Personnel - The site work force will be small enough that accounting for personnel will not be a problem. Accounting for personnel will be the Field Operations Leader's responsibility. This will be accomplished by taking a roll call using the site log book.

d. Rescue and Medical Duties - A physician-approved first aid kit, an ANSI-approved eye wash station, and a Class ABC fire extinguisher will be readily available on site. Site personnel will not be authorized to participate in emergency rescue operations.

e. Activation of Emergency Response Procedures - Should any emergency occur which requires the support of outside services, the appropriate contacts will be made by the Field Operations Leader after consultation with the NSWC Crane safety office. A list of the appropriate contacts will be posted at the Command Post. Hand-held radios will be the primary means of communications.

f. Airborne Chemical Release Contingency Plan -

(1) Chemical Release Monitoring – All field workers must bear in mind the potential for encountering releases of mustard gas, no matter how small the potential. Every member of the site team will be responsible for observing and reporting any gross chemical releases or conditions that could lead to releases. Mustard gas can be described as having a garlic-like odor. Air monitoring will be performed as described in the QAPP and the HASP.

(2) Response to Measured Airborne Chemical Releases - the readings on monitoring instrumentation will be compared to the action levels specified in the HASP for the purpose of protecting the health and safety of onsite personnel. If the concentrations shown on the instruments suggest that the hazardous materials can exceed the following levels at the perimeter of neighboring residential or commercial property, the TtNUS Field Operations Leader and/or the Site Safety Officer will notify the NSWC Crane Fire Department.

Parameter	Action Level	Note:
Total Organic Vapors	50 ppm	Suggested levels only
Flammable Vapors	10% of the Lower Explosive Limit (LEL)	

(3) Response to Sudden Airborne Chemical Releases - if a field operation onsite results in a release of a concentrated vapor from a pressurized container (which will normally result in a visible plume), personnel will leave the area for the predetermined-upwind assembly point quickly, but without panic. The TtNUS Field Operations Leader and/or the Site Safety Officer will notify the NSWC Crane Fire Department as soon as possible. The potential for such an event to occur during planned activities is not considered to be significant.

g. Liquid Release Monitoring - Every member of the site team will be responsible for observing and reporting any liquid chemical releases or conditions that could lead to a release. If field operations on site result in a release of liquid chemicals in the absence of vapors, field personnel will attempt to contain the liquid by means of berms constructed with available equipment. If the work team cannot control the spill, they will leave the area for the assembly point quickly, but without panic. The TtNUS Field Operations Leader and/or the Site Safety Officer will notify the NSWC Crane Fire Department. This is not considered to be a significant event during operations, however, in the unlikely instance that it should occur, field personnel may effect defensive efforts, providing that such a response does not appear to present a chemical overexposure or other personal health or safety concern.

10.0 SAFETY POINTS OF CONTACT

a. NSWC Crane Safety Management Branch
b. NSWC Crane Ordnance Officer and/or EOD Officer
c. NSWC Crane Radiation Officer
d. NSWC Crane Environmental Office

11.0 HAZARD CONTROL BRIEFING

A Health and Safety Hazard Control Briefing will be conducted prior to the start of onsite activities. The briefing will be detailed and will cover the information contained in the SOP and the MGBG Health and

Safety Plan. Refresher briefings will be conducted as necessary for specific or unique activities. New personnel assigned to the project will receive an in-depth briefing prior to starting work. The following information will be given during the briefing:

a. Overview of Task to be Performed

b. Overview of Hazards

- Unexploded Ordnance Hazards
- Chemical Warfare Agent Hazards
- Physical Hazards

c. Overview of Standard Work Practices

d. Overview of Training Requirements

e. Overview of Emergency Response Actions

f. Location of MSDSs

12.0 SECURITY

There are no special security requirements. Field activities under the CLEAN contract are unclassified and normal security measures apply in accordance with references (e) and (i). TtNUS personnel and their subcontractors will check in with the installation's security office and be badged for entry into the work areas.

13.0 ATTACHMENTS

1. Equipment Calibration Log

ATTACHMENT 1
EQUIPMENT CALIBRATION LOG

Tetra Tech NUS, Inc.

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME/MODEL: PID 2020

PROJECT NAME: NSWC CRANE

MANUFACTURER: Photovac

PROJECT NUMBER: CTO-038/7651

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

STANDARD OPERATING PROCEDURE
NUMBER CTO131-2

SOIL AND SEDIMENT SAMPLE FIELD SCREENING TO MEET RADIOACTIVE SAMPLE SHIPPING REQUIREMENTS

1.0 PURPOSE

This procedure describes screening of soil samples to provide radioactivity data to meet US Department of Transportation (DOT), and International Air Transport Association (IATA)/International Civil Aviation Organization (ICAO) requirements for shipment to an offsite analytical laboratory. The purpose of this procedure is to determine whether samples are considered to be radioactive for shipping purposes (that is, have gross radiation levels greater than 2,000 pCi/g [74 Bq/g]), and to establish the level of radioactivity to meet packaging and labeling requirements for shipment. These data may also be supplied to contract laboratories as part of the information required to meet their license activity limits.

2.0 SCOPE

2.1 Applicability

This procedure applies to the use of field radiation measurement instruments (described in Section 5.1) for determining gross levels of radioactivity of samples packaged for shipping.

All radioactive contamination from site operations at the NSWC Crane Mustard Gas Burial Ground should derive from past disposal of thorium nitrate. Therefore, natural thorium is assumed to be the radioactive contaminant. Thorium does not migrate easily to groundwater because it is retained by soil particles. Thorium is also primarily an alpha (α) particle emitter, although beta (β) and gamma (γ) emissions are also radiated from thorium daughters. Alpha particle emissions are easily stopped by a water matrix. Therefore, water samples will not be screened for radioactivity to determine their radioactivity status, but they will be subject to the other screening requirements delineated below for shipping purposes.

According to DOT regulations, there is no limit on the amount of natural thorium that may be packaged for shipment when packaged correctly.

2.2 Training

Radiation surveys for determining compliance with shipping regulations are to be conducted only by qualified health physicists, health protection technicians, or designated radiological screening personnel.

3.0 DEFINITIONS AND ACRONYMS

A. DOT (US Department of Transportation): The organization that regulates the transportation of radioactive materials by carriers and shippers subject to 49 CFR 173 and Subpart I.

B. IATA (International Air Transport Association)/ICAO (International Civil Aviation Organization): Organizations that regulate the air transport of radioactive materials.

C. Curie (Ci): The quantity of radioactive material in which 3.7×10^{10} atoms disintegrate (are transformed) per second. It is the traditional unit for measuring radioactivity. A smaller unit, the picoCurie (pCi), is 1.0×10^{-12} Ci or 2.22 disintegrations per minute (dpm) and is used throughout this procedure.

D. Becquerel (Bq): The quantity of radioactive material in which one atom disintegrates (is transformed) per second. It is the International System (SI) unit for measuring radioactivity. 1 Bq is equal to 2.7×10^{-11} Ci or 27 pCi or 60 dpm.

4.0 BACKGROUND, PRECAUTIONS AND LIMITATIONS

For shipping purposes, samples with gross radiation levels greater than 2,000 pCi/g (74 Bq/g) are considered to be radioactive. Samples that are less than 2,000 pCi/g are not considered to be radioactive and may be shipped without any special labels, postings, or restrictions. This screening procedure allows rapid discrimination between radioactive and non-radioactive samples, and conservatively sets the shipping limit at 1,800 pCi/g rather than 2,000 pCi/g. Another element of conservatism is built into this procedure by using maximum observed radiation levels.

Screening for alpha and beta radiation must be performed on soil that is homogeneous. If the sample is not well mixed or comprises widely varying soil textures, alpha and beta radiation measurements made on the surface of the soil may not accurately reflect the radioactivity of the entire sample. In such a situation, consult the geologist assigned to the site to determine if this procedure is appropriate for the sample.

This procedure does not cover all shipping and labeling requirements. Other shipping and labeling requirements, as well as handling and packaging requirements, are provided in SOPs CTO131-10 and CTO131-24.

The 1,800 pCi/g cutoff radiation level is converted to total counts per minute (cpm) above background so the analyst can know, based on direct observation and simple calculations, whether a sample is radioactive. Packaging and labeling requirements, however, also depend on radiation measurements made at the surface of the shipping container, as described in Section 6.0.

An average detector efficiency is used for computing a sample's radioactivity status in Sections 7.1 and 7.2. This is only an approximation if the actual alpha and the beta + gamma probes exhibit different efficiencies.

5.0 EQUIPMENT AND MATERIALS

5.1 Equipment and Materials

- Ludlum Model 3 Count Rate Meter with a Model 44-9 Pancake Geiger-Muller (G-M) Detector for "beta + gamma" measurements. Other instruments may be substituted if the instruments provide similar detection capabilities.

- Ludlum Model 3 Count Rate Meter and a 43-5 50 cm squared alpha scintillator for alpha measurements. Other instruments may be substituted if the instruments provide similar detection capabilities.

- Ludlum Model 12S Micro-R meter or equivalent

- Large bowl or other suitable container for spreading soil samples during screening

- Mixing rod for mixing soil samples

- Blank swipes (e.g., Whatman filter paper)

- Indelible pen

- Calculator

6.0 PROCEDURE

6.1 Instrument Operational Checks

6.1.1 Confirm that the instrument calibrations are current.

6.1.2 Before collecting samples, perform operational checks (including response checks using an exempt quantity source) on the instruments to be used.

6.1.3 Record instrument settings and information on Radiation Log Sheet 1(Attachment A).

6.2 Instrument Background Measurements and Default Radioactivity Status Limit

For each instrument that will be used on a given day, perform a background measurement in a background radiation setting that is in close proximity to the area being surveyed but outside the MGBG boundary and well enough removed to represent background radiation levels:

6.2.1 Take a reading in at least three different background locations and record these three background values on Radiation Log Sheet 1(Attachment A).

6.2.2 Compute the average of the background readings to obtain the average background reading for that specific instrument for the day and record the average on Attachment A.

6.2.3 Determine the current Radioactivity Status Limit in accordance with Section 7.1 or 7.2, as applicable.

6.2.4 Record, on Attachment A, the current Radioactivity Status Limit.

6.3 Instrument Efficiency Measurements

6.3.1 Locate the certificate of instrument calibration or a calibration tag/sticker on each instrument.

6.3.2 Transcribe the instrument efficiencies from the certificate or sticker to Attachment A.

6.3.3 Compute and record on Attachment A the average detector efficiency.

6.4 Determination of Sample Radioactivity Status

CAUTION: When handling potentially contaminated environmental media or containers, use disposable (i.e., latex or nitrile) gloves at all times.

6.4.1 Record the sample number in column A of Radiation Log Sheet 1 (Attachment A).

6.4.2 Mix the sample in a large mixing bowl or other suitable container and smooth the sample surface to make it uniform in texture and appearance, with a flat surface for presentation to the radiation survey instrument.

6.4.3 Scan the sample with the Beta + Gamma probe and record the maximum observed counts per minute (cpm) in column B of Attachment A.

6.4.4 Subtract the average Beta + Gamma background cpm from the cpm reading in step 6.4.3 and record this value in column C of Attachment A.

6.4.5 Scan the sample with the Alpha probe and record the maximum observed cpm in column D of Attachment A.

6.4.6 Subtract the average Alpha background cpm from the cpm reading in step 6.4.5 and record this value in column E of Attachment A.

6.4.7 Compute and record in column F of Attachment A, the total counts per minute for the sample.

6.4.8 Compare the cpm value in column F of Attachment A with the current Radioactive Status Limit indicated on Attachment A. If the Value in column F exceeds the current Radioactive Status Limit, the sample is radioactive and must be shipped with screening, labeling and packaging requirements as described in Section 6.5. Otherwise, the sample is not radioactive and may be shipped as a non-radioactive sample with no special labeling or packaging requirements.

6.5 Screening of Sample Coolers Containing Radioactive Samples to Determine Labeling Requirements

NOTE: This part of the procedure applies only to samples that exceed the current Radioactivity Status Limit, as determined in accordance with Section 6.4

6.5.1 Before the screening process begins, ensure that the sample cooler is closed tightly.

6.5.2 Using the Micro-R meter, place the meter flush against any outside surface of the cooler and obtain an "on contact" mrem/hr reading of the outside surface of the sample cooler.

6.5.3 Record the maximum "on contact" reading from Step 6.5.2 in column B of the Radiation Log Sheet 2 (Attachment B).

6.5.4 With a blank swipe and while applying moderate pressure, swipe three of the six flat surfaces of the cooler for a total surface area of 300 square centimeters (100 square centimeters per swiped surface).

NOTE: 10 cm (the length of one side of a square that is 100 cm^2) is roughly the width of an adult hand.

6.5.5 Indicate on the back of Attachment B with a diagram which surfaces (e.g., top, bottom, left side) were swiped and identify with marks on the diagram where each surface was swiped.

6.5.6 Cross-reference the diagram to the cooler identified on the front of Attachment B.

6.5.7 Using the Beta + Gamma probe obtain a cpm reading of the swipe and record the maximum observed cpm reading in column C of Attachment B.

6.5.8 Subtract the Beta + Gamma average background cpm from the Beta + Gamma cpm reading of the swipe and record that value in column D of Attachment B.

6.5.9 Using the Alpha probe obtain a cpm reading of the swipe and record the maximum observed cpm reading in column E of Attachment B.

6.5.10 Subtract the Alpha average background cpm (obtained from Attachment A) from the Alpha cpm reading of the swipe and record that value in column F of Attachment B.

6.5.11 Compute the total radioactivity of the swipe in disintegrations per minute (dpm) using the equation at the top of column G on Attachment B.

6.5.12 In column G of Attachment B record the total activity of the sample, in dpm.

6.5.13 If the reading from the Micro-R meter recorded in Step 6.5.3 does NOT exceed 0.5 mrem/hour (500 uR/hr) AND if the swipe radioactivity as recorded in column G of Attachment B does NOT exceed 6,600 dpm per 300 square centimeter swipe:

6.5.13.1 Label the shipment by placing a "Radioactive" label on the outside of the cooler.

6.5.13.2 Include with the shipping papers the following notice:

"This package conforms to the conditions and limitations specified in 49 CFR 173.421 for radioactive material, excepted package-limited quantity of material, UN2910";

6.5.14 If the reading from the Micro-R meter recorded in Step 6.5.2 EXCEEDS 0.5 mrem/hour (500 uR/hr) OR if the swipe radioactivity as recorded on Attachment B EXCEEDS 6,600 dpm per 300 square centimeter swipe, contact the FOL to determine shipping requirements.

7.0 CALCULATONS

7.1 Determining A Default Radioactivity Status Limit

WARNING

Two assumptions were used when converting the conservative 1,800 pCi/g radioactivity shipping limit to a default Radioactivity Status Limit in units of cpm. If these assumptions are not valid, the default limit must be adjusted according to Section 7.2. First, at least 100 grams of soil or sediment sample (8-oz jar one-fourth full) are assumed to be typically present in a sample jar. With the exception of VOC samples more than 100 grams of sample are typically bottled for shipment to a laboratory. Second, an instrument detector efficiency of 10% was assumed for both the α and the $\beta + \gamma$ probes. This efficiency is commonly observed for field screening instruments.

Based on the above assumptions, the default Radioactivity Status Limit is:

(1,800 pCi/g of sample) x (2.22 dpm/pCi) x (0.10 cpm/dpm) x (100g of sample) = 39,960 cpm above background.

If the above assumptions do not apply to this field operation, adjust the limit as described in Section 7.2.

7.2 Adjustments to the Radioactivity Status Limit When Assumptions Are Invalid

If the actual efficiency of either the α or $\beta + \gamma$ detector differs from the value assumed in Section 7.1, OR if the sample mass is less than 100 g (8-oz bottle one-fourth full), the default Radioactivity Status Limit of 39,960 cpm must be adjusted as follows:

$$\text{Radioactivity Status Limit, cpm} = 39{,}960\,\text{cpm} \times \frac{\text{Avg Percent Detector Efficiency}}{10\%} \times \frac{\text{Actual Sample Mass, g}}{100\,\text{g}}$$

where: the Avg Percent Detector Efficiency = the average efficiency for the α and the $\beta + \gamma$ probes.

For example, if the actual average detector efficiency is 15 percent (15%) and the actual sample mass is approximately 5 g (e.g., for encore samplers), the Shipping Cutoff Value will be:

$$\text{Shipping Cutoff Value, cpm} = 39{,}960\,\text{cpm} \times \frac{15\%}{10\%} \times \frac{5}{100\,\text{g}} = 2{,}997\,\text{cpm above background}$$

8.0 REFERENCES

8.1 Department of Energy, "Occupational Radiation Protection," 10 CFR 835, December 14, 1993

8.2 Department of Transportation, "Hazardous Materials Regulations," 49 CFR 172 and 173, October 1, 1994

8.3 Los Alamos National Laboratory Soil Sample Field Screening to Meet Radioactive Sample Shipping Requirements, Los Alamos National Laboratory, LANL ER-SOP-10.11, Revision 0, 3/10/98.

9.0 RECORDS

The following records will be generated when following this procedure:

- Radiation Screening Log

The following records will be generated when following other procedures as directed in this procedure.

- Field Log Book
- Daily Activity Log
- Chain-of-Custody/Request for Analysis Form

10.0 ATTACHMENTS

Attachment A - Radiation Log Sheet 1

Attachment B – Radiation Log Sheet 2

ATTACHMENT A. RADIATION LOG SHEET 1

PAGE _____ OF _____

Analyst_____ Date_____

Source Check:
Radionuclide:_____S/N:_____
Activity (dpm):_____on _____ (Date)

β + γ Ratemeter Calibration:
Model:_____
S/N: _____
Cal. due date:_____

Probe (β + γ):
Model:_____
S/N: _____

α Ratemeter Calibration:
Model:_____
S/N: _____
Cal. due date:_____

Probe (α):
Model:_____
S/N: _____

Backgrounds Determined on: _____ (Date)

Background Readings (Beta + Gamma)
#1 (β + γ):_____ cpm
#2 (β + γ):_____ cpm
#3 (β + γ):_____cpm

Background Readings (Alpha)
#1 (α):_____ cpm
#2 (α):_____ cpm
#3 (α):_____ cpm

Average Background (β + γ) =_____cpm (=[#1 + #2 + #3)]/3)
Average Background (α) =_____cpm (=[#1 + #2 + #3)]/3)
Current Radioactivity Status Limit =_____cpm (from Sec. 7.1 or 7.2, as applicable)

β + γ Instrument Efficiency, Eff (cpm/dpm x 100%):_____Percent

α Instrument Efficiency, Eff (cpm/dpm x 100%):_____Percent

Average detector efficiency, Eff (cpm/dpm x 100%), [Eff_{α} + $Eff_{(\beta+\gamma)}$]/2:_____Percent

SOIL SAMPLE SCREENING FOR DETERMINING RADIOACTIVITY STATUS

A	B	C	D	E	F
SAMPLE ID	**Sample (β + γ), cpm**	**Net Sample (β + γ), cpm:** (Column B) – Background (β + γ)	**Sample (α), cpm**	**Net Sample (α), cpm:** Column D – Background (α)	**Total Radiation, cpm:** Column C + Column E

Reviewed by:_____ **Title:**_____ **Date:**_____

ATTACHMENT B. RADIATION LOG SHEET 2

PAGE _____ OF _____

ANALYST _____ **DATE**_____

Micro-R Meter Calibration:

Model: _____ **Calibration due date:** _____
S/N: _____ **Calibrated by:** _____

Source Check:
Radionuclide:_____S/N:_____ Activity (dpm):_____on _____ (Date)

$\beta + \gamma$ Ratemeter Calibration:
Model:_____
S/N: _____
Calibration due date:_____

Probe ($\beta + \gamma$):
Model:_____
S/N: _____

α Ratemeter Calibration:
Model:_____
S/N: _____
Calibration due date:_____

Probe (α):
Model:_____
S/N: _____

Efficiencies:

Average $\beta + \gamma$ Instrument Efficiency from Attachment A (Eff):_____Percent
Average α Instrument Efficiency from Attachment A (Eff):_____Percent

Backgrounds:

Average $\beta + \gamma$ Background Reading from Attachment A:_____cpm
Average α Background Reading from Attachment A:_____cpm

SCREENING OF SAMPLE COOLERS TO DETERMINE LABELING REQUIREMENTS

A	B	C	D	E	F	G
COOLER ID	**Micro-R Meter Reading, mrem/hr**	**Sample ($\beta + \gamma$), cpm**	**Net Sample ($\beta + \gamma$), cpm:** Column C – Background ($\beta + \gamma$)	**Sample (α), cpm**	**Net Sample (α),cpm:** Column E – Background (α)	**Total Radiation Level, dpm:** [Column D*(100%/$Eff_{(\beta+\gamma)}$) + Column F *(100%/Eff_{α})]

Reviewed by:_____ **Title:**_____ **Date:**_____

STANDARD OPERATING PROCEDURE
NUMBER CTO131-3

SCREENING OF SOIL SAMPLES FOR MUSTARD GAS

1.0 PURPOSE

This Standard Operating Procedure (SOP) was prepared for conducting field activities at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane where mustard gas might be present. This SOP provides procedures for field screening soil samples for the presence of mustard gas. This headspace screening procedure has a detection limit of 0.1 mg/m^3 of bis(2-chloroethyl) sulfide (i.e., mustard gas). If the screening procedure shows no detectable concentration in a soil sample, then the sample will be shipped to the fixed-base analytical laboratory for organic, inorganic, and radiological analyses. If the field screening procedure indicates that mustard gas is present in a sample, the sample may not be shipped to the laboratory. Splits of all samples are being sent to a second fixed-base laboratory for an analysis of mustard gas. Upon laboratory receipt of samples for organic, inorganic, and radiological analyses, the laboratory will preserve VOC samples and withhold analyses until mustard gas concentrations are reported on a quick-turnaround basis by the mustard gas laboratory. If the mustard gas results from the mustard gas laboratory are non-detect, the ordinary chemical and radiological analyses may proceed. If the samples exhibit detectable concentrations of mustard gas, the sample containers will not be opened and the analyses will not be allowed.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

- Toaster Oven
- Aluminum Foil
- Rubber Bands
- Thermometer with 5º C resolution and range from 20º C to 60º C, or wider
- Portable Balance with at least 180 gram capacity
- Mustard gas "go-no go response" detection tube (MSA/Auer CWA Detector Tube) with sensitivity equal to 0.1 mg/m^3
- Bound Notebook and indelible pens

3.0 PROCEDURE

3.1 Calibrate the toaster oven as follows: Preheat the toaster oven to 35º C ± 5º C.

3.2 Mince 160 grams ± 20 grams of background soil and place it in a glass jar (volume of jar should be approximately 12 ounces).

3.3 Cover the jar with aluminum foil such that the foil is taut over the jar opening. Secure the aluminum foil with a rubber band. Place the foil-covered jar into the oven and determine the time it takes the contents of the jar to reach a temperature of 35º C ± 5º C. This will be the "baking time" that will be used for all subsequent analyses of soils.

3.4 When a soil sample is delivered to the field laboratory for mustard gas screening, weigh out 160 grams (± 20 grams) of sample using a balance. Mince the soil aliquot and place it in a 12-ounce glass jar. Secure aluminum foil and rubber band over the jar as in 3.3.

3.5 Insert the foil-covered sample jar into a thermostatically controlled toaster oven preheated and maintained at 35º C ± 5º C. Allow the sample to remain in the oven for the "baking time" determined in 3.3 above.

3.6 Remove the sample jar from the oven and conduct a headspace analysis using a MSA/Auer CWA Detector Tube by following the manufacturer's instructions.

3.7 Record the date, time, and results of the test in the bound field notebook. Identify the person performing the test.

3.8 The detection limit for the test is 0.1 mg/m^3. If the screening procedure shows no detectable concentration of mustard gas in a soil sample, then the sample will be shipped to Southwest Laboratory of Oklahoma (SWLO) for organic, inorganic, and radiological analyses. If the screening procedure indicates that mustard gas is present in a sample, the sample may not be shipped to SWLO.

3.9 A split of every soil sample will be sent to the Edgewood Chemical Biological Center (ECBC) laboratory, which will perform mustard gas analysis with greater accuracy, precision, and sensitivity. If this analysis shows mustard gas is not present in a sample that originally was identified as containing mustard by the field screening procedure, then the sample will be

considered as not containing mustard gas but the sample will not be analyzed further. If the analysis shows mustard gas is present, the remainder of the soil from that boring will be handled as IDW in accordance with SOP CTO131-27.

3.10 If the ECBC laboratory analysis shows detectable concentrations of mustard gas to be present in a sample that was shipped to SWLO, the TtNUS TOM shall notify the SWLO project managers not to conduct chemical analyses on that sample.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-4

CALIBRATION AND USE OF PHOTOIONIZATION DETECTOR

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes procedures for the maintenance, calibration, and use of a photoionization detector (PID). The Photovac 2020 Photoionization Air Monitor will be used during the MGBG investigation. The procedures for its use are discussed in detail in the following sections.

2.0 GLOSSARY

Electron-volt (eV) - A unit of energy equal to the energy acquired by an electron when it passes through a potential difference of 1 volt in a vacuum.

Intrinsically Safe (I.S.) - Based on wiring, configuration, design, operation, gasketing, construction, this instrument may be employed within locations where flammable gases and/or vapors may exist.

Ionization Potential (I.P.) - The energy required to remove an electron from a molecule yielding a positively charged ion and a negatively charged free electron. The instrument measures this energy level.

Photoionization Detector (PID) - Photoionization detector employed as general reference to air monitors of this type. PID's detection method employs ultraviolet (UV) radiation as an energy source. As air and contaminants are drawn through the ionization chamber the UV light source causes the contaminant with ionization potentials equal to or less than the UV source to break into positive and negatively charge ions. The created ions are subjected to an electrostatic field. The voltage difference is measured in proportion to the calibration reference and the concentration of the contaminant.

Ultraviolet Radiation (UV) Lamp - Ultraviolet radiation is the energy source employed by the instrument to ionize collected sample gas streams. The UV lamp source is required to be equal to or greater than the ionization potential of the substance drawn through the instrument in order to create separate ionized species.

3.0 REQUIRED EQUIPMENT

Pen
Equipment Calibration Form
Photoionization Detector
Isobutylene Calibration Gas (i.e., span gas)
Regulator

4.0 PROCEDURES

4.1 Principle of Operation

The Photovac portable photoionizer detects many organic (and a few inorganic). The basis for detection of this instrument is the ionization of components gaseous streams. The incoming gas molecules are subjected to ultraviolet (UV) radiation, which is energetic enough to ionize many compounds associated with industrial activities. Molecules are transformed into charged-ion pairs, creating a current between two electrodes. Each molecule has a characteristic ionization potential, which is the energy required to remove an electron from the molecule, yielding a positively charged ion and a free electron. The instrument measures this energy level.

This instrument measures the concentration of airborne photoionizable gases and vapors and automatically displays and records these concentrations. It does not distinguish between individual substances. Readings displayed represent the total concentration of all photoionizable chemicals present in the sample. This instrument is factory-set to display concentration in units of ppm or mg/m^3. The meter display updates itself once per second.

The 2020 also performs short-term exposure limit (STEL), time-weighted average (TWA) and PEAK calculations. You can view any of these results, but only one mode may be viewed at a time.

The 2020 has 6 keys for alphanumeric entry and for accessing multiple functions. The keys are used to set up and calibrate 2020. They allow you to manipulate the concentration data in various ways.

All information entered with the keys and stored in the 2020's memory is retained when the instrument is switched off. The clock and calendar continue to operate and do not need to be set each time the 2020 is turned on.

4.1.1 Displays

The 2020 has a meter display for reporting detected concentration and a display used for status/ information to guide you through configuration options. All functions of the 2020 will be controlled or reported using one of these displays.

4.1.1.1 Meter Display

The meter display is 4-digits. It will always be used for reporting detected concentration. When the detector and pump are off, the meter display will be blank.

In order to accommodate the range of concentrations the 2020 can detect, the meter reading will be reported using one of 2 resolutions. A resolution of 0.1 will be used for concentrations below 100 ppm, and a resolution of 1 will be used for concentrations above 100 ppm.

4.1.1.2 Status Display

The status display is a 2 line by 16-character display. The top line is used to display status/information and prompts you for your inputs. The bottom line is used for soft key names. Up to 3 names can be displayed for the 3 soft keys. If a name does not appear for a soft key, then the soft key has no associated function.

4.1.2 Keys

4.1.2.1 Fixed Keys

The three round keys below the soft keys each have a fixed function. The first key is the ON/OFF key, the middle key is the EXIT key, and the last key is the ENTER key.

The ON/OFF key is used to both turn power on and off. To turn on the 2020, press the ON/OFF key. To turn the power off, press the ON/OFF key and hold it down for 2 seconds, and then release it. This is done to prevent accidental power off.

The EXIT key provides a way of returning to the default display. In the functional map, the soft keys allow you to advance and the EXIT key provides a way to go back. If you are at the initial entry of the menu, EXIT will return you to the default display.

The ENTER key has a context sensitive function. When you are operating or navigating through the function map, the ENTER key is used to exit the functions and return you to the default display. When entering data such as a name, number, date, or time, ENTER is used to confirm the entry.

4.1.2.2 Soft Keys

The three soft keys on the 2020 are located directly below the status display. Each key has varying functions for configuring the 2020, editing the data logger, and controlling the display. Because only three soft keys are available, each function is broken down into a path.

4.1.2.3 Entering Text With the Soft Keys

For all information that you must enter, the left, center, and right soft keys correspond to the up, down, and right arrow.

The up and down arrows are used to change the character highlighted by the cursor. The right arrow is used to advance the cursor to the next character on the right. When the cursor is advanced past the right most character, it wraps around to the first character again. To accept the changes, press the ENTER key. To ignore the change, press EXIT.

Formatting characters, such as the colon (:) in the time, the decimal (.) in a concentration, and the slash (/) in the date are skipped when advancing the cursor.

All inputs are an 8-character input, which is displayed on the right side of the top line of the status display. The prompt, describing the input, occupies the left half of the top line. The soft keys are defined on the bottom line of the status display.

4.2 Default Display

The meter display shows the detected concentration. The resolution of the display changes with the magnitude of the reading. A reading of 0 to 99.9 will be displayed with a resolution of 0.1 ppm. A reading greater than 99.9 will be shown with a resolution of 1 ppm or 1 mg/m^3. The meter will display concentrations up to 2000 ppm or 2(99) mg/m^3.

The status display is used to display the instrument status, date, time, units, and active soft keys.

The default display provides the following information: instrument status, current detected concentration, time, date, and measurement units. The status display toggles between showing time and units and then the date.

When the display mode is MAX, the date and time correspond to the date and time the MAX concentration was recorded. In TWA mode, the time represents the number of hours and minutes during which the TWA has been accumulating. For PEAK and STEL monitoring, the date and time correspond to the current date and time.

4.3 Monitoring

4.3.1 Instrument Status

The instrument status is shown on the left of the first line of the status display and on the Table and Graph outputs. Each status has a priority assigned to it. If more than one status is in effect, then the status with the highest priority is displayed until the condition is corrected or until the option is turned off.

4.3.2 Alarms

While operating the instrument, any one of three alarm conditions can occur. To accurately identify the source of the alarm, each type of alarm has been given a unique status.

In addition to the status, the 2020 also has an audible alarm and a visual alarm LED. To conserve power, the 2020 alternates between these two alarm indicators, rather than operating both concurrently. Different alarms are identified by the frequency at which the 2020 alternates as follows: PEAK alarm-5 times per second; STEL alarm-2.5 times per second; and TWA alarm-1.25 times per second.

The left soft key is used for acknowledging alarms, and is labeled "Ack." If no alarm exists, then the "Ack" key is not shown. To clear the alarm, press the "Ack" key. Once acknowledged, the alarm indicators are cleared. The alarm status will remain until the alarm condition clears.

The 2020 updates the peak concentration once every second. Following every update, the peak concentration is compared to the peak alarm level, and if exceeded, an alarm is triggered.

If a 15-minute average concentration exceeds the selected STEL, a STEL alarm is generated.

The TWA alarm is generated when the current average concentration over an 8-hour period, since the TWA was last cleared, has exceeded the TWA exposure limit.

During calibration, all alarms are disabled. Once the calibration is complete the alarms are re-enabled.

4.4 STEL, TWA, MAX, and PEAK Operation

The 2020's meter display can be configured to show one of four values: STEL, TWA, PEAK, and MAX.

4.4.1 Short-term Exposure Limit Mode

The STEL mode displays the concentration as a 15-minute moving average. The 2020 maintains 15 samples, each representing a one-minute averaging interval.

Once every minute, the oldest of the 15 samples is replaced with a new one-minute average. This moving average provides a 15-minute average of the last 15 minutes with a one-minute update rate. Because the average is calculated using 15 one-minute averages, the meter display will only update once every minute.

The STEL is set to zero each time the instrument is turned on. Because STEL is a 15-minute moving average, there is no need to clear, or reset the STEL.

STEL calculations are always being performed by the 2020. You can display the results of the calculations by selecting "STEL" as the Display mode.

4.4.2 Time-weighted Average (TWA) Mode

The TWA accumulator sums concentrations every second until 8 hours of data have been combined. If this value exceeds the TWA alarm setting, a TWA alarm is generated. The TWA is not calculated using a moving average. Once 8 hours of data have been summed, the accumulation stops. In order to reset the TWA accumulator, press the "Clr" key.

This sum will only be complete after 8 hours, so the meter displays the current sum divided by 8 hours. While you are in TWA mode, the time on the status display will show the number of minutes and hours of data that TWA has accumulated. When this reaches 8 hours, the 2020 stops accumulating data and the TWA is complete.

TWA calculations are always being performed by the 2020. You can display the results of the calculations by selecting TWA as the Display mode.

4.4.3 MAX Mode

The MAX mode displays the maximum signal, with the date and time that it was recorded. The 2020 continues to log data according to the selected averaging interval, but only the maximum detected concentration is displayed on the meter display.

The right soft key is used to clear the meter when displaying MAX. The "Clr" key only affects the reading that the meter is displaying. For example, if you display the MAX reading, and you press "Clr," only the MAX value is cleared. The TWA is still accumulating in the background.

4.4.4 PEAK Mode

The PEAK mode displays the current detected concentration. The reading is updated once a second. In the background, the 2020 data logger is sampling the concentration and measuring minimum, maximum, and average concentrations for the selected averaging interval. At the end of every interval, one entry is placed in the data logger until the data logger is full. For CTO 131, the instrument should be operated in this mode. Operation within the other specialized modes are the responsibility of the SSO.

4.5 Set Functions

Set functions are used to setup the 2020. There are three functions which can be set on the 2020: Pump, Clock, and Calibration.

4.5.1 Pump

The Pump function is used to control the pump. After selecting “Set Pump”, the 2020 responds by displaying the new pump status.

The detector is also turned off when you turn the pump off. This prevents the detector from being damaged when there is no sample flowing through the detector.

When the pump and the detector are off, the meter display will be blank. Turn the pump and detector off when concentration measurements are not necessary, and the 2020 will only be used for reviewing data

or generating reports. By operating the instrument with the pump and detector off when you do not need them, you will conserve the lives of the battery and ultraviolet (UV) lamp.

To set the pump:

1. Press the ENTER key. The top line of the status display changes to "Select?". The bottom line displays 3 soft key names: "Set," "Log," and "Disp."

2. Press the soft key below "Set."

3. The names of the soft keys change to reflect the Set options. The display now shows 3 devices which can be set: "Clock," "Pump," and "Cal." Press the "Pump" key.

4. The 2020 turns the pump off. If the pump was off, pressing "Pump" will turn the pump on.

5. A message will be displayed to show you the status of the pump. The 2020 reverts back to the previous menu after a few seconds.

6. To return to the default display, press the ENTER key.

4.5.2 Clock

The Clock function is used to set both the current date and time.

To set the clock:

1. Press the ENTER key.

2. Press the "Set" key.

3. When the names of the soft keys change, press the "Clock" key.

   The up and down arrows are used to change the character underlined by the cursor. The right arrow is used to advance the cursor to the next character on the right. When the cursor is advanced past the right-most character, it wraps around to the first character again.

Formatting characters, such as the colon (:) in the time and the slash (/) in the date are skipped when advancing the cursor.

4. Use the "arrow keys" to enter the correct time. The time is formatted as Hour:Minute:Second.

5. Press the ENTER key to confirm the time and move to the date option.

6. When setting the date, the 2020 prompts you for the current date formatted as Year/Month/Day. Use the "arrow keys" to enter the correct date.

7. Press the ENTER key to confirm the date and return to the Set options. You can wait for the display to timeout or press ENTER to return to the default display.

4.5.3 Calibration (Cal)

"Cal" allows you to setup and calibrate the 2020. There are three options under the Cal function: "Zero," "Span," and "Mem."

A calibration memory consists of a name, a response factor, and PEAK, TWA, and STEL alarm levels.

The "Zero" and "Span" keys are covered in detail in the manufacturer's operations manual for the instrument.

To edit the calibration memory, select "Mem" and then "Chng." The 2020 prompts you with two new soft keys: "User" and "Lib."

4.5.4 Library (Lib)

Library selections simplify Cal Memory programming, and provide standard response factors for approximately 70 applications. "Lib" allows you to select an entry from a pre-programmed library. The name, response factor, and three alarm levels are all set from the library. To select a library entry to program the selected Cal Memory:

1. Select "Set," "Cal," "Mem," "Chng," and "Lib."
2. Use the "Next" and "Prev" keys to scroll through the list. See the manufacturer's manual Appendix 8.7 for a list of the library entries.

4.6 Preparing for Field Operation of the Photovac 2020

Turning The 2020 On

1. Turn the 2020 on by pressing the ON/OFF key.

2. The 2020 will display the software version number. Wait for the 2020 to proceed to the default display.

3. Allow 10 minutes for the instrument to warm up and stabilize.

4. Press the Enter Key. The default display will provide 3 soft key selection "Set," "Log," and "Display."

5. Press "Set." From this option, 3 other soft key selections will be offered: "Pump," "Clock," and "Cal."

6. Press "Cal." This will begin the calibration sequence. The first selection is to Zero the instrument.

7. Press Enter, zeroing will begin. (Note: When employing zero gas attach and activate zero gas supply at this time.)

8. The next selection offered will be Span. Press Enter at which time the concentration will be requested. The isobutylene calibration gas employed under general service will be marked on the side of the container. Use the soft keys to toggle into position and to log the concentration. Once the concentration is logged press "Enter." The direction on the status display will indicate spanning. At this time hook up the span gas with a regulator to the Photovac 2020, and open it to supply enough flow to elevate the flow rate indicator to the green indicator line (1/8" from the rest position).

9. Once spanning is complete, the alarms, which have been disabled during calibration, will activate indicating that calibration is complete.

10. Document this calibration procedure using a Document of Calibration form (included in Appendix A).

This instrument is ready for general purpose application.

Calibration is to be performed daily or prior to each use in accordance with this section.

4.7 Maintenance and Calibration Schedule

Function	Frequency
Routine Calibration	Prior to each use
Factory Inspection and Calibration	Once a year, or when malfunctioning
Wipe Down the Outer Casing of the Unit	After each use
Clean UV Light Source	Every 24 hours of operation
Sample Inlet Filter	Change on a weekly basis or as required by level of use
Battery charging	After each use
Clean ionization chamber	Monthly

4.7.1 Cleaning the UV Light Source Window

1. Turn the FUNCTION switch to the OFF position. Use the 2020 multi-tool and remove the lamp housing cover. CAUTION: The UV lamp is delicate and expensive-handle carefully.

2. Tilt the lamp housing with one hand over the opening, slide the lamp out of the housing.

3. The lamp window may now be cleaned with any of the following compounds using lens paper:
   a. 11.7 eV Lamp - Dry Aluminum Oxide Powder (3.0 micron powder)
   b. All other lamps-HPLC Grade Methanol

4. Following cleaning, reassemble by first sliding the lamp back into the lamp housing. Replace the o-ring as necessary, reinstall the lamp housing cover, and tighten it using the 2020 multi-tool. (Do not over tighten).

5. Recalibrate the instrument as per Section 4.6.

4.7.2 Cleaning the Ionization Chamber

1. Turn the FUNCTION switch to the OFF position and remove the lamp housing cover and lamp as per Section 4.7.1.

2. Using a gentle jet of compressed air, gently blow out any dust or dirt.

3. Following cleaning, reassemble by first sliding the lamp back into the lamp housing. Replace the o-ring as necessary, reinstall the lamp housing cover, and tighten it using the 2020 multi-tool. (Do not over tighten).

4. Recalibrate the instrument as per Section 4.6.

4.8 Instrument Advantages

The Photovac 2020 is easy to use in comparison to many other types of monitoring instrumentation. Its detection limit range is in the low parts-per-million range. Response rapidly reaches 90 percent scale of the indicated concentration (less than 3 seconds for benzene). This instrument's automated performance covers multiple monitoring functions simultaneously, incorporating data logging capabilities.

4.9 Limitations of the Photovac 2020 Photoionization Monitor

- Because the 2020 is a nonspecific total gas/vapor detector, it cannot be used to identify unknown chemicals; it can only quantitate them in relationship to a calibration standard (relative response ratio).

- For appropriate application of the 2020, ionization potentials of suspected contaminants must be known.

- Because the types of compounds that the 2020 can potentially detect are only a fraction of the chemicals possibly present at a hazardous waste site or incident, a background or zero reading on this instrument does not necessarily signify the absence of air contaminants.

- The 2020 instrument can only monitor certain vapors and gases in air. Many nonvolatile liquids, toxic solids, particulates, and other toxic gases and vapors cannot be detected.

- PID's are generally not specific. Their response to different compounds is relative to the calibration gas used. This is referred to as relative response ratio. Instrument readings may be higher or lower than the true concentration. This can be an especially serious problem when monitoring for total contaminant concentrations if several different compounds are being detected at once.

- The 2020 is a small, portable instrument which cannot be expected to yield results as accurately as laboratory instruments.

4.9.1 Variables Affecting Monitoring Data

Monitoring a hazardous waste site environment can pose a significant challenge in assessing airborne concentrations and the potential threats to site personnel. Several variables may influence both dispersion and the instrument's ability to detect actual concentrations. Some of the variables, which may impact these conditions, are as follows:

- Temperature - changes in temperature or pressure will influence volatization, and affect airborne concentrations. Additionally, an increase or decrease in temperature ranges may have an adverse effect on the instrument's ability to detect airborne concentrations.

- Humidity - excessive levels of humidity may interfere with the accuracy of monitoring results.

- Rainfall - through increased barometric pressure and water, may influence dispersion pathways affecting airborne emissions.

- Electromagnetic interference - high voltage sources, generators, other electrical equipment may interfere with the operation and accuracy of direct-reading monitoring instruments.

5.0 TROUBLESHOOTING

5.1 Fault Messages

When the "Fault" status is displayed, the 2020's operation is compromised.

Fault 1: Signal from zero gas is too high.

Cause: If another fault occurred while the 2020 was setting its zero point, then this fault is displayed.

Action: Ensure no faults are occurring and calibrate the 2020 again.

Cause: Contamination of sample line, sample probe, or fittings before the detector.

Action: Clean or replace the sample line, sample probe, or the inlet filter.

Cause: Span gas and zero air are switched.

Action: Ensure clean air is used to zero the 2020. If you are using gas bags, mark the calibration and zero gas bags clearly.

Cause: Ambient air is contaminated.

Action: If you are unsure about the quality of ambient air, use a supply of commercial zero grade air to zero the 2020.

Fault 2: Signal from span gas is too small.

Cause: Operator may have switched the span gas and zero air.

Action: Ensure clean air is used to zero the 2020. If you are using gas bags, mark the calibration and zero gas bags clearly.

Action: Ensure the span gas is of a reliable concentration.

Cause: UV lamp window is dirty.

Note: Do not remove the detector lamp in a hazardous location.

Action: Clean the UV lamp window.

Cause: UV lamp is failing.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: Install a new UV lamp.

Cause: Incompatible application.

Action: The concentration and sample gas are incompatible for use with the 2020.

Fault 3: UV lamp fault. UV lamp has not started.

Cause: The UV lamp has not started immediately.

Action: This fault may be seen momentarily when 2020 is first turned on. Allow 30 to 60 seconds for the UV lamp to start and the fault to clear.

Cause: The UV lamp serial number label is blocking the photocell.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the label is blocking the photocell. Rotate the lamp approximately 90 degrees and then try to start the 2020 again. If the fault persists, replace the lamp.

Cause: the UV lamp is not installed.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: Install a UV lamp.

Cause: The UV lamp has failed.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: Install a new UV lamp.

Cause: Electronic problem.

Action: If a new UV lamp still generates this fault, then contact the Photovac Service Department.

Fault 4: Pump current too low or too high.

Cause: If the pump sounds labored, then the pump is operating beyond normal operating parameters.

Action: Check for an obstruction in the sample line. Make sure sample line, sample probe or inlet filter are not plugged.

Note: Do not replace the inlet filter in a hazardous location.

Action: Replace the inlet filter.

Action: Ensure the sample outlet, located on the underside of the 2020, is not obstructed.

Cause: The UV lamp is too wide, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the TtNUS Equipment Manager.

Cause: The 2020 has been exposed to a solvent that can pass through the inlet filter and liquid has been aspirated.

Action: Contact the TtNUS Equipment Manager.

Cause: The pump has failed.

Action: Contact the TtNUS Equipment Manager.

5.2 Specific Problems

Problem: Very low or no instrument response detected, yet compounds are known to be present.

Cause: The 2020 has not been calibrated properly.

Action: Ensure the calibration gas is of a reliable concentration and then calibrate the instrument as outlined in Section 4.6 of the User's Manual. After the instrument has been calibrated, sample the bag of calibration gas. A reading equivalent to the calibration gas should be displayed. If not, contact the TtNUS Equipment Manager.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Disconnect the battery charger before calibrating the 2020.

Cause: Calibration Memories have not been programmed correctly.

Action: Program all the calibration memories you require for your application. You must use the correct calibration gas and concentration for each Cal Memory.

Cause: The response factor has been set to zero.

Action: Enter the correct response factor. Refer to Appendix 8.6 for a list of response factors. If the compound is not listed in Appendix 8.6 or you are measuring gas mixtures, then enter a value of 1.0. See User's Manual.

Cause: You are not using the correct Cal Memory.

Action: Select the correct Cal Memory for your application.

Note: It does not matter which Cal Memory is selected or which response factor is entered. The 2020's response is not specific to any one compound. The reading displayed represents the total concentration of all ionizable compounds in the sample.

Cause: Detector is leaking. A decrease in sensitivity may be due to a leak in the detector.

Note: Do not remove or replace the detection lamp in a hazardous location.

Action: Ensure the UV lamp has been installed correctly.

Action: Ensure the lamp cover has been tightened down. Do not overtighten the cover.

Action: Ensure the o-ring seal on the lamp cover is positioned correctly.

Cause: The UV lamp is too long, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too long for the lampholder. Replace the lamp and contact the TtNUS Equipment Manager.

Cause: UV lamp is too wide, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the TtNUS Equipment Manager.

Cause: The sampling environment is extremely humid.

Action: Water vapor is not ionized by the PID, but it does scatter and absorb the light and results in a lower reading. The 2020 detector has been designed to operate under high humidity conditions. Under extreme conditions you may notice decreased response due to humidity.

Cause: The UV lamp is failing.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: High concentration of non-ionizable compounds. Chemical compounds, such as methane, with IPs greater than the 10.6 eV scatter and absorb the UV light. Sensitivity may be decreased significantly. Application with high backgrounds of such materials, may be incompatible with the 2020. Contact the Photovac Applications Group for more information.

Problem: Erroneously high readings.

Cause: Sampling environment is extremely humid.

Action: Water vapor may contain mineral salts, which carry a charge. The water vapor becomes an electrolytic solution, which becomes ionized when it enters the detector. Atmospheric water in areas around the sea or stagnant water may produce a response in the absence of contaminants. The same effect may be seen when conducting ground water investigations in areas where the water is hard because it contains a significant concentration of minerals.

Cause: The 2020 has not been calibrated properly.

Action: Ensure the calibration gas is of a reliable concentration and then calibrate the instrument as outlined in Section 4.6. After the instrument has been calibrated, sample the bag of calibration gas. A reading equivalent to the calibration gas should be displayed. If not contact the TtNUS Equipment Manager.

Cause: Cal Memories have not been programmed correctly.

Action: Program all the Cal Memories you require for your application. You must use the correct calibration gas and concentration for each Cal Memory. See Section 3.4, of the User's Manual.

Cause: You are not using the correct Cal Memory.

Action: Select the correct Cal Memory for your application. See Section 3.2.2 or 3.3.2, of the User's Manual.

Note: It does not matter which Cal Memory is selected or which response factor is entered. The 2020's response is not specific to any one compound. The reading displayed represents the total concentration of all ionizable compounds in the sample.

Cause: The Detector has been short circuited by foreign matter in the detector cell.

Note: Do not service the 2020 in a hazardous location.

Action: Do not touch the wire grid inside the detector cell. Use a gentle jet of compressed air to remove any dust in the detector cell.

Warning: Do not insert any object, other than the UV lamp, into the lampholder.

Cause: There is an undetermined problem.

Action: Contact the TtNUS Equipment Manager.

Problem: Date and time settings are not retained.

Cause: The battery pack has been removed before the 2020 was turned off.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Replace the battery pack and reset the time and date. Ensure that the 2020 has been turned off before removing the battery pack.

Cause: The 2020 has not been used for 3 months or more and the internal battery (not the external battery pack) has discharged.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Connect the 2020 to the AC adapter and turn the 2020 on. Turn the pump off. While the 2020 is running the internal battery is charging. Leave the instrument running for approximately 24 hours.

Problem: Instrument status shows "Over."

Cause: High concentrations of gases and vapors will cause a rapid change in signal level. The detector and associated electronics may become temporarily saturated.

Action: Wait a few seconds for the status to return to normal. PIDs are designed to detect relatively low concentrations of gases and vapors. Exposure to very high concentrations may result in a very high or maximum response.

Cause: The detector has become saturated.

Action: Move the 2020 to a location where it can sample clean air. Sample clean air until the reading stabilizes around 0.

Cause: Detector has been short circuited by foreign matter in the detector cell.

Note: Do not service the 2020 in a hazardous location.

Action: Do not touch the wire grid inside the detector cell. Use a gentle jet of compressed air to remove any dust or dirt in the detector cell.

Warning: Do not insert any object, other than the UV lamp, into the lampholder.

Cause: There is an undetermined problem.

Action: Contact the TtNUS Equipment Manager.

Problem: Display is blank.

Cause: Battery pack is critically low.

Note: Do not remove or recharge the battery pack in a hazardous location.

Action: Replace the battery pack or connect the 2020 to the AC adapter.

Cause: The battery pack is not connected to the instrument correctly.

Action: Ensure the battery pack connector is securely attached to the connector on the 2020.

Cause: There is an undetermined problem.

Action: Reset the 2020. You must leave the instrument on while you disconnect the battery pack. This will reset the instrument. Reconnect the battery pack and close the battery hatch. Turn on the 2020, set the time and date and program all the calibration memories that you are using.

Action: Contact the TtNUS Equipment Manager.

Problem: Sample flow rate is less than 300 ml/min.

Cause: The inlet filter is plugged.

Note: Do not replace the inlet filter in a hazardous location.

Action: Replace the inlet filter.

Cause: The inlet filter has not been installed properly.

Action: Ensure that the inlet filter has been installed correctly.

Cause: The UV lamp is too long, causing flow to be restricted.

Note: Do not remove or replace the detector lamp in a hazardous location.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too long for the lampholder. Replace the lamp and contact the TtNUS Equipment Manager.

Cause: The UV lamp is too wide, causing flow to be restricted.

Action: If you have a UV lamp with a white serial number label, it is possible that the lamp is too wide for the lampholder. Contact the TtNUS Equipment Manager.

Cause: The 2020 has been exposed to a solvent that can pass through the inlet filter and liquid has been aspirated.

Action: Contact the TtNUS Equipment Manager.

Cause: Sample outlet is obstructed.

Action: Ensure the sample outlet is not obstructed in any way.

Cause: Pump has been damaged.

Action: Contact the TtNUS Equipment Manager.

Problem: Liquid has been aspirated.

Cause: The 2020 has been exposed to a solvent that can pass through the inlet filter.

Action: Contact the TtNUS Equipment Manager.

Problem: Corrosive gases and vapors have been sampled.

Cause: The 2020 has been exposed to corrosive gases and vapors.

Action: Corrosive gases and vapors can affect the electrodes within the detector as well as the lamp window. Prolonged exposure to corrosive materials may result in permanent fogging or etching

of the window. If the 2020 is exposed to corrosive material, contact the TtNUS Equipment Manager.

6.0 SHIPPING

The Photovac may be shipped as cargo or carried on as luggage providing there is no calibration gas cylinder accompanying the kit. When shipping or transporting the calibration gas, a Hazardous Airbill must be completed.

7.0 REFERENCES

Photovac 2020 Photoionization Monitor User's Manual, 1995.

8.0 ATTACHMENTS

1. Equipment Calibration Log

ATTACHMENT 1
EQUIPMENT CALIBRATION LOG

Tetra Tech NUS, Inc.

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME/MODEL: PID 2020

PROJECT NAME: NSWC CRANE

MANUFACTURER: Photovac

PROJECT NUMBER: CTO-038/7651

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

STANDARD OPERATING PROCEDURE
NUMBER CTO131-5

BOREHOLE ADVANCEMENT AND SOIL CORING USING DIRECT PUSH TECHNOLOGY

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures for collecting surface and subsurface soil cores from unconsolidated overburden materials using direct push technology (DPT) at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. For this investigation, a Geoprobe® rig with a Macrocore Sampler will be the type of DPT used.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Cut-resistant Non-latex Impermeable Gloves
Cotton Gloves
Writing Utensil
Boring Log Sheets: A copy of this form is included in SOP CTO131-6.
Geoprobe® or Equivalent DPT Equipment
Geoprobe® Macrocore Sampler or Equivalent
Geoprobe® Sampling Kit or Equivalent
Clear Acetate Liners: one new liner for each soil core
Mustard Gas Soil Screening Test Kit
Required Decontamination Materials (see SOP CTO131-26)
Bentonite Pellets

3.0 BOREHOLE ADVANCEMENT AND SOIL SAMPLING USING A GEOPROBE®

Direct Push Technology (DPT) will be employed to collect soil cores. DPT refers to sampling tools and sensors that are driven directly into the ground without the use of conventional rotary drilling equipment. DPT typically utilizes hydraulic pressure and/or percussion hammers to advance the sampling tools. Geoprobe® is a manufacturer of a hydraulically-powered, percussion/probing machine utilizing DPT to collect subsurface environmental samples. This type of rig with a Macrocore Sampler will be used at the

MGBG to collect soil cores. CAUTION: No boring will be conducted prior to appropriate UXO clearance as described in SOP CTO 131-1.

3.1 Clear the area to be sampled of any surface debris (herbaceous vegetation, twigs, rocks, litter, etc.).

3.2 Place a new clear acetate liner in the detachable Macrocore core barrel and attach coring device to the Geoprobe® rig.

3.3 Drive macrocore sampler (lined with acetate) into the ground to a depth of two feet using hydraulic pressure. The 0 –2 foot depth soil interval is considered to be the surface soil.

3.4 Retract the sampler from the borehole and remove the acetate liner and the soil core from the Macrocore barrel.

3.5 Attach the metal trough from the Geoprobe® Sampling Kit firmly to the tail gate of a vehicle. If a vehicle with a tailgate is not available, secure the trough on another suitable surface.

3.6 Place the acetate liner containing the soil core in the trough.

3.7 Screen the entire length of the unopened soil core for gross beta/gamma radiation using the hand-held radiation meter in accordance with SOP CTO 131-2. Record the readings on the Boring Log Sheet.

3.8 While wearing cut-resistant gloves (constructed of non-latex over cotton), cut the acetate liner through its entire length using the double-bladed knife that accompanies the Geoprobe® Sampling Kit. Then remove the strip of acetate from the trough to gain access to the collected soils. CAUTION: Do not attempt to cut the acetate liner while holding it in your hand.

3.9 Scan the entire length of the soil core for VOCs using the PID. Record the specific depth interval and the associated PID reading on the Boring Log Sheet. Collect a soil VOC sample using Encore samplers from the soil interval that had the highest PID reading. If no above-background PID readings were detected, collect the VOC sample from an interval that is discolored or displays other visual signs of being contaminated. If no visual sign of contamination is evident, collect the soil VOC sample from the center of the core interval (i.e., one foot depth). Details for collecting a VOC sample using the Encore sampler are included in SOP CTO131-8.

3.10 Log the soil core on the Boring Log Sheet (see SOP CTO131-6).

3.11 Place the soil core in a stainless steel mixing bowl, homogenize, and collect the remainder of the soil sample aliquots, as described in SOP CTO131-8. One of the sample aliquots will be used to screen the soil for mustard gas using the field screening procedure (SOP CTO131-3).

3.12 Repeat steps 3.2 through 3.11 for depth intervals of 2 – 6 feet and 6 – 10 feet.

3.13 If the soil boring location is even-numbered (e.g., SB02), then soil coring will continue to 18 feet or top of bedrock, whichever occurs first. No soil samples will be collected from the soil cores below 10 feet. However, the soil materials should be logged on the Boring Logs. The depth to bedrock should be recorded on the Boring Log and the estimated moisture content of the soil and the presence or absence of water in the boring should be noted.

3.14 If perched ground water is present at the bottom of the soil boring, attempt to collect a ground water sample per SOP CTO131-17.

3.15 When 10 feet bgs has been reached for odd-numbered soil borings or 18 feet bgs (or bedrock) has been reached for even-numbered borings, and sampling activities are completed, the soil borings shall be backfilled as described in the next step.

3.16 If readings from the PID, the hand-held beta/gamma radiation meter, and the mustard gas soil screening test are all at background levels below field screening criteria, then excess soil core materials shall be returned to the hole and tamped. If insufficient soil is available to fill the hole to the ground surface, then bentonite pellets mixed with the soil shall be used to backfill the hole.

3.17 If screening instruments or the mustard gas soil screening test indicate that contaminants may be present in the soil materials, then all excess soil core materials will be placed in a plastic bag, the bag will be tagged identifying the location and depths from where the soils came from and the date. The bag will then be placed in a 55-gallon drum and stored onsite until laboratory analyses of the soil are completed and classification of the soil waste materials can be determined (see SOP CTO131-27).

3.18 If soil materials from the boring are suspected of being contaminated (see 3.17 above), then the soil boring will be backfilled with bentonite-cement grout up to the ground surface.

3.19 Decontaminate all soil sampling equipment in accordance with SOP CTO131-26 prior to collecting the next sample.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-6

BOREHOLE AND SOIL SAMPLE LOGGING

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the standard procedures and technical guidance on the logging of soil cores collected at the Mustard Gas Burial Ground, SWMU 1/12, NSWC Crane.

2.0 FIELD FORMS AND EQUIPMENT

Knife
Ruler (marked in tenths and hundredths of feet)
Boring Log: An example of this form is attached.
Writing Utensil

3.0 RESPONSIBILITIES

A field geologist/engineer is responsible for supervising all boring activities and assuring that each borehole is properly and completely logged.

4.0 PROCEDURES FOR BOREHOLE AND SAMPLE LOGGING

To maintain a consistent classification of soil, it is imperative that the field geologist understands and accurately uses the field classification system described in this SOP. This identification is based on visual examination and manual tests.

4.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure 1 (attached to this SOP).

This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no distinguishable size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse-grained soils shall be divided into categories: rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as "(1/4 inchΦ-1/2 inchΦ)" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

4.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Because color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

4.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer-grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in the following table.

CONSISTENCY FOR COHESIVE SOILS

Consistency	Standard Penetration Resistance (Blows per Foot)	Unconfined Compressive Strength (Tons/Sq. Foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented with difficulty by thumbnail

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

The consistency of cohesive soils is determined by hand by determining the resistance to penetration by the thumb. The thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample. The sample shall be broken in half and the thumb pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are shown in the above-listed table.

4.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
Trace	0 - 10 percent
Some	11 - 30 percent
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

4.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the gloved hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire field activity.

4.6 Classification of Soil Grain Size for Chemical Analysis

To determine the gross grain size classification (e.g., clay, silt, and sand) from the USCS classification described above, the following table shall be used.

Gross Soil Grain Size Classification	USCS Abbreviation	Description
Clay	CL	inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays,
	CH	inorganic clays of high plasticity, fat clays
	OH	organic clays of medium to high plasticity, organic silts
Silt	ML	inorganic silts and very fine sands, rock four, silty or clayey fine sands with slight plasticity
	OL	organic silts and organic silty clays of low plasticity
	MH	inorganic silts, micaceous or diatomaceous fine sand or silty soils

Gross Soil Grain Size Classification	USCS Abbreviation	Description
Sand	SW	well graded sands, gravelly sands, little or no fines
	SP	poorly graded sands, gravelly sands, little or no fines
	SM	silty sands, sand-silt mixtures
	SC	clayey sands, sand-clay mixtures

4.7 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Other distinguishing features
- Grain size
- Depositional environment

4.0 ATTACHMENTS

1. Figure 1 - Unified Soil Classification System
2. Boring Log

ATTACHMENT 1

FIGURE 1 - UNIFIED SOIL CLASSIFICATION SYSTEM

FIGURE 1

UNIFIED SOIL CLASSIFICATION (USCS)

FIELD IDENTIFICATIONPROCEDURES
(Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights

COARSE-GRAINED SOILS
More Than Half of Material is LARGER Than No. 200 Sieve Sizes

			GROUP SYMBOL	TYPICAL NAMES
GRAVELS (50%(+)>1/4"Ø	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
	GRAVELS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
SANDS 50%(+)<1/4"Ø	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	SW	Well graded sand, gravelly sands, little or no fines.
		Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.
	SANDS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see MCL)	SM	Silty sands, poorly graded sand-silt mixtures.
		Plastic fines (for identification procedures, see CL)	SC	Clayey sands, poorly graded sand-clay mixtures.

FINE-GRAINED SOILS
More Than Half of Material is SMALLER Than No. 200 Sieve Size

FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)
Identification Procedures on Fraction Smaller than No. 40 Sieve Size

	DAY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)	GROUP SYMBOL	TYPICAL NAMES
SILTS AND CLAYS Liquid Limit <50	None to Slight	Quick to Slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
	Medium to High	None to Very Slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
	Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
SILTS AND CLAYS Liquid Limit >50	Slight to Medium	Slow to None	Slight to Medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
	High to Very High	None	High	CH	Inorganic clays of high plasticity, fat clays.
	Medium to High	None to Very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other organic soils

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example, GW-GC, well graded gravel-sand mixture with clay binder.
All sieve sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS

DESIGNATION	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNC COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb.
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb.
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb.
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail.
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail.

ATTACHMENT 2

BORING LOG

Tetra Tech NUS, Inc.

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING No.: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	PID/FID Reading (ppm): Sampler BZ**	PID/FID Reading (ppm): Borehole**	PID/FID Reading (ppm): Driller BZ**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): ____

Remarks: _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

STANDARD OPERATING PROCEDURE
NUMBER CTO131-7

SAMPLE IDENTIFICATION NOMENCLATURE

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes a consistent sample nomenclature system that will facilitate subsequent data management for the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. The sample nomenclature system has been devised such that the following objectives can be attained:

Sorting of data by matrix
Maintenance of consistency (field, laboratory, and database sample numbers)
Accommodation of all project-specific requirements
Accommodation of laboratory sample number length constraints
Ease of identification and direct link to site, sample type, location, and depth.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Pen with Indelible Ink
Sample Tags:
Sample Container Labels:

3.0 SAMPLE IDENTIFICATION NOMENCLATURE

3.1 Monitoring Samples

All monitoring samples collected at NSWC Crane will be properly labeled with a sample label affixed to the sample container and a tag tied around the neck of the container. Each sample will be assigned a unique sample tracking number. The sample tracking number will consist of a four segment alphanumeric code that identifies the sample's associated solid waste management unit (SWMU) or associated site, sample type, location, and, for aqueous samples where applicable whether a sample is filtered and/or the sample round number.

The alphanumeric coding to be used in the NSWC Crane sample system is explained in the diagram and the subsequent definitions:

NN	AA	A or N 2 to 5 characters	NN and/or A Aqueous only	NNNN Soils and Sediment Only
SWMU or Site Number	Sample Type	Location	Round Identifier and/or filtered	Depth Interval

Character Type:

A = Alpha

N = Numeric

SWMU or Site Number:

01 = Mustard Gas Burial Ground (SWMU 1)

Sample Type:

GW = Ground water sample

SD = Sediment sample

SW = Surface water sample

SB = Soil boring sample

SS = Surface soil sample

SP = Seep or Spring

Location:

The sample location code is the well number, the soil sample location sediment sample location, or the stream sample location (i.e., surface water, springs, or seeps. Existing well numbers are used when unique. Existing well numbers have been abbreviated in the sample IDs. For example, the first sample obtained from well WES-1-9-82 is designated as 01-GW-09-01. "WES-1-9-82" is abbreviated as "09". New wells will be designated by a "T" for Tetra Tech NUS and, followed by a MW for permanent monitoring wells, TW for temporary wells, etc. and numbered sequentially, by SWMU, beginning with zero one (MWT01). Well clusters, two or more wells in close proximity, will be designated with the letter P followed by the number 2, 3, 4 etc. The number signifies the well's depth in relation to other wells in that cluster. This two-digit code will follow the well identification. Using well T02 as an example, of a three well cluster, the well identification will be as follows:

T02 = The deepest well in the cluster.

T02P2 = Intermediate well.

T02P3 = Shallowest well in the cluster.

Note: To keep the sample identification nomenclature to a minimum numbers of characters and to avoid redundancy, MW (monitoring well) is used for text, figures and tables and replaced with GW (groundwater) in the sample identification, example a sample from MWT01 would be GWT01.

Round Identifier:

A two digit round identifier will be used to tract the number of aqueous samples (GW, SW, etc.) taken from a particular aqueous sample location. The first sample collected from a location will be assigned round identifier 01, the second 02, etc. This applies to both existing and proposed monitoring wells and surface water locations.

Filtered:

Water samples that are field filtered (dissolved analysis) will be identified with an "F" in the last code section. No entry in this segment signifies an unfiltered (total) sample.

Depth Interval, Soil and Sediment only:

The depth code is used to note the depth, below ground surface (bgs), at which a soil or sediment sample is collected. The first two numbers of the four number code specify the top interval and the third and fourth specify the bottom, feet bgs (soil) inches bgs (sediment) of the sample. The depths will be noted in whole numbers only, further detail if needed will be recorded on the sample log sheet, boring log, log book, etc.

Depth (for soils, in feet bgs):

0002 = soil collected from 0 to 2 foot bgs

0204 = soil collected from 2 to 4 feet bgs

0810 = soil collected from 8 to 10 feet bgs, etc.

Depth (for sediments, in inches bgs):

0006 = sediment collected from 0 to 6 inches bgs

0612 = sediment collected from 6 to 12 inches bgs

3.1.1 Examples of Sample Nomenclature

The first ground water sample collected from existing monitoring well WES-1-5-81 at the Mustard Gas Burial Ground for a filtered sample would be designated as 01GW0501 F.

The third ground water sample collected from existing monitoring well WES-1-19-83 for an unfiltered sample would be designated as 01GW1903.

The first unfiltered ground water samples collected from a new monitoring well 01T01 at the Mustard Gas Burial Ground would be designated as 01GWT0101.

A surface soil sample collected from location 21 in the Mustard Gas Burial Ground at the 0-2 foot interval would be designated 01SS210002.

A subsurface soil sample from boring 21 at an interval of 4-6 feet bgs would be designated as 01SB210406.

A sediment sample collected from drainage way location 01 at a depth of 0 – 6" would be designated as 01SD010006.

3.2 Field Quality Assurance/Quality Control (QA/QC) Sample Nomenclature

Field QA/QC samples are described in the approved Field Sampling Plan and QAPP. They will be designated using a different coding system. The QC code will consist of a three- to four-segment alphanumeric code that identifies the sample QC type, the date the sample was collected, and the number of this type of QC sample collected on that date.

AA	NNNNNN	NN	F or NNNN
QC Type	Date	Sequence Number (per day)	Filtered (aqueous only, if needed)

The QC types are identified as:

TB = Trip Blank
RB = Rinsate Blank (Equipment Blank)
FD = Field Duplicate
AB = Ambient Conditions Blank

SB = Source Water Blank

The sampling time recorded on the chain-of-custody form, labels, and tags for duplicate samples will be 0000 so that the samples are "blind" to the laboratory. Notes detailing the sample number, time, date, and type will be recorded on the sample log sheets and will document the location of the duplicate sample (sample log sheets are not provided to the laboratory).

3.2.2 Examples of Field QA/QC Nomenclature

The first duplicate of the day for a filtered ground water sample collected on June 3, 1999, would be designated as FD06039901F.

The third duplicate taken of a subsurface soil sample collected on November 17, 2003, would be designated as FD11170303.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-8

SURFACE AND SUBSURFACE SOIL SAMPLING

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures to be used for surface and subsurface soil sampling using direct push technology (DPT), split-barrel samplers, or hand augers during field activities at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. This procedure also describes the collection of samples for analysis of volatile organic compounds (VOCs) using EnCore samplers, and the use of field screening (i.e., photoionization detector [PID]) to select the most appropriate subsurface soil interval for VOC sampling.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Writing utensil with indelible ink

Disposable Medical-Grade Gloves (i.e. latex, nitrile)

Boring Log

Soil Sample Logsheets

Stainless-steel Mixing bbowls

Stainless-steel Trowel or Soup Spoon

EnCore Handle and Samplers

Required Sample Containers: All sample containers including shipping coolers for analysis by fix-based laboratories will be supplied and deemed certified clean by the laboratory.

Required Decontamination Materials

Chain-of-Custody Records

Required Personnel Protective Equipment (PPE)

Photoionization Detector (PID)

Wooden Stakes or Pin Flags

Sealable Polyethylene Bags

Heavy-Duty Cooler

Ice

Razor Knife

Geoprobe and Sampling Equipment

Sample Labels and Tags

3.0 COLLECTION OF SOIL SAMPLES FOR VOLATILE ORGANIC COMPOUNDS (VOCs)

3.1 When soil cores are collected using DPT such as Geoprobe, 2-foot soil intervals will be collected in clear acetate tubes, which can be extracted from the Geoprobe core barrel (see SOP CTO131-05) upon retrieval at the surface.

3.2 As each 2-foot interval is collected, the soil interval will be scanned first for radioactivity before the liner is cut open, per SOP CTO131-01.

3.3 Slit the acetate liner lengthwise with a razor knife, remove a section of the liner, and expose the length of the soil interval (see SOP CTO131-05).

3.4 Scan the soil core interval with a PID, slowly moving the intake nozzle along the length of the core where the acetate liner has been slit open. Note on the Boring Log what the range of PID readings are detected, and the specific location(s) along the sample interval where above-background readings are encountered. If elevated volatile organics are measured via the PID, collect the VOC samples from the specific interval where the highest PID reading is measured. If no above-background PID readings are measured, then the VOC sample will be collected from a specific interval where visual signs of contamination (staining, etc.) are observed. If no above-background PID reading is measured, and no discoloration or odor in the soil core indicate potential contamination, then collect the VOC sample from near the center of a core.

3.5 The 0-2 foot core interval will be collected as a "surface soil" sample. Determine where in this core interval the highest PID reading was encountered. Soil samples collected for volatile organics will be obtained directly from soil cores using four EnCore samplers for each VOC sample. These samples are to be collected by pushing the EnCore samplers directly into the soil core where the highest PID readings were measured, ensuring that the sampler is packed tight with soil, and leaving no headspace between cap and container. All four EnCore sample containers will be collected as close to each other as possible. Make sure that all caps are securely fastened to the samplers and locked in place with both clips (see instructions that come with samplers). Write the sample ID on the strip labels that come with the samplers and place a label on each of the four samplers.

3.6 Place the four EnCore samplers in the ziplock pouches that come with the samplers and fill in appropriate information, including sample ID, date, time, and other information on the label. Place the four pouches in a plastic bag and place the tag on the bag, identifying the sample ID and other necessary information (see SOP CTO131-10).

3.7 Once the samples are properly labeled, bagged, and tagged, place the sample into the cooler containing ice and a trip blank. It should be kept at 4 deg C and shipped to the analytical laboratory for preservation or extraction within 48 hours.

3.8 Fill in the required information on the Soil Sample Log Sheet (attached at the end of this SOP) and fill in the required information on the Chain-of-Custody (COC) form.

3.9 Two cores (2-4 and 4-6 foot depth intervals) will be collected for the intermediate-depth subsurface soil sample. In addition, two other cores (6-8 and 8-10 feet bgs) will be used for a "deep" subsurface soil sample. For these subsurface soil samples, two cores will be scanned with the PID before a specific depth is selected for VOC sampling. Choose the specific location within the two cores that had the highest PID reading and proceed to collect four EnCore samples, as described above in 3.4 through 3.7. If readings are not elevated, samples will be collected from the center of each cored interval. Place the samples in the cooler containing ice, once they have been properly labeled, bagged, and tagged.

3.10 For each soil boring, a VOC sample should be collected from 0-2, 2-6, and 6-10 foot depths, or a total of three samples per soil boring (Note: four EnCore samplers constitutes one VOC sample).

4.0 COLLECTION OF OTHER SOIL SAMPLE ALIQUOTS

Note: A surface soil sample is collected from the 0-2 feet deep (i.e., one core length). The two subsurface soil samples each consist of two 2-foot core segments.

4.1 After the VOC sample has been collected for the soil interval of interest (see 3.0 above), the remainder of the soil interval shall be composited and used to fill the remainder of the sample containers. Any surface debris (e.g., herbaceous vegetation, twigs, rocks, litter, etc.) should be first removed from the top of the surface soil core. For other core intervals, the top two inches of each core should be discarded because it often contains material scraped from the side of the borehole and not fresh material from the bottom of the borehole.

4.2 Slide the remaining core material out of the acetate liner and into a clean, decontaminated stainless steel mixing bowl. Mix the soil thoroughly with a stainless steel spoon and remove gravel, large pebbles, and other coarse materials. Fill the required sample containers in the following order:

- Container for mustard screening
- Containers for organic analyses
- Container for metals
- Container for radiological analyses

The containers (number, size, and type) required for each type of laboratory analysis are listed in Table 4-12 of the QAPP.

4.3 Complete all required information on the sample labels (see SOP CTO131-10).

4.4 Fill in all required information on the sample tag and secure the tag to the sample container.

4.5 Place the sample container in a ziplock plastic bag and seal shut. Place the bag in a cooler containing ice and cool to 4 $\pm$ 2 deg C.

4.6 Record the required information on the Soil Sample Log Sheet and the COC form.

5.0 PACKAGING AND SHIPPING OF SAMPLES

Samples will be packaged and shipped according to SOP CTO131-24. A sample **shall not** be shipped to the analytical laboratory if the field screening test for mustard yields a positive detection. In this case the sample containers will be retained in a cooler on ice and in custody, until the analytical results for mustard is obtained from the fixed-base laboratory performing the mustard analysis. If the analytical results indicate that mustard is not detectable, then the field screening result will be treated as a false positive result. The sample containers will then be shipped immediately to the analytical laboratory for non-mustard analyses. Mustard gas analysis is scheduled to be completed at the ECBC Laboratory on a two-day turnaround.

6.0 ATTACHMENTS

1. Soil and Sediment Sample Log Sheet

ATTACHMENT 1

SOIL AND SEDIMENT SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

STANDARD OPERATING PROCEDURE
NUMBER CTO131-9

GROUND WATER SAMPLE COLLECTION USING GEOPROBE

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides guidance for collecting ground water samples from a soil horizon through the bottom tip of a Geoprobe® Macrocore Sampler. This type of sampling technique will be used to collect ground water at the base of the unconsolidated deposits overlying the bedrock surface at depths of about 12 to 16 feet below ground surface (ft bgs), not to exceed 18 feet. This sampling is related to the soil sampling being performed at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Vehicle-mounted Geoprobe® hydraulic hammer drill
Geoprobe® rods
Drive head assembly with slide hammer
Expendable drive points
Probe jack
Drive cap
Pull cap
Hammer anvil
End point holder
Post run tubing (PRT) adapter with O-ring
Peristaltic pump
3/16" (OD) teflon tubing
Stainless steel fittings
Water sample bottles and labels
Generator (unless 115-v outlet is available on the Geoprobe truck)
Heavy duty UL-approved extension cord
Decontamination equipment (see SOP CTO131-26)
Photoionization Detector (PID)
Water quality meter

Chain-of-custody form

Ground water sample log sheet

Polypropylene tubing

Natural latex surgical tubing

Bentonite chips

3.0 PROCEDURE

3.1 Soil coring at the MGBG will be performed per SOP CTO131-5 and will terminate at 10 feet or top of bedrock. The even-numbered boreholes (e.g., SB02) will extend deeper, to 18 ft bgs or the top of bedrock (i.e., probe refusal), whichever occurs first. If wet saturated soil was encountered at the bottom of the hole, then ground water sampling can proceed.

3.2 Remove the Geoprobe® rods and Macrocore sampler from the borehole.

3.3 Using a supply of clean Teflon® tubing, cut a piece of tubing 16-21 feet long. Flush each piece of tubing with 20 psi compressed breathing air.

3.4 Insert the tubing into a 5-ft length of clean stainless steel (S.S.) drive rod until it protrudes out the other end. (The drive rods consist of a 5-ft long piece of ½-inch outside diameter (O.D.) by ¼-inch inside diameter (I.D.) stainless-steel tube).

3.5 Attach a rubber O-ring to the end of the tubing near the drive tip. (The drive tip is the end of the probe which is designed to hold the drive head). The snug fit of the O-ring allows for the system to hold a vacuum during sampling.

3.6 Insert an expendable drive point into the sampling tip of the drive rod, 2-4 feet of sample tubing should extend from the opposite end of the drive rod.

3.7 Attach the drive head to the top of the drive rod. Be sure that the sample tubing is threaded through the hole in the side of the drive head and will not be damaged or soiled during driving. The purpose of the drive head is to absorb the main brunt of the drive force from either a manual slide hammer, electric drive hammer, or Geoprobe®. The rod will be driven into the ground with the sampling tube already fixated within the probe rod.

3.8 Place the drill string assembly into the borehole and attach to the drive head.

3.9 Using the manual slide hammer, gently drive the rod to the depth where the last soil core was collected.

3.10 After the sample depth has been reached, use the retrieval jack to pull up the drive rod approximately 6 inches.

3.11 Insert the free end of the teflon tubing (which extends from the top end of the drill string) into a short (two foot) section of disposable natural latex surgical tubing and secure the insertion point with a clamp.

3.12 Place the surgical tubing inside the drive track of the peristaltic pump. Attach the flow-through cell of the water quality meter to the end of the surgical tubing.

3.13 Start the peristaltic pump at the lowest flow setting. Water should appear in the tubing within 1 to 3 minutes.

3.14 Let the water flow until it starts to clear. Measure water quality parameters using the water quality meter and flow-through cell attached to the discharge end of the surgical tubing (downstream of the peristaltic pump). See SOP CTO131-18 for details regarding the water quality meter. Measurements of water quality parameters should be performed every minute until the readings stabilize (i.e., all successive readings are within 5% of each other). Record water quality measurements and time of measurement on the Sample Collection Log.

3.15 When water quality parameter shave stabilized, remove the flow-through cell from the discharge tubing. Begin filling sample containers from the end of the discharge tube in the order listed on Table 4-6. Fill in completely and accurately all required information on the sample labels.

3.16 Place the sample containers in plastic bags and place them in an ice-filled cooler. Enter the proper information for the sample on the Chain-of-Custody Form, in accordance with SOP CTO131-25.

3.17 Turn off the peristaltic pump and remove the tubing from the pump. Remove the surgical tubing from the teflon tubing and properly dispose of the surgical tubing.

3.18 Using the retrieval jack, pull the drive rod and sampling tip from the ground.

3.19 Disconnect the teflon tubing from the sampling tip and properly dispose of the tubing.

3.20 Backfill the borehole with a mixture of clean soil and bentonite chips.

3.21 Decontaminate the drive rod and sampling tip per SOP CTO131-26.

4.0 ATTACHMENTS

1. Ground Water Sample Log Sheet

ATTACHMENT 1
GROUND WATER SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

GROUND WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Domestic Well Data
[] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	TBD	TBD
Time:	Visual	Standard	mS/cm	°C	NTU	mg/l		
Method:								

PURGE DATA:

Date:	Volume	pH	S.C.	Temp. (C)	Turbidity	DO	TBD	TBD
Method:								
Monitor Reading (ppm):								
Well Casing Diameter & Material								
Type:								
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS/NOTES:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No.:	

TBD: To Be Determined

STANDARD OPERATING PROCEDURE
NUMBER CTO131-11

INSPECTION OF EXISTING MONITORING WELLS

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes procedures for the inspection and repair of existing monitoring wells at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

The following equipment and field forms are required for inspection of existing monitoring wells.

Monitoring Well Inspection Form: A copy of the monitoring well inspection form is attached.
Bound Field Log Book
Well Keys
Photoionization Detector (PID) (with an 11.7 eV lamp)
Electronic Water-Level Indicator
Steel Rod (about 1-inch diameter with eye bolt at one end)
100 feet of Nylon Rope

3.0 INSPECTION PROCEDURES

3.1 Record the well identification (ID), date, and time on the Monitoring Well Inspection Form. The well identification on the tag for the existing wells has the prefix WES (Waterways Experiment Station), the SWMU number (i.e., 1 is the MGBG SWMU number), the well identification number (i.e., 1, 2, 3, ..., 27), and the year installed. For example, the well ID tag for well number one bears the ID WES-1-1-81.

3.2 Record the condition of the well ID tag. Is the tag in place and legible? If not, note the discrepancies on the Monitoring Well Inspection Form.

3.3 Record the condition of the protective casing, caps, and lock. Has the casing, cap, and/or lock been tampered with or damaged? Has the well been damaged in any way or does it show signs of deterioration?

3.4 Record the condition of the concrete or gravel pads, if a pad is present. Check the condition of the pad (or the area around the well if no pad exists) and note any abnormalities. Are concrete pads cracking or heaving? If a gravel pad is present, is there any erosion or plant growth in the pad area?

3.5 Record the condition of the cement seal surrounding the protective casing. Has the seal cracked or pulled away from the protective casing? Record any visible signs of deterioration in the area of the seal.

3.6 Record the presence of depressions and/or standing water around the casing or pad.

3.7 Unlock the well cap and open the protective cover, if one exists.

3.8 Inspect and record the condition of the PVC riser pipe and the water level reference point. The reference point is a V-notch on the top of the PVC riser pipe. If a notch is not present on top of the riser pipes, add a notch at the highest point using a file.

3.9 Measure the height of the protective casing and riser pipe above the ground surface. Record these readings on the inspection form to the nearest 0.01-foot.

3.10 Check Table 4-4 of the QAPP to determine the total original depth of the monitoring well being inspected.

3.11 Open the well cap and use the PID to screen the air within the well opening to determine whether above-background levels of VOCs are present within the well. Refer to the HASP for procedures to follow for the presence of VOCS in a well.

3.12 Lower the electronic water-level indicator probe down the well casing. If an obstruction is encountered, record the depth of the obstruction, and whether the obstruction is partial or complete.

3.13 If no obstruction is encountered, continue lowering the water-level indicator down the well casing until ground water is encountered. Measure the depth to water to the nearest 0.01 feet (see SOP CTO131-16), and record the depth on the Inspection Log.

3.14 Continue lowering the indicator probe down the casing until a solid bottom is reached or an obstruction is encountered. Record the depth to bottom of well (from top of casing) on the Inspection Log.

3.15 If an obstruction is encountered in the casing before the well bottom is reached, record the depth of obstruction on the Inspection Log, and whether the obstruction is partial or complete.

3.16 Remove the water-level indicator from the well.

3.17 If an obstruction was encountered during steps 3.12 or 3.14, lower a heavy steel rod slowly down the well casing until the obstruction is encountered. Attempt to loosen the obstruction by raising and dropping the steel rod, letting it hit the obstruction with gradually increasing force. Record whether the obstruction could be loosened.

3.18 If step 3.17 is performed, remove the steel rod from the well and remeasure the depth to the obstruction. If the obstruction has been knocked loose and settles to the bottom, then the well may still be used as a piezometer, but will not be used for ground water sampling.

3.19 Close the well cap and lock, if lock is present.

3.20 Decontaminate the water-level indicator and steel rod, if used, per SOP CTO131-26.

3.21 Make recommendations on the Inspection Log, if necessary, for repair of the monitoring well.

3.22 Perform repair of well as soon as possible. For example, if a PVC riser pipe is broken or bent, saw off damaged portion of pipe and add new section of pipe. Measure new "height of riser pipe above ground" and record in field log book and well inspection form.

4.0 ATTACHMENTS

1. Monitoring Well Inspection Sheet

MONITORING WELL INSPECTION SHEET

Well ID: _____

Time: _____ **Date:** _____ **Inspector's Name:** _____

Inspection Item	Types of Problems	Status		Observation
		S	U	
Well Tag	Is it in-place, legible			
Well security	Condition protective case, cap, lock			
Well pad	Concrete or gravel & condition			
Well seal	Condition of…			
Area Immediately around well pad	Record any evidence of/or standing water in area of well			
Dedicated sampling equipment	Condition of…			
PVC Riser	Condition of riser & survey reference point			

Comments:

Signature(s)_____

Note: S= Satisfactory, U= Unsatisfactory
Check one, if unsatisfactory explain

STANDARD OPERATING PROCEDURE
NUMBER CTO131-12

DRILLING AND GEOLOGIC LOGGING OF BOREHOLES IN ROCK

1.0 PURPOSE

This procedure describes the methods and equipment necessary to drill rock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain rock cores and prepare boring logs during drilling activities. Three types of drilling activities and equipment will be used to drill holes and install monitoring wells at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane:

- Auger drilling will be used in the burial area to penetrate through the overburden (about 10 to 15 feet thick) in order to minimize the amount of dust created. The goal is to minimize the risk of human exposure to airborne contaminants and to minimize the potential of spreading contaminants on the land surface. Two holes may be drilled in the burial area – 01T03-00 and 01T04-00. Once the holes are opened in the overburden (i.e., down to the bedrock surface), then the remainder of the boreholes will be completed using other drilling equipment.

- Diamond coring equipment might be used to core the entire depths of holes 01T05-00 and 01T06-00. NX or similar size diamond core barrels will be used to collect 2 to 3 inch diameter continuous rock core. These cores will be used to describe the lithologic characteristics and fracture distributions in the Pennsylvanian-age bedrock. Diamond coring is relatively slow and more expensive compared to the air rotary method of drilling, so only two holes are being cored. Note: Hole 01C01-93 was covered previously at the site, but a description of fracture frequencies, orientations, and distribution were not included in the boring log.

- Air-rotary drilling will be used to ream out to a larger diameter the two diamond core holes mentioned above, and to drill the other four boreholes recommended in Round 1 of the work plan. The holes need to be about 6 to 8 inches in diameter in order to install 2-inch diameter monitoring wells.

2.0 RESPONSIBILITIES

Field Operations Leader (FOL) - The FOL is responsible for coordinating all on-site personnel and for providing technical assistance, when required. The FOL, or designee, will coordinate and lead all

activities and will ensure the availability and maintenance of all materials/equipment. The FOL is responsible for the completion of all field activities, field and chain-of-custody documentation; will assume custody of all samples; and will ensure the proper handling and shipping of samples. The FOL is a highly experienced environmental professional who will report directly to the TtNUS TOM. Specific FOL responsibilities include the following:

- Function as a communications link between field staff members, the Site QA/QC Advisor, Site Safety Officer, the Site Manager, and the TOM.
- Oversee the mobilization and demobilization of all field equipment and subcontractors.
- Coordinate and manage the Field Technical Staff.
- Adhere to the work schedules provided by the TOM.
- Bear responsibility for maintenance of the site logbook and field record keeping.
- Initiate field task modification requests, when necessary.
- Identify and resolve problems in the field, resolve difficulties in consultation with the NSWC Crane Site Manager, implement and document corrective action procedures, and provide communication between the field team and upper management.

Field Geologist - The field geologist is responsible for ensuring that standard and approved drilling procedures are followed. The field geologist will generate a detailed boring log for each borehole. This log shall include a description of geologic materials, samples (if any), method of sampling, and other pertinent information and observations that may be obtained during drilling.

Determination of the exact location for borings is the responsibility of the field geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan and/or Sampling and Analysis Plan. Any deviation from this location will be discussed with the TOM prior to commencing drilling operations. Note: Drilling activities can not be performed in the MGBG (i.e., the former fenced area) unless the drilling location and access lanes have been cleared for UXO (see SOP CTO131-1).

Drilling Subcontractor - Operates under the supervision of the FOL. Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical problems encountered in the field to the FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager). Depending on the subcontract, the Project Manager may need to obtain written authorization from appropriate administrative personnel before approving any changes.

The drilling subcontractor is responsible for following decontamination procedures specified for drilling and coring equipment specified in the project plan documents. The FOL will oversee the in-field equipment decontamination procedures to confirm compliance with the appropriate SOP and specific requirements of the NSWC Crane Environmental Department. Upon completion of the work, the driller is responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

3.0 PROCEDURES

3.1 General

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site, and
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned between samples and borings using appropriate decontamination procedures as outlined in SOP CTO131-26. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the site geologist as they proceed.

3.2 Rock Coring

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond-studded bit attached to the outer core barrel in a double-tube core barrel. The use of single-tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation of this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required. When coring rock, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled.

Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).
- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install monitoring wells in coreholes, the hole will be reamed out to the proper size after boring, using air rotary drilling methods. Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. Rock coring can,

however, proceed for thousands of feet continuously, depending on the size of the drill rig, and yields better quality data than air-rotary drilling, although at a substantially reduced drilling rate.

Borehole diameter can be drilled to various sizes, depending on the information needed. NX, or a similar size (2 to 3 inch diameter core recovery), will be used for the MGBG investigation.

Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately.

Since rock structures and the occurrence of bedding planes, porosity type/distribution, and fracture patterns are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as conditions warrant.

3.3 Rock Core Management and Labeling

Once the core barrel has been recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system (Section 3.5 of this SOP).

Rock cores shall be placed in the sequence of recovery in well-constructed wooden or cardboard boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each. Wood partitions shall be placed at the end of each core run. The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box. The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly,

an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

Project name
Project number
Boring number
Run numbers
Footage (depths)
Recovery
RQD (%)
Box number and total number of boxes for that boring (Example: Box 5 of 7)
Contact person's name and telephone number.

For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number.

Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

3.4 Air Rotary Drilling

Air-rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole.

Advantages of this method include:

- The drilling rate is high (even in rock)
- The cost per foot of drilling is relatively low
- Air-rotary rigs are common in most areas
- No drilling fluid is required (except when water is injected to keep down dust)

- The borehole diameter is large, to allow room for proper well installation procedures

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate
- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow
- In-situ samples cannot be taken, unless the hole is cased
- Air-rotary drill rigs are large and heavy
- Large amounts of Investigation Derived Waste (IDW) may be generated which may require containerization, sampling, and off-site disposal.

4.0 GEOLOGIC DESCRIPTION OF BOREHOLES IN ROCK

These procedures provide descriptions of the standard techniques for borehole and sample logging. These logging techniques shall be used for each boring to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

4.1 Required Field Forms and Equipment

When logging soil and rock samples, the geologist or engineer should be equipped with the following:

Rock hammer
Knife
Camera
10% Dilute hydrochloric acid (HCl)
Ruler (marked in tenths and hundredths of feet)
Hand Lens

Writing utensil with indelible ink

Field logbook

Soil/rock classification sheets

4.2 Classification of Rocks

Claystone - Very fine-grained rock made up of particle less than 1/256mm in diameter. Fractures irregularly.
Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.

Shale - A fissile very fine-grained rock with particles less than 1/256mm in diameter. Fractures along bedding
planes.

Limestone - Rock made up predominantly of calcite ($CaCO_3$, which is mainly fossilized animal and plant debris). Effervesces strongly upon the application of dilute hydrochloric acid.

Coal – A very dark colored rock consisting mainly of organic (mainly fossilized plant debris) remains.

Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record.
The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted: Rocks are grouped into three main divisions: sedimentary, igneous and metamorphic. Sedimentary rocks are by far the predominant type exposed at the earth's surface and are the only type present at NSWC Crane. The following basic names are applied to the types of rocks found in sedimentary sequences:

Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.

Siltstone - Made up of granular materials between 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.

Rock type
Color
Bedding thickness
Hardness
Fracturing
Weathering
Other characteristics

4.2.1 Rock Type

As described above, there are numerous types of sedimentary rocks. In most cases, a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, fossiliferous, etc.

Grain size is the basis for the classification of clastic (sandstones, siltstones, and shales) sedimentary rocks. Figure 4 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification.. For field determination of grain sizes, a scale can be used for the coarse grained rocks. Alternatively, the division between siltstone and shale may be measurable in the field by the use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a shale.

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125 - 0.25 mm
Very Fine Sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm
After Wentworth, 1922	

4.2.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications. Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

4.2.3 Bedding Thickness

The bedding thickness designations listed below will also be used for rock classification.

BEDDING THICKNESS CLASSIFICATION

Thickness (metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	<1/32"	Micro Laminated

(Weir, 1973; Ingram, 1954)

4.2.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).

Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.

Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.

Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the works "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

4.2.5 Fracturing

$$RQD\ \% = r/l \times 100$$

r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

l = Total length of the coring run.

4.2.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.

Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration. Oxidation and weathering may be The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing.

After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

Very broken (V. BR.) - Less than 2-inch spacing between fractures
Broken (BR.) - 2-inch to 1-foot spacing between fractures
Blocky (BL.) - 1- to 3-foot spacing between fractures
Massive (M.) - 3 to 10-foot spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD
(After Deere, 1964)

accentuated along fractures and should be noted.

Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.

Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

4.2.7 Other Characteristics

The following items shall be included in the rock description:

Description of contact between two rock units. These can be sharp or gradational.

- Stratification (parallel, cross stratified).
- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic).
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

4.2.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

Seam - Thin (12 inches or less), probably continuous layer.

Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."

Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."

Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."

Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

4.2.9 Abbreviations

Abbreviations may be used in the description of a rock. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C	-	Coarse	Lt	-	Light	Yl	-	Yellow
Med	-	Medium	BR	-	Broken	Or	-	Orange
F	-	Fine	BL	-	Blocky	SS	-	Sandstone
V	-	Very	M	-	Massive	Sh	-	Shale
Sl	-	Slight	Br	-	Brown	LS	-	Limestone
Occ	-	Occasional	Bl	-	Black	Fgr	-	Fine-grained
Tr	-	Trace						

5.0 BORING LOGS AND DOCUMENTATION

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log is attached at the end of this SOP.

The field geologist/engineer shall use this example as a guide in completing each boring log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the back of the boring log or on a separate sheet, for field use. All data shall be written directly on the boring log. Additional notes may be entered in a field notebook if more space is needed.

5.1 Remarks Column

The following information shall be entered under the "Remarks" column and shall include, but is not limited to, the following:

- Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.

- Angularity - describe angularity of coarse grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.

- Particle shape - flat, elongated, or flat and elongated.

- Maximum particle size or dimension.

- Water level observations.

- Reaction with HCl - none, weak, or strong.

Additional comments:

- Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.

- Indicate odor and Photoionization Detector (PID) or radiation meter readings.

- Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.

- At the bottom of the page indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).

- Vertical lines shall be drawn (as shown in Figure 5) in columns 6 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.

- Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.2 Rock Classification

Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent, and core recovery under the appropriate columns.

Indicate lithology change by drawing a line at the appropriate depth as explained above.

Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.

Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.

Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.

Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.

The following information shall be entered under the remarks column. Items shall include but are not limited to the following:

- Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
- Indicate calcareous zones, description of any cavities or vugs.
- Indicate any loss or gain of drill water.
- Indicate drop of drill tools or change in color of drill water.

Remarks at the bottom of Boring Log shall include:

- Type and size of core obtained.
- Depth casing was set.
- Type of rig used.

As a final check the boring log shall include the following:

- Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.

- If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.3 Classification of Soil and Rock from Drill Cuttings

The previous section describe procedures for classifying rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock" bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.). Cuttings shall be closely examined to determine general lithology.

Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.

Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.

Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.

Record this and any other useful information onto the boring log.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.4 Review

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

Checking for consistency of all logs.
Checking for conformance to the guideline.
Checking to see that all information is entered in their respective columns and spaces.

Originals of the boring logs shall be retained in the project files.

6.0 REFERENCES

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7.0 ATTACHMENTS

1. Boring Log

ATTACHMENT 1

BORING LOG

Tetra Tech NUS, Inc.

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING No.: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS*	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): ____

Remarks: _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

STANDARD OPERATING PROCEDURE
NUMBER CTO131-13

PACKER TESTING OF UNCASED BOREHOLES

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) delineates protocols for performing packer tests in open holes in bedrock at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. These tests will allow hydraulic properties of rock to be determined and ground water samples to be collected, if needed, from specific depth intervals.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Submersible pump with 0.5-10 gpm capacity
Inflatable packers
Drill rig and associated equipment
Teflon-coated drop tube
Stainless-steel cable
Pressure transducer and data recorder
Photoionization Detector (PID)
Water Quality Meter
High Pressure Steel Tubing

3.0 PROCEDURE

3.1 Determine depth intervals of open borehole, which will be tested.

3.2 Lower decontaminated packer assembly down to first desired interval to be tested.

3.3 Pack off the top and bottom of the test interval with inflatable packers which are attached to high-pressure steel tubing.

3.4 Monitor hydraulic pressure in test section, until pressure reaches a constant value (i.e., steady-state). Record times and pressure values on data logger.

3.5 Once pressure has reached steady state, turn on the pump, which will produce water at a rate of about one gpm.

3.6 Monitor hydraulic pressure during pumping. Do not let water level drop below top packer elevation (i.e., do not let packed interval become dewatered).

3.7 If water level drops quickly, reduce pumping rate to lowest steady level and continue to record water pressure.

3.8 Monitor water quality parameters (pH, ORP, temperature, D.O., turbidity, and specific conductance) in accordance with SOP CTO131-17 in-line in the pump discharge line during the test. Record values every two to three minutes.

3.9 Monitor the flow rates during the test and record every two minutes, and every time, if any, when pump rate is intentionally reduced.

3.10 After approximately 15 minutes of pumping and ground water elevation has stabilized and is still well above the top packer elevation, then a step increase in pumping rate may be achievable. Increase the pumping rate to about 5 gpm and repeat steps 3.5 through 3.8.

3.11 If, after about 15 minutes, the ground water elevation has stabilized, attempt to increase pumping rate to 10 gpm. **Do not let water level drop below the top of the packer assembly.** If water pressure drops quickly, cut pumping rate down to 7 or 8 gpm or stop pumping altogether.

3.12 Record water pressures and water quality parameters every 2 to 3 minutes. When pressure transducer readings have stabilized (i.e., remains constant over a 5 minute period), the test is completed.

3.13 Turn off the pump and deflate packers.

3.14 Move pump and packer assembly down to the next interval selected for testing.

3.15 Repeat steps 3.2 through 3.12 for next test interval.

3.16 When testing is completed, remove packer assembly, pump, and other equipment from the hole. Decontaminate all equipment as described in SOP CTO131-26.

3.17 Contain all water produced during testing. Transport IDW water to central storage area per SOP CTO131-27.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-14

MONITORING WELL INSTALLATION

1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper design and installation of ground water monitoring wells. The methods described herein are specific for monitoring well construction at the Mustard Gas Burial Ground MGBG, SWMU 1/12, NSWC Crane. Guidelines by South Division, Naval Facilities Engineering Command, (South Div NavFac, 1997) and the State of Indiana regulatory requirements in Article 16 Water Well Drillers of Chapter 310 of the Indiana Annotated Codes (310 IAC 16) should be consulted.

2.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The drilling contractor personnel must have all of the health and safety training required to perform the work, as specified in the Health and Safety Plan. The driller is also responsible for obtaining, in advance, any required permits for drilling and monitoring well installation and construction.

Field Geologist - The field geologist supervises and documents well installation and construction performed by the driller, and insures that the screen interval for each monitoring well is properly placed to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

Site Safety Officer – The Site Safety Officer is responsible for clearing the drill site for underground and overhead utilities, or other potentially hazardous obstructions.

Site UXO Specialist – The Site UXO Specialist is responsible for clearing all borehole and drilling locations within the MGBG for unexploded ordnance (UXO). This will be accomplished by using geophysical equipment to search for metallic objects (see SOP CTO131-1). No drilling can take place in the MGBG without the completion of the UXO clearance for every drilling location.

3.0 REQUIRED EQUIPMENT/ITEMS

The following list includes equipment and items required for monitoring well installation:

Health and safety equipment as required by the HASP and the Site Safety Officer.

Well drilling and installation equipment with associated materials (typically supplied by the driller).

Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineer's rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, boring logs, soil sample log forms, chain-of-custody records, sample coolers with ice, and a field notebook).

4.0 WELL DESIGN AND CONSTRUCTION

The total depths and screen intervals anticipated for each new background and provisional monitoring well are presented in Table 4-5 of the QAPP. See Section 4.4.2 and Figures 4-2 and 4-3 of the QAPP for locations and discussion regarding the rationale for well locations. New wells will be installed only with Navy concurrence. Based on observations and information gathered during the drilling of each hole, the total depth of the hole and the placement of the well screen may be adjusted at the discretion of the field geologist or the FOL. The decision concerning the monitored interval and well depth will be based on the following (and possibly other) information collected while the well bore is being drilled and logged:

- The specific depths where poorly-cemented sandstone units, fractured rock, or other permeable rock zones are encountered,
- The specific depths where above-average rates of ground water were brought to the surface during drilling,
- The specific depth interval where contaminants (i.e., VOCs), if any, are encountered during drilling.

All of this information will be recorded on the borehole log as the hole is drilled.

Diamond coring (NX) will be performed at one or more borehole locations as specified in Section 4 of this QAPP. For each well, the coring will proceed to the full depth as shown on Table 4-5 of the QAPP. Once

the coring has been completed and the core has been logged (see SOP CTO131-12), then the hole will be reamed out with a 7-inch diameter air rotary bit. The air rotary equipment must have a filter on the compressed air line going to the borehole to prevent oil and other organics from being introduced. Once the hole has been cleaned out using the compressed air of the rig, then packer testing of the hole can proceed (see SOP CTO131-13). Installation of the monitoring well follows the packer testing. Note: all drilling and packer testing equipment must be decontaminated before it is placed in a borehole.

For the two monitoring wells to be installed within the MGBG (01T03-00 and 01T04-00), the overburden will be drilled first using an 8-inch diameter or larger, solid-stem auger. The auger will be used initially to reduce dust and the potential for airborne contaminants (monitored with a PID) which might be contained in the unconsolidated overburden materials. Once the overburden has been removed, the remainder of the boreholes will be drilled using air rotary equipment. Air rotary drilling will terminate at about 50 feet bgs, or sooner if the field geologist or FOL judge that a permeable rock unit has been encountered which will be the monitored interval (i.e., where the well screen will be set). The borehole will be logged using the rock chips and dust blown up the borehole by the return air of the drill bit (see SOP CTO131-12). The borehole will then be cleaned out using compressed air from the drill bit. Packer testing of two 20-foot intervals will occur next (see SOP CTO131-13). When packer testing has been completed, the borehole is ready for monitoring well installation.

For the two background monitoring wells, the boreholes will be drilled and logged using just the air rotary equipment. When each borehole is drilled to the appropriate depth (see Table 4-5 of the QAPP), it will be cleaned out using compressed air from the drill bit. Packer testing will be performed on two to three intervals in each hole as per SOP CTO131-13. The boreholes are then ready for well installation.

All monitoring wells will be constructed of schedule-40, flush-joint threaded, 2-inch ID PVC riser pipe and flush joint threaded, factory slotted well screen with a threaded end cap. The well screens will be factory slotted to 0.020-inch size. Each section of well casing and screen shall be National Sanitation Foundation (NSF) approved. Well screens will be 20-feet long, but may be longer or shorter based on the subsurface conditions encountered. A PVC cap will be placed on the bottom and will also be flush-threaded. Thermoplastic pipe shall comply with ASTM F-480 (1981). Other means of joining casings using glue, gaskets, pop rivets or screws are not allowed. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material.

Monitoring wells will be installed immediately upon completion of packer testing. A well screen section with bottom cap and the proper amount of riser pipe will be assembled and lowered down the borehole. Spacers will be used to ensure that the casing and screen are centered and are aligned straight. Clean

silica sand pack will be installed through a tremie pipe. The sand pack will be extended from 0.5 feet below the well screen to 2.0 feet above the top of the well screen. Clean silica sand of U.S. Standard Sieve Size No. 20 to 40 will be used.

As required in the Navy Guidelines, a minimum 1-ft thick secondary filter pack will be placed immediately above the sand pack to prevent intrusion of the bentonite seal into the primary filter pack. Uniformly graded fine sand with 100% by weight passing the No. 30 U.S. Standard sieve, and less than 2% by weight passing the 200 U.S. Standard sieve should be used as a secondary filter pack.

A minimum 2-foot thick bentonite pellet seal will be installed above the filter pack and allowed to hydrate for a minimum of 3 hours before grout is added above the seal. Only 100-percent, certified pure, sodium bentonite will be used for well construction. The depths of backfill materials will be constantly monitored during well installation using a weighted stainless steel or fiberglass tape measure.

After 3 hours have elapsed, the remaining annulus above the hydrated bentonite seal will be backfilled to the surface using a tremie pipe, with a 20:1 cement/bentonite grout. A maximum of 10 gallons of water per 94-pound bag of Type-1 cement will be used. The grout mixture should be blended in an above-ground rigid container or mixer to produce a thick lump-free mixture.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets extending to the surface. The grout effectively seals the well and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom of the hole upward, to prevent bridging, and to provide a better seal. However, in shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

When the well is completed and grouted to the surface, a protective steel surface casing is placed over the top of the well. The finished well casing shall extend at least 2 ft above the ground level. This casing will have a cap that can be locked to prevent vandalism. A vent hole shall be provided in the cap to allow venting of gases and maintain atmospheric pressure as water levels rise or fall in the well. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

5.0 DOCUMENTATION OF FIELD ACTIVITIES

A critical part of monitoring well installation is recording of significant details and events in the site logbook, on field forms, and a field logbook. Details of borehole logging are contained in SOP CTO131-12.

All wells installed by the TtNUS must be registered with the TtMNUS WOUTHDIV Program Management Office (PMO) geologist. The PMO geologist will request that the Navy prepare well tags for the wells. The following information must be supplied to the PMOI geologist for each well:

Tag number
Installation Name (i.e., NSWC Crane)
Contract Task Order number
TtNUS project number
Well identification number
Date installed
Installer (i.e., TtNUS)
Total well depth
Screened interval
Elevation (Top of casing)
Northing coordinate (ft)
Easting coordinate (ft)
Survey coordinate reference system
Information point of contact.

6.0 ATTACHMENTS

1. Bedrock Monitoring Well Sheet
2. Overburden Monitoring Well Sheet

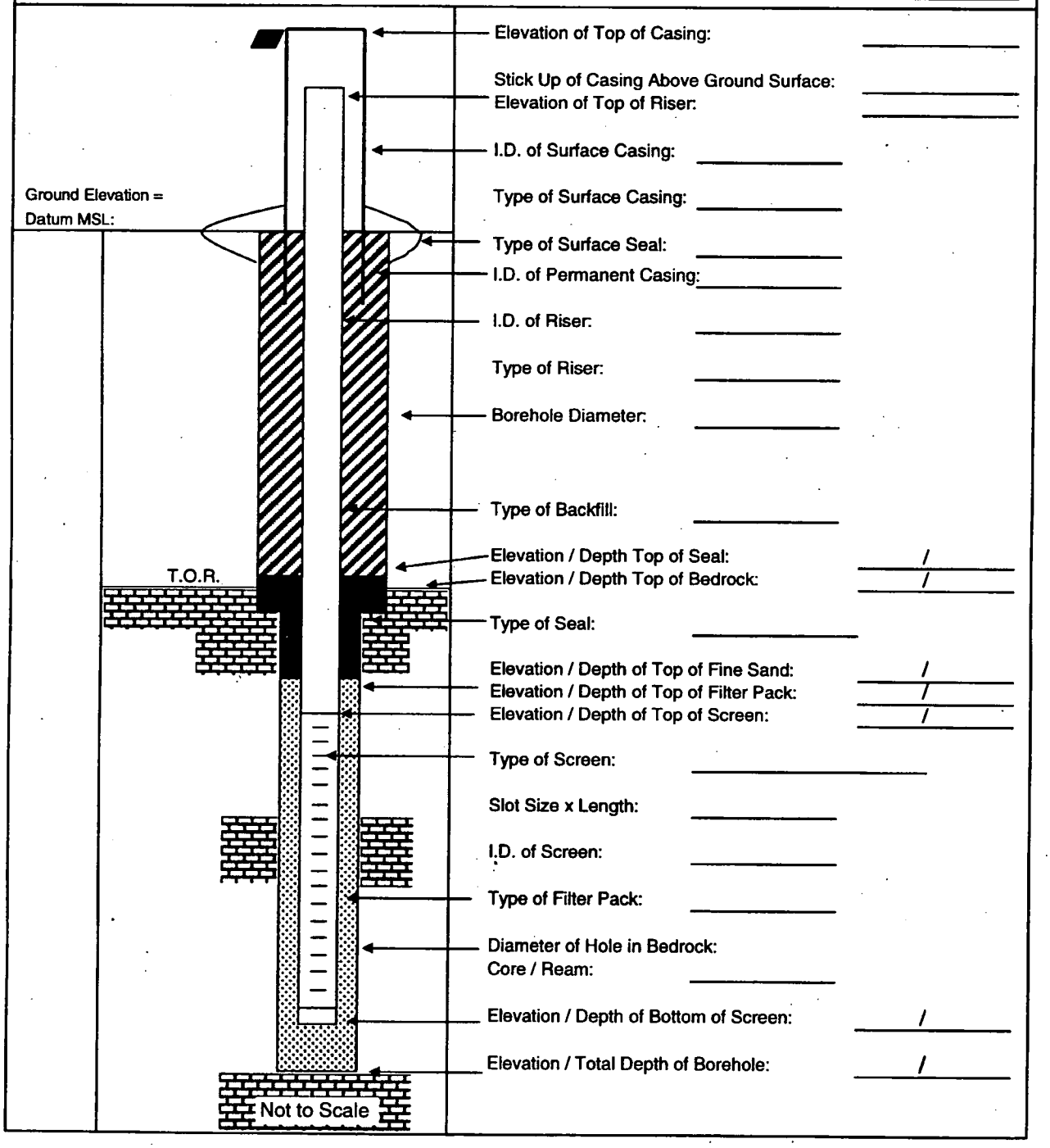
ATTACHMENT 1
BEDROCK MONITORING WELL SHEET

Tetra Tech NUS, Inc.

BEDROCK
MONITORING WELL SHEET

WELL No.: _____
PERMIT No:

PROJECT:		DRILLING Co.:		BORING No.:	
PROJECT No.:		DRILLER:		DATE COMPLETED:	
SITE:		DRILLING METHOD:		NORTHING:	
GEOLOGIST:		DEV. METHOD:		EASTING:	



Elevation of Top of Casing: _____

Stick Up of Casing Above Ground Surface: _____
Elevation of Top of Riser: _____

I.D. of Surface Casing: _____

Type of Surface Casing: _____

Type of Surface Seal: _____

I.D. of Permanent Casing: _____

I.D. of Riser: _____

Type of Riser: _____

Borehole Diameter: _____

Type of Backfill: _____

Elevation / Depth Top of Seal: _____ / _____
Elevation / Depth Top of Bedrock: _____ / _____

Type of Seal: _____

Elevation / Depth of Top of Fine Sand: _____ / _____
Elevation / Depth of Top of Filter Pack: _____ / _____
Elevation / Depth of Top of Screen: _____ / _____

Type of Screen: _____

Slot Size x Length: _____

I.D. of Screen: _____

Type of Filter Pack: _____

Diameter of Hole in Bedrock:
Core / Ream: _____

Elevation / Depth of Bottom of Screen: _____ / _____

Elevation / Total Depth of Borehole: _____ / _____

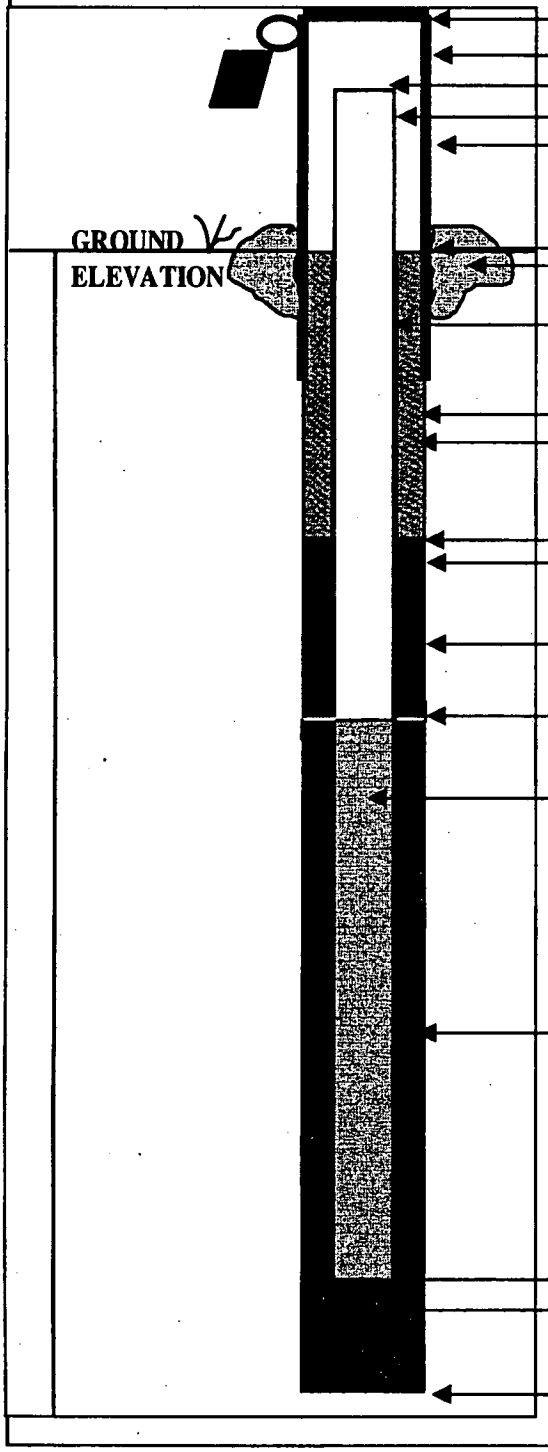
ATTACHMENT 2

OVERBURDEN MONITORING WELL SHEET

BORING NO.: _____

Tetra Tech NUS, Inc. **OVERBURDEN MONITORING WELL SHEET**

PROJECT:		DRILLING Co.:		BORING No.:	
PROJECT No.:		DRILLER:		DATE COMPLETED:	
SITE:		DRILLING METHOD:		NORTHING:	
GEOLOGIST:		DEV. METHOD:		EASTING:	



ELEVATION OF TOP OF SURFACE CASING: _____
STICK -UP TOP OF SURFACE CASING: _____
ELEVATION OF TOP OF RISER PIPE: _____
RISER STICK-UP ABOVE GROUND SURFACE: _____
I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

GROUND ELEVATION: _____
TYPE OF SURFACE SEAL: _____

RISER PIPE I.D.: _____
TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____
TYPE OF SEAL: _____

ELEVATION / DEPTH OF SEAL: ____ / ____
TYPE OF SEAL: _____

ELEVATION / DEPTH TOP OF FILTER PACK: ____ / ____

ELEVATION / DEPTH TOP OF SCREEN: ____ / ____

TYPE OF SCREEN: _____

SLOT SIZE X LENGTH: _____

I.D. OF SCREEN: _____

TYPE OF FILTER PACK: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: ____ / ____
ELEVATION / DEPTH BOTTOM OF FILTER PACK: ____ / ____
TYPE OF BACKFILL BELOW WELL: _____
ELEVATION / DEPTH OF BOREHOLE: ____ / ____

STANDARD OPERATING PROCEDURE
NUMBER CTO131-15

MONITORING WELL DEVELOPMENT

1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper development of new and existing monitoring wells. The methods described herein are specific for monitoring wells located at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. Guidelines by South Division, Naval Facilities Engineering Command, (South Div NavFac, 1997) and the State of Indiana regulatory requirements in Article 16 Water Well Drillers of Chapter 310 of the Indiana Annotated Codes (310 IAC 16) should be consulted.

2.0 RESPONSIBILITIES

The drilling contractor will provide adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing the development of monitoring wells. The drilling contractor personnel must have all of the health and safety training required to perform the work, as specified in the Health and Safety Plan.

3.0 REQUIRED EQUIPMENT/ITEMS

The following list includes equipment and items required for monitoring well installation:

Health and safety equipment as required by the HASP and the Site Safety Officer.

Well development equipment with associated materials (typically supplied by the driller).

Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule,electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).

4.0 WELL DEVELOPMENT METHODS

The development of new wells shall not occur until at least 48 hours after the well has been installed and grouted. This time is required so that the grout in the annulus can set and harden. The purpose of well development is to stabilize and increase the permeability of the sand pack and the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water, if any, is removed from the well.

Sequential measurements of pH, specific conductance, turbidity, and temperature taken during development yield information (stabilized values) that sufficient development is reached. Development should proceed until criteria are met as stated in Navy Guidelines.

A surge plunger (also called a surge block) that is approximately the same diameter as the well casing will be used to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. Site-specific conditions will dictate which type will be used. In formations with low yields, a valved surge plunger may be preferred, as solid plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

Development should proceed until the following criteria are met:

- The well water is clear to the unaided eye AND-

- A minimum removal of five times the standing water volume in the well (to include the well screen and casing plus saturated borehole annulus, assuming 30% annular porosity) OR

- When pH measurements remain constant within 0.1 Standard Units and specific conductance and temperature vary no more than plus or minus 3% for at least three consecutive readings. Turbidity should also show stabilization and ideally be below 10 Nephelometric Turbidity Units (NTUs).

If for any reason the above criteria cannot be met, the site geologist should document the event in writing and consult with the TOM regarding an alternate plan of action.

Well development must be completed at least 24 hours before well sampling. The intent of this hiatus is to provide time for the newly installed well and backfill materials to sufficiently equilibrate to their new environment and for that new environment to re-stabilize after the disturbance of drilling.

5.0 ATTACHMENTS

1. Monitoring Well Development Record

ATTACHMENT 1

MONITORING WELL DEVELOPMENT RECORD

Tetra Tech NUS, Inc.

MONITORING WELL DEVELOPMENT RECORD

Page ___ of ____

Well: _____ Depth to Bottom (ft.): _____ Responsible Personnel: _____
Site: _____ Static Water Level Before (ft.): _____ Drilling Co.: _____
Date Installed: _____ Static Water Level After (ft.): _____ Project Name: _____
Date Developed: _____ Screen Length (ft.): _____ Project Number: _____
Dev. Method: _____ Specific Capacity: _____
Pump Type: _____ Casing ID (in.): _____

Time	Estimated Sediment Thickness (Ft.)	Cumulative Water Volume (Gal.)	Water Level Readings (Ft. below TOC)	Temperature (Degrees C)	pH	Specific Conductance (Units _____)	Turbidity (NTU)	Remarks (odor, color, etc.)

STANDARD OPERATING PROCEDURE
NUMBER CTO131-16

MEASUREMENT OF WATER LEVELS IN MONITORING WELLS

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes procedures for determining water levels in monitoring wells.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

The following equipment and field forms are required for determining water levels in monitoring wells.

Ground Water Level Measurement Form: A copy of the Ground Water Level Measurement Form is attached.

Bound Field Log Book

Photoionization Detector (PID): Operation and calibration of the PID is discussed in SOP CTO131-4.

Well Key

Electronic Water-Level Indicator: The water level indicator must have a cable of sufficient length to reach the water surface and be capable of measurements of 0.01 feet.

Decontamination Supplies: SOP CTO131-26 describes decontamination procedures including decontamination supplies.

3.0 WATER-LEVEL MEASUREMENT PROCEDURES

3.1 Check the operation of the electronic water level indicator or interface meter.

3.2 Record the well identification (ID), date, and time (using military time) on the Ground Water-Level Measurement Form.

3.3 Unlock the well and remove the well cap.

3.4 Place the well cap on a clean piece of plastic.

3.5 Check the well for the presence of organic vapors in the 2-inch PVC riser pipe as follows:

1. Calibration of the PID shall be done in accordance with the calibration procedures described in SOP CTO131-4. Calibration of the PID shall be done at the field office prior to entering the field.

2 Insert the PID sample inlet straw approximately three inches into the riser pipe.

3 Record the PID reading on the Ground Water Level Measurement Form. If the reading is less than concentrations specified in the site-specific HASP, proceed to step 3.6. If the reading is greater than the concentration specified in the HASP, measure the concentration in the breathing zone. If the concentration in the breathing zone is less than the concentration specified in the HASP, proceed to Step 3.6. If the reading is greater than the specified concentration, allow the riser pipe to ventilate for ten minutes and repeat the measurement of breathing zone concentrations until the concentrations fall below the level specified in the HASP before proceeding to step 3.6.

3.6 Ensure that the water level indicator probe has been decontaminated before use in accordance with the procedures outlined in SOP CTO131-26.

3.7 Slowly lower the probe into the well riser pipe until an audible and/or visible signal is produced, indicating contact with the water surface.

3.8 Read the ground water level measurement from the top of the inner casing at the surveyed reference point to the nearest 0.01-foot.

3.9 Record the water level measurement on the Ground Water Level Measurement Form.

3.10 Wind the meter cable measuring tape back onto the spool.

3.11 Replace the well cap and lock.

3.12 Decontaminate the meter's probe and cable following the procedures outlined in SOP CTO131-26.

3.13 Containerize any decontamination fluids and PPE in accordance with the procedures described in SOP CTO131-27.

4.0 ATTACHMENTS

1. Ground Water Level Measurement Sheet

ATTACHMENT 1

GROUND WATER LEVEL MEASUREMENT SHEET

Tetra Tech NUS, Inc.

GROUND WATER LEVEL MEASUREMENT SHEET

Project Name: _____ **Project No.:** _____

Location: _____ **Personnel:** _____

Weather Conditions: _____ **Measuring Device:** _____

Tidally Influenced: Yes ___ No ___ **Remarks:** _____

Well or Piezometer Number	Date	Time	Elevation of Reference Point (feet)*	Total Well Depth (feet)*	Water Level Indicator Reading (feet)*	Thickness of Free Product (feet)*	Groundwater Elevation (feet)*	Comments

* All measurements to the nearest 0.01 foot

Page ___ of ___

STANDARD OPERATING PROCEDURE
NUMBER CTO131-17

LOW-FLOW WELL PURGING AND STABILIZATION

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedure for well purging and stabilization utilizing low-flow techniques.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

The following field forms and equipment are required for low-flow purging.

Low-Flow Purge Data Sheet: A copy of this form is attached at the end of this SOP.
Ground Water Sample Log Sheet: A copy of this form and instructions for its completion are included in SOP CTO131-19.
Bound Field Log Book
Photoionization detector (PID) with a 10.6 eV lamp: The procedures for the operation of the PID are found in the Health and Safety Plan and SOP CTO131-4.
Well key
Electronic water level indicator: The water level indicator must have a cable of sufficient length to reach the water surface and be capable of measurements of 0.01-feet (see SOP CTO131-16).
Electronic Programmable Controller, model 400: This controller regulates air flow in a bladder pump.
Cylinder of compressed nitrogen with regulator: Compressed gas serves as the power source for the bladder pump.
Multiple parameter water quality meter: This unit measures and displays field parameters measured in the field including pH, dissolved oxygen, oxidation-reduction potential (ORP), temperature, and specific conductance (see SOP CTO131-18).
Flow-through cell adapter for water quality meter
LaMotte Turbidity Meter: Used to measure turbidity (see SOP CTO131-18).
Purge water containers
Graduated cylinder and stopwatch: Used to calculate flow rate.
Decontamination supplies: SOP CTO131-26 describes required decontamination supplies.

3.0 PROCEDURES FOR WELL PURGING

3.1 Prior to mobilizing to the site, clean, check for proper operation, and calibrate as per manufacturer requirements above equipment as necessary.

3.2 Follow the steps outlined in SOP CTO131-16 to obtain a static water level measurement of the well to be purged. Record the information on the Ground Water Sample Log Sheet and the Low-Flow Purge Data Sheet. Leave the water level meter suspended in the well casing.

3.3 Calculate one well casing volume as follows:

1. Obtain the total depth of the well from Table 4-4 of this QAPP.

2. Using the static water level determined in Step 3.2 of this SOP and the total depth of the well, calculate the well casing volume using the following formula:

$$V = (0.163)(T)(r^2)$$

where:

V	=	Static casing volume of well (in gallons).
T	=	Vertical height of water column (linear feet of water).
0.163	=	A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.
r	=	Inside radius of the well casing (in inches).

Note: For wells of 1-inch radius (2-inch diameter) V = 0.163 gallons per foot of water column.

3.4 Connect the pump controller to the well pump air supply (at the well cap) by following the instructions in the pump control manual. The pump controller must be turned off when being connected.

3.5 Connect the nitrogen cylinder to the pump controller. The nitrogen cylinder valve must be closed and the regulator line pressure set at zero pounds per square inch (PSI) when being connected.

3.6 Following the instructions found in the water quality meter manual, connect the flow-through cell to the pump discharge line (at the well cap).

3.7 Place the discharge tubing from the flow-through cell to direct the purge water discharge into the graduated cylinder or purge-water container.

3.8 Following the instructions in the pump controller manual, start pumping water from the well.

3.9 Start with the initial pump rate set at approximately 0.1 liters/minute. Use the graduated cylinder and stopwatch to measure the pumping rate. Adjust pumping rates as necessary to prevent drawdown from exceeding 0.3 feet during purging. If no drawdown is noted, the pump rate may be increased (to a max of 0.4 liters/minute) to expedite the purging and sampling event. The pump rate will be reduced if turbidity is greater than 10 NTUs after all other field parameters have stabilized. If ground water is drawn down below the top of the well screen, purging will cease and the well will be allowed to recover before purging continues. Slow recovering wells will be identified and purged at the beginning of the workday. If possible, samples will be collected from these wells within the same 8-hour workday and no later than 24 hours after the start of purging.

The time to sample any given well will vary greatly due to the many variables associated with low flow purging and sampling i.e.:

- Stabilization of parameters
- Possible draw down
- Analytical changes from quarter to quarter
- Varying QA sample requirements from quarter to quarter
- Variable pump rates

Normally, the time from the start of purging to the end of sampling will be between 1 to 4 hours.

3.10 Measure the well water level using the water level meter every five minutes. Record the well water level on the Low-Flow Purge Data Form (attached at the end of this SOP.

3.11 Record on the Low-Flow Purge Data Form every five to ten minutes the water quality parameters (pH, specific conductance, temperature, turbidity, oxidation-reduction potential, and dissolved oxygen) measured by the water quality meter and turbidity meter. If the cell needs to be cleaned during purging operations, continue pumping (allow the pump to discharge into a container) and

disconnect the cell. Rinse the cell with distilled water. After cleaning is completed, reconnect the flow-through cell and continue purging. Document the cell cleaning on the Low-Flow Purge Data Form.

3.12 Measure the flow rate using a graduated cylinder. Remeasure the flow rate any time the pump rate is adjusted.

3.13 During purging, check for the presence of bubbles in the flow-through cell. The presence of bubbles is an indication that connections are not tight. If bubbles are observed, check for loose connections.

3.14 Stabilization is achieved and sampling can begin when a minimum of one casing volume has been removed and three consecutive readings, taken at 5 to 10 minute intervals, are within the following limits:

pH ± 0.1 standard units
Specific conductance ± 3%
Temperature ± 3%
Turbidity less than 10 NTUs
Dissolved oxygen ± 10%

If the above conditions have still not been met after the well has been purged for four hours, purging will be considered complete and sampling can begin. Record the final well stabilization parameters from the Low-Flow Purge Data From onto the Ground Water Sample Log Form.

If there is a need to leave a well during purging, there are two options:

- One, if the sampler must move for 30 minutes or less but still has a clear line of sight to the well, the sampler may leave the pump running and watch the well until the sampler is able to return to the well.

- Two, if for whatever reason, the sampler must stop purging for an extended period of time or a clear line of sight cannot be maintained, the pump and cell will be shut-down. All equipment and supplies will be loaded into the sample vehicle, and the well will be secured before departing.

In both cases, the time purging was stopped and restarted will be noted on the Low-Flow Purge Data Form.

3.15 Once sampling activities have been completed, turn the pump off. Remove pump, hoses, cables, and other equipment from the well.

3.16 Decontaminate pumps, hoses, cables, flow-through cell, and other equipment according to SOP CTO131-26.

4.0 ATTACHMENTS

1. Low-Flow Purge Data Sheet

ATTACHMENT 1

LOW-FLOW PURGE DATA SHEET

Tetra Tech NUS, Inc.

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: _____ **WELL ID.:** _____

PROJECT NUMBER: _____ **DATE:** _____

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Comments

SIGNATURE(S): _____ **PAGE___OF___**

STANDARD OPERATING PROCEDURE
NUMBER CTO131-18

CALIBRATION AND CARE OF WATER QUALITY METER

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedures for the calibration and maintenance of field instruments used to measure water quality, and for the proper documentation of calibration and maintenance. The YSI 6-Series Environmental Monitoring System will be used to measure pH, temperature, oxidation-reduction potential (ORP), specific conductance (SC), dissolved oxygen (DO), and turbidity in water. The YSI meter has a multiprobe sensor, which can be used in conjunction with a flow-through cell attached to a pump discharge tube to measure water quality parameters in a ground water discharge, or can be immersed in a surface water body such as a stream, pond, or drainage ditch.

2.0 FIELD FORMS AND EQUIPMENT LIST

The following log books, forms, equipment and supplies are required.

Site Log Book
Equipment Calibration Log Sheet
YSI Model 610-D and Sonde: multi-parameter water quality meter with flow through cell
Equipment Manual
Calibration Kit
Deionized water, paper towels, spray bottle etc.

3.0 PROCEDURES

This section describes the calibration procedure for the YSI Model 610-D. The meter is supplied with an instruction manual. Sections of this manual are reproduced in this SOP. The manual will be on-site and used as the calibration guidance document for the meter's calibration (page 29 section 2.6 of the manual starts the calibration procedure). This procedure will list requirements for frequency of calibration and checks to be performed on the meter.

The YSI Model 610-D and Sonde is a multi-parameter, water quality meter that may be used to measure open water bodies (streams, ponds, springs, etc.) with the probe guard installed. With the flow through cell attached, the meter has the ability to measure water quality parameters in ground water via a pump discharge line. By performing the measurements in the discharge line coming directly from the well, the parameters are measured prior to the ground water coming in contact with the atmosphere. The parameters measured by the YSI for this field effort are:

- Dissolved Oxygen (DO)
- Specific Conductance (SC)
- Temperature
- pH
- Oxidation-reduction Potential (ORP)
- Turbidity

3.1 Documentation

The Equipment Calibration Log is used to document calibration of measuring equipment used in the field. The Equipment Calibration Log documents that the Manufacturer's instructions were followed for calibration of the equipment, including the frequency of calibration, type of standards used, and checks performed on calibration during the course of using the equipment. An Equipment Calibration Log must be maintained for each measuring device that requires calibration. Entries must be made for each day the equipment is used. A blank Equipment Calibration Log form is attached at the end of this SOP.

3.2 Calibration

All of the parameters listed in Section 3.0 must be calibrated prior to the start of each field effort. After this initial calibration, the YSI will be checked each day that it is used. If the check shows any out-of-spec readings, the specific probe will be recalibrated. Meter specifications can be found in the equipment manual, starting on page 248. Calibration and calibration checks will be documented in the Field Logbook and on the Equipment Calibration Log. The name, lot number, and expiration date for all calibration buffers and standards used will be recorded on the Equipment Calibration Log. The meter's model, serial number, and name of rental company will also be recorded on the equipment calibration form.

3.3 Tips for Good Calibration

- The DO calibration is a water-saturated air calibration. Make certain to loosen the calibration cup seal to allow pressure to equilibrate before calibrating.

- Make certain that sensors are completely submersed in solution and readings are stable when calibration values are entered.

- Use a small amount of calibration solution (previously used solution may be used, then discarded for this purpose) to pre-rinse the sonde.

- Fill a bucket with ambient temperature water to rinse the sonde between calibration solutions.

- Make sure to rinse and dry the probe between calibration solutions. This will reduce carry-over contamination and increase the accuracy of the calibration.

4.0 MAINTENANCE

The YSI Meter will be rented for the duration of each brief field effort. Therefore, little field maintenance will be required. For any maintenance other than the routine cleaning, calibrating, or battery charging, the instrument should be returned to the vender and a replacement sent immediately to the job site.

4.1 Meter Storage

For this field effort, the meter storage will be short term, i.e. over-night or between work shifts (4-day break). During these breaks the meter shall be placed on charge. One-half inch of tap or distilled water shall be placed in the meter calibration cup and the cup threaded onto the sonde. The key for short-term storage of probes is to use a minimal amount of water so that the calibration cup will remain at 100% humidity. The water level must be low enough so that none of the probes are actually immersed. Proper storage of the sonde between usage will extend its life and will also ensure that the unit is ready for use as quickly as possible for the next application.

Multi-parameter short term storage key points:

- Use enough water to provide humidity, but not enough to cover the probe surfaces.
- Make sure the storage vessel is sealed to minimize evaporation.

- Check periodically to make certain that water is still present.

4.2 Probe Cleaning

- Rinse the probe thoroughly with potable water.
- Wash the probe in a mild solution of Liquinox and water and wip with paper towels and/or cotton swabs.
- Rinse and soak the probe in deionized water.
- If stronger cleaning is required, consult section 2.10 page 89 of the equipment manual.

Note: Reagents that are used to calibrate and check the YSI may be hazardous. Review Health and Safety Plan, Appendix A of the equipment manual, and MSDS's, all of which are on file in the field trailer.

5.0 ATTACHMENTS

1. Equipment Calibration Log

ATTACHMENT 1
EQUIPMENT CALIBRATION LOG

Tetra Tech NUS, Inc.

EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME/MODEL: PID 2020

PROJECT NAME: NSWC CRANE

MANUFACTURER: Photovac

PROJECT NUMBER: CTO-038/7651

CALIBRATION DATE	INITIAL SETTINGS	STANDARDS USED	PROCEDURE	ADJUSTMENTS MADE	FINAL SETTINGS	SIGNATURE	COMMENTS

STANDARD OPERATING PROCEDURE
NUMBER CTO131-19

MONITORING WELL SAMPLING

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedure for monitoring well sampling. Low-flow sampling techniques will be used for ground water sampling at the Mustard Gas Burial Ground, SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

The following field forms and equipment are required for low-flow sampling of monitoring wells:
Ground Water Sample Log Form: A copy of this form is attached at the end of this SOP
Bound Field Log Book

Chain-of-Custody Form

Bladder Pump

Surgical Gloves

Labeled sample containers: Sample containers are certified clean by the laboratory supplying the sample containers.
Tag for each sample container
Plastic storage bags
Shipping containers with ice

3.0 MONITORING WELL SAMPLING PROCEDURES

3.1 Ground water sampling may be initiated when the monitoring well has been purged and stabilized in accordance with SOP CTO131-17.

3.2 Record the sample start time (using military time) on the Ground Water Sample Log Sheet. Record the field measurements for pH, ORP, specific conductance, temperature, dissolved oxygen, and turbidity.

3.3 With the pump continuing to run, disconnect the flow-through cell from the pump discharge tube and immediately start filling sample bottles directly from the pump discharge. All sample containers will be supplied by the laboratory, and the laboratory will pre-preserve all sample containers, where appropriate.

3.4 Allow the pump discharge to flow gently down the inside of the container with minimal turbulence when filling sample containers. Avoid immersing the discharge tube into the sample as the sample container is being filled. Sample containers for volatile constituents (VOCs) must be completely filled so that no headspace exists in the container. The VOC vials shall be filled to the top so that a convex meniscus is formed. Gently secure the cap, turn the vial upside down, and check to see if any air has been trapped inside the vial. If so, open the cap, reform the meniscus, and attempt again to secure the lid without trapping air in the sample. All other sample containers can have air space included when the container lid is secured.

3.5 Cap each container immediately after filling.

3.6 Record the sample time on the Ground Water Sample Log Form, the sample tag, and on the sample label.

3.7 Secure the associated tag to each sample container.

3.8 Place the tagged sample container into a plastic storage bag and then into a cooler containing ice.

3.9 Enter the proper information on the Chain-of-Custody form for each sample container (see SOP CTO131-25).

3.10 Repeat steps 3.3 through 3.9 for each sample container collected.

3.11 The pump rate should not be adjusted after sampling has commenced. If it becomes necessary to adjust the pump rate, document the change on the Ground Water Sample Log Form.

3.12 All samples will be collected into pre-preserved bottles (if required) supplied by an approved laboratory. Table 4-13 of the QAPP includes information on preservation requirements. All samples will be collected in the following sequence (where applicable):

Volatile organic compounds (VOCs)
Other organics
Appendix IX Metals plus Sr and Sn (totals)
Thorium isotopes, gross alpha, gross beta

3.13 If the last turbidity measurement prior to the commencement of sampling showed turbidity to be greater than 5 Nephelometric Turbidity Units (NTUs), then filtered aliquots of ground water will be collected and analyzed for dissolved metals and dissolved thorium isotopes. Without turning off the pump, attach a disposable, inline, 0.45-um filter cartridge at the end of the discharge tube. Fill sample containers marked for "dissolved metals" and "dissolved thorium" so that the laboratory knows that these aliquots are distinct sample fractions and that the results should be reported as dissolved analytes.

3.14 Repeat steps 3.5 through 3.9 for the filtered sample containers.

3.15 After completion of sample collection, remove the bladder pump from well and decontaminate following the procedures in SOP CTO131-26.

3.16 Replace the outer protective well cap and lock the well.

3.17 All equipment should be cleaned and packed into the sample vehicle, along with the sample cooler for transport. Disposable gloves and other equipment should be placed in a plastic trash bag and handled as investigation derived waste (SOP CTO131-27).

4.0 ATTACHMENTS

1. Ground Water Sample Log Sheet

Tetra Tech NUS, Inc.

ATTACHMENT 1

GROUND WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Domestic Well Data
[] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	TBD	TBD
Time:	Visual	Standard	mS/cm	°C	NTU	mg/l		
Method:								

PURGE DATA:

Date:	Volume	pH	S.C.	Temp. (C)	Turbidity	DO	TBD	TBD
Method:								
Monitor Reading (ppm):								
Well Casing Diameter & Material								
Type:								
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:	Signature(s):

TBD: To Be Determined

STANDARD OPERATING PROCEDURE
NUMBER CTO131-20

PUMPING TESTS

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides technical guidance for the performance and evaluation of a low-flow pumping test in a permanent monitoring well located at or near the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. This type of test is performed when a well is undergoing low-flow purging for sampling purposes (see SOP CTO131-17). Thus, the purging of the well at a constant rate is considered equivalent to small, single-well pumping test. Water level data collected during this type of test can be evaluated using standard methods used to evaluate a larger single-well test in either a confined or unconfined aquifer. Information about the hydraulic properties of geologic materials will be generated by this type of test, and is necessary because the hydraulic properties of the geologic materials control the movement of ground water and contaminants at the site.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Submersible (capable of very low flow) or bladder pump
Pump cables and hoses
Compressed air cylinder, regulator, and fittings (for bladder pump)
Pressure transducers and data recorder, including instruction manual
Manual water level indicator
Pumping Test Data Sheets for Pumping Well
Generator
Gas tank
5-gallon bucket and stopwatch
55-Gallon Drum or Other Suitable Container to hold Purge Water
Decontamination Equipment and Supplies
Weighted tape
Field logbook
Measuring tape

3.0 PROCEDURES

Existing monitoring wells installed at the site during the 1980s and new wells to be installed during this investigation are scheduled to be sampled using low-flow sampling procedures; this effort will be performed in accordance with SOP CTO131-17 and -19. In conjunction with the standard sampling procedure, the water level in each well will be measured using a pressure transducer and automatic recording data logger to record water levels before, during, and after the low-flow sampling activities. Notes and other data related to the tests will be entered onto the standard "Pumping Test Data Sheet, Pumping Well" (a copy is attached at the end of this SOP). The procedure is summarized below:

3.1 Determine the total depth of the well using a weighted tape or other measuring device. A pressure transducer attached to a data logger shall be placed in the well approximately one foot from the bottom of the well. The pressure transducer will be lowered down the hole at the same time as the pump and its associated discharge tube and cables. The transducer will be positioned so that it is about 5 to 10 feet lower than the pump intake.

3.2 Record the well number, the transducer probe identification number being used, the PSI rating for each probe, the depth below top of casing where each probe is positioned, the static water level in the well, and any other information relative to the setup and performance of the pumping test. Data and information should be recorded in a bound field notebook and on the Pumping Test Data Sheet.

3.3 Set the data logger on the log cycle reading frequency and start recording data with the pump still off. Record the starting time for the data logger on the form sheet.

3.4 Manually measure the depth to water with a water depth indicator and enter the reading onto the form sheet, along with the corresponding transducer reading from the same time.

3.5 Observe the water-level readings over a 10 to 15 minute period and determine if the water level has stabilized since the pump was introduced to the well. Record the times and the readings on the form sheet.

3.6 Turn the pump on and set flow rate to approximately 100 mL/minute. Record the time the pump was started.

3.7 Measure the flow rate with a bucket of known volume and a stopwatch. Record the time and the flow measurement. Repeat this step about every 15 to 20 minutes to ensure that the pumping rate is relatively constant.

3.8 The data logger will record water level changes through the entire sampling process (i.e., filling the sample containers). The pump discharge for purging and sampling is typically set at a constant rate of about 100 to 300 mL/min. Field personnel will observe the transducer readings while well purging is in progress. If the water level stabilizes during the low-flow sampling, record the time when the water level stabilizes. During the pump test, check the data recorder occasionally to make sure it is recording properly. Make sure that drawdown will not cause transducer to be exposed.

3.9 Record the time period(s) when the pump is shut down for any reason during the sampling process and use every effort to minimize the time during which the pump is off.

3.10 After the sampling process is completed, field personnel will note if the water level in the well has stabilized during the purging and sampling process. **DO NOT TURN OFF THE PUMP AT THIS TIME.** Manually measure the depth to water in the well and record the manual measurement, as well as the transducer reading.

3.11 After one or two minutes have elapsed, step the data logger (if the data logger has this capability) or restart the data logger (starting the data logger at time zero). Record the time in the field notebook and the pump test when this occurs.

3.12 Increase the pump rate to approximately to 300 mL/min or more in order to cause a larger drawdown in the well. Continue to monitor and record the discharge flow rate at 15-minute intervals.

3.13 Continue pumping until the water level drops to approximately the top of the pump intake or stabilization of the water level occurs, pumping no longer than 60 minutes. Manually measure the depth to water after it has stabilized or at the end of 60 minutes, whichever occurs first. Record all manual water level measurements, pump discharge rate measurements, and the time of each measurement on the Pump Test Data Sheet.

3.14 After water level stabilization or 60 minutes of pumping at the higher rate, step the data logger, or stop and restart the data logger, to record pressure readings at short frequencies.

3.15 Stop the pump and measure the recovery of water level in the well using the pressure transducer. Record the recovery of water level in the well until 80% recovery has occurred, or 60 minutes elapses, whichever occurs first.

3.16 At the end of the recovery monitoring period, manually measure the depth to water. Record the manual measurement and the corresponding pressure transducer reading on the Pumping Test Data Sheet.

3.17 Remove the pressure transducer, the pump, and the cables from the well and thoroughly decontaminate, per SOP CTP131-26.

3.18 If there is an existing monitoring well or wells located adjacent (e.g., within 20 feet) to the pumping well being sampled and tested, manually record the water level in the non-pumping well at 5 to 10 minute intervals during the purging and sampling process. Measure the distance between the pumping well and the adjacent well(s) using a measuring tape, and record the distance and the identification number of each well in the field notebook. Record the time and the depths to water in the observation wells on a Pumping Test Data Sheet for Observation Wells (a blank form sheet is attached at the end of this SOP).

3.19 Check all field notes, copy, and place into one file for each test. Download the data recorder as soon as possible and check data. Make an electronic file and paper file of all data and place with the pumping test file for evaluation later. Confirm that the data is usable for the intended analysis prior to leaving the field.

4.0 PERSONNEL

A qualified geologist or hydrogeologist, having experience with these test procedures and equipment, will be needed for each sampling team to carry out the low-flow pumping tests.

5.0 ATTACHMENTS

1. Pumping Test Data Sheet

ATTACHMENT 1

Tetra Tech NUS, Inc.

PUMPING TEST DATA SHEET

PROJECT NAME: _____ PUMPING WELL NUMBER: _____
PROJECT NUMBER: _____ MEASURED WELL NUMBER: _____

( ) PUMPING TEST ( ) STEP DRAW DOWN TEST

DATE(s): MONITORING POINT:
MEASUREMENT METHOD: DEPTH CORRECTION (ft):
TEST NUMBER: PUMP SETTING (Ft. below monitoring point):
STATIC WATER LEVEL (ft): DISTANCE FROM PUMPING WELL (ft):
PERSONNEL:
REMARKS:

MILITARY TIME	ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	CORRECTION (Ft.)	DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	PUMPING RATE (GPM)	REMARKS

NOTE: All measurements to nearest 0.01 foot measured from top of well riser pipe unless otherwise noted.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-21

SURFACE WATER AND SEEP SAMPLING

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedure for collecting surface water and seep samples in the vicinity of the Mustard Gas Burial Ground, SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Surface Water Sample Log Sheet: A copy of this form is attached at the end of this SOP.

Field Logbook

Multi-parameter water-quality meter: The water-quality meter is used for the measurement of dissolved oxygen, pH, specific conductance, temperature, oxidation-reduction potential, and turbidity (see SOP CTO131-18).

LaMotte Turbidity Meter: Used to measure turbidity in the field.

Disposable sample containers: disposable sample containers are used to fill sample containers and transport sample(s) to a pump for filtering.

Labeled sample containers: Prelabeled, certified-clean sample containers will be provided by the laboratory that performs the analyses.

Sample Tags: One tag is to be completed and attached to each sample container.

0.45-micron filter assembly: These are single-use filter cartridges used to filter samples scheduled for dissolved metals or dissolved thorium isotope analyses. The filters become investigation-derived waste (IDW) after one use.

Peristaltic pump

Silicon tubing

Ziploc-type plastic storage bags

Shipping containers (coolers)

Trip Blank Sample **(if VOC samples are being collected)**

Temperature Blank

3.0 SURFACE WATER AND SEEP SAMPLING PROCEDURES

3.1 The same methods will be used to collect surface water and seep samples. Sampling will start at the downstream end of a stream and proceed to the farthest upstream location. The surface water and seep sample locations are shown on Figure 4-3 and discussed in Section 4.4.3 of this QAPP.

3.2 Gently remove any floating leaves or twigs, if present, that may be present in a sample pool area, in a manner that will not disturb the bottom sediment.

3.3 If the sample can be obtained from the shore, fill a decontaminated open-mouth drinking glass with sample water, move away from the sampling location, swish the water around all sides of the glass (inside and outside), and discard the water. Place the glass back in the water at the sampling location at a 45-degree angle and lower it to approximately half the sample pool depth. With the mouth of the glass facing upstream, fill the glass with water, being careful not to disturb the sediment.

3.4 If the sample cannot be obtained from the shore, carefully step into the water downstream of the sample location. Make certain that any disturbed sediment clears from the water before sampling. Begin sampling using a decontaminated glass. Obtain the sample upstream of your location. Hold the collection bottle at a 45-degree angle and lower it to approximately half the sample pool depth. With the mouth of the glass facing upstream, fill the glass with water, being careful not to disturb the bottom sediment.

3.5 Transfer the contents of the glass to the sample containers and cap the sample containers. All samples will be collected into certified-clean, pre-preserved bottles (if preservation is required for the analysis to be performed) supplied by the laboratory performing the analyses. Table 4-13 of this QAPP includes information on the preservative requirements for each type of analysis. Sample containers for volatile constituents (VOCs) must be completely filled, so that no headspace exists in the container. Other sample containers should <u>not</u> be filled completely; a small amount of air should be left at the top. Sample containers will be collected in the following sequence:

Volatile organic compounds (VOCs)
Other Organics
Total metals

Total thorium
Gross Alpha/Gross Beta
Total organic carbon (TOC)
Total suspended solids (TSS)
Dissolved metals
Dissolved thorium

3.9 Record the date and time that the sample containers are filled on the Surface Water Sample Log Sheet, the sample labels, the sample tags, and the Chain-of-Custody form.

3.10 After the sample label and sample tag are completed and checked, place the sample container into a ziploc-type plastic storage bag and then place the plastic storage bag holding the sample container into a cooler containing ice.

3.11 Repeat steps 3.3 through 3.10 until all the sample bottles containing unfiltered samples have been filled.

3.12 Fill two 1-liter unpreserved polyethylene bottles. Use these bottles to transfer the sample for field filtering. Set up a peristaltic pump for filtering of the dissolved metals and dissolved thorium samples. Using new, clean, disposable silicone tubing and a 0.45-micron filter, place the intake tubing from the pump into the transfer bottle with the filter attached to the discharge end and start the pump. Pre-rinse the filter with approximately 50-mL of sample water prior to filling the sample containers.

3.13 Using the discharge from the filter cartridge, fill two 1-liter polyethylene sample bottles, one for dissolved metals and one for dissolved thorium isotopes (see Table 4-13 in the QAPP). Repeat steps 3.9 and 3.10 for these sample containers.

3.14 Obtain measurements of dissolved oxygen, pH, specific conductance, temperature, turbidity, and oxidation-reduction potential using the multi-parameter water-quality meter and LaMotte Turbidity Meter (see SOP CTO131-18). Record the readings in the appropriate fields on the Surface Water Sample Log Sheet.

3.15 Estimate the flow rate of the stream or spring as per SOP CTO131-23. This is an estimate only. Round the flow rate to the nearest 5 gallons and record this number on the Surface Water Sample Log Sheet.

3.16 Decontaminate all equipment and load the equipment and the sample cooler in the sample vehicle for transport.

4.0 ATTACHMENTS

1. Surface Water Sample Log Sheet

ATTACHMENT 1

Tetra Tech NUS, Inc.

SURFACE WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Stream
[] Spring
[] Pond
[] Lake
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Time:								
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

STANDARD OPERATING PROCEDURE
NUMBER CTO131-22

SEDIMENT SAMPLING

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedure for sediment sampling in road ditches, surface water courses, and stream channels in the vicinity of the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

The following field forms and equipment are required for sediment sampling.

Sediment Sample Log Forms: A copy of this form is attached at the end of this SOP.
Bound Field Log Book
Tags for each Sample Container
Disposable Plastic Trowels
Survey Stakes and Flagging: Used to mark sampling locations after completion of sampling.
Labeled Sample Containers: See SOP CTO131-10 for sample identification procedures. Sample containers are certified clean by the laboratory supplying the containers.
Plastic Storage Bags
Shipping Containers (containing ice)
Surgical Gloves
Indelible Marker
Chain-of-Custody Form

3.0 SEDIMENT SAMPLE LOCATION SELECTION

The general locations where eight sediment samples should be collected in the vicinity of the MGBG are shown on Figures 4-2 and 4-3 of this QAPP. These general locations include low spots in dirt roads, low spots in road ditches, low spots in erosion gullies, and low spots in ephemeral stream channels. At each of these locations, surface water is seldom flowing. Therefore, sediment samples will be collected from areas of sediment accumulation where the sediment is dry, nearly dry, or moist. If standing or flowing

water is present at the general sampling location, then the sediment sample will be collected close to the edge of the water, but not from beneath the water.

In general, sediments composed of fine-grained materials with greater surface area available for adsorption, are more desirable for sample selection. The fined-grained materials may act as a sink or reservoir for adsorbing heavy metals and organic contaminants even if surface runoff concentrations are below detection limits. Therefore, it is important to locate the specific sampling points where the sediment has the greatest percentage of fine particles. The sampling personnel will determine specific sampling locations with these goals in mind.

3.0 SEDIMENT SAMPLING PROCEDURES

3.1 The sampler will wear clean, disposable, surgical gloves. Clear vegetative matter or debris, if present, from the sample location using a disposable sampling trowel or spoon. Use the trowel to dig up and homogenize the sediment in an 18-inch diameter circular area that is 6 inches deep. Stir the sediment within the circular area; do not move the sediment outside of the circle. Also, do not dig or stir sediment that is deeper than 6 inches below the ground surface.

3.2 Use the same trowel to scoop the homogenized sediment into the requisite labeled sample containers. Table 4-12 of this QAPP includes the bottle requirements for each type of sediment analysis. All sample jars will be filled in the following sequence:

Volatile Organics
TAL metals plus Sr and Sn (total)
Thorium isotopes, gross alpha, gross beta

3.3 Record the sample time (using military time) on the Sediment Sample Log Form and sample container labels and tags. Record all other information required on the labels and tags as specified by SOP CTO131-10.

3.4 Secure the tag to the neck of the sample container using a wire tie.

3.5 Place the tagged sample container into a plastic storage bag and then place the plastic storage bag holding the sample container into a cooler containing ice.

3.6 Record date, sampling site, site conditions, location map, and other information (e.g., presence and flow rate of water in channel) on the Sediment Collection Log Sheet. Enter the sample information onto the Chain-of-Custody form per SOP CTO131-25.

3.7 Using an indelible marker, write the sample ID on a survey stake, drive the stake into the ground at the sample location. Tack on a piece of brightly colored flagging to the stake. In addition, tie a piece of flagging to an overhead tree branch or other eye-level object to improve the ability to relocate the sampling site in the future.

4.0 ATTACHMENTS

1. Soil and Sediment Sample Log Sheet

ATTACHMENT 1

SOIL AND SEDIMENT SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA

	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Date:			
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA

	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Date:				
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle If Applicable

MS/MSD	Duplicate ID No.:

Signature(s):

STANDARD OPERATING PROCEDURE
NUMBER CTO131-23

ESTIMATING FLOW IN SMALL STREAMS

1.0 PURPOSE

This Standard Operating Procedure (SOP) provides technical guidance on the measurement of stream channel cross-section and flow in a small stream. Stream flow measurements will be obtained to evaluate the migration potential of contaminants in a stream channel. This method is applicable for free flowing streams with uniform flow and widths greater than 3 feet and depths greater than about 6 inches. Flow in the unnamed tributaries adjacent to the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane are expected to be low when surface water samples are collected. Stream flow rates will be measured at the same time when surface water samples are collected.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Measuring rod or yardstick
Measuring tape
Waders or rubber boots
Colored flagging tape
2x2 inch wooden stakes
Bound field logbook
Waterproof pen
Orange or apple
Surface water sample log sheet
Indelible marker
Stopwatch

3.0 PROCEDURES

3.1 Establish a transect across the stream, along a straight reach where the stream is relatively narrow and velocity across the stream is relatively uniform. Orient the transect perpendicular to the flow.

3.2 Mark both ends of the transect with colored plastic flagging tape. Tie the flagging to a tree branch or other elevated (about eye level) object. Pound wooden stakes into the ground at both ends of transect and tack a short piece of brightly colored flagging to the stakes. Use a black marker to identify the transect number, which will be the same as the surface water sample location.

3.3 Measure the total distance across the stream with a measuring tape and record the stream width (in feet) in the field logbook.

3.4 Measure the depth of water in the stream at three or four points across the stream. Record these measurements and calculate an average depth. Record the average depth (in feet) in the field logbook.

3.5 Measure a distance of 20 feet upstream of the transect. Tie a piece of flagging on a tree branch or other visable location above the stream.

3.6 Go another 20 feet upstream and place the orange or apple in the center of the stream or where the water current is fastest.

3.7 Using a watch with a timer or a stopwatch, measure the length of time it takes the orange (or apple) to travel from the first marker flag to the transect location (distance of 20 feet). Record the time.

3.8 Repeat step 3.7 two more times. Record the readings and calculate an average time.

3.9 Calculate approximate flow rate in the stream channel by multiplying the stream width (from step 3.3) times the average depth (from step 3.4) times the average velocity (from step 3.8). Record the estimated flow rate (in ft^3/s) in the field logbook and on the Surface Water Sample Collection Log Sheet.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-24

SAMPLE PRESERVATION, PACKAGING, AND SHIPPING

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures for sample preservation, packaging, and shipping to be used in handling ground water, surface water (including seeps), soils, and sediments collected at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Shipping labels

Custody seals

Chain-of-custody (COC) form(s)

Sample containers with preservatives: All sample containers for analysis by fixed-base laboratories will be supplied, with preservatives added (if required) and deemed certified clean by the laboratory.

Sample shipping containers (coolers): All sample shipping containers are supplied by the laboratory.

Packaging material: Bubble wrap, ZipLoc® bags, strapping tape, etc.

3.0 PROCEDURES FOR SAMPLE PRESERVATION, PACKAGING, AND SHIPPING

3.1 Table 4-13 of this QAPP establishes requirements for the preservation of aqueous samples. The laboratory provides sample containers with preservative already included (as required) for the analytical parameter for which the sample is to be analyzed. All samples will be held, stored, and shipped at 4°C. This will be accomplished through refrigeration (used to hold samples prior to shipment) and/or ice.

3.2 The sampler shall maintain custody of the samples until the samples are relinquished to another custodian or to the common carrier.

3.3 Check that each sample container is properly labeled (SOP CTO131-10), the container lid is securely fastened, and the container is sealed in a ZipLoc® bag.

3.4 If the container is glass, place the sample container into a bubble-out shipping bag and seal the bag using the self-sealing, pressure sensitive tape supplied with the bag.

3.5 Inspect the insulated shipping cooler. Check for any cracks, holes, broken handles, etc. If the cooler has a drain plug, make certain it is sealed shut, both inside and outside of the cooler. If the cooler is questionable for shipping, the cooler must be discarded.

3.6 Put ice into ZipLoc® bags and place a layer of the sealed bags on the bottom of the cooler. Place the sample containers into the shipping cooler on top of the ice in an upright position (containers will be upright, with the exception of the 40-ml vials). Place ZipLoc® bags of ice flat against the sides of the cooler. Continue filling the cooler with samples until the cooler is nearly full and the movement of the sample containers is limited.

3.7 Place a temperature blank in the cooler. Make sure that all samples identified for VOC analysis and their associated trip blank are packed in the same cooler (i.e., VOC samples and trip blank that were stored together during sampling activities can not be separated into different coolers for shipping purposes).

3.8 Add a final layer of ice sealed in ZipLoc® bags to the top of the samples just before the cooler is closed and sealed.

3.9 Place the original (top) signed copy of the COC form inside a large ZipLoc® bag. Tape the bag to the inside of the lid of the shipping cooler that contains the samples for VOC analysis.

3.10 Close the cooler and seal the cooler with approximately four wraps of strapping tape at each end of the cooler. Prior to wrapping the last wrap of strapping tape, apply a signed, numbered, and dated custody seal to each side of the cooler (one per side). Cover the custody seal with the last wrap of tape. This will provide a tamper evident custody seal system for the sample shipment.

3.11 Affix a shipping label to the top of the cooler containing samples for VOC analysis, ensuring all of the shipping information is filled in properly. Overnight (e.g., FedEx Priority Overnight) courier services will be used for all sample shipments.

3.12 All samples will be shipped to the laboratory no more than 72 hours after collection. Under no circumstances will sample hold times be exceeded (See Tables 4-12 and 4-13 of this QAPP for maximum hold times).

STANDARD OPERATING PROCEDURE
NUMBER CTO131-25

SAMPLE CUSTODY AND DOCUMENTATION OF FIELD ACTIVITIES

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedures for sample custody and documentation of field sampling and field analyses activities.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

The following logbooks, forms, and labels, are required.

Site Logbook
Field Logbook
Sample label
Chain-of-Custody form
Custody seals
Equipment Calibration Log
Monitoring Well Inspection Form
Water Level Measurement Form
Low-Flow Purge Data Sheet
Ground Water Sample Log Sheet
Surface Water Sample Log Sheet

3.0 PROCEDURES

This section describes custody and documentation procedures. All entries made into the logbooks, custody documents, logs, and log sheets described in this SOP must be made in indelible ink (black is preferred). No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single strike mark, initialed, and dated.

3.1 Site Logbook

The site logbook is a hardbound, paginated, controlled-distribution record book in which all major on-site activities are documented. At a minimum, the following activities/events shall be recorded (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start or completion of sampling activities
- Daily on-site activities performed each day
- Sample pickup information
- Health and safety issues
- Weather conditions

The site logbook is initiated at the start of the first on-site activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day that on-site activities take place.

The following information must be recorded on the cover of each site logbook:

- Project name
- Project number
- Book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). At the completion of each day's entries, the site logbook must be signed and dated by the Field Operations Leader (FOL).

3.2 Field Logbooks

The Field Logbook is a separate dedicated notebook used by field personnel to document his or her activities in the field. This notebook is hardbound and paginated.

3.3 Sample Labels

Adhesive sample container labels must be completed and applied to every sample container. Information on the label includes the project name, location, sample number, date, time, preservative, analysis, matrix, sampler's initials, and the name of the laboratory performing the analysis.

3.4 Chain-of-Custody Form

The Chain-of-Custody form (COC) is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as it is transferred from person to person. Each COC is numbered. This form must accompany any samples collected for laboratory chemical analysis. A copy of a blank chain-of-custody form is attached at the end of this SOP.

The FOL must include the name of the laboratory in the "Remarks" section to ensure that the samples are forwarded to the correct location. If more than one COC is necessary for any cooler, the FOL will indicate "Page __ of __" on each COC. The original (top) signed copy of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. Once the samples are received at the laboratory, the sample custodian checks the contents of the cooler(s) against the enclosed COC(s). Any problems are noted on the enclosed COC form (bottle breakage, discrepancies between the sample labels, COC form, etc.) and will be resolved through communication between the laboratory point-of-contact and the Task Order Manager (TOM). The COC form is signed and retained by the laboratory and becomes part of the sample's corresponding analytical data package.

3.5 Custody Seal

The Custody Seal is an adhesive-backed label with a number on each seal. It is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field and sealed in coolers for transit to the laboratory. The Custody Seals are signed and dated by the samplers and affixed across the opening edges of each cooler (two seals per cooler) containing environmental samples. The laboratory sample custodian will examine the Custody Seal for evidence of tampering and will notify the TOM if evidence of tampering is observed.

3.6 Equipment Calibration Log

The Equipment Calibration Log is used to document calibration of measuring equipment (e.g., multi-parameter water-quality meter) used in the field. The Equipment Calibration Log documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device requiring calibration. Entries must be made for each day the equipment is used.

3.7 Monitoring Well Inspection Form

The Monitoring Well Inspection Form is used to document the inspection of existing monitoring wells conducted in accordance with SOP CTO131-11.

3.8 Water-Level Measurement Form

The Water Level Measurement Form is used to document the determination of water levels in monitoring wells in accordance with SOP CTO131-16.

3.9 Low-Flow Purge Data Sheet

The Low-Flow Purge Data Sheet is used to document field measurements made while purging wells to stabilization in accordance with SOP CTO131-17.

3.10 Ground Water Sample Log Sheet

The Ground Water Sample Log Sheet is used to document the samples taken from a monitoring well at the end of low-flow well purging. This sheet is used in conjunction with SOP CTO131-19.

3.11 Surface Water Sample Log Sheet

The Surface Water Sample Log Sheet is used to document the samples collected from surface waters. This sheet is used in conjunction with SOP CTO131-21.

3.12 Soil and Sediment Sample Log Sheet

The Soil and Sediment Sample Log Sheets are used to document the sampling of soils and sediments. This sheet is used in conjunction with SOP CTO131-8 and SOP CTO131-22.

4.0 ATTACHMENTS

1. Chain-of-Custody Record

ATTACHMENT 1
CHAIN-OF-CUSTODY RECORD

TETRA TECH NUS, INC. | CHAIN OF CUSTODY | NUMBER | PAGE ____ OF _____

PROJECT NO:	SITE NAME:	PROJECT MANAGER AND PHONE NUMBER	LABORATORY NAME AND CONTACT:
SAMPLERS (SIGNATURE)		FIELD OPERATIONS LEADER AND PHONE NUMBER	ADDRESS
		CARRIER/WAYBILL NUMBER	CITY, STATE

STANDARD TAT ☐
RUSH TAT ☐
☐ 24 hr. ☐ 48 hr. ☐ 72 hr. ☐ 7 day ☐ 14 day

CONTAINER TYPE PLASTIC (P) or GLASS (G)
PRESERVATIVE USED
TYPE OF ANALYSIS

DATE YEAR	TIME	SAMPLE ID	MATRIX	GRAB (G) COMP (C)	No. OF CONTAINERS									COMMENTS

1. RELINQUISHED BY	DATE	TIME	1. RECEIVED BY	DATE	TIME
2. RELINQUISHED BY	DATE	TIME	2. RECEIVED BY	DATE	TIME
3. RELINQUISHED BY	DATE	TIME	3. RECEIVED BY	DATE	TIME

COMMENTS

DISTRIBUTION: WHITE (ACCOMPANIES SAMPLE) YELLOW (FIELD COPY) PINK (FILE COPY)

3/99
FORM NO. TINUS-001

STANDARD OPERATING PROCEDURE
NUMBER CTO131-26

DECONTAMINATION OF FIELD SAMPLING EQUIPMENT

1.0 PURPOSE

This Standard Operating Procedure (SOP) establishes the procedures to be followed when decontaminating non-dedicated field sampling equipment during the field investigations at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

Waterproof pens
Non-latex Rubber or Plastic Gloves
Cotton Gloves
Field Log Book
Potable Water
Deionized Water
LiquiNox Detergent
Brushes, Spray Bottles, Paper Towels, etc.
55-Gallon Drum or Other Container to Collect and Transport Decontamination Fluids

3.0 DECONTAMINATION PROCEDURES FOR SAMPLING EQUIPMENT

3.1 Don non-latex and/or cotton gloves and decontaminate sampling equipment (in accordance with the following steps) prior to field sampling and between samples.

3.2 Rinse the equipment with potable water. Rinsing may be conducted by spraying with water from a spray bottle or by dipping. Collect the potable water rinsate into a container.

3.3 Wash the equipment with a solution of LiquiNox detergent. Prepare the LiquiNox wash solution in accordance with the instructions on the LiquiNox container. Collect the LiquiNox wash solution into a container. Use brushes or sprays as appropriate for the equipment.

3.4 Rinse the equipment with potable water. Rinsing may be conducted by spraying with water from a spray bottle or by dipping. Collect the potable water rinsate into a container.

3.5 Rinse the equipment with deionized water. Rinsing may be conducted by spraying with water from a spray bottle or by dipping. Collect the deionized water rinsate into a container.

3.6 Remove excess water by air drying, shaking, or by wiping with paper towels as necessary.

3.7 Document decontamination by recording it in the Field Logbook.

3.8 Containerized decontamination solutions will be managed in accordance with the procedures described in SOP CTO131-27 and Section 4.12 of the CTO 131QAPP.

4.0 DECONTAMINATION PROCEDURES FOR PUMPING EQUIPMENT

This sequence of decontamination applies to the pump, hoses, cables, and other equipment placed in a monitoring well to obtain a groundwater sample.

4.1 Wash pump, hose, and cables in a tub containing potable water. Use brushes as appropriate.

4.2 Wash pump, hose, and cables in a tub containing LiquiNox wash solution. Use brushes as appropriate.

4.3 Rinse pump, hose, and cables in a tub containing clean potable water.

4.4 Pump clean potable water through pump and hoses for 15 minutes.

4.5 Drain and air dry all equipment.

4.6 Place decontaminated equipment into new plastic trash bags and store until next use.

STANDARD OPERATING PROCEDURE
NUMBER CTO131-27

MANAGEMENT OF INVESTIGATION DERIVED WASTE

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes how investigative derived waste (IDW) will be collected, segregated, classified, and managed during the field investigations at the Mustard Gas Burial Ground (MGBG), SWMU 1/12, NSWC Crane. The following types of IDW will be generated during this investigation:

- Excess soil and rock materials remaining from subsurface drilling activities
- Well development water and purge water related to monitoring well installation and sampling
- Decontamination solutions
- Personal protective equipment and clothing (PPE)
- Mustard gas and other chemical test kits
- Miscellaneous trash and incidental items

There is potential at the site for the IDW to be contaminated with mustard gas (a poison), thorium (radioactive), and organic and inorganic hazardous chemicals. Therefore, the careful segregation, containment, and classification of the wastes are essential to minimize the spread of contamination, minimize the risk of accidental exposure or spillage, and to ensure the proper disposal of all wastes.

2.0 REQUIRED FIELD FORMS AND EQUIPMENT

- Health and safety equipment
- Decontamination equipment
- Field logbook and indelible ink pen
- Plastic sheeting and/or tarps
- 55-gallon drums with sealable lids
- IDW labels for drums
- Waste water container tanks
- Plastic garbage bags

3.0 PROCEDURES

Management of IDW includes: the collection, segregation, temporary storage, classification, final disposal, and documentation of the waste handling activities.

3.1 Liquid Wastes

Liquid wastes that will be generated during the site activities include well development water, well purge water (collected during low-flow sampling), and decontamination solutions. As they are collected, these wastewaters will be placed in a 300-gallon (or smaller) portable tank attached to a truck. Whenever the portable tank approaches full, it will be transported to a central location at NSWC Crane (at the wastewater treatment plant or adjacent to a sanitary sewer manhole) where a 500-gallon (or larger) plastic holding tank will be located. The water in the portable tank will be transferred to the larger tank using a submersible pump.

An accurate record will be kept by the FOL of all wastewaters that have been placed in the large holding tank. At a minimum, this information will include:

- the location and type of each water that has been placed in the tank (e.g., purge water from well WES-1-3-81),
- the quantity of water from each source,
- the date the waste water was generated,
- the date and time the waste water was placed in the tank,
- the ID number of any sample associated with the waste water (e.g., sample MG-GW-WES3 would be associated with the purge water from well WES-1-3-81), and
- the person(s) present when the wastewaters were transferred to the holding tank.

When the larger holding tank is approaching full, an aqueous sample will be drawn from the tank using a disposable polyethylene bailer and analyzed for VOCs, SVOCs, total metals, gross alpha, and gross beta. The analytical results will be used to determine if the wastewater in the tank can be accepted for treatment by the NSWC Crane wastewater treatment facility. The TOM will track the progress of the laboratory analyses, and will forward the results to NSWC Crane immediately upon receipt. If the analytical results are acceptable to the wastewater treatment plant, then the wastewater will be pumped directly into the treatment plant or a manhole, using a submersible pump.

If the wastewater does not meet the wastewater treatment plant's acceptance criteria, then the wastewater must be treated and disposed of at an off-site location, as yet to be determined.

3.2 Soil Wastes

As soil cores are removed from a borehole, they will be screened for mustard gas, radioactivity, and VOCs. If these results do not show above-background levels of VOCs or radioactivity, and if the mustard gas screening results indicate that mustard gas is not present, then the excess soil materials will be mixed with bentonite and returned to the borehole when sampling activities in the hole are completed. The backfill materials will be tamped as they are placed in the hole to increase density and reduce permeability of the backfill material.

If any soil materials from a screened borehole interval (0 to 2 feet, 2 to 6 feet, or 6 to 10 feet) shows evidence of contamination (based on the field screening results), then the soil material from the screened interval will be placed in a plastic trash bag and the bag will be tagged. Information included on the tag will consist of the hole from which the material came, the depth interval from which the material came, the date, and the name of the person filling out the tag. The bag will then be placed in a 55-gallon drum and sealed (more than one bag may be placed in a drum). The waste drums will be stored at the MGBG temporarily until laboratory results have been received concerning the soil samples that were collected from the suspect borehole. If the results indicate that no contamination is present in the soil samples, OR the total concentrations of the contaminants are less than the RCRA TCLP limits, then the soils will be disposed of at the MGBG site. If the levels of contamination of any of the samples from a borehole exceed TCLP limits (using the total soil concentrations), then all excess soil from the borehole will be considered as RCRA-hazardous and disposed of offsite in accordance with RCRA waste disposal regulations.

If any soil materials from a borehole contain levels of radioactivity greater than [mean background + (3σ of the background measurements)] (based on the field screening results), then the soil material from the entire borehole will be placed in a plastic trash bag and the bag will be tagged. Information included on the tag will consist of the borehole from which the soil material came, the depth interval from which the soil material came, the date, and the name of the person filling out the tag. The bag will then be placed in a 55-gallon drum segregated for potentially radioactive waste and sealed (more than one bag may be placed in a drum). The waste drums will be stored at the MGBG temporarily until laboratory radioactivity analytical results have been received concerning the soil samples that were collected from the suspect borehole. If the laboratory results indicate that no contamination is present above radiological background levels in the soil samples, they will be considered non-radioactive waste. The bags of soil

must be compared to RCRA-hazardous and mustard gas limits. If concentrations are all within applicable limits, then the soils will be disposed of at the MGBG site. If the levels of contamination of any of the samples from a borehole exceed radioactive waste limits (using the total soil concentrations), then all excess soil from the borehole will be considered as radioactive (or mixed) waste and disposed of offsite in a suitable radioactive waste disposal facility.

If any soil samples from a borehole interval are found to contain mustard gas, then all soils from that borehole interval will be treated and disposed of in accordance with Army Recovered Chemical Warfare Material requirements.

If any soil samples from a borehole are found to contain radioactive and RCRA-hazardous wastes, then all soils from that borehole will be treated as mixed waste and disposed offsite in accordance with RCRA-hazardous and EPA-radioactive waste regulations.

3.3 Rock Wastes

Rock cores collected by diamond drilling will be stored in core boxes until the project is completed. If the ground water sample from the hole where the rock core was obtained does not contain detectable concentrations of mustard gas and does not contain concentrations of organic or inorganic chemicals above the TCLP criteria, then the rock cores will be treated as clean and disposed of, when needed, as regular trash or clean fill material. If not, then the rock core material will be handled as RCRA-hazardous and disposed of accordingly.

For the ground up rock that emanates from an air rotary rig, the material from each hole will be shoveled into a plastic-lined 55-gallon drum and will be stored temporarily until the ground water sample from the well is analyzed. Based on the analytical results, the material will be handled and disposed of in the same manner as described above for the rock core material.

3.4 PPE, Pump Discharge Tubing, and Incidental Trash

All PPE wastes, pump discharge tubes, and incidental trash materials (e.g., wrapping or packing materials from supply cartons, waste paper) will be double-bagged, securely tied shut, and placed in a designated waste receptacle at NSWC Crane.