N00164.AR.000896
NSWC CRANE
5090.3a

Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report

for

SWMU 2 - Dye Burial Grounds

Naval Surface Warfare Center, Crane Division

Crane, Indiana

Volume I of II - Text

NAVFAC
Naval Facilities Engineering Command

Southern Division
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0010

October 2004

030207/P

RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION (RFI) REPORT

FOR

SWMU 2 – DYE BURIAL GROUNDS

NAVAL SURFACE WARFARE CENTER
CRANE DIVISION
CRANE, INDIANA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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CONTRACT NUMBER N62467-94-D-0888
CONTRACT TASK ORDER 0010

OCTOBER 2004

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ACRONYM LIST

%R	Percent Recovery
°C	degrees Centigrade
°F	degrees Fahrenheit
µg/L	Micrograms per Liter
ALPEC	Ammunition Loading and Production Engineering Center
AMSL	Above Mean Sea Level
ANOVA	Analysis of Variance
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criterion
BAf	Bioaccumulation Factor
BCF	Bioconcentration Factor
BERA	Baseline Ecological Risk Assessment
bgs	Below Ground Surface
BTAG	Biological Technical Assistance Group
CAAA	Crane Army Ammunition Activity
CASCO	Central Ammunition Supply Control Office
CCME	Canadian Council of Ministers of the Environment
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CFR	Code of Federal Regulations
CLEAN 3	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
CMS	Corrective Measures Study
COC	Chain of Custody
COPC	Chemical of Potential Concern
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
CTO	Contract Task Order
DE	Depositional Environment
DEPA	Danish Environmental Protection Agency
DI	Deionized

DO	Dissolved Oxygen
DPT	Direct-Push Technology
DQI	Data Quality Indicator
DQO	Data Quality Objective
EDQL	Ecological Data Quality Level
EEQ	Ecological Effects Quotient
EPC	Exposure Point Concentration
EPIWIN	Estimation Program Interface for Windows
ERA	Ecological Risk Assessment
EUC	European Union Commission
FD&C	Food, Drugs, and Cosmetics
FID	Flame Ionization Detector
FOL	Field Operations Leader
FSP	Field Sampling Plan
FTMR	Field Task Modification Record
GPM	Gallons per Minute
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HSS	Hollow-Stem Auger
HSWA	Hazardous and Solid Waste Amendments
IAS	Initial Assessment Study
ICR	Incremental Cancer Risk
IDEM	Indiana Department of Environmental Management
IDW	Investigation Derived Waste
IRIS	Integrated Risk Information System
K_{oc}	Organic Carbon Partition Coefficient
K_{ow}	Octanol/Water Partition Coefficient
LCS	Laboratory Control Sample
LICR	Lifetime Incremental Cancer Risk
LOAEL	Lowest-Observed-Adverse-Effects Level
mg/kg	Milligrams per Kilogram
MCL	Maximum Contaminant Level
MEQ	Milliequivelants

mg/L	Milligrams per Liter
MHSPE	Ministry of Housing, Spatial Planning and Environment
MK	Morrison-Knudsen, Inc.
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NACIP	Navy Assessment and Control of Installation Pollutants
NAD	Naval Ammunition Depot
NAD83	1983 North American Datum
NAVFAC	Naval Facilities Engineering Command
NCEA	National Center for Environmental Assessment
NEESA	Naval Energy and Environmental Support Activity
NFESC	Naval Facilities Engineering Service Center
NGVD88	1988 National Geodetic Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-Observed-Adverse-Effects Level
NSWC	Naval Surface Warfare Center
NTU	Nephelometic Turbidity Unit
NWSCC	Naval Weapons Support Center Crane
OMOE	Ontario Ministry of Environment and Energy
OPPTS	Office of Prevention, Pesticides, and Toxic Substances
ORNL	Oak Ridge National Laboratory
ORP	Oxidation Reduction Potential
OSWER	Office of Solid Waste and Emergency Response
Pa	Vapor Pressure
PAET	Probable Apparent Effects Threshold
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PID	Photoionization Detector
pka	Acid Dissociation Constant
PPE	Personal Protection Equipment
PRG	Preliminary Remediation Goal
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAM	Quality Assurance Manager
QAPP	Quality Assurance Project Plan
QC	Quality Control

QSAR	Quantitative Structure-Activity Relationship
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RFC	Reference Concentration
RfD	Reference Dose
RFI	RCRA Facility Investigation
RME	Reasonable Maximum Exposure
RPD	Relative Percent Difference
RPM	Remedial Project Manager
RQD	Rock Quality Designation
SCS	Soil Conservation Service
SDG	Sample Delivery Group
SdSLs	Sediment Screening Levels
SEL	Screen Effects Level
SERA	Screening-Level Ecological Risk Assessment
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedure
SSL	Soil Screening Level
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
SWSL	Surface Water Screening Level
TAL	Target Analyte List
TEC	Threshold Effects Concentration
TEQ	Toxicity Equivalent
TOC	Total Organic Carbon
TOM	Task Order Manager
TRV	Toxicity Reference Value
TSD	Treatment, Storage, or Disposal
TSS	Total Suspended Solids
TtNUS	Tetra Tech NUS, Inc.
U.S. ACE	U.S. Army Corps of Engineers
U.S. EPA	U.S. Environmental Protection Agency
UCL	Upper 95 Percent Confidence Limit
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
VOC	Volatile Organic Compound

WES	Waterways Experiment Station
WQC	Water-Quality Criteria
WQS	Water-Quality Standards

EXECUTIVE SUMMARY

This report documents the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) for Solid Waste Management Unit (SWMU) 2, Dye Burial Ground (DBG), located at the Naval Surface Warfare Center (NSWC), Crane, Indiana. Tetra Tech NUS, Inc. (TtNUS) prepared this report for the Department of the Navy (Navy) Southern Division (SOUTHDIV) Naval Facilities Engineering Command (NAVFAC) under Contract Task Order (CTO) 0010, Comprehensive Long-Term Environmental Action Navy (CLEAN) III, Contract Number N62467-94-D-0888.

PURPOSE OF REPORT

The report summarizes RFI field activities conducted in year 2001, describes the nature and extent of contamination, and presents human health and ecological risk assessments. All RFI fieldwork and the development of the baseline human health and ecological risk assessment (HHRA) were conducted in accordance with the U.S. EPA Region 5 approved Work Plan for Risk Assessment at SWMU 2 [Tetra Tech NUS, Inc. (TtNUS), May 2001].

SWMU 2 DESCRIPTION

Military smoke dyes and dye-contaminated materials were disposed at the site. Unknown amounts of the specific dyes were buried at the site. Materials reportedly included magnesium, boxes, and rags contaminated with dyes, and open-topped drums of dye. Currently, the site is inactive (i.e., it is not used for waste disposal activities) and an interim-measures cap, which included permanent grass vegetation, has been installed. SWMU 2 lies approximately 500 feet southwest of the crest of a north-northwest trending ridge separating Sulphur Creek and Little Sulphur Creek. SWMU 2 is approximately 12.4 acres in area and consists of a grass-covered cap (4.2 acres), woods (7.8 acres), and one main gravel road (0.4 acre).

PHASE III RFI PROGRAM

The most recent (year 2001) investigation, which is the subject of this report, was a Phase III RFI. The objectives of this investigation were to:

- Refine estimates of the nature and extent of contamination.
- Evaluate human health risks through a baseline risk assessment.

- Estimate risks to the environment through a screening level ecological risk assessment.
- Determine whether an interim cap placed over the DBG is preventing chemical contaminant migration.

The Phase III RFI is intended to support any future RCRA Corrective Measures Study (CMS). Any future CMS will be conducted to identify and evaluate cleanup alternatives for the site. The main focus of that CMS would be to determine whether additional remedial actions are required or if the interim measures already conducted were sufficient to control contaminant migration from the source and, thus, mitigating the potential risks to human and ecological receptors.

FIELD AND ANALYTICAL PROGRAM FOR SWMU 2

Dyes were the primary constituents of concern for the analytical program for soil, ground water, surface water, and sediment. In addition, soil, sediment, surface water, and ground water samples were collected and analyzed for metals per 40 Code of Federal Regulations (CFR) Part 264 Appendix IX, as well as other miscellaneous inorganics. Surface water samples were also analyzed for total and dissolved metals, hardness, and total suspended solids (TSS) and sediment samples were also analyzed for total organic carbon (TOC) to assist in assessing the potential risks for ecological receptors. Additionally, soil characteristic parameters [cation exchange capacity (CEC) and TOC] were collected to determine the likelihood of the potential fate and transport of contaminants at the site (and the potential for risks outside the site boundaries).

HUMAN HEALTH RISK ASSESSMENT

The human receptors evaluated for SWMU 2 were the construction worker, adolescent trespasser, adult recreational user and future adult and child residents. Human exposure pathways for SWMU 2 that were evaluated were surface soil, subsurface soil, ground water, surface water, and sediment.

ECOLOGICAL RISK ASSESMENTS

A screening ecological risk assessment was conducted at SWMU 2. The ecological receptors that were evaluated in the screening assessment included:

- Those directly exposed to chemicals in the surface water, sediment, and surface soil (i.e., plants, soil invertebrates, and aquatic organisms), and

- Those indirectly exposed to chemicals via the food chain (i.e., through the ingestion of plants and invertebrates).

- As presented in Tables 7-1, 7-2, and 7-3 several chemicals were eliminated as COPCs because they were not detected at concentrations greater than background concentrations. For soil, these chemicals included aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, selenium, vanadium, and zinc. For sediment, these chemicals included aluminum, antimony, arsenic, beryllium, cadmium, chromium, iron, lead, nickel, selenium and vanadium. Manganese was eliminated as a COPC for surface water because site concentrations did not exceed background concentrations. Therefore, risks to these chemicals were not evaluated in the ERA, however, any risks would be within background risks and not related to site activities. Note that the use of background concentrations to select chemicals as COPCs was done in accordance with the approved work plan for SWMU 2. However, based on current U.S. EPA and Navy guidance, background will not be used to select chemicals as COPCs for future ERAs at NSWC Crane.

CONCLUSIONS

Upon evaluation of the data obtained during this investigation, consideration of site operational history, data generated during past investigations, and the development of baseline human health risk assessment and screening-level ecological risk assessment for SWMU 2, the following conclusions were reached:

- The soils, ground water, surface water, and sediment data collected during the RFI were adequate to support the development of baseline human health and screening-level ecological risk assessments for SWMU 2.

- Dyes, that were the primary constituents of concern at SWMU 2, were not detected in surface soil, ground water, surface water, or sediment. Two dyes, Acid Orange 10 and Acid Yellow 23, were detected infrequently in subsurface soil samples at concentrations that were below levels of concern.

- SWMU 2 incremental cumulative cancer risks for all human receptor pathways were estimated to be within, or less than, the EPA National Contingency Plan risk range of 10^{-6} to 10^{-4}; therefore, the Navy believes the risk is acceptable.

- Non-carcinogenic hazard estimates [hazard indices (HIs)] calculated for all human receptors were less than unity which is the threshold value for non-carcinogenic hazard, for all exposure pathways other than ground water exposure pathway for SWMU 2.

- Non-carcinogenic hazard estimates all human receptors for the ground water exposure pathway were greater than unity for SWMU 2. However, the exposure point concentrations were primarily influenced by one ground water sample that exhibited an unusually low pH (3.7). The elevated metals concentrations in this particular sample were due to the increased solubility of geologic materials in the acidic environment. The well (02C11P3) where this pH was observed is the most down gradient of the capped area. Intervening wells did not exhibit acid pH. The acidic conditions at this location are believed to be attributable to the geology of this well location. Therefore, the elevated metals concentrations are not attributable to the disposal of materials at the DBG.

- Because of the installation of the cap and because the dyes buried at the site since 1952 have not resulted in dye migration into the ground water (e.g., no dyes were detected in the RFI samples), additional ground water monitoring is not required.

- Risks to terrestrial plants and invertebrates from organic and inorganic chemicals in the surface soil in SWMU 2 were estimated to be low to negligible.

- Risk to aquatic receptors from organic and inorganic chemicals in surface water and sediments were estimated to be low to negligible.

- The interim cap including land use control is acceptable as a final corrective measure.

- A land use control plan should be developed and implemented to prevent land uses that could result in disturbing the integrity of the cap.

- An operation and maintenance (O&M) plan should be developed and implemented to insure the integrity of the cap.

Table ES-1 contains a summary of receptor-specific human risks and hazards, ecological risks, identifies critical pathways and chemicals of concern, for SWMU 2 and, where necessary, recommendations for further actions.

TABLE ES-1

SUMMARY OF RECEPTOR-SPECIFIC HUMAN RISKS, AND HAZARDS AND ECOLOGICAL RISKS, AND RECOMMENDATIONS
SWMU 2 (DYE BURIAL GROUND)
NSWC CRANE
CRANE, INDIANA

Receptor Population	Environmental Media	Overall Carcinogenic Risk (Human)	Overall Hazard Index (Human)	Overall Risk (Ecological)	Critical Pathways & Chemicals of Concern	Recommendations
Future Construction Workers (Adult)	Surface and Subsurface Soil	1.2E-08	0.008	NA	NA	NFA
Future Recreational User (Adult)	Surface Water and Sediment	3.2E-08	0.009	NA	NA	NFA
Current/Future Trespassers (Adolescent)	Surface Water and Sediment	1.7E-08	0.02	NA	NA	NFA
Future Resident (Adult)	Ground Water	2.3E-05	3.8 (1)	NA	Ingestion of ground water (arsenic and nickel)	Implement land usage controls to prevent disturbance of the cap.
Future Resident (Child)	Ground Water	2.0E-05	13 (2)	NA	Ingestion of ground water (aluminum, arsenic, cadmium, cobalt, and nickel)	Implement land usage controls to prevent disturbance of the cap.
Terrestrial Plants and Invertebrates	Surface Soil	NA	NA	acceptable	NA	NFA
Mammals and Birds	Surface Soil, Sediment, and Surface Water	NA	NA	acceptable	NA	NFA
Aquatic Organisms	Surface Water and Sediment	NA	NA	acceptable	NA	NFA

NA = Not applicable.
NFA = No further action.
1 Excluding the results for ground water sample 02GWC11P301, the calculated hazard index is 0.3.
2 Excluding the results for ground water sample 02GWC11P301, the calculated hazard index would be 1.2 and all target organ hazard indices would be below 1.0.

1.0 INTRODUCTION

This Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report was prepared for the Naval Surface Warfare Center (NSWC) facility located in Crane, Indiana, through the U.S. Navy Southern Division Naval Facilities Engineering Command (NAVFAC) under Contract Task Order (CTO) 0010, for the Comprehensive Long-Term Environmental Action Navy (CLEAN 3), Contract Number N62467-94-D-0888. This RFI report addresses one solid waste management unit (SWMU), SWMU 2 (Dye Burial Grounds) at which bags, boxes, and drums of dyes, rags contaminated with dyes, and magnesium were reportedly buried between about 1952 and 1964. The purpose of this RFI Report is to present the results of the investigations and the human health and ecological risk assessments. These risk assessments were conducted using the data resulting from the field investigations.

1.1 PROJECT OBJECTIVES AND SCOPE

The objective of this RFI was to conduct the activities necessary to complete RFI activities, including a baseline human health risk assessment (HHRA) and a screening-level ecological risk assessment (SERA). The plan was to establish the nature and extent of contamination and complete the risk assessments, then draw conclusions concerning whether further activities are warranted at the site. The identification and evaluation of remedial alternatives for the site would be documented in a corrective measures study (CMS) if corrective measures were warranted.

The objectives for this RFI have been attained. This report describes and documents how those objectives were attained.

This report has been prepared in the following format for an RFI Report. Section 1.0 of the report is this introduction, including the project scope, objectives, and background information. Section 2.0 describes field sampling activities associated with the round of data collection described in the approved work plan [Tetra Tech NUS, Inc. (TtNUS), May 2001]. Section 3.0 is a summary of the data evaluation procedures and data quality for the data collected as part of this investigation. Section 4.0 presents an evaluation of the nature and extent of contamination detected at SWMU 2. Section 5.0 presents the statistical methodology and evaluation of the data collected and a discussion of the fate and transport considerations associated with contaminants at SMWU 2. Sections 6.0 and 7.0 present the human health and ecological risk evaluations, respectively, that were conducted as part of this RFI. The Executive Summary presents the overall project conclusions and recommendations that were formulated after

review of all the data collected at SWMU 2. Supporting documentation for this report is attached as Appendices A through H.

This document has been prepared in accordance with the Navy Installation Restoration Laboratory Quality Assurance Guide (Interim Guidance) of the Naval Facilities Engineering Service Center (NFESC, 1996).

1.2 BACKGROUND

1.2.1 Facility Location and Description

NSWC Crane is located in the southern portion of Indiana, immediately east of Crane Village and Burns City. The facility is approximately 75 miles southwest of Indianapolis and 71 miles northwest of Louisville, Kentucky (Figure 1-1). NSWC Crane encompasses approximately 100 square miles (62,463 acres); the majority of the facility is located in the northern portion of Martin County. Smaller portions of the facility are located in Greene, Davies, and Lawrence Counties. NSWC Crane is located in a rural, sparsely populated area. Most of the facility is forested, and the surrounding area is wooded or farmed land. NSWC Crane provides naval support for equipment, shipboard weapons systems, and ordnance. In addition, NSWC Crane supports the Crane Army Ammunition Activity (CAAA) with production and renovation of conventional ammunition and storage, shipment, demilitarization, and disposal of conventional ammunition (Murphy, 1992b). More detailed descriptions of NSWC Crane and SWMU 2 are provided in Section 5.0 of the RFI work plan (TtNUS, May 2001). The location of SWMU 2 is shown on Figure 1-1.

1.2.2 History of Ownership and Operation

In 1940, Congress authorized construction of a Naval Ammunition Depot (NAD) in southern Indiana, and the Naval Ammunition Depot Burns City was commissioned in late 1941. In 1943, NAD Burns City was renamed NAD Crane, and the town of Crane was built to house the rapidly growing number of civil service employees. NAD Crane's overall mission was to load, prepare, renovate, receive, store, and issue ammunition to the fleet.

During World War II, NAD Crane's mission expanded to include pyrotechnics production, mine filling, rocket assembly, field storage, torpedo storage, and ordnance spare parts and mobile equipment storage. During the 1950s, several new departments were created, the Ammunition Loading and Production Engineering Center (ALPEC) was transferred to Crane, and the Central Ammunition Supply Control Office (CASCO) was established. NAD Crane supplied ammunition to the fleet during the Korean and

Vietnam Conflicts. During the Southeast Asia crisis, the number of full-time employees at NAD Crane grew to 6,800.

In 1975, NAD Crane was designated Naval Weapons Support Center Crane (NWSCC). Its new mission was to provide support for ships, aircraft, equipment, shipboard weapons systems, and assigned ordnance items and to perform additional functions as directed.

In 1977, the Single Manager Concept was implemented. The CAAA was created, and the Army assumed ordnance production, storage, and related responsibilities as a tenant organization. Other functions remained Navy, and currently the Navy retains ownership of all real estate and facilities at NSWC Crane. Responsibility for overall station safety, security, and environmental protection remains with the Commanding Officer, NSWC Crane. In 1992, the facility was designated as Naval Surface Warfare Center Crane (NSWC Crane). Presently, approximately 4,000 people are employed at NSWC Crane.

1.2.3 History of Regulatory Actions

Following promulgation of the United States Environmental Protection Agency (U.S. EPA) RCRA hazardous waste regulatory program, NSWC Crane filed notification and application to operate as a RCRA hazardous waste treatment, storage, or disposal (TSD) facility in October 1980. Interim status was granted subject to operating requirements and applicable technical standards found in 40 CFR Part 265.

Corrective action programs, established as part of the 1984 RCRA Hazardous and Solid Waste Amendments (HSWA), required NSWC Crane to address past releases of hazardous waste or hazardous constituents at SWMUs. Accordingly, NSWC Crane submitted a Hazardous Waste Management Report to the U.S. EPA in January 1985. Following the Hazardous Waste Management Report, a RCRA facility assessment (A.T. Kearney, Inc., 1987) was conducted to characterize the potential for releases of hazardous waste or constituents from 100 SWMUs identified during the assessment.

On December 23, 1989, U.S. EPA issued the federal portion of the Final RCRA Part B permit for NSWC Crane to the U.S. Navy. U.S. EPA renewed the permit in 1995. The Indiana Department of Environmental Management (IDEM) now has responsibility for the Federal Corrective Action Program. IDEM recently (October 18, 2001) renewed the Corrective Action Permit. However, ongoing corrective actions will continue under the U.S. EPA IDEM Work Sharing Agreement for Corrective Action Activities at the Naval Surface Warfare Center - Crane Division and the Naval Surface Warfare Center Crane Division Partnering Agreement of July 2000 among the U.S. Navy, U.S. EPA, and IDEM.

The RFI investigation of SWMU 2 was conducted in accordance with the requirements indicated in the Corrective Action Permit.

1.2.4 SWMU 2 Operations

Little information is known about the operational history of the Dye Burial Grounds. The site map for SWMU 2 is presented as Figure 1-1. The approximate boundaries of the site are provided. Although it is known that military smoke dyes and dye-contaminated materials were disposed at the site, no records are available on the specific dyes and quantities. It is estimated that 50,000 pounds of dyes and dye-contaminated materials were deposited in open trenches from 1952 to 1964. Materials reportedly included magnesium, boxes, and rags contaminated with dyes, and about 60 open-topped drums of dye. The sizes of the drums are not known.

SWMU 2 consists of at least four main trenches. Although three trenches were originally thought to be present at the site, additional trenches were located during historical site investigations. The original three trenches are each approximately 10 feet wide, 6 feet deep, and 50 feet long. These three trenches are aligned end to end. All the trenches are situated atop a ridge. All the trenches reportedly were backfilled to the ground surface with soil in 1972, but were not permanently capped. NSWC Crane placed crushed rock along a roadway immediately north of the trench area in 1987 to facilitate access by well drilling vehicles [U.S. Army Corps of Engineers (U.S. ACE), 1998].

Geophysical surveys were conducted at the site in January 1991 to delineate the boundaries of the disposal activities. The results of the survey indicated that there are approximately 17 unidentified anomalies located at the site that may be attributable to site operations and may contain dye-contaminated material. Historically, these disposal activity areas have been referred to as either disposal trenches or waste areas.

1.2.5 Interim Measures Cap Installation

An interim measures cap design was developed for the site (Glynn, Bennett, and Stark, 1995) to minimize potential threats to human health and the environment by the mitigation of the migration of contaminants to ground water. The limits of the cap were identified using the geophysical survey information. The construction of a multi-layered cap began in 1996. The interim measures cap system, from the bottom to the top, consists of:

- Foundation fill
- Geotextile cushion layer
- Geosynthetic clay liner with hydraulic conductivity (K) less than 1 x 10^{-8} cm/sec (Glynn et al., 1995)
- High-density polyethylene geomembrane liner
- 6-inch sand drainage layer [K greater than 1 x 10^{-2} cm/sec (Glynn et al., 1995)] with an overlying geotextile filter fabric
- Perimeter drainage collection system to transport infiltration water away from the cap
- 6-inch gravel biotic barrier layer [K greater than 1 x 10^{-1} cm/sec (Glynn et al., 1995)] with an overyling geotextile filter fabric
- 27-inch cover layer with a vegetated surface

The site was restored by establishing permanent grass vegetation in all disturbed areas and removing debris and trash.

During site preparation (clearing activities), dye-contaminated materials were found outside the planned limits of the cap. An investigation of the extent of contamination outside the cap limits was performed in early July 1996. This investigation consisted of the excavation of 12 potholes approximately 24 inches deep. Dyes were visually observed in eight of the potholes.

NSWC Crane and the U.S. EPA conducted an additional investigation into contamination located outside the planned limits of the cap in early August 1996. Several additional areas and trenches containing dyes and dye-contaminated materials were found during this field investigation. Some of the disturbed areas were deeper and/or wider than the three trenches that were originally thought to comprise the site. Some samples of the various dyes encountered during this investigation were collected by NSWC Crane and are stored at the Base. These samples were subsequently used for development of analytical methods to detect the presence of dyes in various media. Results of the NSWC Crane and U.S. EPA investigation are included in the Interim Measures Completion Report [Morrison Knudsen Corporation (MK), 1999].

The interim measures cap was expanded to include some of the newly identified disturbed areas, thereby delaying the construction of the cap.

In 1997, a revised Work Plan for Interim Measures Cleanup at SWMU 2 was prepared by MK to address the residual contamination found outside the planned cap limits (MK, 1999). Excavation of dye-contaminated soils at the disturbed areas began in November 1996. No confirmatory samples were collected to verify that all residual contamination was removed from the disturbed areas.

As precipitation runoff began collecting in dye-contaminated soil excavations, surface water management became a significant issue. During the winter months, cap construction activities ceased, and dewatering of the western end of the cap excavation was required to manage surface water runoff. Dye-impacted water from the excavations was pumped to three 500-barrel tanks, which were located in a centralized staging area at the site.

Following a large storm, an uncontrolled release of dye-impacted surface water runoff occurred on January 22, 1997. The release occurred on the northside berm of the western (southwestern) excavation, extending to approximately 40 feet north of the berm. The released water was pumped into the tanks. Some of the released water froze on the ground surface. Approximately 9 cubic yards of contaminated ice and soil stuck to the ice were placed into mud boxes. At completion, a total of eight tanks and two mud boxes were required to contain the waste material.

In late 1997, during the construction of the foundation fill for the cap, seeps of dye-contaminated water were observed primarily in the northeastern and northwestern areas within the cap limits. A seepage collection system was constructed at the northeastern area. Liquid was pumped to the tanks; the system was closed after construction of the foundation fill was completed. In September 1998, the cap was completed at the Dye Burial Grounds. The NSWC Crane Laboratory analyzed samples of the dye-contaminated water collected from the tanks (MK, 1999). Following U.S. EPA and IDEM approval, the water in the tanks was designated as non-toxic. In September 1998, the dye-contaminated water was disposed in the NSWC Crane wastewater treatment plant.

Currently, no activities or operations are being conducted at SWMU 2. This investigation was undertaken with the expectation that the cap would remain undisturbed for the foreseeable future and that land use controls to prevent future disturbances would be instituted at a future date.

1.3 PREVIOUS INVESTIGATIONS

A brief description of the historical data collection activities conducted at SWMU 2, Dye Burial Grounds, is contained in this section. A tabular summary of the previous investigations completed for the site is presented in Table 5-1 of the RFI Work Plan (TtNUS, May 2001).

Various investigations were performed at SWMU 2 between 1981 to 1986 as part of several multi-site investigations. The first such study was the Initial Assessment Study (IAS), which was initiated in April 1981 in response to the Navy Assessment and Control of Installation Pollutants (NACIP) Program. The IAS was performed by the Naval Energy and Environmental Support Activity (NEESA) and was completed in May 1983 (NEESA, May 1983) with assistance from the Ordnance Environmental Support Agency and the U.S. ACE WES. The intent of the IAS was to identify and assess sites posing a potential threat to human health and the environment from past hazardous materials operations.

During the installation of eight monitoring wells (wells 02-01 through 02-08) along the perimeter of the site, soil samples were collected and tested for various soil characteristics. After the monitoring wells were installed, ground water samples were collected and analyzed for a comprehensive list of chemical constituents and RCRA water-quality parameters. As part of the IAS, both quarterly and semi-annual sampling of the monitoring wells was initiated at Dye Burial Grounds. Based on the initial conclusions of the IAS, it was determined that disposal activities at Dye Burial Grounds did not present an immediate human health or environmental threat. However, the site was recommended for further study to evaluate potential long-term impacts.

In response to the recommendation presented in the IAS, an RFI Phase II Ground Water Assessment was performed at the Dye Burial Grounds in 1987-1990 (U.S. ACE, March 1991). The objective of the study was twofold: to further refine the nature and extent of contamination at the site and to further refine the hydrogeology at the site. Twelve well clusters (i.e., 33 additional individual wells - labeled 02C09 through 02C19) were installed. In 1988, 26 monitoring wells and one seep were sampled and analyzed for priority pollutant constituents.

The RFI Phase III ground water release characterization commenced in October 1990 with the addition of three monitoring wells (labeled 02C20 through 02C22). In addition to refinement of the nature and extent of contamination, the objective of this effort was to determine regional and site hydrogeology, including distribution of aquifers, characteristics of ground water flow, and the influence of stratigraphy and geologic structure on ground water and constituent migration. This study included the collection of four rounds of

ground water samples from the 44 monitoring wells. These samples were analyzed for Appendix IX constituents, explosives, and miscellaneous water-quality parameters.

In 1991, a geophysical investigation was conducted at the site to delineate the boundaries of the dye burial trenches and identify buried anomalies (see Section 1.2.4). Several anomalies were observed, in addition to the three known trenches.

From June 1996 though September 1998, interim measures (i.e., construction of a cap system) were implemented at the site (see Section 1.2.5). The interim measures included site clearing, relocating an access road, establishing stormwater controls, excavating dye-impacted materials, constructing the multi-layered cap system, and managing and disposing of dye-impacted water. During the site clearing, dye-contaminated soils were found outside the planned limits of the cap. In August 1996, U.S. EPA and NSWC Crane conducted a field investigation. This investigation included the advancement of shallow borings at multiple locations in order to determine the extent of the burials. Dye-contaminated materials were excavated and placed in the subgrade of the area to be capped. Confirmation of excavation was performed by visual observation that no dye remained in the area surrounding the cap. Confirmation sampling was not conducted.

Based on past investigations of ground water and observations made during installation of the Interim Measures multilayered cap, the military dyes were identified as contaminants of primary interest for this investigation. The past investigations provided no quantitative chemical information on dye concentrations at SWMU 2, however visual observations during the installation of the multilayered cap did reveal the presence of dyes in soil. Soil stained with dyes was excavated and placed under the cap. Magnesium is the only metal identified in historical records as having been disposed at SWMU 2, however there was some uncertainty concerning whether or not other metals could have been disposed at SMWU 2. Sampling indicated that only dissolved metals concentrations were observed in the ground water. Although dissolved metals were detected in ground water at concentrations suspected to represent local background conditions they were conservatively retained for further investigation because of the uncertainty associated with their disposal. Only dyes and metals were identified as requiring further investigation as part of this Phase III RFI.

The historical ground water data are summarized in Section 5.0 of the approved Work Plan for this project and the historical metals data are provided in Section 4.0 of this RFI report. As stated in Section 5.5.2.1 of the approved Work Plan, the sampling undertaken in this investigation was designed to be biased toward those locations most likely to be contaminated with dyes if dye contamination persisted at SMWU 2.

Analytical methods for quantification of the dyes in aqueous and solid environmental media were developed, validated, and approved for use by U.S. EPA Region 5 prior to undertaking this Phase III investigation. Dyes disposed at SWMU 2 did not contain metals.

1.4 GENERAL CHARACTERISTICS OF NSWC CRANE AND SWMU 2

1.4.1 Physiography and Topography

NSWC Crane is located in the unglaciated area of the Crawford Uplands physiographic division. This division is described as a rugged, highly vegetated, dissected plateau that is bounded by the Mitchell Plain Physiographic Province to the east and the Wabash Lowland Physiographic Province to the west (Perry and Smith, 1958). The Mitchell Plain is described as 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, eastward-facing Chester Escarpment. Springs, caverns, caves, and other solution weathering features can be found along this escarpment and on the eastern edge of the Facility.

The terrain is predominantly rolling, with moderately incised stream valleys throughout and occasional flat areas in the central and northern portions of NSWC Crane. Deciduous trees and shrubs cover most of the region. The elevations across the Facility range from about 500 feet above mean sea level (AMSL) to about 850 feet AMSL. Greenwood Lake extends west to east across the northern part of the Facility. Topographic relief in the Crawford Upland ranges from 100 to 350 feet (Figure 1-1). Greater relief exists in the eastern part of NSWC Crane near the Chester Escarpment [U.S. ACE Waterways Experiment Station (WES), 1995]. A topographic and surficial geologic map of the entire facility was compiled by Kvale (1992) and Blunck (1995) using U.S. Geological Survey 7.5 minute quadrangle maps (Indian Springs, Scotland, Koleen, Owensburg, Odon, Williams, Loogootee, and Shoals).

The topography of the Dye Burial Grounds is relatively rugged, consisting of a series of steep-sided, narrow ridges and valleys. The SWMU lies approximately 500 feet southwest of the crest of a north-northwest trending ridge separating Sulphur Creek from Little Sulphur Creek. The elevation of SWMU 2 is approximately 740 feet AMSL and rises toward the crest, which is at an elevation of approximately 770 feet AMSL (Figure 1-2).

1.4.2 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 degrees Fahrenheit (°F) to an average minimum January temperature of 26°F. Precipitation is fairly evenly distributed throughout the calendar year; the maximum precipitation is 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 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.

1.4.3 Hydrology

The surface drainage at NSWC Crane has formed a dense, dendritic pattern throughout the installation that flows generally to the south and southwest. Seven primary creeks in five drainage basins carry surface water off the installation, where it eventually drains into the East Fork of the White River and then to the Wabash River to the southwest. The seven creeks that drain NSWC Crane are Furst Creek, Sulphur Creek, Little Sulphur Creek, Boggs Creek, Turkey Creek, Indian Creek, and Seed Tick Creek. Boggs, Sulphur, and Turkey Creek all flow to the south, ultimately exiting NSWC Crane property. Figure 1-1 shows the surface drainage features and the individual drainage basins at NSWC Crane.

Drainage Basin IV consists of Boggs and Turkey Creeks, which are the primary drainageways for the installation and drain the majority of the NSWC Crane area. The northern and northwestern sections (Basin I) are drained by Furst Creek, the eastern portion (Basin III) is drained by the Sulphur Creek complex, the extreme eastern portion (Basin II) is drained by Indian Creek (not shown on Figure 1-1), and the southwestern section (Basin V) is drained by Seed Tick Creek.

Also located within the installation are several small ponds and Lake Greenwood, an 800-acre man-made, spring-fed lake in the northwestern portion of the installation. Lake Greenwood is the main source of water at NSWC Crane and it is also used for recreation (NEESA, May 1983).

The main surface drainage from SWMU 2 is to the south and southwest into Little Sulphur Creek. The majority of the drainageways were dry during the field investigation, which limited surface water sampling

to one location (02SW07). A seep was identified on a slope southwest of the site. Figures 1-2 and 1-3 show the site features, drainageways, and topography. Surface drainage from the ridgetop, where SWMU 2 is located, flows to the west and south into small unnamed tributaries of Little Sulphur Creek (Figure 1-2). These drainageways are dry, except during significant rainstorm and snowmelt events when runoff is occurring. These channels drain south and southwestward for about 2000 feet before they enter the Little Sulphur Creek channel (Figure 1-3). At this juncture, the Little Sulphur Creek channel is also usually dry. Little Sulphur Creek becomes a perennial stream about one mile farther downstream, where several small to moderately-sized springs discharge ground water from Mississippian limestone formations (e.g., "spring C").

Near SWMU 2, Little Sulphur Creek travels about 3.5 to 4.0 stream miles southward before it enters Sulphur Creek beyond the property boundary of NSWC Crane (Figure 1-3). Sulphur Creek travels southwestward to join Indian Creek, which in turn flows southeastward to join the White River.

1.4.4 Geology and Stratigraphy

1.4.4.1 General Geology and Stratigraphy

The geology at NSWC Crane is generally characterized by thin overburden deposits overlying bedrock. The overburden deposits generally range in depth from the surface down to 65 feet below ground surface (bgs) (U.S. ACE WES, September 1998). These deposits generally consist of two types: Quaternary age unconsolidated deposits and unconsolidated residual soil derived from the underlying bedrock. Bedrock underlying the Facility consists of sedimentary rock from the Lower Pennsylvanian-age Raccoon Creek Group and the Upper Mississippian-age Stephensport and West Baden Groups (Figures 1-4 and 1-5. The following subsections describe the unconsolidated deposits and bedrock at NSWC Crane in greater detail.

1.4.4.2 Unconsolidated Deposits

The Quaternary-age deposits consist of alluvial and colluvial deposits, consisting of silt, sand, and gravel; lacustrine deposits consisting of clay, silt, and sand; and loess deposits consisting of clay and silt.

Residual soils at NSWC Crane were derived from the underlying sedimentary rocks of the Lower Pennsylvanian Raccoon Creek Group and the Upper Mississippian Stephensport and West Baden Groups. These soils consist of clay, silt, sand, and fragmented and/or partially weathered bedrock.

Using the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) soil classification system (McElrath, 1988), the soil at NSWC Crane has been classified into 23 different soil series. Each

of these soil series is defined by various soil characteristics (e.g., grain size, erosion, slope, drainage, parent material, or depositional source, etc.) specific to each series. Within these soil series, various sub-classes or soil map units have been defined.

Soil types at NSWC Crane were further evaluated during a basewide background soils investigation conducted by TtNUS in 2001 (TtNUS, January 2001). The objectives of the investigation were to identify and characterize soils based on three factors, depositional environment, grain size, and depth. A total of 16 soil types were identified and evaluated in the report, based on combinations of these three factors. Four depositional environments were identified, based on the mapped geologic parent material (Figure 1-4). Three predominant grain sizes were identified, clay, silt, and sand, and two depths (surface and subsurface) were identified. Soil samples were collected to establish representative background metals concentrations for each of the 16 soil types.

Based on the classification scheme developed in the base-wide background soil study (TtNUS, 2001), the soils encountered at SWMU 2 fall into three different soil classifications. The surface soils (0-2 feet bgs) all belong to Group 3 (surface soils, undifferentiated). The subsurface soils (2-10 feet bgs) are all derived from weathered Pennsylvanian bedrock. These subsurface residual soils are classified as Group 8 soils (subsurface, residual Pennsylvanian bedrock, silt or silty clay) or Group 9 soils (same as 8 except coarser; primarily sand). These groupings will be discussed further in Section 4.0.

1.4.4.3 Bedrock

Bedrock underlying NSWC Crane consists of sedimentary rock units that are Lower Pennsylvanian and Upper Mississippian. The Lower Pennsylvanian bedrock (Raccoon Creek Group) at the site consists primarily of interbedded sandstone, siltstone, shale, and coal with a total thickness varying from 0 to more than 300 feet (Fisher, 1996). The underlying Mississippian bedrock consists of limestones, shales, and sandstones (U.S. ACE WES, 1995; Palmer, 1969). The topographic relief on the erosional unconformity surface between the Pennsylvanian and Mississippian bedrock has been measured to be as much as 100 feet (Kvale, 1992).

Pennsylvanian bedrock is absent in the deepest, present-day drainage channels (e.g., Sulphur Creek, Turkey Creek) primarily due to erosion. In these locations, the Mississippian-age bedrock is exposed. A large number of SWMUs are located on ridges or other topographically high areas, primarily on top of Pennsylvanian bedrock. The surficial geology illustrating the mappable geologic units at NSWC Crane is provided as Figure 1-4. An outline of the SWMU 2 boundary is included in the figure, which illustrates the type of geologic material underlying the SWMU.

The following paragraphs provide brief descriptions of the geologic formations, as described by Palmer (1969), U.S. ACE WES (1995), and Kvale (1992). They are presented from youngest (first) to the oldest units. These geologic units are also illustrated on the stratigraphic column (Figure 1-5).

- The uppermost bedrock unit beneath the Dye Burial Ground includes the Lower Pennsylvanian Mansfield Formation of the Raccoon Creek Group. This unit contains primarily shale, siltstone, and sandstone units, with an approximate total thickness of 40 to 50 feet. The sandstone unit has been further divided and forms the Upper and Lower Pennsylvanian aquifers.

- The Hardinsburg Formation is found immediately below the Mississippian-Pennsylvanian unconformity and is relatively uniform in thickness. This unit contains primarily shale and is approximately 20 to 30 feet thick. The Hardinsburg serves as an aquiclude between the Mansfield sandstone units and the underlying Golconda/Haney Limestone.

- The underlying Golconda Formation is characterized by shaley limestone and limey shales. The thickness ranges from several feet to almost 20 feet. The Golconda/Haney forms the middle aquifer of the Dye Burial Grounds.

- The Big Clifty Formation is divided into two distinctly different lithologic members. The upper member is known as the Indian Springs shale and is approximately 20 feet thick. The Indian Springs serves as an aquiclude at the base of the Golconda/Haney aquifer. The lower member of the Big Clifty Formation consists of 30 to 40 feet of tan to green-gray massive to thick-bedded, fine grained, friable sandstone.

- Beech Creek Limestone Formation consists of fossiliferous, hard, and dense limestone. Joints in the limestone were sparse to numerous in core recovered from the 18 well borings that penetrated the unit. The Beech Creek Limestone displayed moderate to extensive solution-enlarged jointing at another site within NSWC Crane (U.S. ACE WES, 1988). The thickness of this unit ranges from 20 to 25 feet.

- The Elwren Formation consists of a shale and averages approximately 20 feet in thickness; however, the exact thickness beneath the Dye Burial Ground is unknown since none of the borings at the site completely penetrated this unit. The Elwren serves as an effective aquiclude at the base of the Beech Creek Limestone. The base of the Beech Creek (top of the Elwren) is exposed in several

places in the valleys surrounding the Dye Burial Grounds. Ground water typically becomes perched along the Elwren surface and forms springs along valleys that expose this unit to the surface.

- Lower Sample Formation consists of dark greenish-gray shale (Lower Sample), fossiliferous limestone (Beaver Bend Limestone), and a calcareous sandstone and shale (Bethel Formation). The thickness of this unit ranges from 50 to 60 feet.

- Paoli Limestone consists of oolitic limestone and limestone (undifferentiated). The thickness of this unit is at least 35 feet (based on exposure in Boone Hollow at the northeastern corner of the Facility).

Structurally, NSWC Crane is located on the eastern edge of the Illinois Structural Basin, where the Pennsylvanian and Mississippian-age bedrock dips to the west-southwest and southwest at approximately 30 to 35 feet per mile (U.S. ACE WES, 1982; Kvale, 1992). Locally, however, the dip of the Mississippian bedrock can range from 0 to 15 feet per mile to as much as 100 feet per mile to the southwest (in Sulphur Creek) (Kvale, 1992).

1.4.4.4 SWMU 2 Site Geology

The shallow subsurface materials at the Dye Burial Grounds included fill, natural unconsolidated materials, and bedrock. Figure 1-2 shows the locations of the hydrogeologic cross-sections. Figures 1-6, 1-7, and 1-8 show the hydrogeologic cross sections A-A', B-B', and C-C'; respectively. A description of each of the subsurface materials is included in the remainder of this section.

Fill exists beneath the capped area as the result of buried waste material and was also encountered in borings in the surrounding vicinity of the SWMU. Fill was encountered in all the soil borings drilled at the Dye Burial Ground in July 2001 by TtNUS, with the exception of 02SB16 and 02SB17 (Figure 1-2). The fill encountered during the TtNUS investigation consists of reworked natural material composed of silt and clay mixtures. No evidence of buried waste or dye was found in the borings drilled by TtNUS. Fill extends to a maximum depth of approximately 9 feet beneath the ground surface. Thicker sequences of mounded fill exist as cover material overlying bunkers in the immediate SWMU area.

Natural unconsolidated materials (residual soil formed on the Pennsylvanian bedrock) either underlie the fill or exist at the ground surface where the fill is not present. The natural unconsolidated material consists of silt and clay mixtures, with a maximum thickness of approximately 10 feet, and extends downward to the Pennsylvanian bedrock surface (see Figures 1-6 through 1-8).

1.4.5 Hydrogeology

1.4.5.1 Basewide Hydrogeology

U.S. ACE WES (1988) discussed regional ground water trends pertaining to the unglaciated southwestern portion of Indiana. In general, ground water is contained in joint openings of limestone and sandstone aquifers. Surficial unconsolidated aquifers are thin and have limited potential as water supplies.

Aquifers beneath NSWC Crane are considered to be vertically isolated from each other by interlayered shale beds, which act as aquitards. Ground water recharge in the unconsolidated surficial materials occurs through rainfall infiltration at the ground surface. Ground water recharge in the underlying bedrock units can occur where aquifer units crop out or from vertical downward migration through joint openings from overlying units. After entering an aquifer outcrop, ground water flows by gravity down the dip of the aquifer unit. Given that the regional dip of rock units is to the southwest, regional ground water flow in all aquifers is expected to flow toward the southwest (U.S. ACE WES, August 1998).

Local variations in bedding, dip, aquifer and aquitard thicknesses, the presence or absence of fractures, incision by surface drainage, and karstic conditions cause local ground water movement at NSWC Crane to differ from regional trends. Where erosion resulting from surface drainage has cut through aquifer units, springs and seeps are produced, resulting in ground water discharge. Springs and seeps are prevalent at contacts between aquitards and overlying aquifers. Ground water flowing from springs and seeps into surface water can potentially re-enter the ground water system as recharge to a lower aquifer outcropping downstream below aquitards.

In the eastern portion of NSWC Crane, U.S. ACE WES (1988) hypothesized that karstic conditions are present primarily in major drainage valleys where erosion has cut into permeable sandstones overlying easily dissolved limestone units. Rapid infiltration in the Big Clifty Sandstone has caused dissolution and weathering of the underlying Beech Creek Limestone. The result of this occurrence has been the creation of karst and collapse conditions along major drainageways within the eastern part of NSWC Crane.

1.4.5.2 SWMU 2 Hydrogeology

The upper soil materials on the top and sides of the ridge at SWMU 2 are unsaturated. Four zones of water-bearing bedrock units belonging to three aquifers have been investigated at the site. The sandstone belonging to the Lower Pennsylvanian Mansfield Formation is the uppermost aquifer. This

aquifer exists under the SWMU 2 cap area and extends to the north, south, and west; and is terminated on the sides of the ridge where the ground surface intersects the unit. Although Lower Pennsylvanian rocks are present on the ridgetop to the east and northeast of SWMU 2, the sandstone aquifer is absent (e.g., 02C09 well cluster, Figures 1-6 and 1-8). In a small area beneath the eastern half of SWMU 2 area and to the south of SWMU 2, the sandstone aquifer is divided into two parts by a discontinuous lens of shale (Figures 1-6 and 1-7). For this reason the aquifer has been divided into two parts that are referred to in this report as the "Upper Pennsylvanian aquifer" and "Lower Pennsylvanian aquifer." These names are not formal and only apply to this one ridgetop area. Beneath the western portion of SWMU 2 and extending to the south and the east, the sandstone aquifer is not divided by the shale lens. In this area, the upper portion of the Pennsylvanian aquifer is dry. As such, the "Upper Pennsylvanian aquifer" is considered absent. It only exists in a very small area under SWMU 2 (Figure 1-9). All wells screened in the lower portion of the Pennsylvanian aquifer to the north, west, and south of SWMU 2 are classified as "Lower Pennsylvanian aquifer" wells.

Both the physical and saturated extent of the Upper Pennsylvanian aquifer have been described by the U.S. ACE (U.S. ACE 1998). The aquifer is identified as the Upper "B" sand unit on Figure 1-9. The boundary of the Upper Pennsylvanian aquifer is identified where the ground surface slopes downward, intersecting the unit. Ground water in the Upper Pennsylvanian aquifer flows toward the north and southeast, based on the most recent water-level measurements taken by TtNUS in July 2001 (Figure 1-9). The potentiometric surface elevation of the Upper Pennsylvanian aquifer is at approximately 718 feet AMSL. The relatively small areal extent of the Upper Pennsylvanian aquifer limits the distance of possible ground water flow in this aquifer. It is expected that ground water in this aquifer drains vertically into the underlying Lower Pennsylvanian aquifer. Upper Pennsylvanian ground water does not appear to discharge to the surface, because no visible seeps exist where the Upper Pennsylvanian aquifer would be expected to terminate along the slopes of the hills bordering the site.

Ground water in the Lower Pennsylvanian aquifer flows to the southwest toward Little Sulphur Creek at an approximate gradient of 0.01 foot/foot (Figure 1-10). Ground water exists in the Lower Pennsylvanian aquifer under unconfined conditions and the approximate potentiometric surface elevation is 684 feet AMSL beneath SWMU 2. Ground water in this aquifer either seeps out at a very low rate along the hillside or seeps downward into the next underlying aquifer.

Both the upper and lower sandstones of the Pennsylvanian aquifer lie on top of the ridge directly beneath the surface soils. Rainfall and snowmelt percolating downward through the residual soil recharges these sandstone units. Recharge occurs mainly where fractures in the sandstone intersect the bedrock surface. Thus, recharge may be high in a few local areas, and lower in other unfractured portions of the sandstone

aquifer. This concept of uneven distribution of recharge to the Pennsylvanian sandstone aquifer will be used in Section 4.0 to help explain anomalous distributions of and specific conductance in the aquifer.

The Golconda/Haney aquifer is separated from the Pennsylvanian sandstone aquifer above by the Hardinsburg shale, which is approximately 20 to 30 feet thick at the site. The Hardinsburg serves as an aquitard to vertical migration of ground water. Ground water in the Golconda/Haney aquifer north of the site flows to the east, southeast, and south. Figure 1-11 presents the ground water contours. The ground water in this aquifer beneath SWMU 2 flows toward a trough located southwest of the site. Ground water south of the unit flows to the northwest toward the same trough. This hydraulic trough coincides with a structural trough previously identified by U.S. ACE (1998). Ground water in the Golconda/Haney aquifer flows at a gradient of about 0.03 to 0.06 foot/foot under unconfined conditions, and the approximate potentiometric surface elevation is 650 feet AMSL immediately below SWMU 2.

The Beech Creek aquifer (which includes Big Clifty Sandstone) is separated from the shallower aquifers by the Indian Springs shale, which comprises the upper member of the Big Clifty Formation. The Indian Springs shale is characterized as an aquiclude at the bottom of the Golconda/Haney aquifer. Ground water in the Beech Creek aquifer flows under unconfined conditions toward the southwest and Little Sulphur Creek at a gradient of approximately 0.007 foot/foot. Figure 1-12 presents the Beech Creek aquifer ground water contours. The bottom of the Beech Creek aquifer is bounded by the Elwren Shale, which lies continuously beneath the SWMU.

1.4.6 Demography and Land Use

NSWC Crane is situated in a rural area of south-central Indiana. The surrounding communities that form the region are in a period of transition from an economic base of agriculture, mining, and quarrying to an economy built on manufacturing and service industries. The patterns of settlement, population statistics, and median income are similar throughout the region.

There is no state or local planning within the vicinity of NSWC Crane. The only zoning and land use regulations are found in the municipalities within the region. None of these municipalities are close enough to have an impact on NSWC Crane. None of the areas adjacent to NSWC Crane are zoned, and zoning is not anticipated in the near future. This separation distance of approximately 2,760 feet from the nearest eastern NSWC Crane property boundary and the multilayer cap will preclude any off-site impacts. There are no known land use or community actions under consideration or proposed at this time. Current land use at SWMU 2 can be observed by viewing the 1998 aerial photograph provided in Figure 1-13, and by using Figure 1-14 (showing the location and direction of site photographs) in combination with

Figure 1-15 (showing the site photographs taken March 11, 2002). The current and former land use of SWMU 2 is briefly described in the following sections.

1.4.7 Ecology

1.4.7.1 Basewide Ecology

NSWC Crane is a heavily forested facility situated within the Western Mesophytic Forest Region, Hill Section, and Beech-Maple Forest Region (Braun, 1950). Lindsey et al. (1970) further subdivided the area of the installation into the south-central Oak and Mixed Woods Division, including the Beech-Maple and the Beech-Oak-Maple-Hickory sub-elements. Deam (1940) classified the portion of Martin County in which the Facility is located as consisting of the Chestnut Oak Upland, based on the dominant floral components at that time. More recently, Kuchler (1964) mapped this portion of Indiana and classified it as belonging to two distinct vegetation classes, the Oak-Hickory and the Beech-Maple forest components of the Broadleaf Forest Classification. This latter classification most closely resembles the current floristic components observed at the Facility during the ecological studies conducted as part of this program.

The site also contains old agricultural fields in various stages of biological 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 included hickory, white and black oak, red maple, sugar maple, tulip poplar, ash, and beech (NEESA, May 1983). Cleared areas at the Facility have various stages of grassland, oldfield, and scrub/shrub vegetational forms present.

The great variety of habitats present at the Facility (many stages of forest succession, streams, ponds, Greenwood Lake, and grassy open spaces) support a variety of wildlife species. The white-tailed deer is the most conspicuous large wild mammal at the installation. Other mammals include opossum, raccoon, rabbits, mice, bats, chipmunks, squirrels, beaver, groundhogs, gray fox, coyotes, and long-tailed weasel. Fox, coyotes, and hawks are carnivores whose presence indicates a healthy ecosystem because smaller mammals are present to provide a food source (NEESA, May 1983). The threatened and endangered Indiana Bat may be present in the vicinity of SWMU 2.

The birds at NSWC Crane are diverse. Previous studies at the Facility have identified over 100 species present at the site during breeding seasons (Hengeveld, 1987). Because the Facility is largely forested, the species found at the site consist predominantly of those species that frequent wooded habitat types. There are also species of waterfowl that use the facility especially in the vicinity of Lake Greenwood

(Figure 1-1). A large number of bird species frequent the non-forested grassland, oldfield, and scrub/shrub vegetation present over portions of NSWC Crane.

An Endangered Species Management Plan for NSWC Crane was prepared in October 2000 (Comarco Systems, Inc., 2000). As part of this plan, the federal and state endangered and threatened species and species of special concern for the facility were identified. This was accomplished by the compilation of a large amount of information on species present at NSWC Crane. Information included in the Endangered Species Management Plan (Comarco Systems, Inc., 2000) was obtained from studies and surveys conducted by the Navy and other agencies and groups (such as research institutions). A small subset of these studies include the Inventory of Neotropical Migratory Birds, Mist Net and Radiotelemetry Surveys for the Indiana bat, Bobcat Trapping, Rattlesnake Survey, Purdue University Wildlife Studies, and several fish surveys and bird counts. These studies and others that were used in compiling a list of endangered species present at NSWC Crane are described in more detail in the Endangered Species Management Plan (Comarco Systems, Inc., 2000).

Numerous wildlife species are present throughout NSWC Crane. Of these species, some are listed as endangered and threatened species or species of special concern. NSWC Crane occupies Daviess, Greene, Lawrence, and Martin counties in Indiana, although only a very small portion of NSWC Crane is in Daviess, Greene, and Lawrence counties. The Fanshell pearly mussel, tubercled blossom, ring pink, and clubshell are listed as federally endangered species within Martin, Daviess and Lawrence counties. Additionally, the Northern riffleshell and rough pigtoe are listed as federally endangered species in Martin County. These invertebrate species are not likely to be present at SWMU 2 because they prefer medium to large rivers with moderate currents and gravel substrates as habitat. The habitat that these species prefer is absent at NSWC Crane. Additionally, none of these species was identified in Comarco Systems Inc., 2000 as observed at NSWC Crane. The Indiana bat is listed as federally endangered in Greene, Lawrence, and Martin counties but not in Daviess County. See Section 7.2.5.1, Carnivorous Birds and Mammals, for a discussion of the likelihood that the Indiana Bat is present at SWMU 2. Only the bald eagle is listed as a federal threatened species in all four counties. The bald eagle is not likely to be present at SWMU 2 due to a lack of vast expanses of water (i.e., the preferred hunting habitat for the bald eagle) at this SWMU. There are no records of any other species at NSWC that are federally listed as endangered or threatened.

Ten species listed as endangered by the Indiana Department of Natural Resources have been recorded at NSWC and include the Indiana bat, bobcat, timber rattlesnake, bald eagle, osprey, loggerhead shrike, yellow crowned night heron, Virginia rail, king rail, and Henslow's sparrow (Comarco Systems Inc., 2000). No state-listed threatened species have been recorded at NSWC Crane. Bald eagles (as discussed

above) and ospreys are not expected to occur at SWMU 2 due to the absence of preferred foraging habitat (large open waters). Similarly, the Virginia rail and king rail are found in marshes and mudflats, the Henslow's sparrow is found in damp fields, and the yellow crowned night heron is primarily a bird of swamps. These habitats are absent from SWMU 2. The loggerhead shrike prefers open fields with scattered trees, but is occasionally found in open woodlands. Thus, use of the site by the loggerhead shrike would be occasional at most.

Some species that are listed as Federal species of concern in Comarco Systems, Inc. (2000) are also state endangered species (IDNR, 2002). These include the Northern Harrier (Daviess County), American bittern (Greene County), and sedge wren (Lawrence County). These species are not endangered in Martin County. The majority of NSWC Crane is located in Martin County and so it is unlikely that operations at NSWC Crane are affecting these species' populations significantly. See Section 7.7.1 for a discussion of the uncertainties associated with not quantitatively evaluating risks to these species in the ERA.

Previous studies conducted at NSWC Crane (Nelson et al., 1987) identified 21 amphibian species and 22 reptile species (including skinks, lizards, snakes, and turtles). As part of the Endangered Species Management Plan for NSWC Crane (Comarco Systems, Inc., 2000), federal and state endangered and threatened species and species of special concern for the facility were identified, and included one reptilian species. The timber rattlesnake (Comarco Systems Inc., 2000) was identified as a federal endangered species. No state-listed threatened species have been recorded at NSWC Crane. The prime timber rattlesnake habitat is forested land on higher dry ridges with a south or southwestern exposure. SWMU 2 is located on a high dry ridge, so it is possible that the timber rattlesnake is present at the SWMU.

The Rare Animals of Indiana list (Indiana DNR, 2002) was reviewed to verify that no change in status of the timber rattlesnake had occurred since October 2000. This list is much larger than that presented in Comarco Systems, Inc. (2000) and is not reiterated here; however, it was verified that the timber rattlesnake did not experience a change in status. Also, the County Distribution of Indiana's Federally Threatened, Endangered, Proposed, and Candidate Species list (USFWS, 2002) was reviewed to verify that no change in status had occurred since October 2000.

A total of 46 distinct fish species were collected from the installation during a 1987 inventory of the fish fauna at NSWC Crane. Other than Lake Greenwood, the 1987 study observed that the greatest number of individual fish species were recorded from the largest stream (Boggs Creek) and the smallest number of species were recorded from Turkey Creek. Boggs Creek contained 29 species including eight species

of fish characteristic of large river type systems. This included long-nose gar, paddlefish, bowfin, gizzard shad, ribbon shiner, bigmouth buffalo, channel catfish and flathead catfish. By contrast, the Turkey Creek survey yielded 16 species of fish, none of which were unusual. The Sulphur Creek drainage was surveyed and yielded a total of 19 species. Four species from this drainage were not found anywhere else on the installation including southern redbelly dace, blacknose dace, black bullhead, and blackside darter.

The wildlife habitats and vegetation types present at NSWC Crane support a diverse terrestrial and aquatic fauna. The abundance of wildlife on the site is due in large measure to the mixture of land forms and vegetation types that occur over the installation. In addition, the lack of agricultural pressures has enhanced the wildlife abundance and served to provide an installation wide "wildlife enclosure" condition. There is an adequate amount of forage materials, concealment opportunities, and shelter locations to support a highly diverse wildlife community at the site.

The above site conditions do not represent a static condition; rather, the dynamic nature of site development, changes in land use, and changes in the operational emphasis occurring at the installation all affect the wildlife community in some way. For this reason, it is important in considering the operational activities associated with SWMU 2 in this RFI Report. The environmental stresses that have occurred in the past will continue through the present and into the future given continuation of the current operational programs at the installation. For consideration, these environmental stresses have been divided into two categories: naturally occurring stresses and man-made stresses. The following subsections consider the stresses that are attributable to each of these categories.

1.4.7.2 Local Ecology

Dye Burial Grounds (SWMU 2) is approximately 12.4 acres in area and consists of a grass-covered cap (4.2 acres), woods (7.8 acres), and one main gravel road (0.4 acre). The Dye Burial Grounds cap is covered with dense grass; all trees have been cleared from the cap. The tree line is approximately 15 feet from the edge of the cap. Dominant tree species include black oak (*Quercus velutina*), white oak (*Quercus alba*), pignut hickory (*Carya spp.*), and yellow poplar (*Populus spp.*). These stands are relatively young; the average diameter ranges from 6 to 12 inches. No scrubs or shrubs are present; leaf litter, limbs, and fallen saplings cover the understory.

Terrestrial habitats (i.e., wooded areas and grasses) near the site may provide shelter and food sources for various species of mammals such as white-tailed deer, coyote, red fox, rabbits, raccoons, and mice

and of birds such as ducks, geese, wild turkey, bobwhite quail, red-tailed hawks, and American robins. The threatened and endangered Indiana Bat may be a potential receptor at SWMU 2.

The bird population includes a number of threatened, endangered, or species of special concern that use the site as their home range. These species include the bald eagle, osprey, sharp-skinned hawk, red-shouldered hawk, broad-winged hawk, black and white warbler, hooded warbler, and the worm-eating warbler (B&R Environmental, 1997).

No aquatic habitats were identified at SWMU 2. Drainage swales leading away from the site were identified during a site visit in March 2002; however, these swales were grass lined and covered with moderate leaf litter. The occurrence of aquatic receptors (i.e., fish and macroinvertebrates) would be unlikely since these areas only receive surface water during precipitation events. The drainage from SWMU 2 flows-off site toward Little Sulphur Creek. The nearest downstream perennial water body is Little Sulphur Creek which becomes perennial approximately one mile downstream of SWMU 2.

It is unlikely that the upper portion of Little Sulphur Creek closest to the Dye Burial Grounds support fish, although fish may live in some of the downstream portions of the creek. Also, because the drainage ditches near the site and the upper portion of Little Sulphur Creek are intermittent, benthic invertebrates may only be present when the ditches and creek are covered with water for an extended period of time.

The Sulphur Creek-Little Sulphur Creek waterbody segment designated state water uses are aquatic life support, fish consumption, and primary contact. This waterbody segment was assessed as part of the 2004 Indiana Integrated Water Quality Monitoring and Assessment Report to determine if the waterbody was supporting those uses (IDEM, 2004). The Sulphur Creek-Little Sulphur Creek waterbody segment is fully supporting the aquatic life support and primary contact water uses; it was not assessed for the fish consumption water use (IDEM, 2004).

As discussed above, Little Sulphur Creek discharges off-site to the East Fork of the White River. River otters, a state endangered species, are being reintroduced to Indiana. The otters are expanding from their original release sites into other watersheds including the East Fork of the White River (IDFW, 2000). Also, the East Fork of the White River is the site for an ongoing study of lake sturgeon populations, another state endangered species (IDFW, 2000). Finally, spotted darters, a state endangered species, has been found in the East Fork of the White River (IDFW, 2000). Note that other threatened, endangered, or special concern species also may be present in the water bodies just off-site of Crane, as well.

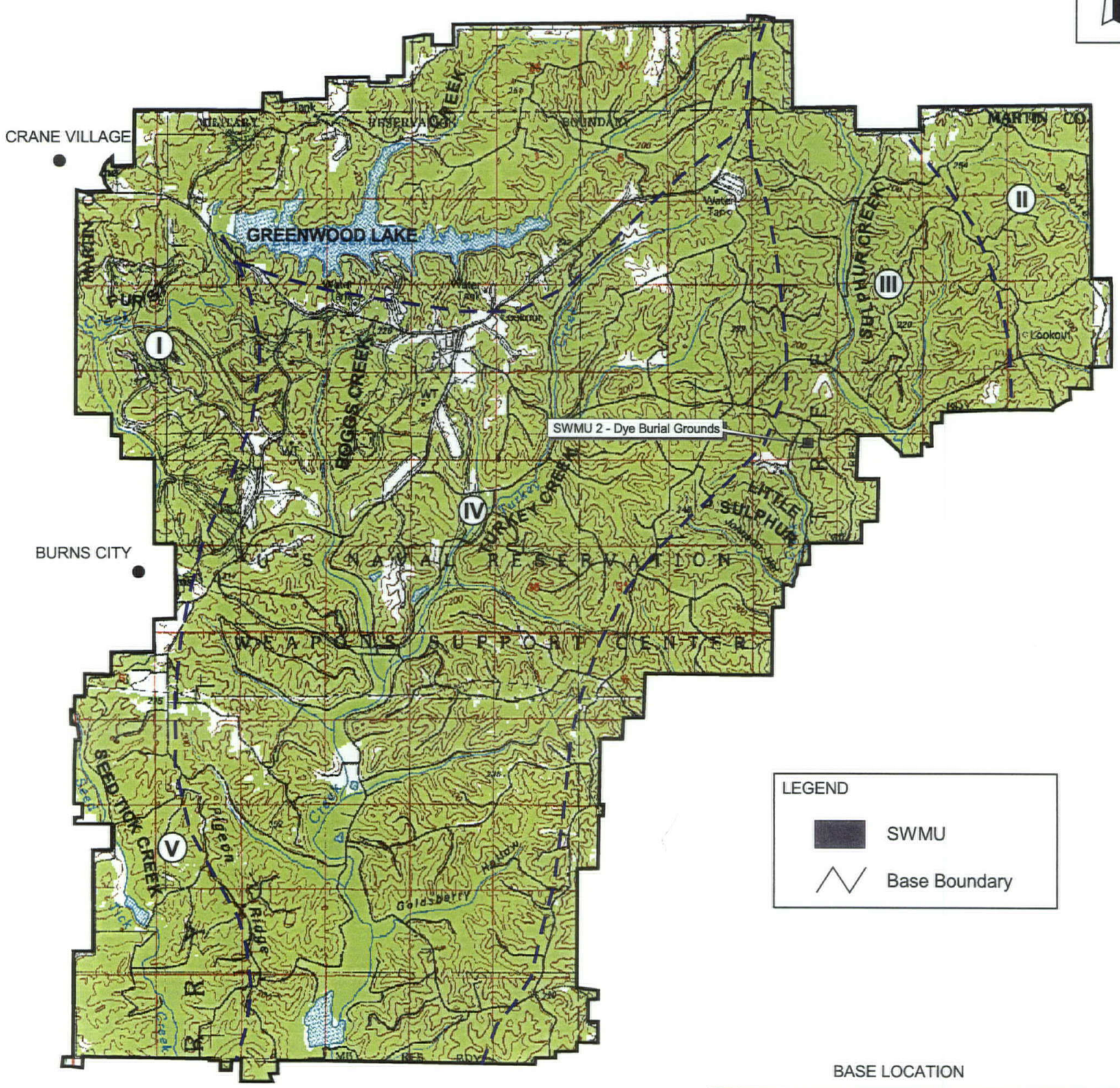
TABLE 1-1

MONITORING WELL CONSTRUCTION INFORMATION AND WATER LEVEL MEASUREMENTS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Well Number	Installation Date	Top of Riser Elevation (ft msl)	Depth to Water (ft btoc)	Groundwater Elevation (ft msl)	Aquifer	Ground Elevation (ft msl)	Total Depth (ft bgs)	Screened Interval			
								Top (ft bgs)	Bottom (ft bgs)	Top (ft msl)	Bottom (ft msl)
02-01	8/26/1981	745.77	25.87	719.90	UP	743.07	34.41	19.66	29.21	723.41	713.86
02-02	9/2/1981	727.67	45.70	681.97	LP	725.46	54.5	39.67	49.27	685.79	676.19
02-03	9/3/1981	722.38	43.56	678.82	HS	720.02	65.6	51.18	60.29	668.84	659.73
02-04	9/4/1981	719.02	38.38	680.64	LP	716.66	50.5	35.9	45.1	680.76	671.56
02-05	9/5/1981	741.28	56.75	684.53	LP	739.24	69.8	50.2	59.68	689.04	679.56
02-06	9/23/1981	744.25	60.24	684.01	LP	742.16	76.21	56.03	65.29	686.13	676.87
02-07	9/24/1981	738.02	54.65	683.37	LP	735.15	63.72	49.18	58.42	685.97	676.73
02-08	9/25/1981	731.80	48.82	682.98	LP	729.66	59.47	45.24	54.14	684.42	675.52
02C09	1/23/1987	740.36	170.25	570.11	BC	737.83	178	167	177	570.83	560.83
02C09P2	1/26/1987	740.66	Dry	Dry	G	737.83	97.5	91.5	96.5	646.33	641.33
02C10	2/13/1988	716.47	146.38	570.09	BC	713.97	153.5	142	152	571.97	561.97
02C10P2	2/16/1988	716.39	40.87	675.52	G	713.89	72.5	61.5	71.5	652.39	642.39
02C10P3	2/22/1988	716.36	29.28	687.08	LP	713.86	37.7	31.7	36.7	682.16	677.16
02C11	2/29/1988	715.31	149.23	566.08	BC	712.81	161.1	148	158	564.81	554.81
02C11P2	3/2/1988	715.36	73.64	641.72	G	712.86	80.8	69.8	79.8	643.06	633.06
02C11P3	3/5/1988	715.66	35.59	680.07	LP	713.16	42.3	36.3	41.3	676.86	671.86
02C12	3/14/1988	741.57	171.22	570.35	BC	739.07	183.7	171.6	181.6	567.47	557.47
02C12P2	3/21/1988	741.82	88.98	652.84	G	739.32	104.2	93.2	103.2	646.12	636.12
02C12P3	3/18/1988	741.83	23.67	718.16	UP	739.33	35	29	34	710.33	705.33
02C13	3/28/1988	725.11	58.25	666.86	G	722.61	83.3	69.3	79.3	653.31	643.31
02C13P2	3/29/1988	724.78	40.11	684.67	LP	722.28	45	34	44	688.28	678.28
02C13P3	3/30/1988	725.51	10.48	715.03	UP	723.01	20	15	20	708.01	703.01
02C14	4/13/1988	716.40	Dry	Dry	BC	713.9	167.2	153.9	163.9	560	550
02C14P2	4/15/1988	716.43	63.95	652.48	G	713.93	85.4	74.4	84.4	639.53	629.53
02C14P3	4/19/1988	716.26	37.13	679.13	LP	713.76	48.1	37.1	47.1	676.66	666.66
02C15	5/10/1988	715.88	69.90	645.98	G	713.38	80.2	66.3	76.3	647.08	637.08
02C15P2	5/11/1988	715.77	34.28	681.49	LP	713.27	40.2	29.2	39.2	684.07	674.07
02C16	5/16/1988	725.36	Dry	Dry	G	722.86	91.3	78.6	88.6	644.26	634.26
02C16P2	5/17/1988	725.18	43.03	682.15	LP	722.68	54.5	43.5	53.5	679.18	669.18
02C17	5/23/1988	732.96	84.75	648.21	G	730.46	100.1	86.1	96.1	644.36	634.36
02C17P2	5/26/1988	732.84	48.91	683.93	LP	730.34	60.7	49.7	59.7	680.64	670.64
02C17P3	5/27/1988	733.38	Dry	Dry	UP	730.88	25.6	20.6	25.6	710.28	705.28
02C18	6/6/1988	737.31	88.50	648.81	G	734.81	101.2	88.3	98.3	646.51	636.51
02C18P2	6/7/1988	737.24	52.86	684.38	LP	734.74	63.4	52.4	62.4	682.34	672.34
02C18P3	6/7/1988	737.45	21.15	716.30	UP	734.95	18.5	13	18	721.95	716.95
02C19	6/14/1988	733.35	87.01	646.34	G	730.85	93	80.2	90.2	650.65	640.65
02C19P2	6/15/1988	733.28	48.89	684.39	LP	730.78	56.6	45.6	55.6	685.18	675.18
02C19P3	6/16/1988	733.68	Dry	Dry	UP	731.18	16.7	10.7	15.7	720.48	715.48
02C20	6/29/1988	715.06	137.54	577.52	BC	712.56	145.7	134.7	144.7	577.86	567.86
02C20P2	6/22/1988	714.92	58.00	656.92	G	712.42	67	56	66	656.42	646.42
02C20P3	6/23/1988	714.78	17.97	696.81	LP	712.27	39	28	38	684.27	674.27
02C21	9/12/1990	No Well								0	0
02C22	10/15/1990	742.99	Dry	Dry	BC	740.49	190	176.7	186.7	563.79	553.79
02C22P2	10/17/1990	742.63	Dry	Dry	G	740.13	105	100	105	640.13	635.13
02C22P3	10/18/1990	742.50	58.67	683.83	LP	740	68.6	58.6	68.6	681.4	671.4

UP - Upper Pennsylvanian
LP - Lower Pennsylvanian
HS - Hardinsburg Shale
BC - Beech Creek
G - Golconda

P:\GIS\NSWC_CRANE\0087.APR SURFACE DRAINAGE - DBG - B SIZED LAYOUT AJ 5/08/02



MAJOR SURFACE DRAINAGE BASINS

I FURST CREEK DRAINAGE BASIN

II INDIAN CREEK DRAINAGE BASIN

III SULPHUR CREEK COMPLEX DRAINAGE BASIN

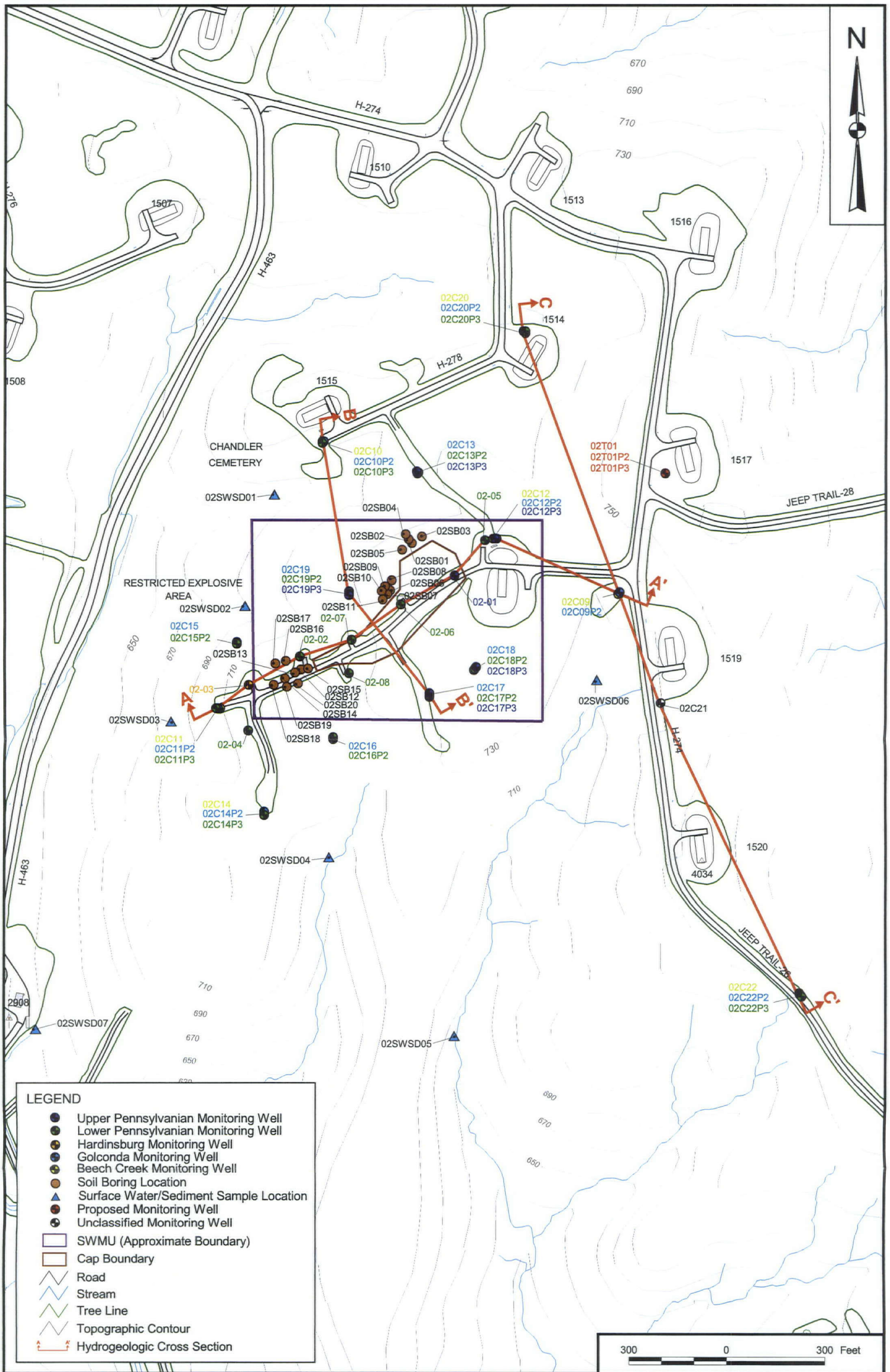
IV BOGGS & TURKEY CREEKS DRAINAGE BASIN

V SEED TICK DRAINAGE BASIN

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

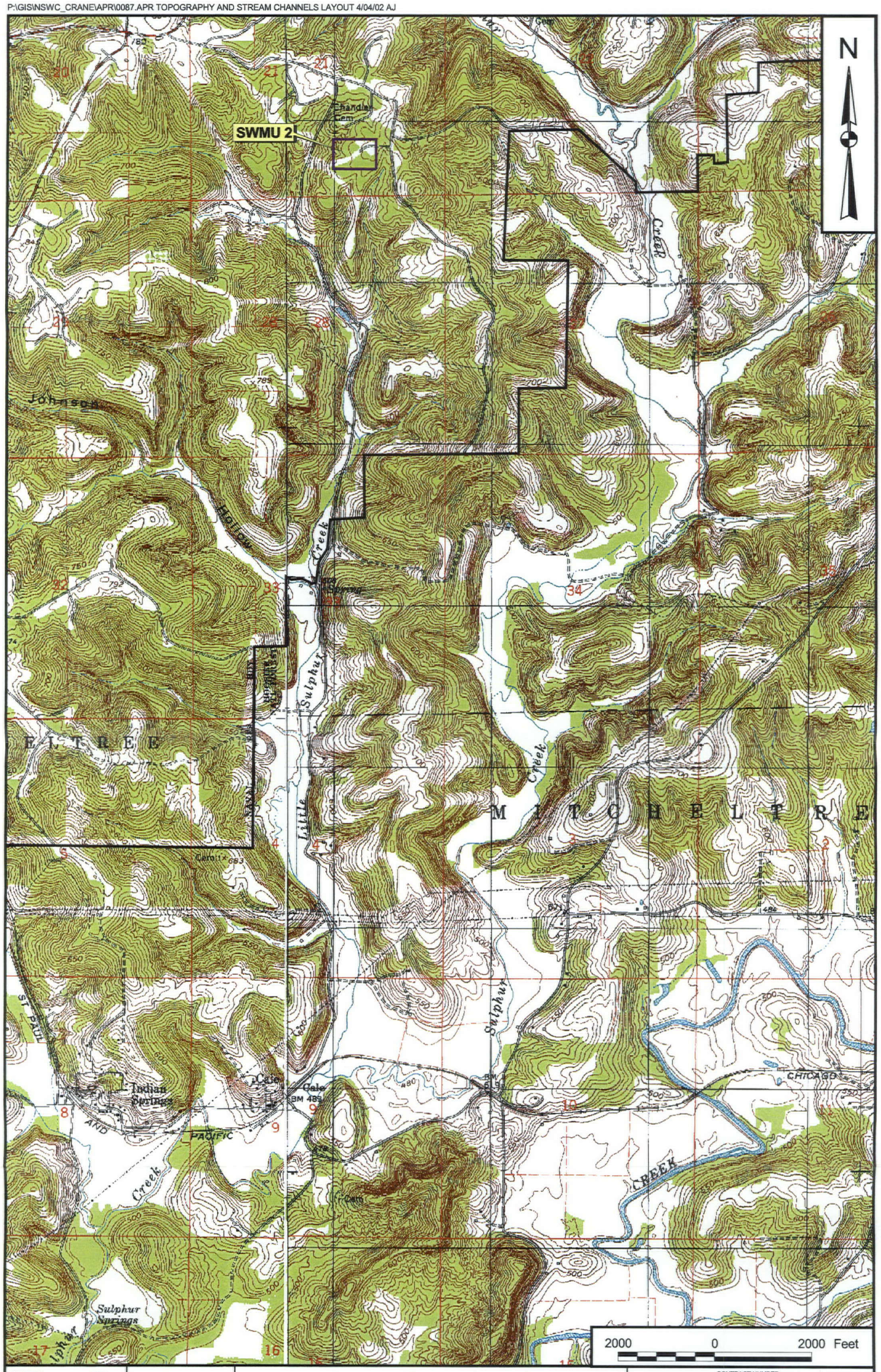
DRAWN BY J. LAMEY	DATE 4/19/99	SITE LOCATION AND SURFACE DRAINAGE SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER 0087
CHECKED BY K. HENN	DATE 7/6/00		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1 - 1 REV 0

P:\GIS\NSWC_CRANE\CTO-10_SWMU02_GW.APR SITE FEATURES AND SAMPLE LOCATIONS 4/03/02 AJ



DRAWN BY J. LAMEY	DATE 10/25/01	SITE FEATURES AND SAMPLE LOCATIONS SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER 7141
CHECKED BY M. COCHRAN	DATE 2/26/02		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1 - 2 / REV 0

P:\GIS\NSWC_CRANE\APR\0087.APR TOPOGRAPHY AND STREAM CHANNELS LAYOUT 4/04/02 AJ



DRAWN BY	DATE
J. LAMEY	3/29/02
CHECKED BY	DATE
J. GOERDT	4/04/02
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

TOPOGRAPHY AND STREAM CHANNELS

IN THE VICINITY OF SWMU 2 - DYE BURIAL GROUNDS

NSWC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
—	
APPROVED BY	DATE
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APPROVED BY	DATE
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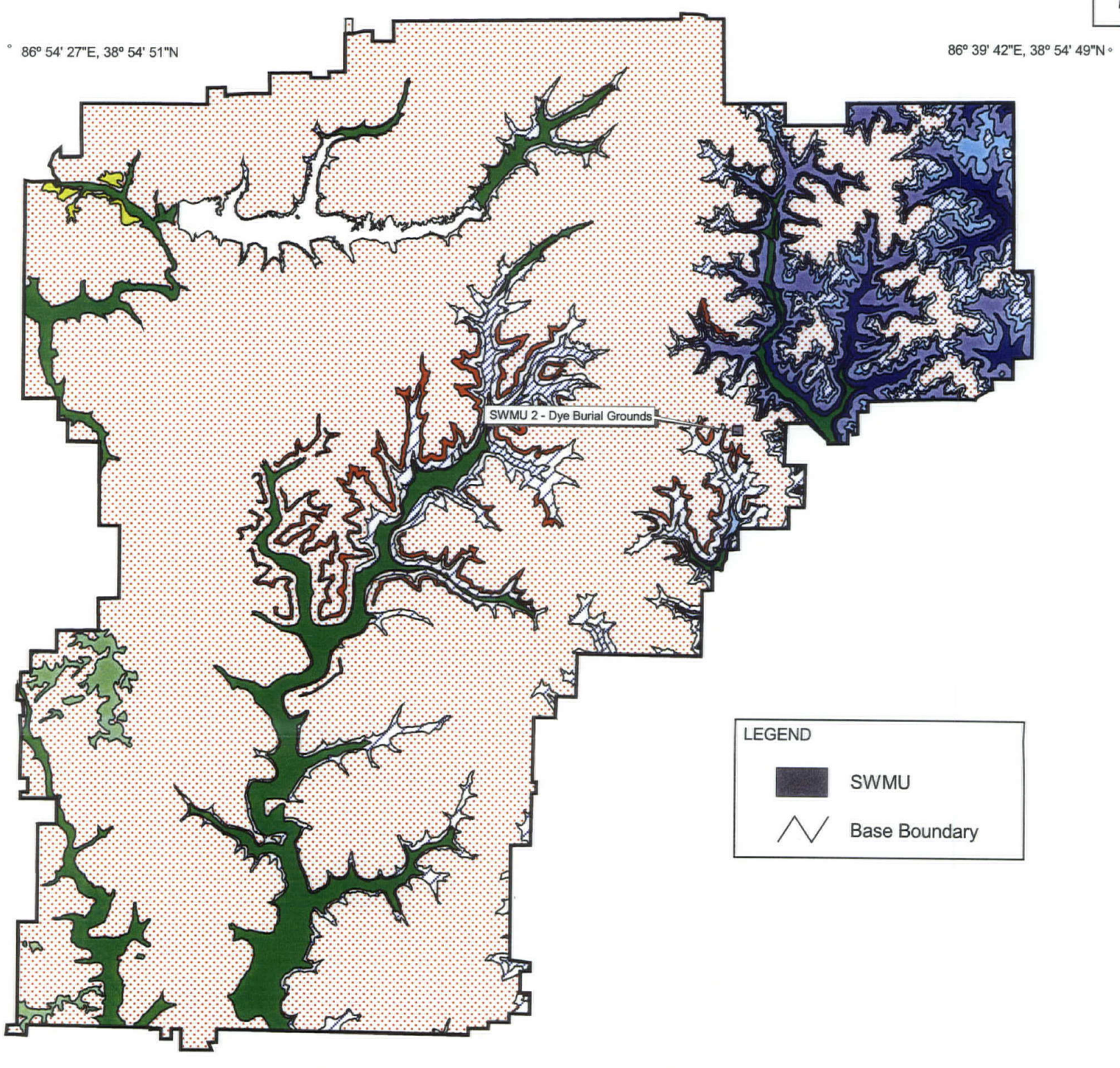
DRAWING NO.	REV
FIGURE 1 - 3	0

P:\GIS\NSWC_CRANE\0087.APR SURFICIAL GEOLOGY - DBG - B SIZED LAYOUT 5/08/02 AJ



Inferred Depositional Environment		Explanation of Geology
Alluvium	Qal	*Alluvium*
Loess/Glacial Outwash	Ql	*Loess*
	Qo	*Glacial Outwash*
Residual Soil derived from Pennsylvanian bedrock/colluvium	P	*Raccoon Creek Group and undifferentiated*
	Ps	*Sandstone-dominated horizon of Lower Pennsylvanian*
Residual soil derived from Mississippian bedrock/colluvium	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*

Source: Background Soils Report. TtNUS 2001. (Modified from Blunck, 1995).

1.5 0 1.5 3 Miles

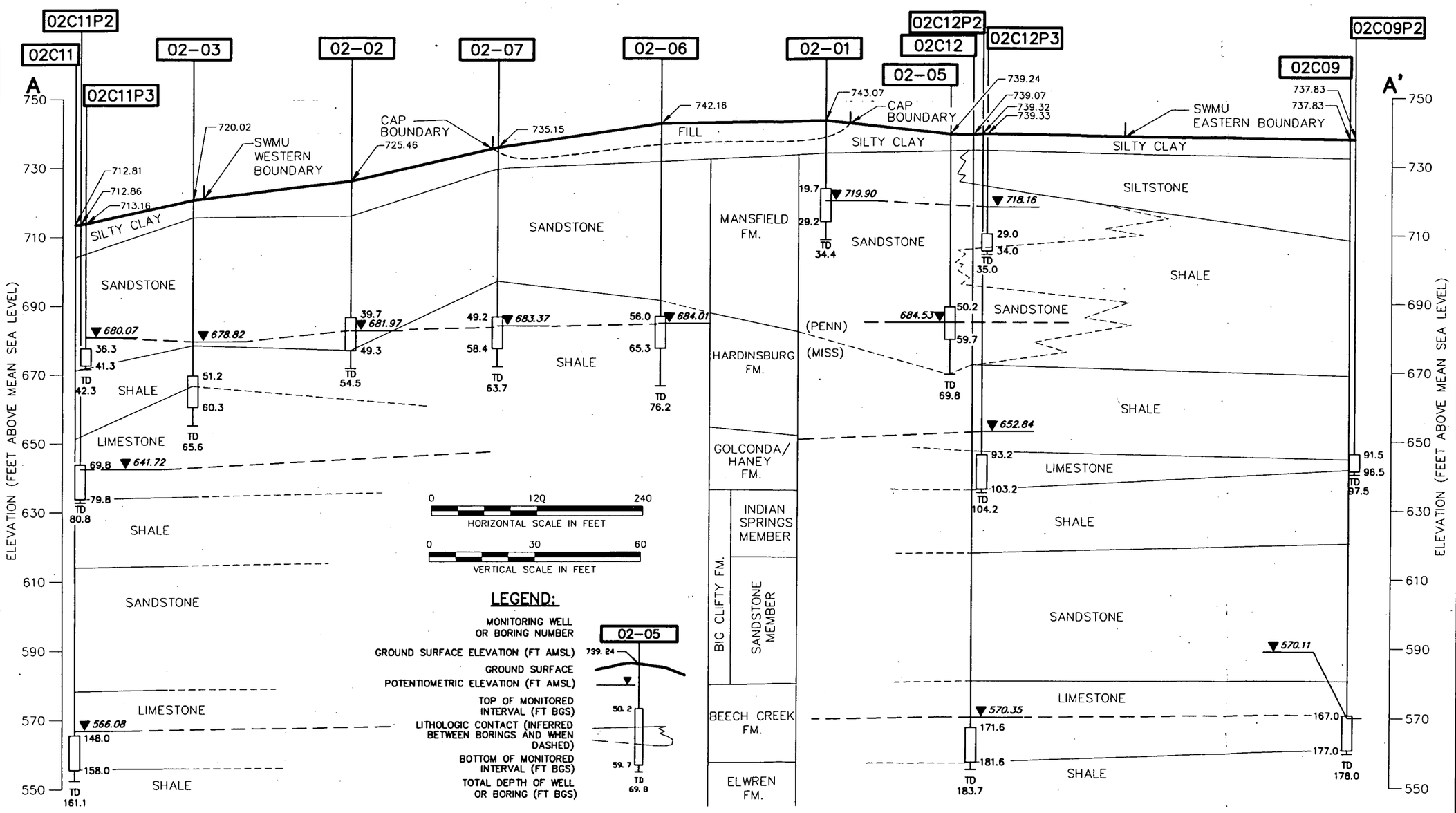
DRAWN BY D. PERRY	DATE 3/15/99	SURFICIAL GEOLOGY AND DEPOSITIONAL ENVIRONMENTS NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER N0504
CHECKED BY J. SCHUBERT	DATE 5/1/00		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1 - 4 REV 0

PERIOD	EPOCH	THICKNESS (FEET)	LITHOLOGY	FORMATION	GROUP
PENN-SYL-VANIAN	POTTS-VILLE	150–300		MANSFIELD FM.	"RACCOON CREEK"
MISSISSIPPI	CHESTER	20–30		GLEN DEAN LS	STEPHENS-PORT
		30–40		HARDINSBURG SS.	
		40–50		GOLCONDA LS.	
		25–40		BIG CLIFTY FM.	
		15–25		BEECH CREEK LS.	
		20–40		ELWREN FM.	WEST BADEN
		0–5		REELSVILLE LS.	
		20–40		SAMPLE FM.	
		10–20		BEAVER BEND LS.	
		12–30		BETHEL FM.	
	MERAMEC	15–20		PAOLI LS.	BLUE RIVER
		100–120		STE. GENEVIEVE LS.	
		100–120		ST. LOUIS LS.	
		90–100		SALEM LS.	SANDERS
		50–80		HARRODSBURG LS.	
	OSAGE	600–800		MULDRAUGH FM.	BORDEN

DRAWN BY A. JANOCHA	DATE 4/03/02	STRATIGRAPHIC COLUMN FOR ROCK UNITS ENCOUNTERED AT THE NAVAL SURFACE WARFARE CENTER NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER 0087
CHECKED BY J. GOERDT	DATE 4/03/02		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1 - 5 REV 0

P:\GIS\NSWC_CRANE\0087.APR STRATIGRAPHIC COLUMN LAYOUT - A SIZE AJ 4/03/02

ACAD: 7141GX19.dwg 03/25/03 DM PIT



CONTRACT NO. 7141

APPROVED BY DATE

APPROVED BY DATE

DRAWING NO. FIGURE 1-6

REV. 0

GEOLOGIC CROSS SECTION A-A'
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

DRAWN BY DM DATE 3/11/02

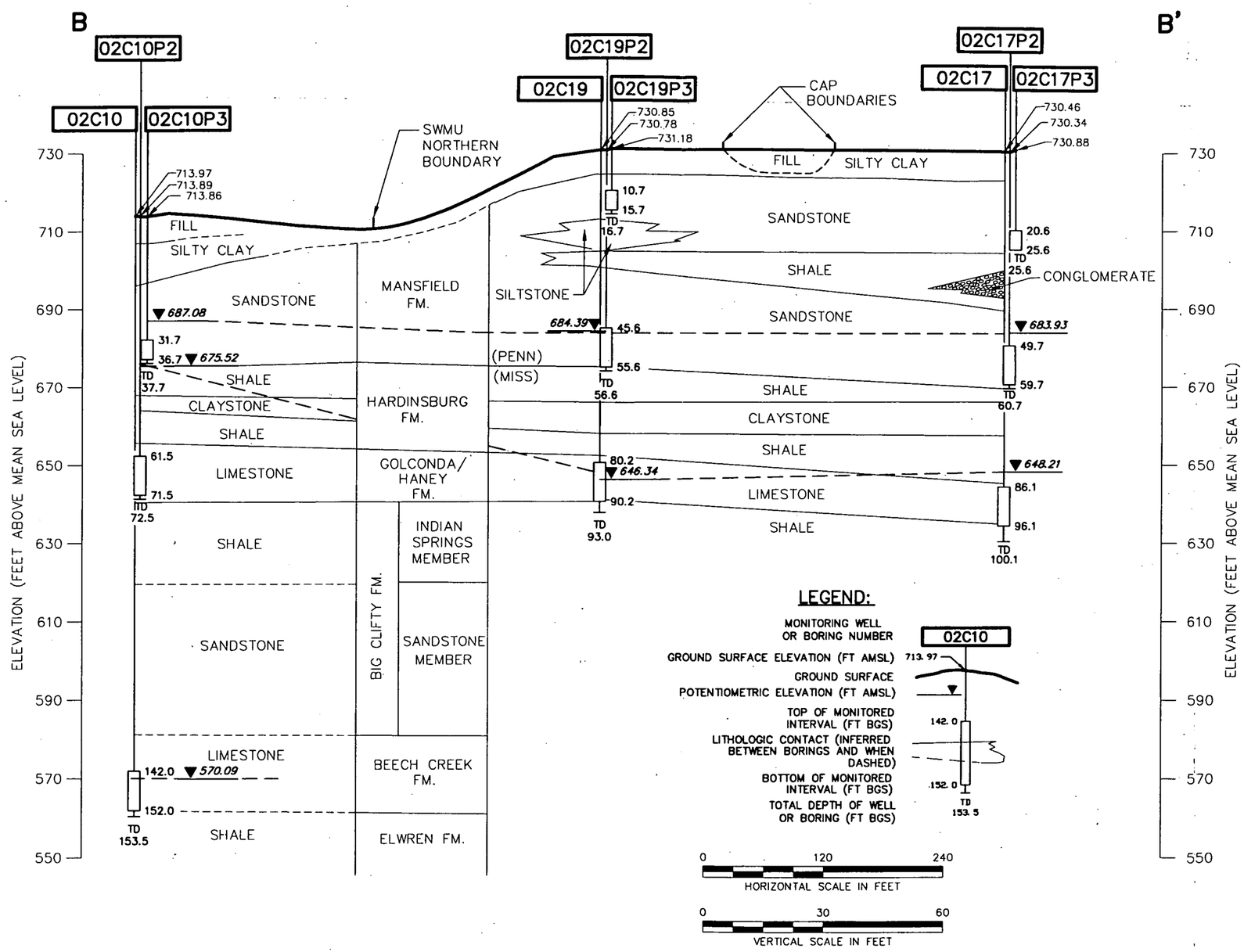
CHECKED BY DATE

COST/SCHED-AREA

SCALE AS NOTED

FORM CADD NO. SDIV_BV.DWG - REV 0 - 1/20/98

ACAD: 7141GX20.dwg 03/25/03 DM PIT



CONTRACT NO. 7141

APPROVED BY DATE

APPROVED BY DATE

DRAWING NO. FIGURE 1-7

REV. 0

GEOLOGIC CROSS SECTION B-B'
SWMU 2 -DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

DRAWN BY DM DATE 2/26/02

CHECKED BY DATE

COST/SCHED-AREA

SCALE AS NOTED

FORM CADD NO. SDIV_BV.DWG - REV 0 - 1/20/98

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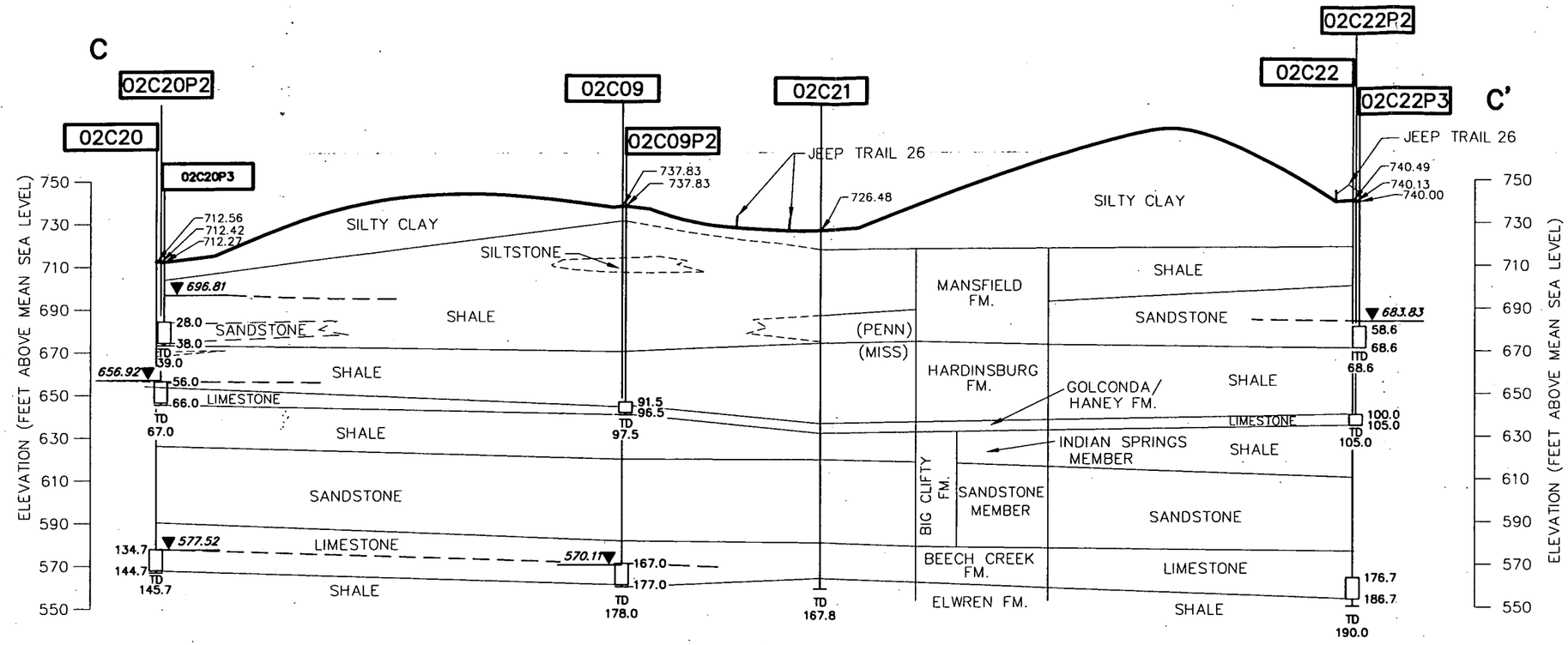
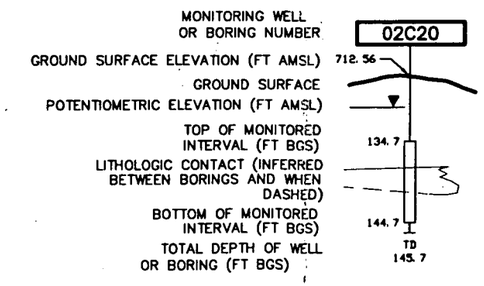


LEGEND:



0 240 480
HORIZONTAL SCALE IN FEET

0 60 120
VERTICAL SCALE IN FEET

CONTRACT NO. 7141

APPROVED BY DATE

APPROVED BY DATE

DRAWING NO. FIGURE 1-8

REV. 0

GEOLOGIC CROSS SECTION C-C'
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

DRAWN BY DM DATE 3/8/02

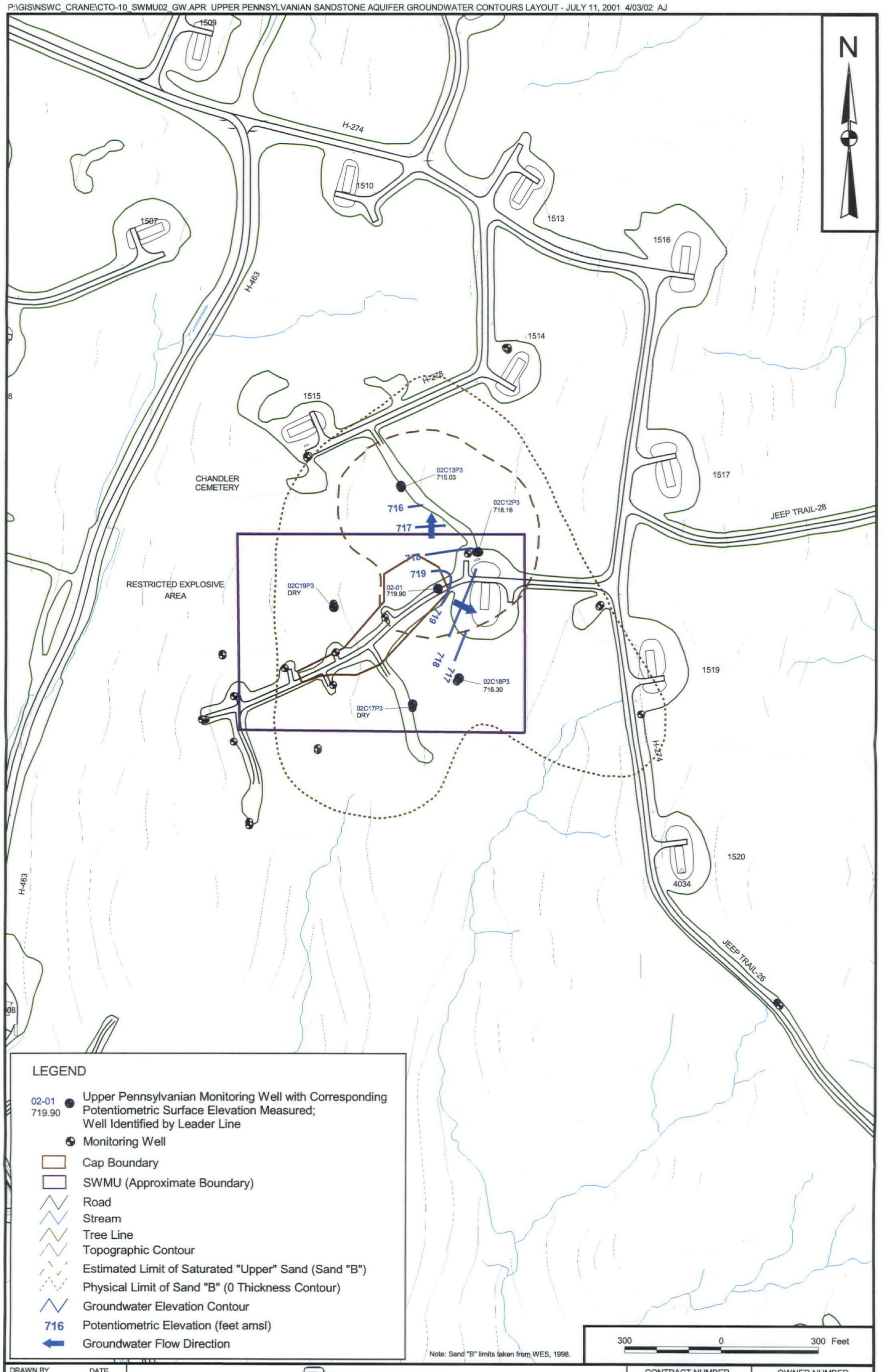
CHECKED BY DATE

COST/SCHED-AREA

SCALE AS NOTED

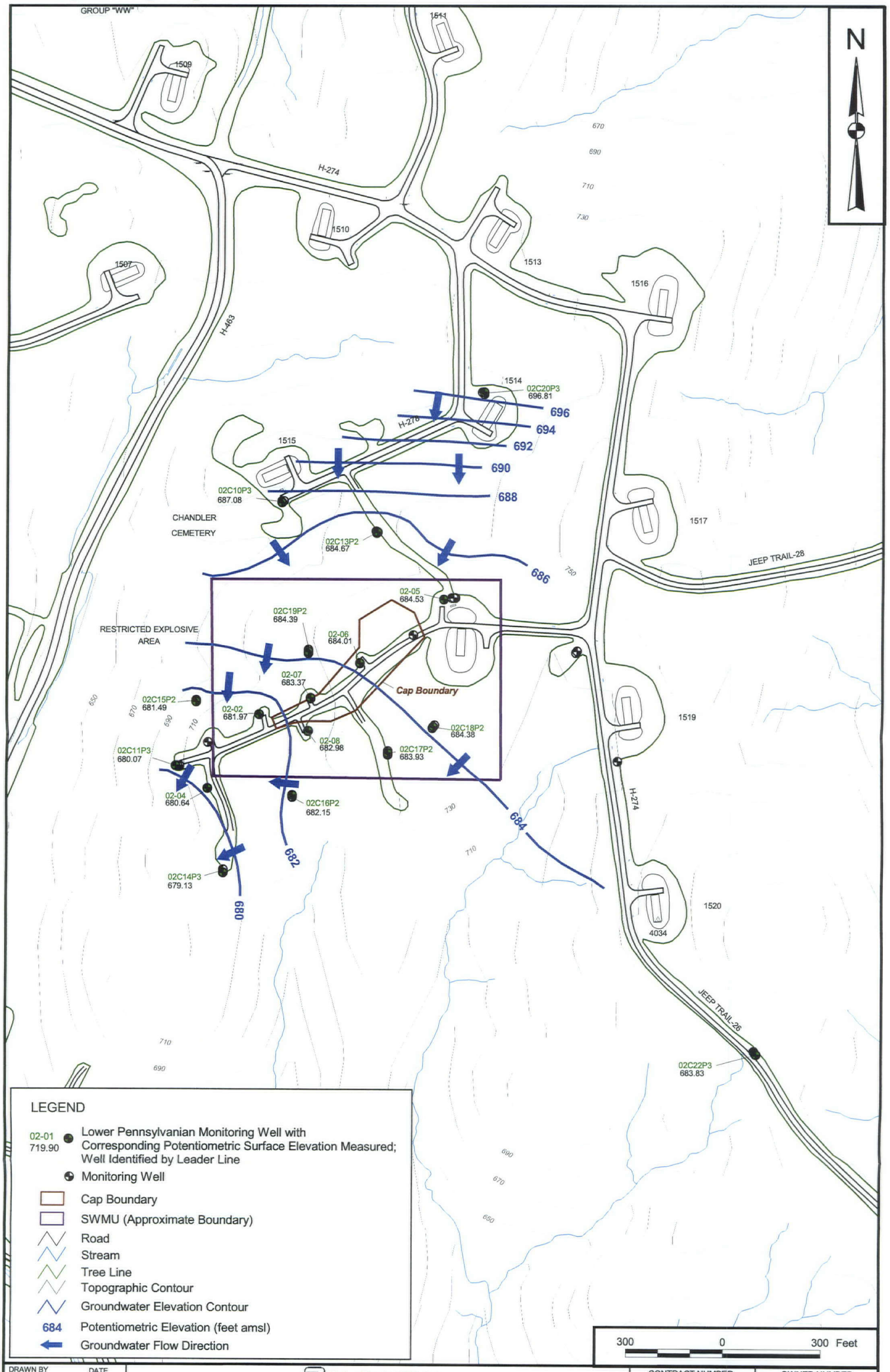
FORM CADD NO. SDIV_BV.DWG - REV 0 - 1/20/98

P:\GIS\NSWC_CRANE\CTO-10_SWMU02_GW.APR UPPER PENNSYLVANIAN SANDSTONE AQUIFER GROUNDWATER CONTOURS LAYOUT - JULY 11, 2001 4/03/02 AJ



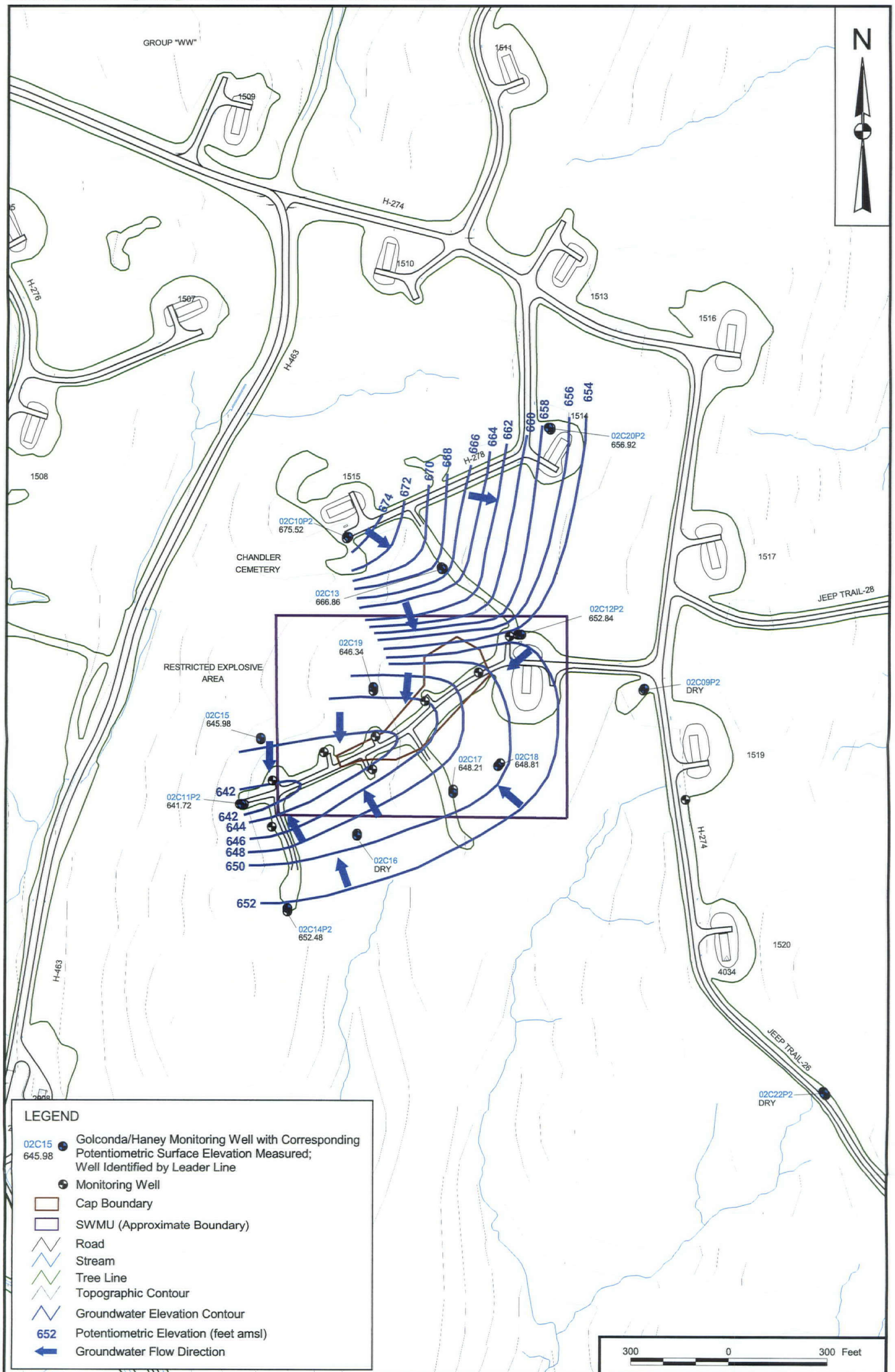
DRAWN BY J. LAMEY — DATE 7/26/01	Tetra Tech NUS, Inc.	CONTRACT NUMBER 7141	OWNER NUMBER CTO 0010
CHECKED BY M. COCHRAN — DATE 2/27/02	UPPER PENNSYLVANIAN SANDSTONE AQUIFER GROUND WATER CONTOURS JULY 11, 2001 SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	APPROVED BY —	DATE —
COST/SCHEDULE-AREA		APPROVED BY —	DATE —
SCALE AS NOTED		DRAWING NO. FIGURE 1 - 9	REV 0

P:\GIS\NSWC_CRANE\CTO-10_SWMU02_GW.APR LOWER PENNSYLVANIAN GW CONTOURS-JULY 11, 2001 4/03/02 AJ



DRAWN BY J. LAMEY DATE 7/25/01	Tetra Tech NUS, Inc.	CONTRACT NUMBER 7141	OWNER NUMBER CTO 0010
CHECKED BY M. COCHRAN DATE 2/27/02	LOWER PENNSYLVANIAN SANDSTONE AQUIFER GROUND WATER CONTOURS JULY 11, 2001 SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	APPROVED BY — DATE —	
COST/SCHEDULE-AREA		APPROVED BY — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 1 - 10	REV 0

P:\GIS\NSWC_CRANE\CTO-10_SWMU02_GW.APR GOLCONDA GW CONTOURS - JULY 11, 2001 5/08/02 AJ



DRAWN BY	DATE	CONTRACT NUMBER
J. LAMEY	7/25/01	7141
CHECKED BY	DATE	APPROVED BY / DATE
M. COCHRAN	2/28/02	— / —
COST/SCHEDULE-AREA		APPROVED BY / DATE
		— / —
SCALE		DRAWING NO. / REV
AS NOTED		FIGURE 1 - 11 / 0

GOLCONDA/HANEY LIMESTONE AQUIFER GROUND WATER CONTOURS

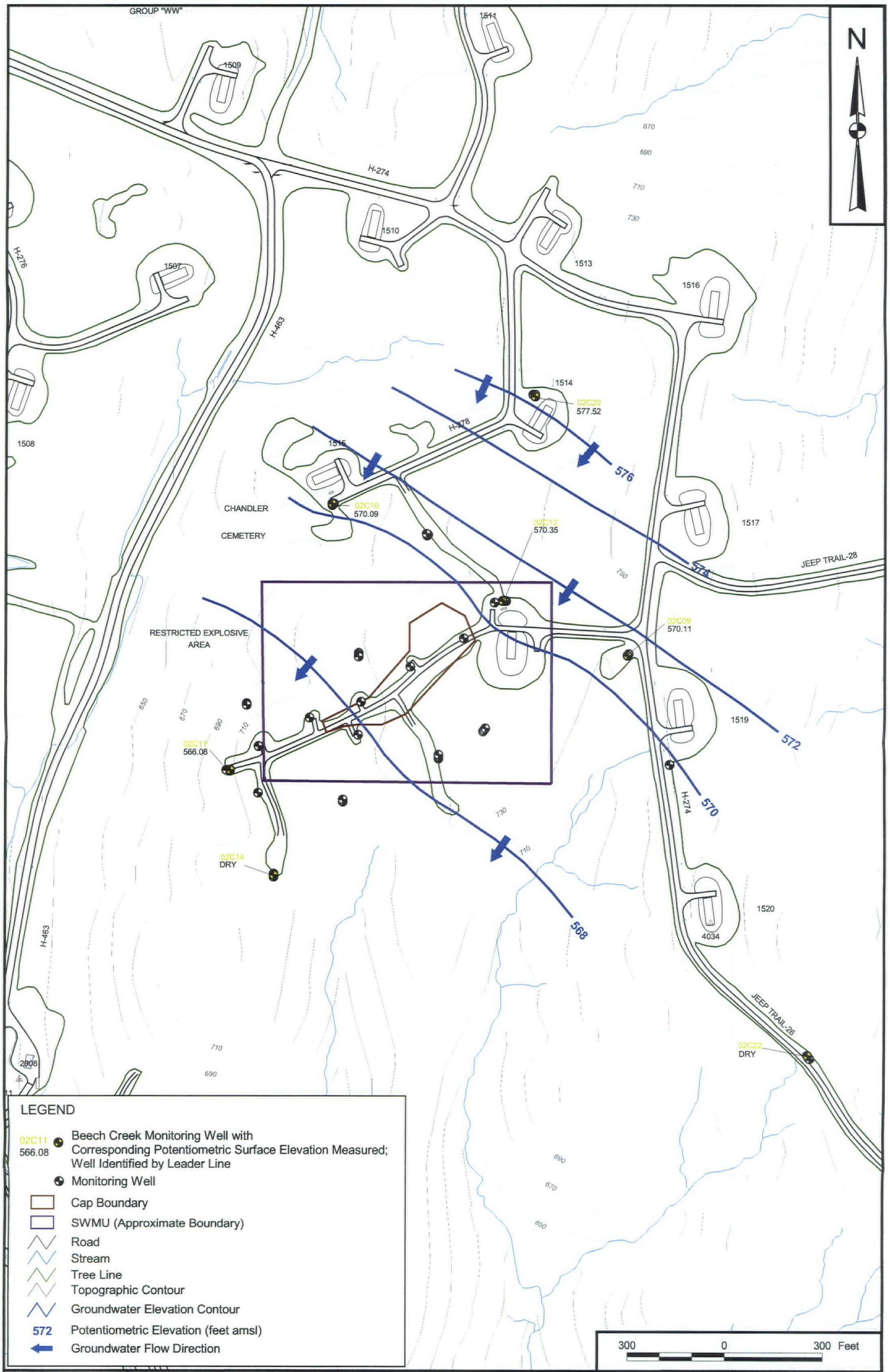
JULY 11, 2001

SWMU 2 - DYE BURIAL GROUNDS

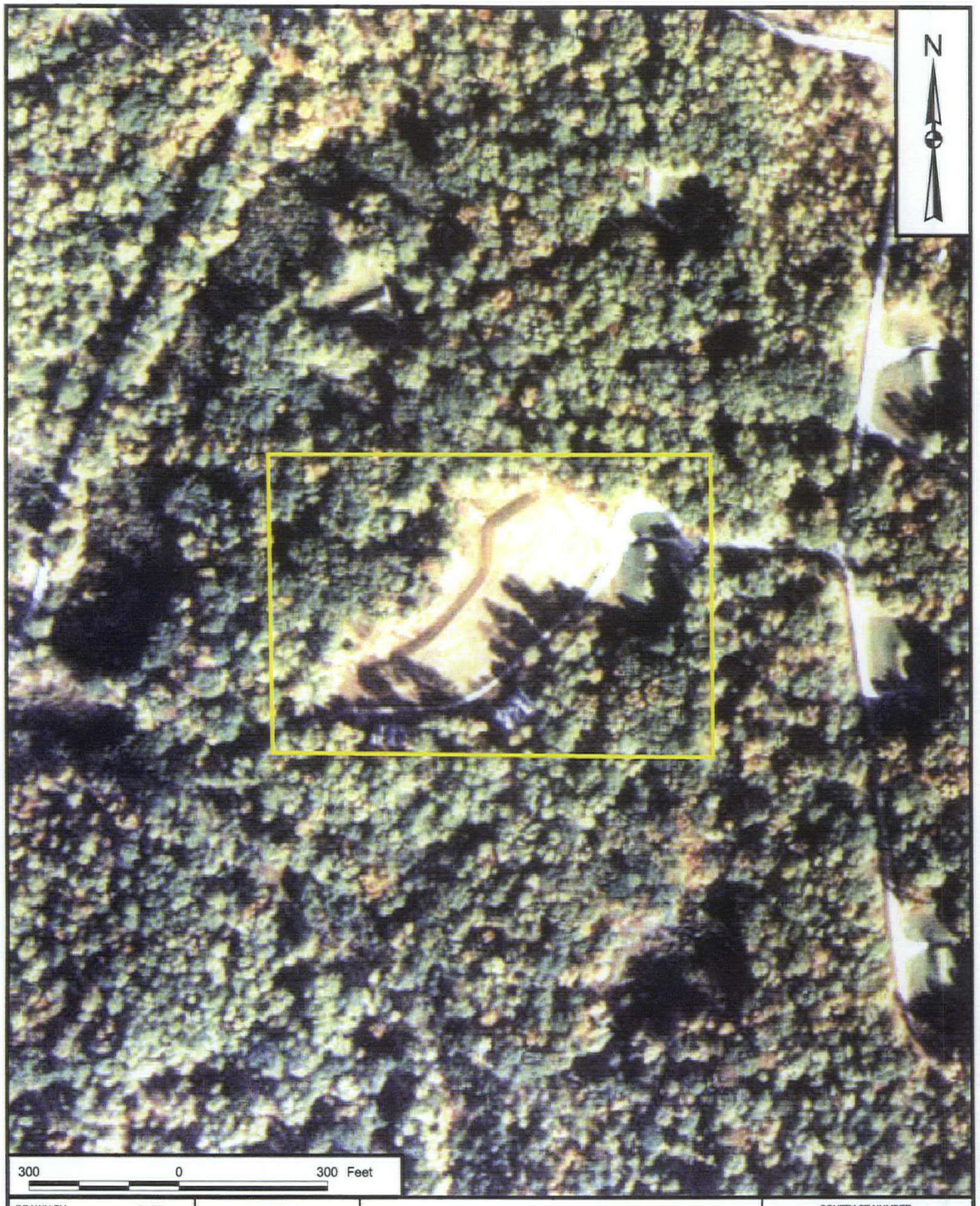
NSWC CRANE

CRANE, INDIANA

P:\GIS\NSWC_CRANE\CTO-10_SWMU02_GW.APR BEECH CREEK GW CONTOURS-JULY 11, 2001 4/03/02 AJ



DRAWN BY J. LAMEY — DATE 7/25/01	Tetra Tech NUS, Inc.	CONTRACT NUMBER 7141	OWNER NUMBER CTO 0010
CHECKED BY M. COCHRAN — DATE 2/28/02	BEECH CREEK LIMESTONE AQUIFER GROUND WATER CONTOURS JULY 11, 2001 SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	APPROVED BY —	DATE —
COST/SCHEDULE-AREA		APPROVED BY —	DATE —
SCALE AS NOTED		DRAWING NO. FIGURE 1 - 12	REV 0



DRAWN BY J. LAMEY	DATE 3/24/03	1998 AERIAL PHOTOGRAPH SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE, INDIANA	CONTRACT NUMBER 7141
CHECKED BY	DATE		APPROVED BY — DATE —
COST/SCHEDULE-AREA			APPROVED BY — DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 1-13 REV 0

P:\GIS\NSWC_CRANE\APR\7141_AERIAL.APR SWMU 2-DYE BURIAL GROUNDS AERIAL PHOTOGRAPH 3/24/03 JAL

FIGURE 1-15

SITE PHOTOGRAPHS (03-11-02)
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE, INDIANA

Photograph 1 - shows the access road to the Dye Burial Ground (DBG) and the highest point of the site - the wooded area left of photograph.

Photograph 2 - showing the north end of the DBG cap (left side of photo) and intermittent stream within the wooded area left of monitoring well ballards.

FIGURE 1-15

SITE PHOTOGRAPHS (03-11-02)
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE, INDIANA

Photograph 3 - showing the north end of the DBG cap. A drainage ditch/swale is located between the cap and gravel road (left side of photo) and runs under (via a culvert) the small section of gravel above the access road at which point flow is diverted toward the intermittent stream shown in photograph 2.

Photograph 4 - showing the east side of the DBG cap with drainage ditches/swales (one running between the cap and gravel road, and one shown just left of the photograph's center and below the wooded area).

FIGURE 1-15

SITE PHOTOGRAPHS (03-11-02)
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE, INDIANA

Photograph 5 - showing underground drainage pipe (bottom of photo) just east of monitoring well 02-08 with the DBG cap in the background. The pipe diverts flow from between the gravel road and DBG cap toward the intermittent stream in the wooded area south of cap.

Photograph 6 - shows the intermittent stream in wooded area just south of the underground drainage pipe shown in photograph 5.

FIGURE 1-15

SITE PHOTOGRAPHS (03-11-02)
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE, INDIANA

Photograph 7 - taken from the south end of the DBG cap showing the road to well cluster 02-11 with monitoring well 02-02 on the right of the photo.

Photograph 8 - taken from the south end of the DBG cap showing the area north of the cap which would ultimately drain toward the Ammunition Burning Grounds (ABG).

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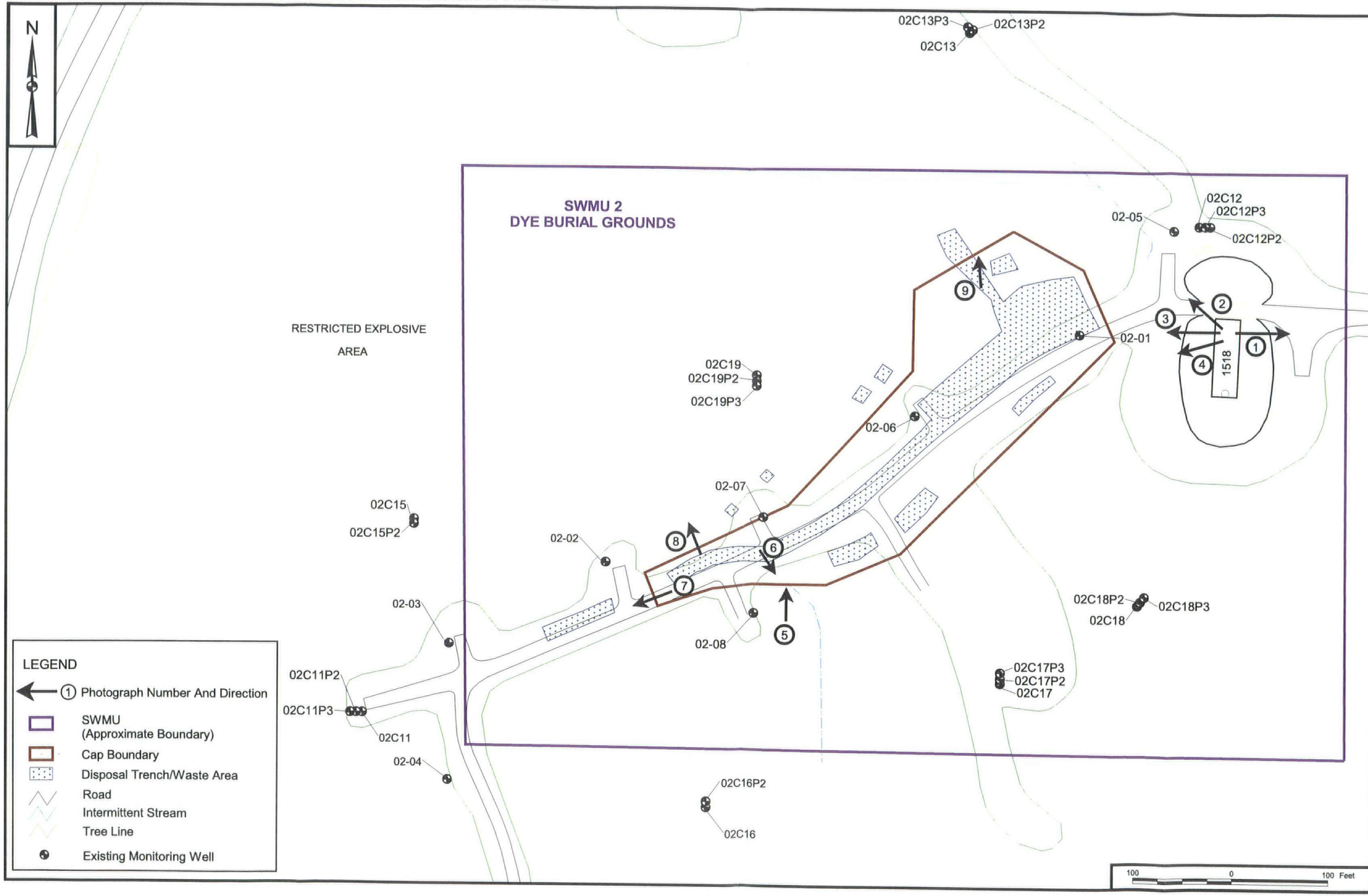


CONTRACT NO. 7141

APPROVED BY ___ DATE ___

APPROVED BY ___ DATE ___

DRAWING NO. FIGURE 1 - 14

REV _

LOCATION & DIRECTION OF SITE PHOTOGRAPHS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

DRAWN BY J. LAMEY DATE 7/03/02

CHECKED BY ___ DATE ___

COST/SCHED-AREA

SCALE AS NOTED

FIGURE 1-15

SITE PHOTOGRAPHS (03-11-02)
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE, INDIANA

Photograph 9 - taken from the north end of the DBG cap showing the area north of the cap where sheet runoff would ultimately flow in the direction of the ABG via tributary to Little Sulfur Creek and the intermittent stream shown in photograph 2.

2.0 FIELD INVESTIGATIONS

This section discusses sampling activities, procedures, and documentation utilized during recent field operations performed in 2001 for SWMU 2 at NSWC Crane Division, Crane, Indiana.

2.1 OVERVIEW

The sampling activities were conducted in July 2001, in accordance with the procedures and methodologies described in the approved work plan (TtNUS, May 2001). Referenced standard operating procedures (SOPs) are included in Appendix B of the Field Sampling Plan (FSP) within the approved Work Plan (TtNUS, May 2001). Copies of the field logbooks and all field notes are provided in Appendices A through D of this document, as follows:

- A Boring Logs and Monitoring Well Construction Sheets
- B Sample Log Sheets and Other Field Forms
- B - 1 Soil Sample Log Sheets
- B - 2 Ground Water Sample Log Sheets
- B - 3 Surface Water Sample Log Sheets
- B - 4 Sediment Sample Log Sheets
- B - 5 Chain-of-Custody Records
- B - 6 Monitoring Well Inspection Sheets
- B - 7 Monitoring Well Development Records
- B - 8 Monitoring Well Water-Level Measurement Sheets
- C Field Log books
- D Survey Data

2.2 MOBILIZATION / DEMOBILIZATION

Following approval of the work plan, TtNUS began mobilization activities. All field team members reviewed the work plan and associated appendices [FSP, Health and Safety Plan (HASP), and Quality Assurance Project Plan (QAPP)] prior to the start of project activities. In addition, the field operations leader (FOL) held a field team orientation meeting to ensure that personnel were familiar with the scope of the field activities.

Before the initiation of fieldwork, the FOL arrived at the site and began on-site mobilization activities. These activities included coordination with base personnel and utility clearance of all proposed boring locations through NSWC Crane Publics Works. The equipment required for the field activities was shipped to the site from the TtNUS Pittsburgh warehouse and from vendors that rent environmental equipment. All field sampling activities and site characterization work were performed in July 2001. After field activities were completed, the FOL completed the decontamination and demobilization of all equipment and cleaned the field office.

2.3 SUBSURFACE INVESTIGATION METHODOLOGIES AND PROCEDURES

2.3.1 Drilling

A total of 20 soil borings (02SB01 through 02SB20, see Figure 1-2) were drilled to a maximum of 11 feet beneath the ground surface using direct-push technology (DPT). Borings were drilled for soil sampling and lithologic descriptive purposes. Each boring was advanced through fill until natural underlying materials were encountered or until DPT refusal, whichever was first. The borings were drilled in accordance with CTO 10 SOP 2-7.

2.3.2 Boring and Sample Logging

All soil samples collected from the soil borings were monitored immediately after the sample tool was opened and the acetate liner was cut open. A photoionization detector (PID) was passed along the length of the exposed soil core. All PID readings were recorded on the boring log. Soil samples collected for chemical analysis were handled in accordance with the procedures outlined in Section 2.5.1.

A lithologic description of each soil sample and a complete log of each boring were maintained by the TtNUS geologist in accordance with CTO 10 SOP 2-14, contained in Attachment B of the FSP. At a minimum, the boring log contained the following information:

- Boring identification
- Name of geologist logging the boring
- Name of drilling contractor
- Sample numbers and types
- Sample depths
- Sample recovery/sample interval
- Soil density or cohesiveness

- Soil color
- Unified Soil Classification System (USCS) material description
- Location of boring

In addition, depths of changes in lithology, sample moisture observations, depth to water, presence of organic vapor (i.e., PID readings), visual observance of dyes, and total depth of each boring were included on each boring log, as well as any other pertinent observations.

2.3.3 Boring Abandonment

When a boring was completed to the desired depth and the appropriate samples were collected, the boring was backfilled. Each boring was backfilled with bentonite chips and hydrated as in accordance with the manufacturer's specifications. None of the borings encountered water during drilling.

2.4 MONITORING WELL INSPECTION AND DEVELOPMENT

All 44 existing monitoring wells within SWMU 2 were inspected (see monitoring well inspection sheets in Appendix B-6) in accordance with CTO 10 SOP 2-1, contained in Attachment B of the FSP.

Eight of the existing wells that were to be sampled were redeveloped in early July 2001. The wells were developed by using a Wattera® pump or by surging and pumping (utilizing a submersible pump), as determined by the field geologist. Approximate recharge rates were noted. Measurements of pH, temperature, specific conductance, and turbidity were collected after each well casing volume and recorded on a well development record form. All well development was performed in accordance with CTO 10 SOP 2-8, contained in Attachment B of the FSP. Monitoring well inspection sheets and development records can be found in Appendices B-6 and B-7.

Development water was containerized in appropriate containers and discharged into the NSWC Crane permitted sanitary sewer system, in accordance with the work plan.

2.5 GENERAL SAMPLING OPERATIONS

This section presents the sampling methodology for all surface soil, subsurface soil, groundwater, surface water, and sediment sampling activities performed at SWMU 2, NSWC Crane, Indiana. A summary of the sampling and analytical program is included in Table 4-1.

2.5.1 Soil Sampling

A total of 33 soil samples were collected at either of two sample intervals from the 20 DPT borings. Surface soil samples were collected from the 0- to 2-foot interval at 13 selected boring locations, and subsurface soil samples were collected from a depth interval greater than 2 feet at each of the 20 soil borings. Soil boring locations are shown on Figure 1-2. All soil samples were collected in accordance with CTO 10 SOP 2-7, contained in Attachment B of the FSP. Soil sample log sheets can be found in Appendix B-1. Field conditions did not indicate a need for the collection of additional samples beyond those that were designated in the approved SWMU 2 Work Plan because no staining associated with dyes was observed during soil sampling.

2.5.1.1 Surface Soil Sampling

A total of 13 surface soil samples were collected from 13 of the soil borings. These samples were divided into two aliquots. Samples to be analyzed for dye parameters were collected from the 0- to 2-foot interval (13 samples) and samples for inorganic parameters (metals, etc.) were collected from 0- to 1-foot interval. The samples were collected using direct-push techniques or a single-use, dedicated plastic trowel. Upon sample retrieval, all samples were monitored with a PID, jarred, labeled, and placed in a cooler containing ice immediately after collection.

2.5.1.2 Subsurface Soil Sampling

A total of 20 subsurface soil samples were collected from each of the soil borings using a dedicated 4-foot clear plastic sleeve inside of the direct-push core sampler. The sample depth targeted the natural soil materials immediately below the fill/natural material interface. All samples collected from the borings were screened with a PID, jarred, labeled, and placed in a cooler containing ice immediately after collection.

2.5.2 Ground Water Sampling

Ground water samples were collected from 8 existing monitoring wells and submitted for laboratory analyses. (Note: Monitoring well 02-06 was originally intended to be sampled. Less than 1 foot of water was found in the well, and a bend in the riser pipe prevented a bailer from being lowered into the well. Therefore, this well was not sampled.)

All ground water sampling was conducted in accordance with CTO 10 SOP 2-4, contained in Attachment B of the FSP. Groundwater sample log forms can be found in Appendix B-2.

2.5.2.1 Water-Level Measurements

One round of synoptic water-level measurements was obtained on July 11, 2001 in all the wells located at the site to provide information regarding ground water flow patterns and flow gradients in all four aquifers. The synoptic round of water-level measurements was taken within a 24-hour period.

Water-level measurements were taken with an electronic water-level indicator, using the top of the riser pipe as the reference point for determining depths to water. A notch or mark was placed on the top of the riser pipe to ensure that measurements were taken from the same reference point between measuring events. All measurements were taken in accordance with CTO 10 SOP 2-2, contained in Attachment B of the FSP. Water-level measurements were recorded on a water-level measurement sheet, as found in Appendix B-8.

2.5.2.2 Well Purging

Purging was accomplished using low-flow techniques, in accordance with CTO 10 SOP 2-3, with either a surface peristaltic pump or downhole bladder pump. The peristaltic pumps used dedicated teflon tubing and the bladder pump used dedicated bladder and tubing. The reusable downhole bladder pump materials were decontaminated between each well. Field measurements of pH, temperature, specific conductance, dissolved oxygen (DO), oxidation-reduction potential (ORP), turbidity, and water levels were taken during the purging process.

When the well cap was opened, a PID reading within the riser pipe was taken prior to purging. Following collection and recording of the PID reading, the water level and the total depth of the monitoring well were measured to within 0.01-foot accuracy from the marked location on the top of the well riser pipe, using the electronic water-level indicator. Water levels were monitored every 5 to 10 minutes as purging occurred.

Initially, the pumping rate was set at approximately 0.1 liter per minute, or lower when possible. If little or no drawdown occurred, the pumping rate was increased to a maximum of 0.4 liter per minute. The pumping rates were adjusted to prevent drawdown from exceeding 0.3 foot, if possible, during purging. If ground water was drawn down below the pump intake, purging ceased, and the well was allowed to recover before purging continued. Slow-recovering wells were identified and purged at the beginning of the workday. Samples were collected from these wells within the same workday. During purging, water-quality parameters (pH, turbidity, specific conductance, temperature, ORP, and DO) were measured and

recorded every 5 to 10 minutes on a low-flow purge data sheet (see Appendix B-2) using a multi-parameter meter. Stabilization of the above parameters was defined as follows:

- Temperature ± 3%
- pH ± 0.1 standard units
- Turbidity < 10 NTUs
- Specific conductance ± 3%
- DO ± 10%

Well purging continued until all parameters stabilized and the minimum purge volume (stabilized well volume plus the extraction tubing volume) had been removed. The pumping rate was reduced if turbidity exceeded 10 Nephelometric Turbidity Units (NTUs) after all field parameters had stabilized. If the parameters did not stabilize within 4 hours or three well volumes had been purged, the information was recorded and sampling was initiated.

Purge water was containerized in appropriate containers and discharged into the NSWC-permitted sanitary sewer system, in accordance with the work plan.

2.5.2.3 Monitoring Well Sampling

All monitoring wells were sampled using low-flow purging and sampling techniques. The monitoring wells were sampled using the same pump (peristaltic or bladder) and tubing that was used during well purging. Immediately following the purging process and before sampling, the temperature, pH, specific conductance, DO, ORP, and turbidity of the water sample were measured and recorded on the ground water sample log form.

All sample containers were filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. Sample aliquots for dye and metals analyses were collected first, followed by total organic carbon (TOC), total suspended solids (TSS), sulfate, and chloride analyses. Immediately after collection, these samples were sealed and placed in a cooler containing ice prior to shipment to the fixed-base laboratory. Sample aliquots for monitored natural attenuation field parameters were also collected for analysis of carbon dioxide, dissolved oxygen, hydrogen sulfide, ferrous iron, alkalinity, sulfide, nitrite and nitrate. All natural attenuation parameters were analyzed at the well location, with the exception of nitrite and nitrate. The nitrite and nitrate aliquots were sealed and placed in a cooler containing ice immediately after collection. Upon arriving at the field office, all nitrite and nitrate samples were either analyzed immediately or refrigerated at 4°C and analyzed within 24 hours.

2.5.3 Surface Water Sampling

One surface water sample was collected during the field investigation. A total of six surface water sampling locations were originally identified for collection; however, all locations were found to be dry in July 2001 when field sampling activities were taking place. The one sample that was collected was a seep discovered during a site reconnaissance south of SWMU 2 (see Figure 1-2).

The surface water sample was collected before the sediment sample at that location to minimize disturbance. The surface water sample was collected using the direct fill method. The aliquot for dissolved metals analyses was collected in an unpreserved polyethylene bottle prior to filtration and was used to transfer the aliquot during filtration to a preserved polyethylene bottle. Immediately after collection, all sample containers were sealed and placed in a cooler containing ice. The sampling location description and all pertinent field data were recorded, including DO, ORP, pH, specific conductance, temperature, and turbidity measurements, on a surface water sample log sheet. The surface water sample was collected in accordance with CTO 10 SOP 2-5, contained in Attachment B of the FSP. The surface water sample log sheet for this one surface water sample is found in Appendix B-3.

2.5.4 Sediment Sampling

A total of seven sediment samples were collected, six from the original locations described in the FSP and one from the seep discussed in Section 2.5.3. Each sediment sample was collected in a depositional area of the stream channel to a depth of 6 inches beneath the ground surface. Sample location 02SWSD05 was located approximately 500 feet further south than originally indicated in the approved SWMU 2 Work Plan. All sample locations were determined by pacing and locating in the field in relation to facility structures. The shifting of this sample location still meets the original objective, because the sample provides data that are reflective of downstream contaminant concentrations, which was the original intent of this sample. Local geology interpretations and the elevation of the sampled seep relative to ground water elevations indicate that the seep is associated with the Golconda/Haney aquifer. The samples were collected using dedicated disposable trowels. Immediately after collection, all samples were cooled to 4°C in a cooler containing ice. The sediment samples were collected in accordance with CTO 10 SOP 2-6, contained in Attachment B of the FSP. The sediment sample log sheets are found in Appendix B-4.

2.6 SAMPLE HANDLING, PACKAGING, AND SHIPPING

Sample handling included the field-related considerations concerning the selection of sample containers, preservatives, allowable holding times, and requested analyses. Sample nomenclature was addressed in CTO 10 SOP 2-10 (Attachment B of the FSP). Sampling containers were wrapped in plastic bubble wrap to minimize the possibility of breakage and secured in a sealed Ziploc-type plastic bag. The secured sample containers were then placed in a sturdy cooler lined with a large plastic garbage bag. The cooler was packed with a noncombustible, cushioning material (bubble wrap) to minimize container breakage. Samples were cooled with bagged ice placed around the shoulders of the sample containers. A temperature blank was placed in the cooler before shipment. The inside plastic bag liner was sealed with a knot, and the chain-of-custody (COC) form was placed in a Ziploc-type plastic bag and taped to the inside of the cooler lid. The cooler was sealed at both ends using strapping tape, and a signed and dated custody seal was applied to the cooler, beneath the last wrap of strapping tape, to provide a tamper-evident seal. A Federal Express airbill was applied to the shipping cooler. TtNUS maintained custody of the samples until they were relinquished to the carrier. The Federal Express tracking number (airbill number) was recorded on the COC form, and the sender's copy of the airbill was maintained for shipment tracking. All samples were shipped to the laboratories using overnight priority shipping and were received within sample holding times. The procedures for sample preservation, packing, and shipment can be found in the FSP and CTO 10 SOP 2-12.

2.7 FIELD SAMPLE DOCUMENTATION

Sample documentation consisted of the completion of sample logsheets, the sample labels, and the COC forms. The sample log sheets contain information such as container source and description; sample type; and time, date, field parameters, and method of sample collection. The sample label contains information on the sample number, media, and analyses required. The COC form tracks each sample from collection to receipt and analyses at the laboratory. The field samples were documented in accordance with CTO 10 SOP 2-11.

2.8 QUALITY CONTROL (QC) SAMPLES

QC samples were collected or generated during environmental sampling activities to monitor both field and laboratory procedures. QC samples included field duplicates, equipment rinsate blanks, batch blanks, source water blanks, matrix spikes and temperature blanks. These types of QC samples are briefly described below:

- Field Duplicates - Field duplicates were two samples collected either independently at a single sampling location at approximately the same time, in the case of ground water and surface water, or as a single sample split into two portions, in the case of soil and sediment. Field duplicates were collected at the rate of 1 in 10 per medium and were used to assess the overall precision of the sampling and analysis program. Duplicates were analyzed for the same parameters in the laboratory and were each labeled with a unique sample number so the identify of the duplicate sample would be unknown to the laboratory (i.e., blind duplicates). During the field investigation of SWMU 2, field duplicates were collected for three surface soil samples, one subsurface soil sample, one ground water sample, one surface water sample, and one sediment sample.

- Equipment Rinsate Blanks - Equipment rinsate blanks were obtained under representative field conditions by collecting the rinse water generated by running analyte-free water through or over sample collection equipment after decontamination and before use. One equipment rinsate blank per 10 samples per aqueous matrix and 20 samples per solid matrix were collected for each type of sampling equipment used (i.e., macro-core sampling barrel) on a daily basis. When pre-cleaned, dedicated, or disposable sampling equipment was used (i.e., tubing, disposable 4-foot plastic sleeves, disposable plastic trowels, etc.), one equipment rinsate blank was collected as a batch blank. Equipment rinsate blanks were analyzed for the same chemical constituents as the associated environmental samples. During the field investigation, a total of five rinsate samples were collected and analyzed.

- Source Water Blanks - Source water blanks were obtained by sampling and analyzing the water used for decontamination of sampling equipment. Two source water blanks were collected to verify the quality of water used decontaminating sampling equipment: SB06230101 was the sample of deionized water and SB06230102 was a sample of tap water from Building 3245 (the field laboratory).

- Matrix Spikes - Matrix spikes (MS) are investigative samples analyzed to provide information about the effect of the sample matrix on the analytical process. All matrix spikes are performed in duplicate (matrix spike duplicate; MSD). MS samples were collected at a frequency of one per every 20 samples for each of the two media sampled (soil, water).

- Temperature Blanks - Temperature blanks were used to determine if samples were adequately cooled during shipment. Temperature blanks consist of analyte-free water poured in a sample container. One temperature blank was submitted to the laboratory in each cooler and the temperature was checked upon receipt at the laboratory. The fixed-base laboratory reported that all

coolers were received with ice and that the temperature blanks were all within the acceptable range of 4±2°C.

2.9 FIELD MEASUREMENTS

Field measurements were taken and recorded during field sampling operations. Ambient air quality was measured using a PID. Ambient air-quality measurements included monitoring of organic vapors in the breathing zone during intrusive field investigation activities and monitoring of organic vapors emanating from site sources such as soil samples, borings, and well casings. CTO 10 SOP 2-13 provides additional details concerning the PID. The YSI Model 610, a multi-parameter water-quality meter, was used for both ground water and surface water field measurements. Water-quality parameters included water temperature, pH, turbidity, specific conductance, ORP, and DO. CTO 10 SOP 2-15 provides additional details concerning the calibration, operation, and maintenance of the water-quality meter. Water-level measurements were obtained using an electronic water-level indicator. CTO 10 SOP 2-2 in the FSP provides additional details concerning the water-level indicator. Natural attenuation parameters, including ferrous iron, carbon dioxide, DO, hydrogen sulfide, alkalinity, nitrate, nitrite, and sulfide, were measured in the field using field test kits. CTO 10 SOP 2-16 provides additional details concerning field test kit analysis.

2.9.1 Equipment Calibration

Instruments used in the field were calibrated daily prior to use. These instruments were calibrated according to manufacturer's specifications. Field equipment calibration was documented on equipment calibration log sheets, which have been filed in the TtNUS project files.

2.9.2 Field Instrument Preventive Maintenance Procedure/Schedule

The field instruments for this project included the PID, water-level indicator, the water-quality meter, and natural attenuation parameter test kits. The specific preventive maintenance procedures that were followed for field equipment were those recommended by the manufacturer.

An appropriate maintenance check was performed daily on each piece of equipment. If damaged or defective parts were identified during the maintenance check and it was determined that the damage could have an impact on the instrument's performance, the instrument was removed from service until the defective parts were repaired or replaced. Critical spare parts were kept on site to reduce downtime. Spare parts included batteries, a DO-probe membrane kit (membranes and a bottle of solution), filters,

and UV light sources. Back-up instruments and equipment were available on site or were shipped within 1 day via overnight courier to avoid delays in the field schedule.

2.10 FIELD CORRECTIVE ACTION

Corrective action is the process of identifying, recommending, approving, and implementing measures to counter unacceptable procedures or "out of quality control" performance that can affect data quality.

Corrective action in the field resulted when the sample network was changed (i.e., more/fewer samples collected, sampling locations other than those specified, etc.) and sampling procedures and/or field analytical procedures required modification. Project personnel were responsible for reporting all suspected technical or quality assurance (QA) nonconformances or suspected deficiencies of any activity or issued document by reporting the situation to the FOL or designee. The Task Order Manager (TOM) was responsible for assessing the suspected problems in consultation with the project QA/QC manager and for making a decision based on the potential for the situation to affect the quality of the data. If it was determined that the situation warranted a reportable nonconformance requiring corrective action, then a nonconformance report was initiated by the TOM. Nonconformances, suspected deficiencies, or field task modification requests did not occur during this field investigation.

2.11 SURVEYING

All soil borings and surface soil, surface water, and sediment sample locations associated with this sampling event were surveyed. All ground surface elevations were surveyed to the nearest 0.01 foot. Vertical elevations were referenced to the 1988 National Geodetic Vertical Datum (NGVD88). Existing survey monuments around NSWC Crane were used as reference points. Horizontal locations of samples, borings, and wells were surveyed to Indiana State Plane coordinates within the nearest 0.10 foot and referenced to the 1983 North American Datum (NAD83).

2.12 DECONTAMINATION

The equipment involved in field sampling activities was decontaminated before beginning work, during drilling and sampling activities, and at the completion of the project. This equipment included the DPT rig and down-hole tools and soil, sediment and groundwater sampling equipment.

All nondedicated reusable sampling equipment used to collect samples was decontaminated both before field sampling, between samples, and before leaving the site. This equipment included DPT rods, macro-core sampler, and bladder pumps. The following decontamination steps were taken:

- Potable water, phosphate-free detergent wash (scrub if necessary)
- Potable water rinse
- Deionized (DI) water rinse
- Air dry (if possible)
- Wrap in aluminum foil (if not used immediately)

The DPT rig was cleaned upon site arrival and prior to leaving the site.

Additional guidance for decontamination was supplied in CTO 10 SOP 2-9 (Attachment B of the FSP).

Disposable equipment used for sampling activities was decontaminated using a detergent wash and potable water rinse, placed in plastic garbage bags, and discarded in dumpsters on the NSWC Crane facility in accordance with procedures described in Section 2.12 of the FSP.

Field analytical equipment such as pH, conductivity, and temperature probes were rinsed with analyte-free water. Water-level measurement devices were also rinsed with analyte-free water after each use.

2.13 INVESTIGATION-DERIVED WASTE (IDW) HANDLING

This investigation generated four types of potentially contaminated residues or investigation-derived waste (IDW):

- Personal protection equipment (PPE)
- Ground water sample tubing and DPT sample liners
- Well development and purge fluids
- Equipment decontamination fluids

IDW was handled as described below:

PPE, Tubing, and DPT Sample Liners - All PPE, tubing, and DPT sample liners were decontaminated and double bagged and placed in trash receptacles at the facility.

Well Development and Purge Fluids - All well development and purge fluids were collected and stored on site in a 500-gallon plastic holding tank. The development and purge fluids were discharged into the NSWC-permitted sanitary sewer system, in accordance with the work plan.

Equipment Decontamination Fluids - All DPT and sampling decontamination fluids were combined with well development and purge fluids and handled in the same manner as described for well development and purge fluids.

2.14 SITE MANAGEMENT AND FACILITY SUPPORT

The FOL was designated as the lead in coordinating all day-to-day activities during the investigation. The FOL was responsible for ensuring that all field team members (including subcontractors) were familiar with the FSP and site-specific HASP. Additionally, the FOL was responsible for all sampling operations, QA/QC, field documentation requirements, and field change orders. The FOL regularly reported to the TOM regarding the status of fieldwork.

All site preparation, mobilization/demobilization, and sampling activities were coordinated through NSWC Crane personnel.

2.15 RECORDKEEPING

Various hardcover, bound record books were maintained for each field activity in accordance with CTO 10 SOP 2-11 (Attachment B of the FSP). The Master Site Logbook served as the overall record of field activities. Information recorded daily in the Master Site Logbook included daily field activities, weather conditions, identity of and arrival and departure times of personnel, management issues, etc. Various field notebooks were also maintained. For example, the site geologist supervising DPT operations maintained a field notebook. Copies of field log books are included in Appendix C.

The FOL was responsible for the maintenance and security of all field records. Eventually, all field records (COCs, sample log sheets, field forms, logbooks, and notebooks) were docketed and incorporated in the central project file.

3.0 DATA QUALITY REVIEW

This section contains a description of the data review procedures used to determine whether analytical laboratory data are of acceptable technical quality prior to decision making. The review begins with data validation, which is a comparison of data quality indicators against prescribed acceptance criteria. The data quality indicators are measures used to assess the bias and precision of the analytical calibrations and sample analyses. The output of this review is a set of alphabetic flags, such as "U," "J," "R," or combinations thereof, that may be assigned to each result based on the validation effort. These flags are used to infer the general quality of the analytical data. The data validation is followed by a summary of quantitative data quality measures to provide the user with a more quantitative estimate of any bias or imprecision associated with the data. Also evaluated are the measures of data completeness, sensitivity, comparability, and representativeness.

Sections 3.1 and 3.2 provide an overview of the data validation process. Section 3.3 presents an evaluation of the data quality beyond data validation. Table 3-1 summarizes concerns raised in the data quality review. This table is meant to be used as a reference to quickly lead the reader to the area of the data quality review where a concern has been identified. For example, Table 3-1 indicates that there is imprecision with the dye results, and the precision section of the text describes what caused the imprecision and its effect on the quality of the laboratory data.

3.1 DATA VALIDATION PROCESS

Assignment of data qualification flags conformed to the U.S. EPA Region 5 Standard Operating Procedures for Validation of Contract Laboratory Program Organic Data (U.S. EPA Region 5, August 1993) and Region 5 Standard Operating Procedures for Validation of Contract Laboratory Program Inorganic Data (U.S. EPA, Region 5, September 1993); and the U.S. EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (U.S. EPA, February 1994a) and U.S. EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (U.S. EPA, February 1994b) to the greatest extent practicable for non-Contract Laboratory Program (CLP) data. Because there are no acceptance criteria for Laboratory Control Samples (LCSs) and matrix spike/matrix spike duplicates (MS/MSDs) in the guidance documents for dyes, the LCSs, and MS/MSDs were validated against criteria listed in Tables 3-3 and 3-4 of the Dye Burial Ground Work Plan (TtNUS, May 2001).

One hundred percent of the analytical laboratory samples were validated according to these data validation specifications. The various data qualifiers are defined as follows:

U – Indicates that the chemical was not detected at the numerical reporting limit (sample-specific quantitation limit) noted. Non-detected results from the laboratory are reported in this manner. This qualifier is also added to a positive result (reported by the laboratory) if the detected concentration is determined to be attributable to contamination introduced during field sampling or laboratory analysis.

UJ – Indicates that the chemical was not detected. However, the reporting limit (sample-specific quantitation limit) is considered estimated based on problems encountered during laboratory analysis. The associated numerical reporting limit is regarded as inaccurate or imprecise.

J – Indicates that the chemical was detected. However, the associated numerical result is not a precise representation of the amount that is actually present in the sample. The laboratory-reported concentration is considered to be an estimate of the true concentration.

UR – Indicates that the chemical may or may not be present. The non-detected analytical result reported by the laboratory is considered to be unreliable and unusable. This qualifier is applied in cases of gross technical deficiencies (i.e., holding times missed by a factor of two times the specified time limit, severe calibration non-compliances, and extremely low quality control recoveries).

R – Indicates that the chemical may or may not be present. The positive analytical result reported by the laboratory is considered to be unreliable and unusable. This qualifier is applied in cases of gross technical deficiencies.

The preceding data qualifiers may be categorized as indicative of major or minor problems. Major problems are defined as issues that result in the rejection of data, qualified with UR and R data validation qualifiers. These data are considered invalid and are not used for decision-making purposes unless they are used in a qualitative way and the use is justified and documented. Minor problems are defined as issues resulting in the estimation of data, qualified with U, J, and UJ data validation qualifiers. Estimated analytical results are considered to be suitable for decision-making purposes unless the data use requirements are very stringent and the qualifier indicates a deficiency that is incompatible with the intended data use. It is notable that a "U" qualifier does not necessarily indicate that a data deficiency exists because all non-detect values are flagged with the "U" qualifier even when no deficiency exists.

3.2 DATA VALIDATION OUTPUTS

After data were validated, a list was developed of non-conformities requiring data qualifier flags which were used to alert the data user to inaccurate or imprecise data. For situations in which several quality control criteria were out of specification, the data validator made professional judgments and/or comments on the validity of the overall data package. This is consistent with industry standards. The reviewer then prepared a technical memorandum presenting qualification of the data, if necessary, and the rationale for making such qualifications. The net result is a data package that has been carefully reviewed for its adherence to prescribed technical requirements. Validators incorporated data qualifiers into the electronic database and submitted the information to the data management group. A complete printout of the data with validation flags is presented in Appendix E. Some of these results are summarized in a more quantitative and manageable format in the following section.

3.3 GENERAL DATA QUALITY REVIEW

Data quality indicators (DQIs) are parameters that are monitored to help establish the quality of data generated during an investigation. Some of the DQIs are generated from analysis of field samples (e.g., field duplicates) and some are generated from the analysis of laboratory samples (e.g., laboratory duplicates). Individually, field and laboratory DQIs provide measures of the performance of the respective investigative operations (field or laboratory). Taken together, the DQIs provide a measure of the overall analytical performance.

The various DQIs are discussed below. In addition to the DQIs discussed below, temperature blanks that accompanied each cooler containing samples were used to assess whether the samples had been stored at the appropriate temperature during shipping. All temperature blanks fell within the acceptable range of 4°C ± 2°C, indicating no deficiencies with regard to shipping temperature.

3.3.1 Precision

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.

Precision is expressed as a relative percent difference (RPD), which is defined as the ratio of the range to the mean. RPDs, which are typically expressed as percentages, are used to evaluate both field and laboratory duplicate precision and are calculated as follows:

$$RPD = \frac{|V1 - V2|}{(V1 + V2)/2} \times 100$$

where RPD = relative percent difference
V1, V2 = two results obtained by analyzing duplicate samples

Field duplicates for Dye Burial Ground soils and sediments were a single sample homogenized, split into two portions and placed into separate sample bottles. Each sample bottle was assigned a unique nomenclature so as to be blind to the laboratory. Field duplicates were collected during a single act of sampling and analyzed for chemical constituents to measure the precision of the sampling and analysis program, as well as natural sample heterogeneity. Field duplicates were collected at a rate no less than one duplicate per 10 environmental samples. Five field duplicates were collected for 40 soil and sediment samples, and two field duplicates were collected for eight ground water and one surface water samples. Therefore, the 10 percent frequency criterion for field duplicates specified in the QAPP was achieved. The precision estimates encompass 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.

Laboratory precision QC samples (i.e., laboratory duplicates for inorganic chemicals and MSDs for organic chemicals) were scheduled to be analyzed at a rate of no fewer than one QC sample per 20 environmental samples. This 5 percent rate as specified in the QAPP was achieved for aqueous samples; two aqueous laboratory duplicates were analyzed per nine aqueous samples. Two soil laboratory duplicates were analyzed per 40 soil samples; this is equal to the 5 percent target rate. However, one of the soil laboratory duplicates was performed on a sample not associated with this sample delivery group (SDG). Therefore, the duplicate results for this sample were not received in the electronic data deliverable and could not be used for precision comparison. Laboratory precision is measured by comparing RPD values to precision control limits specified in the applicable analytical SOPs.

For this general data quality review, the precision points of reference of ±50 percent for solid matrices and ±30 percent for aqueous matrices were employed for both field and laboratory duplicates to assess the degree of precision.

Dyes in Soil and Sediment

RPDs for the spiked compounds ranged from 1.5 percent to 154.1 percent across all spiked analytes in MS/MSD pairs. Solvent Yellow 3 exhibited the 154.1 RPD, and one other value for this compound exceeded 30 percent (39.9 percent); otherwise, all RPD values across all spike compounds were less than 18 percent, indicating performance that is generally well within expectations.

The surrogate compound RPD values ranged from 4.4 percent to 9.1 percent across the MS/MSD and field/laboratory duplicate pairs. These RPDs indicate no unexpected uncertainty associated with the analysis of soils and sediments for dyes in samples collected at the DBG.

Dyes in Ground Water and Surface Water

RPDs for the spiked target compounds ranged from 1.33 percent to 16.7 percent across all spiked analytes in MS/MSD pairs. The surrogate compound RPDs were comparable, ranging from 1.1 percent to 13.4 percent across the MS/MSD and field/laboratory duplicate pairs. These RPDs indicate no unexpected uncertainty associated with the analysis for dyes in ground water and surface water samples collected at the DBG.

Metals in Soil and Sediment

No average RPDs were greater than 30 percent for any individual metal. All maximum RPD values were less than 50 percent except for calcium (67.2 percent) and manganese (65.9 percent). Soils often exhibit RPD values greater than 50 percent due to the general lack of homogeneity present in most soil samples. Furthermore, calcium is a macronutrient that is not typically considered when evaluating health risks. Based on these results, no unexpected uncertainty was observed for metals in soil or sediment samples collected at the DBG.

Metals in Ground Water and Surface Water

No average RPDs were greater than 15 percent for any individual metal. All maximum RPD values were less than 30 percent. This kind of performance is typical for water samples, which are relatively homogeneous by nature. Based on these results, no unexpected uncertainty was observed for metals in aqueous samples collected at the DBG.

Miscellaneous Parameters in Soil and Sediment

Cation Exchange Capacity (CEC) - RPD values for CEC (two results) ranged from 0.5 percent to 10 percent, indicating good precision and no expectation of unusual uncertainty associated with CEC analyses.

Total Organic Carbon (TOC) - RPD values for TOC (two results) ranged from 0.2 percent to 1.2 percent, indicating good precision and no expectation of unusual uncertainty associated with TOC analyses.

pH - Typical precision indicators are not analyzed.

Miscellaneous Parameters in Ground Water and Surface Water

Total Organic Carbon - RPD values for TOC (two results) ranged from 0.0 percent to 0.1 percent, indicating good precision and no expectation of unusual uncertainty associated with TOC analyses.

pH - Typical precision indicators are not analyzed.

3.3.2 Accuracy

Accuracy is the degree of agreement between an observed value and an accepted reference value. Accuracy measurements are designed to detect biases resulting from sample handling and analysis. This parameter is assessed by measuring spiked samples (e.g., surrogate spikes or MSs) or well-characterized samples of certified analyte concentrations (e.g., LCSs) and by measuring blanks.

Accuracy requirements for field measurements made at the DBG were ensured through control over the sample collection and handling and through routine instrument calibration. Field accuracies were monitored through the use of blanks to detect cross-contamination and by monitoring adherence to procedures that prevent sample contamination or degradation. Equipment rinsate blanks were collected for the DBG to assess cross-contamination via sample collection equipment. These blanks were obtained under representative field conditions by collecting the rinse water generated by running analyte-free water through sample collection equipment after decontamination and before use. Rinsate blanks were obtained for each type of sampling equipment for each day that the sampling equipment was decontaminated. Where pre-cleaned, dedicated sampling equipment was used, one rinsate blank was collected as a "batch blank." Rinsate blanks were analyzed for the same chemical constituents as the associated environmental samples. Accuracy was also assured qualitatively through adherence to all sample handling, preservation, and holding time requirements.

Accuracy in the laboratory was 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 was also assessed by monitoring the analytical recovery of select surrogate compounds added to samples that are analyzed by organic chromatographic methods. LCSs were used to assess the accuracy of laboratory operations with minimal sample matrix effects. MS and surrogate compound analyses measure the combined accuracy effects of the sample matrix, sample preparation, and sample measurement. Spiking concentrations equaled or approximated the default concentrations detailed in the applicable sample preparation or analysis SOPs. LCS and MS analyses were performed at a frequency of one per 20 associated samples of like matrix, as required by the QAPP (TtNUS, April 2001). Laboratory accuracy was assessed by comparing calculated percent recoveries to accuracy control limits specified in the applicable laboratory SOP.

Percent recovery was calculated using the following equation:

$$\%R = \frac{Ss - So}{S} \times 100$$

where	%R	=	percent recovery
	Ss	=	result of spiked sample
	So	=	result of non-spiked sample
	S	=	concentration of spiked amount.

In general, a percent recovery range of 75 percent to 125 percent defines the accuracy objective for the analytical data. It should be noted, however, that the analytical laboratory establishes analyte-specific percent recoveries when evaluating performance. Table 3-2 depicts the qualification rates for MS, LCS, and surrogate recoveries.

Dyes in Soil and Sediment

The mean dye recoveries in soil and sediment LCS, MS, and MSD samples were generally acceptable. LCS recoveries ranged from 79.5 percent to 113.2 percent and MS/MSD target compound recoveries ranged from 90.6 percent to 121.3 percent, with the exception of Solvent Yellow 3. The mean Solvent Yellow 3 recovery in LCS samples was 57.9 percent and ranged from 53.4 percent to 68.6 percent in MS and MSD samples, respectively. These recoveries indicate a moderate low bias for Solvent Yellow 3 in soil and sediment samples. By design, only a representative number of target compounds (Acid Orange

10, Acid Yellow 73, Disperse Violet 1, and Solvent Yellow 3) were spiked into the samples subjected to dye analyses, and there are 20 dye target compounds. Thus, the observed MS/MSD results do not directly reflect percent recoveries of all target compounds and must be used to infer the recovery performance for non-spiked compounds.

The mean recoveries of surrogate compounds anthracene and benzanthrone were low at 47.9 percent and 58.1 percent, respectively, across all soil samples and related QC samples (61 results), excluding samples 02SD010006 and 02SD050006, which had zero percent recoveries. This indicates a general moderate low bias for soils and sediments. Occasional extreme values are not unusual for this many results. Sample 02SS050002 had one surrogate recovery below 10 percent indicating a potentially extremely low bias for target analytes. Sample 02SD020006-D had two surrogate recoveries below 10 percent and the original sample 02SD020006 had one surrogate recovery at 10 percent indicating a potentially extremely low bias for target analytes in these samples. Samples 02SD010006 and 02SD050006 had zero percent recoveries for the surrogates, indicating that the laboratory may have forgotten to spike those samples with the surrogate compounds. This assertion is made because it is unusual not to recover any surrogate compound from a sample, especially when samples of similar matrix generally exhibit acceptable recoveries of the same surrogate compounds, as was observed in this investigation. Omission of surrogates from these samples could not be verified so the potential for an extremely low bias still must be viewed to exist for samples 02SD010006 and 02SD050006. The MS and MSD for sample 02SS200002 had recoveries for the surrogate anthracene that were less than 10 percent (2.7 percent and 2.3 percent). However because the original sample (02SS200002) and its duplicate (02SS200002-D) had acceptable recoveries, the extremely low bias was ascribed to the MS and its duplicate and the results for sample 02SS200002 were not qualified.

The surrogate recoveries are consistent with target analyte recoveries from LCSs, MSs, and MSDs in most samples. On this basis, the user can expect a moderately low bias for the dyes in soils and sediments, in general, and a potentially extremely low bias for samples 02SS050002, 02SD010006, 02SD050006, and 02SD020006-D.

Dyes in Ground Water and Surface Water

The mean organic colorants target compound recoveries in ground water and surface water LCS, MS, and MSD samples were generally acceptable. LCS target analyte recoveries ranged from 79.6 percent to 86.6 percent and MS/MSD target analyte recoveries ranged from 75.0 percent to 90.6 percent, with the exception of Acid Yellow 73. The mean Acid Yellow 73 recovery in LCS samples was 85.5 percent and

ranged from 69.2 percent to 71.6 percent in MS and MSD samples, respectively. These data indicate a slight low bias for Acid Yellow 73.

The mean recoveries of surrogate compounds anthracene and benzanthrone were 50.9 percent and 87.7 percent, respectively, across all aqueous samples and related QC samples (25 results). Sample 02GWC11P301 had an anthracene surrogate recovery of 3.9 percent, indicating a potentially extremely low bias for target analytes in this sample. However, anthracene recoveries in all other samples ranged from 41 percent to 66 percent, indicating that this extreme low result is not the norm. The anthracene surrogate recoveries indicate a moderate low bias with the potential for an extremely low bias for sample 02GWC11P301. The MS and MSD for dyes in ground water yielded target analyte recoveries that ranged 78 and 95 percent, indicating excellent performance for those compounds and supporting the assertion that the 3.9 percent recovery of anthracene in sample 02GWC11P301 is an anomaly. The benzanthrone recoveries do not indicate any significant bias with recoveries across all samples ranging from 78 to 98 percent.

Overall, no significant bias is anticipated for dye analysis in ground water and surface water samples. A possible exception is a slight low bias for Acid Yellow 73, as described above.

Metals in Soil and Sediment

Only one LCS sample and one MS soil sample (02SS200001) were analyzed. The LCS and MS percent recoveries across the soil and sediment SDG were within the 75 percent to 125 percent range except the following MS recoveries: barium, 133.9 percent; cadmium, 130.0 percent; iron, 145.7 percent; lead, 133.6 percent; manganese, 165.4 percent; potassium, 129.5 percent; and mercury, 66.2 percent.

The ability to estimate bias for metal target analytes in actual soil and sediment samples is limited because only one MS was performed for SWMU 2. Because all but one of the observed significant biases were greater than 125 percent, there seems to exist a potential to overestimate metal concentrations. Nevertheless, the limited number of recoveries outside the 75 percent to 125 percent range suggests that no bias should generally be anticipated, with the exception of sample 02SS20001. The metals data for sample 02SS20001 indicate a slight high bias for barium, cadmium, iron, lead, manganese, and potassium and a moderately low bias for the mercury result.

Metals in Ground Water and Surface Water

The LCS and mean MS percent recoveries were within the expected ranges across all ground water and surface water SDGs except for iron, selenium, and tin. The lone LCS recovery for selenium was 126.0 percent indicating a potential slight high bias. The iron and tin mean MS percent recoveries were 73.7 percent and 74.8 percent, respectively. The minimum iron and tin MS recoveries were 58.0 percent and 56.3 percent, respectively; otherwise recoveries for these metals were greater than 89 percent. The mean percent recoveries for iron and tin on the whole are barely outside the expected recovery limits of 100 percent ± 25 percent, so no adverse impact to data quality is expected.

Overall, no significant bias is anticipated for metals analysis in ground water and surface water samples.

Miscellaneous Parameters in Soil and Sediment

Total Organic Carbon - No TOC results were qualified and all bias indicators fell within the 75 percent to 125 percent range. The mean LCS and MS/MSD recovery was approximately 105 percent (six values), indicating no significant bias in TOC analyses.

Cation Exchange Capacity - Bias indicators are not analyzed for CEC.

pH - Bias indicators are not analyzed.

Miscellaneous Parameters in Ground Water and Surface Water

Total Organic Carbon - No TOC results were qualified and all bias indicators fell within the 75 percent to 125 percent range. The mean LCS and MS/MSD recovery was approximately 101.7 percent (three values), indicating no significant bias in TOC analyses.

Sulfate - No sulfate results were qualified and all bias indicators fell within the 75 percent to 125 percent range. The mean LCS and MS/MSD recovery was approximately 92.8 percent (four values), indicating no significant bias in sulfate analyses.

Chloride - No chloride results were qualified and all bias indicators fell within the 75 percent to 125 percent range. The mean LCS and MS/MSD recovery was approximately 93.0 percent (six values), indicating no significant bias in chloride analyses.

Hardness, Total Suspended Solids (TSS), and pH - Bias indicators are not analyzed.

3.3.3 Completeness

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.

Field completeness is a measure of the amount of valid field measurements obtained from all the field measurements taken in the project. A completeness criterion of 100 percent applies to these measurements. The calculated percent completeness for field measurements was 100 percent.

Sample completeness is a measure of the number of samples proposed in the Dye Burial Work Plan and the number of samples actually collected. Table 3-3 compares the samples collected to the samples proposed in the work plan. The calculated percent sample completeness for soil samples was 100 percent. The calculated percent completeness for ground water samples was 89 percent. One well (02-06) was dry.

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. Completeness is typically expressed as a percentage and is determined using the following equation:

$$\%C = \frac{V}{T} \times 100$$

where %C = percent completeness
V = number of results determined to be valid
T = total number of results

Under ideal conditions, the laboratory completeness objective would be 100 percent. However, samples can be rendered unusable during shipping and preparation (e.g., bottles broken or extracts accidentally destroyed) or analysis (e.g., loss of instrument sensitivity, strong matrix effects). Laboratory completeness objectives were 95 percent for soil and sediment samples and for ground water and surface water samples. Table 3-4 compares the percent completeness between analytical fractions for soil and sediment samples and ground water and surface water samples.

The calculated percent completeness for laboratory analytical data collected during the field investigation is 100 percent for all parameters analyzed for in ground water and surface water samples. The calculated percent completeness for laboratory analytical data collected during the field investigation is 92.8 percent for dye analysis, 100 percent for metals analysis, and 100 percent for miscellaneous analysis. The percent completeness was not met for the dye analysis due to low surrogate recoveries, but overall the laboratory analytical data met the data completeness objective for SWMU 2. The resulting uncertainty of not meeting the dye completeness goal in soil and sediment is discussed in Sections 6.5.1 and 9.4 of the human health and ecological risk assessments, respectively.

All dye results for samples 02SD010006, 02SD020006-D, 02SD050006, and 02SS050002 were rejected due to surrogate recoveries of less than 10 percent.

3.3.4 Sensitivity

Tables 3-5 and 3-6 compare the observed minimum and maximum reporting limits achieved during laboratory analyses to the target laboratory reporting limits contained in Table 1-1 of the Dye Burial Ground Work Plan (TtNUS, May 2001). Sample reporting limits for the soil and sediment samples listed in Tables 3-5 and 3-6 were adjusted for variations due to sample aliquot and dilution factors. Therefore, only general conclusions can be drawn from a comparison of the sample reporting limits to target laboratory reporting limits for soil and sediment samples. Observed exceedances of the target laboratory reporting limits occur in several instances. The impact of these exceedances is discussed in Sections 6.5.1 and 9.4 of the human health and ecological risk assessments, respectively.

3.3.5 Comparability

Comparability is defined as the confidence with which one data set can be compared with another (e.g., among sampling points; among sampling events). Comparability is achieved by using standardized sampling and analysis methods, as well as data reporting formats. Comparability of laboratory measurements was achieved primarily through the use and documentation of standard sampling and analytical methods. Results were reported in units to ensure comparability with previous data and with current state and federal standards and guidelines. Comparability of field data was ensured by following the Dye Burial Ground FSP and the associated SOPs. Comparability of laboratory measurements was assessed primarily through the use of spike recoveries, RPD values, and adherence to the laboratory quality assurance plan. No corrective actions were required based on insufficient comparability.

Laboratory data were generated using methodologies specified in the Dye Burial Ground Work Plan (TtNUS, May 2001). Results were also reported in the units specified in the plan. The laboratory analyzed matrix and blank spikes in duplicate and compared RPD values to control limits generated using data points from matrix and blank spikes previously analyzed. Data qualification due to field or laboratory imprecision only occurred in the soil and sediment samples for calcium and manganese, as depicted in the Qualification Rate Tables, 3-7 and 3-8. In general, qualification due to imprecision was not a significant cause of data qualification and does not impact the usability of the data.

3.3.6 Representativeness

Representativeness is an expression of the degree to which the data accurately and precisely depict the actual characteristics of a population or environmental condition existing at an individual sampling point and is contingent on a good design for the sampling program. The project planning documents (work plan and field and laboratory SOPs) and the use of standardized sampling, handling, analytical, and reporting procedures are designed so that the final data are accurate representations of actual site conditions. A number of conditions could arise that cause the representativeness of samples to be questioned. For example, data outliers or samples collected from a place different from the intended location could adversely impact representativeness of the data set.

Data were collected from the specified locations using sampling, handling, analytical, and reporting procedures as specified in the Dye Burial Ground Work Plan (TtNUS, May 2001). Therefore, no data representativeness concerns have been raised, and the data are suitable for use as part of the monitoring program.

TABLE 3-1

SUMMARY OF IDENTIFIED CONCERNS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

	Matrix			
Analytical Fraction	**Soil**	**Sediment**	**Ground Water**	**Surface Water**
Dyes	P, A-, C, S	P, A-, C, S	A-, C, S	A-, C, S
Metals	A+, A-	A+, A-	--	--
TOC	--	NA	NA	NA
CEC	--	NA	NA	NA
pH	--	NA	NA	NA
Sulfate	NA	NA	--	NA
Chloride	NA	NA	--	NA
Hardness	NA	NA	NA	--
TSS	NA	NA	--	--

NA = Not applicable.
-- = Uncertainity or bias is not indicated.
P = Imprecision indicated for one or more analytes.
A+ = Potential high bias for one or more analytes.
A– = Potential low bias for one or more analytes.
C = Completeness goals were not achieved.
S = Sensitivity (reporting limit targets not achieved).

TABLE 3-2

RATES OF QUALIFICATION
SURROGATE, MATRIX SPIKE, and BLANK SPIKE
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Soil and Sediment			
	Dyes	Metals	Misc.
Matrix Spike Recovery	<1%	11%	0%
Blank Spike Recovery	2%	5%	0%
Surrogate Recovery	62%	NA	NA
Aqueous			
	Dyes	Metals	Misc.
Matrix Spike Recovery	0%	8%	0%
Blank Spike Recovery	0%	4%	0%
Surrogate Recovery	0%	NA	NA

NA = Not applicable.

TABLE 3-3

NUMBER OF SAMPLES COLLECTED VERSUS NUMBER OF SAMPLES PROPOSED IN FIELD SAMPLING PLAN
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

DYE BURIAL GROUND SAMPLES				
Analytical Fraction	SS/SB[2]	SD[3]	GW	SW[4]
Metals	33/33	7/7	8/9	1/10
Metals (F)	NA	NA	NA	1/10
Organic Colorants[5]	33/33	7/7	8/9	1/10
Chloride	NA	NA	8/9	NA
Sulfate	NA	NA	8/9	NA
CEC	10/10	NA	NA	NA
TOC	10/10	NA	8/9	1/10[1]
Hardness	NA	NA	NA	1/10
pH	10/10	NA	NA	NA
TSS	NA	NA	8/9	1/10

TOC = Total Organic Carbon.
CEC = Cation exchange capacity.
TSS = Total suspended solids.
SS = Surface soil samples.
SB = Soil boring samples.
SD = Sediment samples.
NA = Not applicable.

1 - SW - TOC analyses not proposed in work plan.
2 - SS/SB/SD - All soils analyzed for APP IX + Aluminum, Cadmium, Iron, Manganes, Magnesium, Potassium, and Sodium.
3 - Three additional sediment samples of oppurtunity were not collected.
4 - Only one sample could be collected; all other locations were dry.
5 - Acid Blue 1 and Acid Yellow 3 coelute with other dye compounds. Unless dyes are detected, results for Acid Blue 1 and Acid Yellow 3 will not be reported.

TABLE 3-4

PERCENT COMPLETENESS BETWEEN ANALYTICAL FRACTIONS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

DYE BURIAL GROUND						
	Soil and Sediment			Ground Water and Surface Water		
	Dye	Metals	Misc.	Dye	Metals	Misc.
Total Data Points	1,422	1,176	45	578	456	65
Rejected Data Points	103	0	0	0	0	0
% Completeness	93%	100%	100%	100%	100%	100%

TABLE 3-5

OBSERVED MINIMUM AND MAXIMUM REPORTING LIMITS VERSUS RISK-BASED SOIL AND SEDIMENT TARGET LEVELS AND SOIL AND SEDIMENT EDQLs
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Soil and Sediment							
Parameter	Observed Min RL	Observed Max RL	Target Laboratory RL (mg/kg)	Risk-Based Soil Target Level (mg/kg)	Risk-Based Sediment Target Level (mg/kg)	Soil EDQLs (mg/kg)	Sediment EDQLs (mg/kg)
DYES							
1-AMINOANTHRAQUINONE	9.6	9.6	9.6	14.7	--	--	--
2-AMINOANTHRAQUINONE	14.0	14.0	14	14.7	--	--	--
ACID BLUE 45	14.0	14.0	14	--	--	--	--
ACID BLUE 9	13.6	13.8	13.6	1,630	--	--	--
ACID ORANGE 10	15.1	15.1	15.1	6.46	--	--	--
ACID RED 64	37.5	37.5	37.5	--	--	--	--
ACID YELLOW 23	15.1	15.1	15.1	--	--	--	--
ACID YELLOW 73	13.6	13.6	13.6	--	--	--	--
BASIC VIOLET 10	11.9	11.9	11.9	12	--	--	--
BASIC YELLOW 2	13.9	13.9	13.9	1.3	--	--	--
DISPERSE BLUE 14	11.2	11.2	11.2	--	--	--	--
DISPERSE RED 9	9.9	9.9	9.9	--	--	--	--
DISPERSE VIOLET 1	9.8	9.8	9.8	--	--	--	--
P-(DIMETHYLAMINO)AZOBENZENE[1]	12.0	12.0	--	--	--	--	--
SOLVENT GREEN 3	11.0	11.0	11	--	--	--	--
SOLVENT ORANGE 3	9.6	9.6	9.6	129	--	--	--
SOLVENT ORANGE 7	10.8	10.8	10.8	52	--	--	--
SOLVENT RED 1	17.4	17.4	17.4	--	--	--	--
SOLVENT RED 24	4.3	4.3	4.3	--	--	--	--
SOLVENT YELLOW 14	10.6	10.6	10.6	3.23	--	--	--
SOLVENT YELLOW 2	12.0	12.0	12	0.11	--	--	--
SOLVENT YELLOW 3	11.3	11.3	11.3	0.13	--	--	--
SOLVENT YELLOW 33	10.5	11.5	10.5	--	--	--	--
ACID BLUE 1[2]	--	--	16	10	--	--	--
ACID YELLOW 3[2]	--	--	13.7	--	--	--	--

TABLE 3-5

OBSERVED MINIMUM AND MAXIMUM REPORTING LIMITS VERSUS RISK-BASED SOIL AND SEDIMENT TARGET LEVELS AND SOIL AND SEDIMENT EDQLs
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Soil and Sediment							
Parameter	Observed Min RL	Observed Max RL	Target Laboratory RL (mg/kg)	Risk-Based Soil Target Level (mg/kg)	Risk-Based Sediment Target Level (mg/kg)	Soil EDQLs (mg/kg)	Sediment EDQLs (mg/kg)
METALS							
ALUMINUM	50.00	50.00	20.0	--	--	--	--
ANTIMONY	0.10	0.69	1.0	0.1423	0.3	0.1423	--
ARSENIC	0.02	1.60	1.0	0.39	0.0059	5.7	0.0059
BARIUM	0.10	0.10	1.0	1.04	82	1.04	--
BERYLLIUM	0.10	3.40	1.0	0.1	--	1.06	--
CADMIUM	0.10	0.52	1.0	0.00222	0.4	0.00222	0.596
CALCIUM	36.00	454	500	--	--	--	--
CHROMIUM	0.10	0.10	1.0	2	--	--	--
COBALT	0.10	2.30	1.0	0.14033	50	0.14033	50
COPPER	0.10	0.10	1.0	2.96	16	2.96	16
IRON	18.00	18.00	10.0	--	--	--	--
LEAD	0.10	0.10	1.0	0.05373	31	0.05373	31
MAGNESIUM	391.00	421	500	--	--	--	--
MANGANESE	0.50	0.50	1.5	--	--	--	--
MERCURY	0.02	0.02	0.2	0.073	0.1	0.073	0.174
NICKEL	0.10	0.10	1.0	7	16	13.6	16
POTASSIUM	27.00	688	500	--	--	--	--
SELENIUM	0.10	0.51	1.0	0.02765	0.3	0.02765	--
SILVER	0.10	0.69	1.0	2	0.5	4.04	0.5
SODIUM	170	545	500	--	--	--	--
THALLIUM	0.10	0.69	1.0	0.04	--	0.05692	--
TIN	0.50	3.30	5.0	7.62	45,000	7.62	--
VANADIUM	0.10	7.30	1.0	1.59	300	1.59	--
ZINC	2.10	2.10	1.0	6.62	120	6.62	120

TABLE 3-5

OBSERVED MINIMUM AND MAXIMUM REPORTING LIMITS VERSUS RISK-BASED SOIL AND SEDIMENT TARGET LEVELS AND SOIL AND SEDIMENT EDQLs
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Soil and Sediment							
Parameter	Observed Min RL	Observed Max RL	Target Laboratory RL (mg/kg)	Risk-Based Soil Target Level (mg/kg)	Risk-Based Sediment Target Level (mg/kg)	Soil EDQLs (mg/kg)	Sediment EDQLs (mg/kg)
MISCELLANEOUS							
Cation Exchange Capacity	1.0	1.0	6.0	--	--	--	--
Total Organic Carbon	1,000	1,000	1,000	--	--	--	--

Value exceeds risk-based target level.

1 - P-(DIMETHYLAMINO)AZOBENZENE is the same as Solvent Yellow 2.
2 - Acid Blue 1 and Acid Yellow 3 were only analyzed if other dyes were detected due to coelution problems.

RL = Reporting limit.
EDQL = Ecological data quality level.
mg/kg = milligrams per kilogram

TABLE 3-6

OBSERVED MINIMUM AND MAXIMUM REPORTING LIMITS VERSUS RISK-BASED AQUEOUS TARGET LEVELS AND SURFACE WATER EDQLs
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Ground Water and Surface Water					
Parameter	Observed Min RL	Observed Max RL	Target Laboratory RL (ug/L)	Risk-Based Target Level (ug/L)	Surface Water EDQLs (ug/L)
DYES					
1-AMINOANTHRAQUINONE	16.1	16.1	12.2	2.01	--
2-AMINOANTHRAQUINONE	23.4	23.4	12.6	2.01	--
ACID BLUE 45	23.3	23.3	26.7	--	--
ACID BLUE 9	22.6	22.6	25.1	230,000	--
ACID ORANGE 10	25.1	25.1	13	100	--
ACID RED 64	62.5	62.5	12.1	--	--
ACID YELLOW 23	25.1	25.1	12.8	--	--
ACID YELLOW 73	22.6	22.6	13.5	--	--
BASIC VIOLET 10	19.9	19.9	15	570	--
BASIC YELLOW 2	23.1	23.1	23.1	60	--
DISPERSE BLUE 14	18.7	18.7	16.7	--	--
DISPERSE RED 9	16.5	16.5	14.8	--	--
DISPERSE VIOLET 1	16.3	16.3	11.1	--	--
P-(DIMETHYLAMINO)AZOBENZENE[1]	20.0	20.0			--
SOLVENT GREEN 3	18.4	18.4	18.5	--	--
SOLVENT ORANGE 3	16.0	16.0	11.7	600	--
SOLVENT ORANGE 7	18.0	18.0	6.1	730	--
SOLVENT RED 1	29.0	29.0	7.9	INS	--
SOLVENT RED 24	7.1	7.1	2.9	--	--
SOLVENT YELLOW 14	17.7	17.7	13.5	460	--
SOLVENT YELLOW 2	20.0	20.0	11.8	0.01	--
SOLVENT YELLOW 3	18.9	18.9	16.2	0.02	--
SOLVENT YELLOW 33	17.5	17.5	13.7	--	--
ACID BLUE 1[2]			43.8	450	--
ACID YELLOW 3[2]			24.6	--	--
METALS					
ALUMINUM	200	200	200	--	--
ANTIMONY	1.0	1.0	1.0	6	31
ARSENIC	0.2	0.2	1.0	0.045	53
BARIUM	1.0	1.0	1.0	2,000	5,000
BERYLLIUM	1.0	1.0	1.0	4	7.6
CADMIUM	1.0	1.0	1.0	0.66	0.66
CALCIUM	5,000	5,000	5,000	--	--
CHROMIUM	5.0	5.0	5.0	11	42
COBALT	3.0	3.0	3.0	5	5
COPPER	2.0	2.0	2.0	5	5
IRON	58.0	58.0	100.0	--	--
LEAD	1.0	1.0	1.0	1.3	1.3
MAGNESIUM	5,000	5,000	5,000	--	--

TABLE 3-6

OBSERVED MINIMUM AND MAXIMUM REPORTING LIMITS VERSUS RISK-BASED AQUEOUS TARGET LEVELS AND SURFACE WATER EDQLs
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Ground Water and Surface Water					
Parameter	Observed Min RL	Observed Max RL	Target Laboratory RL (ug/L)	Risk-Based Target Level (ug/L)	Surface Water EDQLs (ug/L)
MANGANESE	15.0	15.0	15.0	--	--
MERCURY	0.1	0.2	0.2	0.0013	0.0013
NICKEL	10.0	10.0	10.0	29	29
POTASSIUM	5,000	5,000	5,000	--	--
SELENIUM	1.0	1.0	1.0	5	5
SILVER	3.0	3.0	3.0	1	1
SODIUM	5,000	5,000	5,000	--	--
THALLIUM	1.0	1.0	1.0	0.56	0.56
TIN	10.0	10.0	10.0	73	73
VANADIUM	2.0	2.0	2.0	19	19
ZINC	10.0	10.0	10.0	58.9	58.9
MISCELLANEOUS					
Chloride[3]	1,000	1,000	--	--	--
Sulfate[3]	1,000	1,000	--	--	--
Total Orgainc Carbon	1,000	1,000	1,000	--	--
Total Suspended Solids	2,000	2,000	2,000	--	--
Hardness[4]	NA	NA	--	1,000	--
Nitrite/Nitrate[5]	--	--	--	--	--

Value exceeds risk-based target level.

1 - P-(DIMETHYLAMINO)AZOBENZENE is the same as Solvent Yellow 2.
2 - Acid Blue 1 and Acid Yellow 3 were only analyzed if other dyes were detected due to coelution problems.
3 - Chloride and sulfate were not listed on the COC Table 1-1 in the QAPP but are listed to be analyzed for in the FSP.
4 - Hardness analysis did not have any NDs.
5 - Nitrite/nitrate analyses was performed in the field and is not included in the laboratory results.

RL = Reporting limits.
EDQL = Ecological data quality levels.

TABLE 3-7

QUALIFICATION RATES FOR AQUEOUS ANALTYICAL DATA
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Parameter	Reason for Qualification	J	UJ
SOLVENT GREEN 3	Calibration non-compliance	0%	100%
IRON	MS/MSD non-compliance	100%	0%
SELENIUM	LCS/LCSD non-compliance	100%	100%
TIN	MS/MSD non-compliance	100%	100%
ZINC	Lab duplicate imprecision	100%	100%
Filtered IRON	MS/MSD non-compliance	100%	0%
Filtered SELENIUM	LCS/LCSD non-compliance	0%	100%
Filtered TIN	MS/MSD non-compliance	0%	100%
Filtered ZINC	Lab duplicate imprecision	0%	100%
TOTAL SUSPENDED SOLIDS	Holding time exceedance	100%	100%

TABLE 3-8

QUALIFICATION RATES FOR SOIL ANALYTICAL DATA
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Parameter	Reason for Qualification	J	U	UJ	UR
1-AMINOANTHRAQUINONE	Surrogate recovery non-compliance	0%	0%	100%	100%
2-AMINOANTHRAQUINONE	Other	0%	7%	0%	0%
	Surrogate recovery non-compliance, Other	0%	0%	4%	0%
	Surrogate recovery non-compliance	0%	0%	96%	100%
ACID BLUE 45	Calibration non-compliance	0%	0%	10%	0%
	Calibration non-compliance, surrogate recovery non-compliance	0%	0%	20%	0%
	Surrogate recovery non-compliance	0%	0%	70%	100%
ACID BLUE 9	Calibration non-compliance	0%	0%	4%	0%
	Calibration non-compliance, surrogate recovery non-compliance	0%	0%	21%	0%
	Surrogate recovery non-compliance	0%	0%	75%	100%
ACID ORANGE 10	Surrogate recovery non-compliance	100%	0%	100%	100%
ACID RED 64	Surrogate recovery non-compliance	0%	0%	100%	100%
ACID YELLOW 23	Calibration non-compliance, surrogate recovery non-compliance	0%	0%	4%	0%
	Other	0%	9%	0%	0%
	Surrogate recovery non-compliance, Other	0%	0%	44%	25%
	Surrogate recovery non-compliance	100%	0%	52%	75%
ACID YELLOW 73	MS/MSD non-compliance, surrogate recovery non-compliance	0%	0%	4%	0%
	Surrogate recovery non-compliance	0%	0%	96%	100%
BASIC VIOLET 10	Surrogate recovery non-compliance	0%	0%	100%	100%
BASIC YELLOW 2	Surrogate recovery non-compliance	0%	0%	100%	100%
DISPERSE BLUE 14	Surrogate recovery non-compliance	0%	0%	100%	100%
DISPERSE RED 9	Surrogate recovery non-compliance	0%	0%	100%	100%
DISPERSE VIOLET 1	MS/MSD non-compliance, surrogate recovery non-compliance	0%	0%	4%	0%
	Surrogate recovery non-compliance	0%	0%	96%	100%
P-(DIMETHYLAMINO)AZOBENZENE	Surrogate recovery non-compliance	0%	0%	100%	100%
SOLVENT GREEN 3	Surrogate recovery non-compliance	0%	0%	100%	100%
SOLVENT ORANGE 3	Surrogate recovery non-compliance	0%	0%	100%	100%
SOLVENT ORANGE 7	Surrogate recovery non-compliance	0%	0%	100%	100%
SOLVENT RED 1	Surrogate recovery non-compliance	0%	0%	100%	100%
SOLVENT RED 24	Surrogate recovery non-compliance	0%	0%	100%	100%

TABLE 3-8

QUALIFICATION RATES FOR SOIL ANALYTICAL DATA
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Parameter	Reason for Qualification	J	U	UJ	UR
SOLVENT YELLOW 14	Surrogate recovery non-compliance	0%	0%	100%	100%
SOLVENT YELLOW 3	MS/MSD non-compliance	0%	0%	11%	0%
	LCS/LCSD non-compliance	0%	0%	0%	79%
	LCS/LCSD non-compliance, surrogate recovery non-compliance	0%	0%	0%	16%
	Surrogate recovery non-compliance	0%	0%	89%	5%
SOLVENT YELLOW 33	Other	0%	7%	0%	0%
	Surrogate recovery non-compliance, Other	0%	0%	4%	0%
	Surrogate recovery non-compliance	0%	0%	96%	100%
MERCURY	MS/MSD non-compliance, LCS/LCSD non-compliance	20%	0%	65%	0%
	MS/MSD non-compliance, Holding time exceedance	55%	0%	30%	0%
	LCS/LCSD non-compliance	25%	0%	5%	0%
ARSENIC	Lab blank contamination	100%	100%	0%	0%
BARIUM	MS/MSD non-compliance	100%	0%	0%	0%
CADMIUM	MS/MSD non-compliance	100%	0%	0%	0%
CALCIUM	Lab duplicate imprecision	83%	0%	0%	0%
	Lab duplicate imprecision, Field duplicate imprecision	17%	0%	0%	0%
LEAD	MS/MSD non-compliance	100%	0%	0%	0%
MANGANESE	Field Duplicate Imprecision	100%	0%	0%	0%
POTASSIUM	MS/MSD non-compliance	100%	0%	0%	0%
	LCS/LCSD non-compliance	0%	0%	100%	0%
SELENIUM	MS/MSD non-compliance	100%	0%	100%	0%
SODIUM	LCS/LCSD non-compliance	0%	0%	100%	0%
VANADIUM	Lab blank contamination	100%	100%	0%	0%
ZINC	Lab blank contamination	5%	100%	0%	0%
	Lab blank contamination, Serial dilution non-compliance	45%	0%	0%	0%
	MS/MSD non-compliance, Serial dilution non-compliance	50%	0%	0%	0%
CATION EXCHANGE CAPACITY	Holding time exceedance	100%	0%	0%	0%
PH	Holding time exceedance	100%	0%	0%	0%

4.0 NATURE AND EXTENT OF CONTAMINATION

Soil (surface and subsurface), ground water, surface water, and sediment samples were collected from SWMU 2 and analyzed for the presence of site-related contamination during the investigation phase of this RFI. Based on analytical data obtained during this investigation, the nature and extent of contamination in the soil, ground water, surface water, and sediment at SWMU 2 are discussed on a matrix-specific basis in the following subsections.

Soil samples at each SWMU were classified according to the soil types defined in the NSWC Crane Basewide Soil Background Study (TtNUS, January 2001). Each soil type is defined by the characteristics of soil parent material (depositional environment), depth (surface or subsurface), and dominant grain size (sand, silt, or clay). The soil types were gathered into soil groups that reflect different classifications of soil throughout NSWC Crane. There are nine different background soil groups however, only three soil types were found within SWMU 2: Soil Group 3 - Alluvial, Mississippian, and Pennsylvanian surface soil; Soil Group 8 - Pennsylvanian subsurface clay and silt; and Soil Group 9 - Pennsylvanian subsurface sand. Metal concentrations in each soil group sampled at a given SWMU were compared to metal concentrations from the corresponding background soil group. These comparisons used the entire data set from the background study for a given soil group and all SWMU samples of the corresponding soil group. The outcome of each comparison was a statistical determination of each metal at a given SWMU as elevated or not elevated relative to background concentrations. A detailed description of this statistical comparison is contained in Appendix F.1. It has been assumed that the concentrations of all organic compounds are zero in each of the background soil groups. Therefore, the detections of organic compounds at SWMU 2 are considered to be site related unless data indicate that they are contaminants (e.g., laboratory contamination) from non-site related sources.

Samples 02GW0501 and 02GWC10P03 were treated as background upgradient samples for the SWMU 2 ground water. The rationale for this deviation from the approved Work Plan is explained in Section 4.3. Surface water samples 03SW01, 03SW02, and 03SW03 (collected from Little Sulphur Creek upgradient of the Main Treatment Area in SWMU 3) were treated as upgradient samples for SWMU 2 surface water. Sediment samples 03SD01, 03SD02, 03SD03, and 03SD04 (also collected from Little Sulphur Creek upgradient of the Main Treatment Area in SWMU 3) were treated as upgradient samples for SWMU 2 sediment samples. A discussion of how these upgradient locations were statistically compared to SWMU 2 site data is contained in Appendices F.2, F.3, and F.4.

The Work Plan for RCRA Facility Investigation, Corrective Measures Study, and Risk Assessment at SWMU 2 - Dye Burial Grounds (TtNUS, May 2001) provides a tabular summary and text discussing historical analytical results for SWMU 2 media. These data are included in this nature and extent discussion in a limited manner because these historical data are of unverifiable data quality. The field analysis related to well stabilization parameters and natural attenuation parameters that were conducted either in the field or the fixed laboratory are discussed as necessary. The well stabilization parameters were used to verify the existence of stable ground water sampling conditions prior to sample collection whereas the natural attenuation parameter data were collected to support any CMS that might follow this site characterization.

4.1 SURFACE SOIL

As detailed in Table 4-1, 13 surface soil samples were collected to evaluate the nature and extent of contamination. Figure 4-1 displays the locations where soil samples were collected. All 13 surface soil samples were analyzed for Target Analyte List (TAL) metals (plus tin) and dyes.

Table 4-2 presents a summary of the results reported for compounds detected in the surface soil samples collected from SWMU 2. Tables 6-4 and 6-5 (see Section 6.1 of the human health risk assessment) presents a summary of descriptive statistics for surface soil detections, including range of detections, frequency of detection, location of maximum, comparison to background, and human health risk assessment screening criteria. Appendix E.1-1 contains a copy of the entire analytical database for SWMU 2 surface soil. Figure 4-1 displays a geographical depiction of positive dye detections and positive metals detections in excess of background in surface soil.

Metals

Twenty metals were detected in the surface soil samples. Sodium, silver, thallium, and tin were not detected in any of these surface soil samples. Of the 20 detected metals, aluminum, arsenic, barium, chromium, cobalt, iron, lead, manganese, nickel, vanadium, and zinc were detected in all 13 samples at concentrations statistically determined to be similar to background concentrations. Three of the detected metals (calcium, magnesium, and potassium) are considered to be essential nutrients and will not be discussed any further.

Antimony and cadmium were detected in four of the 13 samples; the maximum detected concentrations occurred in different samples. The SWMU 2 data sets for these metals were determined to be statistically less than background concentrations.

Mercury was detected in 12 of 13 samples at concentrations ranging from 0.02 mg/kg to 0.05 mg/kg. Selenium was detected in six of 13 samples at concentrations ranging from 0.52 mg/kg to 0.7 mg/kg. The SWMU 2 data sets for these metals were determined to be statistically less than background concentrations.

Beryllium, calcium, copper, and magnesium were the only surface soil metals with data sets that were determined to be statistically greater than background concentrations. As noted above calcium and magnesium are essential nutrients and are not discussed any further. Beryllium was detected in three surface soil samples (02SS190001, 02SB100002, and 02SS090002) at concentrations ranging from 0.56 to 0.85 mg/kg but this metal was not detected in subsurface soil (See Section 4.2). Samples 02SS09002 and 02SS100002 were collected within 50 feet of each other at approximately the same concentration; otherwise there is no pattern of contamination. Because of its sparse spatial distribution, the history of SWMU 2 disposals, and tightly distributed beryllium concentrations in surface soil, this metal does not appear to be a site related contamination. The corresponding background data set had just one sample out of 15 samples that had a beryllium detection (0.49 mg/kg). This is viewed to be the primary reason why the site data appear to be greater than background concentrations. The SWMU 2 beryllium surface soil concentrations are within a factor of two of this concentration and appear to represent a background population local to SWMU 2 rather than site contamination. If the observed beryllium concentrations are actually site related contamination, the scarcity of detections and the limited range of concentrations do not warrant further investigation.

The observed copper concentrations in surface soil (8 to 11.8 mg/kg) fall well within the range of NSWC Crane basewide background concentrations (5.4 to 17.1 mg/kg). The copper concentration distribution for SWMU 2 samples is tighter than for the background samples and this appears to be the reason that SWMU 2 copper concentrations were classified as exceeding background concentrations. Similar to beryllium, this is viewed to be a consequence of the site samples representing a geographically smaller area than the background samples. Although Figure 4-1 shows some copper concentrations in surface soil exceed its ecological data quality level used for selecting COPCs, so do copper background concentrations.

Based on the above observations, neither copper nor beryllium is viewed to be a site contaminant in surface soil and there is no need to discuss the spatial distribution of these chemicals further. To be conservative, however, these metals are considered for COPC selection in Sections 6.0 and 7.0 to preclude the possibility of overlooking any risk associated with their existence at SMWU 02.

Dyes

No dyes were detected in these surface soil samples. Despite the rejection of dye results from sample 02SS05000s, no other surface soil samples contained detectable concentrations of dyes. Therefore, there is no expectation that dye contamination in surface soil was undetected as a consequence of analytical problems.

4.2 SUBSURFACE SOIL

As detailed in Table 4-1, 20 subsurface soil samples were collected to evaluate the nature and extent of contamination. All 20 subsurface soil samples were analyzed for TAL metals (plus tin) and dyes. Ten of these subsurface soil samples were also analyzed for CEC, pH, and TOC.

Table 4-3 presents a summary of the positive results reported for compounds detected in the subsurface soil samples collected from SWMU 2. Tables 6-6 and 6-7 (see Section 6.1 of the human health risk assessment) presents a summary of descriptive statistics for subsurface soil detections, including range of detection, frequency of detection, location of maximum, comparison to background, and human health risk assessment screening criteria. Appendix E.1-2 contains a copy of the entire analytical database for SWMU 2 subsurface soil. Figure 4-1 presents a geographical depiction of positive dye detections and positive metals detections in excess of background in subsurface soil.

Metals

Seventeen metals were detected in the subsurface soil samples. Beryllium, cadmium, sodium, silver, selenium, thallium, and tin were not detected in any of these subsurface soil samples. Of the 17 detected metals, lead and manganese were the only metals detected in all 20 samples that were statistically determined to not exceed background concentrations for these analytes. Aluminum, barium, chromium, copper, iron, and nickel were also detected in all 20 samples; these analytes were statistically determined to be in excess of their respective background data sets. Arsenic, cobalt, vanadium, and zinc were detected in 13 to 19 of the 20 subsurface soil samples and were also statistically determined to exceed background concentrations. Three of the detected metals (calcium, magnesium, and potassium) are considered to be essential nutrients and will not be discussed any further.

Key differences between subsurface Soil Groups 8 and 9 appear to have caused different outcomes of the statistical background comparisons. As explained in Section 4.0, background comparisons are conducted independently for each soil group. The NSWC Crane basewide background data set for Soil Group 8 has nine samples (27 metal results in each sample). None of the SWMU 2 Soil Group 8 metals

was identified as being greater than these background concentrations. By contrast, the background data set for Soil Group 9 has just one concentration value for each of 27 metals. As expected by random chance alone, several of the of SWMU 2 Soil Group 9 metal concentrations, were greater than the single background concentration. When this occurred, the metal was identified as being in excess of background concentrations. The dearth of background data for Soil Group 9 appears to be the reason for Soil Group 9 samples at SWMU 2 appearing to have elevated concentrations of metals. Exceedances of the single background concentrations for Soil Group 9 samples are shown on Figure 4-1.

Sample location 02SB040305 contained maximum concentrations of 10 of the 17 detected metals. Sample location 02SB120507 contained maximum detections of four of the 17 detected metals. Other than this trend, there is no pattern with regard to metals concentrations or spatial distribution across the site.

Concentrations of the metals detected in surface and subsurface soil are similar in concentration. Even though 10 of the detected metals are present at concentrations in excess of the respective background data sets, there is no evidence to suggest that these metals are related to disposal activities at SWMU 2.

Because of the similarity of surface and subsurface soil metal concentrations and considering the statistical artifact caused by having only a single Soil Group 9 background value, the subsurface soil metal concentrations do not appear to be site related contamination. The site history and the lack of spatial metal concentration patterns suggesting a release of metals further support this assertion. There is no need to discuss the extent of these metal concentrations further for these reasons. To be conservative, however, these metals are considered for COPC selection in Sections 6.0 and 7.0 to preclude the possibility of overlooking any risk associated with their existence at SWMU 2.

Dyes

Acid Orange 10 was detected in a single subsurface soil sample (02SB010911) at a concentration of 3.85 mg/kg. Acid Yellow 23 was detected in six subsurface soil samples: 02SB120507 (5.06 mg/kg), 02SB150608 (5.4 mg/kg), 02SB070709 (2.85 mg/kg), 02SB010911 (6.39 mg/kg), 02SB020810 (11.17 mg/kg), and 02SB040305 (11.5 mg/kg). Samples 02SB010911, 02SB020810, and 02SB040305 were all collected within 50 feet of each other and are located 50 to 100 feet from the northern SWMU 2 border. Sample 02SB070709 was collected near the center of SWMU 2. Samples 02SB150608 and 02SB120507 were collected within approximately 25 feet of each other at the southwestern end of the cap boundary.

The maximum Acid Yellow 23 concentration of 11.5 mg/kg coincided with the majority of the maximum metal concentrations. The detection of dyes in these soils near the northwestern section of the Interim Measures cap indicates that subsurface soil dye contamination exists at SMWU 2 outside the multilayered cap. Dye detections are bounded on three sides at the northwestern edge of the cap. The topographically downgradient direction in this area is unbounded with respect to dye detections; however, the concentrations of dyes are low. Dye detections in the other two sample collection areas are completely bounded by the cap and by non-detects. The extent of dye contamination in subsurface soil at SMWU 2 is minimal. The impacts of dyes on human health and ecology are evaluated in Sections 6.0 and 7.0, respectively. Dye contamination does not require further investigation because the detections were low and infrequent, and were nearly completely bounded in all directions by non-detects.

Miscellaneous Parameters

CEC ranged from 2.3 milliequivalents (MEQ)/100g to 19 MEQ/100g; the maximum occurred in sample 02SB120507. Values of soil pH ranged from 4.9 to 6.3, which is slightly acidic. TOC ranged from 100 mg/kg to 1,900 mg/kg; the maximum was in sample 02SB020810.

4.3 GROUND WATER

As detailed in Table 4-1, two ground water samples were collected from within the Upper Pennsylvanian aquifer and four samples were collected from within the Lower Pennsylvanian aquifer to evaluate the nature and extent of contamination. In addition, samples 02GW0501 and 02GWC10P301 were collected and designated the SWMU 2 upgradient ground water samples for both the Upper and Lower Pennsylvanian aquifers. All ground water samples were analyzed for TAL metals (plus tin), dyes, TOC, chloride, sulfate, and TSS.

Well 02C10P3 was the only well originally designated in the approved Work Plan to be the upgradient well for this SMWU 2 investigation. Synoptic water level measurements confirmed that well 02-05 was also hydraulically upgradient of the SMWU 2 Interim Measures multilayered cap. While well 02-05 is located within the approximate SMWU 2 boundary, it is appropriate to note that the SWMU 2 boundary is a somewhat arbitrary perimeter. Dye burials at SMWU 2 occurred downgradient of the well 02-05 location (see Figure 4-2). Of the sampled ground water monitoring wells that are upgradient of the Interim Measures multilayered cap, well 02-05 is the closest well. Thus, well 02-05 is viewed to represent upgradient conditions at a location that is closest to the multilayered capped area without being affected by potential sources of contamination associated with dye burials. Where appropriate, any differences associated with excluding, as opposed to including, well 02-05 as an upgradient well are discussed.

Table 4-4 presents a summary of the positive results reported for compounds detected in the ground water samples collected from SWMU 2. Table 4-5 presents historical data for select inorganics, including metals in the Upper and Lower Pennsylvanian aquifers. Tables 6-8 and 6-9 (see Section 6.1 of the human health risk assessment) present a summary of descriptive statistics for ground water detections, including range of detection, frequency of detection, location of maximum, comparison to background, and human health risk assessment screening criteria. Appendix E.2-1 contains a copy of the entire analytical database for SWMU 2 ground water. Figure 4-2 presents a geographical depiction of positive dye and positive metals detections in excess of the upgradient ground water concentration.

Metals in the Upper Pennsylvanian Aquifer

Arsenic, barium, calcium, cobalt, iron, manganese, magnesium, selenium, sodium, and zinc were detected in the Upper Pennsylvanian samples 02GW0101 and 02GWC12P301; however, of these metals, only the concentrations of selenium and sodium were in excess of upgradient concentrations. Cadmium, cobalt, nickel, and potassium were only detected in sample 02GWC12P301, and of these metals, the concentrations of cadmium and cobalt were in excess of upgradient sample concentrations in well 02C12P3 only. Selenium and zinc were detected in both of these wells and were in excess of upgradient concentrations in both wells (02-01 and 02C12P3). Both samples were collected in the northeastern quadrant of the site. These metals were also detected in surface and subsurface soil samples at SWMU 2 although the evidence indicated that these metals do not represent site related contamination (see Section 4.2). Calcium, magnesium, potassium, and sodium are considered to be essential nutrients and therefore do not warrant further discussion. Also of note, aluminum, antimony, beryllium, chromium, copper, lead, mercury, silver, thallium, tin, and vanadium were not detected in these samples collected within the Upper Pennsylvanian aquifer.

Metals in the Lower Pennsylvanian Aquifer

Arsenic, barium, calcium, iron, manganese, magnesium, nickel, selenium, sodium, and zinc were detected in downgradient wells in samples 02GW0201, 02GW0701, 02GW0801, and 02GWC11P301; however, only the concentrations of arsenic and nickel in these samples were in excess of upgradient concentrations. Aluminum, beryllium, copper and lead were detected only in sample 02GWC11P301 and only the concentrations of aluminum, beryllium, and lead in this sample were in excess of background concentrations. Calcium, magnesium, potassium, and sodium are considered to be essential nutrients and will not be discussed any further. Cadmium and cobalt were detected in samples 02GWC11P301 and 02GWC12P301, cadmium was also detected in sample 02GW0801, and cobalt was also detected in

sample 02GW0201. Of all of these detections the greatest concentrations were generally associated with sample 02GWC11P301. All of these detected metals were also detected in surface and subsurface soils at SWMU 2 although the evidence indicates that these metals do not represent site related contamination (See Section 4.2). Also of note, antimony, chromium, mercury, silver, thallium, tin, and vanadium were not detected in these samples collected from within the Lower Pennsylvanian Aquifer.

Aluminum, beryllium, copper, and lead were not detected in any other groundwater samples except 02GWC11P301. The maximum detected concentrations of cadmium, cobalt, iron, manganese, nickel, and zinc were also found in sample 02GWC11P301. Concentrations of cadmium, cobalt, copper, nickel, and zinc were at least one order of magnitude higher in well 02C11P3 than in the remaining seven Pennsylvanian aquifer samples. This sample had a pH of 3.68; the pH of the remaining seven Pennsylvanian ground water samples ranged from 5.22 to 6.23. The low pH in well 02C11P3 is likely the reason metals concentrations are elevated in this one sample, because acidic conditions increase the solubility of metals in water. As described in Section 5.4.2 of the approved Work Plan, historical data showed that inorganic chemicals were found in most wells at SWMU 2. Well 02C11P3 is located the farthest downgradient and the greatest distance from the cap area, which suggests that the low pH and elevated metals concentrations in this well are not related to disposal activities at SWMU 2.

During planning for this Phase III RFI there was some uncertainty in linking the presence of inorganics in ground water to activities at SWMU 2 based on historical ground water data. One reason for this was that anomalously low pH levels were observed in some wells that exhibited elevated inorganic concentrations (i.e., above the risk-based screening criteria). Low pH (acidic conditions) in sandstone is most likely a natural phenomenon and responsible for the elevated concentrations of inorganics. In addition, the distribution of metals within the aquifers is not necessarily coincident with the proximity of the wells to the dye burial trenches, thereby supporting the suspicion that elevated concentrations of inorganics are naturally occurring. While the historical data quality was unverified the results obtained during this Phase III investigation are consistent with the historical data.

Visual inspection reveals that the metals concentrations obtained during this investigation typically fall within the ranges of the historical data. Some example concentrations ranges are shown below:

- Cobalt historical ground water concentrations in Upper and Lower Pennsylvanian wells ranged from 6 to 697 µg/L whereas cobalt concentrations in this investigation ranged from 1.5 to 445 µg/L.

- Iron historical ground water concentrations in Upper and Lower Pennsylvanian wells ranged from 10 to 121,000 µg/L whereas iron concentrations in this investigation ranged from 465 to 1,810 µg/L.

- Manganese historical ground water concentrations in Upper and Lower Pennsylvanian wells ranged from 5 to 30,100 µg/L whereas manganese concentrations in this investigation ranged from 25.3 to 3,790 µg/L.

- Zinc historical ground water concentrations in Upper and Lower Pennsylvanian wells ranged from 5 to 1,950 µg/L whereas zinc concentrations in this investigation ranged from 10.5 to 2,280 µg/L.

Some of the greatest metal concentrations recorded in the historical data are associated with wells that are upgradient or cross-gradient to the Interim Measures cap and SWMU 2. One of the most remarkable examples is well 02C22P3, which is located cross-gradient approximately 1,500 feet to the southeast of SWMU 2. This well had 30,100 µg/L dissolved manganese in 1991 and there are no existing or former SMWUs upgradient of this well. While the quality of the historical data could not be verified, widespread data quality errors in metals analyses would be uncommon and the consistency of the historical data with current data demonstrate that the metals concentrations observed for this Phase III investigation are not unusual in the SWMU 2 area. Historical data are summarized as temporal trends in Figures 4-3 through 4-8. All results are plotted, including non-detect values, if present. To avoid plotting series of non-detects, only trends for those metals that had a reasonable number of detections are plotted. The historical decreasing concentration trends evident in Figures 4-3 to 4-8 are unexplained. The most recently collected data are consistent with the most recent historical trend data.

If well 02-05 were to be excluded from consideration as a background well, as originally planned, additional exceedances of upgradient contamination would be detected because the concentrations in the remaining upgradient well (02C10P3) are less than those in well 02-05. The impact on human health risk of excluding well 02-05 as an upgradient well is discussed in Section 6.1. The impact on evaluating the nature and extent of contamination while excluding well 02-05 would be the need to identify more locations that are cross-gradient and downgradient of the sole upgradient well (02C10P3) that have metal concentrations greater than that upgradient well. However, the available evidence suggests that, while metal concentrations downgradient of the Interim Measures cap have been detected, the metals do not appear to originate as a result of SWMU 2 operations.

The following presents a possible explanation for the low pH value and the elevated metal concentrations in well 02C11P3. The acidic conditions in well 02C11P3 may be attributable to localized fracturing of the sandstone aquifer in the vicinity of this well. According to the drilling log for well 02C11P3, the Pennsylvania sandstone in the vicinity of well 02C11P3 is fractured (see drilling log for 02C11 in Appendix A); whether the degree of fracturing is more intense in this area compared to adjacent areas is

only speculative. Such fracturing could allow higher rates of recharge in the immediate area, which could in turn result in the specific conductance value (1.559 µS/cm) for the ground water in this area to be lower than in surrounding well samples. Pennsylvanian-age shales, coal, and sandstones commonly contain pyrite. The drilling logs for most wells at the Dye Burial Grounds, including 02C11, do not indicate the presence of coal or pyrite. However, the Pennsylvanian sandstone in 02C11 does become more shaly toward the bottom of the formation between 37.7 and 41.3 feet below ground surface, where well 02C11P3 is screened. In addition, a coal seam has been identified at a depth of about 20 feet below ground surface in well 02C13, and coal seams have been identified in the Mansfield Formation (Lower Pennsylvanian strata) at the Mustard Gas Burial Ground, the Rockeye site (Kvale, 1994), and the Pest Control site (Barnhill and Hansley, 1993). Although coal is not present in 02C11, the sandstone or shaly portions of the sandstone may contain pyrite. When exposed to oxygen, pyrite oxidizes which can result in low-pH ground water with elevated metal concentrations. This appears to be the most reasonable explanation for the low pH, low specific conductance, and elevated metals concentrations in well 02C11P3:

- Because of fracturing, surface infiltration enters the sandstone in the local area.
- The fractured sandstone allows surface water to enter more quickly than other areas, but also drains more quickly allowing atmospheric oxygen to easily enter the fractured rock.
- The sandstone or shaly sandstone near well 02C11P3 contains pyrite, which oxidizes upon exposure to oxygen.
- Acidic ground water results during subsequent recharge and flushing events.

The chemistry of this well is so different than the other well waters that it must be related to localized geologic and/or hydrologic conditions. The fact that the ground water samples collected between the burial area and well 02C11P3 had near-neutral pH and lower concentrations of metals strongly implies that the low pH and elevated metals concentrations found in well 02C11P3 are not related to SWMU 2 disposal activities.

Dyes in the Upper and Lower Pennsylvanian

No dyes were detected in ground water samples collected from within the Upper or the Lower Pennsylvanian aquifers.

Miscellaneous Parameters

Chloride results in the Upper Pennsylvanian ranged from 100 mg/L to 150 mg/L. Chloride results in both the Lower Pennsylvanian ranged from 25 mg/L to 170 mg/L. Chloride values between both aquifers and upgradient samples were similar.

Sulfate results in the Upper Pennsylvanian ranged from 740 mg/L to 970 mg/L. Sulfate results in the Lower Pennsylvanian ranged from 830 mg/L to 1,300 mg/L. Sulfate concentrations between both aquifers and upgradient sample locations were similar.

TOC results in the Upper Pennsylvanian ranged from 3.2 mg/L to 5 mg/L. TOC results in the Lower Pennsylvanian ranged from 1.3 mg/L to 2.2 mg/L. The concentration of TOC in both aquifers and upgradient samples were similar.

TSS results in the Upper Pennsylvanian ranged from 3 mg/L to 7 mg/L. TSS were only detected in sample 02GWC11P301 from the Lower Pennsylvanian at 4 mg/L. TSS was similar between both aquifers and upgradient samples.

4.4 SURFACE WATER

As detailed in Table 4-1, only one surface water (a seep) sample was collected. This sample was analyzed for total and dissolved TAL metals (plus tin), TOC, hardness, and TSS. The Work Plan for RCRA Facility Investigation, Corrective Measures Study, and Risk Assessment at SWMU 2 – Dye Burial Grounds (TtNUS, May 2001) indicated that surface water and sediment samples would be collected at seven locations; however, at the time of the field investigation (July 2001) all but one of these locations were dry. It was therefore possible to collect only one surface water sample.

Surface water samples 03SW01, 03SW02, and 03SW03, which were collected in Little Sulphur Creek upgradient of the main treatment area in SWMU 3, were used as the upgradient surface water samples for the SWMU 2 evaluation. These locations are shown on Figure 4-9.

Table 4-6 presents a summary of the positive results reported for compounds detected in the surface water samples collected from SWMU 2. Table 6-10 (see Section 6.1 of the human health risk assessment) presents a summary of descriptive statistics for surface water detections, including range of detection, frequency of detection, location of maximum, comparison to background, and human health risk assessment screening criteria. Appendix E.3 contains a copy of the entire analytical database for

SWMU 2 surface water. Figure 4-10 presents a geographical depiction of positive detections exceeding upgradient surface water sample concentrations.

Metals

Aluminum, arsenic, barium, calcium, iron, magnesium, manganese, and sodium were the only metals detected in this surface water sample. Concentrations of aluminum (523 µg/L), arsenic (0.41 µg/L), barium (78 µg/L), calcium (49,700 µg/L), iron (874 µg/L), magnesium (11,700 µg/L), and sodium (11,500 µg/L) were in excess of concentrations found in the upgradient samples. Three of the detected metals (calcium, magnesium, and sodium) are considered to be essential nutrients and will not be discussed any further.

This sample was also analyzed for dissolved metals. Barium, calcium, iron, magnesium, and sodium were the only metals detected in the dissolved (filtered) sample. The concentrations of these metals were similar to those found in the total (unfiltered) sample.

With no significant soil or ground water contamination, the source of elevated surface water metal concentrations cannot be identified. The results for dissolved aluminum and iron were much less than the results for total aluminum and iron, respectively, which indicates that those two metals are present primarily in particulate form. The results for dissolved and total metals were otherwise in agreement, indicating that most metals are present in dissolved form in the seep water. The metals with elevated concentrations in the surface water, excluding essential nutrients, do not consistently have elevated concentrations in the Upper or Lower Pennsylvanian ground water. For example, aluminum was detected in just one ground water sample, yet the aluminum concentration in the seep water was elevated. The lack of data for other seeps confounds the determination concerning whether the seep concentrations represent contamination. However, because there was little if any soil or ground water contamination at SWMU 2, there is no apparent site-related source of surface water contamination and these metals in seep water are not discussed further in the context of SWMU 2 contamination. The effect of the upgradient concentration exceedances on human and ecological risks are evaluated further in Sections 6.0 and 7.0.

Dyes

No dyes were detected in the single available seep sample.

Miscellaneous Parameters

The hardness was 170 mg/L, the TOC was 3.7 mg/L, and the TSS was 13 mg/L in this surface water sample:

4.5 SEDIMENT

As detailed in Table 4-1, seven sediment samples were collected to evaluate the nature and extent of contamination. All sediment samples were analyzed for TAL metals (plus tin) and dyes.

Table 4-7 presents a summary of the positive results reported for compounds detected in the sediment samples collected from SWMU 2. Table 6-11 (see Section 6.1 of the human health risk assessment) presents a summary of descriptive statistics for sediment detections, including range of detection, frequency of detection, location of maximum, comparison to background, and human health risk assessment screening criteria. Appendix E.4 contains a copy of the entire analytical database for SWMU 2 sediment. Figure 4-3 presents a geographical depiction of positive detections exceeding upgradient sediment sample concentrations.

Sediment samples 03SD01, 03SD02, 03SD03, and 03SD04 were collected in Little Sulphur Creek upgradient of the main treatment area in SWMU 3 and were used as the upgradient sediment samples for the SWMU 2 evaluation. These locations are shown on Figure 4-9.

Metals

Twenty metals were detected in these sediment samples. Silver, tin, thallium, and sodium were not detected in these sediment samples. Of the 20 metals detected, only the maximum detected concentrations of barium and manganese were in excess of their respective background concentrations. Three of the detected metals (calcium, magnesium, and potassium) are considered to be essential nutrients and will not be discussed any further. Antimony, beryllium, cadmium, and selenium were the only metals that were detected in fewer than all seven samples. The majority of the remaining detected metals were found in all sediment samples. Maximum detected metals concentrations were divided among several samples. There is no pattern with respect to the spatial distribution of metals nor is there a known source of metals at this SWMU.

Dyes

No dyes were detected in the seven sediment samples collected from within SWMU 2. Despite the rejection of dye results associated with samples 02SD010006 and 02SD050006, no other sediment, ground water, or surface soil samples contained detectable concentrations of dyes. Therefore, there is no expectation that dye contamination in sediment was undetected as a consequence of analytical problems.

4.6 SUMMARY

Military dyes are the primary constituent of concern at SWMU 2. All military dyes disposed at SWMU 2 were organic compounds and did not contain metals. Dyes were detected in six of the subsurface soil samples that were collected at depths ranging from 3 feet to 11 feet bgs. Dyes were not detected in any of the surface soil, ground water, surface water, or sediment samples. Ground water samples were collected from the Upper Pennsylvania aquifer because this aquifer is in direct contact with the dye burial trenches and would receive any leachates from the disposal area. The Upper Pennsylvanian aquifer is of limited areal extent. The Upper Pennsylvanian ground water is not discharging as seeps. It is likely that the Upper Pennsylvanian is draining downward into the Lower Pennsylvanian aquifer. Therefore, ground water samples were also collected from the Lower Pennsylvania aquifer.

Metals were detected in all sampled media. In general, the majority of the detected metals were present at concentrations comparable to or less than background, except in subsurface soil. In subsurface soil samples, the majority of the detected metals were present at concentrations in excess of background. Most of the background exceedances are attributable to having only a single background concentration value for each of the metals (Soil Group 9). When the results are compared to background data for the other subsurface soil group present at SMWU 2 (Soil Group 8), the SWMU 2 metal concentrations in subsurface soil appear to be similar to background concentrations.

Concentrations of metals were greater in downgradient Lower Pennsylvanian wells than in upgradient wells. The highest metals concentrations were observed in MW02C11P3. In this well, eight metals (aluminum, arsenic, beryllium, cadmium, cobalt, lead, nickel, and zinc) were detected in excess of background and human health criteria. This was the only Lower Pennsylvanian well in which both aluminum and beryllium were detected. The measured pH at this well of 3.68 was much lower when compared to the pH in the other Lower Pennsylvanian wells. This is likely to be the reason metals concentrations were elevated in this well, because the solubilities of most metals increases as pH decreases. This low pH is not attributable to the dyes disposed at SWMU 2. Measured pHs at the other

monitoring wells ranged from 5.22 to 6.23. The metals concentrations also were lower. Since the ground water between the Dye Burial Grounds and well 02C11P3 has not been adversely affected by dyes or dye-related constituents, there is no reason to connect the low pH value and elevated metals concentrations observed in 02C11P3 with the burial site. Coal was only observed in only one boring at the Dye Burial Grounds (location 02C13). However, coal seams are present in the Lower Pennsylvanian rock strata at other locations of NSWC Crane, including the Rockeye and the Pest Control Sites (see Section 4.3). It is hypothesized that the low pH and elevated metal concentrations found in the ground water sample from well 02C11P3 is caused by contact of the ground water with oxidized pyritic rock in close proximity of well 02C11P3.

The approved SWMU 2 Work Plan, Table 5-8, indicates that additional soil samples could be collected at locations and/or depths other than the planned locations and depths if contamination was detected in the soils. The lack of evidence for significant metals contamination at SWMU 2 indicated that additional soil sampling was not warranted.

The lack of dye detections in ground water samples demonstrates that dyes are not migrating from soils at SWMU 2 into the ground water. Section 5.5.2.2 of the approved Work Plan indicates that a second round of ground water sampling would be conducted to evaluate the nature and extent of ground water contamination if detected inorganic concentrations exceed upgradient concentrations. While some SWMU 2 ground water metals were detected at concentrations greater than upgradient concentrations, the number of such occurrences, the concentration levels observed, and the lack of spatial patterns with such detections are evidence that ground water is not contaminated with metals as a result of SWMU 2 operations. Therefore, the presence of metals in downgradient wells cannot be attributed to SWMU 2 operations and the need to collect additional ground water samples does not exist. The cessation of further sampling is supported by the historical data. Although the quality of the historical data is unverified, the historical data and the most recently collected data are consistent, and indicates that elevated metals concentrations are not related to SWMU 2 activities.

With these observations in mind, no significant ground water contamination is considered to have been identified at SWMU 2. The metals in ground water are of interest because their concentrations vary widely from well to well. Metals are naturally present in ground water and naturally occurring fluctuations in metal concentrations can be expected. The ground water metals concentrations are apparently not related to disposal activities at SWMU 2. Because the ground water between the Dye Burial Grounds and well 02C11P3 has not been adversely affected by dyes or dye-related constituents, there is no reason to associate the low pH value and elevated metals concentrations observed in 02C11P3 with the SWMU 2 activities. Coal was observed in only one boring at the Dye Burial Grounds (location 02C13);

however, coal seams are present in the Lower Pennsylvanian rock strata at other locations of NSWC Crane, including the Rockeye and the Pest Control Sites (see Section 4.3). It is hypothesized that the low pH and elevated metal concentrations found in the ground water sample from well 02C11P3 are caused by the contact of ground water with oxidized pyritic rock that is in close proximity to well 02C11P3.

Even with the biased soil and ground water sampling strategy that was used in this investigation, dye contamination was detected in just seven out of 23 subsurface soil samples located near to the Interim Measures cap, and the concentrations that were detected were less than 12 mg/kg (most of the detections were less than 6 mg/kg). During cap installation soil that was visibly contaminated with dyes was excavated and placed under the cap. No dyes were detected in ground water and there are no COPC screening levels available for the two dyes (Acid Yellow 23 and Acid Orange 10) that were detected in subsurface soil only. The potential for dye migration into ground water was the primary consideration during planning for this project. These data indicate that SWMU 2 has had little impact on environmental media.

Despite the lack of evidence for metals contamination in soils and ground water at SWMU 2, metals exceeding the upgradient or background concentrations and COPC screening levels were conservatively carried into the risk assessment to preclude the possibility of not evaluating potentially harmful chemicals in those media. Well 02-05 was interpreted to be an upgradient well for this investigation, although only well 02C10P3 was originally identified as the single upgradient well. The exclusion of well 02-05 as an upgradient well was also considered in the human health risk assessment uncertainty analysis (see Section 6.0).

The approved SWMU 2 Work Plan, Table 5-8, indicates that additional soil samples could be collected at locations and/or depths other than the planned locations and depths if contamination was detects in the soils. The lack of evidence for significant metals contamination at SWMU 2 indicated that additional soil sampling was not warranted.

TABLE 4-1

SUMMARY OF ANALYTICAL PROGRAM
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Sample Number	Analytical Fraction								
	CEC	Dyes	Metals	pH	TOC	Chloride	Sulfate	TSS	Hardness
Surface Soil Samples									
02SS030001			X						
02SS030002		X							
02SS040001			X						
02SS040002		X							
02SS050001			X						
02SS050002		X							
02SS080001			X						
02SS080002		X							
02SS090002		X	X						
02SS100002		X	X						
02SS110001			X						
02SS110002		X							
02SS150001			X						
02SS150002		X							
02SS160001			X						
02SS160002		X							
02SS170001			X						
02SS170002		X							
02SS180001			X						
02SS180002		X							
02SS190001			X						
02SS190002		X							
02SS200001			X						
02SS200002		X							
Subsurface Soil Samples									
02SB010911	X	X	X	X	X				
02SB020810	X	X	X	X	X				
02SB030709	X	X	X	X	X				

TABLE 4-1

SUMMARY OF ANALYTICAL PROGRAM
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Sample Number	Analytical Fraction								
	CEC	Dyes	Metals	pH	TOC	Chloride	Sulfate	TSS	Hardness
02SB040305		X	X						
02SB050809		X	X						
02SB060709	X	X	X	X	X				
02SB070709	X	X	X	X	X				
02SB080810		X	X						
02SB090709		X	X						
02SB100810	X	X	X	X	X				
02SB110406		X	X						
02SB120507	X	X	X	X	X				
02SB130507	X	X	X	X	X				
02SB140709	X	X	X	X	X				
02SB150608	X	X	X	X	X				
02SB160507		X	X						
02SB170608		X	X						
02SB180507		X	X						
02SB190406		X	X						
02SB200608		X	X						
Sediment Samples									
02SD010006		X	X						
02SD020006		X	X						
02SD030006		X	X						
02SD040006		X	X						
02SD050006		X	X						
02SD060006		X	X						
02SD070006		X	X						
Ground Water (Upper Pennsylvanian)									
02GW0101		X	X	X	X	X	X	X	
02GWC12P301		X	X	X	X	X	X	X	

TABLE 4-1

SUMMARY OF ANALYTICAL PROGRAM
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Sample Number	Analytical Fraction								
	CEC	Dyes	Metals	pH	TOC	Chloride	Sulfate	TSS	Hardness
Ground Water (Lower Pennsylvanian)									
02GW0201		X	X	X	X	X	X	X	
02GW0501(Upgradient)		X	X	X	X	X	X	X	
02GW0701		X	X	X	X	X	X	X	
02GW0801		X	X	X	X	X	X	X	
02GWC10P301 (Upgradeint		X	X	X	X	X	X	X	
02GWC11P301		X	X	X	X	X	X	X	
Surface Water									
02SW0701		X	X		X			X	X
02SW0701-F			X						

CEC - Cation exchange capacity.
TOC - Total organic carbon.
TSS - Total suspended solids.

TABLE 4-2

SUMMARY OF POSITIVE ANALYTICAL RESULTS
SURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Sample	02SS030001	02SS040001	02SS050001	02SS080001	02SS090002	02SS100002	02SS110001	02SS150001	02SS160001	02SS170001	02SS180001	02SS190001	02SS200001
Depth Range (feet bgs)	0 - 1	0 - 1	0 - 1	0 - 1	0 - 2	0 - 2	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1.5
Soil Group	3	3	3	3	3	3	3	3	3	3	3	3	3
Inorganics (MG/KG)													
ALUMINUM	8810	10300	10300	10300	9630	10100	10100	7750	9550	8630	9160	12400	12500
ANTIMONY	0.44 U	0.42 U	0.45	0.45	0.5	0.46	0.43 U	0.4 U	0.47 U	0.43 U	0.42 U	0.47 U	0.48 U
ARSENIC	6.3	4.9 J	6.7 J	5 J	5.9 J	6 J	3.6 J	4.9	5.4	4.7	2.6	7.2 J	8.4 J
BARIUM	68.8	77 J	70 J	68.7 J	131 J	138 J	63.1 J	61.5	209	178	55	131 J	71.3 J
BERYLLIUM	2.2 U	2.1 U	2.3 U	2 U	0.79	0.85	2.1 U	2 U	2.3 U	2.1 U	2.1 U	0.56	0.49 U
CADMIUM	0.44 U	0.43 U	0.45 U	0.4 U	0.43 J	0.45 U	0.42 U	0.4 U	0.62	0.48	0.42 U	0.52 J	0.49 U
CALCIUM	7840	1280 J	13400 J	962 J	1720 J	1340 J	1210 J	13000	1440	842	421 U	14600 J	15400 J
CHROMIUM	13.6	16.1	13.3	13.8	9.9	10.5	18	11	10.5	10.4	12.2	40.8	14
COBALT	7.9	7.8	8.6	5.6	13.2	13.2	6.7	6.1	19	15	3.9	9.9	5.7
COPPER	9.2	9.9	10.7	10.2	8.9	8.5	10.7	8.9	8.7	8	8.7	10.9	11.8
IRON	17700	21000	17900	17600	14000	14000	23500	14700	12200	11400	14400	17000	19800
LEAD	13.2	13.6 J	12.6 J	10.6 J	18.5 J	18 J	11.2 J	10.8	20.2	17.5	9.3	184 J	13 J
MAGNESIUM	1320	1300	3310	1490	1210	1250	1380	3240	1360	1230	1080	2030	2480
MANGANESE	527	604	684	365	1400	1470	422	530	1800	1570	124	923	423
MERCURY	0.03 J	0.03 J	0.03 J	0.03 J	0.04 J	0.04 J	0.03 J	0.02 J	0.05 J	0.04 J	0.02 UJ	0.05 J	0.05 J
NICKEL	9.1	9.9	11.9	9.8	9.9	10.7	11.9	8.9	15	13.5	6.6	10.4	8.2
POTASSIUM	561 J	606 J	724 J	695 J	695 J	663 J	606 J	547 J	697 J	587 J	421 U	892 J	881 J
SELENIUM	0.44 U	0.43 U	0.45 U	0.4 U	0.65	0.7	0.42 U	0.4 U	0.67	0.52	0.42 U	0.59	0.53
VANADIUM	24.2	25.9 J	22 J	21.4 J	18.6 J	19.7 J	23.9 J	21.3	21.6	20	22.3	21.8 J	22.8 J
ZINC	27.7 J	31.3 J	33.9 J	32.3 J	40.9 J	41.4 J	33.4 J	24.8 J	45.6 J	41.1 J	15.9 J	50.2 J	40.4 J

Blank cells indicate sample was not analyzed for this parameter.

Data Validation Qualifiers:

U - Indicates that the chemical was not detected at the numerical detection limit (sample-specific quantitation limit) noted. Nondetected results from the laboratory are reported in this manner. This qualifier is also added to a positive result (reported by the laboratory) if the detected concentration is determined to be attributable to contamination introduced during field sampling or laboratory analysis.

UJ - Indicates that the chemical was not detected. However, the detection limit (sample-specific quantitation limit) is considered to be estimated based on problems encountered during laboratory analysis. The associated numerical detection limit is regarded as inaccurate or imprecise.

J - Indicates that the chemical was detected. However, the associated numerical result is not a precise representation of the amount that is actually present in the sample. The laboratory-reported concentration is considered to be an estimate of the true concentration.

Soil Group 3 - Alluvial, Mississippian, and Pennsylvanian surface soil as per "Basewide Background Soil Investigation Report," NSWC Crane, Indiana (TtNUS, January 2001).

bgs = Below ground surface.

TABLE 4-3

SUMMARY OF POSITIVE ANALYTICAL RESULTS
SUBSURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Sample	02SB010911	02SB020810	02SB030709	02SB040305	02SB050809	02SB060709	02SB070709	02SB080810	02SB090709	02SB100810	02SB110406
Depth Range (feet bgs)	9 - 11	8 - 10	7.5 - 9.5	3 - 5	8 - 8.8	7 - 9	7 - 9	8 - 10	7 - 9	8 - 9.5	4 - 6
Soil Group	9	9	9	8	9	9	9	9	9	9	9
Inorganics (MG/KG)											
ALUMINUM	1570	2300	1990	10900	1820	2910	1620	3400	3370	1800	4920
ANTIMONY	0.4 U	0.41 U	0.4 U	0.93	0.41 U	0.43 U	0.39 U	0.39 U	0.41 U	0.42 U	0.44 U
ARSENIC	0.68	0.41	0.41	7.5 J	1.3 U	0.91	3.5 J	0.53 U	1.9 J	0.21 U	2.5 J
BARIUM	11.4	31.7	26.6	73.8 J	27.9 J	26.6	12.7 J	33 J	30.6 J	14.2 J	23.1 J
CALCIUM	396 U	414 U	403 U	1030 J	421 U	465	391 U	399 U	411 U	416 U	425 U
CHROMIUM	8.8	11.5	8.7	15.9	3.8	9.7	4.3	9.6	14.7	3.4	7.9
COBALT	15.4	5.2	10.4	8.4	0.42 U	2.2 U	0.59	17.7	2.3	0.74	1
COPPER	6.4	5.5	5.8	12.6	2	4.9	6.9	7.2	4.2	4.9	4
IRON	20700	21300	12100	22100	2300	8280	2760	15500	7840	714	10100
LEAD	11.3	6.2	8.3	13.6 J	4.4 J	6.7	7.4 J	9 J	5.1 J	7.3 J	5.1 J
MAGNESIUM	396 U	414 U	403 U	1500	421 U	508	391 U	548	423	416 U	448
MANGANESE	226 J	70.3 J	100 J	798	1.9	4.1 J	3.5	99.6	172	2	6.9
MERCURY	0.02 UJ	0.02 UJ	0.02 UJ	0.03 J	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ
NICKEL	17.5	7.7	13.9	10.7	1.1	2.8	1.7	25.3	2.9	1.7	2.2
POTASSIUM	396 U	414 U	403 U	630 J	421 U	435 U	391 U	458 J	411 U	497 U	425 U
VANADIUM	12.9	14.7	10.5	27 J	5.9 U	8.9	7.3 U	13 J	9.1 J	5.1 U	12.8 J
ZINC	57.8 J	23.3 J	33.4 J	35.6 J	2.1 U	7.7 J	11.5 J	42 J	10.6 J	2.5 J	6.6 J
Dyes (MG/KG)											
ACID ORANGE 10	3.8484 J	15.078 U	15.078 UJ	15.078 UJ	15.078 U	15.078 UJ	15.078 U	15.078 U	15.078 U	15.078 U	15.078 UJ
ACID YELLOW 23	6.3881 J	11.1732	15.078 UJ	11.5059 J	15.078 U	15.078 UJ	2.8544	15.078 U	15.078 U	15.078 U	15.078 UJ
Miscellaneous Parameter (MEQ/100)											
CATION EXCHANGE CAPACITY	2.3 J	6 J	4.8 J			6.1 J	3 J			3 J	
Miscellaneous Parameter (S.U.)											
PH	5.7 J	5.5 J	5.3 J			5.4 J	5.6 J			5.9 J	
Miscellaneous Parameter (MG/KG)											
TOTAL ORGANIC CARBON	1100	1900	1000			1500	1200			1000	

TABLE 4-3

SUMMARY OF POSITIVE ANALYTICAL RESULTS
SUBSURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Sample Depth Range (feet bgs) Soil Group	02SB120507 5 - 7 8	02SB130507 5 - 7 8	02SB140709 7 - 9 9	02SB150608 6 - 8 8	02SB160507 5 - 7 9	02SB170608 6 - 8 9	02SB180507 5 - 6.8 9	02SB190406 4 - 6 8	02SB200608 6 - 8 8
Inorganics (MG/KG)									
ALUMINUM	11300	6730	1770	4080	6910	4530	6750	6250	8590
ANTIMONY	0.43 U	0.45 U	0.4 U	0.4 U	0.41 U	0.45 U	0.41 U	0.46 U	0.43 U
ARSENIC	1.7	1.8	0.43	0.4	1.3	1.3	1.5	2.4	1.6 U
BARIUM	70.3	52	12	20.4	43.5	48.9	30.5	42.8	27.5 J
CALCIUM	432 U	454 U	397 U	400 U	414 U	454 U	457	488	476 J
CHROMIUM	19.1	9.4	5.5	7.8	11	10.9	13.6	10.9	9.6
COBALT	3.8	2.3 U	2 U	2 U	2.1 U	2.3	4.4	2.3 U	2.1
COPPER	9.3	4.6	4.5	3.8	6.1	5.2	6.3	4.9	5.1
IRON	24100	10600	3000	11100	10300	10100	14100	9600	18700
LEAD	10.3	7.4	7.5	5.1	6.2	9.4	9.5	7.7	6.7 J
MAGNESIUM	926	712	397 U	400 U	635	491	607	663	763
MANGANESE	30.4 J	12.1 J	5.9 J	6.8 J	16.6 J	10.7 J	16 J	5.4 J	25.1
MERCURY	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ	0.02 UJ
NICKEL	7.8	4.5	3.3	2.5	3.6	5.4	6.6	4.7	4.4
POTASSIUM	432	454	397	400	414 U	454 U	413 U	457 U	462 U
VANADIUM	28.5	18	6.6	11.8	17.1	17.7	22.2	17.3	15.5 J
ZINC	20.5 J	7.3 J	8.3 J	5 J	16.2 J	15.1 J	17.6 J	7.2 J	12.3 J
Dyes (MG/KG)									
ACID ORANGE 10	15.078 UJ	15.078 UJ	15.078 U	15.078 UJ	15.078 U	15.078 U	15.078 UJ	15.078 UJ	15.078 UJ
ACID YELLOW 23	5.0558 J	15.078 UJ	15.078 U	5.4501 J	15.078 U	15.078 U	15.078 UJ	15.078 UJ	15.078 UJ
Miscellaneous Parameter (MEQ/100)									
CATION EXCHANGE CAPACITY	19 J	13 J	3.7 J	6.9 J					
Miscellaneous Parameter (S.U.)									
PH	4.9 J	5.1 J	6.3 J	5.3 J					
Miscellaneous Parameter (MG/KG)									
TOTAL ORGANIC CARBON	1800	1300	1200	1200					

Blank cells indicate sample was not analyzed for this parameter.
Data Validation Qualifiers:
U - Indicates that the chemical was not detected at the numerical detection limit (sample-specific quantitation limit) noted. Nondetected results from the laboratory are reported in this manner. This qualifier is also added to a positive result (reported by the laboratory) if the detected concentration is determined to be attributable to contamination introduced during field sampling or laboratory analysis.
MEQ = Milliequivalents
Soil Group 8 - Pennsylvanian subsurface clay and silt as per "Basewide Background Soil Investigation Report," NSWC Crane, Indiana (TtNUS, January 2001).
Soil Group 9 - Pennsylvanian subsurface sand as per "Basewide Background Soiil Investigation Report," NSWC Crane, Indiana (TtNUS, January 2001).
bgs = Below ground surface.

TABLE 4-4

SUMMARY OF POSITIVE ANALYTICAL RESULTS
GROUNDWATER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Well No. Sample Aquifer	02-01 02GW0101 UP	02-02 02GW0201 LP	02-07 02GW0701 LP	02-08 02GW0801 LP	02C11P3 02GWC11P301 LP	02C12P3 02GWC12P301 UP	02-05 02GW0501 UP and LP (Background)	02C10P3 02GWC10P301 UP and LP (Background)
Inorganics (UG/L)								
ALUMINUM	200 U	200 U	200 U	200 U	23300	200 U	200 U	200 U
ARSENIC	1.2	0.85	1.6	0.9	1.4	0.63	0.81	0.2 U
BARIUM	13.6	38.8	19.3	17	9	10.6	23.2	13.4
BERYLLIUM	1 U	1 U	1 U	1 U	4.7	1 U	1 U	1 U
CADMIUM	1 U	1 U	1 U	1.3	16.1	1.3	1 U	1 U
CALCIUM	142000	295000	412000	360000	131000	166000	501000	11900
COBALT	3 U	6.4	3 U	3 U	445	6.5	8.7	3.8
COPPER	2 U	2 U	2 U	2 U	21.5	2 U	2.1	2 U
IRON	465 J	1420 J	778 J	684 J	3350 J	440 J	2110 J	1810 J
LEAD	1 U	1 U	1 U	1 U	4.8	1 U	1 U	1 U
MAGNESIUM	83100	78700	152000	129000	55600	121000	181000	10400
MANGANESE	35	1410	25.3	689	1720	440	3790	554
NICKEL	10 U	67.1	28	56.6	868	16	26.9	10 U
POTASSIUM	5000 U	5000 U	5000 U	5050	5000 U	9360	8100	5000 U
SELENIUM	15.7 J	2.4 J	11.4 J	4 J	5.1 J	3.6 J	2.9 J	1 UJ
SODIUM	213000	33600	70200	61100	53600	141000	52600	23800
ZINC	10.9 J	24 J	10.5 J	76.7 J	2280 J	53 J	21.2 J	26 J
Miscellaneous Parameters (MG/L)								
CHLORIDE	150	25	170	96	47	100	75	8
SULFATE	740	890	1300	1100	830	970	1900	50
TOTAL ORGANIC CARBON	3.2	1.3	1.8	2.2	1 U	5	1.5	1.4
TOTAL SUSPENDED SOLIDS	7 J	2 UJ	2 UJ	2 UJ	4 J	3 J	5 J	2 UJ
Field Parameters (MG/L)								
ALKALINITY	175	275	260	500	10 U	65	350	70
CARBON DIOXIDE	114	50	125	250	380	225	275	152
DISSOLVED OXYGEN	3.5	2	4	2.5	1	2	0.7	0.6
Field Parameters (MG/L)								
DIVALENT IRON	0	0.71	0.08	0	1.05	0.05	1.09	1.7
HYDROGEN SULFIDE	0	0	0	0	0	0	0	0
NITRATE	0.69	0.1	0.08	0.01	0.01	1.08	0.01	0
NITRITE	0	0	0.003	0.006	0.005	0	0.002	0.001
SULFIDE	0.02	0.01	0.02	0.05	0	0.01	0.03	0.01
Field Parameters								
OXIDATION REDUCTION POTENTIAL (mV)	584	502	661	481	476.3	483	341.6	412
PH (S.U.)	5.9	6.23	5.22	6.12	3.68	5.61	6.11	5.5
SPECIFIC CONDUCTANCE (mS/cm)	2.029	1.905	2.798	2.573	1.559	12.353	3.285	0.278
TEMPERATURE (degree C)	20.99	22	25.55	17.41	15.26	18.4	18.15	15.76
TURBIDITY (NTU)	10	2	1.6	1.8	2.1	4.6	6.6	10

Blank cells indicate sample was not analyzed for this parameter.

Data Validation Qualifiers:

U - Indicates that the chemical was not detected at the numerical detection limit (sample-specific quantitation limit) noted. Nondetected results from the laboratory are reported in this manner. This qualifier is also added to a positive result (reported by the laboratory) if the detected concentration is determined to be attributable to contamination introduced during field sampling or laboratory analysis.

UJ - Indicates that the chemical was not detected. However, the detection limit (sample-specific quantitation limit) is considered to be estimated based on problems encountered during laboratory analysis. The associated numerical detection limit is regarded as inaccurate or imprecise.

J - Indicates that the chemical was detected. However, the associated numerical result is not a precise representation of the amount that is actually present in the sample. The laboratory-reported concentration is considered to be an estimate of the true concentration.

UP - Upper Pennsylvanian.
LP - Lower Pennsylvanian.

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLVANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

UPPER PENNSYLVANIAN AQUIFER

LOCATION	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02-01	02C12P3	02C13P3	02C12P3	02C13P3	02C12P3	02C13P3	02-01	02C12P3	02C13P3	02-01	02C12P3	02C13P3
SAMPLE NUMBER	02-01 (11/30/81)	02-01 (82a) (03/05/82)	02-01 (82a) (03/09/82)	02-01 (82b) (06/08/82)	02-01 (82c) (07/18/82)	02-01 (82d) (10/19/82)	02-01 (82e) (11/08/82)	02-01 (83a) (01/14/83)	02-01 (83b) (02/23/83)	02-01 (83c) (07/27/83)	02-01 (84) (02/01/84)	02-01 (85a) (01/09/85)	02-01 (85b) (06/17/85)	02-01 (86a) (02/02/86)	02-01 (86b) (06/05/86)	02-01 (88) (06/27/88)	02C12P3 (88) (06/27/88)	02C13P3 (88) (06/27/88)	02C12P3 (91a) (03/16/91)	02C13P3 (91a) (03/16/91)	02C12P3 (91b) (06/01/91)	02C13P3 (91b) (06/01/91)	02-01 (91c) (11/13/91)	02C12P3 (91c) (11/13/91)	02C13P3 (91c) (11/13/91)	02-01 (92) (03/28/92)	02C12P3 (92) (03/28/92)	02C13P3 (92) (03/28/92)
SAMPLE DATE	11/30/1981	3/5/1982	3/9/1982	6/8/1982	7/18/1982	10/19/1982	11/8/1982	1/14/1983	2/23/1983	7/27/1983	2/1/1984	1/9/1985	6/17/1985	2/2/1986	6/5/1986	6/27/1988	6/27/1988	6/27/1988	3/16/1991	3/16/1991	6/1/1991	6/1/1991	11/13/1991	11/13/1991	11/13/1991	3/28/1992	3/28/1992	3/28/1992
Dissolved Inorganics (ug/L)																												
ALUMINUM																			10 U	10 U	10 U	10 U	10 U	10 U	10 U	30 U	30 U	30 U
ANTIMONY																5 U	6	5 U	13.7	3	14	12.4	3 U	6.8	16.6	3 U	5.3	3 U
ARSENIC	10 U		10 U	10 U		10 U						4 U		2		5 U	13	24	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	6.1	2 U
BARIUM	100 U		100 U	100 U		100 U						80		1400					17	20	18	18	17	10 U	15	20 U	20 U	20 U
BERYLLIUM																5 U	5 U	5 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
CADMIUM	5 U		5 U	5 U		5 U						0.4 U		10 U		0.1 U	0.1 U	0.3	4 U	4 U	6	4 U	4 U	4 U	4 U	0.2 U	0.2 U	0.27
CALCIUM																			251000	13900	337000	12900	237000	303000	19600	199000	2260	12200
CHROMIUM	10 U		10	70		10 U						20 U		20 U		1	2	1 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	21	5 U
COBALT																			6	6 U	35	12	40	37	28	20 U	20 U	20 U
COPPER																1 U	26	1	5 U	5 U	21	29	5 U	5 U	26	5 U	32	5 U
CYANIDE																			5 U	5 U	5 U	0.5 U	5 U	5 U	5 U			
IRON	110		250	290		80			30 U		10	40		20 U					70	172	10 U	418	10 U	181	8220	40 U	40 U	189
LEAD	10 U		10 U	10 U		10 U						5 U		30 U		1 U	6	1	1 U	1 U	1	1 U	1 U	1 U	1 U	1 U	1.2	1 U
MAGNESIUM																			194000	10100	234000	8510	126000	241000	15300	113000	1700	8480
MANGANESE	30		120	60	120	60	60	60	60		9	130		20 U					1350	265	1260	319	25	2050	946	5 U	5 U	183
MERCURY	0.2 U		0.6	0.2 U		0.4						0.3 U		0.2 U		0.8 U	0.8 U	0.8 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL																3	12	54	11	6	14	16	7	13	11	5 U	13	13
POTASSIUM																			25500	1000 U	34500	1140	3360	15000	1340	2870	218000	923
SELENIUM	5 U		5 U	5 U		5 U						8		11		7	5	9	2 U	2 U	2 U	2 U	9	2 U	2 U	10.7	4 U	2 U
SILVER	10 U		10 U	10 U		10 U						10		8		10 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
SODIUM	208000		196000	242000		224000			238000		210000	204000		19000		214000	133000	27400	174000	33200	138000	39000	213000	127000	34800	205000	213000	38300
THALLIUM																1 U	1 U	1 U	2 U	2 U	8 U	8 U	2 U	2 U	2 U	2 U	2 U	2 U
TIN																			35 U	35 U	35 U	35 U	50 U	50 U	50 U	50 U	50 U	50 U
VANADIUM																			5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	16	10 U
ZINC																30 U	30 U	36	7	6 U	6 U	21	5 U	5 U	5 U	10 U	10 U	10 U
Miscellaneous Parameters																												
AMMONIUM (MG/L)																0.028	0.121	0.062										
BROMINE (MG/L)											0.03			0.03														
CHLORIDE (MG/L)	21.3		205	220		220			216		180	1 U		210		226.4	84.4	32.1										
CHLORINE (MG/L)											0.04			0.02	0.01 U													
FLUORIDE (MG/L)	0.27		0.29	0.27		0.27								0.2														
IODINE (MG/L)											0.076			0.07	0.07													
NITRATE (MG/L)	0.35		0.36	0.4		0.45										0.715	0.752	0.141								0.669	0.837	0.187
NITRITE (MG/L)																										0.008	0.06	0.005 U
PH	7		6.5	6.6	6.4	6.9			6.8	6.8	6.6	6.5	7.2	6.6	6.8													
SPECIFIC CONDUCTANCE (MS/CM)	2480		2045	2450		1560			2500	2400	2300	2900	2200	2300	1895													
SULFATE (MG/L)	845	845	920	770	920	800	770	800	810		860	840		42		750	726	99										
SULFIDE (MG/L)																			0.02 U	0.02 U	0.02 U	0.02 U	0.162	0.02 U	0.02 U			
TOTAL KJELDAHL NITROGEN (MG/L)																0.503	1.97	0.434										
TOTAL METHYLPHENOL (MG/L)	0.01 U		0.01 U	0.05		0.01			0.01 U		0.004 U	0.05 U		0.01 U		0.011 U	0.01 U	0.011 U										
TOTAL ORGANIC CARBON (MG/L)	9.8		8	50		41			34	57	14	12.6	8.7	6	8	4.3	2.3	1 U										
TOTAL ORGANIC HALIDES (MG/L)	0.106		0.14	0.06		0.14			0.06	0.069		0.052	0.0792															

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOWER PENNSYLVANIAN AQUIFER

LOCATION	02-02	02-04	02-05	02-06	02-07	02-08	02-02	02-04	02-05	02-06	02-07	02-08	02-02	02-04	02-05	02-06	02-07	02-08	02-02	02-04	02-05	02-06	02-07	02-08	02-02	02-04	02-05	02-06	02-07	02-08	02-02
SAMPLE NUMBER	02-02 (81)	02-04 (81)	02-05 (81)	02-06 (81)	02-07 (81)	02-08 (81)	02-02 (82a)	02-04 (82a)	02-05 (82a)	02-06 (82a)	02-07 (82a)	02-08 (82a)	02-02 (82a)	02-04 (82a)	02-05 (82a)	02-06 (82a)	02-07 (82a)	02-08 (82a)	02-02 (82b)	02-04 (82b)	02-05 (82b)	02-06 (82b)	02-07 (82b)	02-08 (82b)	02-02 (82c)	02-04 (82c)	02-05 (82c)	02-06 (82c)	02-07 (82c)	02-08 (82c)	02-02 (82d)
SAMPLE DATE	(11/30/81)	(11/30/81)	(11/30/81)	(11/30/81)	(11/30/81)	(11/30/81)	(03/05/82)	(03/05/82)	(03/05/82)	(03/05/82)	(03/05/82)	(03/05/82)	(03/09/82)	(03/09/82)	(03/09/82)	(03/09/82)	(03/09/82)	(03/09/82)	(06/08/82)	(06/08/82)	(06/08/82)	(06/08/82)	(06/08/82)	(06/08/82)	(07/18/82)	(07/18/82)	(07/18/82)	(07/18/82)	(07/18/82)	(07/18/82)	(10/19/82)
	########	########	11/30/1981	11/30/1981	11/30/1981	11/30/1981	3/5/1982	3/5/1982	3/5/1982	3/5/1982	3/5/1982	3/5/1982	3/9/1982	3/9/1982	3/9/1982	3/9/1982	3/9/1982	3/9/1982	6/8/1982	6/8/1982	6/8/1982	6/8/1982	6/8/1982	6/8/1982	7/18/1982	7/18/1982	7/18/1982	7/18/1982	7/18/1982	7/18/1982	10/19/1982
Dissolved Inorganics (ug/L)																															
ALUMINUM																															
ANTIMONY																															
ARSENIC	10 U	10 U	10 U	10 U	10 U	10 U							10 U	10 U	10 U	11	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U							
BARIUM	100 U	100 U	100 U	100 U	100 U	100 U							100 U	100 U	100 U	300	100 U	100	100 U	100 U	100 U	100 U	100 U	100 U							10 U
BERYLLIUM																															100 U
CADMIUM	5 U	5 U	5 U	5 U	5 U	5 U							5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U							
CALCIUM																															5 U
CHROMIUM	10 U	20	20	40	40	20							10 U	10 U	10 U	20	10 U	10 U	20	20	40	10 U	10 U	10 U							
COBALT																															10 U
COPPER																															
CYANIDE																															
IRON	230	350	300	350	620	260		350		350	620		270	30 U	70	60	50	80	550	30 U	30 U	160	70	30 U							
LEAD	10 U	10 U	10 U	10 U	10 U	10 U							10 U	10 U	10 U	10	10 U	10 U	10 U	10 U	10 U	10	10 U	10 U							670
MAGNESIUM																															10 U
MANGANESE	7200	4000	10700	2600	4500	2400	7200	4000	10700	2600	4500	2400	7500	5300	17900	6500	6300	4700	5600	5200	12800	6100	6200	2900	7500	5300	17900	6500	6300	4700	8200
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U							0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U							0.2 U
NICKEL																															
POTASSIUM																															
SELENIUM	5 U	5 U	5 U	5 U	5 U	5 U							5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U							5 U
SILVER	10	10 U	10 U	10 U	10 U	10 U							10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10							10 U
SODIUM	37000	53000	91000	79000	47000	60000							34000	44000	78000	66000	44000	54000	30000	35000	98000	90000	34000	38000							30000
THALLIUM																															
TIN																															
VANADIUM																															
ZINC																															
Miscellaneous Parameters																															
AMMONIUM (MG/L)																															
BROMINE (MG/L)																															
CHLORIDE (MG/L)	21.9	62.1	90.4	156	67.3	57.1							25.3	63.3	82.8	171	61.6	63.6	30	860	80	200	66	61							
CHLORINE (MG/L)																															30
FLUORIDE (MG/L)	0.23	1.5	0.15	0.16	0.16	0.14							0.28	2	0.14	0.3	0.17	0.19	0.29	2	0.15	0.86	0.2	0.22		2					
IODINE (MG/L)																															0.25
NITRATE (MG/L)	0.05 U	0.05	0.05 U	0.05 U	0.05 U	0.05 U							0.05 U	0.09	0.05 U	0.08	0.05 U	0.05 U	0.05 U	0.11	0.05 U	0.32	0.05 U	0.07							
NITRITE (MG/L)																															0.26
PH	6.7	6.7	7.3	6.9	6.9	6.7							6.5	6.2	6.4	6.3	6.3	6.2	6.5	6.2	6.4	6.5	6.6	6.3		6.2	6.4	6.3	6.3	6.2	6.5
SPECIFIC CONDUCTANCE (MS/CM)	1700	2500	2850	4180	2720	2500							1840	2425	2949	3001	2598	2450	1925	2510	3000	4500	2600	2500							1200
SULFATE (MG/L)	712	827	1380	2420	1380	1070	712	827	1380	2420	1380	1070	930	1770	1220	2560	1230	570	830	1270	1430	2760	1250	1010	930	1770	1220	2560	1230	570	816
SULFIDE (MG/L)																															
TOTAL KJELDAHL NITROGEN (MG/L)																															
TOTAL METHYLPHENOL (MG/L)	0.01 U	0.01 U	0.02	0.01 U	0.01 U	0.01 U							0.01 U	0.01 U	0.01 U	0.02	0.01	0.01	0.03	0.01 U	0.01	0.01	0.01	0.01							0.01 U
TOTAL ORGANIC CARBON (MG/L)	11.7	4.5	16.4	5.2	6	5.2							5	3	10	4	3	3	54	49	87	78	69	91							32
TOTAL ORGANIC HALIDES (MG/L)	0.059	0.061	0.07	0.042	0.01 U	0.027							0.087	0.065	0.16	0.065	0.028	0.045	0.011	0.012	0.047	0.023	0.019	0.018							0.15

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLVANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOWER PENNSYLVANIAN AQUIFER

LOCATION	02-04	02-05	02-06	02-07	02-08	02-02	02-04	02-05	02-06	02-07	02-08	02-02	02-04	02-05	02-06	02-07	02-08	02-04	02-05	02-06	02-07	02-08	02-02	02-02	02-04	02-05	02-06	02-07	02-08	02-04	02-07	02-08
SAMPLE NUMBER	02-04 (82d)	02-05 (82d)	02-06 (82d)	02-07 (82d)	02-08 (82d)	02-02 (82e)	02-04 (82e)	02-05 (82e)	02-06 (82e)	02-07 (82e)	02-08 (82e)	02-02 (83a)	02-04 (83a)	02-05 (83a)	02-06 (83a)	02-07 (83a)	02-08 (83a)	02-04 (83b)	02-05 (83b)	02-06 (83b)	02-07 (83b)	02-08 (83b)	02-02 (83b)	02-02 (83c)	02-04 (83c)	02-05 (83c)	02-06 (83c)	02-07 (83c)	02-08 (83c)	02-04 (84)	02-07 (84)	02-08 (84)
SAMPLE DATE	(10/19/82) 10/19/1982	(10/19/82) 10/19/1982	(10/19/82) 10/19/1982	(10/19/82) 10/19/1982	(10/19/82) 10/19/1982	(11/08/82) 11/8/1982	(11/08/82) 11/8/1982	(11/08/82) 11/8/1982	(11/08/82) 11/8/1982	(11/08/82) 11/8/1982	(11/08/82) 11/8/1982	(01/14/83) 1/14/1983	(01/14/83) 1/14/1983	(01/14/83) 1/14/1983	(01/14/83) 1/14/1983	(01/14/83) 1/14/1983	(01/14/83) 1/14/1983	(02/23/83) 2/23/1983	(02/23/83) 2/23/1983	(02/23/83) 2/23/1983	(02/23/83) 2/23/1983	(02/23/83) 2/23/1983	(02/28/83) 2/28/1983	(07/27/83) 7/27/1983	(07/27/83) 7/27/1983	(07/27/83) 7/27/1983	(07/27/83) 7/27/1983	(07/27/83) 7/27/1983	(07/27/83) 7/27/1983	(01/31/84) 1/31/1984	(01/31/84) 1/31/1984	(01/31/84) 1/31/1984
Dissolved Inorganics (ug/L)																																
ALUMINUM																																
ANTIMONY																																
ARSENIC	10 U	10 U	10 U	10 U	10 U																											
BARIUM	100 U	100 U	200	100 U	100 U																											
BERYLLIUM																																
CADMIUM	5 U	5 U	5 U	5 U	5 U																											
CALCIUM																																
CHROMIUM	10 U	10 U	10 U	10 U	10 U																											
COBALT																																
COPPER																																
CYANIDE																																
IRON	50	30	70	220	190	550						670						170	490	70	50	80	80									
LEAD	10 U	10 U	13	10 U	10 U																									180	20	150
MAGNESIUM																																
MANGANESE	4900	12700	7400	6700	5100	5600	5200	12800	6100	6200	2900	8200	4900	12700	7400	6700	5100	6400	14100	1610	6000	3900	5700									
MERCURY	0.2 U	0.5	0.2 U	0.5	0.2 U																									4100	500	2400
NICKEL																																
POTASSIUM																																
SELENIUM	5 U	5 U	5 U	5 U	5 U																											
SILVER	10 U	10 U	10	10 U	10 U																											
SODIUM	43000	62000	66000	38000	47000																											
THALLIUM																		46000	61000	96000	40000	49000	29000							45000	69000	53000
TIN																																
VANADIUM																																
ZINC																																
Miscellaneous Parameters																																
AMMONIUM (MG/L)																																
BROMINE (MG/L)																																
CHLORIDE (MG/L)	81	81	190	65	59		860											74	67	200	58	59	22							0.002 U	0.005	0.002 U
CHLORINE (MG/L)																														66	120	82
FLUORIDE (MG/L)	2	0.13	1	0.19	0.18		2						2																	0.03	0.1	0.01 U
IODINE (MG/L)																																
NITRATE (MG/L)	0.06	0.08	0.42	0.29	0.25																									0.005	0.029	0.015
NITRITE (MG/L)																																
PH	6.5	6.3	6.5	6.6	6.4	6.4	6.2	6.4	6.4		6.3		6.4	6.3			6.4	6.4	6.4	6.3	6.4	6.2	6.2	6.6	6.1	6.5	6.5	6.6	6.5	5.8	6.5	6.4
SPECIFIC CONDUCTANCE (MS/CM)	2180	1880	2630	2300	1500													2320	2900	4650	2500	2400	1790	2200	1800	3100	4500	3000	2650	2200	2700	2700
SULFATE (MG/L)	1190	1420	2460	1090	950	830	1270	1430	2760	1250	1010	816	1190	1420	2460	1090	950	1300	1440	2810	1110	1360	940							1500	1400	1300
SULFIDE (MG/L)																																
TOTAL KJELDAHL NITROGEN (MG/L)																																
TOTAL METHYLPHENOL (MG/L)	0.01 U	0.02	0.01 U	0.01 U	0.01 U													0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01							0.004 U	0.004 U	0.004 U
TOTAL ORGANIC CARBON (MG/L)	21	42	35	24	51													42	98	95	60	40	74	58	33	89	66	71	98	2 U	2 U	2 U
TOTAL ORGANIC HALIDES (MG/L)	0.016	0.01 U	0.031	0.01 U	0.01 U													0.017	0.11	0.076	0.032	0.021	0.012	0.036	0.07	0.01 U	0.06	0.01 U	0.01 U			

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLVANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOWER PENNSYLVANIAN AQUIFER

LOCATION	02-02	02-05	02-02	02-04	02-07	02-08	02-05	02-06	02-02	02-04	02-05	02-06	02-07	02-08
SAMPLE NUMBER	02-02 (84)	02-05 (84)	02-02 (85a)	02-04 (85a)	02-07 (85a)	02-08 (85a)	02-05 (85a)	02-06 (85a)	02-02 (85b)	02-04 (85b)	02-05 (85b)	02-06 (85b)	02-07 (85b)	02-08 (85b)
SAMPLE DATE	(02/01/84) 2/1/1984	(02/01/84) 2/1/1984	(01/08/85) 1/8/1985	(01/08/85) 1/8/1985	(01/08/85) 1/8/1985	(01/08/85) 1/8/1985	(01/09/85) 1/9/1985	(01/09/85) 1/9/1985	(06/17/85) 6/17/1985	(06/17/85) 6/17/1985	(06/17/85) 6/17/1985	(06/17/85) 6/17/1985	(06/17/85) 6/17/1985	(06/17/85) 6/17/1985
Dissolved Inorganics (ug/L)														
ALUMINUM														
ANTIMONY														
ARSENIC			4 U	4 U	4 U	4 U	4 U	4 U						
BARIUM			50	80	50 U	50 U	60	50 U						
BERYLLIUM														
CADMIUM			0.4 U	0.4 U	0.8 U	0.4 U	0.4 U	1						
CALCIUM														
CHROMIUM			20 U	20 U	20	20 U	20	20 U						
COBALT														
COPPER														
CYANIDE														
IRON	50	30	420	200	20 U	40	760	1280						
LEAD			5 U	5 U	5 U	5 U	5 U	5 U						
MAGNESIUM														
MANGANESE	7100	7500	4080	5650	160	1490	8490	5780						
MERCURY			0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U						
NICKEL														
POTASSIUM														
SELENIUM			4 U	4 U	4 U	4 U	4 U	4 U						
SILVER			10 U	10 U	10 U	10 U	10 U	10						
SODIUM	52000	55000	15000	31000	45000	38000	49000	46000						
THALLIUM														
TIN														
VANADIUM														
ZINC														
Miscellaneous Parameters														
AMMONIUM (MG/L)														
BROMINE (MG/L)	0.002 U	0.002 U												
CHLORIDE (MG/L)	19	67	1 U	1 U	1 U	1 U	1 U	1 U						
CHLORINE (MG/L)	0.09	0.01 U												
FLUORIDE (MG/L)														
IODINE (MG/L)	0.02	0.019												
NITRATE (MG/L)														
NITRITE (MG/L)														
PH	6.6	6.5	6.3	6.9	6.3	6.4	6.5	5.5	7.3	5.8	6.8	7.2	7.1	7.1
SPECIFIC CONDUCTANCE (MS/CM)	1800	3200	2280	3000	2320	3400	3780	5160	1500	1800	2900	3900	2800	2400
SULFATE (MG/L)	880	1600	920	1340	1380	1240	1650	1890						
SULFIDE (MG/L)														
TOTAL KJELDAHL NITROGEN (MG/L)														
TOTAL METHYLPHENOL (MG/L)	0.004 U	0.004 U	0.05 U	0.05	0.05 U	0.05 U	0.05 U	0.05 U						
TOTAL ORGANIC CARBON (MG/L)	14	6	3.7	10.8	5.9	9.2	4.5	6.5	2.4	6.2	7.9	3.1	5	3.8
TOTAL ORGANIC HALIDES (MG/L)			0.0089	0.017	0.032	0.015	0.013	0.013	0.0086	0.0113	0.029	0.0226	0.0193	0.0062

LOCATION	02-04	02-05	02-06	02-07	02-08	02-02	02-02	02-04	02-05	02-06	02-07	02-08	02-04	02-05	02C10P3	02C11P3	02C13P2	02C14P3
SAMPLE NUMBER	02-04 (86a)	02-05 (86a)	02-06 (86a)	02-07 (86a)	02-08 (86a)	02-02 (86a)	02-02 (86b)	02-04 (86b)	02-05 (86b)	02-06 (86b)	02-07 (86b)	02-08 (86b)	02-04 (88)	02-05 (88)	02C10P3 (88)	02C11P3 (88)	02C13P2 (88)	02C14P3 (88)
SAMPLE DATE	(02/02/86) 2/2/1986	(02/02/86) 2/2/1986	(02/02/86) 2/2/1986	(02/02/86) 2/2/1986	(02/02/86) 2/2/1986	(02/03/86) 2/3/1986	(06/05/86) 6/5/1986	(06/05/86) 6/5/1986	(06/05/86) 6/5/1986	(06/05/86) 6/5/1986	(06/05/86) 6/5/1986	(06/05/86) 6/5/1986	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988
Dissolved Inorganics (ug/L)																		
ALUMINUM																		
ANTIMONY																		
ARSENIC	1 U	1	1 U	1 U	1 U	2							5 U	5 U	5 U	5 U	11	5 U
BARIUM	2700	3700	4700	2900	3400	2300							14	5 U	19	5 U	22	5 U
BERYLLIUM																		
CADMIUM	10 U	10 U	10 U	10 U	10 U	10 U							5 U	5 U	5 U	5	5 U	5 U
CALCIUM													5.3	0.9	0.1 U	3.9	0.1 U	0.1 U
CHROMIUM	20 U	20 U	20	20 U	20 U	20 U												
COBALT													1 U	1 U	1 U	1 U	1 U	1 U
COPPER																		
CYANIDE													1	1 U	1 U	5	86	1 U
IRON	190	330	1400	20	20 U	20 U												
LEAD	30 U	30 U	30 U	30 U	30 U	30 U												
MAGNESIUM													1	1 U	1	10	5	1 U
MANGANESE	3000	6300	8100	20 U	440	2800												
MERCURY	0.2 U	0.2 U	3.4	0.2 U	0.2 U	0.2 U												
NICKEL													0.8 U	0.8 U	0.8 U	0.8 U	0.8 U	0.8 U
POTASSIUM													30	59	12	817	12	535
SELENIUM																		
SILVER	5 U	5 U	10 U	10 U	5 U	1 U							5 U	5 U	7	6	7	5 U
SODIUM	8	12	18	8	10	7							1 U	1 U	1 U	1 U	1 U	1 U
THALLIUM	44000	53000	66000	59000	53000	27000							44900	58900	22600	54100	25800	36200
TIN													1 U	1 U	1 U	1 U	1 U	1 U
VANADIUM																		
ZINC													722	64	75	1950	45	82
Miscellaneous Parameters																		
AMMONIUM (MG/L)													0.156	0.358	0.051	3.42	1.44	0.05
BROMINE (MG/L)	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U						
CHLORIDE (MG/L)	80	43	180	130	130	20							69.9	78.6	9	50.5	21.6	89.6
CHLORINE (MG/L)	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U	0.01 U						
FLUORIDE (MG/L)	2.8	3	1.9	0.6	0.6	0.2												
IODINE (MG/L)	0.01 U	0.01 U	0.01 U	0.01 U	0.01	0.01	0.01 U	0.01 U	0.02	0.01 U	0.01	0.01						
NITRATE (MG/L)																		
NITRITE (MG/L)													0.612	0.104	0.119	1.08	0.908	0.569
PH	5.6	6.3	6.3	6.6	6.5	6.6	6.7	6.5	6.3	6.4	6.5	6.5						
SPECIFIC CONDUCTANCE (MS/CM)	2100	2800	5400	2400	2700	1800	1940	1916	1875	1837	1836	1887						
SULFATE (MG/L)	25	23	10	29	24	38							1312	1635	140	369	192	836
SULFIDE (MG/L)																		
TOTAL KJELDAHL NITROGEN (MG/L)													0.404	0.685	0.155	3.42	8.9	0.773
TOTAL METHYLPHENOL (MG/L)	0.01 U	0.01 U	0.02	0.01 U	0.01 U	0.01 U							0.01 U	0.012 U	0.011 U	0.01 U	0.01 U	
TOTAL ORGANIC CARBON (MG/L)	1 U	1 U	1 U	2	1 U	3	5	1	3	1	2	1 U	1 U	1.3	1 U	1 U	1.3	1 U
TOTAL ORGANIC HALIDES (MG/L)																		

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOWER PENNSYLVANIAN AQUIFER

LOCATION	02C15P2	02C16P2	02C17P2	02C18P2	02-02	02-04	02-06	02-07	02-08	02C10P3	02C11P3	02C13P2	02C14P3	02C15P2	02C16P2	02C17P2	02C18P2	02C19P2	02C20P3	02C22P3
SAMPLE NUMBER	02C15P2 (88)	02C16P2 (88)	02C17P2 (88)	02C18P2 (88)	02-02 (91a)	02-04 (91a)	02-06 (91a)	02-07 (91a)	02-08 (91a)	02C10P3 (91a)	02C11P3 (91a)	02C13P2 (91a)	02C14P3 (91a)	02C15P2 (91a)	02C16P2 (91a)	02C17P2 (91a)	02C18P2 (91a)	02C19P2 (91a)	02C20P3 (91a)	02C22P3 (91a)
SAMPLE DATE	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(06/27/88) 6/27/1988	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991	(03/16/91) 3/16/1991
Dissolved Inorganics (ug/L)																				
ALUMINUM					10 U	4630	356	10 U	10 U	10 U	29500	10 U	10 U	10 U	703	10 U	10 U	10 U	10 U	963
ANTIMONY	5 U	5 U	5 U	10	3 U	3	3 U	3.2	11.6	4.2	12.3	6.3	12.8	4.1	12.7	3.7	17.8	4.1	5.1	15.6
ARSENIC	5 U	8	5 U	19	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2.8	2.2	2 U	2 U	2 U	2 U	2.8
BARIUM					16	10 U	10 U	10 U	10 U	19	10 U	29	10 U	13	10 U	10 U	10 U	10 U	10 U	10 U
BERYLLIUM	5 U	5 U	5 U	5 U	1 U	1 U	1 U	1 U	1 U	1 U	5	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	5
CADMIUM	0.1 U	0.1 U	1.6	0.1 U	4 U	4 U	4 U	4 U	4 U	4 U	5	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U
CALCIUM					314000	331000	577000	363000	496000	27700	166000	263000	24100	184000	69900	495000	379000	157000	203000	350000
CHROMIUM	4	1	1 U	2	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
COBALT					38	327	638	39	48	6 U	442	28	19	66	46	85	67	48	12	224
COPPER	1	1 U	7	14	5 U	5 U	5 U	5 U	5 U	5 U	10	5 U	5 U	5 U	6	5 U	5 U	5 U	5 U	5 U
CYANIDE					5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U		5 U	5 U	5 U
IRON					342	583	526	17	55	350	4700	1080	10 U	4150	45	306	3040	3260	26.1	103000
LEAD	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	16	1 U	1	1 U	1.4	1 U	1 U	1 U	1 U	2.4
MAGNESIUM					79600	109000	333000	115000	162000	209000	68200	177000	7830	39000	29300	189000	115000	69600	178000	297000
MANGANESE					3550	3490	14800	5 U	1220	1470	1920	2250	74	1430	464	1140	1550	2490	445	30100
MERCURY	0.8 U	0.8 U	0.8 U	0.8 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	2	259	168	19	34	1150	1670	5 U	57	5 U	944	29	5 U	66	224	116	93	81	5 U	593
POTASSIUM					4310	5220	5700	2310	3170	1000 U	4550	7490	1000 U	6210	3130	7100	7700	6020	3470	14300
SELENIUM	8	8	5 U	5	2 U	2 U	2.2	4.3	2.9	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
SILVER	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
SODIUM	25800	23200	71100	33300	32700	45200	71500	53900	63300	27400	49700	80000	8540	22300	20500	77000	51400	34100	163000	22500
THALLIUM	1 U	1 U	1 U	1 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	8 U	8 U	8 U	8 U	8 U	2 U	8 U
TIN					35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U
VANADIUM					5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	6	5 U	5 U	5 U	6
ZINC	30 U	30 U	155	30 U	6 U	755	1170	6 U	70	27	1780	6 U	6 U	37	69	116	6 U	6 U	6 U	373
Miscellaneous Parameters																				
AMMONIUM (MG/L)	0.129	0.049	0.225	0.481																
BROMINE (MG/L)																				
CHLORIDE (MG/L)	12	46.9	162.8	28.4																
CHLORINE (MG/L)																				
FLUORIDE (MG/L)																				
IODINE (MG/L)																				
NITRATE (MG/L)	0.747	0.519	0.48	0.096																
NITRITE (MG/L)																				
PH																				
SPECIFIC CONDUCTANCE (MS/CM)																				
SULFATE (MG/L)	267	323	1504	1438																
SULFIDE (MG/L)					0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U		0.02 U	0.02 U	0.02 U
TOTAL KJELDAHL NITROGEN (MG/L)	0.687	0.934	0.907	2.26																
TOTAL METHYLPHENOL (MG/L)	0.014 U	0.01 U	0.011 U	0.01 U																
TOTAL ORGANIC CARBON (MG/L)	1.2	1 U	1.2	1 U																
TOTAL ORGANIC HALIDES (MG/L)																				

LOCATION	02-02	02-04	02-05	02-06	02-07	02-08	02C10P3	02C11P3	02C13P2	02C14P3	02C15P2
SAMPLE NUMBER	02-02 (91b)	02-04 (91b)	02-05 (91b)	02-06 (91b)	02-07 (91b)	02-08 (91b)	02C10P3 (91b)	02C11P3 (91b)	02C13P2 (91b)	02C14P3 (91b)	02C15P2 (91b)
SAMPLE DATE	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991
Dissolved Inorganics (ug/L)											
ALUMINUM	10 U	1190	10 U	704	10 U	10 U	10 U	21400	10 U	702	320
ANTIMONY	3 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
ARSENIC	8.2	14.3	16.2	17.1	8.3	11	12	14.7	14.4	6.1	15.2
BARIUM	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
BERYLLIUM	30	28	24	10	15	12	17	10 U	30	31	22
CADMIUM	1 U	1 U	1 U	1	1 U	1 U	1 U	5	1 U	1 U	1 U
CALCIUM	4 U	6	8	13	4 U	4	4 U	11	4 U	4 U	4 U
CHROMIUM	346000	442000	649000	676000	397000	622000	29000	197000	245000	298000	164000
COBALT	5 U	5 U	6	5 U	5 U	5 U	5 U	6	5 U	5 U	5 U
COPPER	7	226	32	605	11	15	18	389	34	162	57
CYANIDE	5 U	6	18	5 U	5 U	5 U	11	14	21	5 U	5 U
IRON	5 U	5 U	5 U	5 U	5 U	5 U	0.5 U	5 U	0.5 U	5 U	5 U
LEAD	77	144	303	2990	34	48	1440	4910	1060	1120	4380
MAGNESIUM	3.3	1 U	1 U	1 U	1 U	1 U	1 U	7.9	1 U	1.4	1 U
MANGANESE	96000	113000	215000	413000	137000	215000	19800	81600	142000	97400	29800
MERCURY	1300	4060	7100	16400	5	7	1660	1790	1860	2480	770
NICKEL	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
POTASSIUM	10	905	48	1840	5 U	27	7	923	39	514	88
SELENIUM	4810	5420	8470	7080	2830	4280	1460	4810	8590	3690	6420
SILVER	2 U	2 U	2 U	2 U	5.4	4.6	2 U	2 U	2 U	2 U	2 U
SODIUM	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
THALLIUM	33700	40600	52000	81000	60100	70000	26900	58700	72300	32500	24100
TIN	8 U	8 U	8 U	8 U	8 U	8 U	8 U	8 U	8 U	8 U	8 U
VANADIUM	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U	35 U
ZINC	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Miscellaneous Parameters											
AMMONIUM (MG/L)	6 U	418	6 U	1580	6 U	58	31	1390	37	75	183
BROMINE (MG/L)											
CHLORIDE (MG/L)											
CHLORINE (MG/L)											
FLUORIDE (MG/L)											
IODINE (MG/L)											
NITRATE (MG/L)											
NITRITE (MG/L)											
PH											
SPECIFIC CONDUCTANCE (MS/CM)											
SULFATE (MG/L)											
SULFIDE (MG/L)											
TOTAL KJELDAHL NITROGEN (MG/L)	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.02 U	0.047	0.02 U	0.02 U
TOTAL METHYLPHENOL (MG/L)											
TOTAL ORGANIC CARBON (MG/L)											
TOTAL ORGANIC HALIDES (MG/L)											

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLVANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOWER PENNSYLVANIAN AQUIFER

LOCATION	02C16P2	02C17P2	02C18P2	02C19P2	02C20P3	02C22P3	02-02	02-04	02-05	02-06	02-07	02-08	02C10P3	02C11P3	02C13P2	02C14P3	02C15P2	02C16P2	02C17P2	02C18P2	02C19P2	02C20P3	02C22P3	02-02	02-04	02-05	02-06	02-07	02-08	02C10P3	02C11P3
SAMPLE NUMBER	02C16P2 (91b)	02C17P2 (91b)	02C18P2 (91b)	02C19P2 (91b)	02C20P3 (91b)	02C22P3 (91b)	02-02 (91c)	02-04 (91c)	02-05 (91c)	02-06 (91c)	02-07 (91c)	02-08 (91c)	02C10P3 (91c)	02C11P3 (91c)	02C13P2 (91c)	02C14P3 (91c)	02C15P2 (91c)	02C16P2 (91c)	02C17P2 (91c)	02C18P2 (91c)	02C19P2 (91c)	02C20P3 (91c)	02C22P3 (91c)	02-02 (92)	02-04 (92)	02-05 (92)	02-06 (92)	02-07 (92)	02-08 (92)	02C10P3 (92)	02C11P3 (92)
SAMPLE DATE	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(06/01/91) 6/1/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(11/13/91) 11/13/1991	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992	(03/28/92) 3/28/1992
Dissolved Inorganics (ug/L)																															
ALUMINUM	883	76	10 U	10 U	10 U	1310	10 U	1140	10 U	614	10 U	10 U	19	25600	10 U	768	87	675	417	10 U	10 U	10 U	2140	30 U	1760	30 U	206	30 U	30 U	30 U	23100
ANTIMONY	13.1	13.2	18.4	11.8	7.6	15.8	19.4	11.3	12	13.3	13.6	15.2	13.1	13	13.8	22.1	14.8	6	13.8	4.6	12.7	12.8	13	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U
ARSENIC	2 U	2 U	2 U	2 U	2 U	2.2	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
BARIUM	10 U	10 U	10 U	10 U	10 U	10 U	43	19	15	11	14	16	10 U	10 U	10 U	12	22	10 U	10	11	10 U	10 U	10 U	30	20	22	20 U	20 U	20 U	20 U	20 U
BERYLLIUM	1 U	1 U	1 U	1 U	1 U	7	1 U	1 U	1 U	2	1 U	1 U	1 U	5	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	6	1 U	2	1 U	1	1 U	1 U	1 U	6
CADMIUM	4 U	6	4	4 U	4 U	7	4 U	4 U	4 U	4 U	4 U	4 U	4 U	5	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	4 U	0.38	2.22	0.2 U	4.56	0.2 U	0.48	0.49	9.33
CALCIUM	62200	580000	403000	198000	175000	363000	410000	407000	605000	549000	410000	521000	16900	214000	250000	261000	144000	58600	556000	404000	192000	218000	334000	285000	418000	569000	570000	284000	498000	17100	183000
CHROMIUM	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	10	5 U	5 U	5	8	5 U	5 U	6	5 U
COBALT	24	69	35	14	17	186	34	272	33	697	42	43	18	462	43	167	72	45	101	38	44	34	224	30	284	28	510	28	28	20 U	493
COPPER	5 U	5 U	5 U	5 U	5 U	5 U	44	50	33	32	36	39	25	31	13	56	27	5 U	28	5 U	29	21	47	13	5 U	59	64	5 U	37	16	5 U
CYANIDE	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U								
IRON	14	313	2480	5180	160	108000	43	165	443	17600	38	10 U	347	5620	843	3310	2790	274	368	5620	6220	378	121000	40 U	295	462	9550	44	56	843	5440
LEAD	1 U	1 U	1 U	1 U	1 U	2	1 U	1 U	1 U	1 U	1 U	1 U	1 U	4.4	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1.1	1 U	1 U	1.1	1 U	1 U	1 U	1 U	1 U	2.8
MAGNESIUM	26800	218000	127000	86200	161000	318000	122000	140000	220000	384000	165000	201000	14200	93700	154000	93800	31100	26000	219000	123000	90900	192000	281000	88200	123000	224000	325000	142000	163000	14100	82300
MANGANESE	484	841	1640	2500	403	29500	757	3530	6290	13000	34	13	721	1850	1710	2380	815	433	906	1520	3240	490	30100	163	3610	6220	12400	5 U	90	621	2040
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	250	118	78	69	14	513	23	955	38	1850	12	43	8	985	43	524	98	233	177	67	144	5 U	615	11	1000	50	1430	6	47	18	1020
POTASSIUM	3140	6970	7740	8490	3810	13500	5480	6540	8750	8310	4140	4910	1170	5900	7880	4640	6520	4570	9320	8460	7310	4080	15400	4820	5740	11200	10400	3980	5710	1220	5410
SELENIUM	2 U	2.2	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	3	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2.3	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	5.2	2.1	2 U	2 U
SILVER	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
SODIUM	20100	82700	53100	27500	141000	26300	37200	42600	57800	77000	55100	62500	29000	48700	65500	34300	26600	20700	82100	55600	20900	153000	21800	41800	41500	58300	73100	62300	63800	30000	49700
THALLIUM	8 U	8 U	8 U	8 U	8 U	8 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
TIN	35 U	35 U	35 U	35 U	35 U	35 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
VANADIUM	5 U	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	23	10 U	10 U	10 U	18	10 U
ZINC	43	152	14	9	6	360	5 U	484	15	1610	5	62	30	1610	5 U	109	185	42	266	6	21	5 U	396	10 U	585	10 U	1140	10 U	92	22	1790
Miscellaneous Parameters																															
AMMONIUM (MG/L)																															
BROMINE (MG/L)																															
CHLORIDE (MG/L)																															
CHLORINE (MG/L)																															
FLUORIDE (MG/L)																															
IODINE (MG/L)																															
NITRATE (MG/L)																								0.175	0.02 U	0.02 U	0.096	0.238	0.154	0.044	0.029
NITRITE (MG/L)																								0.008	0.008	0.006	0.005	0.005	0.009	0.009	0.006
PH																															
SPECIFIC CONDUCTANCE (MS/CM)																															
SULFATE (MG/L)																															
SULFIDE (MG/L)	0.02 U	0.02 U	0.02 U	0.02 U	0.02. U	0.02 U	0.089	0.02 U	0.02 U	0.02 U	0.249	0.02 U	0.02 U	0.023	0.054	0.02 U	0.02 U	0.03	0.02 U	0.02 U	0.148	0.04	0.03								
TOTAL KJELDAHL NITROGEN (MG/L)																															
TOTAL METHYLPHENOL (MG/L)																															
TOTAL ORGANIC CARBON (MG/L)																															
TOTAL ORGANIC HALIDES (MG/L)																															

TABLE 4-5

HISTORICAL DATA FOR UPPER AND LOWER PENNSYLANIAN AQUIFERS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOWER PENNSYLVANIAN AQUIFER

LOCATION	02C13P2	02C14P3	02C15P2	02C16P2	02C17P2	02C18P2	02C19P2	02C20P3	02C22P3
SAMPLE NUMBER	02C13P2 (92) (03/28/92)	02C14P3 (92) (03/28/92)	02C15P2 (92) (03/28/92)	02C16P2 (92) (03/28/92)	02C17P2 (92) (03/28/92)	02C18P2 (92) (03/28/92)	02C19P2 (92) (03/28/92)	02C20P3 (92) (03/28/92)	02C22P3 (92) (03/28/92)
SAMPLE DATE	3/28/1992	3/28/1992	3/28/1992	3/28/1992	3/28/1992	3/28/1992	3/28/1992	3/28/1992	3/28/1992
Dissolved Inorganics (ug/L)									
ALUMINUM	30 U	843	1260	727	833	30 U	30 U	30 U	2040
ANTIMONY	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U	3 U
ARSENIC	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
BARIUM	20 U	20 U	24	20 U	20 U	20 U	20 U	20 U	20 U
BERYLLIUM	1 U	1	3	1 U	1	1 U	1 U	1 U	2
CADMIUM	0.2 U	0.36	3.08	1.51	4.84	0.2 U	1.81	0.2 U	1.34
CALCIUM	260000	283000	128000	56800	472000	360000	166000	213000	302000
CHROMIUM	5 U	5 U	5 U	5 U	5 U	5 U	5 U	11	5 U
COBALT	20 U	201	160	66	115	54	64	20 U	239
COPPER	5 U	5 U	6	12	5 U	33	5 U	13	73
CYANIDE									
IRON	275	4910	7630	51	427	4710	7840	449	120000
LEAD	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	9.2
MAGNESIUM	155000	107000	31300	24800	183000	118000	76400	168000	301000
MANGANESE	1540	2590	961	410	710	1590	3270	525	28000
MERCURY	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL	47	550	211	242	196	104	127	5	565
POTASSIUM	8300	4060	6030	3280	6930	8430	6720	4050	14400
SELENIUM	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
SILVER	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
SODIUM	67200	35400	32100	19600	80500	54800	22100	155000	22100
THALLIUM	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U	2 U
TIN	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U
VANADIUM	11	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U
ZINC	10 U	101	489	69	344	10	12	10 U	397
Miscellaneous Parameters									
AMMONIUM (MG/L)									
BROMINE (MG/L)									
CHLORIDE (MG/L)									
CHLORINE (MG/L)									
FLUORIDE (MG/L)									
IODINE (MG/L)									
NITRATE (MG/L)	0.02 U	0.02 U	0.02 U	0.023	0.123	0.02 U	0.02 U	0.02 U	0.02 U
NITRITE (MG/L)	0.009	0.005 U	0.007	0.005 U	0.01	0.006	0.009	0.007	0.017
PH									
SPECIFIC CONDUCTANCE (MS/CM)									
SULFATE (MG/L)									
SULFIDE (MG/L)									
TOTAL KJELDAHL NITROGEN (MG/L)									
TOTAL METHYLPHENOL (MG/L)									
TOTAL ORGANIC CARBON (MG/L)									
TOTAL ORGANIC HALIDES (MG/L)									

TABLE 4-6

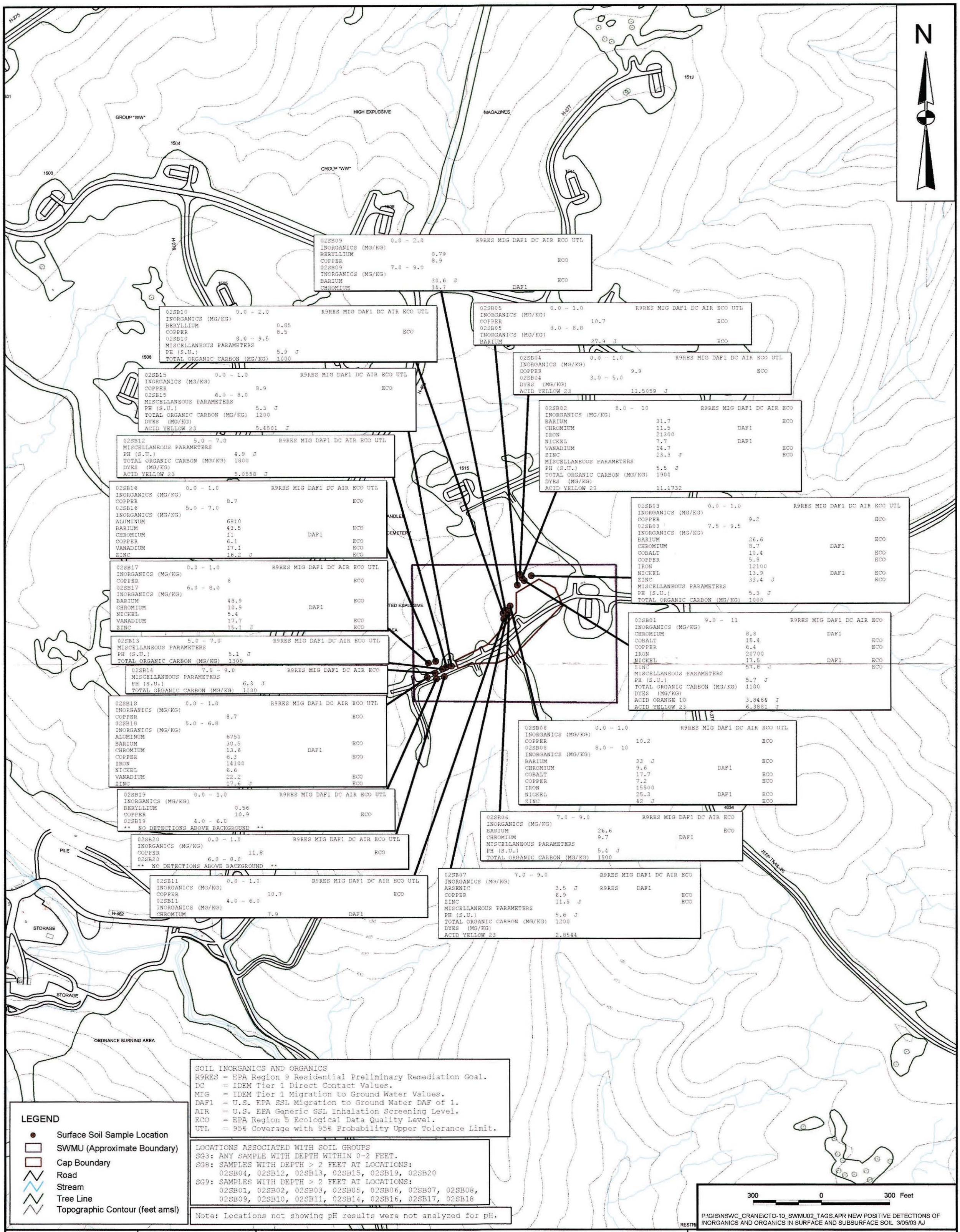
SUMMARY OF POSITIVE ANALYTICAL RESULTS
SURFACE WATER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

LOCATION	02SWSD07	02SWSD07	(upgradient) 03SWSD01	(upgradient) 03SWSD01	(upgradient) 03SWSD02	(upgradient) 03SWSD02	(upgradient) 03SWSD03	(upgradient) 03SWSD03
NSAMPLE	02SW0701	02SW0701-F	03SW0101	03SW0101-F	03SW0201	03SW0201-F	03SW0301	03SW0301-F
SAMPLE	02SW0701	02SW0701-F	03SW0101	03SW0101-F	03SW0201	03SW0201-F	03SW0301	03SW0301-F
MATRIX	SW	SW	BACK SW	BACK SW	BACK SW	BACK SW	BACK SW	BACK SW
SACODE	DUP	DUP	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
QC_TYPE	NM	NM	NM	NM	NM	NM	NM	NM
STATUS	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
SAMPLE DATE	7/29/2001	7/29/2001	37053	37053	37054	37054	37054	37054
VALIDATED	Y	Y	Y	Y	Y	Y	Y	Y
Total Metals (UG/L)								
ALUMINUM	523		221 J		53.9 J		368 J	
ARSENIC	0.41		0.24		0.20 U		0.30	
BARIUM	78		63.0 J		76.0 J		73.9 J	
BERYLLIUM	1 U		0.10 U		0.10 U		0.13	
CADMIUM	1 U		0.70 U		0.70 U		0.70 U	
CALCIUM	49700		12700		10800		7620	
COBALT	3 U		0.30		0.17		1.0	
COPPER	2 U		0.78		0.41		1.4	
IRON	874 J		451		148		543	
LEAD	1 U		0.43		0.14		0.88	
MAGNESIUM	11700		6280 J		7160 J		5870 J	
MANGANESE	43.4		25.8		48.2		141	
NICKEL	10 U		1.2 J		3.7 J		5.3 J	
POTASSIUM	5000 U		1160		1230		1360	
SODIUM	11500		9080		5320		4070	
VANADIUM	2 U		0.41		0.10 U		0.58	
Dissolved Metals (UG/L)								
ALUMINUM		200 U		18.8 U		23.8 U		18.2 U
ANTIMONY		1 U		1.5 J		0.10 U		0.11 U
ARSENIC		0.2 U		0.20 U		0.20 U		0.20 U
BARIUM		74.1		58.2 J		72.8 J		60.9 J
BERYLLIUM		1 U		0.10 U		0.10 U		0.10 U
CADMIUM		1 U		5.8		0.70 U		0.70 U
CALCIUM		51500		12100		10400		7380
COBALT		3 U		0.10 U		0.14		0.51
COPPER		2 U		0.44		0.79		0.62
IRON		140 J		45.7 J		31.5 J		43.2 J
LEAD		1 U		0.10 U		0.10 U		0.13
MAGNESIUM		12400		5970 J		6970 J		5790 J
MANGANESE		15 U		2.4		45.6		135
NICKEL		10 U		0.80 J		3.4 J		3.2 J
POTASSIUM		5000 U		1100		1180		1320
SODIUM		12200		9180		5190		4140
VANADIUM		2 U		0.10 U		0.10 U		0.10 U
Miscellaneous Parameters (MG/L)								
HARDNESS	170		---	---	---	---	---	---
TOTAL ORGANIC CARBON	3.7		---	---	---	---	---	---
TOTAL SUSPENDED SOLIDS	13 J		78.0 J		2.0 J		31.0 J	

TABLE 4-7

SUMMARY OF POSITIVE ANALYTICAL RESULTS
SEDIMENT
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Location	02SWSD01	02SWSD02	02SWSD03	02SWSD04	02SWSD05	02SWSD06	02SWSD07	(upgradient) 03SWSD01	(upgradient) 03SWSD02	(upgradient) 03SWSD03	(upgradient) 03SWSD04
Nsample	02SD010006	02SD020006	02SD030006	02SD040006	02SD050006	02SD060006	02SD070006	03SD010006	03SD020006	03SD030006	03SD040006
Sample	02SD010006	02SD020006	02SD030006	02SD040006	02SD050006	02SD060006	02SD070006	03SD010006	03SD020006	03SD030006	03SD040006
Depth Range (feet bgs)	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5	0 - 0.5
Matrix	SD	SD	SD	SD	SD	SD	SD	BACK SD	BACK SD	BACK SD	BACK SD
Sacode	NORMAL	DUP	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
QC_Type	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Status	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	#N/A	#N/A	#N/A	#N/A
Sample Date	7/27/2001	7/27/2001	7/27/2001	7/27/2001	7/27/2001	7/27/2001	7/29/2001	37053	37054	37054	37054
Validated	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Inorganics (MG/KG)											
ALUMINUM	10300	9170	7870	6370	8140	8000	4580	9570 J	6650	5480	9720
ANTIMONY	0.74	0.52 U	0.74	0.69 U	0.48 U	0.48 U	0.53 U	0.49 U	0.65 U	0.68 U	0.43 U
ARSENIC	11 J	6.1	.9 J	8.4	9	6	5.6	5.6	42.4	7.9	12.9
BARIUM	165	143	87.6	169	134	131	128	57.8 J	65.8 J	45.4 J	37.3 J
BERYLLIUM	1.2	2.6 U	0.54	3.4 U	2.3 U	2.4 U	2.7 U	0.95	1.7	0.68	1.5
CADMIUM	0.56	0.52 U	0.46 U	0.69	0.55	0.48 U	0.68	0.79 J	0.54 J	0.32 J	0.31 U
CALCIUM	1390	973	1310	1710	873	1440	2550	1940	464 J	277 J	959 J
CHROMIUM	24.6	16	22.2	23.4	30.1	12	11.3	27.1 J	42.1 J	15.1 J	18.3 J
COBALT	25.4	21.8	8.4	21.2	29.5	17.4	12.6	11.9	29.6	16.0	19.4
COPPER	8.9	9.3	8.9	8.4	9.1	9.3	9.6	7.7 J	12.0	8.7	25.3
IRON	36400	15400	26100	30700	38700	14200	17900	33500 J	52400 J	20200 J	42900 J
LEAD	33.4	30.1	21.3	17.6	26.7	18.9	30.4	13.0 J	32.9	20.2	23.6
MAGNESIUM	1040	1120	952	900	760	998	960	2320 J	511 J	628 J	2440 J
MANGANESE	3200	2160	762	631	2410	2240	1470	342 J	1680 J	952 J	364 J
MERCURY	0.05	0.06 J	0.04	0.05 J	0.05 J	0.05 J	0.03 UJ	0.03	0.020	0.05	0.07
NICKEL	13.6	17.7	7.9	41.8	21	12.6	20	27.6	37.1 J	13.9 J	70.7 J
POTASSIUM	571	559	561	688 U	460 U	511	830	2230 J	330 J	369 J	1140 J
SELENIUM	0.57	0.65 J	0.46 U	0.69 UJ	0.46 UJ	0.5 J	0.53 UJ	0.22 U	0.60 U	0.64 U	0.61 U
SILVER	0.54 U	0.52 U	0.46 U	0.69 U	0.46 U	0.48 U	0.53 U	0.05 U	0.04 U	0.05 U	0.04
SODIUM	545 U	524 UJ	462 U	688 UJ	460 UJ	484 UJ	533 UJ	64.1 J	3.5 U	7.2 U	13.5 U
THALLIUM	0.54 U	0.52 U	0.46 U	0.69 U	0.46 U	0.48 U	0.53 U	0.11	0.11	0.09	0.08
VANADIUM	31.7 J	24.4	28.1 J	31.3	37.7	22.4	14.9	19.1	34.5	18.8	16.6
ZINC	46.2 J	35.9	30 J	39	44.2	35.6	47.1	33.1 J	62.4 J	36.2 J	176 J



02SB09 0.0 - 2.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BERYLLIUM 0.79
COPPER 8.9 ECO
02SB09 7.0 - 9.0
INORGANICS (MG/KG)
BARIUM 30.6 J ECO
CHROMIUM 14.7 DAF1

02SB10 0.0 - 2.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BERYLLIUM 0.85
COPPER 8.5 ECO
02SB10 8.0 - 9.5
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.9 J
TOTAL ORGANIC CARBON (MG/KG) 1000

02SB05 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 10.7 ECO
02SB05 8.0 - 8.8
INORGANICS (MG/KG)
BARIUM 27.9 J ECO

02SB04 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 9.9 ECO
02SB04 3.0 - 5.0
DYES (MG/KG)
ACID YELLOW 23 11.5059 J

02SB15 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 8.9 ECO
02SB15 6.0 - 8.0
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.3 J
TOTAL ORGANIC CARBON (MG/KG) 1200
DYES (MG/KG)
ACID YELLOW 23 5.4501 J

02SB02 8.0 - 10 R9RES MIG DAF1 DC AIR ECO
INORGANICS (MG/KG)
BARIUM 31.7 ECO
CHROMIUM 11.5 DAF1
IRON 21300
NICKEL 7.7 DAF1
VANADIUM 14.7 ECO
ZINC 23.3 J ECO
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.5 J
TOTAL ORGANIC CARBON (MG/KG) 1900
DYES (MG/KG)
ACID YELLOW 23 11.1732

02SB12 5.0 - 7.0 R9RES MIG DAF1 DC AIR ECO UTL
MISCELLANEOUS PARAMETERS
PH (S.U.) 4.9 J
TOTAL ORGANIC CARBON (MG/KG) 1800
DYES (MG/KG)
ACID YELLOW 23 5.0558 J

02SB16 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 8.7 ECO
02SB16 5.0 - 7.0
INORGANICS (MG/KG)
ALUMINUM 6910
BARIUM 43.5 ECO
CHROMIUM 11 DAF1
COPPER 6.1 ECO
VANADIUM 17.1 ECO
ZINC 16.2 J ECO

02SB03 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 9.2 ECO
02SB03 7.5 - 9.5
INORGANICS (MG/KG)
BARIUM 26.6 ECO
CHROMIUM 8.7 DAF1
COBALT 10.4 ECO
COPPER 5.8 ECO
IRON 12100
NICKEL 13.9 DAF1 ECO
ZINC 33.4 J ECO
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.3 J
TOTAL ORGANIC CARBON (MG/KG) 1000

02SB17 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 8 ECO
02SB17 6.0 - 8.0
INORGANICS (MG/KG)
BARIUM 48.9 ECO
CHROMIUM 10.9 DAF1
NICKEL 5.4
VANADIUM 17.7 ECO
ZINC 15.1 J ECO

02SB01 9.0 - 11 R9RES MIG DAF1 DC AIR ECO
INORGANICS (MG/KG)
CHROMIUM 8.8 DAF1
COBALT 15.4 ECO
COPPER 6.4 ECO
IRON 20700
NICKEL 17.5 DAF1 ECO
ZINC 57.8 J ECO
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.7 J
TOTAL ORGANIC CARBON (MG/KG) 1100
DYES (MG/KG)
ACID ORANGE 10 3.8484 J
ACID YELLOW 23 6.3881 J

02SB13 5.0 - 7.0 R9RES MIG DAF1 DC AIR ECO UTL
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.1 J
TOTAL ORGANIC CARBON (MG/KG) 1300

02SB14 7.0 - 9.0 R9RES MIG DAF1 DC AIR ECO
MISCELLANEOUS PARAMETERS
PH (S.U.) 6.3 J
TOTAL ORGANIC CARBON (MG/KG) 1200

02SB18 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 8.7 ECO
02SB18 5.0 - 6.8
INORGANICS (MG/KG)
ALUMINUM 6750
BARIUM 30.5 ECO
CHROMIUM 13.6 DAF1
COPPER 6.3 ECO
IRON 14100
NICKEL 6.6
VANADIUM 22.2 ECO
ZINC 17.6 J ECO

02SB08 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 10.2 ECO
02SB08 8.0 - 10
INORGANICS (MG/KG)
BARIUM 33 J ECO
CHROMIUM 9.6 DAF1
COBALT 17.7 ECO
COPPER 7.2 ECO
IRON 15500
NICKEL 25.3 DAF1 ECO
ZINC 42 J ECO

02SB19 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BERYLLIUM 0.56
COPPER 10.9 ECO
02SB19 4.0 - 6.0
** NO DETECTIONS ABOVE BACKGROUND **

02SB06 7.0 - 9.0 R9RES MIG DAF1 DC AIR ECO
INORGANICS (MG/KG)
BARIUM 26.6 ECO
CHROMIUM 9.7 DAF1
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.4 J
TOTAL ORGANIC CARBON (MG/KG) 1500

02SB20 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 11.8 ECO
02SB20 6.0 - 8.0
** NO DETECTIONS ABOVE BACKGROUND **

02SB11 0.0 - 1.0 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
COPPER 10.7 ECO
02SB11 4.0 - 6.0
INORGANICS (MG/KG)
CHROMIUM 7.9 DAF1

02SB07 7.0 - 9.0 R9RES MIG DAF1 DC AIR ECO
INORGANICS (MG/KG)
ARSENIC 3.5 J R9RES DAF1
COPPER 6.9 ECO
ZINC 11.5 J ECO
MISCELLANEOUS PARAMETERS
PH (S.U.) 5.6 J
TOTAL ORGANIC CARBON (MG/KG) 1200
DYES (MG/KG)
ACID YELLOW 23 2.8544

SOIL INORGANICS AND ORGANICS
R9RES = EPA Region 9 Residential Preliminary Remediation Goal.
DC = IDEM Tier 1 Direct Contact Values.
MIG = IDEM Tier 1 Migration to Ground Water Values.
DAF1 = U.S. EPA SSL Migration to Ground Water DAF of 1.
AIR = U.S. EPA Generic SSL Inhalation Screening Level.
ECO = EPA Region 5 Ecological Data Quality Level.
UTL = 95% Coverage with 95% Probability Upper Tolerance Limit.

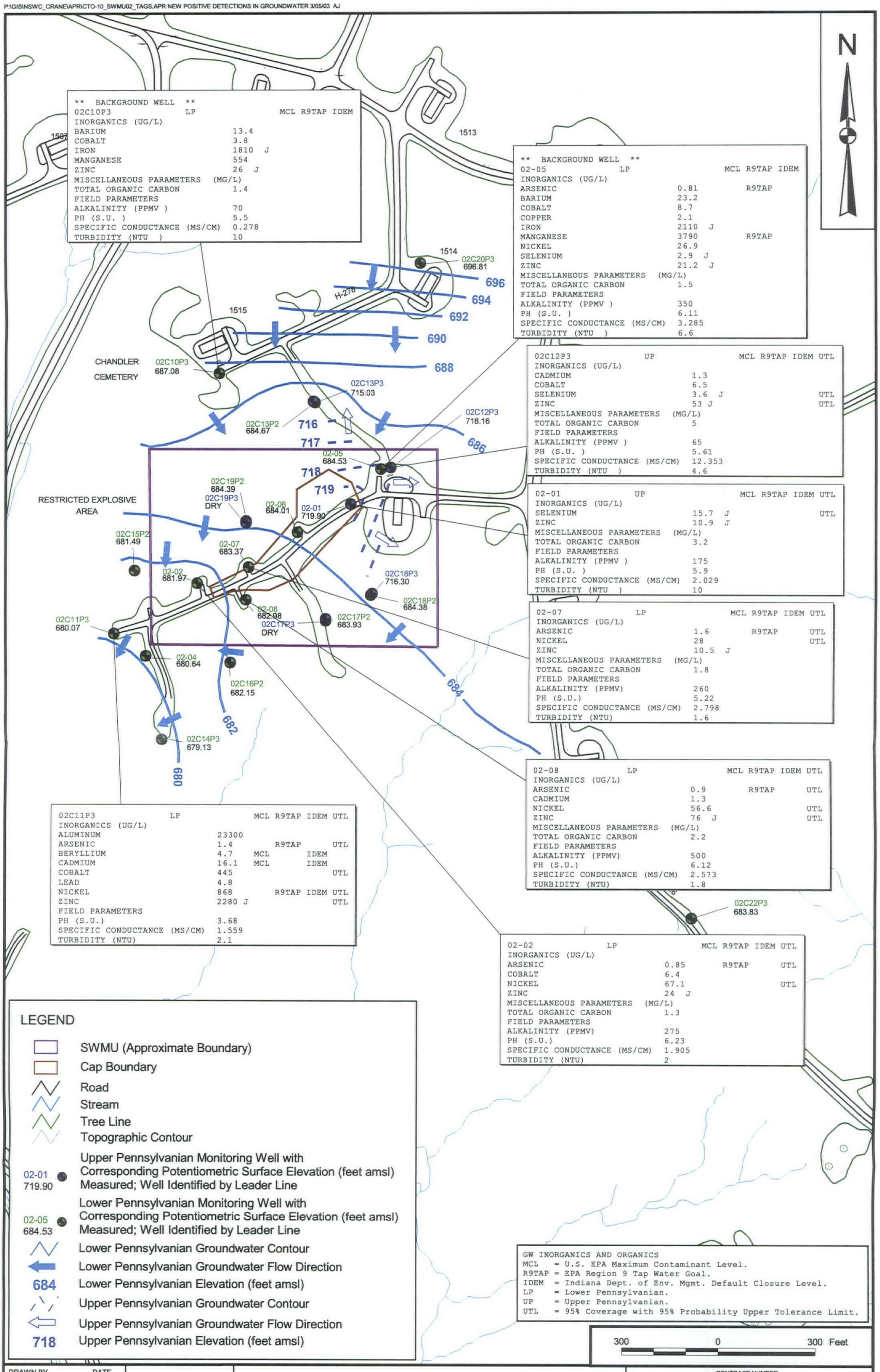
LOCATIONS ASSOCIATED WITH SOIL GROUPS
SG3: ANY SAMPLE WITH DEPTH WITHIN 0-2 FEET.
SG8: SAMPLES WITH DEPTH > 2 FEET AT LOCATIONS:
02SB04, 02SB12, 02SB13, 02SB15, 02SB19, 02SB20
SG9: SAMPLES WITH DEPTH > 2 FEET AT LOCATIONS:
02SB01, 02SB02, 02SB03, 02SB05, 02SB06, 02SB07, 02SB08, 02SB09, 02SB10, 02SB11, 02SB14, 02SB16, 02SB17, 02SB18

Note: Locations not showing pH results were not analyzed for pH.

LEGEND
- Surface Soil Sample Location
- SWMU (Approximate Boundary)
- Cap Boundary
- Road
- Stream
- Tree Line
- Topographic Contour (feet amsl)

DRAWN BY	DATE	ORGANICS AND INORGANICS DETECTED ABOVE BACKGROUND CONCENTRATIONS IN SURFACE AND SUBSURFACE SOILS SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	CONTRACT NUMBER 7141	
J. LAMEY	1/29/02		APPROVED BY	DATE
CHECKED BY	DATE		APPROVED BY	DATE
COST/SCHEDULE-AREA			DRAWING NO. FIGURE 4 - 1	REV 0
SCALE AS NOTED				

P:\GIS\NSWC_CRANE\APR\CTO-10_SWMU02_TAGS.APR NEW POSITIVE DETECTIONS IN GROUNDWATER 3/05/03 AJ



** BACKGROUND WELL ** 02C10P3	LP	MCL	R9TAP	IDEM
INORGANICS (UG/L)				
BARIUM	13.4			
COBALT	3.8			
IRON	1810 J			
MANGANESE	554			
ZINC	26 J			
MISCELLANEOUS PARAMETERS (MG/L)				
TOTAL ORGANIC CARBON	1.4			
FIELD PARAMETERS				
ALKALINITY (PPMV)	70			
PH (S.U.)	5.5			
SPECIFIC CONDUCTANCE (MS/CM)	0.278			
TURBIDITY (NTU)	10			

** BACKGROUND WELL ** 02-05	LP	MCL	R9TAP	IDEM
INORGANICS (UG/L)				
ARSENIC	0.81		R9TAP	
BARIUM	23.2			
COBALT	8.7			
COPPER	2.1			
IRON	2110 J			
MANGANESE	3790		R9TAP	
NICKEL	26.9			
SELENIUM	2.9 J			
ZINC	21.2 J			
MISCELLANEOUS PARAMETERS (MG/L)				
TOTAL ORGANIC CARBON	1.5			
FIELD PARAMETERS				
ALKALINITY (PPMV)	350			
PH (S.U.)	6.11			
SPECIFIC CONDUCTANCE (MS/CM)	3.285			
TURBIDITY (NTU)	6.6			

02C12P3	UP	MCL	R9TAP	IDEM	UTL
INORGANICS (UG/L)					
CADMIUM	1.3				
COBALT	6.5				
SELENIUM	3.6 J				UTL
ZINC	53 J				UTL
MISCELLANEOUS PARAMETERS (MG/L)					
TOTAL ORGANIC CARBON	5				
FIELD PARAMETERS					
ALKALINITY (PPMV)	65				
PH (S.U.)	5.61				
SPECIFIC CONDUCTANCE (MS/CM)	12.353				
TURBIDITY (NTU)	4.6				

02-01	UP	MCL	R9TAP	IDEM	UTL
INORGANICS (UG/L)					
SELENIUM	15.7 J				UTL
ZINC	10.9 J				
MISCELLANEOUS PARAMETERS (MG/L)					
TOTAL ORGANIC CARBON	3.2				
FIELD PARAMETERS					
ALKALINITY (PPMV)	175				
PH (S.U.)	5.9				
SPECIFIC CONDUCTANCE (MS/CM)	2.029				
TURBIDITY (NTU)	10				

02-07	LP	MCL	R9TAP	IDEM	UTL
INORGANICS (UG/L)					
ARSENIC	1.6		R9TAP		UTL
NICKEL	28				UTL
ZINC	10.5 J				
MISCELLANEOUS PARAMETERS (MG/L)					
TOTAL ORGANIC CARBON	1.8				
FIELD PARAMETERS					
ALKALINITY (PPMV)	260				
PH (S.U.)	5.22				
SPECIFIC CONDUCTANCE (MS/CM)	2.798				
TURBIDITY (NTU)	1.6				

02-08	LP	MCL	R9TAP	IDEM	UTL
INORGANICS (UG/L)					
ARSENIC	0.9		R9TAP		UTL
CADMIUM	1.3				
NICKEL	56.6				UTL
ZINC	76 J				UTL
MISCELLANEOUS PARAMETERS (MG/L)					
TOTAL ORGANIC CARBON	2.2				
FIELD PARAMETERS					
ALKALINITY (PPMV)	500				
PH (S.U.)	6.12				
SPECIFIC CONDUCTANCE (MS/CM)	2.573				
TURBIDITY (NTU)	1.8				

02C11P3	LP	MCL	R9TAP	IDEM	UTL
INORGANICS (UG/L)					
ALUMINUM	23300				
ARSENIC	1.4		R9TAP		UTL
BERYLLIUM	4.7	MCL		IDEM	
CADMIUM	16.1	MCL		IDEM	
COBALT	445				UTL
LEAD	4.8				
NICKEL	868		R9TAP	IDEM	UTL
ZINC	2280 J				UTL
FIELD PARAMETERS					
PH (S.U.)	3.68				
SPECIFIC CONDUCTANCE (MS/CM)	1.559				
TURBIDITY (NTU)	2.1				

02-02	LP	MCL	R9TAP	IDEM	UTL
INORGANICS (UG/L)					
ARSENIC	0.85		R9TAP		UTL
COBALT	6.4				
NICKEL	67.1				UTL
ZINC	24 J				
MISCELLANEOUS PARAMETERS (MG/L)					
TOTAL ORGANIC CARBON	1.3				
FIELD PARAMETERS					
ALKALINITY (PPMV)	275				
PH (S.U.)	6.23				
SPECIFIC CONDUCTANCE (MS/CM)	1.905				
TURBIDITY (NTU)	2				

GW INORGANICS AND ORGANICS
MCL = U.S. EPA Maximum Contaminant Level.
R9TAP = EPA Region 9 Tap Water Goal.
IDEM = Indiana Dept. of Env. Mgmt. Default Closure Level.
LP = Lower Pennsylvanian.
UP = Upper Pennsylvanian.
UTL = 95% Coverage with 95% Probability Upper Tolerance Limit.

DRAWN BY	DATE
J. LAMEY	1/29/02
CHECKED BY	DATE
T. JOHNSTON	2/10/03
COST/SCHEDULE-AREA	
SCALE	AS NOTED

ORGANICS, SELECT MISCELLANEOUS PARAMETERS, AND INORGANICS DETECTED ABOVE BACKGROUND LEVELS IN GROUND WATER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

CONTRACT NUMBER N7141 CTO 0010
APPROVED BY — DATE —
APPROVED BY — DATE —
DRAWING NO. FIGURE 4 - 2
REV 0

FIGURE 4-3

HISTORICAL DATA - DISSOLVED ALUMINUM
UPGRADIENT AND CROSSGRADIENT WELLS
NSWC CRANE
CRANE, INDIANA

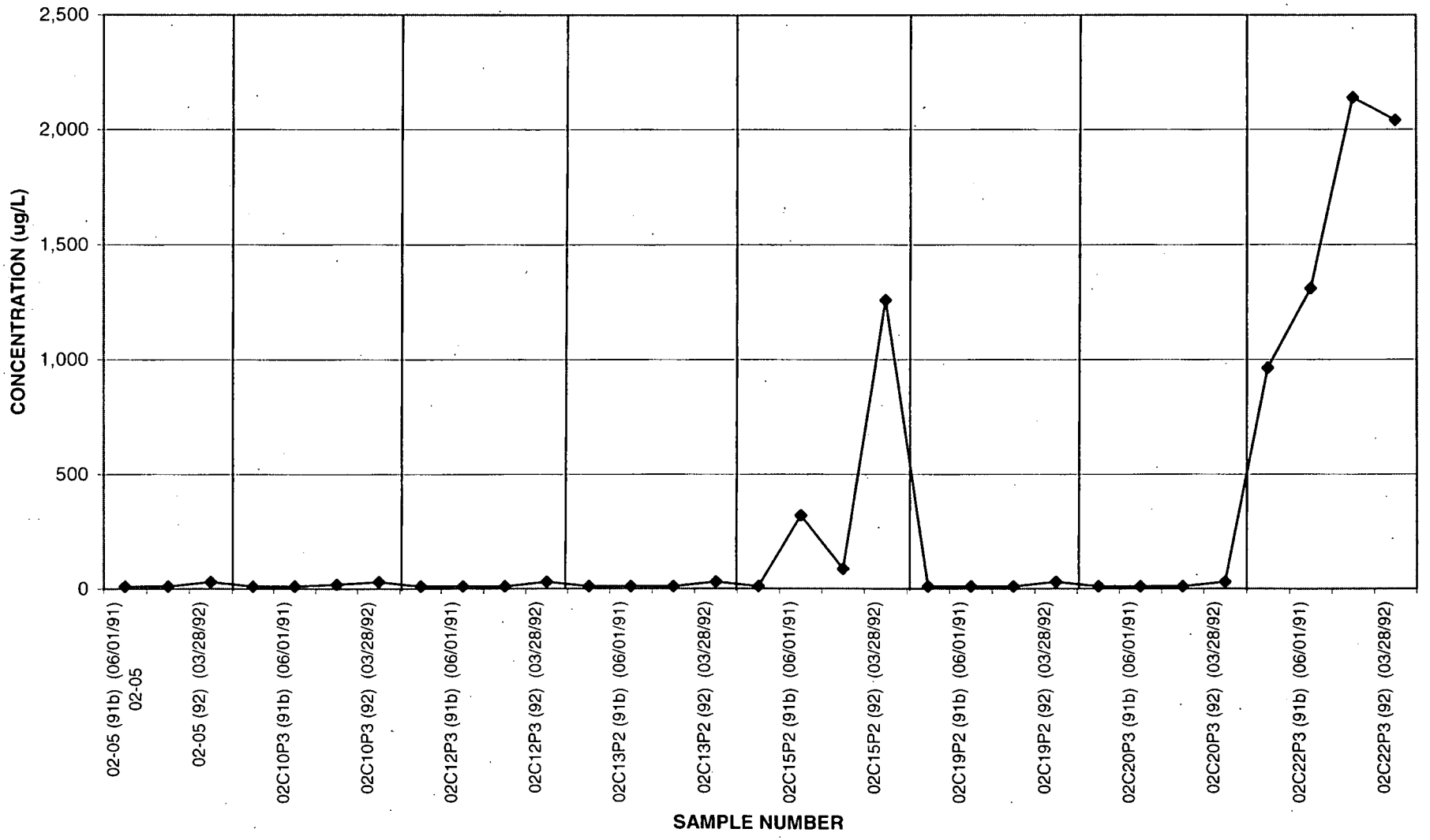


FIGURE 4-4

HISTORICAL DATA - DISSOLVED CALCIUM AND MAGNESIUM
UPGRADIENT AND CROSSGRADIENT WELLS
NSWC CRANE
CRANE, INDIANA

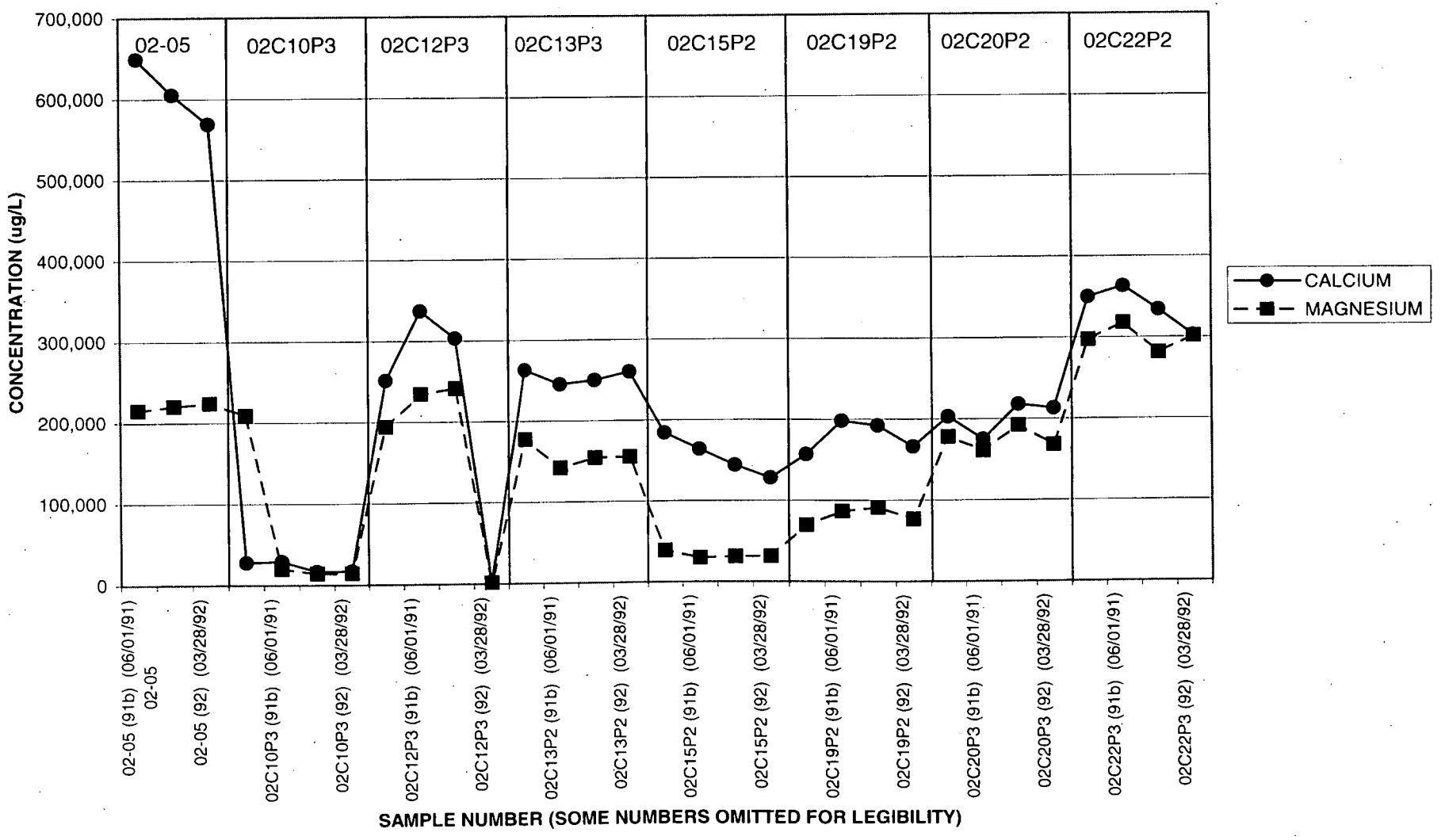


FIGURE 4-5

HISTORICLA DATA - DISSOLVED POTASSIUM AND SODIUM
UPGRADIENT AND CROSSGRADIENT WELLS
NSWC CRANE
CRANE, INDIANA

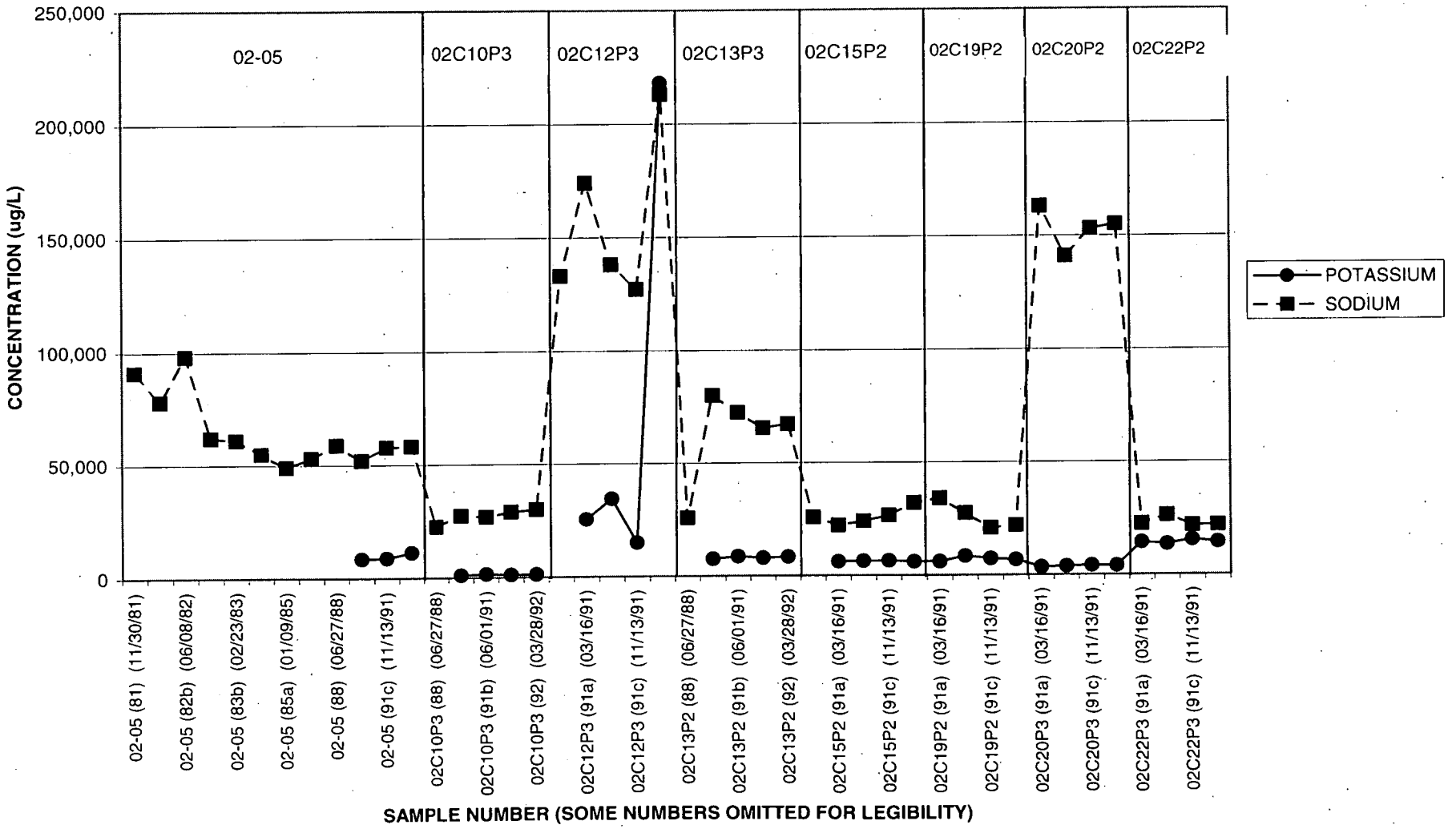


FIGURE 4-6

HISTORICAL DATA - DISSOLVED COBALT AND ZINC
UPGRADIENT AND CROSSGRADIENT WELLS
NSWC CRANE
CRANE, INDIANA

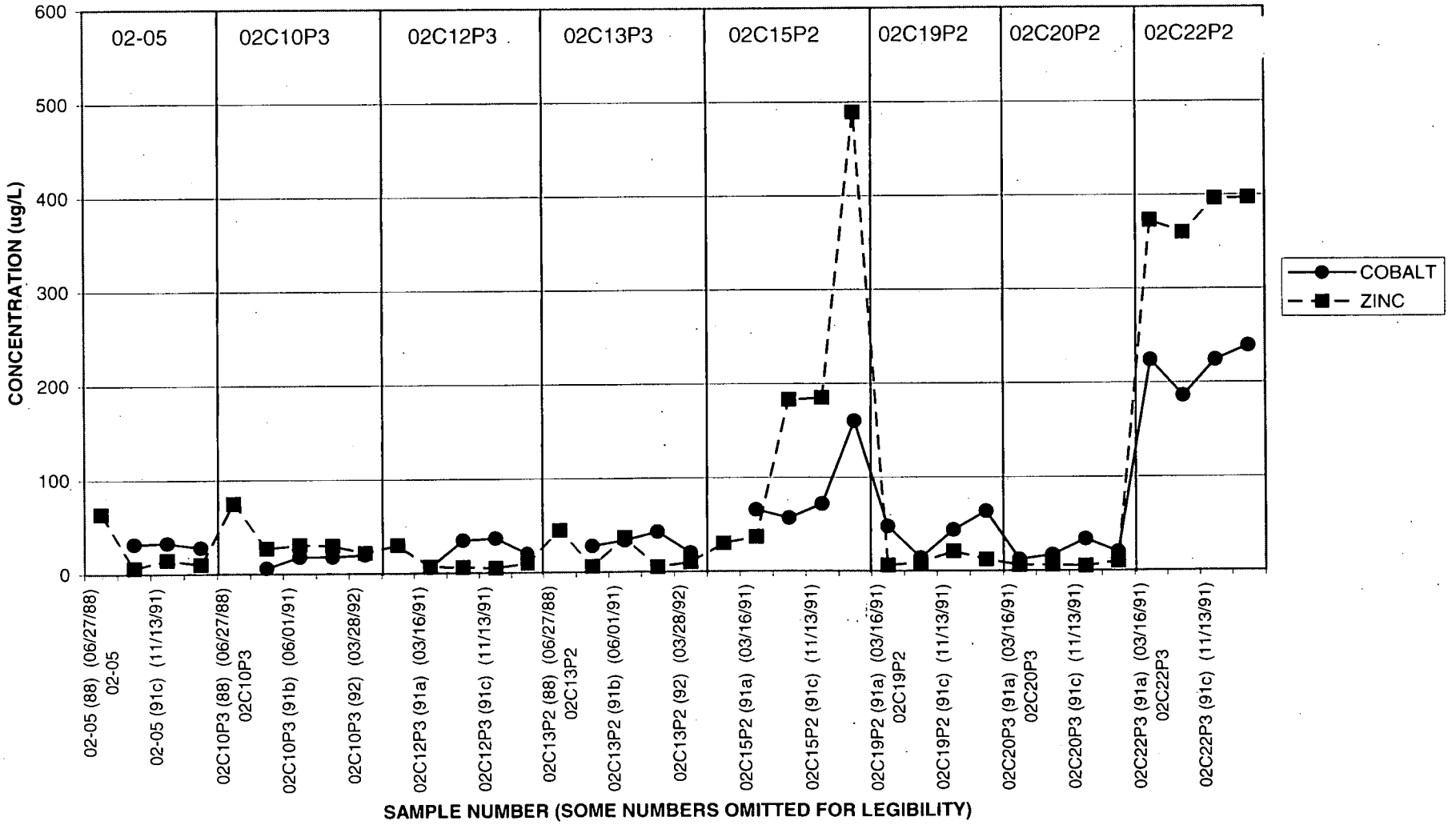


FIGURE 4-7

HISTORICAL DATA - DISSOLVED COPPER AND NICKEL
UPGRADIENT AND CROSSGRADIENT WELLS
NSWC CRANE
CRANE, INDIANA

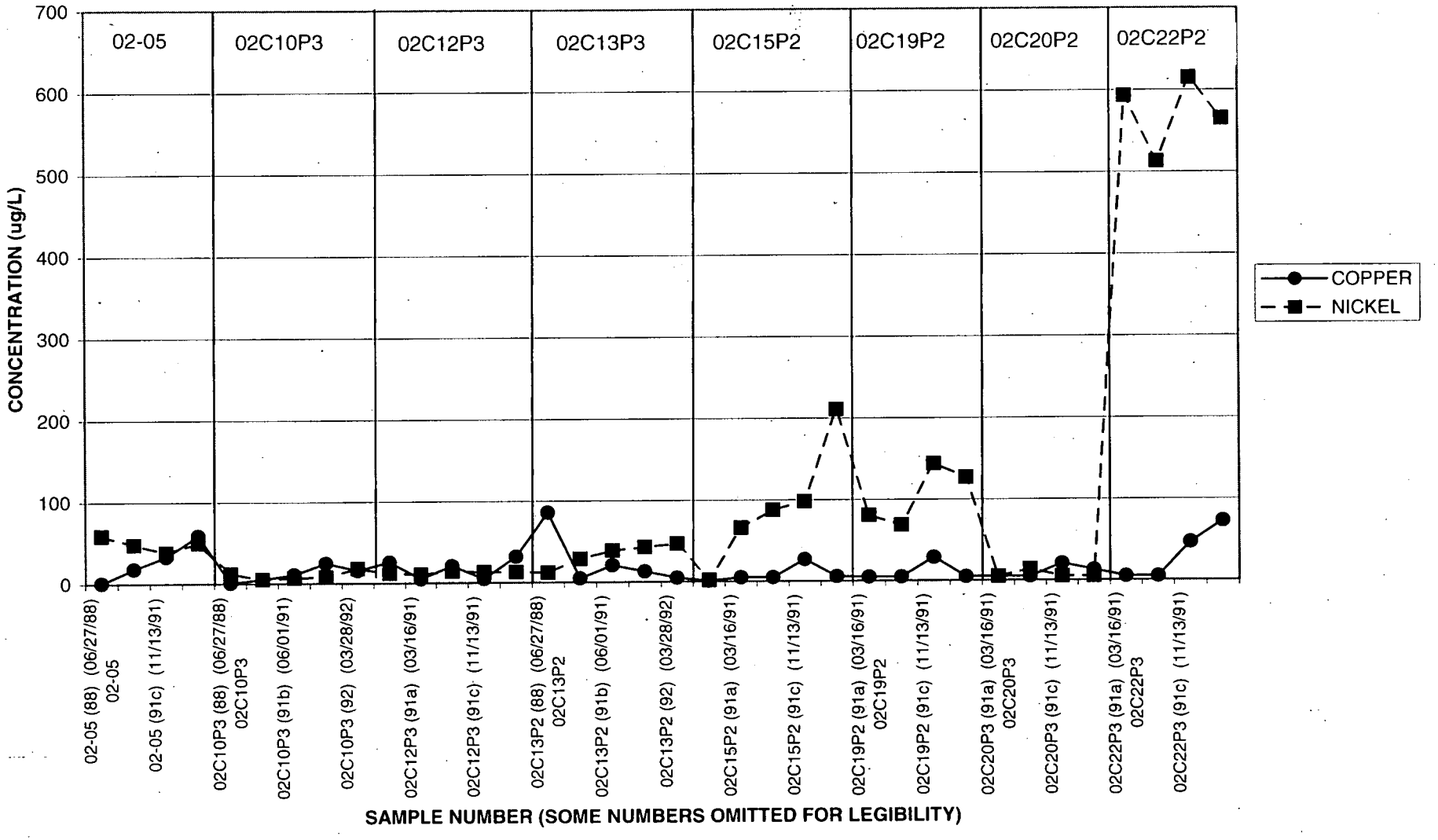
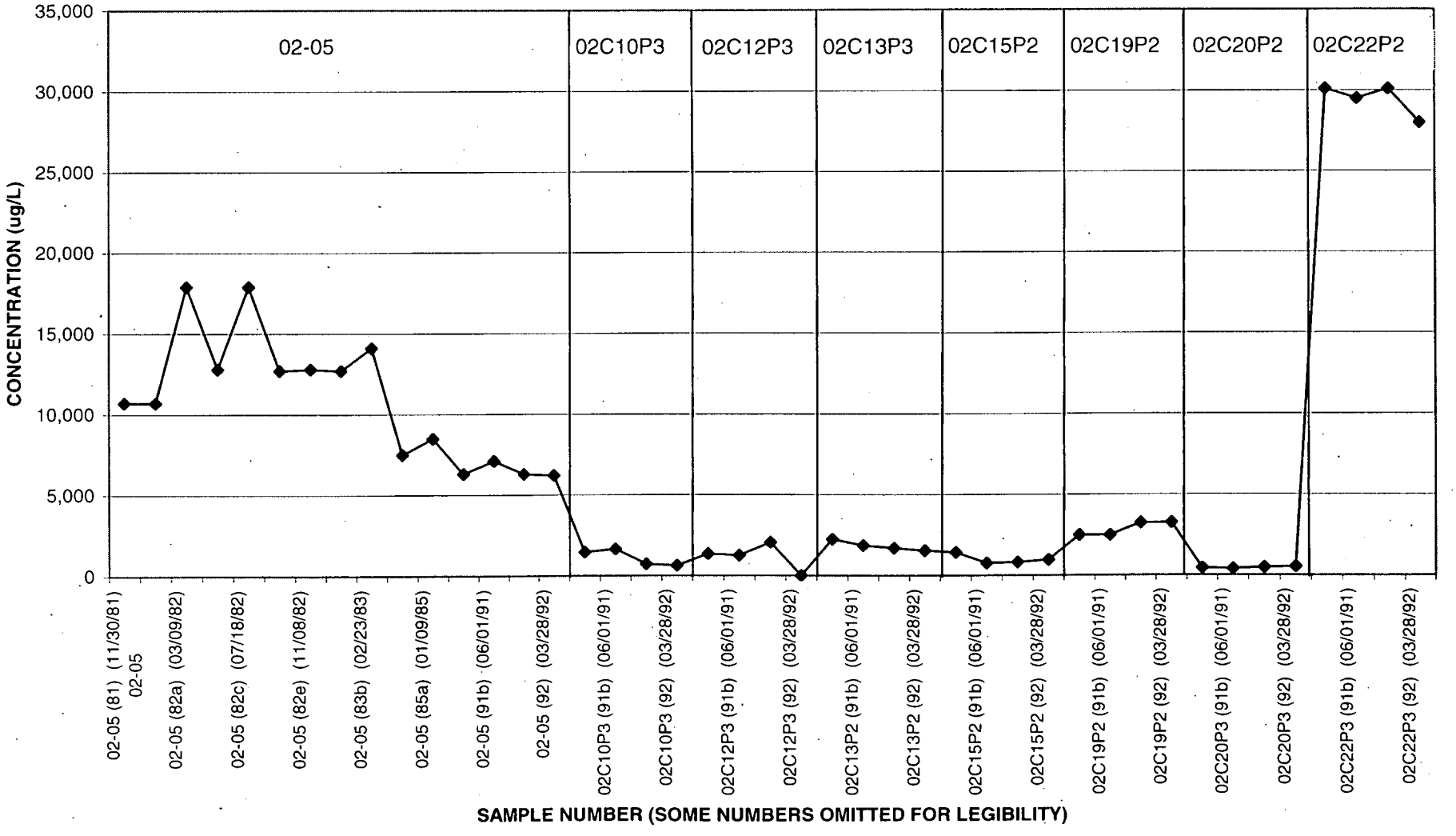
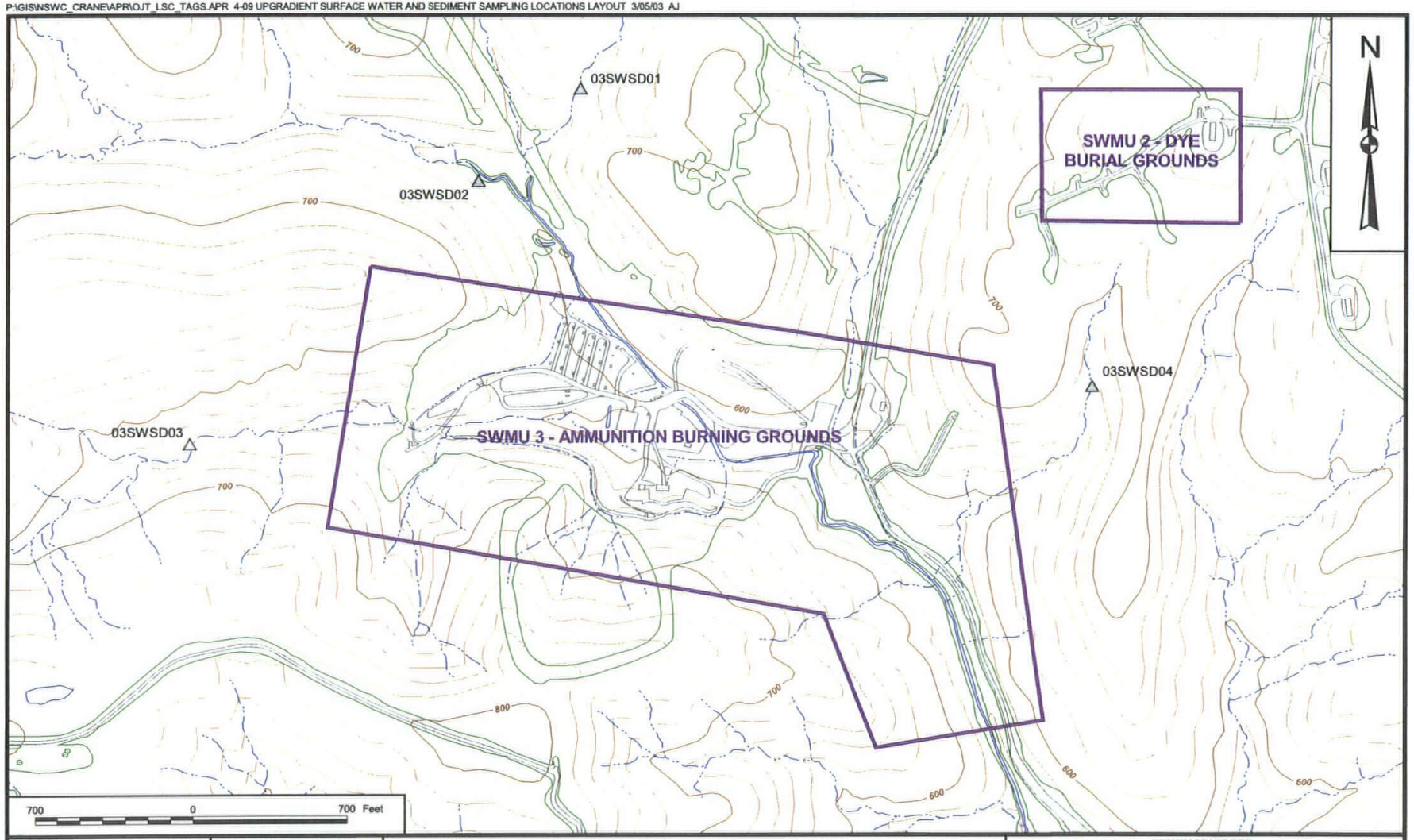


FIGURE 4-8

HISTORICAL DATA - DISSOLVED MANGANESE
UPGRADIENT AND CROSSGRADIENT WELLS
NSWC CRANE
CRANE, INDIANA



P:\GIS\NSWC_CRANE\APR\OJT_LSC_TAGS.APR 4-09 UPGRADIENT SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS LAYOUT 3/05/03 AJ



DRAWN BY	DATE
A. JANOCHA	2/10/03
CHECKED BY	DATE
T. JOHNSTON	2/10/03
COST/SCHEDULE-AREA	
SCALE	
AS NOTED	

UPGRADIENT SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

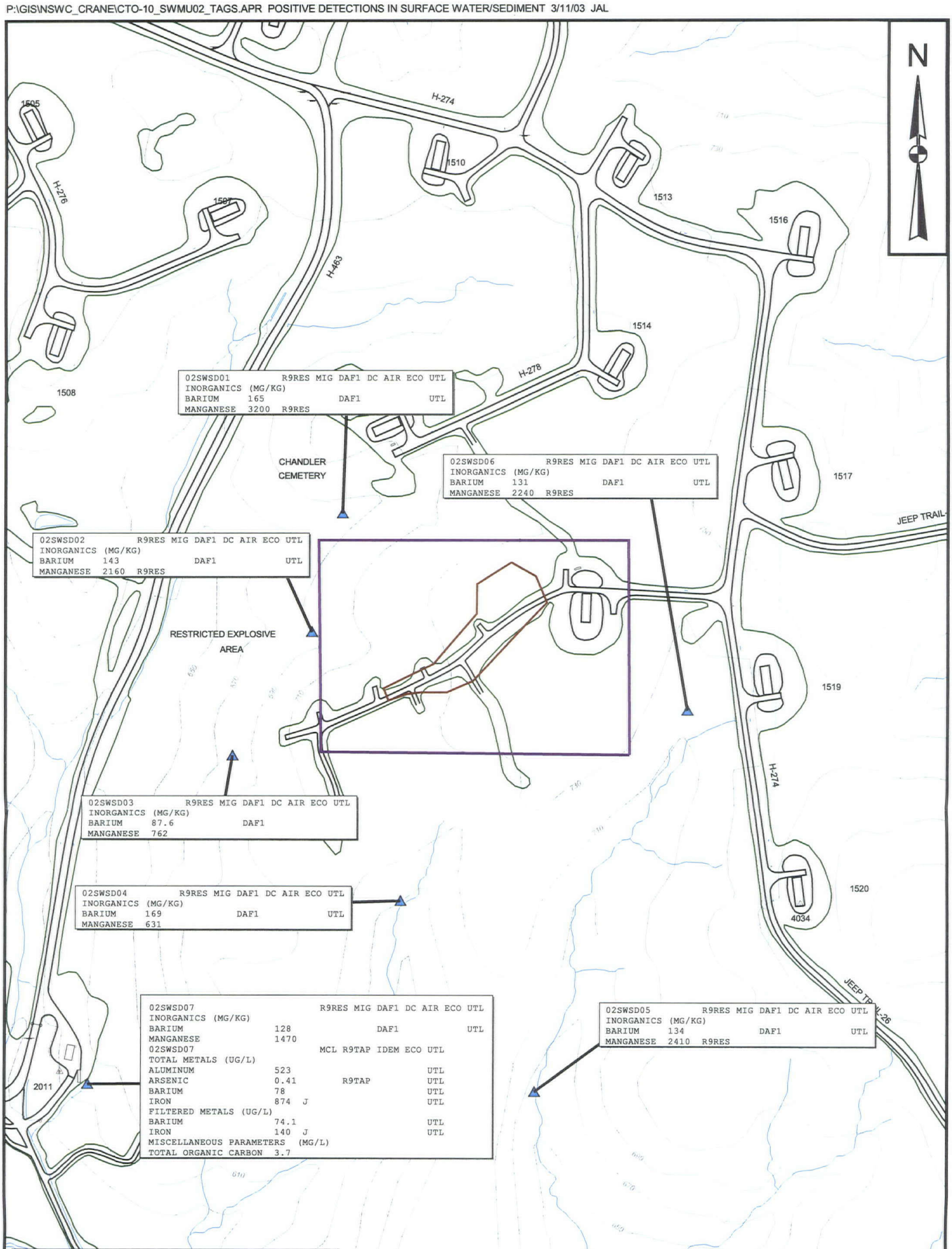
SWMU 2 - DYE BURIAL GROUNDS

NSWC CRANE

CRANE, INDIANA

CONTRACT NUMBER	
N7141 CTO 0010	
APPROVED BY	DATE
—	—
APPROVED BY	DATE
—	—
DRAWING NO.	REV
FIGURE 4 - 9	0

P:\GIS\NSWC_CRANE\CTO-10_SWMU02_TAGS.APR POSITIVE DETECTIONS IN SURFACE WATER/SEDIMENT 3/11/03 JAL



02SWSD01 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 165 DAF1 UTL
MANGANESE 3200 R9RES

02SWSD06 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 131 DAF1 UTL
MANGANESE 2240 R9RES

02SWSD02 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 143 DAF1 UTL
MANGANESE 2160 R9RES

02SWSD03 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 87.6 DAF1
MANGANESE 762

02SWSD04 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 169 DAF1 UTL
MANGANESE 631

02SWSD07 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 128 DAF1 UTL
MANGANESE 1470
02SWSD07 MCL R9TAP IDEM ECO UTL
TOTAL METALS (UG/L)
ALUMINUM 523 UTL
ARSENIC 0.41 R9TAP UTL
BARIUM 78 UTL
IRON 874 J UTL
FILTERED METALS (UG/L)
BARIUM 74.1 UTL
IRON 140 J UTL
MISCELLANEOUS PARAMETERS (MG/L)
TOTAL ORGANIC CARBON 3.7

02SWSD05 R9RES MIG DAF1 DC AIR ECO UTL
INORGANICS (MG/KG)
BARIUM 134 DAF1 UTL
MANGANESE 2410 R9RES

LEGEND

- Surface Water/Sediment Sample Location
- SWMU (Approximate Boundary)
- Cap Boundary
- Road
- Stream
- Tree Line
- Topographic Contour (feet amsl)

Note: Surface water samples only collected at Location 07.
Locations not showing pH results were not analyzed for pH.

SW INORGANICS AND ORGANICS
MCL = U.S. EPA Maximum Contaminant Level.
R9TAP = EPA Region 9 Tap Water Goal.
IDEM = Indiana Dept. of Env. Mgmt. Default Closure Level.
ECO = EPA Region 5 Ecological Data Quality Level.
UTL = 95% Coverage with 95% Probability.

SD INORGANICS AND ORGANICS
R9RES = EPA Region 9 Residential Preliminary Remediation Goal.
DC = IDEM Tier 1 Direct Contact Values.
MIG = IDEM Tier 1 Migration to Groundwater Values.
DAF1 = U.S. EPA SSL Migration to Groundwater DAF of 1.
AIR = U.S. EPA Generic SSL Inhalation Screening Level.
ECO = EPA Region 5 Ecological Data Quality Level.
UTL = 95% Coverage with 95% Probability Upper Tolerance Limit.

300 0 300 Feet

DRAWN BY J. LAMEY	DATE 1/29/02	Tetra Tech NUS, Inc.	CONTRACT NUMBER 7141 / OWNER NUMBER CTO 0010
CHECKED BY	DATE	ORGANICS AND INORGANICS DETECTED ABOVE BACKGROUND CONCENTRATIONS IN SURFACE WATER/SEDIMENT SWMU 2 - DYE BURIAL GROUNDS NSWC CRANE CRANE, INDIANA	APPROVED BY / DATE
COST/SCHEDULE-AREA			APPROVED BY / DATE
SCALE AS NOTED			DRAWING NO. FIGURE 4-10 / REV 0

5.0 CHEMICAL FATE AND TRANSPORT ANALYSIS

This section presents a brief overview of contaminant fate and transport issues at the Dye Burial Grounds. This discussion focuses on the chemicals which were analyzed in the RFI field program. The two classes of chemicals are dyes and metals. Knowledge of a contaminant's potential to migrate and persist in an environmental medium is critical when evaluating the potential for a chemical to elicit an adverse human health or ecological effect. This section contains information on various aspects of contaminant fate and transport and the chemical properties affecting contaminant migration at the Dye Burial Grounds, SWMU 2. Section 5.1 discusses the classes of chemicals that were disposed or detected at SWMU 2 and identifies those that are potentially site related and the focus of the current investigation. Section 5.2 contains a discussion of chemical properties for organic dyes and inorganics, including specific properties for substances detected in the current investigation. Section 5.3 reviews the site-specific contaminant potential transport pathways. Section 5.4 presents a brief discussion of contaminant persistence, and Section 5.5 presents a summary of potential contaminant migration.

5.1 CLASSES OF CHEMICALS DISPOSED OR DETECTED AT SWMU 2

The concentrations of several metals (aluminum, arsenic, beryllium, cadmium, cobalt, nickel, and zinc) in ground water collected from monitoring wells screened in Pennsylvanian rock are greater than screening levels and were determined to be statistically greater than background concentrations. However, two facts suggest that the elevated metal concentrations found in the wells are not the result of migration from buried wastes contained in SWMU 2. First, well 02C11P3 contained the greatest concentrations of these metals. However, this well is located the farthest downgradient and three other monitoring wells (02-02, 02-07, and 02-08) with relatively low concentrations of the metals in question are located between SWMU 2 and well 02C11P3. It is extremely doubtful that contaminated ground water migrating from the disposal area could have impacted well 02C11P3 without affecting the other three wells. Thus, the spatial distribution of metal concentrations does not support a migration-from–the-burial-grounds hypothesis. Secondly, the concentrations of iron, manganese, and copper found in well 02C11P3 during the RFI are less than concentrations historically detected in six or more out of thirteen wells that are located upgradient or side-gradient of SWMU 2. Thus, the levels of metals found in well 02C11P3 may appear at first to be elevated, but are not when one considers the levels historically detected in wells that are upgradient or side-gradient of the burial site. The most plausible explanation for the elevated metals concentrations that are found sporadically around the site is that naturally-occurring sulfide minerals contained in the Pennsylvanian shale and sandstone are oxidizing and locally affecting the metal concentrations in the ground water. However, for the purpose of this RFI and to be conservative, the

metals determined to be above background in Section 4.0 (using recent data from background wells 02-05 and 02C10P3, not historical data) and above screening levels have been retained as COPCs and have been evaluated for risk in Sections 6.0 and 7.0.

Two azo dyes (Acid Orange 10 and Acid Yellow 23) were detected in some subsurface soil samples from the current investigation, and no dyes were found in any ground water, surface water, sediment, or surface soil samples. In the current investigation, metals that were found at concentrations possibly greater than background levels include arsenic, beryllium, cadmium, lead, and nickel in the Lower Pennsylvania Aquifer, cadmium and selenium in the Upper Pennsylvanian Aquifer, barium and manganese in sediment, 14 metals in subsurface soil, four metals in surface soil, and 12 metals in surface water. Statistical background tests were performed only for surface and subsurface soil because the limited number of background samples for the other media that were investigated allowed only a qualitative comparison of maximum site concentration to maximum background concentration. Therefore, there is uncertainty associated with the background comparison for surface water, sediment, ground water, and metals identified as exceeding background levels which may be site related.

5.2 CHEMICAL AND PHYSICAL PROPERTIES THAT AFFECT FATE AND TRANSPORT

In general, organic dyes are classified based on their solubility or reactivity. Ionic dyes are water soluble and are categorized as either anionic (able to bind with substances that have basic groups and typically that have carboxylic or sulfonic groups) or basic (able to bind with substances that have acidic properties and contain basic functional groups such as amines). Solvent dyes are large organic molecules that are water insoluble and soluble in organic solvents. Reactive dyes encompass azo dyes, which form covalent bonds, and contain specific functional groups, which can undergo addition or substitution reactions with the reactive -OH, -SH, and -NH2 groups. Disperse dyes are sparingly soluble in water and are applied from an aqueous suspension in the dyeing of synthetic hydrophobic fibers. Mordant dyes are hydrophobic dyes that form an insoluble metal-dye complex, typically including chromium, aluminum, copper, or iron.

The following are important physical and chemical properties of dyes and inorganics that can be used to determine the environmental mobility and fate of site contaminants. Empirically determined literature values of the water solubility, octanol/water partition coefficient, organic carbon partition coefficient, vapor pressure, Henry's Law constant, bioconcentration factor, and acid dissociation constant are presented, when available. Calculated and measured values were extracted from a report entitled, "Survey of Azo-colorants in Denmark," prepared by the Danish Environmental Protection Agency (DEPA, 1998). A discussion of the environmental significance of each of these parameters follows.

5.2.1 Vapor Pressure

Vapor pressure provides an indication of the rate at which a chemical volatilizes from both soil and water. It is of primary importance at environmental interfaces such as surface soil/air and surface water/air. Volatilization is not as important when evaluating contaminated ground water and subsurface soils that are not exposed to the atmosphere. Vapor pressures for organic dyes are generally very low, as shown in the table below. Vapor pressures for the two dyes detected in subsurface soil at SWMU 2, Acid Orange 10 and Acid Yellow 23, are 4.43E-16 Pa and 1.32E-17 Pa, respectively. Therefore, volatilization from soil is not likely to be an important loss mechanism for dyes at SWMU 2.

Dye Group	Measured Vapor Pressure, Pa	Estimated Vapor Pressure, Pa
Acid azo dyes		6.8×10^{-33} - 3.6×10^{-15}
Basic azo dyes		3.4×10^{-12} - 2.6×10^{-4}
Direct azo dyes		1.4×10^{-45} - 1.5×10^{-24}
Disperse azo dyes	2.7×10^{-11} - 2.7×10^{-8}	1.9×10^{-19} - 6.9×10^{-5}
Mordant azo dyes		3.5×10^{-22} - 3.5×10^{-8}
Reactive azo dyes		3.0×10^{-42} - 1.3×10^{-22}
Solvent azo dyes		4.9×10^{-26} - 1.3×10^{-2}

Table excerpted from DEPA, 1998.

5.2.2 Water Solubility

The rate at which a chemical is leached from a waste deposit by infiltrating precipitation is proportional to its water solubility. More soluble chemicals are more readily leached than less soluble chemicals. A wide range of solubilities is reported for azo dyes. In general, ionic dyes have substantial solubility and tend to dissociate in aqueous solution. The water solubilities for Acid Orange 10 and Acid Yellow 23 are 80,000 mg/L and 1,000,000 mg/L, respectively.

Dye Group	Measured Water Solubility, mg/L	Estimated Water Solubility, mg/L
Acid azo dyes	>500, 80000	6×10^{-5} - ∞ Solubility
Basic azo dyes		0.6 - 139.2
Direct azo dyes	<100, 40000	9.2×10^{-7} - 2.2×10^{5}
Disperse azo dyes	6.3×10^{-4} - 1.2	8.5×10^{-7} - 10.3
Mordant azo dyes	>1000	1.7 - 527.1
Reactive azo dyes	>100000	22.1 - 98600
Solvent azo dyes	1.4, 33.5	5.1×10^{-8} - 20.5

Table excerpted from DEPA, 1998.

The solubility of inorganics is strongly influenced by their valence state(s) and forms (hydroxides, oxides, carbonates, etc.). The solubility is also dependent on pH, Eh (redox potential), temperature, and other ionic species in solution (the Debye-Huckel theory). The solubility products reported in the literature vary with the type of complex formed, but generally it can be noted that, for example, cadmium and copper complexes are more soluble than lead and nickel complexes.

5.2.3 Octanol/Water Partition Coefficient

The octanol/water partition coefficient (K_{ow}) is a measure of the equilibrium partitioning of chemicals between octanol and water. A linear relationship has been established between the K_{ow} and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor) (Lyman et al., 1990). It is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available, especially for non-polar organic chemicals. The K_{ow} is also used to estimate bioconcentration factors in aquatic organisms. The disperse, mordant, and solvent dyes have a high K_{ow} and low water solubility. These dyes are characterized as non-ionic or neutral dyes and are hydrophobic in character. Conversely, ionic dyes typically have very low K_{ow} values. The K_{ow} for Acid Orange 10 and Acid Yellow 23 are 2.75E-5 and 6.76E-11, respectively, which indicates that these dyes do not bind to soil or bioconcentrate in animals.

Dye Group	Measured log K_{ow}	Estimated log K_{ow}
Acid azo dyes		-10.5 - 5.9
Basic azo dyes		2.1 - 3.9
Direct azo dyes		-2.7 - 4.1
Disperse azo dyes	2.4 - >6	3.6 - 7.0
Mordant azo dyes		0.3 - 4.8
Reactive azo dyes		-7.8 - 8.2
Solvent azo dyes	3.4, 4.6	3.2 - 8.7

Table excerpted from DEPA, 1998.

5.2.4 Organic Carbon Partition Coefficient

The organic carbon partition coefficient (K_{oc}) indicates the tendency of a chemical to adhere to soil particles containing organic carbon. Chemicals with high K_{oc} values generally have low water solubilities and vice versa. This parameter may be used to infer the relative rates at which the more mobile chemicals are transported in the ground water. Several factors affect the measured value of K_{oc}. Values of K_{oc} usually decrease with increasing temperature. The fine silt and clay fraction of soil and sediments may have a great tendency to absorb chemicals. The different clay fractions have different adsorptive capacities. Chemicals that tend to ionize have soil sorption properties that are strongly affected by the pH. Dyes that are weak acids or weak bases show the greatest sensitivity to pH changes in the range normally found in soil and surface waters (pH 5 to pH 9). Changes in the water content of soil or sediment will change the fraction of the chemical that is adsorbed. As the water content is lowered, the fraction that is adsorbed will increase as the concentration in solution does.

Generally, substances with a log K_{oc} below 2.7 may be considered potentially mobile. Except for the solvent dyes, all classes of dyes include some compounds estimated to be potentially mobile and others with estimated high adsorption potential. However, the latter can be easily transported by erosional processes when they are present in surface soils. A literature survey of dyes indicates that acid dyes tend to have low soil/sediment adsorption due to their high solubility, basic dyes typically display high adsorption, disperse dyes vary in the high-to-medium range, and reactive dyes exhibit very low adsorption (DEPA, 1998). The log K_{oc} for Acid Orange 10 is 4.3 which indicates this dye is not very mobile in the environment. No log K_{oc} was available for Acid Yellow 23.

Dye Group	Estimated Koc (EPIWIN)	Estimated Koc (QSAR 1)	Estimated Koc (QSAR 2)
Acid azo dyes	1.9 - 9.2	0.9 - 2.9	0.1 - 4.1
Basic azo dyes	4.1 - 5.1	1.8 - 3.2	2.1 - 3.0
Direct azo dyes	3.6 - 10.8	1.4 - 3.9	0.7 - 3.5
Disperse azo dyes	1.3 - 5.5	3.0 - 5.8	2.9 - 4.7
Mordant azo dyes	2.5 - 4.8	1.0 - 4.0	1.2 - 3.5
Reactive azo dyes	3.1 - 7.0		1.1, 1.2
Solvent azo dyes	2.7 - 8.5	2.7 - 4.7	3.2 - 3.9(5.6)

EPIWIN = Estimation Program Interface for Windows.
QSAR 1,2 = different approximation models involving quantitative structure-activity relationships
Table excerpted from DEPA, 1998.

5.2.5 Henry's Law Constant

The partitioning between water and air is a physical property that is described by the Henry's Law constant, H. The magnitude of H provides the equilibrium chemical concentrations in the vapor (air) phase versus the liquid (water) phase for the dilute solutions commonly encountered in environmental settings. In general, chemicals with a Henry's Law constant of less than 1×10^{-5} atm-m^3/mole should volatilize very little and should be present only in minute amounts in the atmosphere or soil gas. For chemicals with a Henry's Law constant greater than 5×10^{-3} atm-m^3/mole, volatilization and diffusion in soil gas could be significant. The estimated Henry's Law constants are generally low for dyes. The Henry's Law constant for Acid Orange 10 and Acid Yellow 23 are 1.88E-20 atm-m^3/mole and 5.29E-33 atm-m^3/mole, respectively. This indicates that evaporation from surface water for dyes is expected to be insignificant or negligible.

Dye Group	H calc., Pa m^3/mol	H $_{bond}$, Pa m^3/mol
Acid azo dyes	1.0×10^{-28} - 4.0×10^{-16}	
Basic azo dyes	1.5×10^{-10} - 4.8×10^{-4}	8.3×10^{-20} - 9.1×10^{-18}
Direct azo dyes	1.1×10^{-37} - 1.0×10^{-22}	3.0×10^{-39}
Disperse azo dyes	2.1×10^{-14} - 2.0×10^{-3}	1.3×10^{-22} - 2.7×10^{-9}
Mordant azo dyes	5.4×10^{-22} - 5.7×10^{-9}	1.4×10^{-14} - 2.0×10^{-11}
Reactive azo dyes	3.0×10^{-44} - 3.7×10^{-21}	
Solvent azo dyes	6.9×10^{-14} - 2.3	5.7×10^{-12} - 5.5×10^{-5}

H calc. = vapor pressure × molecular weight / water solubility.
H bond = QSAR estimations of H based on group and bond contributions.
Table excerpted from DEPA, 1998.

5.2.6 Bioconcentration Factor

The bioconcentration factor (BCF) represents the ratio of aquatic-animal-tissue concentration to water concentration. The ratio is both contaminant and species specific. Compounds with log BCFs larger than 3 have a high potential for bioaccumulation, and compounds with log BCFs between 1.47 and 3, the risks of biomagnification are still important (DEPA, 1998). Log BCFs for Acid Orange 10 and Acid Yellow 23 are -5.2 and -10.1, respectively, indicating that risks of biomagnification are not important for these dyes.

Dye Group	Experimental Log BCF	$QSAR_{EUC}$ Log BCF	$QSAR_{Anl.}$ Log BCF
Acid azo dyes	<-0.5 - 1.9	-9.3 - 4.3	-15.6 - -0.2
Basic azo dyes		1.1 - 2.6	0.7 - 1.8
Direct azo dyes		-3 - 3.3	-3.2 - 1.8
Disperse azo dyes	<-0.5 - 1.6	2.4 - 16.4	0.6 - 2.0
Mordant azo dyes	0.6	-0.4 - 3.4	-0.8 - 2.2
Reactive azo dyes	1.0	-7.1 - -0.4	-13.1 - -1.7
Solvent azo dyes	1.0	2.0 - 22.5	0.5 - 2.6

$QSAR_{EUC}$: Model equations from European Union Commission (EUC), 1996.
$QSAR_{Anl.}$: Model equations from Anliker et al. (1988).
Table excerpted from DEPA, 1998.

5.2.7 Acid Dissociation Constant

The acid dissociation constant (pK_a) is a measure of the equilibrium distribution of the dissociated form of an acidic chemical or ion relative to the undissociated parent species in aqueous systems. The larger the magnitude of the pK_a, the greater the tendency for a compound to dissociate and the greater water solubility. For this reason, acidic and basic compounds have solubilities that vary depending on pH.

5.2.8 Summary of Properties of Specific Dyes Detected in the Current Investigation

Values of chemical-specific properties for the two organic dyes detected in the current sampling investigation are presented in the following table. Both dyes are acidic and exhibit high water solubility and a relatively low octanol water partition coefficient, which suggests potential mobility in ground water and the ability to adsorb onto soils with cationic properties. Bioconcentration factors for these two dyes were estimated to be very low.

Property | Chemical:	Acid Orange 10	Acid Yellow 23
Acid Dissociation Constant (pKa)	11.5**	NA
Vapor Pressure (Pa)	4.43E-16	1.32E-17
Solubility (mg/L @ 20°C)	80,000	1.00E+06
Octanol/Water Partition Coefficient	2.75E-05	6.76E-11
Organic Carbon Partition Coefficient	1.91E+04	NA
Henry's Law Constant (atm-m^3/mole)	1.88E-20	5.29E-23
Bioconcentration Factor Earthworm Est. (mg/L/mg/kg) (1)	6.92E-06	1.70E-11

1 - BCF for earthworm is cited because of detection of dyes in soil and lack of nearby surface water.
** - pKa reported from Online Database: Syracuse Research Corporation, www.esc.syrres.com/efdb.htm.
NA - Value not reported or calculable.
Table excerpted from DEPA, 1998, except where otherwise noted.

5.3 CONTAMINANT TRANSPORT PATHWAYS

This section presents a brief overview of contaminant transport issues at SWMU 2. Based on the evaluation of existing physical conditions at SWMU 2, the following potential contaminant transport pathways may exist at SWMU 2:

- Leaching of soil contaminants to ground water
- Migration of ground water contaminants
- Leaching of sediment contaminants to surface water
- Migration of contaminants in surface water
- Erosion and runoff of contaminated particles from soil

Release mechanisms, which are expected to contribute to the contaminant transport, include discharge of ground water via springs or seeps to surface water and sediment (Little Sulphur Creek), re-entry of impacted surface water to lower aquifers, and deposition via surface water runoff. Volatilization from soil or ground water is not considered a significant pathway due to the chemical properties of the dyes and inorganics detected at the site.

The SWMU lies several hundred feet southwest of the crest of a ridge separating Sulphur Creek from Little Sulphur Creek, which allows drainage from the site to the south and southwest into Little Sulphur Creek. Little Sulphur Creek is in contact with the Beech Creek aquifer; therefore, any contaminants carried by surface drainage may enter the aquifer (Baedke, 1998). Surface runoff from the Dye Burial Grounds is rapid, leaving the site in drainage channels that head at the edge of the ridges. The major springs at the site are located in the valleys below the Dye Burial Grounds. One ground water seep was identified on the southwest slope of the site, but flow from the seep is intermittent throughout the year.

5.3.1 Leaching of Soil Contaminants to Ground Water

Contaminants that adhere to soil particles or have accumulated in soil pore spaces can leach and migrate vertically to the ground water as a result of infiltration or precipitation. The rate and extent of this leaching are influenced by the depth of the water table, amount of precipitation, rate of infiltration, the physical and chemical properties of the soil, and the physical and chemical properties of the contaminant.

Based on the physicochemical properties (e.g., solubility) of dyes that potentially could have been placed in the open trenches, the migration and percolation (leaching) of constituents from surface soil to subsurface soil to ground water are highly possible at the site. However, no dye compounds were detected in ground water at SWMU 2, which suggests that soil leaching is restricted by the presence of a multi-layered cap that serves as a barrier to water infiltration over the dye burial grounds. Were infiltration to occur, soil leaching would be likely for acidic dyes, reactive dyes, and, to a lesser extent, disperse dyes. Basic dyes, if present, would tend to show high adsorption onto soil but, under some conditions (for example, alkaline pH), would be expected to leach gradually.

Based on the soil-to-ground water screening presented in Section 6.2.3, no inorganic contaminants were identified in surface soil with the potential to leach into ground water at concentrations exceeding screening levels. Arsenic, chromium, and nickel exceeded soil-to-ground water screening criteria in subsurface soil. However, given that the soil concentrations of these three metals were very low and typical of levels encountered across much of the region, it is likely that ground water concentrations are stable and already within a range that is in equilibrium with the native levels of these substances found in area soils. In addition, the screening criteria assumed that chromium is present in the more soluble hexavalent form. Since no chromium speciation was performed at SWMU 2, this was an appropriate, conservative assumption. However, this approach may overpredict the likelihood of future ground water concentration increases for chromium because, in the majority of circumstances, trivalent chromium is the predominant species present in soil samples.

In summary, it does not appear that the leaching of dyes and inorganics to ground water is a significant contaminant transport pathway at SWMU 2.

5.3.2 Migration of Ground Water Contaminants

Contaminants can migrate in either a dissolved phase or as an immiscible liquid. Movement of an immiscible liquid is controlled by entry conditions and flow conditions (Feenstra, et al., 1995). Once in a subsurface system, the rate and direction of flow depend on the density and viscosity of the fluid, the pressure driving the fluid, the hydraulic conductivity of the formation, and the degree of saturation of the fluid in the formation (Feenstra, et al., 1995). Currently, there is no evidence that dye substances are present in the form of immiscible liquids rather than dilute solutions because the two dyes that were detected in soil were both the water-soluble variety.

Contaminant concentrations may be affected by one or more mechanisms during transport. Volatilization is not expected to be a significant pathway for organic dyes, but precipitation onto soil/sediment may be significant and reactive dyes would be expected to have undergone permanent chemical reactions to form insoluble substances that would be hydrophobic and capable of adsorbing onto soil and sediment.

Organics leaching from the soil into the ground water can migrate as dissolved constituents in ground water. Three general processes govern the migration of dissolved constituents in ground water: advection, dispersion, and retardation. Advection is a process by which solutes are carried by ground water movement. Dispersion is a mixing of contaminated and uncontaminated water during advection. Retardation is a slowing of contaminant migration caused by the reaction of the solute with the aquifer media.

No dyes were detected in the ground water samples. Therefore, it does not appear that dyes are migrating with ground water from SWMU 2. As discussed in Section 4.0, concentrations of metals were higher in downgradient Lower Pennsylvanian wells than upgradient wells, although the presence of metals in downgradient wells cannot be attributed to the composition of dyes disposed at SWMU 2. Metals are naturally present in ground water and the fluctuation in concentrations are not related to disposal activities at SWMU 2. Therefore, it does not appear that migration of contaminants in ground water is a significant contaminant transport pathway at SWMU 2.

5.3.3 Leaching of Sediment Contaminants to Surface Water

Contaminants that adhere to sediment particles or have accumulated in sediment pore spaces can leach and migrate to the surface water. The rate and extent of this migration are influenced by the physical and chemical properties of the soil and the physical and chemical properties of the contaminant. No dye compounds were detected in sediments at SWMU 2, and concentrations of inorganics were generally within background levels. The surface of the site is overlain by a multi-layered cap to restrict infiltration, leaching, and overland migration, and the existing drainage pathways have been found to be dry much of the time. Together, these factors greatly restrict the quantity of substances that currently could leach from the site. Consequently, the leaching of sediment contaminants to surface water is not expected to be a significant contaminant transport pathway at SWMU 2.

5.3.4 Migration of Contaminants in Surface Water

Contaminants leaching from soils to surface water can migrate as dissolved constituents in surface water in the direction of surface water flow. Three general processes govern the migration of dissolved contaminants caused by the flow of water: movement caused by the flow of surface water, movement caused by the irregular mixing of water, and chemical mechanisms occurring during the movement of surface water. Sediment particles can disassociate from the sediment into surface water and migrate by one of the aforementioned methods.

Surface water at the site is intermittent and there are no flowing streams. The creek beds are dry except during rainfall events. Consequently, migration of contaminants in surface water is not a significant contaminant transport pathway at SWMU 2.

5.3.5 Erosion and Runoff of Contaminated Particles from Soil

Surface soil sampling around the perimeter of the multi-layer cap did not reveal the presence of organic dyes and did not identify inorganics at concentrations exceeding screening levels, although beryllium, calcium, copper, and magnesium were identified at low concentrations that slightly exceeded background levels but, were within ranges typically associated with soils. Based upon existing data and site conditions, migration of contaminants in surface soil does not represent a pathway of concern.

5.4 CHEMICAL PERSISTENCE

The persistence of various classes of chemicals is discussed in this section. Several transformation mechanisms affect chemical persistence, such as hydrolysis, biodegradation, photolysis, and oxidation/reduction reactions.

5.4.1 Organic Dyes

The azo-groups present in organic dyes have electron-withdrawing characteristics that make these compounds less susceptible to aerobic (oxidative) degradation (DEPA, 1998). In addition, dyes generally possess a degree of chemical and photolytic stability as a prerequisite to prolonging the lifetime of their dyed products. However, under biologic conditions, the azo bond may be broken to generate aromatic amines, which in turn can be absorbed in the intestine and excreted through the urinary path. In some cases, the degradation by-products are more important than the parent compounds due to carcinogenicity.

Photoreduction is likely to be slow, except in oxygen-poor water, given the known stability of dyes to visible and UV light. However, the presence of humic material can accelerate photodecomposition (DEPA, 1998). The role of hydrolysis is not considered important except for the reactive dyes, which are hydrolyzed rapidly in water. For other dyes, reductive cleavage of the azo bond is considered the major degradation pathway (DEPA, 1998).

Volatilization from either water or soil/sediment is not considered a significant pathway for all dye classes.

Dyes can be adsorbed onto soil/sediment through several processes. Anionic dyes can react with calcium, magnesium, etc. to form insoluble salts that are less available for bioaccumulation or other degradation reactions. Extensive adsorption onto soil and sediment has been shown for several types of dyes (DEPA, 1998), leading to the conclusion that adsorption is the major route of removal for dyes in the environment. Sulfonation reduces adsorption, which makes some of the acid dyes more soluble and mobile. Basic dyes have typically high levels of adsorption, and sediment cation exchange is anticipated to be rapid. Disperse dyes have medium to high adsorption due to their hydrophobic nature. Reactive dyes have low adsorption. Adsorption increases with decreasing pH or increasing molecular size, water hardness, or salinity.

Bioaccumulation rates for organic dyes are strongly influenced by K_{ow} properties, which in turn vary considerably among the different classes of dyes. Biouptake is also affected by molecular size.

Bioelimination is considered a slow process for hydrophobic chemicals. Bioconcentration factors are considered significant for some, but not all, dyes.

Biodegradation of azo dyes can occur in both aerobic and anaerobic situations; however, azo dyes are more likely to end up in anaerobic sediments and ground water because they are more recalcitrant in aerobic environments. The initial step is the cleavage of the azo bond. As summarized by DEPA's survey (DEPA, 1998), certain functional groups have been found to affect biodegradability, with ionic azo dyes possessing hydroxy or amino groups being more likely to be biodegraded than those with methyl, methoxy, sulfo, or nitro groups. The non-ionic dyes are more readily degraded in cases where functional groups include hydroxyl, amino, acetamido, or nitro groups as opposed to unsubstituted rings. Overall, biodegradation rates may vary from hours to several months or more. Some of the metabolites may also be biodegraded.

5.4.2 Metals

Metals are highly persistent environmental contaminants. They do not biodegrade, photolyze, hydrolyze, etc. The major fate mechanisms for metals are adsorption to the soil matrix (as compared to being part of the soil structure) and bioaccumulation.

The mobility of metals is influenced primarily by their physical and chemical properties, in combination with the physical and chemical characteristics of the soil matrix. Factors that assist in predicting the mobility of inorganic species are the soil/pore water pH, soil/pore water Eh, and cation exchange capacity. The mobility of metals generally increases with decreasing soil pH and cation exchange capacity (Table 5-1).

5.5 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

Evidence for chemical migration at SWMU 2, Dye Burial Grounds, is very limited. No dyes were detected in surface soil, ground water, surface water, or sediment samples. Traces of two dyes were detected in subsurface soil, but the presence of a multi-layered cap restricts the opportunity for any substantial quantities of buried dyes to leach via water infiltration or overland runoff. Acidic dyes, which were detected in soil, have high water solubility and would be expected to leach. Acidic dyes tend to adsorb onto sediment, thereby slowing their rate of migration. Many dyes would be expected to ultimately biodegrade, but their rates of degradation may be moderate to slow, depending on conditions and their chemical-specific properties. Persistence of dyes is prolonged in the environment due to sorption on soil/sediment, low volatility, and resistance to chemical, photolytic, and biodegradation. The potential for

bioaccumulation is considered significant for some dyes, but estimated BCFs were not significant for the particular acidic dyes detected in subsurface soil at SWMU 2.

Metals were detected at low concentrations in all media sampled. As discussed in Section 4.0, no source area was identified for metals at SWMU 2. In general the majority of the detected metals were present at concentrations less than background, except in subsurface soil. The presence of metals in site media cannot be attributed to the composition of dyes disposed at SWMU 2. Metals are naturally present in the environment and fluctuations in concentrations are not related to disposal activities at SWMU 2.

TABLE 5-1

RELATIVE MOBILITIES OF INORGANICS AS A FUNCTION OF ENVIRONMENTAL CONDITIONS (Eh,pH)
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

	Environmental Conditions			
Relative Mobility	**Oxidizing**	**Acidic**	**Neutral/Alkaline**	**Reducing**
Very High			Se	
High	Se, Zn	Se, Zn, Cu, Ni, Hg,Ag		
Medium	Cu, Ni, Hg, Ag, As, Cd	As, Cd	As, Cd	
Low	Pb, Ba, Se	Pb, Ba, Be	Pb, Ba, Be	
Very Low	Fe, Cr	Cr	Cr, Zn, Cu, Ni, Hg, Ag	Cr, Se, Zn, Cu, Ni, Hg, Pb, Ba, Be, Ag

Notes:

As = Arsenic
Ag = Silver
Ba = Barium
Be = Beryllium
Cd = Cadmium
Cr = Chromium
Cu = Copper
Fe = Iron
Hg = Mercury
Ni = Nickel
Pb = Lead
Se = Selenium
Zn = Zinc
Eh = Standard Redox Potential

Source: Swartzbaugh, et al. Remediating Sites Contaminated with Heavy Metals. Hazardous Materials Control, November/December 1992.

6.0 HUMAN HEALTH RISK ASSESSMENT

This section presents the HHRA for SWMU 2 at NSWC Crane. The objective of the risk assessment is to determine whether detected concentrations of chemicals at SWMU 2 pose a significant threat to potential human receptors under current and/or future land use. As discussed in Section 1.2.5, an interim measures cap has been installed at SWMU 2 to minimize potential threats to human health and the environment by the mitigation of the migration of contaminants to ground water. The cap will be part of the Final Corrective Measures at the site. Therefore, the cap was considered as a contaminant release control in the HHRA.

6.1 INTRODUCTION

The following current U.S. EPA and IDEM risk assessment guidance was used to develop the framework for the HHRA:

- U.S. EPA, 1989. Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part A). EPA 540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C., December.

- U.S. EPA, 1991. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. OSWER Directive 9285.6-03, Washington, D.C., March.

- U.S. EPA, 1992. Supplemental Guidance to RAGS: Calculating the Concentration Term. OSWER Publication No. 9285.7-081, May.

- U.S. EPA, 1993. 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., May.

- U.S. EPA, 1996. Soil Screening Guidance: Technical Background Document. EPA/540/R-95/128, Office of Solid Waste and Emergency Response, Washington, D.C., May.

- U.S. EPA, 1997. Exposure Factors Handbook. EPA/600/P-95/002Fa, Office of Health and Environmental Assessment, Washington, D.C., August.

- U.S. EPA, 1998. Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments), Publication 9285-7-01D, Office of Emergency and Remedial Response, Washington, D.C.

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A HHRA consists of five components: data evaluation, exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis. Sections 6.2 through 6.6 contain detailed discussions of the five components of the HHRA. A schematic diagram of the general risk assessment process is provided as Figure 6-1.

Three major aspects of chemical contamination and environmental fate and transport must be considered to evaluate potential risks: Contaminants with toxic characteristics must be found in environmental media and must be released by either natural processes or by human action; potential exposure points must exist; and 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.

6.2 DATA EVALUATION

Data evaluation, the first component of an HHRA, is a medium-specific task involving the compilation and evaluation of analytical data. The main objective of the data evaluation is to develop a medium-specific list of COPCs, which are used to quantitatively determine potential human health risks for site media.

6.2.1 Data Usability

Data collected from the field investigation were used to assess risks to potential human receptors. All analytical data used in the quantitative estimation of potential risks were subject to data evaluation. A discussion of data validation protocol is provided in Section 3.1 of this report. A data quality report is

included in Section 3.0 that provides information on precision, accuracy, representativeness, completeness, and comparability of the analytical data.

Only target analyte data generated in a fixed location laboratory were used in the quantitative risk evaluation. Typically, unfiltered results for ground water and surface water are used to assess risks associated with these media. Field measurements and data regarded as unreliable (i.e., qualified as "R" during the data validation process) were not used in the quantitative risk assessment.

Because of uncertainties associated with data quality, historical data collected during previous RFIs were not used to quantitatively assess potential risks at SWMU 2. The quality associated with the historical data has not been adequately documented; and there is no documentation indicating that the data have been validated. Additionally, 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. The 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 is not significant.

6.2.2 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 HHRA to those site-related constituents that dominate overall potential risks. Screening of site data against risk-based concentrations and background levels is used to focus the risk assessment on meaningful chemicals and exposure routes.

In general, a chemical is selected as a COPC and retained for further quantitative risk evaluation if the maximum detection in a sampled medium exceeds a conservative concentration(s) and the chemical is determined to be present at concentrations exceeding background. Note that this second condition applies only to those chemicals for which background comparison is appropriate (e.g., metals). Chemicals eliminated from further evaluation at this time are assumed to present minimal risks to potential human receptors.

6.2.2.1 COPC Screening Levels

Several types of screening levels were used to identify COPCs for SWMU 2. Screening concentrations based on U.S. EPA Region 9 Preliminary Remediation Goals (PRGs) (U.S. EPA Region 9, November, 2000) were used, as well as other IDEM and U.S. EPA criteria. The risk-based screening concentrations

correspond to a systemic Hazard Quotient (HQ) of 0.1 (for noncarcinogens) or a lifetime cancer risk of 1×10^{-6} (for carcinogens). Note that the Region 9 PRGs are based on an HQ of 1.0 and the screening concentrations are based on an HQ of 0.1. Conservatively, PRGs used as screening levels for non-carcinogenic chemicals have been divided by a factor of 10 to further account for the potential cumulative effects of several chemicals affecting the same target organ or producing the same adverse noncarcinogenic health effect. The screening levels used for each medium in the risk assessment are briefly discussed below.

Soil/Sediment

The following criteria were used to select COPCs for soil (surface and subsurface soil):

- U.S. EPA Region 9 PRGs for Residential Soil (U.S. EPA Region 9, November 2000)
- U.S. EPA generic soil screening levels (SSLs) for migration to ground water (U.S. EPA, May 1996)
- U.S. EPA generic SSLs for transfers from soil to air (U.S. EPA, May 1996)
- IDEM residential default closure levels for direct contact (IDEM, July 2001)
- IDEM residential default closure levels for migration to ground water (IDEM, July 2001)

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 levels), the chemical was selected as a COPC for soil and carried through to the quantitative risk assessment.

Because of the different exposure scenarios for potential human receptors, COPCs are identified separately for surface and subsurface soil. Surface soil is defined as soil collected from 0 to 2 feet bgs and subsurface soil is defined as soil collected from depths greater than 2 feet bgs.

Site soil data are compared to U.S. EPA generic SSLs for transfers from soil to air 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 is performed. Otherwise, the risks associated with the inhalation pathway are considered insignificant, and the exposure pathway is eliminated from further evaluation.

No specific screening levels exist for human exposure to sediment. COPCs for sediment are selected by comparing detected site concentrations to the following:

- U.S. EPA Region 9 PRGs for residential soil (U.S. EPA Region 9, November 2000)
- IDEM residential default closure levels for direct contact (IDEM, July 2001)

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.

The risk-based screening levels and health-based standards used in the COPC selection for soil and sediment are presented in Table 6-1.

Ground Water/Surface Water

Screening criteria based on the following criteria were used to select COPCs for ground water and surface water. The same screening levels are used to select COPCs for ground water and surface water. The following criteria are used:

- U.S. EPA Region 9 PRGs for tap water (U.S. EPA, Region 9, November 2000)
- IDEM residential default closure levels for ground water (IDEM, July 2001)
- U.S. EPA Maximum Contaminant Levels (MCLs) (U.S. EPA, Summer 2000)

If the maximum concentration of a constituent exceeds any of these criteria and the constituent is considered to be present at concentrations greater than background levels, the chemical was selected as a COPC and carried through to the quantitative risk assessment.

Risk-based COPC screening levels for tap water ingestion, which are based on daily, residential exposure assumptions, were 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 SWMU 2 because ground water at the site is not used as a potable drinking water source. Currently, there is no direct exposure to ground water at SWMU 2. In addition, potential human exposure to surface water at SWMU 2 is expected to be limited to incidental exposures (such as those which occur during trespassing), 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) were not used to select COPCs for surface water. AWQC applicable to the protection of human health were not used since surface water present at SWMU

2 is not currently used and will not be used in the future as a potable drinking water source. In addition, the intermittent 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 impacted by historical operations at SWMU 2 does discharge to nearby surface water bodies (Little Sulfur Creek and its tributaries). However, none of the surface water bodies affect Lake Greenwood.

The risk-based screening levels and health-based standards used in the COPC selection for ground water and surface water are presented in Table 6-2.

6.2.2.2 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 U.S. EPA has not derived toxicity values for lead. However, recommended screening levels are available for lead in soil that 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) recommends 400 mg/kg as the lowest screening level for lead-contaminated soil in a residential setting, where children are frequently present (U.S. EPA, July 14, 1994). 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.

At this time, no screening level is available for non-residential areas involving adult and adolescent exposure only. A value of 400 mg/kg was used as a screening level for soil and sediment. The Safe Drinking Water Act action level of 15 µg/L was used as the screening level for lead in ground water and surface water.

6.2.2.3 Essential Nutrients and Chemicals without Toxicity Criteria

The essential nutrients calcium, magnesium, potassium, and sodium were not included as COPCs for SWMU 2. These inorganic chemicals are naturally abundant in environmental matrices and are only toxic at high doses. EPA Region 9 PRGs and IDEM closure levels are not currently available for the dye compounds detected at SWMU 2. Therefore, risk-based screening levels for dyes were derived using the same methodology and exposure assumptions that were used to develop the EPA Region 9 PRGs. The risk-based screening levels for dyes were previously submitted to EPA Region 5 (TtNUS, August 2000, and September 2000) and approved.

6.2.2.4 Determination of Site-Related Chemicals

Chemicals found at concentrations indicative of background levels are not considered to be site-related contaminants and were not retained as COPCs for the quantitative risk assessment. The methodology for determining whether concentrations of inorganics detected in site media were within background levels was presented in Section 4.0 and Appendix F.

For SWMU 2, inorganics were eliminated from the quantitative risk assessment as follows:

- Surface and subsurface soil - Site soil data were compared to data from the NSWC Crane Basewide Background Soil Investigation (TtNUS, January 2001) using Wilcoxon Rank Sum Test at the 95 percent confidence level. The background data sets used for these comparisons were the representative soil types described in the Basewide Background Soil Investigation that most closely matched the site soil samples in terms of depositional environment, depth, and grain size.

- Ground water, surface water, and sediment - Basewide background data are not available for these media. Therefore, the concentrations in upgradient/upstream samples were used for background comparison by comparing the maximum site concentration of a constituent with the concentration in the upgradient sample. This approach is appropriate because of the limited size of the site and upgradient data sets.

6.2.3 Selection of Chemicals of Potential Concern

COPCs at SWMU 2 were selected for soil, ground water, sediment, and surface water using the risk-based COPC screening levels described in Section 6.2.2.1 and are presented in Table 6-3. A discussion of the chemicals identified as COPCs and the rationale for COPC selection are provided in the following subsections. RAGS Part D tables for COPC selection are included in Appendix G.3.

Surface Soil

No dyes and 20 metals were detected in surface soil samples collected at SWMU 2. A comparison of the maximum detected surface soil metals concentrations to U.S. EPA Region 9 PRGs for residential exposures and IDEM residential default closure levels for direct contact is presented in Table 6-4. The maximum detected concentrations of all metals were less than the screening criteria, with the exception of aluminum, arsenic, chromium, iron, and manganese. However, detected concentrations of these metals were within background levels. Therefore, no chemicals were retained as COPCs for surface soil at SWMU 2.

A comparison of the maximum detected surface soil concentration to U.S. EPA SSLs for chemical migration from soil to air is presented in Table 6-5. Concentrations reported for all inorganics were less than the U.S. EPA SSLs for soil to air; therefore, exposures through inhalation of fugitive dust emissions from surface soil at SWMU 2 were not evaluated quantitatively in the HHRA.

A comparison of the maximum detected surface soil metals concentrations to U.S. EPA SSLs for chemical migration from soil to ground water and IDEM residential default closure levels for migration to ground water is presented in Table 6-5. Concentrations of antimony, arsenic, barium, cadmium, chromium, lead, nickel, and selenium exceeded the screening criteria. However, reported concentrations of these metals were within site-specific background concentrations. In addition, antimony and chromium were not detected in ground water at SWMU 2. Therefore, inorganics were not retained as COPCs for the soil-to-ground water migration pathway.

Subsurface Soil

Seventeen inorganics and two dye compounds were detected in subsurface soil samples collected at SWMU 2. A comparison of the maximum detected subsurface soil concentrations to U.S. EPA Region 9 PRGs for residential exposures and IDEM residential default closure levels for direct contact is presented in Table 6-6. The maximum detected concentration of the two dyes was below screening levels. The maximum detected concentrations of all inorganics were less than the screening criteria, with the exception of aluminum, arsenic, iron, and manganese. However, detected manganese concentrations were within background levels. Therefore, only aluminum, arsenic, and iron were retained as COPCs for subsurface soil at SWMU 2.

A comparison of the maximum detected subsurface soil concentrations to U.S. EPA SSLs for chemical migration from soil to air is presented in Table 6-7. Concentrations reported for all inorganics were less than the U.S. EPA SSLs for soil to air; therefore, exposures through inhalation of fugitive dust emissions from subsurface soil at SWMU 2 were not evaluated quantitatively in the HHRA.

A comparison of the maximum detected subsurface soil concentration to U.S. EPA SSLs for chemical migration from soil-to-ground water and IDEM residential default closure levels for migration to ground water is presented in Table 6-7. Concentrations of arsenic, chromium, and nickel exceeded the screening criteria. However, detected concentrations of antimony were within background levels. Therefore, only arsenic, chromium, and nickel were retained as COPCs for the soil to ground water migration pathway.

Ground Water - Upper Pennsylvanian Aquifer

No dyes and 13 inorganics were detected in ground water samples collected from the Upper Pennsylvanian aquifer. A comparison of the maximum detected ground water concentrations to U.S. EPA Region 9 PRGs for ingestion of tap water, EPA MCLs, and IDEM ground water closure levels is presented in Table 6-8. The maximum detected concentrations of all inorganics were less than the screening criteria, with the exception of arsenic, iron, and manganese. The maximum detected concentrations of arsenic, iron, and manganese exceeded the screening criteria but were within background levels. Therefore, no chemicals were retained as COPCs for ground water in the Upper Pennsylvanian aquifer.

Ground Water - Lower Pennsylvanian Aquifer

No dyes and 17 inorganics were detected in ground water samples collected from the Lower Pennsylvanian aquifer. A comparison of the maximum detected ground water concentrations to U.S. EPA Region 9 PRGs for ingestion of tap water, EPA MCLs, and IDEM ground water closure levels is presented in Table 6-9. Aluminum, arsenic, beryllium, cadmium, cobalt, nickel, and zinc were detected at maximum concentrations that exceeded the risk-based COPC screening levels; they were retained as COPCs. The maximum detected concentrations of iron and manganese exceeded the screening criteria but were within background levels; therefore, these chemicals were not retained as COPCs for ground water in the Lower Pennsylvanian aquifer.

It should be noted that all exceedances of the screening criteria except for arsenic, iron, and manganese occurred in the ground water sample collected from monitoring well 02GWC11P3. As discussed in Section 4.3, this sample also had a pH of 3.68 and the pH of the remaining three samples ranged from 5.22 to 6.23. The low pH (acidic) in well 02GWC11P3 is likely to be the reason that metals concentrations are elevated because acidic conditions increase the solubility of metals in water. As discussed in Section 2.0, the acidic conditions at this location are attributable to the local geology and not due to SWMU 2.

Surface Water

No dyes and eight inorganics were detected in surface water samples. A comparison of the maximum detected surface water concentrations to U.S. EPA Region 9 PRGs for ingestion of tap water, EPA MCLs, and IDEM ground water closure levels is presented in Table 6-10. Aluminum, arsenic, and iron were

detected at maximum concentrations in surface water that exceeded the risk-based COPC screening levels; they were retained as COPCs for surface water.

Sediment

No dyes and 20 inorganics were detected in sediment samples collected at SWMU 2. A comparison of the maximum detected sediment concentrations to U.S. EPA Region 9 PRGs for residential exposures and IDEM residential default closure levels for direct contact is presented in Table 6-11. The maximum detected concentrations of all inorganics were less than the screening criteria, with the exception of aluminum, arsenic, chromium, iron, and manganese. Expect for manganese, the maximum detected concentrations of these metals were within background levels.

6.3 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 intakes under the identified exposure scenarios.

Actual or potential exposures at SWMU 2 at NSWC Crane were 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: a source of chemicals that can be released to the environment, a route of contaminant transport through an environmental medium, and an exposure or contact point for a human receptor.

6.3.1 General Conceptual Site Model

This section discusses the CSM for SWMU 2. A conceptual site model facilitates consistent and comprehensive evaluation of the potential risks to human health by creating a framework for identifying the pathways by which human receptors may come in contact with contaminated media resulting from the source area. A CSM depicts the relationships among the following elements, which are necessary for defining complete exposure pathways:

- Site sources of contamination
- Contaminant release mechanisms
- Transport/migration pathways

- Exposure routes
- Potential receptors

Physical site characteristics, results of previous site investigations, hazard identification (detected chemicals of interest based on the previous investigations), and current and future land use scenarios also were considered during the development of the site-specific CSM. Details on the site background, physical setting, previous investigations, and hazard identification were presented in Section 1.0. The site-specific CSM for SWMU 2 is presented in this section. Figure 6-2 illustrates the CSM for SWMU 2.

The elements of the CSM (contaminant source, release mechanisms, transport/migration pathways, exposure routes, and potential receptors) establish the manner and degree to which a potential receptor may be exposed to chemicals present at the site. The degree of risk incurred by a potential receptor varies according to the means of exposure, the duration of exposure, and the specific chemical to which the receptor is exposed. An exposure, however long in duration, does not necessarily result in an "unacceptable" health or environmental risk, although risks generally increase with increased frequency and/or duration of exposure.

The elements of the CSM, including how they pertain to SWMU 2, are presented in Sections 6.3.1.1 through 6.3.1.4.

6.3.1.1 Site Sources of Contamination

SWMU 2 was identified as a solid waste management unit because dyes and dye-contaminated materials were discharged onto surface soils and buried in open trenches. As indicated in previous RFI reports prepared for SWMU 2, materials reportedly buried included bags and boxes of dyes, magnesium, rags contaminated with dyes and open drums of dyes.

6.3.1.2 Contaminant Release Mechanisms and Transport Pathways

Past activities at SWMU 2 may have resulted in contaminant releases to the surrounding environment. A summary of the contaminant release mechanisms that may have occurred at SWMU 2 is as follows:

- Dyes may have spilled onto soil (subsurface and surface) during burial activities.
- Dyes may have leaked from the containers in which they were buried.
- Dye-contaminated soils may have been displaced during trench backfilling operations and/or cap construction activities.

Consequently, contaminants may have been released to the surrounding soil, drainageways, or ground water. A discussion of potential contaminant transport pathways was presented in Section 5.3.

6.3.1.3 Exposure Routes

The manner in which a receptor comes into contact with contaminants is generally the result of interactions between a receptor's behavior or lifestyle and an exposure medium. Potential receptors could come into contact with potentially contaminated soil (surface and subsurface), ground water, surface water, sediment, and air. Brief explanations of the potential routes of exposure per medium are provided in this section.

Soil

Exposure to contaminated soil at SWMU 2 is unlikely under current and future land use because the multilayered cap system has covered all dye-contaminated soils and all contaminated soils outside the cap have been placed underneath the cap. In addition, no COPCs were identified in surface soil at SWMU 2. A receptor may be exposed to COPCs in subsurface soil via inadvertent ingestion of a small amount of soil or via dermal absorption of certain contaminants from the soil.

Ground Water

A detailed discussion of ground water at NSWC Crane is provided in Section 1.4. Ground water at NSWC Crane is not used for drinking water or any other purposes. Lake Greenwood, an 800-acre man-made, spring-fed lake in the northwestern portion of the installation (Figure 1-1), is the main source of water at NSWC Crane. Depth to ground water at SWMU 2 is 20 feet or deeper. Because of the ground water flow pattern and the distance of SWMU 2 from the nearest eastern NSWC Crane boundary (approximately, 2,760 feet to the west of NSWC Crane boundary), off-site drinking water sources would not be expected to receive recharge from site impacted ground water.

Ground water use in the area as discussed in Section 1.4.6. Direct exposure to ground water at SWMU 2 is not expected to occur under current and/or future land use. As mentioned previously, the integrity of the cap system is not expected to be disturbed, and land use control will be placed on the capped area. However, to aid in risk management decision making, an evaluation of direct exposure to ground water (potable use) will be conducted in this HHRA. Under the hypothetical residential exposure scenario, exposure routes for ground water include ingestion and dermal contact. Inhalation of chemicals in ground water is not considered to be an exposure pathway of concern because organic compounds were not detected in ground water at SWMU 2.

Since ground water at the site discharges to surface water bodies (creeks, streams, tributaries, and seeps) located near the site, contact with ground water discharged to surface water bodies is expected to occur.

Surface Water and Sediment

Receptors also may come into direct contact with surface water and sediment in the various seeps, springs, creeks, and drainageways present at SWMU 2. In most cases, because of the intermittent nature of a majority of the surface water bodies present near SWMU 2, exposure to surface water and sediment is expected to be limited. Individuals may be exposed primarily via dermal contact and incidental ingestion. Exposure via inhalation is expected to be insignificant because volatile compounds are not constituents of concern at the site.

Air

This exposure pathway is based on the scenario that a receptor is immersed in air that contains suspended particulates and volatile organic vapors originating from the source areas. Subsequent exposure of the receptor occurs upon inhalation of (and partial subsequent ingestion) of particulates in ambient air. As noted previously, this pathway is not expected to be significant for SWMU 2. As discussed in Section 6.2.3, concentrations of all chemicals in surface and subsurface soil were below the EPA SSLs for migration from soil to air. Additionally, a multilayered cap system has been constructed over a large portion of the site, which eliminates the potential for particulate generation.

6.3.1.4 Potential Receptors

A variety of potential receptors could be exposed to site media under current and future land use. Six general classes of receptor groups have been identified for evaluation at SWMU 2 to focus the risk assessment on potentially meaningful exposures and, in general, to streamline the risk assessment process. These general receptors were identified by analyzing the interaction of current land use practices, potential future land use, and the identified sources of contamination. The general receptor classes are as follows:

- Construction Workers - Potential receptor under current and future land use. Includes adult civilian personnel who may be involved in a short-term, one-time construction project. Extensive ground-intrusive activities are not expected to occur at the site because it is unlikely that the cap placed over a large portion of the site will be disturbed. As presented in Table 1-1, depth to ground water at

SWMU 2 is 20 feet or deeper, consequently it is very unlikely that a construction worker would be exposed to ground water even if excavation did occur at SWMU 2. Therefore, this receptor is not expected to come into contact with ground water. Exposure to surface water and sediment is not expected to occur. The construction worker would potentially be exposed to surface and subsurface soil outside of the capped area to an estimated maximum depth of 10 feet bgs (a conservative estimate based on professional judgment) and air.

- Maintenance Workers – Potential receptor under current or future land use. Includes adult military or civilian personnel assigned to groundskeeping activities at SWMU 2. This receptor could potentially be exposed to surface soil and air. Maintenance workers are not assumed to be exposed to surface water, sediment, and ground water. No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil by maintenance workers are regarded as minimal, and no further evaluation was performed.

- Adolescent Trespassers (Ages 6 to 17) – Potential receptor under current and future land use. Older children and teenagers (civilians or family of military personnel living outside SWMU 2 boundary) trespassing on or near the site while exploring, playing, etc. were evaluated. This receptor could potentially be exposed to surface soil, air, surface water, and sediment. Direct exposure to ground water is not anticipated for this receptor. No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil by adolescent trespassers are regarded as minimal, and no further evaluation was performed for surface soil.

- Recreational Users (Adults) – Potential receptor under future land use, assuming that the facility were to close and be developed into a state park [includes civilians involved in recreational activities (hiking, biking, hunting, etc.)]. This receptor could potentially be exposed to surface soil, air, surface water, and sediment. No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil by adult recreational users are regarded as minimal, and no further evaluation was performed for surface soil. Direct exposure to ground water is not anticipated for this receptor. Fishing is not considered to be applicable for the recreational user because the intermittent creeks, stream, and tributaries located near the SWMU do not support substantial fish populations.

- Residents (Adults/Children) – Potential receptor under a hypothetical future land use, assuming that the ground water at the site is used for potable purposes (i.e., drinking, bathing, washing, etc.). This scenario was evaluated for decision-making purposes only. Inhalation of chemicals that have volatilized from ground water were not evaluated since no organics were detected in ground water. Although enlisted and officer personnel reside at the facility under current conditions, the residential

scenario is not applicable for these receptors because they do not and would not be expected to reside within the boundaries of SWMU 2. Because a cap exists at the site, land use control will prohibit future development of the site. Consequently, residential exposure to soil, surface water, and sediment is unlikely and was not evaluated during the HHRA.

- Occupational workers are not identified as potential receptors under current and/or future land use. Currently, this area is not active. In addition, it is not likely that the site will be developed in the future for occupational use because of the land use limitations associated with the multilayered cap. Also, no COPCs were identified in surface soil. Therefore, occupational workers were not be addressed in the HHRA.

Table 6-12 provides a site-specific listing of all exposure pathways considered and the basis for inclusion or exclusion of each exposure pathway for each receptor. Table 6-13 provides a site-specific summary of the potential receptors and exposure routes that are addressed quantitatively in the HHRA.

6.3.2 Central Tendency Exposure vs. Reasonable Maximum Exposure

Traditionally, exposures evaluated in the HHRA 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, February, 1992) 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 were evaluated in the site-specific risk assessments for SWMU 2 at NSWC Crane. The available guidance (U.S. EPA, May 1993) concerning the evaluation of CTE is limited and at times vague. Therefore, professional judgment is used when defining CTE conditions for a particular receptor at a site. Exposure factors and assumptions for both the RME and the CTE are presented in Table 6-14.

6.3.3 Exposure Point Concentrations

The exposure point concentration (EPC), which is calculated for COPCs only, is a reasonable maximum estimate of the chemical concentration that is likely to be contacted over time by a receptor and is used to calculate estimated exposure intakes. The 95 percent upper confidence limit on the arithmetic mean (UCL), which is based on the distribution of a data set, is considered to be the best estimate of the exposure concentration for data sets with 10 or more samples (U.S. EPA, May 1992). The 95 percent UCL is used as the exposure concentration to assess RME and CTE risks (U.S. EPA, May 1993). For

data sets with fewer than 10 samples, the UCL was considered to be a poor estimate of the mean, and the exposure concentration was defined as the maximum detection.

Conventional statistical methods (i.e., the Shapiro-Wilk W-Test) were used to determine the distribution and UCL of a particular data set (Gilbert, 1987; U.S. EPA, May 1992). Nondetected data points were utilized; in general, one-half the sample-specific detection limit represented these analytical results in the statistical analysis. If the calculated 95 percent UCL exceeded the maximum detected concentration, the maximum was selected as the exposure concentration.

EPCs were calculated as follows:

- There were fewer than 10 ground water, surface water, and sediment samples; therefore, the EPC for the RME and CTE case was defined as the maximum detected concentration.

- Twenty surface/subsurface soil samples were collected; therefore, the 95 percent UCL on the arithmetic mean, which is based on the distribution of the data set, was 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) were used to determine the distribution and UCL. The "best fit" distribution (normal or lognormal) was assumed if the data set distribution was undefined. If the calculated 95 percent UCL exceeded the maximum detected concentration, the maximum concentration was used as the EPC.

EPCs for COPCs for surface/subsurface soil, ground water, surface water, and sediment are summarized in Table 6-15. No COPCs were identified for surface soil; therefore, no EPCs were calculated for this medium. RAGS Part D tables for the EPCs are presented in Appendix G.3.

6.3.4 Chemical Intake Estimation

The methodologies and techniques used to estimate exposure intakes are presented here. Intakes for the identified potential receptor groups are calculated using current U.S. EPA risk assessment guidance (U.S. EPA, December 1989 and September 2001) and presented in the risk assessment spreadsheets (Appendix G). Risk assessment spreadsheets are appended to the site-specific risk assessments as support documentation.

Noncarcinogenic intakes were estimated using the concept of an average daily exposure. Carcinogenic intakes are calculated as an incremental lifetime average daily exposure, which will assume a life

expectancy of 70 years. Equations used to calculate estimated intakes are provided below. Exposure factors and assumptions regarding exposure are presented in Table 6-14.

6.3.4.1 Inhalation of Air and Fugitive Dust/Volatile Emissions

As mentioned previously in Section 6.2.2.1, a qualitative evaluation of exposure (i.e., comparison of maximum site soil concentrations to U.S. EPA generic SSLs for chemical transfers from soil to air) was used to identify whether a quantitative analysis of the inhalated exposure pathway was warranted. As shown in Tables 6-5 and 6-7, the concentrations of all chemicals detected in soil at SWMU 2 are less than the inhalation SSLs. Therefore, a quantitative evaluation of inhalation risks from soil is not required and was not performed. The potential risks associated with the inhalation pathway are regarded as minimal.

6.3.4.2 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, December 1989, and September 2001):

$$\text{Intake}_{si} = \frac{(C_{si})(SA)(AF)(ABS)(CF)(EF)(ED)}{(BW)(AT)}$$

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 (1×10^{-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 the 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, August 1997; U.S. EPA, September 2001) was 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, November 1997, TtNUS, 2001) were also reviewed to develop the exposed surface areas. The rationales used to select the skin areas are as follows:

- For construction workers exposed to surface/subsurface soil, the surface area available for soil contact is assumed to be the head, hands, and forearms of an adult male. The skin surface area is 3,300 cm^2 for the CTE and the RME. These values represent the 50th percentile areas for the head, hands, and forearms (U.S. EPA, September 2001).

- For adolescent trespassers, 25 percent of the total body surface area for an adolescent (aged 6 to 16) was assumed to be available for sediment contact. The RME value (3,820 cm^2) was derived from the 95th percentile surface area data, and the CTE value (3,100 cm^2) was derived from the 50th percentile data, as provided in Table 6-6 of the Exposure Factors Handbook (U.S. EPA, August 1997).

- For adult recreational users assumed to be exposed to sediment, the exposed surface area available for contact is the sum of the head, arms, hands, lower legs, and feet of an adult male. This skin surface area is 9,070 cm^2 for the CTE and for the RME. This value represents the 50th percentile areas for the arms, hands, lower legs, and feet (U.S. EPA, August 1997).

The following values of soil adherence factors provided in RAGS Part E (U.S. EPA, September 2001) are used to evaluate risks from exposure to soil and sediment.

- Construction workers - 0.3 mg/cm^2 for the RME and 0.1 mg/cm^2 for the CTE (Exhibit 3-3; U.S. EPA, September 2001).

- Adolescent trespassers - 0.2 mg/cm^2 for the RME and 0.04 mg/cm^2 for the CTE (Exhibit 3-3; September U.S. EPA, 2001).

- Future adult recreational users - 0.07 mg/cm^2 for the RME and 0.01 mg/cm^2 for the CTE (Exhibit 3-3; September U.S. EPA, 2001).

For the constituents identified as COPCs in soil and sediment, the following absorption factors were used (U.S. EPA, September 2001):

- Arsenic - 0.03
- Cadmium - 0.001

As indicated in RAGS Part E, absorption factors for other metals have not been developed due to insufficient data to support a default value. Therefore, risks from dermal absorption of metals (other than arsenic and cadmium) from soil were not quantified in this risk assessment. The uncertainty associated with the omission of these constituents is discussed in the uncertainty analysis.

6.3.4.3 Incidental Ingestion of Soil/Sediment

Incidental ingestion of soil (and sediment) by potential receptors coincides with dermal exposure. Exposures associated with incidental ingestion were estimated in the following manner (U.S. EPA, December 1989):

$$Intake_{si} = \frac{(C_{si})(IR_s)(FI)(EF)(ED)(CF)}{(BW)(AT)}$$

where:

$Intake_{si}$	=	intake of contaminant "i" from soil or sediment (mg/kg/day)
C_{si}	=	concentration of contaminant "i" in soil or sediment (mg/kg)
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 (1×10^{-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 (See Table 6-14) used in the estimation of dermal intakes are used to estimate exposure via incidental ingestion. The default value of 1.0 is used for the fraction of soil ingested from the source for the RME and CTE exposure scenarios.

6.3.4.4 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 SWMU 2 is limited. As mentioned previously, the site is not expected to be developed under future land use because of the nature of the site (i.e., a burial area, which is covered with a multilayered cap system). An evaluation of the hypothetical future use of ground water by a resident is provided for informational purposes only to aid risk managers in making risk management decisions.

The use of ground water for domestic purposes (i.e., bathing, showering, washing dishes), which can result in a dermal exposure. 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 was used to assess exposures resulting from dermal contact with water (U.S. EPA, September 2001):

$$DAD_{wi} = \frac{(DA_{event})(EV)(ED)(EF)(A)}{(BW)(AT)}$$

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

A resident is typically exposed to his/her domestic water supply on a daily basis. Exposure to surface water for trespassers and recreational users will be limited to infrequent exposure events. Dermal intakes for residents will assume total body exposure. For 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 sediment.

The absorbed dose per event (DA_{event}) was estimated using the following steady-state equation:

$$DA_{event} = (K_p)(C_{wi})(t_{event})$$

In general, the recommended default value of 0.001 is used for the dermal permeability of inorganic constituents, unless otherwise indicated in RAGS Part E.

6.3.4.5 Incidental/Direct Ingestion of Ground Water/Surface Water

Residents may be exposed to ground water via direct ingestion. Direct contact with surface waters could also result in the inadvertent ingestion of small amounts of water. Intakes associated with ingestion of water are evaluated using the following equations (U.S. EPA, December 1989):

$$Intake_{wi} = \frac{(C_{wi})(IR_w)(EF)(ED)}{(BW)(AT)} \quad \text{for groundwater}$$

$$Intake_{wi} = \frac{(C_{wi})(CR)(ET)(EF)(ED)}{(BW)(AT)} \quad \text{for surface water}$$

where:

$Intake_{wi}$	=	intake of chemical "i" from water (mg/kg/day)
C_{wi}	=	concentration of chemical "i" in water (mg/L)
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 are used to estimate intakes for ingestion of water (Table 6-14).

6.3.4.6 Inhalation of Volatiles in Ground Water

As shown in the COPC selection tables, organics were not detected in ground water at SWMU 2. Therefore, a quantitative evaluation of inhalation risks from ground water is not required and was not

performed. The potential risks associated with the inhalation pathway are regarded as minimal; no further evaluation was performed.

6.3.4.7 Summary of Exposure Parameters

A summary of the exposure input parameters for all exposure pathways is presented in Table 6-14 for the identified potential receptor groups at SWMU 2. In general, standard default parameters (U.S. EPA, March 1991, August 1997, and September 2001), which combine mid-range and upper-end exposure factors, are used to assess RME conditions. CTE scenarios are assessed primarily by the use of mid-range exposure factors presented in current risk assessment guidance (U.S. EPA, December 1989 and May 1993).

6.4 TOXICITY ASSESSMENT

The objective of the toxicity assessment is to identify the potential for 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 were defined for the identified COPCs. Quantitative toxicity values determined during this component of the risk assessment were 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).

6.4.1 Toxicity Criteria

Oral and inhalation RfDs and CSFs used in the site-specific risk assessments for SWMU 2 were obtained from the following primary literature sources:

- Integrated Risk Information System (IRIS) (on-line, March 2002)
- Annual Health Effects Assessment Summary Tables (HEAST)
- National Center for Environmental Assessment (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. The U.S. EPA Region 9 PRG tables and Region 3 RBC tables were also used as a source of toxicity criteria. The CSFs and

RfDs for the constituents selected as COPCs for SWMU 2 are presented in Tables 6-16 and 6-17, respectively.

6.4.1.1 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 to an absorbed dose was made using chemical-specific absorption efficiencies published in RAGS Part E (U.S. EPA, September 2001) 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

6.4.2 Toxicity Profiles

Toxicological profiles for each COPC are presented in Appendix G.2. These brief profiles present a summary of the currently available literature on the carcinogenic and noncarcinogenic health effects associated with human exposure to COPCs.

6.5 RISK CHARACTERIZATION

This section provides a characterization of the potential human health risks associated with the potential exposures to COPCs at SWMU 2. Section 6.5.1 outlines the methods used to quantitatively estimate the type and magnitude of potential risks for human receptors. A summary of the risk characterization for SWMU 2 is provided in Section 6.5.2.

6.5.1 Quantitative Analysis

Quantitative estimates of risk were calculated according to risk assessment methods outlined in U.S. EPA guidance (U.S. EPA, December 1989). Lifetime cancer risks are expressed in the form of dimensionless

probabilities, referred to as lifetime incremental cancer risks (LICRs), based on CSFs. Noncarcinogenic risk estimates are presented in the form of HQs that are determined through a comparison of intakes with published RfDs.

LICR estimates are generated for each COPC using estimated exposure intakes and published CSFs, as follows:

$$LICR = (\text{Estimated Exposure Intake})(CSF)$$

If the above equation resulted in an ICR greater than 0.01, the following equation was used:

$$LICR = 1-[\exp(-\text{Estimated Exposure Intake})(CSF)]$$

A LICR of 1×10^{-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 were 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:

$$HQ = (\text{Estimated Exposure Intake})/(RfD)$$

An HI was 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.

6.5.1.1 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 are compared to typical benchmarks. Calculated ICRs are interpreted using the U.S. EPA's target range (1×10^{-4} to 1×10^{-6}), and HIs will be evaluated using a value of 1.0.

U.S. EPA has defined the range of 1×10^{-4} to 1×10^{-6} as the LICR target range for hazardous waste facilities addressed under RCRA. Individual or cumulative LICRs greater than 1×10^{-4} are generally considered to be "unacceptable" by the U.S. EPA

An HI exceeding unity (1.0) indicates that there may be potential noncarcinogenic health risks associated with exposure. If an HI exceeds unity, target organs effects associated with exposure to COPCs are segregated. Only those chemicals that affect the same target organ(s) or exhibit similar critical effect(s) are 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.

6.5.2 Results of the Risk Characterization

This section contains a summary of the results of the risk characterization for SWMU 2. Quantitative risk estimates for potential human receptors are developed for those chemicals identified as COPCs. Uncertainties associated with the risk estimates are discussed in Section 6.6. The methodology used to calculate the risks presented in this section is provided in Sections 6.3 and 6.4. No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil are regarded as minimal and no further evaluation was performed for this medium. Potential cancer risks and HIs were calculated for construction workers, adolescent trespassers, adult recreational users, and on-site residents under the RME and CTE scenarios and are summarized in Tables 6-18 and 6-19, respectively. Sample calculations are presented in Appendix G.1, and the results of the risk assessment in RAGS Part D format are included in Appendix G.3. Cancer risks and HIs were not calculated for maintenance workers since maintenance workers are only exposed to surface soil and no COPCs were identified in surface soil.

6.5.2.1 Noncarcinogenic Risks – RME

Cumulative HIs for the construction worker, adult recreational user, and adolescent trespasser under the RME scenario are less than unity (1), indicating that adverse non-carcinogenic effects are not anticipated for these receptors under the defined exposure conditions.

Cumulative HIs for the future adult and child residents are 3.8 and 13, respectively. These elevated risks result from exposure to aluminum (child HI = 2.2), cadmium (child HI = 3.2), cobalt (HI - 2.1), and nickel (adult HI = 1.2, child HI = 4.2) in ground water, primarily by ingestion. The HIs calculated for residential exposure to ground water are subject to the following sources of uncertainty:

- As discussed previously, the risk estimates are based on analytical results for four unfiltered ground water samples. The EPC was influenced by one sample (02GWC11P301), that exhibited an unusually low pH (3.7), which suggests that the metal concentrations may be elevated because of

increased solubility of geologic minerals in an acidic environment and are not site related. If this sample was removed from the database, then all risks would be within acceptable levels.

- The residential ground water scenario assumes that ground water at the site is used as a source of domestic drinking water source. However, it is unlikely that residences would ever be located at this site. Although enlisted and officer personnel reside at the facility under current conditions, the residential scenario is not applicable for these receptors because they do not and would not be expected to reside within the boundaries of SWMU 2. Because a cap exists at the site, land use control will prohibit future development of the site. Therefore, it is unlikely that ground water at the site would be used as a source of potable water in the future.

The HIs associated with direct exposure to other media at the site are minimal for all receptors (i.e., HIs are less than unity).

6.5.2.2 Carcinogenic Risks - RME

Cumulative ILCRs for the construction worker, adult recreational user, and adolescent trespasser are less than the U.S. EPA target risk range of 1×10^{-6} to 1×10^{-4}. The total residential ILCR (child and adult) is 4.2×10^{-5}, which is within the target risk range.

As shown in the RAGS Part D tables located in Appendix G.3, the carcinogenic risks for residents are attributable to exposure to arsenic in ground water (by ingestion). As indicated above, the risks estimated for domestic use of ground water are subject to various uncertainties, especially the fact that the concentrations of arsenic in site samples may be within naturally occurring levels. In addition, carcinogenic risks from exposure to arsenic may be overestimated based on the body's ability to metabolize arsenic (see Section 6.6).

The significant sources of uncertainty are further discussed in Section 6.6.

6.5.2.3 Noncarcinogenic Risks - CTE

Cumulative HIs for the construction worker, adult recreational user, and adolescent trespasser under the CTE scenario are less than unity (1), indicating that no toxic effects are anticipated for these receptors under the CTE exposure conditions. Cumulative HIs for the CTE for future adult and child residents are 1.8 and 3.9, respectively. The HI calculated for nickel (ingestion route of exposure) in ground water exceeds 1 for the future child resident.

6.5.2.4 Carcinogenic Risks - CTE

Cumulative ILCRs for the future construction worker, adult recreational user, and adolescent trespasser are less than the U.S. EPA target risk range, 1×10^{-4} to 1×10^{-6}, and ILCRs for the future residents (child and adult) were within the target risk range.

6.5.3 Qualitative Risk Evaluation of Metals Eliminated as COPCs Based on Background

Aluminum, arsenic, chromium, iron, and manganese were detected in soils and/or sediments at concentrations exceeding the conservative screening levels established for COPC selection but were not selected as COPCs because study area concentrations did not exceed background concentrations. The following table provides a qualitative risk evaluation of these metals by comparing the maximum detected concentrations to the EPA Region 9 PRGs for soil exposure assuming residential land use:

Parameter	Surface Soil Concentration (mg/kg)	Subsurface Soil Concentration (mg/kg)	Sediment Concentration (mg/kg)	Region 9 PRG (mg/kg)
Aluminum	12,500		10,300	76,000
Arsenic	8.4		11	0.39
Chromium(1)	40.8			210
Iron	23,500		38,700	23,000
Manganese	1,800	798		1,800

1 The PRG presented for chromium assumes a 1:6 ratio of hexavalent chromium to trivalent chromium. The PRG for hexavalent chromium was used in the selection of COPCs.

The PRGs presented for aluminum, iron, and manganese are based on the potential for non-cancer health effects (the values are 10 times the COPC screening levels used in this HHRA). The maximum concentration of aluminum is one-fifth the relevant PRG. The maximum concentration of manganese is the PRG. However, based on toxicity information provided by EPA Region 1, the Region 9 PRG for aluminum is very conservative and may over predict the potential for non-cancer effects. The maximum concentration of iron does exceed the PRG; however, the PRG for iron is actually based a recommended daily intake for iron. Consequently, an exceedance of the PRG for iron is not a definitive indication of the potential for adverse non-cancer health effects. The PRGs presented for arsenic and chromium are based on the potential for cancer effects and represent the 1×10^{-6} (one-in-one-million) cancer risk level (the values are the COPC screening levels used in this HHRA). PRGs representing the 1×10^{-5} and 1×10^{-4} cancer risk levels would be 10 and 100 times the values, respectively presented for the 1×10^{-6} cancer risk level. Consequently, the maximum detected concentrations of chromium and arsenic do not exceed the 1×10^{-6} and 1×10^{-4} cancer risk levels, respectively.

Arsenic, iron, and manganese were detected in the ground waters of the Upper Pennsylvanian and/or Lower Pennsylvanian aquifers at concentrations exceeding the conservative screening levels established for COPC selection but were not selected as COPCs because study area concentrations did not exceed background concentrations. The following table provides a qualitative risk evaluation of these metals by comparing the maximum detected concentrations to the EPA Region 9 PRGs for tap water and the Federal SDWA MCLs:

Parameter	Upper Pennsylvanian Concentration (µg/L)	Lower Pennsylvanian Concentration (µg/L)	Region 9 PRG (µg/L)	Federal SDWA MCL (µg/L)
Arsenic	1.2		0.045	10
Iron(1)	465	3,350	11,000	300
Manganese(1)	440	1,720	880	50

1 Secondary (aesthetic-based) MCLs are presented for iron and manganese.

The PRGs for iron and manganese are based on the potential for non-cancer effects. The maximum detected iron concentration is less than one-third of the PRGs. The maximum detected concentration of manganese in the Upper Pennsylvania is one half of the PRG. The maximum detected concentration of manganese in the Lower Pennsylvania Aquifer is approximately twice the PRG. As noted above, the PRG for iron is a very conservative risk-based concentration because it is actually based on a recommended daily intake for iron. The PRG presented for arsenic is based on the potential for cancer effects and represent the $1x10^{-6}$ (one-in-one-million) cancer risk level (the values are the COPC screening levels used in this HHRA). PRGs representing the $1x10^{-5}$ and $1x10^{-4}$ cancer risk levels would be 10 and 100 times the values, respectively presented for the $1x10^{-6}$ cancer risk level. Consequently, the maximum detected arsenic concentration does not exceed the $1x10^{-4}$ cancer risk level. Additionally, the maximum detected arsenic concentration does not exceed the current SDWA MCL of 10 µg/L.

6.6 UNCERTAINTY ANALYSIS

There is uncertainty associated with all aspects of the baseline human health risk assessment presented in this section. A summary of the uncertainties, including a discussion of how they may affect the final risk numbers, is provided in this section.

Uncertainty in the selection of COPCs is related to the current status of the predictive databases, the grouping of samples, the numbers, types and distributions of samples, and the procedures used to

include or exclude constituents as COPCs. Uncertainty associated with the exposure assessment includes the values used as input variables for a given intake route or scenario, the assumptions made to determine exposure point concentrations, and the predictions regarding future land use and population characteristics. Uncertainty in the toxicity assessment includes the quality of the existing toxicity data needed to support dose-response relationships and the weight-of-evidence used to determine the carcinogenicity of COPCs. Uncertainty in risk characterization includes that associated with exposure to multiple chemicals and the cumulative uncertainty from combining conservative assumptions made in earlier steps of the risk assessment process.

Whereas there are various sources of uncertainty, the direction of uncertainty can be influenced by the assumptions made throughout the risk assessment, including selection of COPCs and selection of values for dose-response relationships. Throughout the entire risk assessment, assumptions, which consider safety factors, are made so that the final calculated risks are overestimated.

Generally, risk assessments carry two types of uncertainty: measurement and informational uncertainty. Measurement uncertainty refers to the usual variance that accompanies scientific measurements. For example, this type of uncertainty is associated with analytical data collected for each site. The risk assessment reflects the accumulated variances of the individual values used.

Informational uncertainty stems from inadequate availability of information needed to complete the toxicity and exposure assessments. Often, this gap is significant, such as the absence of information on the effects of human exposure to low doses of a chemical, on the biological mechanism of action of a chemical, or the behavior of a chemical in soil.

Once the risk assessment is complete, the results must be reviewed and evaluated to identify the type and magnitude of uncertainty involved. Reliance on results from a risk assessment without consideration of uncertainties, limitations, and assumptions inherent in the process can be misleading. For example, to account for uncertainties in the development of exposure assumptions, conservative estimates must be made to ensure that the particular assumptions made are protective of sensitive subpopulations or the maximum exposed individuals. If a number of conservative assumptions are combined in an exposure model, the resulting calculations can propagate the uncertainties associated with those assumptions, thereby producing a much larger uncertainty for the final results. This uncertainty is biased toward overpredicting both carcinogenic and noncarcinogenic risks. Thus, both the results of the risk assessment and the uncertainties associated with those results must be considered when making risk management decisions.

This interpretation is especially relevant when the risks exceed the point of departure for defining "acceptable" risk. For example, when risks calculated using a high degree of uncertainty are less than an acceptable risk level (i.e., 10^{-6}), the interpretation of no significant risk is typically straightforward. However, when risks calculated using a high degree of uncertainty exceed an acceptable risk level (i.e., 10^{-4}), a conclusion can be difficult unless uncertainty is considered.

6.6.1 Uncertainty in Selection of COPCs

The most significant issues related to uncertainty in COPC selection are the usability of existing databases (i.e., the use of validated and unvalidated sample results, and the completeness, precision, and accuracy of the data set), the inclusion of chemicals potentially attributable to background, the screening levels that are used, and the absence of screening levels for a few chemicals detected in the site media. A brief discussion of each of these issues is provided in the remainder of this section.

Usability of Existing Databases

All data used in the risk assessments for SWMU 2 were obtained from samples collected in July and August 2000 and January 2001 (and reported in Appendix E of this report). No historical data were used for risk assessment purposes because the quality associated with the historical data has not been adequately documented. 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. 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.

All the fixed-base laboratory data for the samples collected in 2001 were validated as discussed in Section 3.1. A review of data quality is also provided in this section. The qualification of data during the formal data validation process is not expected to compromise the results of the baseline human health risk assessment. Analytical data qualified as estimated were utilized. Although use of estimated data adds to the uncertainty associated with the risk assessment, the associated uncertainty is expected to be negligible compared to the other uncertainties inherent in the risk evaluation process (i.e., uncertainties in sampling variability, land uses, exposure scenarios, toxicological criteria, etc.).

For arsenic, vanadium, and zinc, blank-qualified data were used in the baseline risk assessment, but only a few positive values at the lower range of concentrations were qualified as not detected due to blank contamination (higher range positives were confidently identified). This results in negligible impacts on

data uncertainty because generally only the upper range of database concentrations heavily influence the RME exposure point concentration and selection of EPCs.

When exposure concentrations were determined via statistical procedures, chemicals not detected were conservatively assumed to be present at a concentration equal to one-half the sample-specific quantitation limit. Non-detected analytical results for 22 dye compounds were qualified "UR," unreliable, and were not used in the risk assessment. Of these dye chemicals, only nine were found as positively detected in other samples at SWMU 2. In every case, the majority of results for each dye chemical were usable and not qualified "R." The sporadic rejection of analytical results for a few samples does not result in a significant underestimation of contaminant concentration at SWMU 2, or adversely impact the estimation of maximum detected concentrations used in selecting COPCs.

Chemicals Potentially Attributable to Background

COPCs for SWMU 2 were selected using available background concentrations for soil, ground water, surface water, and sediment. Metal concentrations in soil were compared to background concentrations provided in the NSWC Crane Basewide Background Soil Investigation (TtNUS, January 2001) using the Wilcoxon Rank Sum Test at the 95 percent confidence level. The background data sets used for these comparisons were the representative soil types described in the Basewide Background Soil Investigation, which most closely matched the site soil samples in terms of depositional environment, depth, and grain size. The use of matching soil types reduces the uncertainty in the background comparisons for soils.

Basewide background data are not available for ground water, surface water, and sediment. Consequently, concentrations in upgradient samples were used for background comparison. A chemical was not selected as a COPC if the maximum site concentration was less than the upgradient concentration. This method of screening inorganic compounds may result in the selection of inorganic compounds as COPCs that would have been deleted as COPCs based on a more rigorous background evaluation. Therefore, site-related risks for these media may be overestimated. For example, arsenic is the primary risk driver in ground water. However, arsenic was detected in four of four Lower Pennsylvanian aquifer ground water samples with a maximum concentration of 1.6 µg/L which is below the MCL of 10 µg/L. Although arsenic was not detected in upgradient ground water samples from this aquifer, the existing background data may or may not be representative because only two samples were collected and it is likely that the concentrations of arsenic in ground water at the site are within naturally occurring levels.

Monitoring wells 02GW0501 and 02GWC10P301 were used as background wells in the selection of COPCs. The work plan had indicated that only monitoring well 02GWC10P301 would be used to establish

background conditions in ground water and monitoring well 02GW0501 would be used to characterize ground water conditions within SWMU 2. Although monitoring well 02GW0501 is located within the SWMU 2 boundary, it is located outside and hydraulically upgradient of the landfill cap. Consequently, as discussed in Section 4.3, it is believed that ground water samples from 02GW0501 are representative of background conditions. If 02GW0501 had been included in the database for SWMU 2 then manganese and iron would also have been retained as COPCs for ground water from the lower Pennsylvania Aquifer in addition to the COPCs previously identified. HIs for exposures to ground water by hypothetical child and adult residents under the RME scenario would be 30 and 8.7, respectively. Aluminum (HQ = 2.2), cadmium (HQ = 3.2), cobalt (HQ = 2.1), iron (HQ = 1.1), manganese (HQ = 16), and nickel (HQ = 4.2) are the major contributors to the HI for the child resident under the RME scenario. Manganese (HQ = 4.6) and nickel (HQ = 1.2) are the major contributors to the HI for adult resident under the RME scenario. Under the CTE scenario, HIs for exposures to ground water by hypothetical child and adult residents would be 8.9 and 4.1, respectively. Manganese (HQ = 4.6) and nickel (HQ = 1.2) are the major contributors to the HI for the child resident under the CTE scenario. Manganese (HQ = 2.1) is the major contributor to the HI for adult resident under the CTE scenario. Since manganese and iron are noncarcinogens, the ILCRs presented in Section 6.5.2 for hypothetical residential exposures to ground water would not change.

COPC Screening Levels

The use of risk-based screening values based on conservative land use scenarios (i.e., residential land use for soil and sediment and ingestion of tap water for ground water and surface water), corresponding to an ILCR of 10^{-6} and HI of 0.1, should ensure that all the significant contributors to risk from a site are evaluated. The elimination of chemicals that are present at concentrations that correspond to an ILCR less than 10^{-6} and an HI less than 0.1 should not affect the final conclusions of the risk assessment because these chemicals are not expected to cause a potential health concern at the detected concentrations.

Chemicals Without Established Screening Levels

No U.S. EPA Region 9 PRGs or IDEM closure levels are available for dyes. Therefore, risk-based screening levels for dyes were derived using the same methodology and exposure assumptions that was used to develop the EPA Region 9 PRGs. The risk-based screening levels for dyes were submitted to U.S. EPA Region 5 (TtNUS, August 2000, September 2000) and subsequently approved. Although these screening levels are based on conservative assumptions, there is additional uncertainty because the toxicity factors upon which these dye screening levels are based are not considered consensus toxicity

values with the same wide level of peer review acceptance that is reserved for those substances published on IRIS or HEAST.

Toxicity data were only available to derive screening levels for one of the two dyes detected in site media (Acid Orange 10). Screening levels could not be developed for Acid Yellow 23. Acid Yellow 23 was detected in 6 of 20 subsurface soil samples at concentrations ranging from 2.85 mg/kg to 11.5 J mg/kg. Screening levels for water soluble dyes ranged from 300 mg/kg to 380,000 mg/kg. The maximum detected concentration of Acid Yellow 23 is approximately 26 times lower than the lowest screening level for the water soluble dyes. In addition, Acid Yellow 23, also known as FD&C Yellow 5, is approved by the Food and Drug Administration as a food color additive and for use in cosmetics, which indicates that Acid Yellow 23 is safe for use by humans. Therefore, the absence of screening levels for Acid Yellow 23 does not introduce any uncertainty in the risk assessment.

6.6.2 Uncertainty in the Exposure Assessment

Uncertainty in the exposure assessment arises because of the methods used to calculate exposure point concentrations, the determination of land use conditions, the selection of locations and numbers of samples, the selection of receptors and scenarios, the estimation of exposure point concentrations, and the selection of exposure parameters. Each of these is discussed below.

Land Use

The current land use patterns at NSWC Crane are well established, thereby limiting the uncertainty associated with land use assumptions. As a result of limitations on land use required because of the multilayered cap atop soil in the dye burial trench area, land use at SWMU 2 is currently limited and is expected to be limited in the future, as long as NSWC remains open (construction workers, maintenance workers, and potential and infrequent trespassers are the only current receptors). To be conservative, risks to future potential residents and construction workers were estimated for the site.

Selection of Locations and Numbers of Samples

To ensure that chemical concentration data used to assess exposure are representative of areas of potential site contamination, a sufficient number of samples should be collected to avoid missing significant hot spots and to allow a statistically accurate estimate of RME concentrations.

Only one surface water sample was collected and only four ground water samples were collected for the Lower Pennsylvanian aquifer. Consequently, these datasets may not be representative of potential site

conditions for exposed receptors. This may result in overestimation of risks because maximum concentrations are used as EPCs when datasets contain fewer than 10 samples. In addition, the surface water pathway is very limited at SWMU 2 because most sediment locations were dry due to intermittent drainage patterns. Therefore, risks due to surface water exposure are likely to be overestimated because receptor contact is expected to be infrequent given the intermittent and limited nature of water flow.

Exposure Point Concentrations

Uncertainty is associated with the use of the 95 percent UCL on the mean concentration as the EPC. As a result of using the 95 percent UCL, the estimations of potential risk for the RME scenario are most likely to be overstated since this is a representation of the upper limit that potential receptors would be exposed to over the entire exposure period. In some cases (because datasets were less than 10 samples or because the UCL was greater than the maximum concentration), the maximum concentration was used as the EPC. Use of the maximum concentration tends to overestimate potential risks because receptors are assumed to be exposed continuously to the maximum concentration for the entire exposure period. Uncertainty is also introduced when the nondetects are assigned a value of one-half the nondetect quantitation limit in the calculation of the EPC. This may either overstate or understate the risks to the receptors.

There is uncertainty in assuming that current ground water concentrations will not change in the future, and this would introduce additional uncertainty in the EPC and risks for any ground water COPC. Concentrations in ground water may diminish over time due to natural attenuation processes involving source depletion and dilution. Alternatively, concentrations could increase if soil leaching processes contribute a substantial loading of contaminants to ground water. Soil-to-ground water pathway screening was conducted to determine if any substances might be present at levels sufficient to leach into ground water. This analysis indicated that arsenic, chromium, and nickel are the only substances that might conceivably leach from subsurface soil to produce noteworthy ground water concentrations in the future. Future ground water risks would be underestimated if these substances were to migrate to the extent predicted by the screening model. However, given that the soil concentrations of these three metals were very low and typical of levels encountered across much of the region, it is likely that ground water concentrations are stable and already within a range that is in equilibrium with the native levels of these substances found in area soils. In addition, the screening criteria assumed that chromium is present in the more soluble and more toxic hexavalent form. Since no chromium speciation was performed at SWMU 2, this was an appropriate, conservative assumption. However, this approach may overpredict the likelihood of future ground water concentration increases for chromium, because in the majority of circumstances, trivalent chromium is the predominant species present in soil samples.

Exposure Routes and Receptor Identification

The determination of various receptor groups and exposure routes of potential concern was based on current land use observed at the site and the anticipated future land use. Therefore, the uncertainty associated with the selection of exposure routes and potential receptors is minimal because they are considered to be well defined. Although residential use of ground water was evaluated as an exposure scenario, ground water is not currently used at the site. There is good reason to believe that future direct exposure to ground water at SWMU 2 is not expected to occur because the integrity of the cap system is not expected to be disturbed and land use control will be placed on the capped area. Therefore, the evaluation of direct exposure to ground water (domestic use) that was performed in this baseline HHRA was included primarily to aid in risk management decision making.

Exposure Parameters

Each exposure factor (for RME and CTE scenarios) selected for use in the risk assessment has some associated uncertainty. Generally, exposure factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid underestimation of exposure, in most cases, the U.S. EPA guidelines (U.S. EPA, March 1991) on the RME receptor were used, which generally specify the use of the 95th percentile for most parameters. Therefore, the selected values for the RME receptor represent the upper bound of the observed or expected habits of the majority of the population.

Generally, the uncertainty can be assessed quantitatively for many assumptions made in determining factors for calculating exposures and intakes. Many of these parameters were determined from statistical analyses on human population characteristics. Often, the database used to summarize a particular exposure parameter (i.e., body weight) is quite large. Consequently, the values chosen for such variables in the RME scenario have low uncertainty.

For many parameters for which limited information exists (i.e., dermal absorption of chemicals from soil), greater uncertainty exists. For example, current U.S. EPA guidance (U.S. EPA, September 2001) does not provide dermal absorption factors for exposure to most metals (except arsenic and cadmium) in soil. Therefore, risks for dermal contact from soil are not evaluated for most metals in this risk assessment. Consequently, risks from exposure to soil may be underestimated.

Many of the exposure parameters used to calculate exposures and risks in this report are selected from a distribution of possible values, including U.S. EPA guidance (U.S. EPA, March 1991, May 1993) and dermal guidance (U.S. EPA August 1997 and September 2001). For the RME scenario, the value representing the 95th percentile is generally selected for each parameter to ensure that the assessment bounds the actual risks from a postulated exposure. This risk number is used in risk management decisions but does not indicate what a more average or typical exposure might be or what risk range might be expected for individuals in the exposed population.

To address these issues, U.S. EPA (February 1992) has suggested the use of the CTE receptor, whose intake variables are often set at approximately the 50th percentile of the distribution. The risks for this receptor seek to incorporate the range of uncertainty associated with various intake assumptions. Some of the parameters presented in this risk assessment were estimated using professional judgment, although U.S. EPA does provide limited guidance for the CTE evaluation (U.S. EPA, May 1993).

6.6.3 Uncertainty in the Toxicological Evaluation

Uncertainties associated with the toxicity assessment (determination of RfDs and CSFs and use of available criteria) are presented in this section.

Derivation of Toxicity Criteria

Uncertainty associated with the toxicity assessment is associated with hazard assessment and dose-response evaluations for the COPCs. The hazard assessment 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. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using the U.S. EPA methods. Positive animal cancer test data suggest that humans contain tissue(s) that may manifest a carcinogenic response; however, the animal data cannot necessarily be used to predict the target tissue in humans. In the hazard assessment of noncancer effects, however, positive animal data often suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans.

Uncertainty in hazard assessment arises from the nature and quality of the animal and human data. Uncertainty is reduced when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose related; when pharmacokinetic data indicate a similar fate in humans and animals; when postulated mechanisms of toxicity are similar for humans and animals;

and when the chemical of concern is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainty in the dose-response evaluation includes the determination of a CSF for the carcinogenic assessment and derivation of an RfD for the noncarcinogenic assessment. Uncertainty is introduced from interspecies (animal to human) extrapolation, which, in the absence of quantitative pharmacokinetic or mechanistic data, is usually based on consideration of interspecies differences in basal metabolic rate. Uncertainty also results from intraspecies variation. Most toxicity experiments are performed with animals that are very similar in age and genotype, so intragroup biological variation is minimal, but the human population of concern may reflect a great deal of heterogeneity, including unusual sensitivity or tolerance to the COPC. Even toxicity data from human occupational exposure reflect a bias because only those individuals sufficiently healthy to attend work regularly (the "healthy worker effect") and those not unusually sensitive to the chemical are likely to be occupationally exposed. Finally, uncertainty arises from the quality of the key study from which the quantitative estimate is derived and the database. For cancer effects, the uncertainty associated with dose-response factors is mitigated by assuming the 95 percent upper bound for the slope factor. Another source of uncertainty in carcinogenic assessment is the method by which data from high doses in animal studies are extrapolated to the dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from animal data, is based on a nonthreshold assumption of carcinogenesis. Evidence suggests, however, that epigenetic carcinogens, as well as many genotoxic carcinogens, have a threshold below which they are noncarcinogenic. Therefore, the use of the linearized multistage model is conservative for chemicals that exhibit a threshold for carcinogenicity.

For noncancer effects, additional uncertainty factors may be applied in the derivation of the RfD to mitigate poor quality of the key study or gaps in the database. Additional uncertainty for noncancer effects arises from the use of an effect level in the estimation of an RfD, because this estimation is predicated on the assumption of a threshold less than which adverse effects are not expected. Therefore, an uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises in estimation of an RfD for chronic exposure from subchronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in the subchronic study. Uncertainty in the derivation of RfDs is mitigated by the use of uncertainty and modifying factors that normally range between 3 and 10. The resulting combination of uncertainty and modifying factors may reach 1,000 or more.

The derivation of dermal RfDs and CSFs from oral values may cause uncertainty. This is particularly the case when no gastrointestinal absorption rates are available in the literature or when only qualitative statements regarding absorption are available.

Uncertainty Associated with Evaluation of the Dermal Exposure Pathway

According to RAGS Part E (U.S. EPA, September 2001), risks for dermal absorption of chemicals in soil are to be quantitatively evaluated for arsenic, cadmium, chlordane, 2,4-dichlorophenoxyacetic acid, DDT, TCDD (and other dioxins), Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), pentachlorophenol, and semivolatile organic compounds only because of the limited information guidance available to evaluate dermal exposure to other constituents. Therefore, risks from dermal exposure to aluminum, iron, and manganese (the only COPC metals found in SWMU 2 solid media aside from arsenic) were not quantified in the risk assessment. Consequently, potential risks may be underestimated by excluding these constituents from the dermal risk assessment calculations.

The model for dermal exposure to soil and sediment assumes that only a very thin, constant thickness layer of soil is available for contaminant transfer to the stratum corneum and that a constant amount of contaminant, proportional to the soil concentration, will be absorbed per unit area of skin and per exposure event. However, adherence to skin varies with such factors as particle size, soil type, and organic carbon content. As estimated by U.S. EPA (U.S. EPA, September 2001), the absorbed dermal dose could vary by as much as a factor of 50 from the model estimates, even assuming that activity patterns lead to the exposure duration applied in the experimental trials used to develop absorption factors.

Experimental determination of absorption rates indicates that interspecies differences are considerable, which, along with other variabilities related to condition and age of skin, differences in lag time, and site of application effects, yields appreciable uncertainty in estimated dermal exposures using published chemical-specific permeation functions. In addition, literature data indicate a variation by as much as a factor of 300 in chemical absorption rates for skin in different anatomical areas of the body. It should also be noted that children generally have greater absorption rates than adults.

Uncertainty Associated with Evaluation of Arsenic

Although the more restrictive basis for evaluating risk associated with exposure to arsenic is to assume it is a carcinogen, carcinogenic effects are not the primary health effects expected to be manifested on exposure to arsenic. Scientific information indicates that humans are capable of metabolizing arsenic to expedite its elimination from the body (ATSDR, 1997). Its elimination from the body obviously mitigates

the possibility for arsenic to manifest carcinogenic effects. Therefore, evaluating arsenic as a noncarcinogen would be more appropriate. However, arsenic was conservatively evaluated as a carcinogen in this risk assessment. Consequently, risks for this chemical are probably overestimated to some degree.

Specifically, the body methylates the arsenic to form monomethyl arsenic and dimethyl arsenic. A limited capacity exists for the body to methylate arsenic, but this limit is generally reached when the body's intake of arsenic approximately exceeds 500 µg/day. This intake is far greater than the 1.2 µg/day intake associated with the amount of arsenic found in SWMU 2 soil, assuming a construction worker exposure scenario. Although some humans may be more sensitive to arsenic, in that they are "poor methylators," the average exposure concentration for the site is orders of magnitude less than the normal limit of metabolic saturation and is likely less than levels that would trigger responses even in sensitive individuals.

Use of Aluminum and Iron Toxicity Criteria

NCEA provisional RfDs are used to evaluate noncarcinogenic effects from exposure to aluminum and iron. The provisional RfDs for these chemicals are based on allowable intakes rather than adverse effect levels. Therefore, there is some degree of uncertainty associated with the use of the RfDs. Note that some U.S. EPA regions (e.g., Region 1) consider the use of the oral RfD for aluminum and iron inappropriate and recommend that these metals not be evaluated quantitatively in risk assessments.

6.6.4 Uncertainty in the Risk Characterization

Uncertainty in risk characterization results from assumptions made regarding additivity of effects from exposure to multiple COPCs from various exposure routes. High uncertainty exists when summing noncancer risks for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Even when compounds affect the same target organs, they may have different mechanisms of action or differ in their fate in the body, so additivity may not be an appropriate assumption. However, the assumption of additivity is considered because in most cases it represents a conservative estimate of risk.

Risks to any individual may also be overestimated by summing multiple assumed exposure pathway risks for any single receptor. Although every effort was made to develop reasonable scenarios, not all individual receptors may be exposed via all pathways considered.

Finally, the risk characterization does not consider antagonistic or synergistic effects. Little or no information is available to determine the potential for antagonism or synergism for the COPCs. Because chemical-specific interactions cannot be predicted, the likelihood for risks to be overpredicted or underpredicted cannot be defined, but the methodology that was used is based on current U.S. EPA guidance.

6.7 SUMMARY AND CONCLUSIONS

This section summarizes the results of the human health risk assessment performed for SWMU 2. A brief summary of the information contained in the human health risk assessment is provided. Table 6-20 contains a summary of conclusions and recommendations.

Dyes and dye-contaminated materials were desposited in open trenches at the site from 1952 to 1964. Materials reportedly included magnesium, boxes and rags contaminated with dyes, and about 60 open-topped drums of dye. The trenches were reportedly backfilled with surface soil in 1972 but were not permanently capped. A multilayered cap system was installed at the site in 1998 to minimize potential threats to human health and the environment by limiting the potential for migration of contaminants to ground water.

The baseline human health risk assessment for SWMU 2 was performed to characterize the potential risks to likely human receptors under current and potential future land use. Potential receptors under current land use are construction workers, maintenance workers, and adolescent trespassers. Potential receptors under future land use are recreational users and hypothetical residents (children and adults). Although future land use is likely to be the same as current land use, the potential future receptors were evaluated in the baseline human health risk assessment, primarily for decision-making purposes. The results of the RFI have indicated the need for land use controls at SWMU 2. The details of the land use control, such as the type of controls to be used and the schedule in which they will be implemented, have not yet been established. Therefore, a land use control program is not currently in place at NSWC Crane.

Potential risks associated with inhalation exposures are considered to be minimal. Inhalation of volatile emissions and fugitive dust was evaluated qualitatively via a comparison of site data with U.S. EPA generic SSLs for transfers from soil to air. Inhalation exposure was considered to be relatively insignificant because all detected soil concentrations were less than the SSLs. Inhalation of volatiles from surface water and sediment was also considered an insignificant exposure compared to ingestion and dermal exposures. The inhalation of volatiles from ground water, which could occur during showering, bathing, and other routine

household activities, was not evaluated for SWMU 2 because no volatile organics were identified as COPCs in ground water.

The list of COPCs for SWMU 2 includes the following:

- Surface soil - no COPCs were identified for surface soil.
- Surface/Subsurface soil - aluminum, arsenic, and iron.
- Ground water in Upper Pennsylvanian aquifer - no COPCs were identified for ground water in the Upper Pennsylvanian aquifer.
- Ground water in Lower Pennsylvanian aquifer - aluminum, arsenic, beryllium, cadmium, cobalt, nickel, and zinc.
- Surface Water - aluminum, arsenic, and iron.
- Sediment - manganese.

Dyes, which were the primary constituents of concern at SWMU 2, were not detected in surface soil, ground water, surface water, or sediment. Two dyes, Acid Orange 10 and Acid Yellow 23, were detected infrequently in subsurface soil samples at concentrations which were below levels of concern. The infrequent, low concentration occurrences of dyes were insufficient to warrant additional investigation of soils.

Quantitative estimates of noncarcinogenic and carcinogenic risks (HIs and ILCRs, respectively) were developed for potential human receptors. Cumulative HIs for the construction worker, maintenance worker, adult recreational user, and adolescent trespasser under the RME scenario are less than unity (1), indicating that adverse non-carcinogenic effects are not anticipated for these receptors under the defined exposure conditions. Cumulative HIs for the future adult and child resident exceed unity. Cumulative ILCRs for all receptors were less than or within U.S. EPA's target risk range.

The elevated HIs were attributable to exposure to aluminum, cadmium, cobalt, and nickel in ground water, primarily by ingestion. The HIs calculated for residential exposure to ground water are subject to the following sources of uncertainty:

- As discussed previously, the elevated HIs were associate with one ground water sample (02GWC11P301). If this sample was removed from the database, then all HIs would be within acceptable levels. This sample exhibited an unusually low pH (3.7) which is likely the reason metals

concentrations are elevated because acidic conditions increase the solubility of metals in water. The acidic conditions at this location are believed to be attributable to the geology of the site.

- The residential land use scenario assumes that ground water at the site is used as a source of domestic drinking water. However, it is unlikely that residences would ever be located at this site. Although enlisted and officer personnel reside at the facility under current conditions, the residential scenario is not applicable for these receptors because they do not and would not be expected to reside within the boundaries of SWMU 2. Because a cap exists at the site, land use control will prohibit future development of the site. Therefore, it is unlikely that ground water at the site would be used as a source of potable water in the future.

In conclusion, for SWMU 2, no significant potential human health risks are expected under current or future land use. All ILCRs were less or within EPA's target risk range of 10^{-4} to 10^{-6} and HIs were less than the acceptable level of 1 for exposures to all media with the exception of future residential exposure to ground water. HIs for future residential exposures to aluminum, cadmium, and nickel exceeded 1, but the concentrations of these metals are believed to be naturally occurring and not associated with SWMU 2.

TABLE 6-1

SCREENING CRITERIA USED IN SELECTION OF COPCS
SOIL/SEDIMENT
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

CAS Number	Chemical	EPA Region 9 PRG (1) Residential (mg/kg)	EPA Soil Screening Levels (2)		IDEM (3)	
			Soil to Air (mg/kg)	Soil to Ground Water (mg/kg)	Residential (mg/kg)	Soil to Ground Water (mg/kg)
Inorganics						
7429-90-5	Aluminum	76000 N	NA	NA	NA	NA
7440-36-0	Antimony	31 N	NA	0.3	140 N	5.4 N
7440-38-2	Arsenic	0.39 C	750 C	1	3.9 C	29 C
7440-39-3	Barium	5400 N	690000 N	82	23000 N	1600 N
7440-41-7	Beryllium	150 N	1300 C	3	680 N	63 C
7440-43-9	Cadmium	37 N	1800 C	0.4	12 N	7.5 C
7440-70-2	Calcium	NA	NA	NA	NA	NA
7440-47-3	Chromium	30(4) C	270(4) C	2	430 C	38 C
7440-48-4	Cobalt	4700 N	NA	NA	NA	NA
7440-50-8	Copper	2900 N	NA	NA	13000 N	580 N
7439-89-6	Iron	23000 N	NA	NA	NA	NA
7439-92-1	Lead	400	NA	NA	400	81
7439-95-4	Magnesium	NA	NA	NA	NA	NA
7439-96-5	Manganese	1800 N	NA	NA	NA	NA
7439-97-6	Mercury	23 N	10 N	0.1	55 N	2.1 N
7440-02-0	Nickel	1600 N	13000 C	7	6900 N	950 C
7440-09-7	Potassium	NA	NA	NA	NA	NA
7440-23-5	Sodium	NA	NA	NA	NA	NA
7782-49-2	Selenium	390 N	NA	0.3	1700 N	5.2 N
7440-62-2	Vanadium	550 N	NA	300	NA	NA
7440-66-6	Zinc	23000 N	NA	620	100000 N	14000 N
Dyes						
1936-15-8	ACID ORANGE 10	150 (5) N	NA	NA	NA	NA
1934-21-0	ACID YELLOW 23	NA	NA	NA	NA	NA

Notes:

1 U.S. EPA Region 9 Preliminary Remediation Goal Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 1.0)

2 U.S. EPA Soil Screening Level Guidance: Technical Background Document. May 1996. A dilution attenuation factor of 1 is used for the soil to ground water criteria.

3 Indiana Department of Environmental Management (IDEM), Risk Integrated System of Closure (RISC) residential closure levels for ground water, July 2001.

4 Value is for hexavalent chromium.

5 Calculated according to U.S. EPA Region 9 PRG methodology.

Definitions:

N/A = Not applicable.
C = Carcinogenic.
N = Non-carcinogenic.
PRG = Preliminary remediation goal.
SSL = Soil screening level.

TABLE 6-2

SCREENING CRITERIA USED IN SELECTION OF COPCS
GROUND WATER/SURFACE WATER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

CAS Number	Chemical	EPA Region 9 PRG (1) Tap Water (ug/L)	EPA MCL (2) (ug/L)	IDEM Ground Water Residential (3) (ug/L)
Inorganics				
7429-90-5	Aluminum	36000 N	50 to 200(4)	NA
7440-38-2	Arsenic	0.045 C	10	50
7440-39-3	Barium	2600 N	2000	2000
7440-39-3	Beryllium	73 N	4	4
7440-41-7	Cadmium	18 N	5	5
7440-70-2	Calcium	NA	NA	NA
7440-47-3	Chromium	110(5) N	100	100
7440-48-4	Cobalt	2200 N	NA	NA
7440-50-8	Copper	1400 N	1300(6)	1300
7439-89-6	Iron	11000 N	300(4)	NA
7439-92-1	Lead	NA	15(6)	15
7439-95-4	Magnesium	NA	NA	NA
7439-96-5	Manganese	880 N	50(4)	NA
7439-97-6	Mercury	11 N	2	2
7440-02-0	Nickel	730 N	NA	730
7440-09-7	Potassium	NA	NA	NA
7439-96-5	Selenium	180 N	50	50
7440-23-5	Sodium	NA	NA	NA
7440-62-2	Vanadium	260 N	NA	NA
7440-66-6	Zinc	11000 N	5000(4)	11000

Notes:

1 U.S. EPA Region 9 Preliminary Remediation Goal Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 1.0)

2 U.S. EPA Drinking Water Regulations and Health Advisories, Summer 2000.

3 Indiana Department of Environmental Management (IDEM), Risk Integrated System of Closure (RISC) residential closure levels for ground water, July 2001.

4 Secondary MCL.

5 Value is for hexavalent chromium.

6 Action level (U.S. EPA, Summer 2000).

TABLE 6-3

CHEMICALS RETAINED AS COPCs
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical	Surface Soil			Subsurface Soil			Ground Water		Surface Water	Sediment
	Direct Contact	Soil to Air	Soil to Ground Water	Direct Contact	Soil to Air	Soil to Ground Water	Upper Pennsylvanian	Lower Pennsylvanian		
Inorganics										
Aluminum				X				X	X	
Arsenic				X		X		X	X	
Beryllium								X		
Cadmium								X		
Chromium						X				
Cobalt								X		
Iron				X					X	
Manganese										X
Nickel						X		X		
Zinc								X		

Notes
X - Indicates chemical was retained as a COPC.

TABLE 6-4

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN - DIRECT CONTACT WITH SURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects(2)	Concentration Used for Screening(3)	Site Above Background? (4)	EPA Region 9 PRG-Residential (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection(6)
	Inorganics															
7429-90-5	ALUMINUM	7750		12500		MG/KG	02SS200001	13/13	NA	12500	No	7600 N	NA	NA	No	BKG
7440-36-0	ANTIMONY	0.45		0.5		MG/KG	02SS090002	4/13	0.4 - 0.48	0.5	No	3.1 N	140	IDEM	No	BSL, BKG
7440-38-2	ARSENIC	2.6		8.4	J	MG/KG	02SS200001	13/13	NA	8.4	No	0.39 C	3.9	IDEM	No	BKG
7440-39-3	BARIUM	55		209		MG/KG	02SS160001	13/13	NA	209	No	540 N	23000	IDEM	No	BSL, BKG
7440-41-7	BERYLLIUM	0.56		0.85		MG/KG	02SS100002	3/13	0.49 - 2.3	0.85	Yes	15 N	680	IDEM	No	BSL
7440-43-9	CADMIUM	0.43	J	0.62		MG/KG	02SS160001	4/13	0.4 - 0.49	0.62	No	3.7 N	12	IDEM	No	BSL, BKG
7440-70-2	CALCIUM	842		15400	J	MG/KG	02SS200001	12/13	421	15400	Yes	NA	NA	NA	No	NUT
7440-47-3	CHROMIUM	9.9		40.8		MG/KG	02SS190001	13/13	NA	40.8	No	30 (7) C	430	IDEM	No	BKG
7440-48-4	COBALT	3.9		19		MG/KG	02SS160001	13/13	NA	19	No	470 N	NA	NA	No	BSL, BKG
7440-50-8	COPPER	8		11.8		MG/KG	02SS200001	13/13	NA	11.8	Yes	290 N	13000	IDEM	No	BSL
7439-89-6	IRON	11400		23500		MG/KG	02SS110001	13/13	NA	23500	No	2300 N	NA	NA	No	BKG
7439-92-1	LEAD	9.3		184	J	MG/KG	02SS190001	13/13	NA	184	No	400	400	IDEM	No	BSL, BKG
7439-95-4	MAGNESIUM	1080		3310		MG/KG	02SS050001	13/13	NA	3310	Yes	NA	NA	NA	No	NUT
7439-96-5	MANGANESE	124		1800		MG/KG	02SS160001	13/13	NA	1800	No	180 N	NA	NA	No	BKG
7439-97-6	MERCURY	0.02	J	0.05	J	MG/KG	02SS200001, 02SS160001, 02SS190001	12/13	0.02	0.05	No	2.3 N	55	IDEM	No	BSL, BKG
7440-02-0	NICKEL	6.6		15		MG/KG	02SS160001	13/13	NA	15	No	160 N	6900	IDEM	No	BSL, BKG
7440-09-7	POTASSIUM	547	J	892	J	MG/KG	02SS190001	12/13	421	892	No	NA	NA	NA	No	NUT, BKG
7782-49-2	SELENIUM	0.52		0.7		MG/KG	02SS100002	6/13	0.4 - 0.45	0.7	No	39 N	1700	IDEM	No	BSL, BKG
7440-62-2	VANADIUM	18.6	J	25.9	J	MG/KG	02SS040001	13/13	NA	25.9	No	55 N	NA	NA	No	BSL, BKG
7440-66-6	ZINC	15.9	J	50.2	J	MG/KG	02SS190001	13/13	NA	50.2	No	2300 N	100000	IDEM	No	BSL, BKG

Notes:
1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - To determine whether metal concentrations were within background levels, soil concentrations were compared to background data presented in the Basewide Background Soil Investigation Report (TtNUS, Inc., January 2001) by means of the Wilcoxon Rank Sum Test. If the Wilcoxon Test determined that a constituent concentration was not significantly different from background, that chemical was not selected as a COPC.
5 - U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 0.1).
6 - Rationale Codes
Selection Reason: Above Screening Levels (ASL)
No Toxicity Information (NTX)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)
Below Background Value (BKG)
7 - Value is for hexavalent chromium.
Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Definitions:
NA = Not applicable.
SQL = Sample quantitation limit.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
C = Carcinogenic.
N = Noncarcinogenic.
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential levels for direct contact with soil (IDEM, July 2001).

Associated Samples

02SS030001	02SS080001	02SS150001	02SS180001
02SS030002	02SS080002	02SS150002	02SS180002
02SS040001	02SS090002	02SS160001	02SS190001
02SS040002	02SS100002	02SS160002	02SS190002
02SS050001	02SS110001	02SS170001	02SS200001
02SS050002	02SS110002	02SS170002	02SS200002

TABLE 6-5

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN - MIGRATION FROM SURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Surface Soil
Exposure Medium: Surface Soil
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects(2)	Concentration Used for Screening(3)	Site Above Background? (4)	USEPA Generic SSL for Soil to Air (5)	USEPA Generic SSL for Migration to Ground Water (6)	IDEM SSL for Migration to Ground Water (6)	COPC Flag	Rationale for Contaminant Deletion or Selection(7)
	Inorganics															
7429-90-5	ALUMINUM	7750		12500		MG/KG	02SS200001	13/13	NA	12500	No	NA	NA	NA	No	BKG
7440-36-0	ANTIMONY	0.45		0.5		MG/KG	02SS090002	4/13	0.4 - 0.48	0.5	No	NA	0.3	5.4	No	BKG
7440-38-2	ARSENIC	2.6		8.4	J	MG/KG	02SS200001	13/13	NA	8.4	No	750	1	29	No	BKG
7440-39-3	BARIUM	55		209		MG/KG	02SS160001	13/13	NA	209	No	690000	82	1600	No	BKG
7440-41-7	BERYLLIUM	0.56		0.85		MG/KG	02SS100002	3/13	0.49 - 2.3	0.85	Yes	1300	3	63	No	BSL, BKG
7440-43-9	CADMIUM	0.43	J	0.62		MG/KG	02SS160001	4/13	0.4 - 0.49	0.62	No	1800	0.4	7.5	No	BKG
7440-70-2	CALCIUM	842		15400	J	MG/KG	02SS200001	12/13	421	15400	Yes	NA	NA	NA	No	NUT
7440-47-3	CHROMIUM	9.9		40.8		MG/KG	02SS190001	13/13	NA	40.8	No	270	2	38	No	BKG
7440-48-4	COBALT	3.9		19		MG/KG	02SS160001	13/13	NA	19	No	NA	NA	NA	No	BKG
7440-50-8	COPPER	8		11.8		MG/KG	02SS200001	13/13	NA	11.8	Yes	NA	NA	580	No	BSL
7439-89-6	IRON	11400		23500		MG/KG	02SS110001	13/13	NA	23500	No	NA	NA	NA	No	BKG
7439-92-1	LEAD	9.3		184	J	MG/KG	02SS190001	13/13	NA	184	No	NA	NA	81	No	BKG
7439-95-4	MAGNESIUM	1080		3310		MG/KG	02SS050001	13/13	NA	3310	Yes	NA	NA	NA	No	NUT
7439-96-5	MANGANESE	124		1800		MG/KG	02SS160001	13/13	NA	1800	No	NA	NA	NA	No	BKG
7439-97-6	MERCURY	0.02	J	0.05	J	MG/KG	02SS200001, 02SS160001, 02SS190001	12/13	0.02	0.05	No	10	0.1	2.1	No	BSL, BKG
7440-02-0	NICKEL	6.6		15		MG/KG	02SS160001	13/13	NA	15	No	13000	7	950	No	BKG
7440-09-7	POTASSIUM	547	J	892	J	MG/KG	02SS190001	12/13	421	892	No	NA	NA	NA	No	NUT, BKG
7782-49-2	SELENIUM	0.52		0.7		MG/KG	02SS100002	6/13	0.4 - 0.45	0.7	No	NA	0.3	5.2	No	BKG
7440-62-2	VANADIUM	18.6	J	25.9	J	MG/KG	02SS040001	13/13	NA	25.9	No	NA	300	NA	No	BSL, BKG
7440-66-6	ZINC	15.9	J	50.2	J	MG/KG	02SS190001	13/13	NA	50.2	No	NA	620	14000	No	BSL, BKG

Notes:
1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - To determine whether metal concentrations were within background levels, soil concentrations were compared to background data presented in the Basewide Background Soil Investigation Report (TtNUS, Inc., January 2001) by means of the Wilcoxon Rank Sum Test. If the Wilcoxon Test determined that a constituent concentration was not significantly different from background, that chemical was not selected as a COPC.
5 - Soil Screening Guidance: Technical Background Document. (U.S. EPA, May 1996). The migration to ground water value represents a dilution attenuation factor (DAF) of 1.
6 - Residential levels for migration from soil to groundwater (IDEM, July 2001).
7 - Rationale Codes
Selection Reason: Above Screening Levels (ASL)
No Toxicity Information (NTX)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)
Below Background Value (BKG)

Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Definitions:
NA = Not applicable.
SQL = Sample quantitation limit.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential levels for migration from soil to ground water (IDEM, July 2001).

Associated Samples

02SS030001	02SS080001	02SS150001	02SS180001
02SS030002	02SS080002	02SS150002	02SS180002
02SS040001	02SS090002	02SS160001	02SS190001
02SS040002	02SS100002	02SS160002	02SS190002
02SS050001	02SS110001	02SS170001	02SS200001
02SS050002	02SS110002	02SS170002	02SS200002

TABLE 6-6

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN - DIRECT CONTACT WITH SUBSURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects(2)	Concentration Used for Screening(3)	Site Above Background? (4)	EPA Region 9 PRG-Residential (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection(6)
	Inorganics															
7429-90-5	ALUMINUM	1570		11300		MG/KG	02SB120507	20/20	NA	11300	Yes	7600 N	NA	NA	Yes	ASL
7440-36-0	ANTIMONY	0.93		0.93		MG/KG	02SB040305	1/20	0.39 - 0.46	0.93	No	3.1 N	140	IDEM	No	BSL, BKG
7440-38-2	ARSENIC	0.4		7.5	J	MG/KG	02SB040305	16/20	0.21 - 1.6	7.5	Yes	0.39 C	3.9	IDEM	Yes	ASL
7440-39-3	BARIUM	11.4		73.8	J	MG/KG	02SB040305	20/20	NA	73.8	Yes	540 N	23000	IDEM	No	BSL
7440-70-2	CALCIUM	457		1030	J	MG/KG	02SB040305	5/20	391 - 454	1030	Yes	NA	NA	NA	No	NUT
7440-47-3	CHROMIUM	3.4		19.1		MG/KG	02SB120507	20/20	NA	19.1	Yes	30 (7) C	430 (7)	IDEM	No	BSL
7440-48-4	COBALT	0.59		17.7		MG/KG	02SB080810	13/20	0.42 - 2.3	17.7	Yes	470 N	NA	NA	No	BSL
7440-50-8	COPPER	2		12.6		MG/KG	02SB040305	20/20	NA	12.6	Yes	290 N	13000	IDEM	No	BSL
7439-89-6	IRON	714		24100		MG/KG	02SB120507	20/20	NA	24100	Yes	2300 N	NA	NA	Yes	ASL
7439-92-1	LEAD	4.4	J	13.6	J	MG/KG	02SB040305	20/20	NA	13.6	No	400	400	IDEM	No	BSL, BKG
7439-95-4	MAGNESIUM	423		1500		MG/KG	02SB040305	12/20	391 - 421	1500	No	NA	NA	NA	No	NUT, BKG
7439-96-5	MANGANESE	1.9		798		MG/KG	02SB040305	20/20	NA	798	No	180 N	NA	NA	No	BKG
7439-97-6	MERCURY	0.03	J	0.03	J	MG/KG	02SB040305	1/20	0.02	0.03	No	2.3 N	55	IDEM	No	BSL, BKG
7440-02-0	NICKEL	1.1		25.3		MG/KG	02SB080810	20/20	NA	25.3	Yes	160 N	6900	IDEM	No	BSL
7440-09-7	POTASSIUM	397		630	J	MG/KG	02SB040305	6/20	391 - 497	630	Yes	NA	NA	NA	No	NUT
7440-62-2	VANADIUM	6.6		28.5		MG/KG	02SB120507	17/20	5.1 - 7.3	28.5	Yes	55 N	NA	NA	No	BSL
7440-66-6	ZINC	2.5	J	57.8	J	MG/KG	02SB010911	19/20	2.1	57.8	Yes	2300 N	100000	IDEM	No	BSL
	Dyes															
1936-15-8	ACID ORANGE 10	3.85	J	3.85	J	MG/KG	02SB010911	1/20	15.1	3.85	Yes	15 N	NA	NA	No	BSL
1934-21-0	ACID YELLOW 23	2.85		11.5	J	MG/KG	02SB040305	6/20	15.1	11.5	Yes	NA	NA	NA	No	BSL
	Miscellaneous Parameters															
	CATION EXCHANGE CAPACITY	2.30	J	19.0	J	MEQ/1	02SB120507	10/10	NA	19.0	NA	NA	NA	NA	No	NTX
	pH	4.90	J	6.30	J	S.U.	02SB140709	10/10	NA	6.30	NA	NA	NA	NA	No	NTX
	TOTAL ORGANIC CARBON	1000		1900		MG/KG	02SB020810	10/10	NA	1900	NA	NA	NA	NA	No	NTX

Notes:
1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - To determine whether metal concentrations were within background levels, soil concentrations were compared to background data presented in the Basewide Background Soil Investigation Report (TINUS, Inc., January 2001) by means of the Wilcoxon Rank Sum Test. If the Wilcoxon Test determined that a constituent concentration was not significantly different from background, that chemical was not selected as a COPC.
5 - U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 0.1)
6 - Rationale Codes
Selection Reason: Above Screening Levels (ASL)
No Toxicity Information (NTX)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)
Below Background Value (BKG)
7 - Value is for hexavalent chromium.
Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Definitions:
NA = Not applicable.
SQL = Sample quantitation limit.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
C = Carcinogenic.
N = Noncarcinogenic.
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential levels for direct contact with soil (IDEM, July 2001).

Associated Samples

02SB010911	02SB060709	02SB110406	02SB160507
02SB020810	02SB070709	02SB120507	02SB170608
02SB030709	02SB080810	02SB130507	02SB180507
02SB040305	02SB090709	02SB140709	02SB190406
02SB050809	02SB100810	02SB150608	02SB200608

TABLE 6-7

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN - MIGRATION FROM SUBSURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Subsurface Soil
Exposure Medium: Subsurface Soil
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects(2)	Concentration Used for Screening(3)	Site Above Background? (4)	USEPA Generic SSL for Soil to Air (5)	USEPA Generic SSL for Migration to Ground water (5)	IDEM SSL for Migration to Ground water (6)	COPC Flag	Rationale for Contaminant Deletion or Selection(7)
	Inorganics															
7429-90-5	ALUMINUM	1570		11300		MG/KG	02SB120507	20/20	NA	11300	Yes	NA	NA	NA	No	NTX
7440-36-0	ANTIMONY	0.93		0.93		MG/KG	02SB040305	1/20	0.39 - 0.46	0.93	No	NA	0.3	5.4	No	BKG
7440-38-2	ARSENIC	0.4		7.5	J	MG/KG	02SB040305	16/20	0.21 - 1.6	7.5	Yes	750	1	29	Yes	ASL
7440-39-3	BARIUM	11.4		73.8	J	MG/KG	02SB040305	20/20	NA	73.8	Yes	690000	82	1600	No	BSL
7440-70-2	CALCIUM	457		1030	J	MG/KG	02SB040305	5/20	391 - 454	1030	Yes	NA	NA	NA	No	NUT
7440-47-3	CHROMIUM	3.4		19.1		MG/KG	02SB120507	20/20	NA	19.1	Yes	270	2	38	Yes	ASL
7440-48-4	COBALT	0.59		17.7		MG/KG	02SB080810	13/20	0.42 - 2.3	17.7	Yes	NA	NA	NA	No	NTX
7440-50-8	COPPER	2		12.6		MG/KG	02SB040305	20/20	NA	12.6	Yes	NA	NA	580	No	BSL
7439-89-6	IRON	714		24100		MG/KG	02SB120507	20/20	NA	24100	Yes	NA	NA	NA	No	NTX
7439-92-1	LEAD	4.4	J	13.6	J	MG/KG	02SB040305	20/20	NA	13.6	No	NA	NA	81	No	BSL, BKG
7439-95-4	MAGNESIUM	423		1500		MG/KG	02SB040305	12/20	391 - 421	1500	No	NA	NA	NA	No	NUT, BKG
7439-96-5	MANGANESE	1.9		798		MG/KG	02SB040305	20/20	NA	798	No	NA	NA	NA	No	BKG
7439-97-6	MERCURY	0.03	J	0.03	J	MG/KG	02SB040305	1/20	0.02	0.03	No	10	0.1	2.1	No	BSL, BKG
7440-02-0	NICKEL	1.1		25.3		MG/KG	02SB080810	20/20	NA	25.3	Yes	13000	7	950	Yes	ASL
7440-09-7	POTASSIUM	397		630	J	MG/KG	02SB040305	6/20	391 - 497	630	Yes	NA	NA	NA	No	NUT
7440-62-2	VANADIUM	6.6		28.5		MG/KG	02SB120507	17/20	5.1 - 7.3	28.5	Yes	NA	300	NA	No	BSL
7440-66-6	ZINC	2.5	J	57.8	J	MG/KG	02SB010911	19/20	2.1	57.8	Yes	NA	620	14000	No	BSL
	Dyes															
1936-15-8	ACID ORANGE 10	3.85	J	3.85	J	MG/KG	02SB010911	1/20	15.1	3.85	Yes	NA	NA	NA	No	BSL
1934-21-0	ACID YELLOW 23	2.85		11.5	J	MG/KG	02SB040305	6/20	15.1	11.5	Yes	NA	NA	NA	No	BSL
	Miscellaneous Parameters															
	CATION EXCHANGE CAPACITY	2.30	J	19.0	J	MEQ/1	02SB120507	10/10	NA	19.0	NA	NA	NA	NA	No	NTX
	pH	4.90	J	6.30	J	S.U.	02SB140709	10/10	NA	6.30	NA	NA	NA	NA	No	NTX
	TOTAL ORGANIC CARBON	1000		1900		MG/KG	02SB020810	10/10	NA	1900	NA	NA	NA	NA	No	NTX

Notes:
1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - To determine whether metal concentrations were within background levels, soil concentrations were compared to background data presented in the Basewide Background Soil Investigation Report (TtNUS, Inc., January 2001) by means of the Wilcoxon Rank Sum Test. If the Wilcoxon Test determined that a constituent concentration was not significantly different from background, that chemical was not selected as a COPC.
5 - Soil Screening Guidance: Technical Background Document. (U.S. EPA, May 1996). The migration to ground water value represents a dilution attenuation factor (DAF) of 1.
6 - Residential levels for migration from soil to groundwater (IDEM, July 2001).
7 - Rationale Codes
Selection Reason: Above Screening Levels (ASL)
No Toxicity Information (NTX)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)
Below Background Value (BKG)

Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Definitions:
NA = Not applicable.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential levels for migration from soil to ground water (IDEM, July 2001).

Associated Samples

02SB010911	02SB060709	02SB110406	02SB160507
02SB020810	02SB070709	02SB120507	02SB170608
02SB030709	02SB080810	02SB130507	02SB180507
02SB040305	02SB090709	02SB140709	02SB190406
02SB050809	02SB100810	02SB150608	02SB200608

TABLE 6-8

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN IN UPPER PENNSYLVANIAN AQUIFER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Ground Water
Exposure Medium: Upper Pennsylvania Aquifer
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits (2)	Concentration Used for Screening (3)	Site Above Background? (4)	Screening Toxicity Value (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection (6)
	Inorganics															
7440-36-0	ARSENIC	0.63		1.2		UG/L	02GW0101	2/2	NA	1.2	No	0.045 C	10 50	FED-MCL IDEM	No	BKG
7440-38-2	BARIUM	10.6		13.6		UG/L	02GW0101	2/2	NA	13.6	No	260 N	2000 2000	FED-MCL IDEM	No	BSL, BKG
7440-41-7	CADMIUM	1.3		1.3		UG/L	02GWC12P301	1/2	1	1.3	Yes	1.8 N	5 5	FED-MCL IDEM	No	BSL
7440-43-9	CALCIUM	142000		166000		UG/L	02GWC12P301	2/2	NA	166000	No	NA	NA NA	NA NA	No	NUT, BKG
7440-70-2	COBALT	6.5		6.5		UG/L	02GWC12P301	1/2	3	6.5	No	220 N	NA NA	NA IDEM	No	BSL, BKG
7440-48-4	IRON	440	J	465	J	UG/L	02GW0101	2/2	NA	465	No	1100 N	300 NA	FED-SMCL NA	No	BKG
57-12-5	MAGNESIUM	83100		121000		UG/L	02GWC12P301	2/2	NA	121000	No	NA	NA NA	NA NA	No	NUT
7439-89-6	MANGANESE	35		440		UG/L	02GWC12P301	2/2	NA	440	No	88 N	50 NA	FED-SMCL NA	No	BKG
7439-92-1	NICKEL	16		16		UG/L	02GWC12P301	1/2	10	16	No	73 N	NA 730	NA IDEM	No	BSL, BKG
7439-95-4	POTASSIUM	9360		9360		UG/L	02GWC12P301	1/2	5000	9360	No	NA	NA NA	NA NA	No	NUT, BKG
7439-96-5	SELENIUM	3.6	J	15.7	J	UG/L	02GW0101	2/2	NA	15.7	Yes	18 N	50 50	FED-MCL IDEM	No	BSL
7440-02-0	SODIUM	141000		213000		UG/L	02GW0101	2/2	NA	213000	Yes	NA	NA NA	NA NA	No	NUT
7440-09-7	ZINC	10.9	J	53	J	UG/L	02GWC12P301	2/2	NA	53	No	1100 N	5000 11000	FED-SMCL IDEM	No	BSL, BKG
	Miscellaneous Parameters															
	CHLORIDE	100		150		MG/L	02GW0101	2/2	NA	150	NA	NA	NA	NA	No	NTX
	SULFATE	740		970		MG/L	02GWC12P301	2/2	NA	970	NA	NA	NA	NA	No	NTX
	TOTAL ORGANIC CARBON	3.2		5		MG/L	02GWC12P301	2/2	NA	5	NA	NA	NA	NA	No	NTX
	TOTAL SUSPENDED SOLIDS	3	J	7	J	MG/L	02GW0101	2/2	NA	7	NA	NA	NA	NA	No	NTX

Notes:

1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.

2 - Values presented are sample-specific quantitation limits.

3 - The maximum detected concentration is used for screening purposes.

4 - To determine whether metal concentrations were within background levels, ground water concentrations were statistically compared to concentrations in upgradient ground water samples. If the site groundwater concentrations were less than the upgradient concentrations, that metal was not selected as a COPC. See Section 4.

5 - U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 0.1)

6 - Rationale Codes

Selection Reason:
- Above Screening Levels (ASL)
- No Toxicity Information (NTX)

Deletion Reason:
- Essential Nutrient (NUT)
- Below Screening Level (BSL)
- Below Background Value (BKG)

Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Associated Samples

02GW0101 02GWC12P301

Definitions:

NA = Not applicable.
SQL = Sample quantitation limit.
COPC = Chemical of pocential Concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
C = Carcinogenic.
N = Non-carcinogenic.
FED-MCL = Federal maximum contaminant level (U.S. EPA, Summer 2000).
SMCL = Federal secondary maximum contaminant level based on aesthetic FED-water quality (U.S. EPA, Summer 2000).
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential closure levels for ground water (IDEM, July 2001).

TABLE 6-9

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN IN LOWER PENNSYLVANIAN AQUIFER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Ground Water
Exposure Medium: Lower Pennsylvania Aquifer
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits (2)	Concentration Used for Screening (3)	Site Above Background? (4)	Screening Toxicity Value (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection (6)
	Inorganics															
7429-90-5	ALUMINUM	23300		23300		UG/L	02GWC11P301	1/4	200	23300	Yes	3600 N	50 to 200 NA	FED-SMCL NA	Yes	ASL
7440-36-0	ARSENIC	0.85		1.6		UG/L	02GW0701	4/4	NA	1.6	Yes	0.045 C	10 50	FED-MCL IDEM	Yes	ASL
7440-38-2	BARIUM	9		38.8		UG/L	02GW0201	4/4	NA	38.8	No	260 N	2000 2000	FED-MCL IDEM	No	BSL, BKG
7440-39-3	BERYLLIUM	4.7		4.7		UG/L	02GWC11P301	1/4	1	4.7	Yes	7.3 N	4 4	FED-MCL IDEM	Yes	ASL
7440-41-7	CADMIUM	1.3		16.1		UG/L	02GWC11P301	2/4	1	16.1	Yes	1.8 N	5 5	FED-MCL IDEM	Yes	ASL
7440-43-9	CALCIUM	131000		412000		UG/L	02GW0701	4/4	NA	412000	No	NA	NA NA	NA NA	No	NUT, BKG
7440-70-2	COBALT	6.4		445		UG/L	02GWC11P301	2/4	3	445	Yes	220 N	NA NA	NA NA	Yes	ASL
7440-47-3	COPPER	21.5		21.5		UG/L	02GWC11P301	1/4	2	21.5	No	140 N	1300 (7) 1300	FED-MCL IDEM	No	BSL, BKG
7440-48-4	IRON	684	J	3350	J	UG/L	02GWC11P301	4/4	NA	3350	No	1100 N	300 NA	FED-SMCL NA	No	BKG
7440-50-8	LEAD	4.8		4.8		UG/L	02GWC11P301	1/4	1	4.8	Yes	NA	15 (7) 15	FED-MCL IDEM	No	BSL
57-12-5	MAGNESIUM	55600		152000		UG/L	02GW0701	4/4	NA	152000	No	NA	NA NA	NA NA	No	NUT, BKG
7439-89-6	MANGANESE	25.3		1720		UG/L	02GWC11P301	4/4	NA	1720	No	88 N	50 NA	FED-SMCL NA	No	BKG
7439-92-1	NICKEL	28		868		UG/L	02GWC11P301	4/4	NA	868	Yes	73 N	NA 730	NA IDEM	Yes	ASL
7439-95-4	POTASSIUM	5050		5050		UG/L	02GW0801	1/4	5000	5050	No	NA	NA NA	NA NA	No	NUT, BKG
7439-96-5	SELENIUM	2.4	J	11.4	J	UG/L	02GW0701	4/4	NA	11.4	No	18 N	50 50	FED-MCL IDEM	No	BSL, BKG
7440-02-0	SODIUM	33600		70200		UG/L	02GW0701	4/4	NA	70200	No	NA	NA NA	NA NA	No	NUT, BKG
7440-09-7	ZINC	10.5	J	2280	J	UG/L	02GWC11P301	4/4	NA	2280	Yes	1100 N	5000 11000	FED-SMCL IDEM	Yes	ASL
	Miscellaneous Parameters															
	CHLORIDE	25		170		MG/L	02GW0701	4/4	NA	170	NA	NA	NA	NA	No	NTX
	SULFATE	830		1300		MG/L	02GW0701	4/4	NA	1300	NA	NA	NA	NA	No	NTX
	TOTAL ORGANIC CARBON	1.3		2.2		MG/L	02GW0801	3/4	NA	2.2	NA	NA	NA	NA	No	NTX
	TOTAL SUSPENDED SOLIDS	4	J	4	J	MG/L	02GWC11P301	1/4	NA	4	NA	NA	NA	NA	No	NTX

TABLE 6-9

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN IN LOWER PENNSYLVANIAN AQUIFER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Ground Water
Exposure Medium: Lower Pennsylvania Aquifer
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits (2)	Concentration Used for Screening (3)	Site Above Background? (4)	Screening Toxicity Value (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection (6)

Notes:

1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.

2 - Values presented are sample-specific quantitation limits.

3 - The maximum detected concentration is used for screening purposes.

4 - To determine whether metal concentrations were within background levels, ground water concentrations were statistically compared to concentrations in upgradient ground water samples. If the site groundwater concentrations were less than the upgradient concentrations, that metal was not selected as a COPC. See Section 4.

5 - U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 0.1)

6 - Rationale Codes

Selection Reason:
- Above Screening Levels (ASL)
- No Toxicity Information (NTX)

Deletion Reason:
- Essential Nutrient (NUT)
- Below Screening Level (BSL)
- Below Background Value (BKG)

7 - Action level (U.S. EPA, Summer 2000).

Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Associated Samples

02GW0201
02GW0701
02GW0801
02GWC11P301

Definitions:

NA = Not applicable.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
C = Carcinogenic.
N = Non-carcinogenic.
FED-MCL = Federal maximum contaminant level (U.S. EPA, Summer 2000).
FED-SMCL = Federal secondary maximum contaminant level based on aesthetic water quality (U.S. EPA, Summer 2000).
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential closure levels for groundwater (IDEM, July 2001).

TABLE 6-10

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN IN SURFACE WATER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Surface Water
Exposure Medium: Surface Water
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits (2)	Concentration Used for Screening (3)	Site Above Background? (4)	Screening Toxicity Value (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection (6)
	Inorganics, Unfiltered															
7429-90-5	ALUMINUM	523		523		UG/L	02SW0701	1/1	NA	523	Yes	3600 N	50 to 200 NA	FED-SMCL NA	Yes	ASL
7440-36-0	ARSENIC	0.41		0.41		UG/L	02SW0701	1/1	NA	0.41	Yes	0.045 C	10 50	FED-MCL IDEM	Yes	ASL
7440-38-2	BARIUM	78		78		UG/L	02SW0701	1/1	NA	78	Yes	260 N	2000 2000	FED-MCL IDEM	No	BSL
7440-43-9	CALCIUM	49700		49700		UG/L	02SW0701	1/1	NA	49700	Yes	NA	NA NA	NA NA	No	NUT
7440-48-4	IRON	874	J	874	J	UG/L	02SW0701	1/1	NA	874	Yes	1100 N	300 NA	FED-SMCL NA	Yes	ASL
57-12-5	MAGNESIUM	11700		11700		UG/L	02SW0701	1/1	NA	11700	Yes	NA	NA NA	NA NA	No	NUT
7439-89-6	MANGANESE	43.4		43.4		UG/L	02SW0701	1/1	NA	43.4	No	88 N	50 NA	FED-SMCL NA	No	BSL, BKG
7440-02-0	SODIUM	11500		11500		UG/L	02SW0701	1/1	NA	11500	Yes	NA	NA NA	NA NA	No	NUT
	Inorganics, Filtered															
7440-39-3	BARIUM, FILTERED	74.1		74.1		UG/L	02SW0701-F	1/1	NA	74.1	Yes	260 N	2000 2000	FED-MCL IDEM	No	ASL
7440-70-2	CALCIUM, FILTERED	51500		51500		UG/L	02SW0701-F	1/1	NA	51500	Yes	NA	NA NA	NA NA	No	NUT
7439-89-6	IRON, FILTERED	140	J	140	J	UG/L	02SW0701-F	1/1	NA	140	Yes	1100 N	300 NA	FED-SMCL NA	No	BSL
7439-95-4	MAGNESIUM, FILTERED	12400		12400		UG/L	02SW0701-F	1/1	NA	12400	Yes	NA	NA NA	NA NA	No	NUT
7440-23-5	SODIUM, FILTERED	12200		12200		UG/L	02SW0701-F	1/1	NA	12200	Yes	NA	NA NA	NA NA	No	NUT
	Miscellaneous Parameters															
	HARDNESS	170		170		MG/L	02SW0701	1/1	NA	NA	NA	NA	NA	NA	No	NTX
	TOTAL ORGANIC CARBON	3.7		3.7		MG/L	02SW0701	1/1	NA	NA	NA	NA	NA	NA	No	NTX
	TOTAL SUSPENDED SOLIDS	13	J	13	J	MG/L	02SW0701	1/1	NA	NA	NA	NA	NA	NA	No	NTX

Notes:
1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - To determine whether metal concentrations were within background levels, surface water concentrations were statistically compared to concentrations in upgradient surface water samples. If the site surface water concentrations were less than the upgradient concentrations, that metal was not selected as a COPC. See Section 4.
5 - U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 0.1)
6 - Rationale Codes
Selection Reason: Above Screening Levels (ASL)
No Toxicity Information (NTX)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)
Below Background Value (BKG)

Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Associated Samples
02SW0701
02SW0701-F

Definitions:
NA = Not applicable.
SQL = Sample quantitation limit.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
C = Carcinogenic.
N = Non-carcinogenic.
FED-MCL = Federal maximum contaminant level (U.S. EPA, Summer 2000).
FED-SMCL = Federal secondary maximum contaminant level based on aesthetic water quality (U.S. EPA, Summer 2000).
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential closure levels for groundwater (IDEM, July 2001).

TABLE 6-11

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN IN SEDIMENTS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe: Current/Future
Medium: Sediment
Exposure Medium: Sediment
Exposure Point: SWMU 2 - Dye Burial Grounds

CAS Number	Chemical	Minimum Concentration (1)	Minimum Qualifier	Maximum Concentration (1)	Maximum Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Nondetects(2)	Concentration Used for Screening(3)	Site Above Background? (4)	EPA Region 9 PRG-Residential (5)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Contaminant Deletion or Selection(6)
	Inorganics															
7429-90-5	ALUMINUM	4580		10300		MG/KG	02SD010006	7/7	NA	10300	No	7600 N	NA	NA	No	BKG
7440-36-0	ANTIMONY	0.74		0.74		MG/KG	02SD030006, 02SD010006	2/7	0.48 - 0.69	0.74	No	3.1 N	140	IDEM	No	BSL, BKG
7440-38-2	ARSENIC	5.6		11	J	MG/KG	02SD010006	7/7	NA	11	No	0.39 C	3.9	IDEM	No	BKG
7440-39-3	BARIUM	87.6		169		MG/KG	02SD040006	7/7	NA	169	Yes	540 N	23000	IDEM	No	BSL
7440-41-7	BERYLLIUM	0.54		1.2		MG/KG	02SD010006	2/7	2.3 - 3.4	1.2	No	15 N	680	IDEM	No	BSL, BKG
7440-43-9	CADMIUM	0.55		0.69		MG/KG	02SD040006	4/7	0.46 - 0.52	0.69	No	3.7 N	12	IDEM	No	BSL, BKG
7440-70-2	CALCIUM	873		2550		MG/KG	02SD070006	7/7	NA	2550	No	NA	NA	NA	No	NUT, BKG
7440-47-3	CHROMIUM	11.3		30		MG/KG	02SD050006	7/7	NA	30	No	30 (7) C	430 (7)	IDEM	No	BSL, BKG
7440-48-4	COBALT	8.4		29.5		MG/KG	02SD050006	7/7	NA	29.5	No	470 N	NA	NA	No	BSL, BKG
7440-50-8	COPPER	8.4		9.6		MG/KG	02SD070006	7/7	NA	9.6	No	290 N	13000	IDEM	No	BSL, BKG
7439-89-6	IRON	14200		38700		MG/KG	02SD050006	7/7	NA	38700	No	2300 N	NA	NA	No	BKG
7439-92-1	LEAD	17.6		33.4		MG/KG	02SD010006	7/7	NA	33.4	No	400	400	IDEM	No	BSL, BKG
7439-95-4	MAGNESIUM	760		1120		MG/KG	02SD020006	7/7	NA	1120	No	NA	NA	NA	No	NUT, BKG
7439-96-5	MANGANESE	631		3200		MG/KG	02SD010006	7/7	NA	3200	Yes	180 N	NA	NA	Yes	ASL
7439-97-6	MERCURY	0.04		0.06	J	MG/KG	02SD020006	6/7	0.03	0.06	No	2.3 N	55	IDEM	No	BSL, BKG
7440-02-0	NICKEL	7.9		41.8		MG/KG	02SD040006	7/7	NA	41.8	No	160 N	6900	IDEM	No	BSL, BKG
7440-09-7	POTASSIUM	511		830		MG/KG	02SD070006	5/7	460 - 688	830	No	NA	NA	NA	No	NUT, BKG
7782-49-2	SELENIUM	0.5	J	0.65	J	MG/KG	02SD020006	3/7	0.46 - 0.69	0.65	No	39 N	1700	IDEM	No	BSL, BKG
7440-62-2	VANADIUM	14.9		37.7		MG/KG	02SD050006	7/7	NA	37.7	No	55 N	NA	NA	No	BSL, BKG
7440-66-6	ZINC	30	J	47.1		MG/KG	02SD070006	7/7	NA	47.1	No	2300 N	100000	IDEM	No	BSL, BKG

Notes:
1 - Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 - Values presented are sample-specific quantitation limits.
3 - The maximum detected concentration is used for screening purposes.
4 - To determine whether metal concentrations were within background levels, sediment concentrations were statistically compared to concentrations in upgradient sediment samples. If the site sediment concentrations were less than the upgradient concentraiotns, that metal was not selected as a COPC. See Section 4.
5 - U.S. EPA Region 9 Preliminary Remediation Goals Table, November 1, 2000. (Cancer benchmark value = 1E-06, HI = 0.1)
6 - Rationale Codes
Selection Reason: Above Screening Levels (ASL)
No Toxicity Information (NTX)
Deletion Reason: Essential Nutrient (NUT)
Below Screening Level (BSL)
Below Background Value (BKG)
7 - Value is for hexavalent chromium.
Shaded cells indicate that the specified criterion has been exceeded or that the chemical has been selected as a COPC.

Definitions:
NA = Not applicable.
SQL = Sample quantitation limit.
COPC = Chemical of potential concern.
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/to be considered.
J = Estimated value.
C = Carcinogenic.
N = Noncarcinogenic.
IDEM = Indiana Department of Environmental Management, Risk Integrated System of Closure (RISC) residential levels for direct contact with soil (IDEM, July 2001).

Associated Samples
02SD010006
02SD020006
02SD030006
02SD040006
02SD050006
02SD060006
02SD070006

TABLE 6-12

SELECTION OF EXPOSURE PATHWAYS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Surface Soil	Surface Soil	Surface Soil	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Construction workers may have contact with soil outside the capped area during excavation activities.
				Maintenance Worker	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers may contact surface soil outside the capped area during normal work activities. No COPCs were identified in surface soil; therefore, this pathway is not evaluated.
				Trespassers	Adolescents	Ingestion Dermal	On-Site On-Site	None None	Although access to the base is controlled, once inside the base, access to the SWMU 2 is not limited by any physical restraint. No COPCs were identified in surface soil; therefore, this pathway is not evaluated.
		Air	Surface Soil	Construction Workers	Adult	Inhalation	On-Site	None	Construction workers may be exposed to fugitive dust and volatile emissions during construction activities. No COPCs were identified in soil for the inhalation pathway.
				Maintenance Worker	Adult	Inhalation	On-Site	None	Maintenance workers may be exposed to fugitive dust and volatile emissions during work activities. No COPCs were identified in surface soil; therefore, this pathway is not evaluated.
				Trespassers	Adolescents	Inhalation	On-Site	None	Although access to the base is controlled, once inside the base, access to the SWMU 2 is not limited by any physical restraint. No COPCs were identified in surface soil; therefore, this pathway is not evaluated.
	Subsurface Soil	Subsurface Soil	Subsurface Soil	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Construction workers may have contact with soil outside the capped area during excavation activities.
				Maintenance Worker	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers are not exposed to subsurface soil.
				Trespassers	Adolescents	Ingestion Dermal	On-Site On-Site	None None	Trespassers are not exposed to subsurface soil.
		Air	Subsurface Soil	Construction Workers	Adult	Inhalation	On-Site	None	Construction workers may be exposed to fugitive dust and volatile emissions during construction activities. No COPCs were identified in soil for the inhalation pathway.
				Maintenance Worker	Adult	Inhalation	On-Site	None	Maintenance workers are not exposed to subsurface soil.
				Trespassers	Adolescents	Inhalation	On-Site	None	Trespassers are not exposed to subsurface soil.
	Ground Water	Ground Water	Upper/Lower Pennsylvanian Aquifer	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Extensive ground-intrusive activities are not expected to occur at the site because it is unlikely that the cap will be disturbed. Therefore, construction workers are not expected to come into contact with ground water.
				Maintenance Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers are not expected to have contact with ground water.
				Trespassers	Adolescents	Ingestion Dermal	On-Site On-Site	None None	Adolescent trespassers are not expected to have contact with ground water.
		Air	Upper/Lower Pennsylvanian Aquifer	Construction Workers	Adult	Inhalation	On-Site	None	Extensive ground-intrusive activities are not expected to occur at the site because it is unlikely that the cap will be disturbed. Therefore, construction workers are not expected to come into contact with ground water.
				Maintenance Workers	Adult	Inhalation	On-Site	None	Maintenance workers are not expected to have contact with ground water.
				Trespassers	Adolescents	Inhalation	On-Site	None	Adolescent trespassers are not expected to have contact with ground water.

TABLE 6-12

SELECTION OF EXPOSURE PATHWAYS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Current/Future	Surface Water	Surface Water	Surface Water	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Construction workers are not expected to contact surface water.
				Maintenance Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers are not expected to contact surface water.
				Trespassers	Adolescents	Ingestion Dermal	On-Site On-Site	Quant Quant	Adolescent trespassers may be exposed to surface water while at the site.
	Sediment	Sediment	Sediment	Construction Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Construction workers are not expected to contact sediment.
				Maintenance Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Maintenance workers are not expected to contact sediment.
				Trespassers	Adolescents	Ingestion Dermal	On-Site On-Site	Quant Quant	Trespassers may be exposed to sediment while at the site.
Future	Surface Soil	Surface Soil	Surface Soil	Recreational Users	Adult	Ingestion Dermal	On-Site On-Site	None None	This scenario is evaluated on the assumption that the Facility would close and be turned into a state park in the future. No COPCs were identified in surface soil, therefore these pathways were not evaluated.
				Residents	Child	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use control will prohibit future development of the site.
					Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use control will prohibit future development of the site.
				Occupational Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use control will prohibit future development of the site.
		Air	Surface Soil	Recreational Users	Adult	Inhalation	On-Site	None	Recreational users may be exposed to fugitive dust and volatile emissions while at the site. No COPCs were identified in surface soil, therefore this pathway was not evaluated.
				Residents	Child	Inhalation	On-Site	None	Because the site is capped, land use control will prohibit future development of the site.
					Adult	Inhalation	On-Site	None	Because the site is capped, land use control will prohibit future development of the site.
				Occupational Workers	Adult	Inhalation	On-Site	None	Because the site is capped, land use control will prohibit future development of the site.
	Ground Water	Ground Water	Upper/Lower Pennsylvanian Aquifer	Recreational Users	Adult	Ingestion Dermal	On-Site On-Site	None None	Recreational users are not expected to have contact with ground water.
				Residents	Child	Ingestion Dermal	On-Site On-Site	Quant Quant	Although it is unlikely that ground water at the site would be used as a potable water supply, this scenario is included to aid in future risk management decisions.
					Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Although it is unlikely that ground water at the site would be used as a potable water supply, this scenario is included to aid in future risk management decisions.
				Occupational Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use control will prohibit future development of the site.

TABLE 6-12

SELECTION OF EXPOSURE PATHWAYS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
		Air	Upper/Lower Pennsylvanian Aquifer	Recreational Users	Adult	Inhalation	On-Site	None	Recreational users are not expected to have contact with ground water. In addition, VOCs were not detected in ground water at SWMU 2.
				Residents	Child	Inhalation	On-Site	None	VOCs were not detected in ground water at SWMU 2
					Adult	Inhalation	On-Site	None	VOCs were not detected in ground water at SWMU 2
				Occupational Workers	Adult	Inhalation	On-Site	None	Because the site is capped, land use restriction will prohibit future development of the site.
	Surface Water	Surface Water	Surface Water	Recreational Users	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Because the site is capped, land use restriction will prohibit future development of the site.
				Residents	Child	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use restriction will prohibit future development of the site.
					Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use restriction will prohibit future development of the site.
				Occupational Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use restriction will prohibit future development of the site.
Future	Sediment	Sediment	Sediment	Recreational Users	Adult	Ingestion Dermal	On-Site On-Site	Quant Quant	Because the site is capped, land use restriction will prohibit future development of the site.
				Residents	Child	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use restriction will prohibit future development of the site.
					Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use restriction will prohibit future development of the site.
				Occupational Workers	Adult	Ingestion Dermal	On-Site On-Site	None None	Because the site is capped, land use restriction will prohibit future development of the site.

TABLE 6-13

EXPOSURE ROUTES FOR QUANTITATIVE EVALUATION
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Receptors	Exposure Routes[1]
Construction Workers	• Surface/subsurface soil dermal contact • Surface/subsurface soil ingestion
Maintenance Workers	• No complete exposure pathways
Adolescent Trespassers□(6 to 17 Years)	• Surface water/sediment dermal contact • Surface water/sediment ingestion
Adult Recreational Users	• Surface water/sediment dermal contact • Surface water/sediment ingestion
Residents (Adult/Children)	• Direct ingestion of ground water • Ground water dermal contact (showering/bathing)

1 - No COPCs were identified in surface soil; consequently, exposures to surface soil were not evaluated for any receptor.

TABLE 6-14

SUMMARY OF EXPOSURE ASSUMPTIONS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Receptor	Exposure Assumptions			Rationale/Reference
	Input Parameter	RME	CTE	
Construction Worker	EF (days/yr)	10	10	Professional judgment. Short-term, relatively un-intrusive activities are anticipated; a 2-week, 5-days/week project.
	ED (yrs)	1	1	Estimated length of construction project (professional judgment).
	BW (kg)	70	70	U.S. EPA, May 1993.
	SA (cm^2/day)	3,300	3,300	Recommended values for adult worker skin surface area assumed to be available for soil contact (U.S. EPA, September 2001).
	IR_S (mg/day)	480	240	Convention for the RME (U.S. EPA, March 1991). CTE is assumed to be one-half the RME value.
Adolescent Trespasser (6 to 17 Years)	EF (days/yr)	52	26	Professional judgment; 1 day/week for the RME and 1 day/every other week 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 (U.S. EPA, May 1989).
	SA (cm^2/day)	3,820	3,820	25 percent of the total body surface area will be assumed to be available for soil, sediment, and surface water contact. Areas represent the mean of 95th percentile values for ages 6 to 17, respectively, as provided in Table 6-6 of the Exposure Factors Handbook (U.S. EPA, August 1997).
	IR_S (mg/day)	100	50	Assumed similar to adult exposure (U.S. EPA, May 1993).
	EV (events/day)	1	1	Professional judgment.
	CR (L/hr)	0.01	0.01	Intake rates for exposure to surface water during wading (U.S. EPA, November 1995).
Adult Recreational User	EF (days/yr)	52	26	Professional judgment; 1 day/week for the RME and 1 day/every other week for the CTE.
	ED (yrs)	30	9	U.S. EPA, May 1993. Assumed length of residence for an adult living near the facility.
	ET (hours/day) and t_{event} (hr/event)	4	2	Professional judgment.
	BW (kg)	70	70	U.S. EPA, May 1993.

TABLE 6-14

SUMMARY OF EXPOSURE ASSUMPTIONS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Receptor	Exposure Assumptions			Rationale/Reference
	Input Parameter	RME	CTE	
Adult Recreational User (continued)	SA (cm^2/day)	9,070	9,070	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 (U.S. EPA, August 1997, Table 6-2).
	IR_S (mg/day)	100	50	Based on U.S. EPA, May 1993.
	EV (events/day)	1	1	Professional judgment.
	CR (L/hr)	0.05	0.05	Intake rates for exposure to surface water during wading (U.S. EPA, November 1995).
Resident (Adult/Child)	EF (days/yr or showers/yr)	350	234	U.S. EPA, May 1993. One shower assumed to be taken per day.
	ED (yrs)	6 (child) 24 (adult)	2 (child) 7 (adult)	U.S. EPA, May 1993.
	t_{event} (hr/event)	0.25	0.167	15 min/event for RME and 10 min/event for CTE (U.S. EPA, January 1992).
	BW (kg)	15 (child) 70 (adult)	15 (child) 70 (adult)	U.S. EPA, May 1993.
	SA (cm^2/day)	6,600 (child) 18,000 (adult)	6,600 (child) 18,000 (adult)	Recommended values for total skin surface area for children and adults (U.S. EPA, August 1997).
	IR_W (L/day)	1.5 (child) 2 (adult)	0.66 (child) 1.4 (adult)	USEPA, May 1993 for adult exposure. U.S. EPA, August 1997, Table 3-30 for child exposure.

Definitions

BW Body weight.
CR Contact rate (for surface water ingestion).
ED Exposure duration.
EF Exposure frequency.
ET Exposure time.
EV Event frequency.
IR_S Soil ingestion rate.
IR_w Ground water ingestion rate.
SA Skin surface area available for contact.

TABLE 6-15

EXPOSURE POINT CONCENTRATIONS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical	Surface Soil (mg/kg)	Surface/ Subsurface Soil (mg/kg)	Upper Pennsylvanian Ground Water (ug/L)	Lower Pennsylvanian Ground Water (ug/L)	Surface Water (ug/L)	Sediment (mg/kg)
Inorganics						
Aluminum	NA	6588 (1)	NA	23300 (2)	523 (2)	NA
Arsenic	NA	2.91 (1)	NA	1.6 (2)	0.41 (2)	NA
Beryllium	NA	NA	NA	4.7 (2)	NA	NA
Cadmium	NA	NA	NA	16.1 (2)	NA	NA
Cobalt	NA	NA	NA	445 (2)	NA	NA
Iron	NA	14438 (1)	NA	NA	874 (2)	NA
Manganese	NA	NA	NA	NA	NA	3200 (2)
Nickel	NA	NA	NA	868 (2)	NA	NA
Zinc	NA	NA	NA	2280 (2)	NA	NA

Notes:
RAGS Part D Tables for the exposure point concentrations are included in Appendix G.
NA - Not applicable - Chemical is not a COPC for this medium.
1 - 95% UCL for lognormal distribution.
2 - Insufficient number of samples to calculate an UCL; therefore, the maximum detected concentration is used as the exposure point concentration.

TABLE 6-16

CANCER TOXICITY DATA -- ORAL/DERMAL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal Cancer Slope Factor (2)	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date (3) (MM/DD/YY)
Inorganics							
Aluminum	NA	NA	NA	NA	NA	NA	NA
Arsenic	1.5E+00	100%	1.5E+00	$(mg/kg\text{-}day)^{-1}$	A	IRIS	03/27/02
Beryllium	NA	NA	NA	NA	B1	IRIS	03/27/02
Cadmium	NA	NA	NA	NA	B1	IRIS	03/27/02
Cobalt	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	D	IRIS	03/27/02
Nickel	NA	NA	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	D	IRIS	03/27/02

TABLE 6-16

CANCER TOXICITY DATA -- ORAL/DERMAL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal Cancer Slope Factor (2)	Units	Weight of Evidence/ Cancer Guideline Description	Source	Date (3) (MM/DD/YY)

Notes:

1 - EPA, 2001: Risk Assessment Guidance for Superfund (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005.

2 - CSFdermal = CSForal/Oral to Dermal Adjustment Factor.

3 - Dates of IRIS, HEAST, or NCEA.

Definitions:

IRIS = Integrated Risk Information System.

HEAST= Health Effects Assessment Summary Tables.

NA = Not available.

EPA Group:

A - Human carcinogen.

B1 - Probable human carcinogen - indicates that limited human data are available.

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans .

C - Possible human carcinogen.

D - Not classifiable as a human carcinogen.

E - Evidence of noncarcinogenicity.

TABLE 6-17

NON-CANCER TOXICITY DATA -- ORAL/DERMAL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal RfD (2)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ (3) (MM/DD/YY)
Inorganics										
Aluminum	Chronic	1.0E+00	mg/kg/day	100%	1.0E+00	mg/kg/day	Immunological, Nails	NA	NCEA	9/25/01
Arsenic	Chronic	3.0E-04	mg/kg/day	100%	3.0E-04	mg/kg/day	Skin, CVS	3/1	IRIS	03/27/02
Beryllium	Chronic	2.0E-03	mg/kg/day	0.7%	1.4E-05	mg/kg/day	GS	300/1	IRIS	03/27/02
Cadmium	Chronic	5.0E-04	mg/kg/day	5%	2.5E-05	mg/kg/day	Kidney	10/1	IRIS	03/27/02
Cobalt	Chronic	2.0E-02	mg/kg/day	100%	2.0E-02	mg/kg/day	Immunological, CVS	NA	NCEA	9/25/2001
Iron	Chronic	6.0E-01	mg/kg/day	100%	6.0E-01	mg/kg/day	Liver, Blood, GS	NA	NCEA	9/25/01
Manganese (Soil)	Chronic	7.2E-02	mg/kg/day	4%	2.9E-03	mg/kg/day	CNS	1/1	IRIS	03/27/02
Nickel	Chronic	2.0E-02	mg/kg/day	4%	8.0E-04	mg/kg/day	Body Weight	300/1	IRIS	03/27/02
Zinc	Chronic	3.0E-01	mg/kg/day	100%	3.0E-01	mg/kg/day	Blood	3/1	IRIS	03/27/02

Notes:
1 - EPA, 2001: Risk Assessment Guidance for Superfund (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005.
2 - RfDdermal = RfDoral x Oral to Dermal Adjustment Factor.
3 - Dates of IRIS, HEAST, or NCEA.

Definitions:
CNS = Central nervous system.
CVS = Cardiovascular system.
Immune = Immunological.
GS = Gastrointestinal.
NA = Not applicable.
IRIS = Integrated Risk Information System.
HEAST= Health Effects Assessment Summary Tables.
NCEA = U.S. EPA National Center for Environmental Assessment (U.S. EPA Region 3 RBC Table, September 2001).

TABLE 6-18

CUMULATIVE RISK SUMMARY - REASONABLE MAXIMUM EXPOSURE
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Exposure Route	Construction Worker	Adult Recreational User	Adolescent Trespasser	Future Child Resident	Future Adult Resident
HAZARD INDEX					
Ingestion of Ground Water	NA	NA	NA	10	3.7
Dermal Contact with Ground Water	NA	NA	NA	0.1	0.10
Inhalation of Volatiles from Ground Water While Showering	NA	NA	NA	NA	NA
Total HI for Ground Water	**NA**	**NA**	**NA**	**10**	**3.8**
Incidental Ingestion of Surface/Subsurface Soil	0.008	NA	NA	NA	NA
Dermal Contact with Surface/Subsurface Soil	0.0001	NA	NA	NA	NA
Total HI for Surface/Subsurface Soil	**0.008**	**NA**	**NA**	**NA**	**NA**
Incidental Ingestion Surface Water	NA	0.0003	0.0004	NA	NA
Dermal Contact with Surface Water	NA	0.00006	0.0001	NA	NA
Total HI for Surface Water	**NA**	**0.0004**	**0.0006**	**NA**	**NA**
Incidental Ingestion of Sediment	NA	0.009	0.01	NA	NA
Dermal Contact with Sediment	NA	NA	NA	NA	NA
Total HI for Sediment	**NA**	**0.009**	**0.01**	**NA**	**NA**
Total HI for All Media:	**0.008**	**0.009**	**0.02**	**10**	**3.8**

NOTES
No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil are regarded as minimal and no further evaluation was performed on this medium.
NA - Not applicable; exposure route is not applicable for this receptor.
Chemical-specific risks presented in Appendix G.

TABLE 6-18

CUMULATIVE RISK SUMMARY - REASONABLE MAXIMUM EXPOSURE
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Exposure Route	Construction Worker	Adult Recreational User	Adolescent Trespasser	Future Child Resident	Future Adult Resident	Future Lifetime Resident
INCREMENTAL CANCER RISK						
Ingestion of Ground Water	NA	NA	NA	2.0E-05	2.3E-05	4.2E-05
Dermal Contact with Ground Water	NA	NA	NA	2.2E-08	5.1E-08	7.2E-08
Inhalation of Volatiles from Ground Water While Showering	NA	NA	NA	NA	NA	NA
Total Risk for Ground Water	**NA**	**NA**	**NA**	**2.0E-05**	**2.3E-05**	**4.2E-05**
Incidental Ingestion of Surface/Subsurface Soil	1.2E-08	NA	NA	NA	NA	NA
Dermal Contact with Surface/Subsurface Soil	7.3E-10	NA	NA	NA	NA	NA
Total Risk for Surface/Subsurface Soil	**1.2E-08**	**NA**	**NA**	**NA**	**NA**	**NA**
Incidental Ingestion Surface Water	NA	2.7E-08	1.3E-08	NA	NA	NA
Dermal Contact with Surface Water	NA	4.9E-09	4.2E-09	NA	NA	NA
Total Risk for Surface Water	**NA**	**3.2E-08**	**1.7E-08**	**NA**	**NA**	**NA**
Incidental Ingestion of Sediment	NA	NA	NA	NA	NA	NA
Dermal Contact with Sediment	NA	NA	NA	NA	NA	NA
Total Risk for Sediment	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Total Risk for All Media:	**1.2E-08**	**3.2E-08**	**1.7E-08**	**2.0E-05**	**2.3E-05**	**4.2E-05**

NOTES
No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil are regarded as minimal and no further evaluation was performed on this medium.
NA - Not applicable; exposure route is not applicable for this receptor.
Chemical-specific risks presented in Appendix G.

TABLE 6-19

CUMULATIVE RISK SUMMARY - CENTRAL TENDENCY EXPOSURE
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Exposure Route	Construction Worker	Adult Recreational User	Adolescent Trespasser	Future Child Resident	Future Adult Resident
HAZARD INDEX					
Ingestion of Ground Water	NA	NA	NA	3.8	1.7
Dermal Contact with Ground Water	NA	NA	NA	0.06	0.03
Inhalation of Volatiles from Ground Water While Showering	NA	NA	NA	NA	NA
Total HI for Ground Water	**NA**	**NA**	**NA**	**3.9**	**1.8**
Incidental Ingestion of Surface/Subsurface Soil	0.004	NA	NA	NA	NA
Dermal Contact with Surface/Subsurface Soil	0.00004	NA	NA	NA	NA
Total HI for Surface/Subsurface Soil	**0.004**	NA	NA	NA	NA
Incidental Ingestion Surface Water	NA	0.0002	0.0001	NA	NA
Dermal Contact with Surface Water	NA	0.00003	0.00003	NA	NA
Total HI for Surface Water	NA	**0.0002**	**0.0001**	NA	NA
Incidental Ingestion of Sediment	NA	0.002	0.004	NA	NA
Dermal Contact with Sediment	NA	NA	NA	NA	NA
Total HI for Sediment	**NA**	**0.002**	**0.004**	**NA**	**NA**
Total HI for All Media:	**0.004**	**0.002**	**0.004**	**3.9**	**1.8**

NOTES
No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil are regarded as minimal and no further evaluation was performed on this medium.
NA - Not applicable; exposure route is not applicable for this receptor.
Chemical-specific risks presented in Appendix G.

TABLE 6-19

CUMULATIVE RISK SUMMARY - CENTRAL TENDENCY EXPOSURE
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Exposure Route	Construction Worker	Adult Recreational User	Adolescent Trespasser	Future Child Resident	Future Adult Resident	Future Lifetime Resident
INCREMENTAL CANCER RISK						
Ingestion of Ground Water	NA	NA	NA	1.9E-06	3.1E-06	5.0E-06
Dermal Contact with Ground Water	NA	NA	NA	3.2E-09	6.6E-09	9.8E-09
Inhalation of Volatiles from Ground Water While Showering	NA	NA	NA	NA	NA	NA
Total Risk for Ground Water	**NA**	**NA**	**NA**	**1.9E-06**	**3.1E-06**	**5.0E-06**
Incidental Ingestion of Surface/Subsurface Soil	5.9E-09	NA	NA	NA	NA	NA
Dermal Contact with Surface/Subsurface Soil	2.4E-10	NA	NA	NA	NA	NA
Total Risk for Surface/Subsurface Soil	**6.1E-09**	**NA**	**NA**	**NA**	**NA**	**NA**
Incidental Ingestion Surface Water	NA	4.0E-09	3.2E-09	NA	NA	NA
Dermal Contact with Surface Water	NA	7.3E-10	9.9E-10	NA	NA	NA
Total Risk for Surface Water	**NA**	**4.8E-09**	**4.2E-09**	**NA**	**NA**	**NA**
Incidental Ingestion of Sediment	NA	NA	NA	NA	NA	NA
Dermal Contact with Sediment	NA	NA	NA	NA	NA	NA
Total Risk for Sediment	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
Total Risk for All Media:	**6.1E-09**	**4.8E-09**	**4.2E-09**	**1.9E-06**	**3.1E-06**	**5.0E-06**

NOTES
No COPCs were identified in surface soil; therefore, potential risks associated with exposures to surface soil are regarded as minimal and no further evaluation was performed on this medium.
NA - Not applicable; exposure route is not applicable for this receptor.
Chemical-specific risks presented in Appendix G.

TABLE 6-20

SUMMARY OF CONCLUSIONS
HUMAN HEALTH RISK ASSESSMENT
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical of Concern[1]	Impact on Human Receptors	Comments
GROUND WATER - LOWER PENNSYLVANIAN AQUIFER		
Aluminum	Child resident HQ = 2.2	Risks for aluminum, cadmium, cobalt, and nickel are based on the hypothetical future residential use of ground water. The risk estimates are based on analytical results for four unfiltered ground water samples. The EPC was influenced by one sample (02GWC11P301) that exhibited an unusually low pH (3.7), which suggests that the metal concentrations may be elevated because of increased solubility of geologic minerals in an acidic environment. In addition, since a cap exists at the site, a deed restriction will prohibit future development of the site.
Cadmium	Child resident HQ = 3.2	
Cobalt	Child Resident HQ = 2.1	
Nickel	Child resident HQ = 4.2, Adult resident HQ = 1.2	

HQ Hazard Quotient.
1 - Chemicals that contribute to a cumulative ILCR of greater than 1.0E-4 or a noncarcinogenic chemical contributing to target organ Hazard Indices (HI) greater than 1.0.

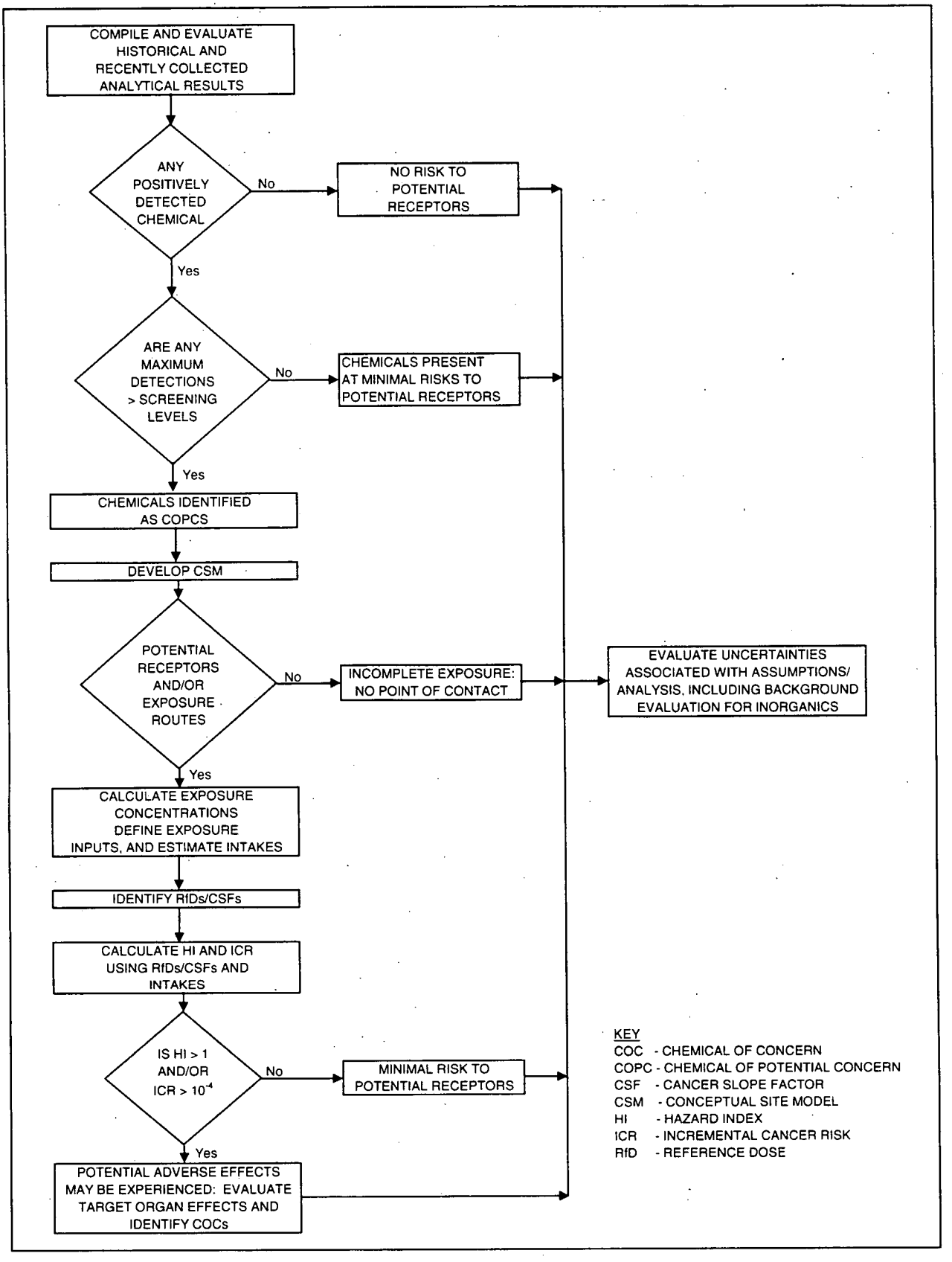
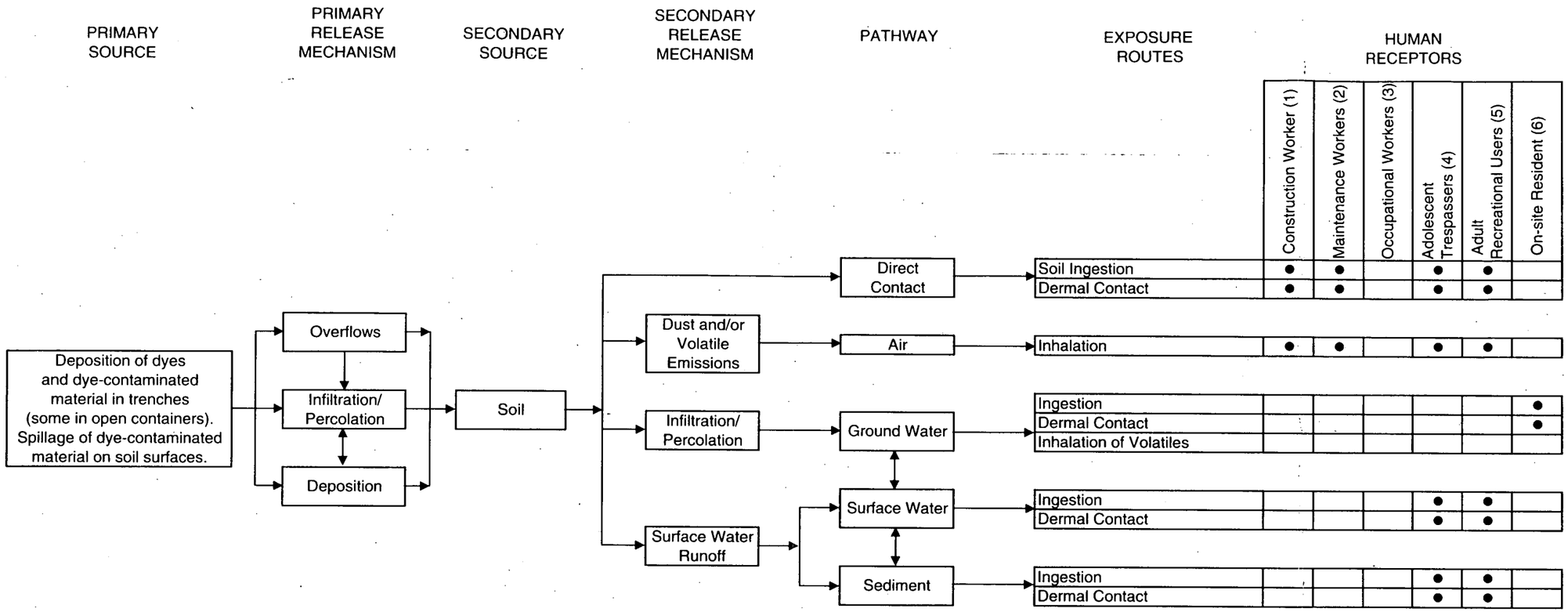


FIGURE 6-1

SUMMARY OF HUMAN HEALTH RISK ASSESSMENT PROCESS
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA



KEY

(1) Potential receptor under future land use. A short-term, limited project may occur outside the cap. Exposure to ground water is not expected because intrusive activities are expected to be limited.
(2) Potential receptor under current and future land use. The site is currently maintained.
(3) Unlikely receptor. The site will not be developed for occupational purposes because of land use limitations associated with the cap (i.e., land use controls, etc.).
(4) Potential receptor under current and future land use. Although access to NSWC Crane is physically restricted by a chain-link fence, the access to the site is not restricted once inside the facility.
(5) Potential receptor under future land use. Base could close and be turned into a state park.
(6) Unlikely receptor under future land use. Evaluated for decision-making purposes only for exposure to ground water. The site is not likely to be developed because of limitations associated with the cap.
(7) Evaluated for soils outside the cap.

● = COMPLETE EXPOSURE PATHWAY

FIGURE 6-2

CONCEPTUAL SITE MODEL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

7.0 ECOLOGICAL RISK ASSESSMENT

The goal of the SERA was 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 SWMU 2 at NSWC Crane.

7.1 INTRODUCTION

This SERA provides information to scientists and managers that enables them to conclude that ecological risks at the site are negligible. The SERA methodology used at NSWC Crane follows the guidance presented in the Department of Navy Environmental Policy Memorandum 97-04, Use of Ecological Risk Assessments (May 16, 1997), Chief of Naval Operations Letter 5090 Ser N453E/9U 59 5335 (April 5, 1999), Navy Policy for Conducting Ecological Risk Assessment, Final Guidelines for Ecological Risk Assessment (U.S. EPA, April 1998), and the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (U.S. EPA, June 1997). A schematic diagram of the general risk assessment process is provided in Figure 7-1.

The Ecological Risk Assessment (ERA) consists of Steps 1, 2, and 3A of the eight steps required by U.S. EPA guidance (U.S. EPA, June 1997 and April 1998) and the Navy Policy for Conducting Ecological Risk Assessments (Navy, 1999). The first two steps are the SERA. Step 3A is the first step of the baseline ecological risk assessment (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, which they were not for this SERA. Finally, Step 8, Risk Management, is incorporated throughout the ERA process, in cooperation with the Region 5 Biological Technical Assistance Group (BTAG).

7.2 PROBLEM FORMULATION

Problem formulation is the first step of a SERA. It results in three products (U.S. EPA, April 1998):

- Assessment endpoints that adequately reflect management goals and the ecosystems they represent.
- Conceptual models that describe the key relationships between a stressor and assessment endpoint or among several stressors and assessment endpoints.
- An analysis plan.

Problem formulation includes identification of the following:

- Ecosystems potentially at risk
- Source and stressor characteristics
- Exposure characteristics
- Ecological effects

The problem formulation process enables the risk assessor to identify the ecological resources to be protected (known as assessment endpoints); the measurements to be used to evaluate risks to those resources (known as measures of effects); and the chemicals, geographic areas, and environmental media relevant to the risk assessment.

7.2.1 Site Description

A site description of the local ecology for SWMU 2 was provided in Section 1.4.5. An ecological assessment checklist was completed for SWMU 2 and can be found in Appendix H.5.

7.2.2 Potential Sources of Contamination and Associated Exposure Pathways

SWMU 2 was identified at NSWC Crane as an area potentially warranting further investigation. A limited variety of chemicals were potentially released at this site; constituents include dyes and several metals. The results of the surface soil, surface water, and sediment sampling for SWMU 2 are presented in Section 4.0. Specific information for SWMU 2, including a site description and detected chemicals of interest, was provided in Section 1.4.

Chemicals released either to surface or subsurface soils could migrate downward to the shallow aquifer and south-southwestward into Little Sulphur Creek via ground water flow. A ground water seep with intermittent flow was identified on the southwestern slope of the site. Although most ecological receptors do not directly contact the ground water while it is in the ground, they may be exposed to chemical contaminants after the ground water discharges to a surface water body or to the surface via springs or seeps in the area. Surface runoff from the Dye Burial Grounds is rapid, leaving the site via drainage channels that originate at the edge of the ridges. Contaminants in surface soil may become suspended or dissolved in surface water runoff and eventually reach Little Sulphur Creek via overland flow. Ecological receptors could potentially be exposed to chemical contaminants via direct contact and ingestion of water from seeps and/or Little Sulphur Creek.

7.2.3 Ecological Effects/Physical and Chemical Characteristics

Metals were the only chemical parameters detected in the surface water, sediment, or surface soil samples. Appendix H.1 presents toxicity data for metals. Physical and chemical characteristics of contaminants may affect their mobility, transport, and bioavailability in the environment. These characteristics include the organic carbon-water partition coefficient, octanol-water partition coefficient, and vapor pressure. These characteristics are summarized in Section 5.0 for the contaminants that were detected.

In addition to physical and chemical characteristics, the SERA specifically uses plant and invertebrate bioaccumulation factors (BAFs) to predict contaminant loading in plants and invertebrates. The following are the sources of the BAFs and bioconcentration factors that were used in the SERA:

- Plant BAFs - Inorganics: Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants (ORNL, 1998a)

- Soil Invertebrate BAFs - Inorganics: Development and Validation of Bioaccumulation Models for Earthworms (Sample et al., 1998a)

Some of the BAFs presented in these documents estimate the tissue concentrations in dry weight. These values must be converted to wet weight for use in exposure estimation in the food chain 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 was used to adjust the BAFs (Sample et al., 1997).

Food Type	Percent Water Content	Percent Dry Weight
Terrestrial Invertebrates (earthworms)	84	16
Terrestrial Plants (monocots-young grass)	70 to 88	12 to 30

7.2.4 Potential Exposure Pathways

The potential pathways by which ecological receptors may be exposed to COPCs at each site were identified, along with the species that could be adversely affected by these chemicals. The potential sources of contamination were caused by various activities that have occurred at the site. The

contaminants at the site were primarily buried in 55 gallon drums in burial trenches and then may have migrated to other media (i.e., ground water, surface water, and sediment). Several potential exposure pathways may exist at the site(s). The following subsections discuss these exposure pathways in detail, and if they will be evaluated in the ERA.

7.2.4.1 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 is not 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 are 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.

7.2.4.2 Ground Water

Ecological receptors are not directly exposed to contaminants in the ground water at the site while the water is in the ground, so this exposure pathway is not complete. Exposure to ground water after it discharges as a seep or directly to a surface water body is evaluated as part of the surface water pathway.

7.2.4.3 Surface Water/Sediment

Contaminants in the ground water may discharge as a seep that then drains to a surface water body or may discharge directly to a surface water body. Contaminants in the soil may also enter the intermittent streams via overland flow.

Most of the water bodies immediately adjacent to the site are small drainage ditches that have poor ecological habitat and probably only support small invertebrate populations. The only waterbody that could support a small fish population near SWMU 2 is Little Sulphur Creek. These receptors could be exposed to the water or sediment by direct contact and ingestion of water. Piscivorous wildlife may consume fish that have accumulated chemicals from the surface water or sediment, and bats may consume insects after they emerge from the water. Because the drainage ditches associated with the site are relatively small and only receive drainage during rain events, the pathway is not considered complete for aquatic receptors. This pathway is complete for Little Sulphur Creek, although it is not expected to account for a significant portion of the diet for piscivorous wildlife because this portion of the creek is intermittent. However, this exposure pathway was evaluated in the SERA to address potential impacts further downstream should migration of contaminants occur.

7.2.4.4 Air

Although inhalation of particulates may be a complete pathway, it is expected to be insignificant compared to other pathways, such as ingestion of food items that have accumulated contaminants from soil. Also, inhalation pathways typically are not evaluated in SERAs because of the uncertainty in exposures and effects concentrations. Therefore, this pathway was not evaluated in the SERA.

7.2.5 Endpoints

7.2.5.1 Assessment Endpoints

Assessment endpoints are explicit expressions of the environmental value that is to be protected (U.S. EPA, June 1997). 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.

The habitat at and adjacent to the site consists of forested areas, open fields with grasses, and aquatic habitats. For this SERA, the assessment endpoints are the 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- and sediment invertebrate-eating birds and mammals
- Carnivorous mammals
- Carnivorous birds
- Benthic invertebrates
- Fish

The following paragraphs discuss why the assessment endpoints listed above 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 and 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 that can then be transferred to the higher trophic level organisms that consume invertebrates.

Terrestrial Vegetation - Terrestrial vegetation at the 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 can also accumulate some contaminants that 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. Their role in the community is essential because, without them, higher trophic levels could not exist. They may be exposed to and accumulate contaminants that are present in the plants they consume.

Carnivorous Birds and Mammals - Carnivorous birds and mammals consume invertebrates, fish, and other mammals and birds. Soil invertebrate-eating birds and mammals are present throughout the base in different terrestrial habitats (i.e., forested, open field). These are considered first-level carnivores, and they serve as a food source for higher trophic level carnivores. Piscivorous birds and mammals may be present along Little Sulfur Creek. 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.

The Indiana bat, a federally endangered species, is known to forage at NSWC Crane. During a mist net and radiotelemetry survey conducted for NSWC Crane, a female Indiana bat was captured along Sulphur

Creek. Because of the bat and its potential habitat, the cutting of trees is restricted to certain times during the year, and the cutting of shagbark hickory trees is prohibited. The federally endangered Indiana bat has been recorded at NSWC Crane near the perennial portion of Little Sulphur Creek, although Indiana bats have not been captured near SWMU 2 in either of two multiple night field surveys in which bats were collected at various locations using mist nets (Whitaker 1996, BHE 1999). Indiana bats (especially females and juveniles) forage primarily in riparian and floodplain forests. These habitats are absent from SWMU 2. Male Indiana bats also forage primarily in riparian and floodplain forests but are known to occasionally forage in upland forests and over old fields (USFWS, 1999). Thus, while the presence of Indiana bats at SWMU 2 cannot be ruled out, the site does not provide preferred habitat for this species, and they have not been captured in either of two studies conducted near SWMU 2.

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 can also accumulate some contaminants that can then be transferred to the higher trophic level organisms that consume invertebrates.

Fish - Fish are likely to be present in Little Sulphur Creek. Fish are exposed to contaminants and can accumulate contaminants from the food items they consume or from the surface water in which they live.

All the initial assessment endpoints are not evaluated in the SERA. As indicated in U.S. EPA guidance (U.S. EPA, June 1997), "it is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem at a site. Instead, assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site." Therefore, the SERA focuses on the endpoints that will tend to yield the highest risks, which should then account for endpoints that will have lower risks.

Large carnivorous mammals (i.e., red fox) and birds (i.e., red-tailed hawk) are not specifically evaluated in this SERA because the site (or the areas of potential contamination) is small and is well below the typical home and feeding ranges of carnivorous animals. Also, the greatest exposure to site contaminants is expected to occur to the small mammals and birds that ingest earthworms or plants.

The omnivores also are not specifically evaluated in this SERA because exposure to contaminants in plants will be highest for herbivores and exposure to contaminants in animals will be highest for carnivores. Therefore, the omnivores should be protected by protecting the herbivores and carnivores.

7.2.5.2 Measurement Endpoints

Measurement endpoints are estimates of biological impacts (e.g., mortality, growth, reproduction) that are used to evaluate the assessment endpoints. The following measures of effects are used to evaluate the assessment endpoints in this SERA, where applicable.

- Soil screening values - Mortality, growth, and reproduction of plants and soil invertebrates are 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 or reproductive and/or developmental effects to birds and mammals are evaluated by comparing the estimated ingested dose (based on conservative and average assumptions) from contaminants in the surface water, sediment, surface soil, plants, invertebrates, and/or fish to these levels.

- Sediment screening values - Mortality and other adverse effects (e.g., those on growth, feeding rates, behavior) of benthic macroinvertebrates are evaluated by comparing the measured concentrations (maximum 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 (e.g., those on growth, feeding rates, behavior) of aquatic organisms are evaluated by comparing the measured concentrations (maximum and averages) of chemicals in the surface water to screening values designed to be protective of ecological receptors.

7.2.5.3 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 is required so that intake through eating, and drinking 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 and 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.

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. 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 are used for the food chain modeling:

- Herbivorous mammal: meadow vole
- Herbivorous bird: bobwhite quail
- Carnivorous bird: American robin
- Carnivorous mammals: short tail shrew and little brown bat
- Piscivorous mammal: raccoon
- Piscivorous bird: belted kingfisher

Note that the little brown bat is being used as an indicator species for the Indiana bat, based on the availability of exposure parameters for the little brown bat. Receptor profiles for each of these species are presented in Appendix H.2.

7.2.6 Conceptual Model

A conceptual model in problem formulation is a written description and visual representation of predicted relationships between ecological entities and the stressors to which they may be exposed (U.S. EPA, April 1998). The conceptual model consists of two primary components: predicted relationships among stressor, exposure, and assessment endpoint response and a diagram that illustrates the relationships (U.S. EPA, April 1998). The following risk hypotheses describe these relationships and are evaluated as part of this SERA:

- Contaminants in the surface soil at the site do not cause an increase in mortality to plants and earthworms/invertebrates.

- Contaminants in the surface soil at the site do not cause an increase in mortality, decrease in reproduction, and/or developmental effects in birds and mammals.

- Contaminants in the surface water or sediment impacted by the site do not cause an increase in mortality to benthic macroinvertebrates and fish or an increase in mortality, decrease in reproduction, and/or developmental effects to piscivorous wildlife.

The primary source of the contamination at SWMU 2 was identified based on past operational practices. The primary stressors are contaminants in the surface soil, surface water, sediment, and ground water. Because ecological receptors are not directly exposed to contaminants in the ground water, the secondary stressors are contaminants in the surface water and sediment. The primary receptors for contaminants in the surface soil are plants and invertebrates, and the secondary receptors are birds and mammals. Figure 7-2 presents the conceptual site model.

7.3 SELECTION OF CONTAMINANTS OF POTENTIAL CONCERN

7.3.1 Screening Levels

The first step in the analysis phase was to select COPCs by comparing the maximum detected contaminant concentrations in the surface water, sediment, and surface soil samples to U.S. EPA Region 5 ecological data quality levels (EDQLs) (U.S. EPA, Region 5, October 1999). Section 7.4 summarizes the procedures that were used to select COPCs. Calcium, magnesium, potassium, and sodium were not retained as COPCs in any medium because of their relative low toxicity to ecological receptors and their high variability in natural concentrations. They are not expected to be related to site activities. Contaminants without EDQLs were retained as COPCs. If a chemical was not detected in any of the samples in a particular medium and the reporting limit exceeded the EDQL, the chemical was not quantitatively carried through the risk assessment as a COPC. However, the chemical, its reporting limit, and the EDQL were summarized in Tables 3-5 and 3-6 of Section 3.0 and qualitatively discussed in the uncertainty analysis section. If a chemical was detected in at least one sample, one-half of the reporting limit was substituted for the non-detects for calculating summary statistics (e.g., mean concentrations).

7.3.2 Risk Characterization

The risk characterization 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 was evaluated.

An Ecological Efforts Quotient (EEQ) approach was used to characterize the risk to terrestrial receptors. This approach characterizes the potential effects by comparing exposure concentrations with the effects data. The EEQs for terrestrial receptors were calculated as follows:

$$EEQ = \frac{C_{ss}}{SSSL}$$

where:

C_{ss} = Contaminant concentration in surface soil (µg/kg or mg/kg)

SSSL = Surface Soil Screening Level (µg/kg or mg/kg)

The EEQs for the aquatic receptors were calculated as follows:

$$EEQ = \frac{C_{sw}}{SWSL} \; or \; \frac{C_{sd}}{SSL}$$

where:

EEQ = Ecological Effects 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 of greater than "1.0" was considered to be indicative of potential risk. Such values do not necessarily indicate that an effect will occur but only that a lower threshold has been exceeded.

7.4 ECOLOGICAL SCREENING

The following procedures were used to retain or eliminate chemicals as COPCs.

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

- Inorganic contaminants in the surface water whose maximum concentrations do not exceed the maximum concentration in the upgradient sample as discussed in Appendix F-2 are not retained as COPCs.

- Inorganic contaminant concentrations in the sediment that are not statistically elevated compared to upgradient/reference concentrations as discussed in Appendix F-3 are not retained as COPCs.

Surface Soil for Invertebrates, Plants, and Terrestrial Wildlife

- Inorganic and organic contaminants whose maximum concentrations do not exceed EDQLs are not retained as COPCs.

- Inorganic contaminant concentrations that are not statistically elevated compared to the background soil data set, as discussed in Appendix F-1, are not retained as COPCs.

Contaminants that are retained as COPCs are further evaluated as part of Step 3A of the eight-step ERA process.

7.4.1 Surface Soil

Table 7-1 is the screening table for plants, invertebrates, and terrestrial wildlife exposed to chemicals detected in the surface soil samples. In addition to summary statistics (e.g., frequency of detection), the table also includes a comparison to the representative soil background values, which are used to select COPCs. Twenty inorganic chemicals were detected in the surface soil samples. Copper was retained as a COPC because the maximum concentration exceeded the surface soil COPC screening level and the site concentrations are statistically above the background concentrations. See Section 4.1 for a discussion of the statistical tests.

7.4.2 Sediment

Table 7-2 is the screening table for aquatic receptors and piscivorous wildlife exposed to chemicals detected in the sediment. In addition to summary statistics (e.g., frequency of detection), the table also includes a comparison to the sediment background, which are used to select COPCs. See Section 4.1 for a discussion of the statistical background comparison. Twenty inorganic chemicals are detected in the sediment samples. Barium and manganese were retained as COPCs because no sediment COPC

screening levels are available for these chemicals, and the site concentrations are statistically above the background concentrations.

7.4.3 Surface Water

Table 7-3 is the surface water screening table for aquatic receptors and piscivorous wildlife. In addition to summary statistics (e.g., frequency of detection), the table also includes a comparison to the surface water background values, which are used to select COPCs. See Section 4.1 for a discussion of the background comparison. Eight inorganic chemicals (in the unfiltered samples) and five filtered inorganic chemicals were detected in the surface water/seep sample. Only aluminum and iron are retained as COPCs because no surface water COPC screening levels are available for these chemicals and the site concentrations are above the background concentrations.

7.5 SCIENTIFIC/MANAGEMENT DECISION POINT

The SERA includes the estimation of exposure levels and screening for ecological risks. The SERA is concluded by a Scientific/Management Decision Point (SMDP) at which point one of the following decisions is made (DON, 1999):

(1) Adequate information exists to conclude that ecological threats at a site are negligible; no further evaluations of ecological risks are necessary.

(2) Adequate information exists and there is a potential for adverse ecological effects. In this case, the decision can be to either conduct an interim cleanup (if cost-effective to do so) or continue to Step 3.

Included in the decisions listed above is an evaluation of the adequacy of the available information on which the decisions are based. Questions are answered during this evaluation such as: were adequate numbers of samples collected in the appropriate locations and were the samples analyzed for the appropriate parameters with sufficient sensitivity.

This section of the ERA describes whether or not the collected data are adequate for making ecological risk decisions for SWMU 2. Section 4.0 of this report contains discussion of the nature and extent of contamination at SWMU 2, and Figures 1-3 and 1-15 show the site topography (with stream channels) and site photographs, respectively.

Military smoke dyes and dye-contaminated materials were disposed at SWMU 2. Unknown amounts of the specific dyes were buried at the site. Materials reportedly included magnesium, boxes, and rags contaminated with dyes, and open-topped drums of dye. Currently, the site is inactive (i.e., it is not used for waste disposal activities) and an interim-measures cap, which included permanent grass vegetation, has been installed. SWMU 2 is approximately 12.4 acres in area and consists of a grass-covered cap (4.2 acres), woods (7.8 acres), and one main gravel road (0.4 acre).

The terrain is predominantly rolling, with moderately incised stream valleys throughout and occasional flat areas in the central and northern portions of NSWC Crane. Deciduous trees and shrubs cover most of the region. The topography of the Dye Burial Grounds is relatively rugged, consisting of a series of steep-sided, narrow ridges and valleys. The SWMU lies approximately 500 feet southwest of the crest of a north-northwest trending ridge separating Sulphur Creek from Little Sulphur Creek. The elevation of SWMU 2 is approximately 740 feet AMSL and rises toward the crest, which is at an elevation of approximately 770 feet AMSL (Figure 1-2). A seep was identified on a slope southwest of the site. Surface drainage from the ridgetop, where SWMU 2 is located, flows to the west and south into small unnamed tributaries of Little Sulphur Creek (Figure 1-2). These drainage pathways are dry, except during significant rainstorm and snowmelt events when runoff is occurring. These channels drain south and southwestward for about 2,000 feet before they enter the Little Sulphur Creek channel (Figure 1-3). At this juncture, the Little Sulphur Creek channel is also usually dry. Little Sulphur Creek becomes a perennial stream about one mile farther downstream, where several small to moderately-sized springs discharge ground water from Mississippian limestone formations (e.g., "spring C"). Near SWMU 2, Little Sulphur Creek travels about 3.5 to 4.0 stream miles southward before it enters Sulphur Creek beyond the property boundary of NSWC Crane (Figure 1-3). Sulphur Creek travels southwestward to join Indian Creek, which in turn flows southeastward to join the White River.

In order to characterize the extent of contamination at SWMU 2 and any associated ecological risks, soil, surface water, and sediment samples were collected. Surface soil samples were analyzed for metals and dyes. Additionally, soil characteristic parameters, cation exchange capacity (CEC) and total organic carbon (TOC) were collected to determine the likelihood of the potential fate and transport of contaminants at the site (and the potential for risks outside the site boundaries). Sediment samples were analyzed for metals, dyes, and TOC. Surface water samples were analyzed for total and dissolved metals, dyes, hardness, and total dissolved solids (TSS). Table 4-1 presents a summary of all media collected at SWMU 2 and the selected analyses.

7.5.1 Surface Soil

Thirteen surface soil samples were collected at SWMU 2. Section 1.4.4 presents a detailed description of SWMU 2 geology and stratigraphy. Table 4-2 presents a summary of the positive surface soil analytical results and Table 7-1 is the ecological risk screening table. Surface soil samples were divided into two aliquots. Samples to be analyzed for dye parameters were collected from the 0- to 2-foot interval (13 samples) and samples for inorganic parameters (metals, etc.) were collected from 0- to 1-foot interval (20 samples). All of the surface soil samples were collected within the SWMU boundaries surrounding the historically disturbed soil areas outside the cap that were identified during the clearing stage of the cap installation (see Figure 4-1). Therefore, the soil samples were biased in the areas where the chemical contamination and risk for ecological exposure was expected to be greatest. Twenty metals were detected in surface soil samples. Of these, only copper was retained as a COPC with an EEQ of 3.99 because the maximum detected concentration in sample 02SS200001 exceeded the Region 5 EDQL and was statistically above background concentrations. Although copper was detected at concentrations statistically greater than background concentrations, there is no known history of copper disposal at SWMU 2. Overall, metals were detected relatively frequently with maximum concentrations in varying samples. Metals detections were spatially distributed evenly across SWMU 2 indicating no clear pattern of contamination (see Figure 4-1). The absence of a clear pattern of metals contamination is further evidenced by the majority of sample concentrations below NSWC Crane background concentrations. However, because copper was retained as a COPC, copper will be further evaluated in Step 3A of the BERA.

7.5.2 Sediment

Seven sediment samples were collected from the tributaries of Little Sulphur Creek surrounding SWMU 2. Table 4-6 presents a summary of the positive sediment analytical results and Table 7-2 is the ecological risk screening table. Twenty metals were detected in sediment samples. Of these, only barium and manganese were retained as COPCs because the maximum concentrations exceeded the background concentrations and no EDQLs are available for comparison. Because EDQLs are not available for barium and manganese, EEQs are unable to be calculated. The COPCs, as well as all metals in general, were detected relatively frequently with maximum concentrations in varying samples. Metal detections were spatially distributed evenly across SWMU 2 indicating no clear pattern of contamination, although manganese results were relatively variable. Manganese was detected over a large concentration range of 631 mg/kg to 3200 mg/kg (see Figure 4-10). Additionally, there is no known history of metals disposal at SWMU 2. However, because barium and manganese were retained as COPCs due to a lack of Region 5 EDQLs, they will be further evaluated in Step 3A of the BERA.

7.5.3 Surface Water

The majority of the drainage pathways were dry during the field investigation, which limited surface water sampling to one seep location (02SW07). The sample was analyzed for the total and dissolved metals fractions. Eight metals were detected in the total metals sample. Of these, only aluminum and iron were retained as COPCs because the detected concentrations exceeded the background concentrations and no Region 5 EDQLs are available for comparison. Five metals were detected in the dissolved metals sample. Of these, only iron was retained as a COPC because the detected concentration exceeded the background concentration and no EDQL is available for comparison. Because EDQLs are not available for aluminum and iron, EEQs are unable to be calculated. Due to the lack of additional surface water samples for comparison, aluminum and iron will be further evaluated against alternate values in Step 3A of the BERA.

7.5.4 Summary

In summary, a SERA was performed for SWMU 2. Based on the results of the collected data, adequate information exists to determine that potential risks are possible to receptors from exposure to the selected COPCs. Also, the samples were placed in areas where the contamination, if present, should be detected. The data is of adequate quality to make these determinations as outlined in Section 3.0. Therefore, the SERA is advancing to the Step 3A of the BERA – the refinement of the site-related COPCs.

7.6 STEP 3A – REFINEMENT OF THE SCREENING

Step 3A consists of refining the conservative exposure assumptions/concentrations when evaluating potential risks to ecological receptors (i.e., plants, invertebrates, and wildlife receptors) and re-evaluating the analytical data using benchmarks that may be more appropriate for the assessment endpoints. The objective of the Step 3A evaluation is to further reduce the number of chemicals retained as chemicals of concern (COCs), if possible, to focus any additional efforts on those chemicals causing ecological concern. The Step 3A evaluation is designed to eliminate chemicals from further evaluation for certain groups of receptors. For example, a chemical may not be retained as a COC in soil based on risks to soil invertebrates but may be retained for evaluating risks to plants or wildlife. Therefore, chemicals are evaluated during Step 3A in order of plants/invertebrates, aquatic receptors, and wildlife.

Surface Soil

Chemicals that were selected as COPCs in surface soil were carried through three independent flow paths: 1) to further evaluate risks to plants, 2) to further evaluate risks to invertebrates, and 3) to further evaluate risks to wildlife (i.e., mammals and birds). This further evaluation was conducted for copper to determine if there are potential risks to all three receptor groups (i.e., plants, invertebrates, and wildlife), or to only one or two of the receptor groups. This is important because if the site proceeds further in a BERA, the studies in the BERA should only focus on the receptors that are at potential risk. Because most of the Region 5 soil screening levels are based on risks to mammals or birds, potential risks to plants and invertebrates are not known. Therefore, the first step in the Step 3A evaluation was to compare the maximum copper chemical concentration in the soil to no-effects benchmarks for plants and invertebrates. The following bullets outline decisions that were made based on this comparison:

- If the concentration was less than the no-effects benchmark, it was concluded that the chemical is not causing an unacceptable risk to that receptor group and the chemical was not evaluated further in Step 3A.

- If the chemical concentration was greater than the no-effects benchmark (or the chemical did not have a no-effects benchmark), the chemical was further evaluated in Step 3A to determine if the risks are great enough to warrant additional evaluations [i.e., proceed to a BERA, develop cleanup levels, proceed to a corrective measures study (CMS), etc.].

Concurrent with the evaluation of risks to plants and invertebrates, copper was further evaluated to determine if unacceptable risks to wildlife exist. Even though the screening level for copper was based on risks to wildlife, risks to wildlife were further evaluated in Step 3A to calculate risks from copper under a more realistic exposure scenario. Copper was evaluated in the food chain modeling because it is included on the USEPA (2000) list of bioaccumulative chemicals. The following bullets outline decisions that were made based on the results of the food chain model:

- If the EEQ (see Section 7.3.2) was less than 1.0 using average contaminant concentrations and exposure factors and the No Observable Adverse Effects Level (NOAEL) as the TRV, it was concluded that the chemical is not causing an unacceptable risk to wildlife and the chemical was not evaluated further in Step 3A.

- If the EEQ was greater than 1.0 using average contaminant concentrations and exposure factors and the NOAEL as the TRV, the chemical was further evaluated in Step 3A to determine if the risks are

great enough to warrant additional evaluations [i.e., proceed to a BERA, develop cleanup levels, proceed to a corrective measures study (CMS), etc.].

For chemicals evaluated further in Step 3A, the factors described below were used to determine if the risks are great enough to warrant additional evaluations [i.e., proceed to a BERA, develop cleanup levels, proceed to a corrective measures study (CMS), etc.].

Sediment

Chemicals selected as COPCs in sediment were carried through two independent flow paths: 1) to further evaluate risks to invertebrates, and 2) to further evaluate risks to wildlife (i.e., mammals and birds). This further evaluation was conducted to determine if there were potential risks from that chemical to both receptor groups (i.e., invertebrates and wildlife), to only one of the receptor groups, or to neither of the receptor groups. This is important because if the site proceeds further in a BERA, the studies in the BERA should only focus on the receptors that are at potential risk. Because many of the Region 5 sediment screening levels are based on equilibrium partitioning, the maximum contaminant concentration were compared to an alternate lower effects level following the order of preference listed below (as applicable):

- USEPA (2003) Sediment Quality Benchmarks for dieldrin and endrin
- Consensus-Based Threshold Effect Concentrations (TECs) (MacDonald et al., 2000)
- Canadian Sediment Guidelines (OMOE, 1993) Lowest Effects Levels
- Canadian Environmental Quality Guidelines (EC, 2002)
- Long and Morgan (1991) Effects-Range Low
- Long et al., (1995) Effects-Range Low
- Ecotox Thresholds (USEPA, 1996) Sediment Quality Benchmarks
- Other values, as necessary and available

The following bullets outline decisions that were made based on this comparison:

- If the concentration was less than the lower-effects benchmark, it was concluded that the chemical was not causing an unacceptable risk to invertebrates and the chemical was not evaluated further in Step 3A.

- If the concentration was greater than the lower-effects benchmark, the chemical was further evaluated in Step 3A to determine if the risks are great enough to warrant additional evaluations [i.e., proceed to a BERA, develop cleanup levels, proceed to a corrective measures study (CMS), etc.].

Surface Water

Chemicals selected as COPCs in surface water were carried through two independent flow paths: 1) to further evaluate risks to aquatic organisms, and 2) to further evaluate risks to wildlife (i.e., mammals and birds). This further evaluation was conducted to determine if there are potential risks from that chemical to both receptor groups (i.e., invertebrates and wildlife), or to only one of the receptor groups. This was important because if the site proceeds further in a BERA, the studies in the BERA should only focus on the receptors that are at potential risk. Organic chemicals that were retained as COPCs were evaluated directly in Step 3A. Note that no organic chemicals were retained as COPCs in surface water; however, for metals, the following decisions were made:

- If the metal was either not detected in the filtered samples, or was detected at a concentration less than the screening level in the filtered samples, it was concluded that the chemical is not causing an unacceptable risk to aquatic organisms and the chemical was not evaluated further in Step 3A.

- If the metal was detected in the filtered samples at a concentration greater than the screening level, the chemical was evaluated further in Step 3A.

Other Step 3A Factors

For chemicals that were evaluated further in Step 3A, the following factors were evaluated, as appropriate, to determine if the risks are great enough to warrant additional evaluations [i.e., proceed to a BERA, develop cleanup levels, proceed to a corrective measures study (CMS)].

- Magnitude of criterion exceedance: Although the magnitude of the risks may not relate directly to the magnitude of a criterion exceedance, the magnitude of the criterion exceedance may be one item used in a lines-of-evidence approach to determine the need for further site evaluation. The greater the criterion exceedance, the greater the probability and concern that an unacceptable risk exists.

- Frequency of chemical detection and spatial distribution: A chemical detected at a low frequency typically is of less concern than a chemical detected at higher frequency if toxicity and concentrations

and spatial areas represented by the data are similar. All else being equal, chemicals detected frequently were 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 was considered when evaluating the exposures of receptors to site contaminants. Contaminants with generally less bioavailability are considered to be less toxic than the more bioavailable contaminants, all other factors being equal.

- Habitat: Although exceedances 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 was used qualitatively when considering additional evaluation. Areas with little habitat were less of a concern than areas with suitable habitat to support the receptors of interest.

- Alternate benchmarks: These benchmarks are used to further evaluate risks to specific groups of ecological receptors (e.g., plants, invertebrates) because while EDQLs are useful for initial screening they are the most conservative values available for soil and sediment evaluation. Use of alternate benchmarks ensures that more realistic exposure assumptions are evaluated. However, some of the alternate benchmarks are overly protective for some receptors and may not have been in some cases. For example, the EDQLs for soil may be based on risks to small mammals. Therefore, an exceedance of that EDQL does not necessarily indicate that potential risks to plants or invertebrates exist, so other more appropriate benchmarks were used to evaluate potential risks to those receptors. Use of these alternate benchmarks was case-specific.

In addition to the general Step 3A factors above, other factors were evaluated in Step 3A for each receptor group. The following sections discuss the other factors that may be used, including the specific alternate benchmarks that may be used in Step 3A.

Terrestrial Plants and Invertebrates: The alternate benchmarks that were used to further evaluate risks to plants and invertebrates are listed below. The ecological endpoint for the each benchmark that was used in this step was provided in the ERA. For example, if a benchmark is based on a 25% reduction in growth to a lettuce plant, that information was presented in the ERA.

- 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).

Additional sources of toxicity data from the literature may be used to evaluate potential risks to terrestrial vegetation and invertebrates from contaminants in the surface soil not evaluated in the above documents but no additional sources were used for this ERA.

Sediment: In addition to the Step 3A factors presented above, additional evaluations for sediment included comparing the chemical concentrations in the sediment to higher effects levels to show the probability of a range of possible effects. The higher effects levels that were used to further evaluate risks to benthic invertebrates was from the same sources listed in order of preference in the sediment subsection where a description of what the higher effects levels that are used in this step represent was provided in Section 7.6.1.2.

Surface Water: In addition to the Step 3A factors presented above, additional evaluations for surface water may include comparing the chemical concentrations in the surface water to acute water quality standards/criteria to show a range of possible effects. Also, emphasis was placed on average surface water concentrations because the aquatic organisms were exposed to average chemical concentrations as they swim in the water or the water flow over them (for organisms that are relatively sessile), although for SWMU 2 only one surface water sample was collected. Finally, more emphasis was placed on the dissolved metals concentrations (compared to total metals concentrations) because dissolved metals are a better indicator of potential bioavailability than are total recoverable metals.

7.6.1 Terrestrial Plants, Terrestrial and Aquatic Invertebrates, and Fish

Potential risks to terrestrial plants, terrestrial and aquatic invertebrates, and fish from exposure to COPCs were evaluated using the methodologies described above. The following subsections discuss whether chemicals that were initially retained as COPCs are further retained as final Chemicals of Concern (COCs) for terrestrial plants and invertebrates (Section 7.6.1.1) and sediment invertebrates (Section 7.6.1.2).

7.6.1.1 Terrestrial Plants and Invertebrates

Risks to terrestrial plants and invertebrates resulting from exposure to the COPCs are evaluated using the methodologies described above. Table 7-4 presents a summary of some of the common alternate benchmarks available for copper in surface soil, along with a summary of the Step 3A evaluation. Also, the toxicological basis of the alternate benchmarks is presented below as well. As presented in Table 7-1 several chemicals were eliminated as COPCs because they were not detected at concentrations greater than background concentrations. For soil, these chemicals included aluminum, antimony, arsenic, barium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, selenium, vanadium, and zinc. Therefore, risks to these chemicals were not evaluated in the ERA, however, any risks would be within background risks and not related to site activities.

Copper

Copper was retained as a COPC because the maximum soil concentration (11.8 mg/kg) exceeded the EDQL of 2.96 mg/kg and was statistically greater than background concentrations. However, because the EDQL is based on risks to small mammals, the following alternate benchmarks were used to further evaluate risks to plants and soil invertebrates:

- Canadian Soil Quality Guideline (SQG) – 63 mg/kg [Canadian Council of Ministers of the Environment (CCME), 1997]
- Oak Ridge National Laboratory (ORNL) Plant – 100 mg/kg (Efroymson et al., 1997a)
- ORNL Earthworm – 60 mg/kg (Efroymson et al., 1997b)

The copper Canadian SQG of 63 mg/kg is the 25th percentile of effects and no effects data distribution for plants and invertebrates, which is the 17th of 69 data points and corresponds to an effect on radish seedling emergence (CCME, 1997). Therefore, some studies showed effects below 63 mg/kg but many more studies did not show effects at this concentration. The Canadian SQG for copper is similar to the ORNL benchmarks for plants and invertebrates, which were developed using fewer plant studies than were used to develop the Canadian SQG.

The copper ORNL benchmark for plants (100 mg/kg) was based on toxicity data from three studies. Two of the studies resulted in reductions in root and shoot weights of little bluestem grown of sandy soil to

which 100 ppm copper (as copper sulfate) was added (Miles and Parker, 1979). The third study showed no effect on leaf and stem weights of bush beans grown in soil to which 100 ppm copper (as copper sulfate) was added, but leaf weight was reduced 26% when 200 ppm copper was added (Wallace et al., 1977). The copper ORNL benchmark for invertebrates (60 mg/kg) was based on toxicity data from 10 to 20 studies. The endpoints for most of the studies cited in Efroymson et al., (1997) are survival or reproduction (i.e., cocoon production, hatchling success). Because there were more than 10 studies the benchmark was based on a 10th percentile LOEC value. However, a review of the data in Appendix A.1 of Efroymson et al., (1997) shows that most of the studies cited in that document have NOECs that are greater than 60 mg/kg.

Copper concentrations below the Canadian SQG of 63 mg/kg are expected to be protective of plants and invertebrates. The copper sulfate, copper nitrate, and copper chloride that was used in the toxicity studies are likely to be much more bioavailable than the copper in the soils from the site. Also, as discussed above, although some studies had effects on plants and invertebrates at copper concentrations less than 63 mg/kg, the effects concentrations in many other studies were much greater than 63 mg/kg. Therefore, because the maximum detected copper concentration (11.8 mg/kg) is well below the Canadian SQG of 63 mg/kg, impacts to plants and invertebrates are not expected to occur from the levels of copper in the soil.

Although the site sample set was statistically greater than the background sample set, copper concentrations at the DBG site are within the range of background concentrations (5.4 - 17.1 mg/kg). Figure 4-1 shows a comparison of NSWC Crane background surface soil copper concentrations to DBG surface soil copper concentrations. All detected copper concentrations at the DBG are within the detected background range. This suggests that the DBG copper surface soil concentrations are a subset of NSWC Crane background surface soil concentrations and are probably not an indication of site-related contamination. The background soils were collected from several widely scattered areas throughout the nearly 100-square-mile NSWC Crane facility. The 12.4-acre DBG is a small fraction of the total background investigation area; therefore, it is quite plausible that the DBG could represent a subset of the overall base-wide background concentrations.

In summary, risks to plants and invertebrates from copper, the only COPC in surface soil at DBG, are acceptable. Copper is, therefore, eliminated as a COPC from further evaluation for risks to plants or invertebrates. Because copper is a bioaccumulative chemical, risks to wildlife from copper are evaluated in Section 7.6.2 of this ERA.

7.6.1.2 Sediment

Table 7-5 presents a summary of the common alternate benchmarks that were used in refining the list of COPCs in sediment, along with a summary of the Step 3A evaluation. As presented in Table 7-2, several chemicals were eliminated as COPCs because they were not detected at concentrations greater than background concentrations. For sediment, these chemicals included aluminum, antimony, arsenic, beryllium, cadmium, chromium, iron, lead, nickel, selenium, and vanadium. Risks to these chemicals were not evaluated in the ERA, however, any risks would be within background risks and not related to site activities.

Barium

Barium was retained as a COPC because no EDQLs are available and was statistically greater than site-specific background sediment concentrations. No alternate benchmarks are available for barium and so the other step 3A factors discussed above are considered.

It does not appear the barium is related to site activities for several reasons. Barium concentrations in the surface soil are statistically less than the background surface soil data set. The range of barium concentrations in the surface soil is 55 to 209 mg/kg, which encompassed the range of barium concentrations in the sediment. SWMU 2 is at the top of a ridge so the soil at the SWMU is the source of the sediment in the ditches. Because the barium in the soil is within background concentrations it is likely that the sediment in the ditches is within background concentrations, especially because the maximum barium concentration in the sediment (169 mg/kg) is lower that the maximum barium concentration in the soil. Also, the habitat in the drainage ditches is poor for aquatic receptors; the only location with surface water was a seep near a tributary to Little Sulphur Creek (by SD07). Although there is no toxicity data available to evaluate risks from barium in the sediment, the potential risks are acceptable because of the poor habitat of the drainage ditches and the likelihood that the barium is not related to site activities. Therefore, barium was eliminated as a COPC for risks to sediment invertebrates.

Manganese

Manganese was retained as a COPC because no EDQLs are available and was statistically greater than site-specific background sediment concentrations. Because an EDQL and consensus based TEC are not available for the screening, manganese concentrations are compared to the Canadian SQGs.

- Canadian Sediment Guidelines Lowest Effects Level (LEL) – 460 mg/kg (OMOE, 1993)
- Canadian Sediment Guidelines Severe Effects Level (SEL) – 1,100 mg/kg (OMOE, 1993)

The LEL indicates the level of sediment contamination which has no effect on and can be tolerated by the majority of sediment-dwelling organisms. The SEL indicates the level at which pronounced disturbance of the sediment-dwelling community can be expected. This level is considered heavily polluted and would be detrimental to the majority of sediment-dwelling organisms. The Canadian sediment guidelines were developed by first calculating the 90th percentile of the concentrations where a species was present, and then plotting the 90th percentile concentrations for all of the species that were used to develop the guideline. The 5th percentile of the plot was selected as the LEL and the 95th percentile from the plot was selected as the SEL for metals. All of the manganese detections are greater than the LEL and five of the seven detections are greater than the SEL.

Similarly to barium above, it does not appear the manganese is related to site activities for several reasons. Manganese concentrations in the surface soil are statistically less than the background surface soil data set. The range of manganese concentrations in the surface soil is 124 to 1800 mg/kg, which slightly lower than the range of manganese concentrations in the sediment. SWMU 2 is at the top of a ridge so the soil at the SWMU is the source of the sediment in the ditches. Because the manganese in the soil is within background concentrations it is likely that the sediment in the ditches is within background concentrations. The slightly higher concentrations in the sediment may be due to the samples being collected in depositional areas, where the fine sediment particles, which typically contain higher chemical concentrations, accumulate. Also, the habitat in the drainage ditches is poor for aquatic receptors; the only location with surface water was a seep near a tributary to Little Sulphur Creek (by SD07). Although several of the samples have manganese concentrations greater than the SEL, impacts to benthic invertebrates are not likely because the poor habitat would preclude their presence in the ditches. Therefore, because impacts to benthic invertebrates are not likely and because of the likelihood that the manganese is not related to site activities, risks from manganese are determined to be acceptable. Therefore, manganese was eliminated as a COPC for risks to sediment invertebrates.

Summary

In summary, barium and manganese were initially retained as COPCs in the sediment at the DBG; however, at the step 3A evaluation it was determined that risks to aquatic receptors by these chemicals is acceptable. Barium and manganese are, therefore, eliminated as COPCs from further evaluation for risks to aquatic receptors. Because barium and manganese are not considered to be important bioaccumulative chemicals (USEPA, 2000), food chain modeling for piscivorous wildlife exposed to these chemicals is not necessary.

7.6.1.3 Surface Water

Water-quality standards (WQS) for surface water have been developed for Indiana (IDEM, 1998). In addition, U.S. EPA has established water-quality criteria (WQC) for a few contaminants (U.S. EPA, April 1999). The Indiana WQS were reviewed as part of the Step 3A evaluation but were not used in the evaluation because the WQS are based on the U.S. EPA WQC, which were updated after the IDEM numbers were promulgated. Therefore, it is more appropriate to use the updated U.S. EPA WQC. All values are collectively referred to as surface water screening levels (SWSLs). As presented in Table 7-3, manganese was eliminated as a COPC because it was not detected at concentrations greater than background concentrations. Risk to manganese was not evaluated in the ERA, however, any risks would be within background risks and not related to site activities.

Aluminum

Aluminum was retained as a COPC because an EDQL was not available, and it was detected above the site-specific background concentration. The maximum aluminum detection of 523 µg/L in the unfiltered sample is greater than the chronic U.S. EPA AWQL of 87 µg/L, but is less than the acute U.S. EPA AWQL of 750 µg/L. Also, aluminum was not detected in the filtered surface water sample. Because dissolved metals are a better indicator of potential bioavailability than are total recoverable metals and because aluminum was not detected in the dissolved fraction it is not expected that aluminum in the surface water will cause a risk to aquatic organisms. Additionally, very little aquatic habitat, if any is present at the DBG because the only water present was in one seep sample. Therefore, risks from aluminum in surface water to aquatic receptors, when present, are expected to be negligible.

Iron

Iron was retained as a COPC in surface water samples because an EDQL was not available and concentrations were greater than the site-specific background concentration. However; the maximum detected iron concentration in both the unfiltered sample (874 µg/L) and filtered sample (140 µg/L) are below the U.S. EPA AWQC (U.S. EPA, 1999) for iron (1,000 µg/L). As mentioned previously, aquatic habitat at the DBG is poor, and is evidenced by the single seep sample. Therefore, iron is not expected to cause unacceptable risks to aquatic organisms.

Summary

In summary, aluminum and iron were initially retained as COPCs in the surface water at the DBG; however, at the step 3A evaluation it was determined that risks to aquatic receptors by these chemicals

are acceptable. Aluminum and iron are, therefore, eliminated as COPCs from further evaluation for risks to aquatic receptors. Because aluminum and iron are not considered to be important bioaccumulative chemicals (USEPA, 2000), food chain modeling for piscivorous wildlife exposed to these chemicals is not necessary.

7.6.2 Terrestrial Food Chain Modeling

The above-mentioned alternate benchmark values are not designed to evaluate risks to wildlife ingestion of soil, sediment, surface water, plants, invertebrates, and fish. Therefore, a terrestrial wildlife intake model is used to estimate the exposure of terrestrial receptors to the COPCs. However, COPCs that U.S. EPA does not consider to be bioaccumulative are not placed in the terrestrial food chain model (U.S. EPA, February 2000). The primary reason for including only bioaccumulative chemicals in the food chain model is based on the assumption that although wildlife can be exposed to chemicals that do not accumulate in food items (i.e., plants, invertebrates), via direct ingestion of the media (i.e., soil), the exposure of the animal consuming that chemical will be low if the chemical is not accumulating in the food item. Food chain modeling for the raccoon, kingfisher, and bat was not performed because none of the COPCs in the sediment (barium and manganese) and surface water (aluminum and iron) were considered to be bioaccumulative; therefore, food chain modeling is not appropriate for these chemicals.

Risk to terrestrial receptors from the COPCs in the soil, sediment, and surface water is determined by estimating the chronic daily intake (CDI) and comparing the CDI to TRVs representing acceptable daily doses in mg/kg/day. The TRVs are developed from NOAELs and lowest-observed-adverse-effect-levels (LOAELs) obtained from wildlife studies, if available. The majority of the TRVs are obtained from the ORNL Toxicological Benchmarks for Wildlife: 1996 Revision (Sample et al., 1996). Appendix H.3 presents the TRVs that are used in this report and the derivation of the TRVs using the body-weight scaling equation presented below. The appendix also presents the ecological endpoints for the TRVs.

For avian species, the NOAEL (or LOAEL) for the test species is 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 is adjusted to a NOAEL (or LOAEL) for the surrogate species using the following body-weight scaling equation from Sample et al. (1996):

$$NOAELw = NOAELt*(bwt/bww)$$

where:

NOAELw = no-observed-adverse-effect-level for the surrogate wildlife species

NOAELt = no-observed-adverse-effect-level for the test species

bwt = body weight of the test species

bww = body weight of the surrogate wildlife species

The body-weight scaling was performed 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, a scaling factor of 1.0 is used for birds in this SERA. Table H.2-1 in Appendix H.2 presents the body weights that are used for the surrogate and potential test species.

When a subchronic study is used to develop the TRV, the final value is multiplied by a factor of 0.1 to account for uncertainty between subchronic and chronic effects. Also, when a LOAEL study is used to develop the NOAEL TRV, the LOAEL is multiplied by a factor of 0.1 to obtain the NOAEL.

Total exposure of the terrestrial receptors to the COPCs in the soil was determined by estimating the daily doses in mg/kg-day using exposure equations. The contaminant concentrations in the surface soil are used to calculate the CDI doses. The following equation presents the food chain model that was used to estimate the contaminated dose to the surrogate species that were selected for the food chain model:

$$CDI = \frac{[(Cs * BAF * IR) + (Cs * Is)]H}{BW}$$

where:

CDI	=	Chronic Daily Intake (mg/kg-day)
Cs	=	Contaminant concentration in surface soil (mg/kg)
BAF	=	Bioaccumulation factor (unitless) (plant BAF for vole and quail models; invertebrate BAF for shrew and robin models)
IR	=	Ingestion Rate (kg/day)
Is	=	Rate of incidental surface soil ingestion or sediment (kg/day)
H	=	Contaminated area/home area range area ratio (unitless)
BW	=	Body weight (kg)

The food chain model was run using the following very conservative assumptions:

- 95 percent UCL soil concentration (or maximum when the UCL was greater than the maximum detection).
- Lowest receptor body weight.
- Conservative receptor ingestion rate (see Table H.2-2).
- Receptors spend 100 percent of their time at the site.

Normally, a second food chain model using less conservative assumptions (i.e., average soil concentrations, average receptor body weight and ingestion range, and consideration of the receptor's home range) is run. However, this was not necessary at SMWU 2 because of the low calculated risks under the very conservative scenario (see below for a summary of the food chain modeling results).

The exposure assumptions (i.e., ingestion rate, body weight) were obtained from the Wildlife Exposure Factors Handbook (U.S. EPA, December 1993), or other sources if necessary (see Table H.2-2 in Appendix H.2).

The EEQ for the terrestrial wildlife model were calculated as follows:

$$EEQ = \frac{CDI}{TRV}$$

where:

EEQ = Ecological Effects Quotient (unitless)
CDI = Chronic Daily Intake Dose (mg/kg-day)
TRV = Terrestrial Reference Value (NOAEL or LOAEL) (mg/kg-day)

Two terrestrial wildlife EEQs were calculated in the SERA to present the range of risks using the following: (1) $NOAEL_{max}$ (EEQ using maximum exposure and NOAEL), and (2) $LOAEL_{max}$ (EEQ using maximum exposure and LOAEL). The NOAEL was considered the most conservative because it was based on conservative assumptions and NOAEL toxicity values. The LOAEL was considered the least conservative because it was based on less conservative assumptions and LOAEL toxicity values.

Summary of food chain modeling

For the terrestrial receptors (vole, shrew, robin, and the quail), copper was the only COPC evaluated in the food chain model. None of the EEQs were greater than 1.0 using the NOAEL, maximum concentrations, and conservative exposure parameters for copper (Table 7-7); therefore, risks to terrestrial receptors are acceptable. The calculation of an average exposure scenario was not necessary. Appendix H.4 presents the back-up calculation sheets. Because EEQs were less than 1.0 using the most conservative scenario, risks to terrestrial receptors at the site from exposure to copper via the food chain are not expected. Copper is, therefore, eliminated as a COPC from further evaluation for risks to wildlife.

7.7 UNCERTAINTY ANALYSIS

Uncertainties are associated with most steps of an SERA, from selecting endpoints, collecting data, and evaluating toxicity to the receptors. The following sections describe some of the sources of uncertainty that may be associated with this SERA.

7.7.1 Endpoints

Measures of effects were used to evaluate the assessment endpoints that were selected for the SERA. For this SERA, the measures of effects were not the same as the assessment endpoints. Therefore, the measures were used to predict effects to the assessment endpoints by selecting surrogate species that were evaluated. For example, a decrease in reproduction of a robin is used to assess a decrease in the reproduction of the song bird population. However, predicting a decrease in reproduction to a robin may either under- or overprotect the song bird population resulting from differences in ingestion rates, toxicity, food preferences, etc. among different bird species.

Several endpoints were not quantitatively evaluated in this SERA. Risks to burrowing animals were not quantitatively evaluated because the methods for quantifying risks to these species have not been well developed. In addition, risks to reptiles and amphibians were not evaluated because exposure factors are not established for most species, and toxicity data are very limited (see below for a discussion of potential risks to the timber rattlesnake).

There are also uncertainties for potential risks to protected species (i.e., endangered, threatened, or species of special concern) at the site because risks to those species were not specifically evaluated in the ERA. Risks to these species were not specifically calculated so the uncertainties of not calculating risks to these species are presented here. Risks to these species were considered qualitatively, however, using surrogate receptor species. An Endangered Species Management Plan for NSWC Crane

was prepared in October 2000 (Comarco Systems, Inc. 2000). As part of this plan, the federal and state endangered, threatened, and species of special concern for the facility were identified as described in Section 1.4.7 of this report. Several birds, mammals, and one reptile are listed species that are present at NSWC Crane. Of the mammals, the risks to the Indiana bat were concluded to be negligible because none of the COPCs in the sediment and surface water were considered to be bioaccumulative; therefore, food chain modeling was not conducted for this species. Risks to the bobcat from contaminants at SWMU 2 also are expected to be negligible because of the general absence of bioaccumulative chemicals detected in the surface soil at the site (only copper) and the large home range of the bobcat versus the small size of the site. Risks to large carnivorous mammals and birds are expected to be negligible so risks to the bobcat, bald eagle, Northern harrier, and osprey are expected to be negligible.

Of the birds, there is a potential that some of them may be present in the area around SMWU 2, because of the open grass area at the site and/or the wooded area surrounding the SWMU. However, based on the most conservative food chain model (maximum exposure parameters and the NOAEL as the TRV), adverse risks to herbivorous and carnivorous (insectivorous) birds were not expected. Loggerhead shrikes and the sedge wren consume mostly aboveground insects such as caterpillars, beetles, spiders, and flies, as opposed to the worms that are consumed by the American robin in the food-chain model. Because worms are in direct contact with exposure to the soil, it is expected that they would have greater levels of contaminants at SWMU 2 than aboveground insects; therefore, risks to the robin from consuming worms are expected to be greater than risks to the loggerhead shrike and sedge wren from consuming aboveground insects. Risks to the worm eating American robin from chemicals in the surface soil and surface water were determined to be low; therefore, risks to the loggerhead shrike and sedge wren also are expected to be even lower than risks to robins. The American bittern is a marshland loving bird that feeds on fish, frogs, eels, insects, and water snakes. Because there is very little aquatic habitat present at SWMU 2, the presence of the American bittern is unlikely. Therefore, no risks to the listed birds from contaminants at SWMU 2 would be expected.

Finally, there are uncertainties in risks to reptiles because there is a lack of exposure factors for reptiles and a lack of reptile toxicity data for the detected chemicals. As discussed in Section 1.4.7.1, one threatened reptilian species is listed as potentially present at NSWC Crane. Based on the preferred habitat of the timber rattlesnake and the ecology of SWMU 2, this species may potentially inhabit areas of SWMU 2. Risks to these species were not specifically calculated so uncertainties exist as to how this species would be affected if an exposure to site chemical concentrations occurred. However, because copper was the only bioaccumulative chemical retained as a COPC in the soil, and because it was detected at similar concentrations to background, risks to the timber rattlesnake from chemicals related to SWMU 2 are not expected.

7.7.2 Exposure Characterization

The contaminant dose to terrestrial wildlife was calculated using an equation that incorporates ingestion rates, body weights, BAFs, and other exposure factors. These exposure factors were obtained from literature studies or predicted using various equations. Ingestion rates and body weights vary among species, especially among 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 (U.S. EPA, December 1993). Therefore, there is uncertainty in applying exposure factors from the literature to the species at NSWC Crane.

Bioaccumulation of contaminants into various biological media (i.e., plants and invertebrates) depends on characteristics of the media such as pH, organic carbon, etc. Therefore, actual BAFs at the site may be different than those used in the SERA, which were obtained from the literature.

There is uncertainty in the chemical data collected at the site. Sampling programs are frequently biased toward locations that have a higher expectation of being contaminated. Therefore, the concentrations do not actually represent the site, but they represent the higher concentrations at a site. As such, predicted exposure doses were probably higher than actual exposure doses.

Under the conservative scenario, terrestrial wildlife are assumed to live and feed only at the site or only in the portion of a water body affected by 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. Risk also may be overpredicted in the average scenario, where home range is taken into account, because of the biased sampling in the most contaminated areas.

Surface soil was collected from the 0' to 2' bgs depth interval. These samples were divided into two aliquots. Samples to be analyzed for dye parameters were collected from the 0' to 2' interval and samples for inorganic parameters were collected from the 0' to 1' interval. Background surface soil data were collected from 0' to 1' bgs depth interval as a compromise depth for all NSWC Crane projects for which a variety of surface soil depths may be used. There is uncertainty in this approach depending on the source of contamination, how it was disposed at the site (i.e., buried), and the subsequent degradation of the buried materials because the two different depth intervals represent slightly different soil populations. However, the uncertainty was not viewed to be unacceptably large given all of the other uncertainties associated with environmental investigations.

As presented in Section 3.3.3, the dye results for three sediment samples and one surface soil sample were rejected. No dyes were detected in any of the other four sediment or 12 soil samples. In the samples with the rejected dye data, it is not likely that dyes would have been present at significant concentrations, because these samples were collected either in close proximity (soil) or downgradient (sediment) of samples where dyes were not detected. Therefore, the uncertainty in not having dye data from these locations is not expected to adversely impact the conclusions of the risk assessment.

7.7.3 Ecological Effects Data

Table 3-5 presents the reporting limits versus the EDQLs. As seen on the table, several of the metals have maximum reporting limits that are greater than the EDQLs. This is not expected to significantly impact the conclusions of the risk assessment for several reasons. Several of the metals with reporting limits greater than the EDQLs were detected at greater concentrations in other soil or sediment samples and were determined to be below background levels. Also, although the reporting limits are greater than the EDQLs, they are lower than alternate benchmarks that are typically used to determine if a chemical needs to be further evaluated.

There is uncertainty in the ecological toxicity values. The AWQC developed by the U.S. EPA in theory protect 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 SWSLs are overpredictive of risk if the sensitive species used to develop the criteria are not present. 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 in the sediment to screening values. 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 values 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 sulfide, TOC) also will have a large impact on the bioavailability and toxicity of constituents. Finally, screening values based on equilibrium partitioning have uncertainty associated with log K_{ow} values: the assumed relationship between K_{ow} and K_{oc}, and the assumption that pore water exposure is the most important route for sediment-dwelling organisms. There is also uncertainty in applying the SSLs to the sediment in the drainage ditches because of their limited potential for significant aquatic populations.

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 values. The SSSLs are similar to the sediment screening values in that they are less established than the SWSLs. Fewer studies and less 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 end points depending on the preference of the agency that developed them. Therefore, they have more uncertainty than surface water and sediment screening levels.

The NOAELS and LOAELs that were selected for the wildlife endpoint species likely 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.

As discussed in Section 7.3.2, EEQs of greater than 1.0 were considered to be indicative of potential risk. However, such values do not necessarily indicate that an effect will occur but only that ecological effects are possible because a lower threshold has been exceeded. There are uncertainties in the calculated EEQs based on inherent uncertainties associated with the screening values and their derivation and the NOAELs (see above). The confidence in the EEQs is therefore directly related to the confidence in the exposure concentrations and NOAELs that are used to calculate the EEQ exceedances.

The toxicity of chemical mixtures is not well understood. All the toxicity information used in the SERA 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.

7.7.4 Risk Characterization

Unacceptable risks are possible if an EEQ is greater than or equal to 1.0. 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.

7.8 ECOLOGICAL RISK SUMMARY AND CONCLUSIONS

An ERA was performed for SWMU 2, the DBG. Surface water was only present at one seep location during the sampling event; no surface water was present at any of the stream/drainage ditch locations. Because the drainage channels are dry most of the year, the habitat for aquatic receptors is poor.

Only copper was retained as a surface soil COPC after the initial screening, while two metals (barium and manganese) were retained as sediment COPCs and two metals (aluminum and iron) were retained as surface water COPCs after the initial screening in Step 2. Based on the re-evaluation in Step 3A, it was determined that surface soil COPCs at the 12-acre DBG site pose acceptable risks to terrestrial ecological receptors, so all chemicals were eliminated as COPCs in surface soil for further evaluation regarding risks to plants and invertebrates. Similarly, based on the re-evaluation in Step 3A it was determined that sediment and surface water COPC concentrations pose acceptable risks to ecological receptors, so all chemicals were eliminated as COPCs in sediment and surface water for further evaluation regarding risks to sediment invertebrates. Finally, risks to wildlife from exposure to copper concentrations were acceptable so copper was eliminated as a COPC in surface soil for further evaluation regarding risks to mammals or birds.

TABLE 7-1

ECOLOGICAL RISK SCREENING - SURFACE SOIL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical	Frequency of Detection (1)	Minimum Concentration (1)	Maximum Concentration (1)	Location of Maximum Concentration	Average of All Results	Site Above Background Concentration?	Surface Soil COPC Screening Level (2)	Ecologcial Effects Quotient (3)	Retained as COPC?	Rationale for Contaminant Deletion or Selection(4)
Inorganics (MG/KG)										
ALUMINUM	13/13	7750	12500	02SS200001	9964	NO	NA	NA	NO	BKG
ANTIMONY	4/13	0.45	0.5	02SS090002	0.30	NO	0.1423	3.51	NO	BKG
ARSENIC	13/13	2.6	8.4 J	02SS200001	5.5	NO	5.7	1.47	NO	BKG
BARIUM	13/13	55	209	02SS160001	102	NO	1.04	201	NO	BKG
BERYLLIUM	3/13	0.56	0.85	02SS100002	0.93	YES	1.06	0.80	NO	BSL
CADMIUM	4/13	0.43 J	0.62	02SS160001	0.31	NO	0.00222	279	NO	BKG
CALCIUM	12/13	842	15400 J	02SS200001	5634	YES	NA	NA	NO	NT
CHROMIUM	13/13	9.9	40.8	02SS190001	14.9	NO	NA	NA	NO	BKG
COBALT	13/13	3.9	19	02SS160001	9.4	NO	0.14033	135	NO	BKG
COPPER	13/13	8	11.8	02SS200001	9.6	YES	2.96	3.99	YES	ASL
IRON	13/13	11400	23500	02SS110001	16554	NO	NA	NA	NO	BKG
LEAD	13/13	9.3	184 J	02SS190001	27.1	NO	0.05373	3425	NO	BKG
MAGNESIUM	13/13	1080	3310	02SS050001	1745	YES	NA	NA	NO	NT
MANGANESE	13/13	124	1800	02SS160001	834	NO	NA	NA	NO	BKG
MERCURY	12/13	0.02 J	0.05 J	02SS200001, 02SS160001, 02SS190001	0.035	NO	0.073	0.68	NO	BSL
NICKEL	13/13	6.6	15	02SS160001	10.4	NO	13.6	1.10	NO	BKG
POTASSIUM	12/13	547 J	892 J	02SS190001	643	NO	NA	NA	NO	NT
SELENIUM	6/13	0.52	0.7	02SS100002	0.40	NO	0.02765	25.32	NO	BKG
VANADIUM	13/13	18.6 J	25.9 J	02SS040001	22.0	NO	1.59	16.29	NO	BKG
ZINC	13/13	15.9 J	50.2 J	02SS190001	35.3	NO	6.62	7.58	NO	BKG

Shaded chemical was selected as a COPC.

Footnotes:
1 Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 As presented in Table 3.5.
3 The maximum detected concentration was used for screening purposes and for calculation of Ecological Effects Quotients (see Section 7.3.2).
4 Rationale Codes:
For Selection as a COPC:
ASL = Above COPC screening level.

For Elimination as a COPC:
BKG = Below background level.
BSL = Below COPC screening level.
NT = Nontoxic.

Definitions:
COPC = Chemical of potential concern.
NA = Not available.

TABLE 7-2

ECOLOGICAL RISK SCREENING - SEDIMENT
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical	Frequency of Detection (1)	Minimum Concentration (1)	Maximum Concentration (1)	Location of Maximum Concentration	Average of All Results	Site Above Background Concentration?	Sediment COPC Screening Level (2)	Ecological Effects Quotient (3)	Retained as COPC?	Rationale for Contaminant Deletion or Selection(4)
Inorganics (MG/KG)										
ALUMINUM	7/7	4580	10300	02SD010006	7776	NO	NA	NA	NO	BKG
ANTIMONY	2/7	0.74	0.74	02SD030006, 02SD010006	0.40	NO	NA	NA	NO	BKG
ARSENIC	7/7	5.6	11 J	02SD010006	7.9	NO	5.9	1.86	NO	BKG
BARIUM	7/7	87.6	169	02SD040006	137	YES	NA	NA	YES	NTX
BERYLLIUM	2/7	0.54	1.2	02SD010006	1.21	NO	NA	NA	NO	BKG
CADMIUM	4/7	0.55	0.69	02SD040006	0.46	NO	0.596	1.16	NO	BKG
CALCIUM	7/7	873	2550	02SD070006	1464	NO	NA	NA	NO	NT
CHROMIUM	7/7	11.3	30.1	02SD050006	19.9	NO	NA	NA	NO	BKG
COBALT	7/7	8.4	29.5	02SD050006	19.5	NO	50	0.59	NO	BSL,BKG
COPPER	7/7	8.4	9.6	02SD070006	9.07	NO	16	0.60	NO	BSL,BKG
IRON	7/7	14200	38700	02SD050006	25629	NO	NA	NA	NO	BKG
LEAD	7/7	17.6	33.4	02SD010006	25.5	NO	31	1.08	NO	BKG
MAGNESIUM	7/7	760	1120	02SD020006	961	NO	NA	NA	NO	NT
MANGANESE	7/7	631	3200	02SD010006	1839	YES	NA	NA	YES	NTX
MERCURY	6/7	0.04	0.06 J	02SD020006	0.05	NO	0.174	0.34	NO	BSL,BKG
NICKEL	7/7	7.9	41.8	02SD040006	19.2	NO	16	2.61	NO	BKG
POTASSIUM	5/7	511	830	02SD070006	515	NO	NA	NA	NO	NT
SELENIUM	3/7	0.5 J	0.65 J	02SD020006	0.40	NO	NA	NA	NO	BKG
VANADIUM	7/7	14.9	37.7	02SD050006	27.2	NO	NA	NA	NO	BKG
ZINC	7/7	30 J	47.1	02SD070006	39.7	NO	120	0.39	NO	BSL,BKG

Shaded chemicals were selected as COPCs.

Definitions:
COPC = Chemical of potential concern.
NA = Not available.

Footnotes:
1 Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 As presented in Table 3-5.
3 The maximum detected concentration was used for screening purposes and for calculation of Ecological Effects Quotients (see Section 7.3.2).
4 Rationale Codes:
For Selection as a COPC:
NTX = No toxicity information available.

For Elimination as a COPC:
BSL = Below COPC screening level.
NT = Nontoxic.
BKG - Below background concentration.

TABLE 7-3

ECOLOGICAL RISK SCREENING - SURFACE WATER
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA

Chemical	Frequency of Detection [1]	Minimum Concentration [1]	Maximum Concentration [1]	Location of Maximum Concentration	Average of All Results	Site Above Background Concentration?	Surface Water COPC Screening Level [2]	Ecological Effects Quotient [3]	Reatained as COPC?	Rationale for Contaminant Deletion or Selection[4]
Total Metals (UG/L)										
ALUMINUM	1/1	523	523	02SW0701	523	YES	NA	NA	YES	NTX
ARSENIC	1/1	0.41	0.41	02SW0701	0.41	YES	53	0.008	NO	BSL
BARIUM	1/1	78	78	02SW0701	78	YES	5000	0.016	NO	BSL
CALCIUM	1/1	49700	49700	02SW0701	49700	YES	NA	NA	NO	NT
IRON	1/1	874 J	874 J	02SW0701	874	YES	NA	NA	YES	NTX
MAGNESIUM	1/1	11700	11700	02SW0701	11700	YES	NA	NA	NO	NT
MANGANESE	1/1	43.4	43.4	02SW0701	43.4	NO	NA	NA	NO	BKG
SODIUM	1/1	11500	11500	02SW0701	11500	YES	NA	NA	NO	NT
Dissolved Metals (UG/L)										
BARIUM, FILTERED	1/1	74.1	74.1	02SW0701-F	74.1	YES	5000	0.015	NO	BSL
CALCIUM, FILTERED	1/1	51500	51500	02SW0701-F	51500	YES	NA	NA	NO	NT
IRON, FILTERED	1/1	140 J	140 J	02SW0701-F	140	YES	NA	NA	YES	NTX
MAGNESIUM, FILTERED	1/1	12400	12400	02SW0701-F	12400	YES	NA	NA	NO	NT
SODIUM, FILTERED	1/1	12200	12200	02SW0701-F	12200	YES	NA	NA	NO	NT
Miscellaneous Parameters (UG/L)										
HARDNESS	1/1	170	170	02SW0701	170	---	NA	NA	NO	NT
TOTAL ORGANIC CARBON	1/1	3.7	3.7	02SW0701	3.7	---	NA	NA	NO	NT
TOTAL SUSPENDED SOLIDS	1/1	13 J	13 J	02SW0701	13	---	NA	NA	NO	NT

Shaded chemicals were selected as COPCs.

Footnotes:
1 Only the original of duplicate samples was considered for COPC selection. The duplicate was used for quality control purposes only.
2 As presented in Table 3-6.
3 The maximum detected concentration was used for screening purposes and for calculation of Ecological Effects Quotients (see Section 7.3.2).
4 Rationale Codes:
For Selection as a COPC:
NTX = No toxicity information available.

For Elimination as a COPC:
BSL = Below COPC screening level.
NT = Nontoxic.
BKG = Below background concentration.

Definitions:
COPC = Chemical of potential concern.
NA = Not available.

TABLE 7-4

STEP 3A EVALUATION FOR RISKS TO PLANTS AND INVERTEBRATES
SURFACE SOIL COPCs
SWMU 02 - DYE BURIAL GROUND
NSWC CRANE
CRANE, INDIANA

Chemical	FOD	Maximum Detection (mg/kg)	Screening Level (mg/kg)	Max. EEQ[1]	Number of Samples > Screening Level[2]	Step 3a Evaluation						Risk Determination (Acceptable/ Unacceptable)	Retained as a COC?
						Alternate Benchmarks					Other Step 3a Factors Considered in Evaluation[3]		
						Eco SSL		ORNL Benchmarks		Canadian SQG			
						Plant	Earthworm	Plant	Earthworm				
Copper	13/13	11.8	2.96	4.0	13	NA	NA	100	60	63	- Maximum detection well below all alternate benchmarks - Site concentrations are within background concentration range (5.4 to 17.1 mg/kg)	Acceptable	No

1 - Maximum EEQ = Maximum detection divided by the screening level
2 - Number of samples with concentrations greater than the screening level
3 - See section 7.6.1.1 for a more detailed Step 3a evaluation

EEQ - Ecological Effects Quotient
FOD - Frequency of Detection
NA - Not available or not applicable
SQG - Soil Quality Guideline

TABLE 7-5

STEP 3A EVALUATION FOR RISKS TO BENTHIC ORGANISMS
SEDIMENT COPCs
SWMU 02 - DYE BURIAL GROUND
NSWC CRANE
CRANE, INDIANA

Chemical	FOD	Maximum Detection ug/kg)	Screening Level (ug/kg)	Max. EEQ[1]	Number of Samples > Screening Level[2]	Step 3a Evaluation			Risk Determination (Acceptable/ Unacceptable)	Retained as a COC?
						Alternate Benchmarks Canadian SQG				
						LEL (ug/kg)	SEL (ug/kg)	Other Step 3a Factors Considered in Evaluation[3]		
Barium	7/7	169	NA	NA	NA	NA	NA	- Little aquatic habitat - Site soil concentrations are within background soil concentration range (55 to 209 mg/kg)	Acceptable	No
Manganese	7/7	3200	NA	NA	NA	460	1,100	- Little aquatic habitat - Site soil concentrations are within background soil concentration range (124 to 1800 mg/kg)	Acceptable	No

1 - Maximum EEQ = Maximum detection divided by the screening level
2 - Number of samples with concentrations greater than the screening level
3 - See section 7.6.1.2 for a more detailed Step 3a evaluation

EEQ - Ecological Effects Quotient
FOD - Frequency of Detection
NA - Not available or not applicable

TABLE 7-6

STEP 3A EVALUATION FOR RISKS TO BENTHIC ORGANISMS
SURFACE WATER COPCs
SWMU 02 - DYE BURIAL GROUND
NSWC CRANE
CRANE, INDIANA

Chemical	FOD	Maximum Detection (ug/L)	Screening Level (ug/L)	Max. EEQ[1]	Number of Samples > Screening Level[2]	Step 3a Evaluation			Risk Determination (Acceptable/ Unacceptable)	Retained as a COC?
						Alternate Benchmarks AWQC				
						Chronic (ug/L)	Acute (ug/L)	Other Step 3a Factors Considered in Evaluation[3]		
Aluminum	1/1	523	NA	NA	NA	87	750	- Not detected in filtered samples, which represents the most bioavailable portion of the chemical in water - Sample collected from a seep; little aquatic habitat	Acceptable	No
Iron	1/1	874	NA	NA	NA	1,000	NA	- Maximum detection below AWQC - Sample collected from a seep; little aquatic habitat	Acceptable	No
Iron, filtered	1/1	140	NA	NA	NA	1,000	NA	- Maximum detection below AWQC - Sample collected from a seep; little aquatic habitat	Acceptable	No

1 - Maximum EEQ = Maximum detection divided by the screening level
2 - Number of samples with concentrations greater than the screening level
3 - See section 7.6.1.3 for a more detailed Step 3a evaluation

EEQ - Ecological Effects Quotient
FOD - Frequency of Detection
NA - Not available or not applicable

TABLE 7-7

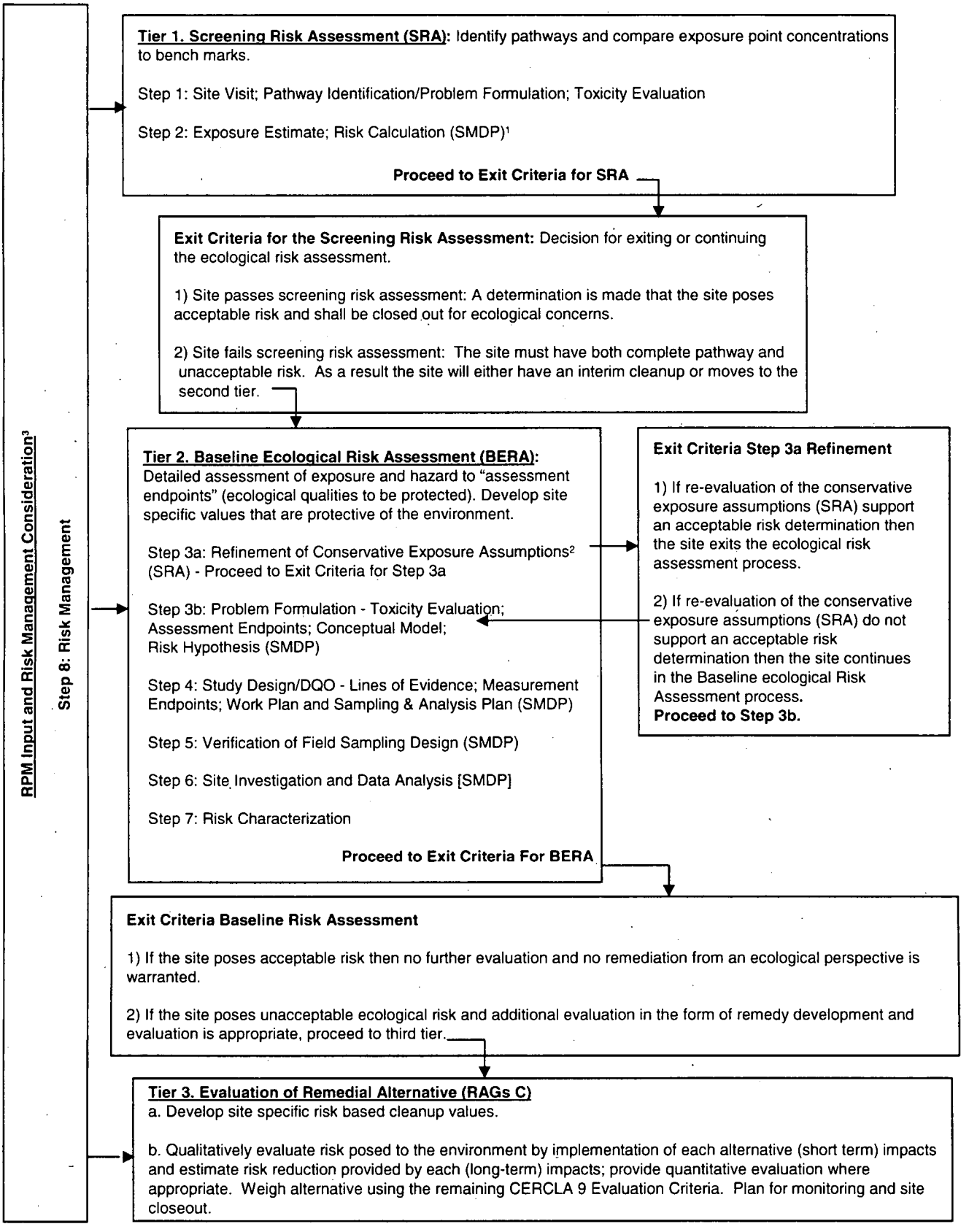
TERRESTRIAL WILDLIFE MODEL-MAXIMUM EEQS
SWMU 2 - DYE BURIAL GROUND
NSWC CRANE
CRANE, INDIANA

Parameter	Meadow Vole EEQ_{NOAEL}	Meadow Vole EEQ_{LOAEL}	Short-Tailed Shrew EEQ_{NOAEL}	Short-Tailed Shrew EEQ_{LOAEL}	American Robin EEQ_{NOAEL}	American Robin EEQ_{LOAEL}	N. Bobwhite Quail EEQ_{NOAEL}	N. Bobwhite Quail EEQ_{LOAEL}
Inorganics								
COPPER	2.8E-03	2.2E-03	6.7E-03	5.2E-03	1.2E-01	9.2E-02	5.9E-03	4.5E-03

Notes:
EEQ - Ecological Effects Quotient
NOAEL - No Observed Adverse Effects Level
LOAEL - Lowest Observed Adverse Effects Level

FIGURE 7-1

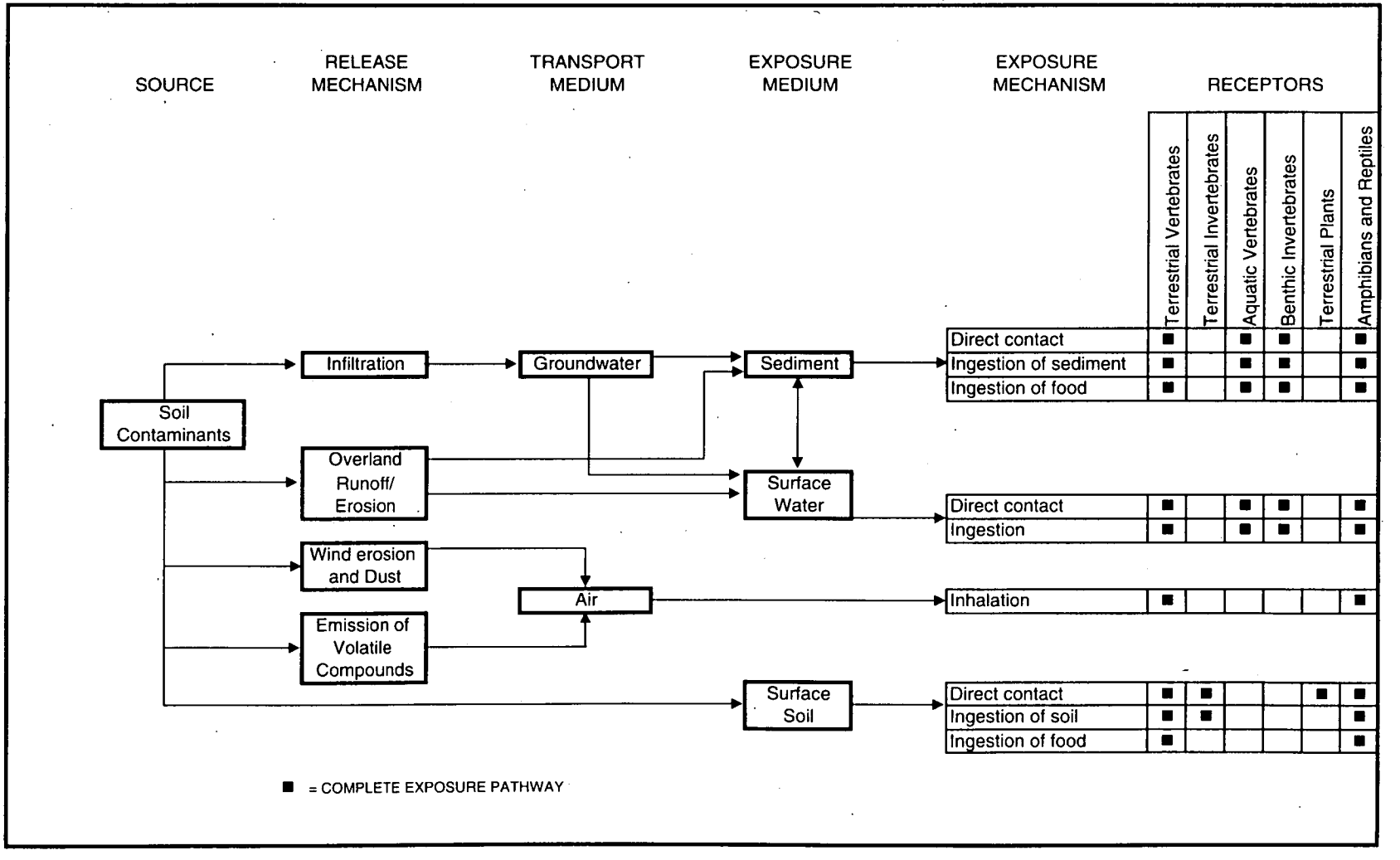
THE NAVY'S ECOLOGICAL RISK ASSESSMENT TIERED APPROACH



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 7-2

ECOLOGICAL CONCEPTUAL SITE MODEL
SWMU 2 - DYE BURIAL GROUNDS
NSWC CRANE
CRANE, INDIANA



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