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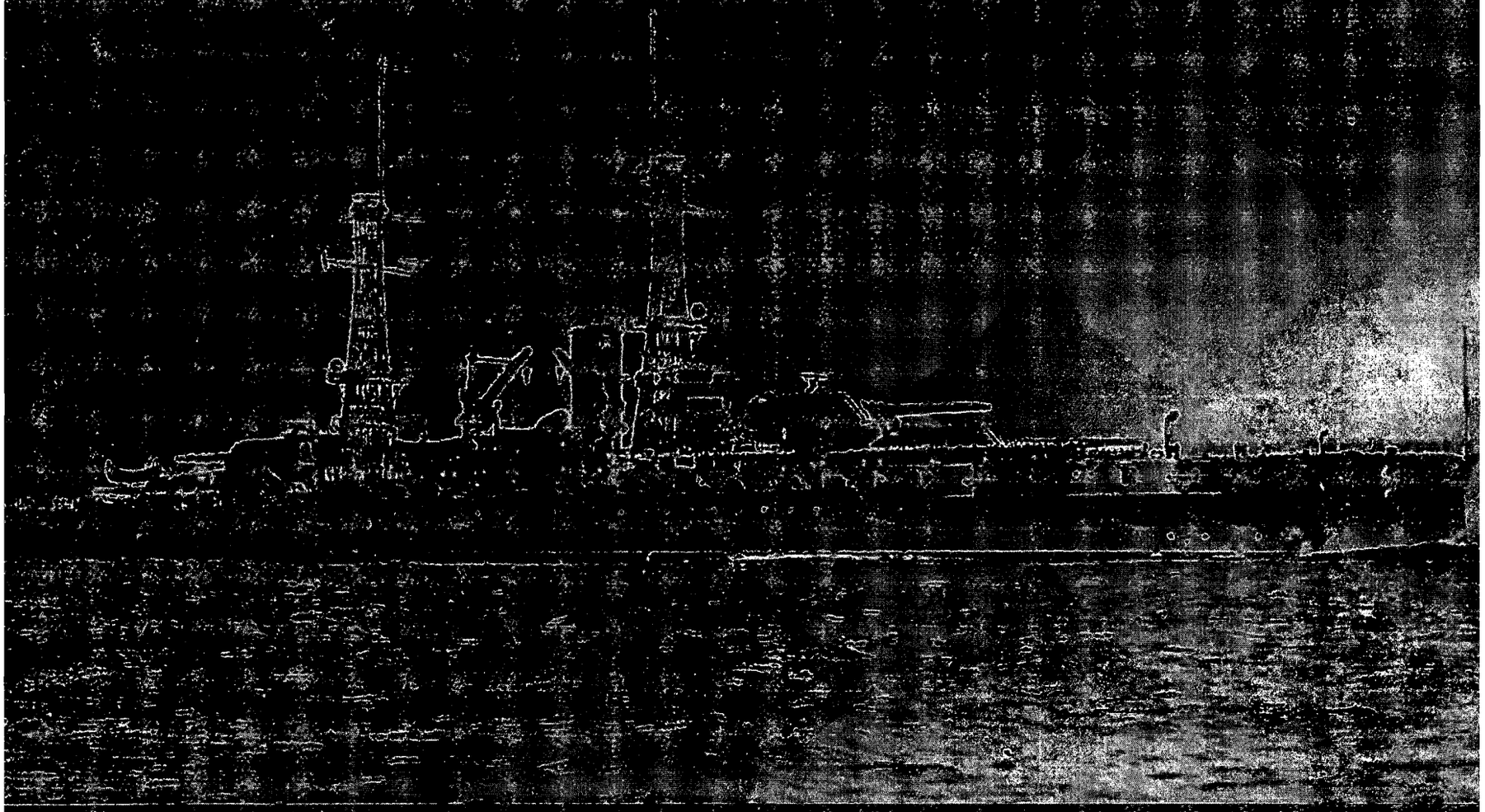
Water Area Munitions Study

Lake Greenwood Pyro Test Area Near Dam

Naval Surface Warfare Center
Crane Division, Indiana

April 2005



FINAL
WATER AREA MUNITIONS STUDY
LAKE GREENWOOD PYRO TEST AREA NEAR DAM
NAVAL SURFACE WARFARE CENTER
CRANE DIVISION, INDIANA

April 2005

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LAKE GREENWOOD PYRO TEST AREA NEAR DAM
NAVAL SURFACE WARFARE CENTER
CRANE DIVISION, INDIANA

DoD Contract Number: N62472-02-D-1300

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April 2005

Table of Contents

ACRONYMS I
GLOSSARY OF TERMS III
EXECUTIVE SUMMARY ES-1
1. INTRODUCTION 1-1
1.1. PURPOSE 1-2
1.2. PROJECT MANAGEMENT 1-2
1.3. WATER AREA MUNITIONS STUDY APPROACH 1-2
2. INSTALLATION BACKGROUND 2-1
2.1. LOCATION AND SETTING 2-1
2.2. INSTALLATION HISTORY 2-3
2.3. MUNITIONS RELATED TRAINING / STORAGE / USAGE 2-4
3. PHYSICAL AND ENVIRONMENTAL CHARACTERISTICS 3-1
3.1. CLIMATE 3-1
3.2. TOPOGRAPHY 3-1
3.3. GEOLOGY 3-1
3.4. SOIL AND VEGETATION TYPES 3-2
3.5. HYDROLOGY 3-3
3.6. HYDROGEOLOGY 3-3
3.7. CULTURAL AND NATURAL RESOURCES 3-4
3.8. ENDANGERED AND SPECIAL STATUS SPECIES 3-5
4. SUMMARY OF DATA COLLECTION EFFORT 4-1
4.1. HISTORICAL ARCHIVE REPOSITORIES (OFF-SITE) 4-1
4.2. PERSONAL INTERVIEWS 4-4
4.3. ON-SITE DATA REPOSITORIES 4-6
4.4. VISUAL SURVEY 4-7
4.5. OFF-SITE DATA SOURCES 4-7
5. SITE CHARACTERISTICS 5-1
5.1. HISTORY AND SITE DESCRIPTION 5-1
5.1.1. Topography 5-4
5.1.2. Geology 5-4
5.1.3. Soil and Vegetation Types 5-4
5.1.4. Hydrology 5-5
5.1.5. Hydrogeology 5-5
5.1.6. Cultural and Natural Resources 5-5
5.1.7. Endangered and Special Status Species 5-1
5.2. VISUAL SURVEY OBSERVATIONS AND RESULTS 5-1
5.3. MUNITIONS AND MUNITIONS RELATED MATERIALS ASSOCIATED WITH THE SITE 5-2
5.4. MEC PRESENCE 5-4
5.4.1. Known MEC Areas 5-4

5.4.2. Suspected MEC Areas *5-4*
5.4.3. Areas Not Suspected to Contain MEC *5-5*
5.5. ORDNANCE PENETRATION ESTIMATES **5-5**
5.6. MUNITIONS CONSTITUENTS **5-5**
5.7. CONTAMINANT MIGRATION ROUTES **5-6**
5.8. RECEPTORS **5-7**
5.8.1. Nearby Populations *5-7*
5.8.2. Buildings Near/Within Site *5-8*
5.8.3. Utilities On/Near Site *5-8*
5.9. LAND USE **5-8**
5.10. ACCESS CONTROLS / RESTRICTIONS **5-8**
5.11. CONCEPTUAL SITE MODEL **5-8**
5.12. SUMMARY **5-19**

APPENDICES

Appendix A: References

Appendix B: Project Source Data-General

Appendix C: Project Source Data – Site Specific

Appendix D: Ordnance Technical Data Sheets

MAPS

MAP 2-1: AREA LOCATION MEC SITE: LAKE GREENWOOD PYRO TEST AREA NEAR DAM 2-2

MAP 5-1: VISUAL SURVEY: LAKE GREENWOOD PYRO TEST AREA NEAR DAM .. 5-20

MAP 5-2: RANGE/SITE DETAILS: LAKE GREENWOOD PYRO TEST AREA NEAR DAM5-21

MAP 5-3: MUNITIONS CHARACTERIZATION: LAKE GREENWOOD PYRO TEST AREA NEAR DAM 5-22

FIGURES

FIGURE 5.1-1: CURRENT VIEW OF LAKE GREENWOOD FROM OFFICER'S CLUB ... 5-2

FIGURE 5.1-2: CURRENT VIEW OF LAKE GREENWOOD LOOKING EAST FROM ATOP DAM ... 5-3

FIGURE 5.1-3: NORTH END OF DAM AT LAKE GREENWOOD'S WESTERN SHORE. 5-3

FIGURE 5.11-1: MEC EXPOSURE PATHWAY ANALYSIS ... 5-15

FIGURE 5.11-2: MC EXPOSURE PATHWAY ANALYSIS ... 5-16

FIGURE 5.11-3: GRAPHICAL ILLUSTRATION: LAKE GREENWOOD PYRO AREA NEAR DAM ... 5-17

FIGURE 5.11-4: GRAPHICAL ILLUSTRATION: LAKE GREENWOOD OFFICER'S CLUB TEST AREA ... 5-18

TABLES

TABLE 2.2-1: HISTORY OF NSWC CRANE ... 2-3

TABLE 3.8-1: SUMMARY OF KNOWN OR POTENTIAL PROTECTED SPECIES ... 3-5

TABLE 5.3-1: PYROTECHNICS AND ASSOCIATED HAZARDS ... 5-4

TABLE 5.11-1: CONCEPTUAL SITE MODEL INFORMATION PROFILES – LAKE GREENWOOD PYRO TEST AREA NEAR DAM ... 5-9

ACRONYMS

°F	Degrees Fahrenheit
BRAC	Base Realignment and Closure
bgs	Below Ground Surface
CAAA	Crane Army Ammunition Activity
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CSM	Conceptual Site Model
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
EFANE	Engineering Field Activity Northeast
EOD	Explosive Ordnance Disposal
FUDS	Formerly Used Defense Site
GIS	Geographic Information System
KY	Kentucky
LANTDIV	Atlantic Division
MEC	Munitions and Explosives of Concern
MC	Munitions Constituents
Mg	Magnesium
MK	Mark
MRP	Military Munitions Response Program
$NaNO_3$	Sodium Nitrate
NAVFAC	Naval Facilities Engineering Command
NSWC	Naval Surface Warfare Center
OE	Ordnance and Explosives
OESO	Ordnance Explosives Support Office
PAO	Public Affairs Office
POC	Point of Contact
RG	Record Groups
RPM	Remedial Project Manager
U.S.	United States
USACE	United States Army Corps of Engineers

USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
WAMS	Water Area Munitions Study

GLOSSARY OF TERMS

Base Realignment and Closure (BRAC) – A Department of Defense (DoD) program that focuses on compliance and cleanup efforts at military installations undergoing closure or re-alignment, as authorized by Congress in four rounds of base closures for 1988, 1991, 1993, and 1995. (DERP Management Guidance, September, 2001)

Closed Range – A range that has been taken out of service as a range and that either has been put to new uses that are incompatible with range activities or is not considered by the military to be a potential range area. A closed range is still under the control of a DoD component. (DERP Management Guidance, September, 2001)

Defense Site – All locations that are or were owned by, leased to, or otherwise possessed or used by the DoD. The term does not include any operational range, operating storage or manufacturing facility, or facility that is used or was permitted for the treatment or disposal of military munitions. (10 U.S.C. 2710(e)(1))

Discarded Military Munitions – Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include unexploded ordnance, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of consistent with applicable environmental laws and regulations. (10 U.S.C. 2710(e)(2))

Explosive Ordnance Disposal (EOD) – The detection, identification, field evaluation, rendering-safe, recovery, and final disposal of unexploded explosive ordnance (UXO). It may also include the rendering-safe and/or disposal of EO (explosive ordnance) which has become hazardous by damage or deterioration, when disposal of such EO requires techniques, procedures, or equipment which exceed the normal requirements for routine disposal. (OPNAVINST 8027.1G, 14 Feb 92)

Explosives Safety – A condition where operational capability and readiness, personnel, property, and the environment are protected from the unacceptable effects of an ammunition or explosives mishap. (DoD Directive 6055.9 July 1996)

Formerly Used Defense Site (FUDS) – Real property that was formerly owned by, leased by, possessed by, or otherwise under the jurisdiction of the Secretary of Defense or the Components (including governmental entities that are the legal predecessors of DoD or the Components) and those real properties where accountability rested with DoD but where activities at the property were conducted by contractors (i.e., government-owned, contractor-operated (GOCO) properties) that were transferred from DoD control prior to October 17, 1986. The status of a site as a FUDS is irrespective of current ownership or current responsibility within the federal government. (DERP Management Guidance, September, 2001)

Munitions Constituents (MC) – Any materials originating from unexploded ordnance, discarded military munitions or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710 (e)(4))

Munitions and Explosives of Concern (MEC) – This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks, means: unexploded ordnance, discarded military munitions or munitions constituents (e.g., TNT, RDX) present in high enough concentrations to pose an explosive hazard. (OUSD(AT&L) 18 December 2003)

Operational Range – A range that is under the jurisdiction, custody, or control of the Secretary of Defense and that is used for range activities, or although not currently being used for range activities, that is still considered by the Secretary to be a range and has not been put to a new use that is incompatible with range activities. (10 U.S.C. 101 (e)(3))

Other than Operational Range – Encompasses closed, transferred and transferring ranges.

Range – A designated land or water area set aside, managed, and used for range activities of the DoD. Ranges include firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, electronic scoring sites, buffer zones with restricted access and exclusionary areas, and airspace areas designated for military use in accordance with regulations and

procedures prescribed by the Administrator of the Federal Aviation Administration. (10 U.S.C. 101 (e)(3))

Transferred Range – A property formerly used as a military range that is no longer under military control and had been leased by the DoD, transferred, or returned from the DoD to another entity, including federal entities. This includes a range that is no longer under military control but was used under the terms of a withdrawal, executive order, special-use permit or authorization, right-of-way, public land order, or other instrument issued by the federal land manager. (DERP Management Guidance, September, 2001)

Transferring Range – A range that is proposed to be transferred or returned from the DoD to another entity, including federal entities. This includes a range that is used under the terms of a withdrawal, executive order, act of Congress, special-use permit or authorization, right-of-way, public land order, or other instrument issued by the federal land manager or property owner. An operational or closed range will not be considered a "transferring range" until the transfer is imminent. (DERP Management Guidance, September, 2001)

Unexploded Ordnance – Military munitions that have been primed, fused, armed, or otherwise prepared for action; have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and remain unexploded either by malfunction, design, or any other cause. (10 U.S.C. 101(e)(5))

EXECUTIVE SUMMARY

The Department of Defense (DoD) has established the Military Munitions Response Program under the Defense Environmental Restoration Program (DERP) to address munitions and explosives of concern (MEC) (including unexploded ordnance and discarded military munitions) and munitions constituents (MC) at other than operational military ranges and other sites. Closed, transferred, and transferring military ranges and sites not located on an operational range are considered other than operational. This report addresses other than operational ranges and sites at an active installation. It may include transferred and/or transferring ranges and munitions disposal sites associated with an active installation if they are not included in the Formerly Used Defense Sites (FUDS) and Base Realignment and Closure (BRAC) Programs.

However, by definition, munitions related sites located in water are not addressed under the Navy Military Munitions Response Program (MRP). For example, deep-sea sites including former munitions disposal areas and ranges are not addressed under the MRP. In order to document the history of these areas in a standard format, a Water Area Munitions Study (WAMS) report is completed. This report represents the WAMS for the Lake Greenwood Pyro Test Area Near Dam associated with the Naval Surface Warfare Center, Crane Division (NSWC Crane), Indiana.

NSWC Crane is located in Martin County in south-central Indiana. NSWC Crane is the third largest naval installation in the world encompassing 100 square miles and employing approximately 3,400 Naval employees and 550 Army employees. The installation was originally built to prepare, load, renovate, receive, store, and issue all ammunition, including pyrotechnics and illuminating projectiles, and to act as a principal source of supply at a most critical time - the early days of World War II; however, due to its expertise in engineering and electronics, NSWC Crane today is a multi-mission, multi-service product center with both fleet support and industrial base missions.

There are two sites associated with Lake Greenwood. The first testing site is located along the dam and includes a section of the lake approximately 200-300 yards offshore. The second test site is located offshore on the southern side of Lake Greenwood in front of the Officer's Club. According to site personnel, the Lake Greenwood Pyro Test Area Near Dam was used from 1954 to 1958 to test marine location markers [Mark (MK) 5 Mod 4, MK 7 Mod 2, MK 6 Mod 3, and MK 25]. The markers were loaded into a boat and were floated approximately 200-300 yards

offshore to a deep section of Lake Greenwood (about 30 feet in depth). All retrievable parts of the munitions were collected after the test as they were made of wooden bodies and floated to the surface. In the 1950s, several tests were performed offshore at the Officer's Club using green illuminating materials.

No evidence was found during the site visit indicating that MEC remain at the site. There is a probability that MC is present at the site because of the MC associated with the munitions themselves. In addition, since the flares were fired over the water, evidence of MEC or MC in the surface water would have dissipated over the years.

1. INTRODUCTION

TThe Department of Defense (DoD) has established the Military Munitions Response Program under the Defense Environmental Restoration Program (DERP) to address munitions and explosives of concern (MEC) (including unexploded ordnance and discarded military munitions) and munitions constituents (MC) at other than operational ranges. The term "other than operational ranges" includes closed, transferred and transferring military ranges, as well as any other past-use site known or suspected to contain MEC or MC that is not located on an operational range. This report addresses other than operational ranges and sites at an active installation. It may include transferred and/or transferring ranges and munitions disposal sites associated with an active installation if they are not included in the Formerly Used Defense Sites (FUDS) and Base Realignment and Closure (BRAC) Programs.

However, by definition, munitions related sites located in water are not addressed under the Navy Munitions Response Program (MRP). For example, deep-sea sites including former munitions disposal areas and ranges are not addressed under the MRP. In order to document the history of these areas in a standard format, a Water Area Munitions Study (WAMS) report is compiled. This report represents the WAMS for the Lake Greenwood Pyro Test Area Near Dam associated with the Naval Surface Warfare Center, Crane Division (NSWC Crane), Indiana.

This WAMS is organized into the following five sections:

- Section 1 – Introduction
- Section 2 – Installation Background
- Section 3 – Physical and Environmental Characteristics
- Section 4 – Summary of Data Collection Effort
- Section 5 – Site Characteristics

The following supporting information is appended to this WAMS:

- References (Appendix A)
- Project Source Data – General (Appendix B)
- Project Source Data – Site Specific (Appendix C)
- Ordnance Technical Data Sheets (Appendix D)

1.1. Purpose

This WAMS summarizes the history of munitions use at the Lake Greenwood Pyro Test Area Near Dam at NSWC Crane and provides an assessment of the current conditions with respect to MEC and MC. The WAMS provides the necessary information for United States (U.S.) Navy (Navy) and regulatory decision-makers to develop a Conceptual Site Model (CSM) for the site. The CSM presents information regarding: 1) MEC and/or MC known or suspected to be at the site; 2) current and future reasonably anticipated or proposed uses of the real property; and 3) actual, potentially complete, or incomplete exposure pathways that link them. The CSM is the basis for the risk evaluation, prioritization, and remediation cost estimate.

1.2. Project Management

This WAMS is being coordinated and managed by the Navy Engineering Field Activity Northeast (EFANE), a component of the Atlantic Division (LANTDIV) of the Naval Facilities Engineering Command (NAVFAC). The EFANE performs engineering functions for Navy installations throughout the northeast U.S. and is the Program Manager for this WAMS. Malcolm Pirnie, Inc. has been contracted to prepare this WAMS. The Navy Remedial Project Manager (RPM) for Southern Division and the installation points of contact (POC) for NSWC Crane provided valuable information and assistance throughout the WAMS data collection process. The Navy RPM is the responsible party for this WAMS.

1.3. Water Area Munitions Study Approach

The WAMS process for the Lake Greenwood Pyro Test Area Near Dam involved collecting and reviewing existing and available information about the site; data collection activities included off-site and on-site research and interviews. The Malcolm Pirnie data collection team conducted the on-site portion of the data collection and visual survey on March 18-20, 2003. A summary of the data collection process is presented in Section 4.

This WAMS is inclusive and makes use of all available data relating to munitions use at the Lake Greenwood Pyro Test Area Near Dam, including historical records, field data, anecdotal evidence, interviews with site personnel, and professional knowledge and experience. It is based,

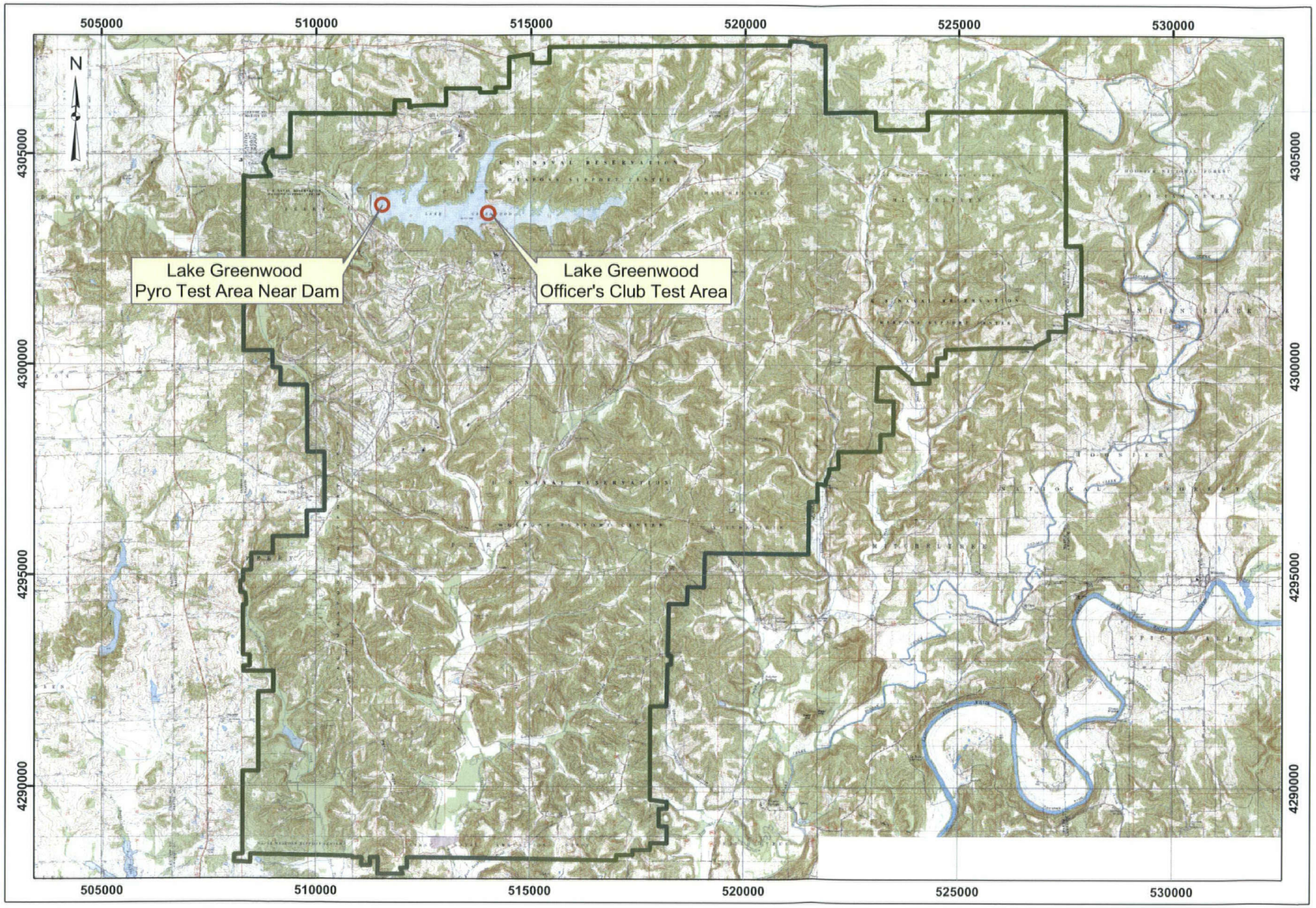
in part, on information provided in documents referenced in Appendix A and is subject to the limitations and qualifications presented in the referenced documents.

2. INSTALLATION BACKGROUND

The following sections provide general information about NSWC Crane, including its location and setting; a brief history of the installation; its missions over time; and a history of munitions related training, storage, and usage.

2.1. Location and Setting

NSWC Crane covers roughly the northern third of Martin County with a small overlap into Greene County to the north and an even smaller overlap into Lawrence County on the east. The approximately 63,000-acre base is approximately 37 miles southwest of Bloomington, Indiana, and approximately 70 miles southwest of Indianapolis, Indiana, as shown in Map 2-1. NSWC Crane is situated in a rural setting in southwest Indiana. Surrounding towns include Crane Village to the northwest, Burns City to the west and Bedford to the east. An 800-acre lake, Lake Greenwood, is located along the north-central portion of the base and serves as the primary water supply for the base. Map 2-1 depicts the location of Lake Greenwood Pyro Area Near Dam on the installation.



Water Area Munitions Study
NSWC Crane, Indiana

MALCOLM PIRNIE

Map 2-1
Area Location Map
Lake Greenwood Pyro Test Area

Legend

Installation Boundary

Lake Greenwood Pryo Test Area

1,250 0 1,250 2,500 3,750 Meters

Data Source: USGS. 7.5 Minute Series
Topographic Survey Map
Owensburg, IN (1976)
Indian Springs, IN (1979)
Scotland, IN (1979)
Williams, IN (1979)
Koleen, IN (1979)
Loogootee, IN (1976)
Odon, IN (1976)
Schoals, IN (1960)

Coordinate System: UTM Zone 16N
Datum: NAD83
Units: Meters

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2.2. Installation History

NSWC Crane began in 1941 as the Naval Ammunition Depot. Since its inception, NSWC Crane has been under four different commands. The Ammunition Quality Evaluation Unit was added in 1947, which led NSWC Crane into expanded activities, capabilities, and expertise. In 1975, the installation name changed to Naval Weapons Support Center, Crane (NWSC Crane) to reflect its true function of weapons support. The Crane Army Ammunition Activity (CAAA) was established in 1977 to assume the loading, assembly and storage of ammunition at the installation. After merging with the Naval Ordnance Station at Louisville, Kentucky (KY), in 1992, the installation received its current name: Crane Division, Naval Surface Warfare Center, and continues to be a recognized leader in highly technical product lines servicing the Navy. Table 2.2-1 contains a summary of NSWC Crane's history.

Table 2.2-1: History of NSWC Crane

Time Period	Significant Events
Prior to 1795	Indian Territory
1795 – 1940	Greenville Treaty signed and settlers arrived. The White River Project was dedicated in 1939, which provided a state park and restored forest productivity.
1941	Established in 1941 as the *Naval Ammunition Depot* for the production, testing, and storage of ordnance, including pyrotechnics and illuminating projectiles, under the command of the Bureau of Ordnance.
1947	Ammunition Quality Evaluation Unit was added by the Bureau of Ordnance to expand the quality control system and establish a laboratory at Crane.
1950s	Crane came under command of the Bureau of Weapons and expanded activities, capabilities, and expertise to include small arms, sonobouy surveillance, microwave tubes, POLARIS missiles, and other engineering support.
1960s	Crane came under command of the Naval Ordnance Systems Command and began providing technical support for weapons systems.
1974	Crane came under the Naval Sea Systems Command and Naval Ship Systems Command.
1975	The installation name changed to *NWSC, Crane* to reflect its true function.
1977	Establishment of the tenant command CAAA. The CAAA assumed the loading, assembly and storage of ammunition at the installation.
1992	Crane was merged with the Naval Ordnance Station at Louisville, KY, to form the *Crane Division, NSWC.*
Present	NSWC Crane serves a modern and sophisticated Navy as a recognized leader in highly technical product lines.

2.3. Munitions Related Training / Storage / Usage

During World War II, the Korean Conflict and the Vietnam Conflict, NSWC Crane developed, tested, stored, trained with and used all types of Naval munitions including small arms, detonators, cartridge actuated devices, propellant actuated devices and various pyrotechnics.

3. PHYSICAL AND ENVIRONMENTAL CHARACTERISTICS

The following sections provide general information for NSWC Crane, including its climate; topography; geology; soil and vegetation types; hydrology; hydrogeology; cultural and natural resources; and endangered species.

3.1. Climate

NSWC Crane is located in a temperate climate zone, which has a wide temperature range between summer and winter. According to the National Climatic Data Center, the summers are warm and humid, and the winters, though generally mild, often have very cold periods of short duration. The average minimum temperature in January is 21 degrees Fahrenheit (°F), and the average maximum temperature is 38°F. The average minimum temperature in July is 66°F, and the average maximum temperature is 88°F. Precipitation totals almost 44.3 inches annually, with an average rainfall of 3.7 inches per month. Average humidity ranges from 40 to 90 percent in summer and 60 to 90 percent in winter. Winds in southwestern Indiana are generally from the south-southwest at an average speed of 8.2 miles per hour. The frost line in southern Indiana is approximately 2.5 feet below ground surface (bgs).

3.2. Topography

The topography of NSWC Crane is composed of flat to gently undulating terrain dissected by numerous well-defined drainage ways. Elevation at NSWC Crane ranges from a maximum of 860 feet in the eastern part to a minimum of 425 feet in the western part of the installation. The V-shaped drainages in the north progress to 2,000-foot wide floodplains in the south and rise approximately 150 to 200 feet to the ridgelines on slopes of 20 to 30 degrees. Soil erosion could occur along the slopes of the drainage paths at NSWC Crane.

3.3. Geology

Indiana is a large anticline that plunges to the northwest. Consequently, this large structural feature governs the age and type of rocks in Indiana. Some of the youngest rocks are in the southwestern corner of the state. The youngest rocks are mostly sandstones and shales with minor amounts of limestone and coal. The distribution of rock types is the major control on the

physiographic provinces in the south-central part of the state. In the southwestern part of the state, the rocks of the Raccoon Creek Group overlie the Mississippian-Pennsylvanian Unconformity. This group consists of mostly sandstone and shale with minor amounts of coal, limestone, and clay.

The sedimentary bedrock beneath NSWC Crane dips gently to the west-southwest. The inclination of the strata reflects NSWC Crane's location on the eastern flank of the Illinois Basin. This section of the basin is comprised of Pennsylvanian and Mississippian strata consisting of shale, sandstone, limestone, and coal (Pennsylvanian) beds. The Pennsylvanian Mansfield Formation (Raccoon Creek Group) unconformably overlies the Mississippian Stephensport and West Baden Groups at the site.

Rocks of lower Pennsylvania and upper Mississippian Ages underlie the region of Indiana in which NSWC Crane is located. With the exception of minor outwash and lacustral deposits in the northwest corner of the facility, there are no Pleistocene glacial deposits covering the installation. Surface deposits at NSWC Crane consist of recent (Holocene) and Pleistocene unconsolidated alluvial silt, sand, and gravel, and residual soils developed from the underlying rock.

3.4. Soil and Vegetation Types

According to the Soil Survey of Martin County, Indiana, conducted by the U.S. Department of Agriculture (USDA), Forest Service, in cooperation with the Indiana Department of Natural Resources, Soil and Water Conservation Committee, the primary soil types located in the area of the NSWC Crane, Martin County, are various silt loams with a variety of slopes.

The following silt loams identified within the area are nearly level and/or gently sloping, deep, poorly drained, moderately permeable soils that are prone to flooding for varying lengths of time: Birds silt loam, Bonnie silt loam, Burnside loam, Haymond silt loam, Johnsburg silt loam, Wakeland silt loam, and Wilbur silt loam. Most of these soil types are used for cultivated crops, grasslands, or woodlands. Frost heave may be associated with these types of soils due to the silty fine grain and poorly drained soils.

Some silt loams located in the area are nearly level and gently sloping, deep, well drained, moderately permeable soils: Camden silt loam, Hosmer silt loam, Pike silt loam, Pekin silt loam, Wellston silt loam, and Zanesville silt loam. These soil types are well suited to trees, grasses, crops, and sites for dwellings. Some are also good for septic tank absorption fields. Even though these soils contain fine grains, frost heave may not be a concern since the soils are very well drained.

Soil erosion could occur within all types of soils located at NSWC Crane if located on the higher slopes that are along the drainage paths.

3.5. Hydrology

NSWC Crane is located within the Lower East Fork White watershed. The East Fork White River flows approximately 40 miles southwest before joining the Muscatatuck River, which eventually joins the Ohio River. NSWC Crane is located approximately 10 miles northwest of the East Fork White River. The surface drainage from Crane has formed a dense, dendritic pattern throughout the installation. Six creeks in four drainage basins carry surface water off the installation. Drainage from the basin in the extreme eastern part of Crane consists of several small drainage ways. The north and northwest drainage basin eventually empties into Furst Creek, which flows in a westerly direction and crosses the installation boundary. Rainey Hollow, Sulphur Creek, and Little Sulphur Creek drain the eastern basin. The drainage basin occupying the central portion of the installation is where Boggs Creek and Turkey Creek receive drainage from the industrial area and that portion of the containment area south of Roads H43 and H5.

3.6. Hydrogeology

Groundwater resources at NSWC Crane have not been studied extensively because the facility utilizes surface waters from Lake Greenwood for human consumption, process operations, recreation, and several soil and water conservation ponds. However, the existing lithologies, occurrences of springs and seeps, and the well-developed surface drainage indicate the existence of groundwater that is hydraulically connected to the surface environment. Available groundwater data from the 1940s indicates that limited water is located at 141 and 313 feet bgs, with the shallowest water level observed at 85 feet bgs. The groundwater at NSWC Crane appears to be divided into two distinct regimes--one associated with the soil cover and one associated with bedrock. The shallow groundwater is probably transient; during periods of

excessive, prolonged rainfall and during the early spring months, there is probably saturated soil and free water above the soil-rock contact. This condition dissipates by percolation into the bedrock and into intermittent or perennial streams. The groundwater associated with the bedrock is stable and probably fluctuates only a minor amount (less than 10 feet) per year. Possibly more than one zone of saturation exists in the bedrock due to the successive beds of sandstone, shale, and limestone. The shale beds should be the least permeable of the series and, where underlying a permeable sandstone or limestone, would support a saturated or free water zone. These shale zones grade laterally to zones of sandstone, so the downward percolating water would be free to move continually downward.

3.7. Cultural and Natural Resources

On a national level, NSWC Crane is considered historically significant as the primary ammunition depot for the east coast requirements of the Navy; however, according to the Cultural Resources Survey completed in June of 1992, there were no previously identified historic resources on the installation, and no buildings or structures were listed in local or state inventories or the National Register of Historic Place. The survey did identify a total of nineteen historic or prehistoric locations or possible locations, which were recorded on state survey forms. In addition, six building locations may have been eligible for listing on the National Register of Historic Places. However, according to the Indiana Department of Natural Resources Historic Preservation & Archaeology Department, no historical or archaeological sites located at NSWC Crane are listed on the National Register of Historic Places or the state inventory.

There are at least 14 caves on NSWC Crane, which range in size from small crevices or pits to the 1,500 feet that have been mapped as the Aunt Liz Cave. Cave exploration is not permitted for safety reasons and to prevent disturbance of bats that inhabit some of the caves.

Twenty-eight cemeteries are located within NSWC Crane's boundaries. The cemeteries range in size from single graves to the nearly 700 graves in Salem Cemetery. Many of the early settlers of the area are buried in these cemeteries.

NSWC Crane is vitally concerned with the conservation of the natural environment, both on and off the installation. The Navy and the DoD have recognized these efforts with awards for excellence in natural resources management. In 1995 and 1996, NSWC Crane won the Chief of

Naval Operations Award for the best natural resources program. To share its abundant natural beauty with its neighbors, NSWC Crane has opened its 800-acre Lake Greenwood to the public for fishing and boating.

NSWC Crane provides stewardship to over 63,000 acres of land, of which about 49,000 acres are forested. This is the largest forested tract of land in Indiana under a single ownership. It has been and, hopefully, will continue to be an important part of the Indiana ecosystem.

The NSWC Crane forest has been important to the re-establishment of deer, turkey, ruffed grouse and bald eagles in Indiana. Wildlife research is conducted at NSWC Crane by both Purdue University and Indiana University to observe species, number, and overall condition of the wildlife located at NSWC Crane. The timber is managed and harvested at NSWC Crane to provide financial means for the installation and associated counties.

3.8. Endangered and Special Status Species

According to NSWC Crane's Natural Resources Guide, protected species that are known or have the potential to inhabit NSWC Crane are listed in Table 3.8-1:

Table 3.8-1: Summary of Known or Potential Protected Species

Ecological Receptors	Species
Federal Endangered	Indiana Bat (Myotis sodalis)
Federal Threatened	Bald eagle (Haliaeetus leucocephalus)
State Endangered	Bobcat, osprey, yellow-crowned night heron, timber rattlesnake
State Threatened	Bald eagle (Haliaeetus leucocephalus)
Other Ecological Receptors	• Approximately 20 species of amphibians including the bullfrog, spotted salamander and gray treefrog • Over 100 species of birds including the wood duck, barn swallow and marsh hawk • Approximately 30 species of mammals including the white-tailed deer, coyote, raccoon,

	cottontail rabbit and wild turkey • Over 45 species of fish including bluegill, crappie, largemouth bass and channel catfish • Approximately 20 species of reptiles including the snapping turtle, northern copperhead, and eastern spiny softshell turtle • Giant Canadian Geese • Ginseng • Grouse • Several types of edible mushrooms

4. SUMMARY OF DATA COLLECTION EFFORT

Five primary sources of information were researched as part of the data collection effort for the WAMS. The sources of data included:

1) Historical archives;
2) Personal interviews;
3) Installation data repositories;
4) Visual survey; and
5) Off-site data sources and repositories, such as local libraries and museums.

These five sources of data are discussed below, along with their relative application to this WAMS.

4.1. Historical Archive Repositories (off-site)

The data collection team reviewed archival records located at the National Archives in College Park, Maryland, and in Washington, D.C., as well as the regional branches located in Philadelphia and New York City. The data collection team researched the following records and record groups (RG) for documents relating to munitions usage at NSWC Crane. Records marked with "*" indicate boxes were pertinent information was identified and photocopied for use in the PA.

Textual Records:

RG 71, Bureau of Yards and Docks

Entry 12, General Correspondence, 1917-1925

Entry 13, General Correspondence re: Shore Establishments, 1916-1925

Entry 17, Index to General Correspondence, 1917-1925

Entry 21, Index to General Correspondence, 1925-1942

Entry 74, Blueprints of Naval Bases, 1940-1942

Entry 75, Drawings, 1898-1939, Vol.1, Vol.2, Box 1*

RG 72, Bureau of Aeronautics

Entry 62, General Correspondence, 1925-1942, Boxes 2797, 3842, 3843, 3844, 3845, 3920, 4014, 4019, 4020, 4036

Confidential Correspondence, 1922-1944, Box 1209

Entry 62-B, General Correspondence

1943-45, Boxes 2933, 2978, 2996, 3000, 3010, 3050, 3066*, 3078, 3385*, 3475

1946, Boxes 333, 416, 417, 418*, 419-426, 427*, 433, 436*, 437-438, 488*, 495, 503, 506, 509, 512, 513,

1947, Boxes 318, 363, 364, 365, 366*, 379*, 380, 405, 421, 426*, 430, 431, 434,

1948-1949, Boxes 371, 377*, 378*, 379, 430

1950, Box 199

1951, Boxes 163-164

1953, Boxes 242-243

1955, Boxes 193-194

1956, Boxes 184-185

1957, Boxes 192-193

1958, Box 147

RG 74, Bureau of Ordnance

Entry 25, General Correspondence, 1912-1926, Box 277*, 2317, 2318, 3087, 3093, 3112*, 3113*, 3142

Entry 25, General Correspondence, 1926-1944, Boxes 751, 754, 758*, 771, 777, 786, 787, 788*, 789*, 1060, 1078*, 1652

Entry 25-C, General Correspondence, Confidential, 1926-1939, Boxes 76, 638, 103

Entry 25-E, General Correspondence, Confidential, 1940-1942, Boxes 183, 192*

Entry 33, Index to General Correspondence, 1914-1926, Boxes 24, 33

General Correspondence, 1912-1926, Box 277*, 3112*, 3113*

Entry 33, Index to General Correspondence, 1926-1943, Boxes 21, 27

Entry1001, General Correspondence, 1907-1949, Boxes 8, 10, 11, 13, 14, 25, 26, 35-37, 51, 61, 62, 70*, 88, 101, 105, 106

Entry 1003 A-B, General Correspondence, 1948-1959, Boxes 584, 587

Construction and Procurement Files

1945, Boxes 1077*, 1190*, 1209*, 1220*, 1222, 1256*, 1257*, 1264, 1265, 1284*, 1285, 1390-1393, 1443*, 1444*, 1445*, 1446*, 1488*, 1489*, 1519-1539, 1600, 1643-1645, 1695-1696

1946, Boxes 193, 253*, 258, 265, 266, 280, 282, 289, 349*, 350*, 366*, 379*, 380*, 381*, 382*, 383*, 384*, 385*, 386*, 434*, 435

1947, Boxes 129, 188*, 199, 210*, 211, 263-265, 279*, 280, 288, 289*, 290*, 291*, 292, 330-331

RG 80, Secretary of the Navy

Entry 13, Spindle File, Letters Sent, 1918-1942, Boxes 115-118, 309, 352-353, 371-372

Entry 19, General Correspondence, 1897-1915, Boxes 1239-1241

Entry 19, General File, 1897-1926, #26395, 27280, 27812, 28332

Entry 22, General Correspondence, 1916-1926, Boxes 379, 680*, 681*, 682*, 1605, 1800, 1808, 1878*, 1879-1882, 2022, 2159, 2255*

Entry 22, General Correspondence, 1926-1940, Boxes 90,

Entry 22, General Correspondence, 1926-1944, Boxes 3071-3072, 3260

General Correspondence, 1940-1942, Box 833

Entry 130, Alphabetical File of the Assistant Secretary, 1921-1940, Box 4

Microfilm 1067, Index to General Correspondence of Secretary of Navy, 1930-1942, Rolls 29, 38, 63, 66, 90, 157

Microfilm 1052, General and Special Indexes to General Correspondence of Secretary of Navy, 1897-1926, Rolls 12, 13, 15, 24, 35, 36, 49, 62, 83, 100, 116, 119

RG 71, Bureau of Yards and Docks

Naval Property Case Files, Boxes 442, 443*, 444-450, 451*, 452

Unprocessed Naval Property Case Files, Boxes 31, 40

RG 72, Bureau of Aeronautics: [NT1-18]

Entry 62-B, General Correspondence, 1943-45, Boxes 2933, 2978, 2996, 3010, 3050, 3078, 3475

Entry 67, Confidential General Correspondence, 1922-1944, Box 1209

RG 74, Bureau of Ordnance

Entry 1001, General Correspondence, 1907-1949, Boxes 8, 10, 11, 13, 14, 25, 26, 35-37, 51, 61, 62, 70*, 88, 101, 105, 106

Entry 1003 A-B, General Correspondence, 1948-1959, boxes 584, 587

Entry 1529, Construction and Procurement Subject Files, 1945, Boxes 1519-1524, 1525*, 1526-1528, 1529*, 1530-1532, 1533*, 1534-1539

Entry 4444, Construction and Procurement Subject Files, 1946, Box 379*, 380*, 381*, 382*

Entry 1529, Construction and Procurement Subject Files, 1947, Boxes 289-291

Cartographic Records:

RG 71, Bureau of Yards and Docks

Maps for facility 903, codes 1, 2, 3, 15, 16, 32, 34, 42, 44-48

Series I microfilm, Roll 649.4*

RG 385, Naval Facilities Engineering Command, 1917-1989

Architectural and Engineering Plans, Boxes 223*, 224, 225*, 226*, 227, 228, 229, 230*

4.2. Personal Interviews

The data collection team visited the following offices located at NSWC Crane to interview representatives and research records related to the munitions/ordnance usage at the installation:

- Environmental Department
- Public Works Department
- Geographic Information Systems (GIS) Department
- Explosive Ordnance Disposal (EOD)
- Explosive Safety Office
- Base Historian Office
- Public Affairs Office (PAO)
- Pyrotechnics Development Department
- Ordnance Test Group

According to the personnel located at the installation, most people having specific knowledge regarding munitions activities at the site identified within this report are either deceased or retired and un-locatable. The data collection team attempted to locate these individuals; however, none were found. A summary of the personnel interviewed and general information obtained from each office are presented below.

Environmental Department – The data collection team interviewed the Environmental Protection Specialist, Mr. Phil Keith. Mr. Keith has been employed at NSWC Crane for 19 years. He provided the team access to current installation maps along with various other environmental information pertaining to areas within the installation. Mr. Keith did not have any information pertaining directly to the Lake Greenwood Pyro Test Area Near Dam. Mr. Keith is the POC for the Navy range inventory and the data collection portion of the WAMS.

Public Works and GIS Department – The data collection team interviewed the Environmental Protection Specialist, Mr. Thomas Brent. Mr. Brent has been employed at NSWC Crane for approximately 15 years. He provided the team access to various environmental documents and studies conducted throughout various areas of installation; however, no specific documentation regarding the Lake Greenwood Pyro Test Area Near Dam was available. Mr. Brent provided the team with electronic map files for the installation.

EOD – The data collection team interviewed Lieutenant Ron Zitzman. Lt. Zitzman, EOD Officer-in-Charge, has been stationed at NSWC Crane for 18 months. He provided the investigating team with several binders of EOD response records from fiscal years 2000 to 2003. However, these EOD response records did not provide any specific information related to the Lake Greenwood Pyro Test Area Near Dam or any records of munitions/ordnance usage at the site.

Explosive Safety Office – The data collection team interviewed the Explosive Safety Officer, Ms. Linda Stoll. Ms. Stoll confirmed the dates of pyrotechnic testing at the dam on Lake Greenwood. She did not have any specific records of munitions/ordnance usage at the site.

Base Historian Office – The data collection team interviewed the Base Historian, Mr. John Allen. Mr. Allen was born and raised in the area surrounding NSWC Crane and has been employed in a variety of positions at NSWC Crane for approximately the past 60 years. He provided the team with historical summaries and other useful information regarding the history of NSWC Crane. Mr. Allen confirmed that testing occurred at the site and provided some approximate dates of use.

PAO - The data collection team spoke with Ms. Sue Webster who oversees PAO at NSWC Crane. She did not have any specific information related to the Lake Greenwood Pyro Test Area Near Dam or any records of munitions/ordnance usage at the site.

Pyrotechnics Development Department – The data collection team spoke with Dr. Bernie Douda, an engineer employed at NSWC Crane for over 50 years, regarding munitions/ordnance usage at the site. Dr. Douda stated that the Lake Greenwood Pyro Test Area Near Dam was used for testing underwater illuminating flares, which were tested from a boat floated into Lake Greenwood. The dates of use of the site occurred during the 1950s according to Dr. Douda. He also described the testing that occurred in front of the Officer's Club, which is located on the southeastern side of the lake.

Ordnance Test Group – The data collection team interviewed Mr. Steve Schantz who had some knowledge of munitions/ordnance usage at the site. Mr. Schantz is the Range Safety Officer at NSWC Crane and has been employed for numerous years. Mr. Schantz confirmed Dr. Douda's account of the pyrotechnic testing off the Lake Greenwood Dam.

4.3. On-Site Data Repositories

There is no central data repository, such as a library or museum, located at the NSWC Crane except for continuing EOD response records; however, these records did not contain any information on explosive/munitions usage occurring at the site.

The base historian provided the data collection team with a copy of the book written by Mr. Robert L. Reid and Mr. Thomas E. Rodgers, entitled A Good Neighbor: The First Fifty Years at Crane 1941-1991. This book provided historical information pertaining to the installation.

A copy of the Preliminary Review/Visual Site Inspection Report from March 1987 was received from the Environmental Department to provide information pertaining to the environmental setting at the installation.

Various email correspondence relating to information regarding the installation was also received from the Environmental Department.

4.4. Visual Survey

The data collection team conducted a visual survey of the site as part of the data collection effort for the WAMS. The purpose of the visual survey was to identify any MEC ordnance related materials (e.g., expended rounds, fragmentation, range debris, old targets), any evidence of MC (such as ground scarring, stressed vegetation, or chemical residue) and/or surface features that could provide additional information to aid in the characterization of the site. The visual survey was also used to enhance, augment, or confirm the archival data and, in some cases, provide new data to the team. A description of the area surveyed and the results of the survey are provided in Section 5.

4.5. Off-Site Data Sources

The data collection team contacted the following libraries and historical societies to obtain additional historical information regarding the site; however, no information was obtained pertaining to the identified site.

- Indiana Historical Society
- Indiana State Library
- Bedford Public Library
- Bloomfield Library
- Shoals Public Library
- Martin County Historical Society

In addition, the data collection team reviewed archival records located at the Ordnance Explosives Support Office (OESO) Library at NSWC Indian Head, Maryland. OESO provides Navy-wide environmental program support for ordnance and munitions. The data collection team researched the files available for NSWC Crane, and the following sources were of value to this WAMS:

Textual Records:

Proposed Development Plan for Station, December 21, 1940

Chief of Bureau of Yards & Docks, July 14, 1941 indicating revisions of boundary lines.

Installation Assessment of NWSC Crane, Indiana, March 1978.

Cultural Resources Survey, Crane Division NSWC, Crane, Indiana, June 1992.

Environmental Impact Assessment, for Open Burning/Detonation of Waste Munitions/Propellant, August 1975.

Records Research On-Site Survey by OESO and the Army Records Research, Pollution Control Program, 1971.

Geology and Hydrology Study for the Ammunition Burning Grounds, October 1987.

Preliminary Review/Visual Site Inspection Report of Naval Weapons Support Center, Crane, Indiana, March 1987.

Maps:

NWSC Crane, Indiana, General Development Map, updated April 1974.

U.S. Naval Ammunition Depot Crane, Indiana, Production Areas Map.

The data collection team researched environmental information such as soil and endangered species information pertaining to the installation from the U.S. Department of Fish & Wildlife and the USDA. Historical and other environmental information was researched using the Internet. A complete list of Internet sources can be found in Appendix A.

5. SITE CHARACTERISTICS

The following sections provide site-specific information about the Lake Greenwood Pyro Test Area Near Dam at NSWC Crane, including history and site description; visual survey observation and results; munitions characterization; contaminant migration routes; receptors; land use; access controls and restrictions; and the CSM.

5.1. History and Site Description

Lake Greenwood is located in the north-central portion of NSWC Crane. Highway 5 and Highway 45 parallel the lake to the south. The lake is the largest water body at the installation and is oriented in an east-west direction. Lake Greenwood has an average water depth of approximately 15 feet and a maximum depth of approximately 35 feet.

Lake Greenwood was used for pyrotechnic testing from approximately 1954 to 1958. Testing occurred at two locations on Lake Greenwood: an offshore point in front of the dam on the west side and an offshore point directly in front of the Officer's Club on the southeastern side of the lake. Testing of marine location markers and underwater illuminating flares occurred at the Lake Greenwood Pyro Test Area Near Dam, including the Mark (MK) 25, MK 72, MK 5 Mod 4, MK 7 Mod 2, and MK 6 Mod 3. Nearly one dozen tests occurred at the Lake Greenwood Pyro Test Area Near Dam. Around 1958, there were about six experimental underwater illuminating flares tested. A boat would be sent into the lake approximately 200-300 yards offshore from the dam, and illuminating flares suspended from cables attached to the boat would be tested underwater. These tests occurred on the deepest spot of the lake at nearly 35 feet. All of the materials used for testing were recovered. They were either tethered to the boat or they had wooden bodies and were recovered easily after testing, as they floated on the surface of the lake.

The Lake Greenwood Officer's Club Test Area was also used during the mid 1950s for developing markers. Green flares were fired into the water from the shore to test the burning time. The green markers contained illuminating material, burning Mg, and binders such as Carbon Monoxide-Carbon Dioxide (CO-CO_2). During one of the tests of the flares, the prevailing winds that day blew the red phosphorous cloud into the clothesline of the Commanding Officer's residence setting fire to the clothes as well as the clothesline. Tests were no longer permitted at the Officer's Club following the fire incident.

Lake Greenwood is identified on numerous historic maps, but its use as a range is not indicated on the maps. The Lake Greenwood Pyro Test Area Near Dam was identified as a range in the Navy Range Inventory.

According to Dr. Douda, it was Navy policy at the time to recover all retrievable fragments or residue associated with testing. A record of this policy was not found during the data collection effort, but additional NSWC Crane personnel corroborated the policy. It is assumed that all feasible fragments were recovered; however, it is possible that small fragments were unrecoverable. There are no records of EOD responses for testing at Lake Greenwood.

The lake is primarily surrounded by woodland to the north, west and east. At the south side of the lake, the Officer's Club was constructed up on the hill. Figure 5.1-1 is a photograph taken while standing at the Officer's Club looking north out over Lake Greenwood. The terrain and vegetation of the area is well depicted in this photograph. Figure 5.1-2 is a photograph of Lake Greenwood taken from the dam at the western edge of the lake, looking in an easterly direction. Approximately 200-300 yards into the lake is the site of the pyrotechnics testing that occurred from the boat. Figure 5.1-3 is a picture of the entire dam, forming the western edge of Lake Greenwood. The dam runs north and south along the western side of the lake.

Figure 5.1-1: Current view of Lake Greenwood from Officer's Club

Figure 5.1-2: Current view of Lake Greenwood looking east from atop dam

Figure 5.1-3: North end of dam at Lake Greenwood's western shore

5.1.1. Topography

The elevation of Lake Greenwood is approximately 600 feet. The lake is surrounded by gently rolling terrain, sloping towards the lake. The area to the north and west of the lake has an elevation of 600 and slopes upward to an elevation of 725 feet within 100 feet of the lake. On the southern side of the lake, the terrain slopes upward at a moderate rate to 675 feet. The Officer's Club is located on the top of a hill at an elevation of 700 feet. The east side of the lake also slopes upward to elevations near 725 feet.

5.1.2. Geology

There are no wells located at Lake Greenwood; therefore, the specific geology of the site is unknown. A description of the regional geology can be found in Section 3.3.

5.1.3. Soil and Vegetation Types

The soil types listed in Section 3.4 would be applicable to the land surrounding Lake Greenwood. The Final Lake Greenwood Diagnostic Study describes the sediments of Lake Greenwood:

> Lake Greenwood's sediments have a relatively large percentage of sand-sized particles. This is likely due to the primarily parent material of local soils – sandstone and shale. Since clay is only a minor component of the local soils, there is less clay in the sediments compared to sand or silt. Nevertheless, clay still ranges between 17% and 24% in the sediments of the lake... The various small side channels along the lake deliver enough sand- and silt-sized particles to maintain a relative homogeneity in particle size along the lake.

NSWC Crane constructed the earthen dam at Lake Greenwood. The soil composition of the dam is unknown. The primary soil types located in the area of the NSWC Crane, Martin County, are various silt loams with a variety of slopes.

The lake is primarily surrounded by woodland, and the earthen dam is covered in grass.

5.1.4. Hydrology

Lake Greenwood was formed by the construction of a dam on Furst Creek. The lake has a maximum depth of 35 feet and an average depth of 15 feet. Numerous unnamed small creeks and streams drain into Lake Greenwood. Lake Greenwood is the source of drinking and production water at NSWC Crane.

5.1.5. Hydrogeology

There are no wells directly at Lake Greenwood; therefore, the specific hydrogeology of the site is unknown. A description of the regional hydrogeology can be found in Section 3.6.

5.1.6. Cultural and Natural Resources

Although the potential for cultural resources exists for the area in which the site is located, there have not been any archeological or cultural sites identified near the site. No records were found identifying specific cultural resources at the Lake Greenwood Pyro Test Area Near Dam in the Cultural Resources Survey from June 1992, nor were any sites identified on the Indiana Register of Historic Sites and Structures (State Register) or the National Register of Historic Places.

The NSWC Crane forest that surrounds the Lake Greenwood Pyro Test Area Near Dam has been important to the re-establishment of deer, turkey, ruffed grouse and eagles in Indiana. The Initial Assessment Study lists the following aquatic animals for NSWC Crane Division:

- Crayfish
- Freshwater mussels
- Golden shiner
- Redear sunfish
- Channel catfish
- Spotted sucker
- Carp
- Yellow perch
- Warmouth
- Largemouth bass
- White bass
- Brown bullhead
- Bluegill sunfish
- Walleye pike
- White crappie
- Yellow bullhead
- Longear sunfish

Although no records were found to confirm the presence of these specific aquatic animals for Lake Greenwood, it is assumed that a variety of the aquatic animals may be present at Lake Greenwood as it used for recreational fishing.

The Final Lake Greenwood Diagnostic Study lists the following littoral vegetation associated with Lake Greenwood:

- American waterwillow
- Eurasian watermilfoil
- Brittle Nalad
- Rushes
- Sedges
- Water-thread pondweed
- E. Watermilfoil/Slender naiad
- Spadderdock
- Fragrant water lily
- Vallisneria
- Chara
- Broad-leaf cattail
- American Pondweed

5.1.7. Endangered and Special Status Species

Currently, the only species on the federal endangered species list that has been identified at NSWC Crane is the Indiana bat. Any area having trees with exfoliating bark has the potential to harbor the Indiana Bat from April to September. State listed endangered species include the bobcat, osprey, yellow-crowned night heron and the timber rattlesnake. Other species, such as the state and federally listed (threatened) bald eagle (Haliaeetus leucocephalus), occur in the area. The Lake Greenwood Pyro Test Area Near Dam and surrounding area do not contain any additional endangered or special status species. It is possible that the state and federally listed bald eagle may nest or forage in the vicinity of Lake Greenwood because of its large hunting radius.

5.2. Visual Survey Observations and Results

The Malcolm Pirnie survey team included Ms. Molly Howard, Mr. Hien Dinh, Mr. Svend Egholm, and Mr. Terry Stark. Mr. Phil Keith and Mr. Steve Schantz of NSWC Crane accompanied the survey team. The survey team was able to walk 100% of the area along the dam on March 20, 2003. The total area surveyed by the team was approximately 550 meters along the

dam. The survey team did not observe any munitions related debris along the dam or in the surrounding land. There are no structures on-site at the Lake Greenwood Pyro Test Area Near Dam. The team did not go into the water of the lake to investigate.

A visual depiction of the site reconnaissance is provided on Map 5-1 located at the end of Section 5. Additional range/site details are illustrated on Map 5-2 also located at the end of Section 5.

5.3. Munitions and Munitions Related Materials Associated with the Site

This section describes the munitions or munitions related materials known or suspected to be at the site. This includes both MEC and non-hazardous munitions related scrap (e.g., fragmentation, base plates, inert mortar fins).

The data collection team was unable to locate specific records of the types and quantities of pyrotechnics tested at the Lake Greenwood Pyro Test Area Near Dam. Interviews with installation personnel indicated the use of underwater illuminating flares. It is expected that the following munitions may be found on-site:

- Signal, Illumination, Marine, MK 5 Mod 4
- Signal, Smoke, Marine, MK 25
- Signal, Smoke, Marine, MK 7 Mod 2
- Signal, Smoke, Marine, MK 6 Mod 3
- Underwater Illuminating Flares

A marine smoke signal, such as the MK 6 Mod 3, is a pyrotechnic device that is launched from surface craft only to produce a day or night floating reference point. One of its principal uses is as a man-overboard marker. A marine signal such as the MK 25 location marker is also launched from a surface craft. It provides day or night reference points for marking the course of enemy submarines in antisubmarine warfare operations. The MK 25 is suitable for any type of sea-surface reference point marking that calls for both smoke and flame for a period of 10 to 20 minutes.

No records were located to indicate the specifics of the underwater illuminating flares tested at the Lake Greenwood Pyro Test Area Near Dam or the green markers tested at the Officer's Club.

The marine illumination signals are designed to be fired from a Pyrotechnic Pistol, MK 5 either from the surface or from aircraft, primarily as a distress signal. The composition filler in the signals would ignite once fired from the pistol. Incomplete burning may occur, creating the potential for MEC.

Pyrotechnic and screening devices contain combustible chemicals which, when ignited, rapidly generate a flame of intense heat, flash, infrared radiation, smoke or sound display (or combinations of these effects) for a variety of purposes. Compared to other explosive substances, pyrotechnics are more adversely affected by moisture, temperature, and rough handling. Some compositions may become more sensitive, and even ignite, when exposed to moisture or air. Mixtures which contain chlorates and sulfur are susceptible to spontaneous combustion. Most pyrotechnics produce a very hot fire that is difficult to extinguish and most burn without serious explosions. Many chemicals used in pyrotechnics produce toxic effects when ignited. Other pyrotechnics, which contain propelling charges create an extremely hazardous missile hazard if accidentally ignited. The following are the different types of devices that pyrotechnic material may be found at the Lake Greenwood Pyro Test Area Near Dam.

Table 5.3-1 is a summary of the hazards associated with these types of pyrotechnic devices.

- SIGNALING. Pyrotechnics for signaling can be projected or released from small pistol-like devices, hand held devices, hand manipulated devices, rifle launched devices and colors delivered by .38 caliber or 9 mm ammunition. Other signaling devices are used to indicate the impact points of bombs or large rounds. Such devices produce a variety of colors (red, green yellow white, orange, red/orange, blue and others).

- ILLUMINATING. Illuminating devices are normally powdered magnesium mixed with an oxidizer. Depending upon the size and application, the devices may be capable of providing a high intensity white light for relatively long periods of time (one half to six minutes). They burn with a high temperature and once ignited are difficult to extinguish. They may be ignited or activated by rough handling. Delivery can be by aircraft, mortar, gun, grenade or may be hand emplaced as a booby trap.

Table 5.3-1: Pyrotechnics and Associated Hazards

Class of Pyrotechnic	Type of Potential Hazard/Safety Precautions
Signaling	• Cocked firing mechanisms • Lack of safety devices on many projectors • Ballistic damage upon firing from the projector • Possible injury of user or nearby personnel • Very intense fire produced by pyrotechnic • Potential toxic hazard
Illuminating	• Very intense fire produces by pyrotechnic • Difficult to extinguish fire • Ballistic damage upon firing from the canister • Possible injury of user or nearby personnel

Additional technical information and specifics about the types of ordnance used at the Lake Greenwood Pyro Test Area Near Dam are included in Appendix D.

Based on the information obtained during the data collection process, no special consideration munitions (chemical warfare materiel filled munitions, electrically fuzed munitions, depleted uranium associated munitions) are known or suspected to have been used at the site; therefore, the Lake Greenwood Pyro Test Area Near Dam is not suspected to contain special consideration MEC.

5.4. MEC Presence

The entire site has been subdivided and categorized into one of three levels of MEC presence including: Known MEC Areas, Suspect MEC Areas, and Areas Not Suspected to Contain MEC. The MEC presence is discussed below.

Map 5-3 illustrates the munitions characterization of the Lake Greenwood Pyro Test Area Near Dam and is provided at the end of Section 5.

5.4.1. Known MEC Areas

There are no known MEC areas associated with the site.

5.4.2. Suspected MEC Areas

The entirety of Lake Greenwood is a suspected MEC area. Although flares and pyrotechnics were fired into two specific locations of the lake, the MEC is not contained in those areas due to

the natural flow of water. There is a potential for MEC to be located throughout the lake. Lake Greenwood is identified as a site where evidence of MEC is suspected. MEC have the potential to be present in the sediment of the 800-acre lake as a result of the underwater illumination flare and marine signal marker testing. There is also a potential for MEC to be present at the Lake Greenwood Dam because the pyrotechnics, flares and signals were fired into the water from the dam. The suspect MEC area is depicted in Map 5-3.

5.4.3. Areas Not Suspected to Contain MEC

Based on the site history, the areas surrounding the Lake Greenwood Pyro Test Area Near Dam are not suspected to contain MEC.

5.5. Ordnance Penetration Estimates

The depth to which munitions penetrate below the ground surface depends on many factors, including the type of soil, the angle of impact, the size of the munitions, the velocity at impact, and site-specific environmental conditions. Over the years, the DoD has studied and modeled munitions penetration depths and has issued various guidance and technical documents on the subject. For the purposes of the WAMS, maximum probable penetration depths are estimated following guidance listed in the latest draft (July 2002) of the DoD Directive on Explosives Safety issued by the DoD Explosives Safety Board [*DoD Directive 6055.9* (*DoD Ammunition and Explosives Safety Standards*)]. The Directive refers to *TM 5.855.1* and *NAVFAC P-1080.*

All of the ordnance listed in Section 5.3 is only anticipated to have been present in the lake waters. It is not anticipated that the ordnance tested at the Lake Greenwood Pyro Test Area Near Dam would have penetrated the sediments or subsurface soils during testing. However, it is possible that partially consumed flares and markers and their associated components may have settled to the bottom of the lake and are present in the lake sediments.

5.6. Munitions Constituents

There is the potential for MC to be associated with the types of munitions suspected to have been used at the Lake Greenwood Pyro Test Area Near Dam. The illumination signal described in Section 5.3 contains red phosphorus composition as the filler. Green markers contain an illuminating material, such as $NaNO_3$ and Mg. Potential MC associated with the smoke filler

may include a combination of various chemicals that are contained in burning-type colored smoke munitions and explosive-type colored smoke munitions. Some chemicals used in typical smoke compositions include zinc oxide, sulfur, sodium hydrogen carbonate, sodium chloride, and potassium chlorate. The following is a partial list of chemicals that could be contained in combination in burning-types smokes:

- Red Smoke - 9-diethylamino-phenyl-5-benzo (a) phenazinone, 1-(tolylazoxylylazo)-2-naphthol
- Green Smoke - 1, 8-di-p-toluidinoanthraquinone
- Orange Smoke (burn-type) - could contain 1-aminoanthraquinone

A complete list of dyes that have been used in burning-type colored smoke munitions, typical smoke compositions, and some dyes which have been used in explosive-type colored smoke munitions at NSWC Crane Division can be found in Appendix B.

Around 1958, there were about six experimental underwater illuminating flares tested that contained Magnesium (Mg), Sodium Nitrate ($NaNO_3$), and polyester binder.

5.7. Contaminant Migration Routes

Studies have shown that ordnance can migrate due to environmental factors such as frost heave or erosion. However, contaminants (if present) at Lake Greenwood would potentially migrate in the surface water and sediment. All surface water eventually discharges to the East Fork of the White River. Numerous drainage channels are present at NSWC Crane. Lake Greenwood is part of the northern drainage basin, which empties into Furst Creek, which flows west and crosses the NSWC Crane boundary.

MEC items may potentially be located within the sediment of the Lake. Small MEC items may migrate off-site via water flowing into Furst Creek. Heavier or larger items would most likely not migrate due to surface and subsurface water flow and would remain in the sediments of the lake.

MC present in the surface water during testing either would have settled to the sediment or migrated off-site via Furst Creek. Since testing occurred in the mid 1950s, it is assumed that MC are no longer present in the surface water, and any MC remaining at the site would be present in the sediment. The sediment has the potential to migrate downstream if it is suspended in the

surface water flow. Since the soils present at the surrounding site are well drained and moderately well drained soils, there is a potential for contaminants to leach from the soil to the groundwater. Even though these soils contain fine grains, frost heave may not be a concern since the soils are very well drained. Since the depth to groundwater and groundwater flow paths at the site are unknown, the specific contaminant migration route for MC in the groundwater is unknown.

5.8. Receptors

The potential contaminant receptors at the Lake Greenwood Pyro Test Area Near Dam are receptors of MC in surface water and sediment and receptors of MEC in the sediment. Only surface water and sediment are expected to have the potential for receptor interaction since the lake was the impact area of the illuminating flares and marine markers. Surface water at Lake Greenwood is the source of drinking and production water for NSWC Crane. Users of surface water also include several species of vegetation and indigenous animals. Surface water from Lake Greenwood eventually discharges to the East Fork of the White River. Lake Greenwood is used for recreational activities, including fishing, by both the public and private sector. The White River is also used for fishing and recreation. Potential receptors of surface water include current and future Navy personnel, authorized visitors, trespassers, fauna and flora. Potential receptors of the sediment include aquatic fauna and floral that may burrow, forage, or grow in the sediment.

5.8.1. Nearby Populations

NSWC Crane makes up the majority of Martin County. The rest of Martin County is essentially rural with some residential areas surrounding NSWC Crane. Martin County has a population of 10,383, which comprises 0.16 percent of the state's population. The population per square mile in Martin County is 30.9. NSWC Crane is the second largest employer in southwest Indiana with over 3,400 Navy employees and over 550 Army employees. A Combined Bachelors Quarters (approximately 36 rooms) and family housing (approximately 30 units) are located at NSWC Crane. Lake Greenwood is used for recreational fishing, boating, and water skiing.

5.8.2. Buildings Near/Within Site

There are no structures near the dam test site at Lake Greenwood. The Officer's Club is approximately 200 feet from the shoreline where testing occurred. Numerous Naval facility buildings, as well as storage magazines, are located within one mile of the lake.

5.8.3. Utilities On/Near Site

The buildings and facilities near the Lake Greenwood Pyro Test Area Near Dam have utilities; however, it is not known whether underground utilities exist at the site. The Officer's Club has utilities including water, electricity, and phone lines. NSWC Crane did not have utility maps available for review. The Public Works Department indicated that no maps were available and field verification of utilities would be required.

5.9. Land Use

The Lake Greenwood Pyro Test Area Near Dam is no longer used for pyrotechnic testing and is considered closed. The area is to remain closed for such use and continue its use as a recreational and fishing area. The land use is not anticipated to change during the foreseeable future; therefore, the reasonably anticipated future land use for the area is recreation.

5.10. Access Controls / Restrictions

Access to the NSWC Crane is restricted. The NSWC Crane property is surrounded by locked, secured gates, with security at all entrances, as well as a security patrol. There are no access controls or restrictions in place to limit access to the Lake Greenwood Pyro Test Area Near Dam once on the installation. Navy personnel, contractors, and visitors are not specifically restricted from the former test area. There are no known zoning/land use restrictions for the Lake Greenwood Pyro Test Area Near Dam.

5.11. Conceptual Site Model

This CSM was developed following guidance documents issued by the U.S. Environmental Protection Agency (USEPA) for hazardous waste sites and the U.S. Army Corps of Engineers

(USACE) for ordnance and explosives (OE) sites. Guidance documents included the USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (EPA/540/G-89/004) and the USACE CSM Guidance Development of Integrated Conceptual Site Models for Environmental OE Sites, which was final as of February 2003.

The CSM describes the site and its environmental setting. The CSM presents information regarding: 1) MEC and/or MC known or suspected to be at the site; 2) current and future reasonably anticipated or proposed uses of the real property; and 3) actual, potentially complete, or incomplete exposure pathways that link them. The CSM is the basis for the risk evaluation, prioritization, and remediation cost estimate.

The CSM is presented in a series of information profiles that presents information about the site. The information profiles are included in Table 5.11-1.

Table 5.11-1: Conceptual Site Model Information Profiles – Lake Greenwood Pyro Test Area Near Dam

Profile Type	Information Needs	Preliminary Assessment Findings
Range/Site Profile	Installation Name	NSWC Crane
	Installation Location	Crane, Martin County, Indiana
	Range/Site Name	Lake Greenwood Pyro Test Area Near Dam
	Range/Site Location	North-central portion of NSWC Crane
	Range/Site History	Lake Greenwood Pyro Test Area Near Dam was used for pyrotechnic testing from approximately 1954 to 1958 to test marine location markers, including MK 5 Mod 4, MK 25, MK 7 Mod 2, and MK 6 Mod 3. Around 1958, there were about six experimental underwater illuminating flares tested that contained Mg, $NaNO_3$, and polyester binder, and all parts were recovered. The test location was about 200-300 yards offshore at a deep spot (~30 ft.) near the dam.
	Range/Site Area and Layout	The lake is approximately 800 acres in size.
	Range/Site Structures	Grass covered earthen dam
	Range/Site Boundaries	N: Highway 331 S: Highway 5 W: Highway 331 E: Highway 45

Table 5.11-1: Conceptual Site Model Information Profiles – Lake Greenwood Pyro Test Area Near Dam

Profile Type	Information Needs	Preliminary Assessment Findings
	Range/Site Security	The installation is fenced; the Lake Greenwood Pyro Test Area Near Dam is not fenced.
Munitions/ Release Profile	Munitions Types	Illuminating flares and marine markers
	Maximum Probability Penetration Depth	Any munitions used would have been deployed within the water column of the lake; therefore, no penetration of the lakebed is expected to have occurred.
	MEC Density	Minimal range related debris is expected to be at the site based upon the Navy operating procedures to collect and remove related debris immediately after testing.
	MEC Scrap/Fragments	None found along the dam at the lake. The team did not go into the water of the lake to investigate.
	Associated Munitions Constituents	Minimal amount of metals and other inorganics. No explosives were found during the site visit.
	Migration Routes/Release Mechanisms	Potential leaching, wave action and sedimentation
Physical Profile	Climate	Temperate climate zone, which has a wide temperature range between summer and winter
	Topography	Water
	Geology	The area is located on the eastern flank of the Illinois Basin consisting of shale, sandstone, limestone, and coal beds. The specific geology of the site is unknown.
	Soil	Sandy-clay, silty-clay
	Hydrogeology	Specific hydrogeology of the site is unknown.
	Hydrology	The lake is approximately 800 acres. At its deepest point, the lake is approximately 35 feet; the average depth of the lake is 15 feet.
	Vegetation	Water. Surrounding vegetation is grass, trees, and shrubbery.
Land Use and Exposure Profile	Current Land Use	The lake and surrounding land is used for recreational purposes.
	Current Human Receptors	Naval personnel, contractors, trespassers, and authorized visitors
	Current Activities (frequency, nature of activity)	The lake is currently used for recreational fishing and boating.

Table 5.11-1: Conceptual Site Model Information Profiles – Lake Greenwood Pyro Test Area Near Dam

Profile Type	Information Needs	Preliminary Assessment Findings
	Potential Future Land Use	No change in land use is expected.
	Potential Future Human Receptors	Naval personnel, contractors, trespassers and authorized visitors
	Potential Future Land Use-Related Activities:	Future land use is expected to remain the same as current uses.
	Zoning/Land Use Restrictions	No known zoning/land use restrictions
	Demographics/Zoning	NSWC Crane employs approximately 4,000 personnel, both civilian and military. Martin County has a population of 10,383, which comprises 0.16 percent of the state's population. The population per square mile in Martin County is 30.9.
	Beneficial Resources	Recreational resource
Ecological Profile	Habitat Type	Lacustrine
	Degree of Disturbance	If current conditions continue, the degree of disturbance at the site will be low. Low – Site is/will be unused; habitat and species present are/will be undisturbed (i.e., undisturbed grassland and forest).
	Ecological Receptors	
	Federal Endangered Species:	No federal endangered species are known at the site.
	Federal Threatened Species:	The Bald Eagle *(Haliaeetus leucocephalus)* could be located at the site based on the large hunting range of the eagle.
	State Endangered Species:	None have been identified at the site.
	State Threatened Species:	The Bald Eagle (*Haliaeetus leucocephalus*) could be located at the site based on the large hunting range of the eagle.
	Other Ecological Receptors:	The habitat at the site and the surrounding area is home to many woodland wildlife species, such as deer, rabbits, raccoons, and wild turkeys. Aquatic plants and animals may reside in the lake waters.

Table 5.11-1: Conceptual Site Model Information Profiles – Lake Greenwood Pyro Test Area Near Dam		
Profile Type	**Information Needs**	**Preliminary Assessment Findings**
	Relationship of MEC/MC Sources to Habitat and Potential Receptors	Ecological receptors may come into direct contact with MC in the sediment or surface water. No contact is anticipated with MEC at the site. Wildlife that inhabit or utilize the area may come into contact with MC that have been incorporated into the food chain (bioaccumulated in plants and animals).

A key element of the CSM is the exposure pathway analysis. For MEC, a complete or potentially complete exposure pathway must include the following components: 1) a source (e.g., locations where MEC are expected to be found); 2) access (e.g., controlled or uncontrolled access, items on the surface or within the subsurface); 3) an activity (e.g., non-intrusive grounds maintenance or intrusive construction); and 4) receptors (e.g., Navy personnel, construction workers, recreational users or authorized visitors). It is important to recognize that environmental mechanisms (e.g., erosion) and/or human intervention may result in the repositioning of MEC.

For MC, a complete or potentially complete exposure pathway must include the following components: 1) a source (e.g., locations where MC are expected to be found); 2) an exposure medium (e.g., surface soil); 3) an exposure route (e.g., dermal contact); and 4) receptors (e.g., Navy personnel, construction workers, recreational users or authorized visitors). If the point of exposure is not at the same location as the source, the pathway may also include a release mechanism (e.g., volatilization) and a transport medium (e.g., air).

The potential interactions between the source and receptors are assessed differently between MEC and MC. For MC, interaction between the source and receptors involves a release mechanism for the MC, an exposure medium that contains the MC, and an exposure route that places the receptor into contact with the contaminated medium. For MEC, interaction between the potential receptors and an MEC source has two components. The receptor must have access to the source and must engage in some activity that results in contact with individual MEC items within the source area.

As seen in Figure 5.11-1, the MEC Exposure Pathway Analysis, there is potential for MEC to be located at the Lake Greenwood Pyro Test Area Near Dam. MEC may be located in the subsurface soils along the lake, or in the sediments at the lake bottom. Potential receptors of

MEC the dam include naval personnel, contractors, trespassers, and biota that would come into contact with MEC following intrusive activities via handle or underfoot tread. Biota including fish and other aquatic species are potential receptors of MEC located in the sediments of Lake Greenwood.

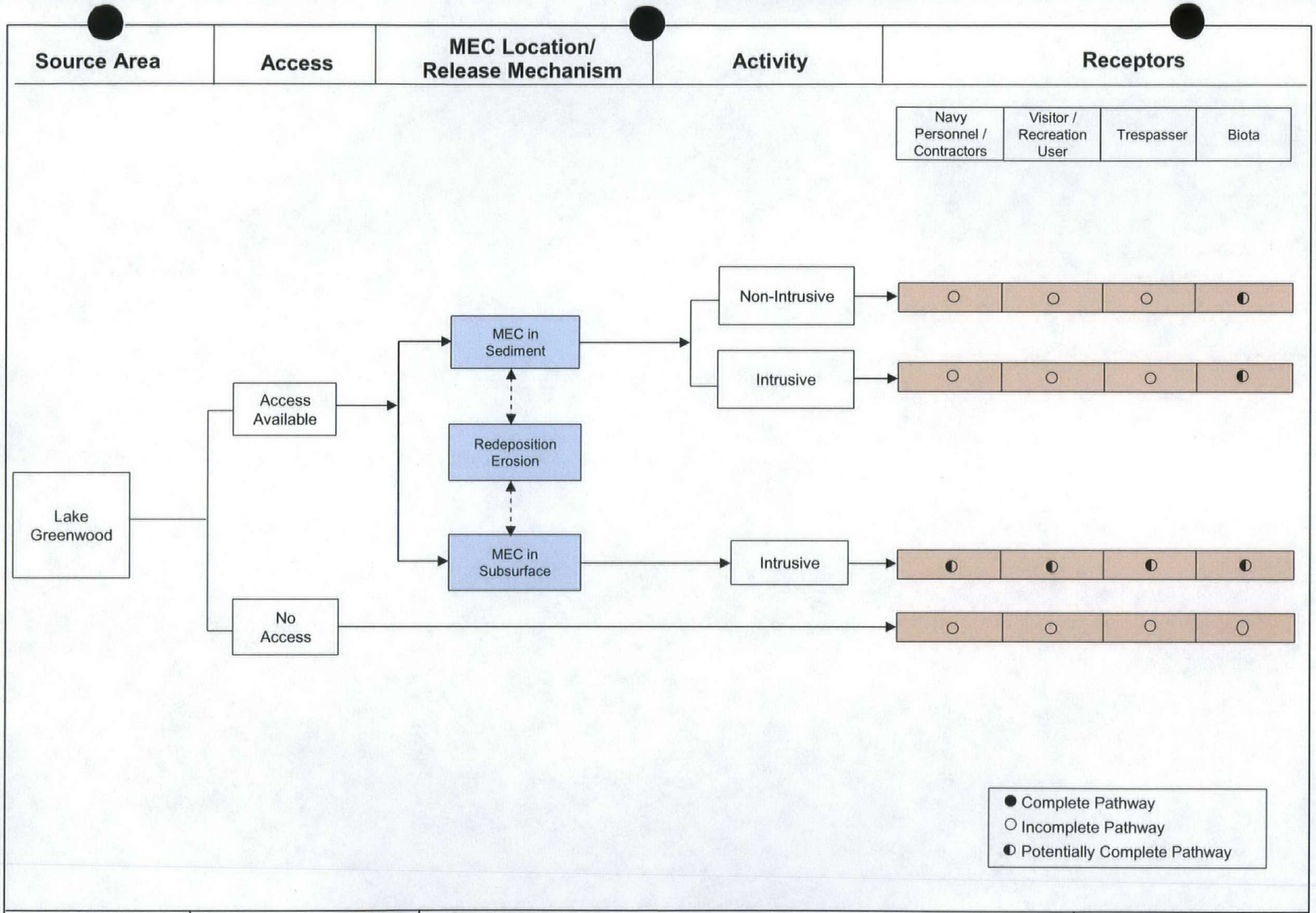
As seen in Figure 5.11-2, the MC Exposure Pathway Analysis, the potential for MC exists on the site. Given this potential, the figure identifies the exposure pathways through which site receptors could come in contact with or be impacted by MC. A potentially complete pathway exists for surface water/sediments through dermal contact for human receptors (Navy personnel, contractors, visitors and trespassers). A potentially complete pathway exists for surface water/sediments through dermal contact and ingestion for ecological (biota) receptors. Navy personnel, visitors and trespassers could come into contact with surface water through recreational activities, such as fishing. Contractors may be exposed during site investigations or from potential future land use changes that may require construction. Biota on the site may disturb the sediment through nesting or feeding. Potential accumulation in game animals can pose a threat to human receptors, as fishing is allowed at the lake. The food chain may also be affected for ecological receptors.

Graphical illustrations of the details of the CSM are included in Figure 5.11-3 and Figure 5.11-4 at the end of Section 5. Figure 5.11-3 illustrates the infiltration and runoff directions and potential areas for MEC/MC contamination for the Lake Greenwood Pyro Test Area Near Dam. Figure 5.11-4 illustrates the infiltration and runoff for the area in which the testing occurred off shore near the Officer's Club, known as the Lake Greenwood Officer's Club Test Area.

The illustration in Figure 5.11-3 shows the lake and wooded area and vegetation that surround the site, creating a potential habitat for flora and fauna. Red arrows indicate the direction of precipitation infiltration and surface water runoff across the site, which follow the topography of the site draining into Lake Greenwood. Blue arrows above the lake indicate the potential for evaporation from the surface of the lake. The dark red arrows shown in the deep water of the lake show the potential for leaching into sediments at the bottom of the lake. In addition, the graphical illustration identifies the suspected groundwater flow direction in accordance with the depicted topography. The dam is shown in the illustration as the light green area along the western edge of the lake. The suspected MEC and MC area is shown with a red dotted line. Although all of Lake

Greenwood is a suspect MEC area due to the natural flow of water, the circles show the actual areas into which the flares and pyrotechnics were fired.

Figure 5.11-4 is the illustration for the area approximately 200 yards offshore which was the target for green markers fired from the shore in front of the Officer's Club. This illustration shows the targeted MEC and MC area in the middle of the lake. Although this area is the historical target area for the flares and illuminating materials, the entirety of Lake Greenwood is a suspected MEC area. The illustration also shows the runoff from the surrounding shores into the lake. The suspected groundwater flow is shown in the blue arrows. The deep red arrows in the deep water of the lake show potential leaching.



MALCOLM PIRNIE

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WATER AREA MUNITIONS STUDY – FINAL REPORT
LAKE GREENWOOD – MEC EXPOSURE PATHWAY ANALYSIS
NSWC CRANE, INDIANA

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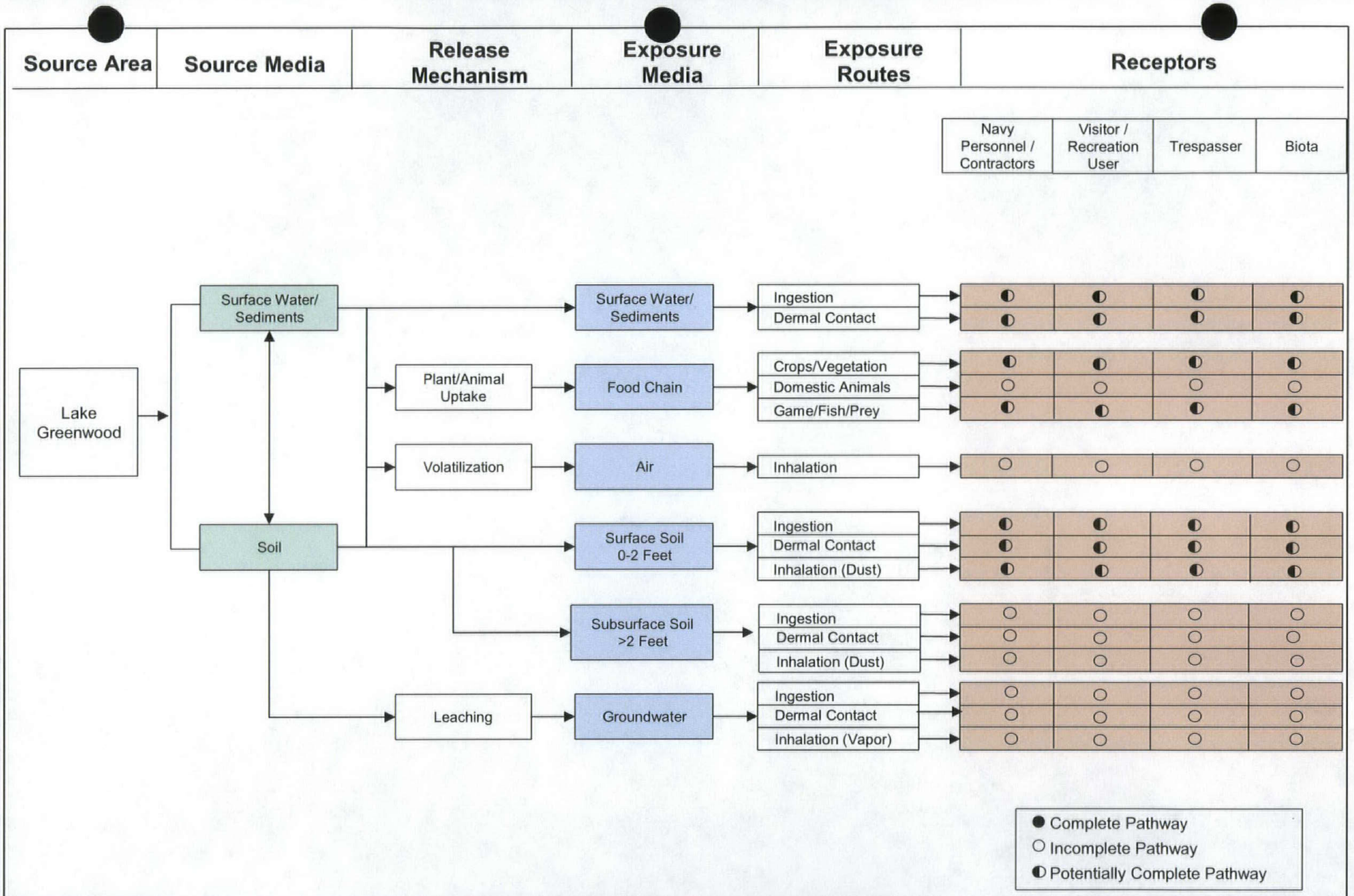
FIGURE 5.11-1 DRAFT FINAL
APRIL 2005



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WATER AREA MUNITIONS STUDY – FINAL REPORT
LAKE GREENWOOD – MC EXPOSURE PATHWAY ANALYSIS
NSWC CRANE, INDIANA

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FIGURE 5.11-2 DRAFT FINAL
APRIL 2005

FIGURE 5.11-3
LAKE GREENWOOD
PYRO TEST AREA NEAR DAM
GRAPHICAL ILLUSTRATION

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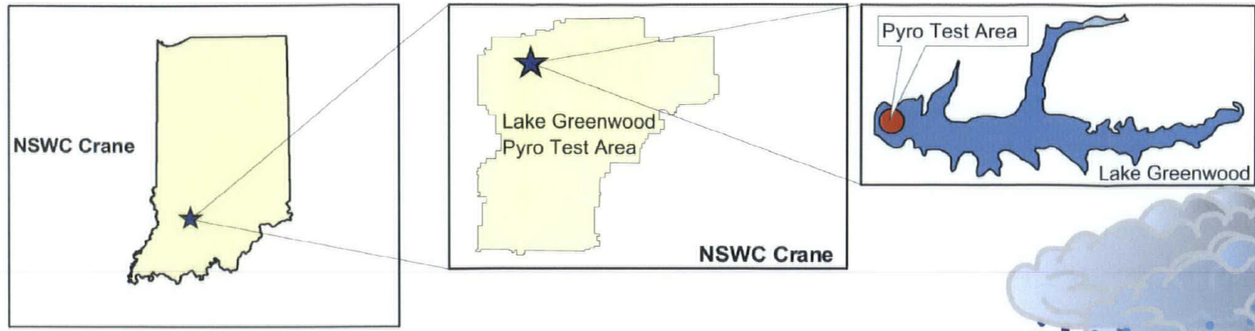

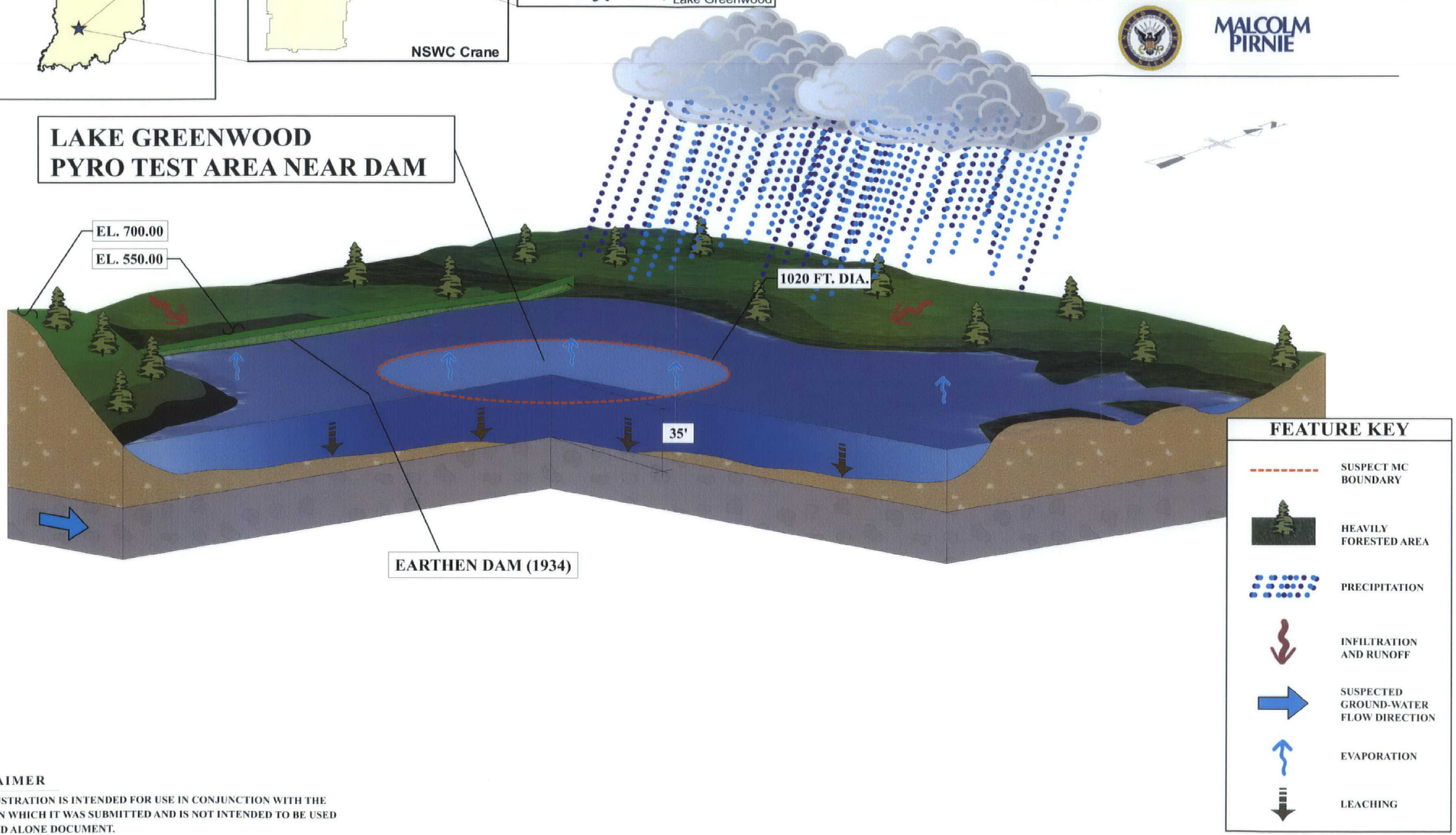

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FIGURE 5.11-4
LAKE GREENWOOD OFFICER'S CLUB TEST AREA GRAPHICAL ILLUSTRATION

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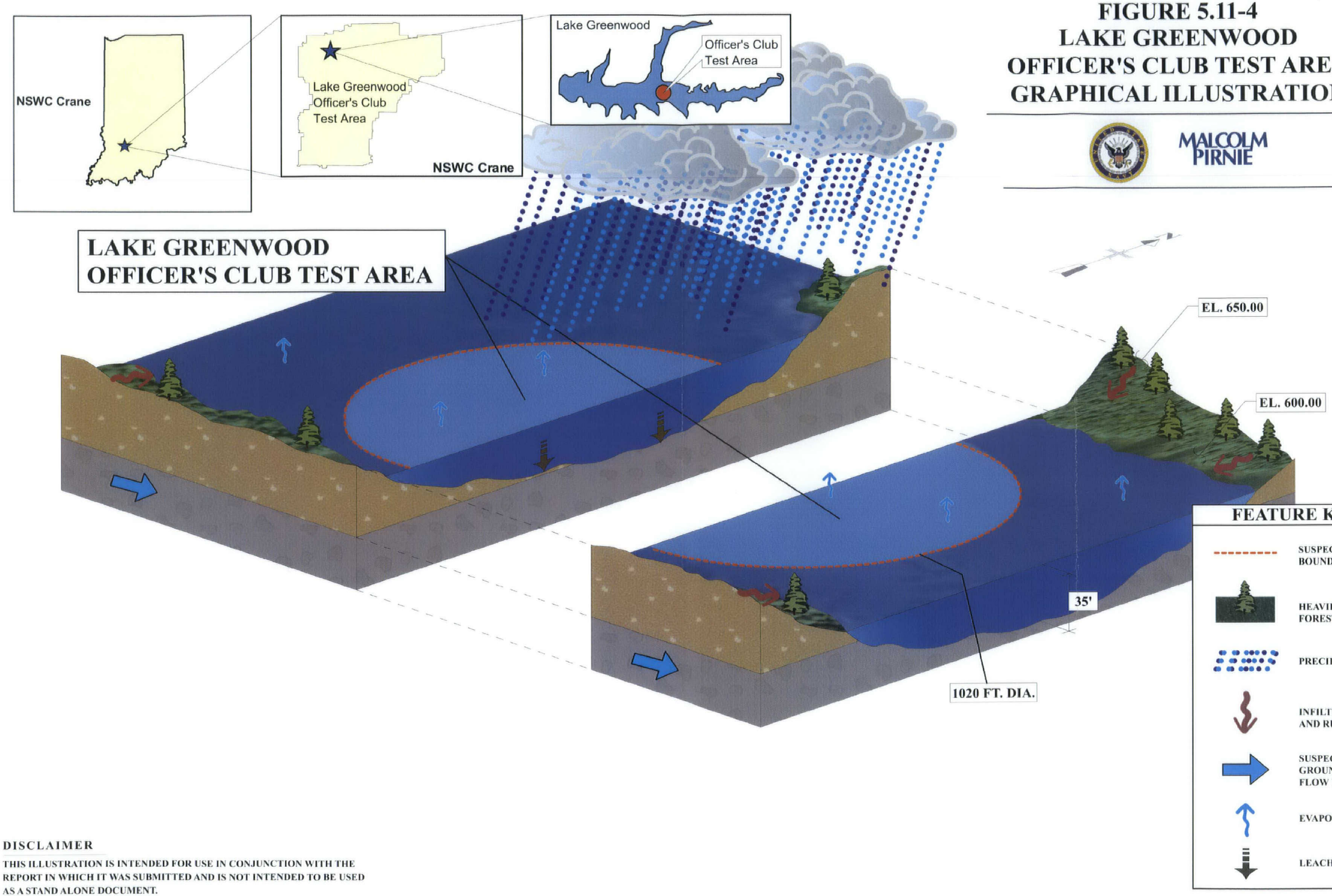

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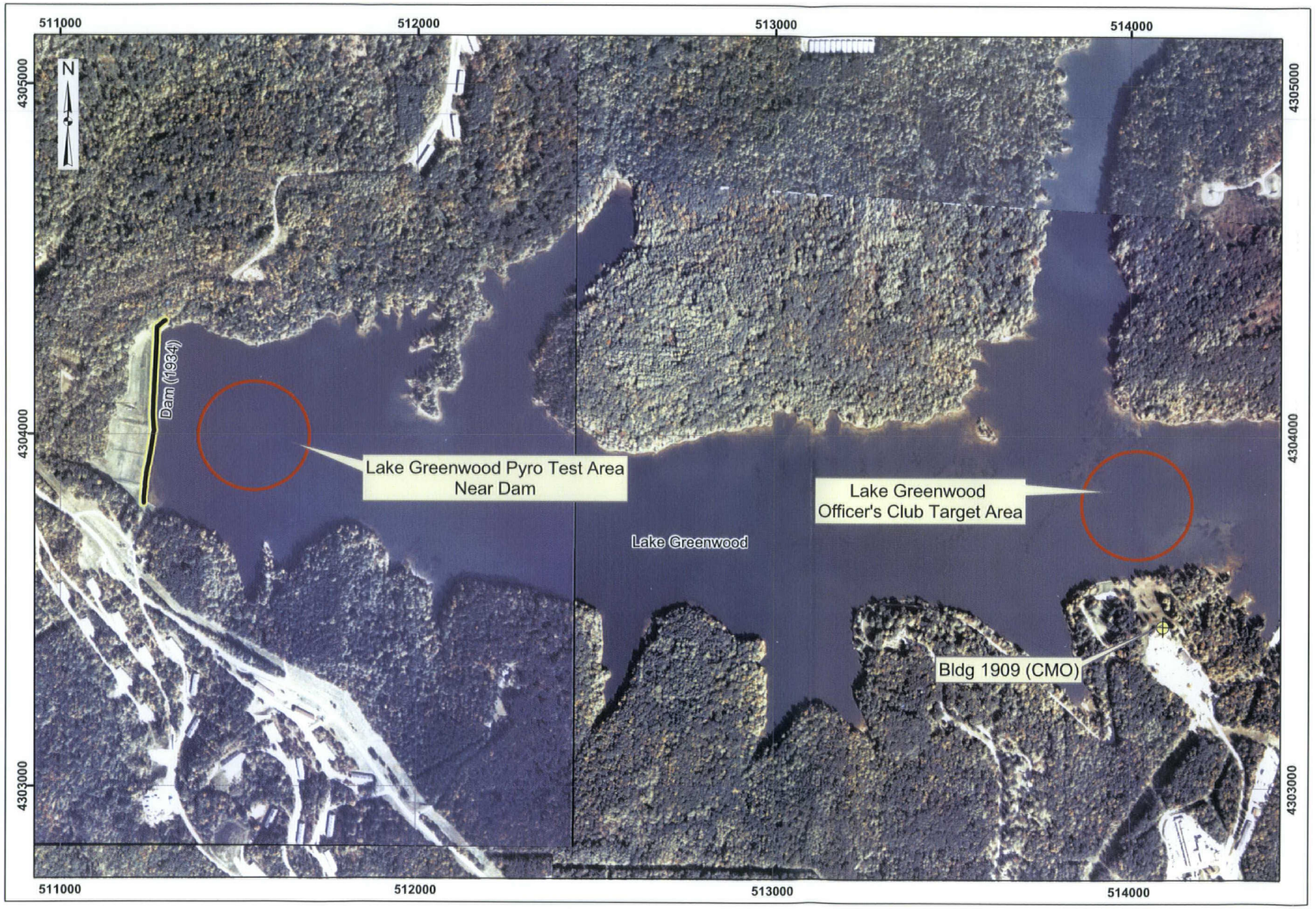
5.12. Summary

The history of the Lake Greenwood Pyro Test Area Near Dam dates from the 1950s. The site was used for testing of green markers, underwater illuminating flares, and marine markers from a boat floated into the lake and from the shoreline. Lake Greenwood is currently used as a recreational area for fishing and boating. There are no current plans to change that use. No evidence was found during the site visit indicating that MEC remain at the site. There is a minimal probability that MC are present at the site because of the minimal amounts of MC associated with the munitions themselves. In addition, since the markers and illuminating flares were fired over the water, evidence of MEC or MC in the surface water would have dissipated over the years. Potential receptors at the site include Navy personnel and authorized visitors who work in the nearby facilities or use the lake for recreation, trespassers, as well as biota.



Water Area Munitions Study
NSWC Crane, Indiana

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Map 5-1
Visual Survey
Lake Greenwood Pyro Test Area

Legend

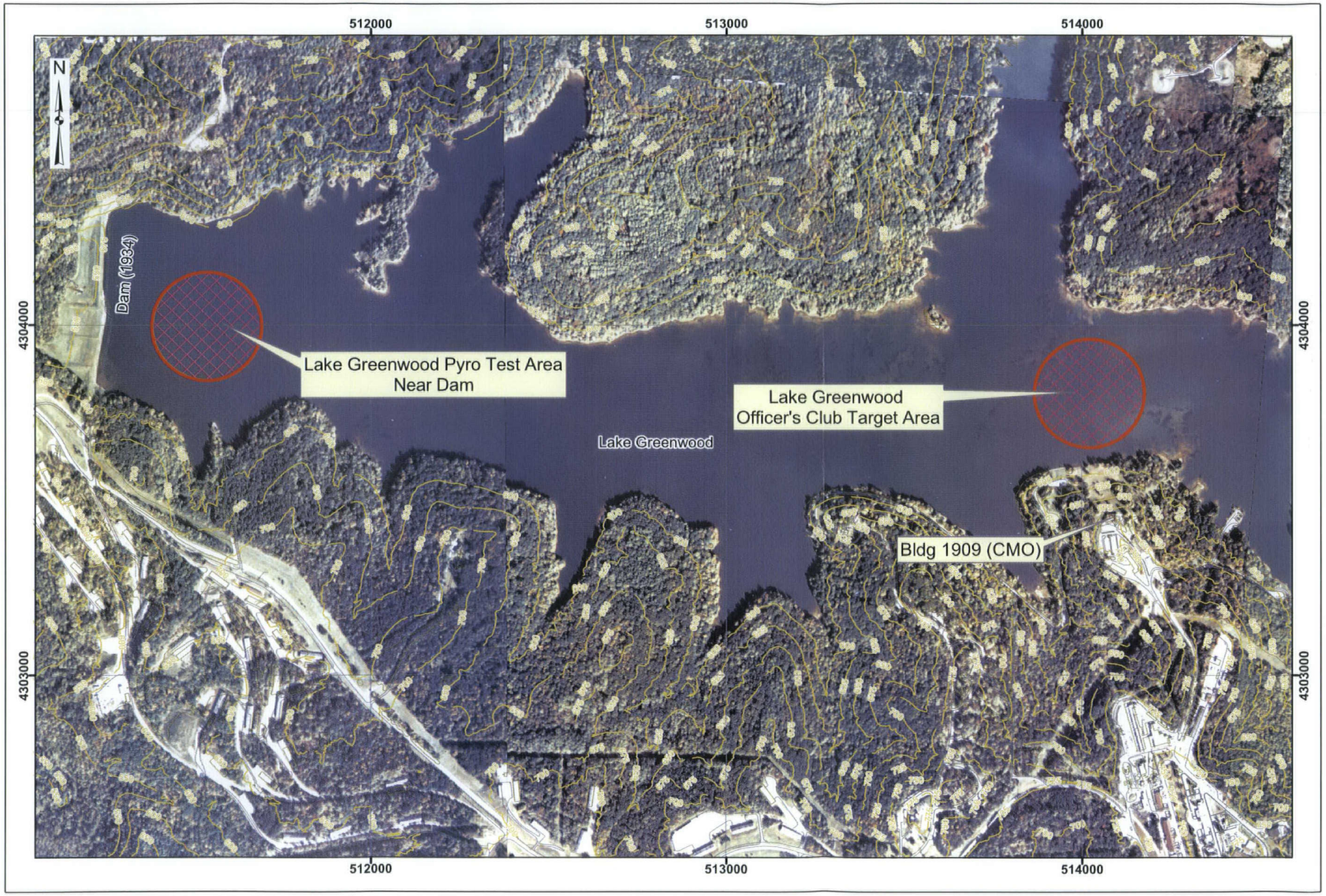
- Installation Boundary
- Lake Greenwood Pryo Test Area
- Building 1909 (GPS)
- Site Reconnaissance

200 0 200 400 600 Meters

Data Source: NSWC Crane, Orthophoto, 1998
NSWC Crane, GIS Data, 2003

Coordinate System: UTM Zone 16N
Datum: NAD83
Units: Meters

Contract: N62472-02-D-1300
Edition: Final Water Area Munitions Study
Date: April 2005



Water Area Munitions Study
NSWC Crane, Indiana

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Map 5-2
Range/Site Details
Lake Greenwood Pyro Test Area

Legend

- Installation Boundary
- Roads
- Contours
- Structures
- Target Area
- Lake Greenwood Pyro Test Area

200 100 0 200 400 Meters

Data Source: NSWC Crane, Orthophoto, 1998
NSWC Crane, GIS Data, 2003

Coordinate System: UTM Zone 16N
Datum: NAD83
Units: Meters

Contract: N62472-02-D-1300
Edition: Final Water Area Munitions Study
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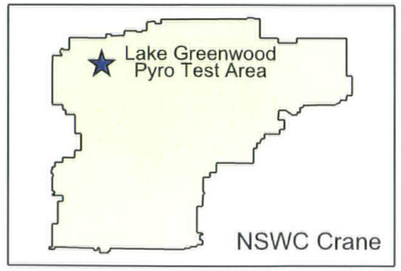

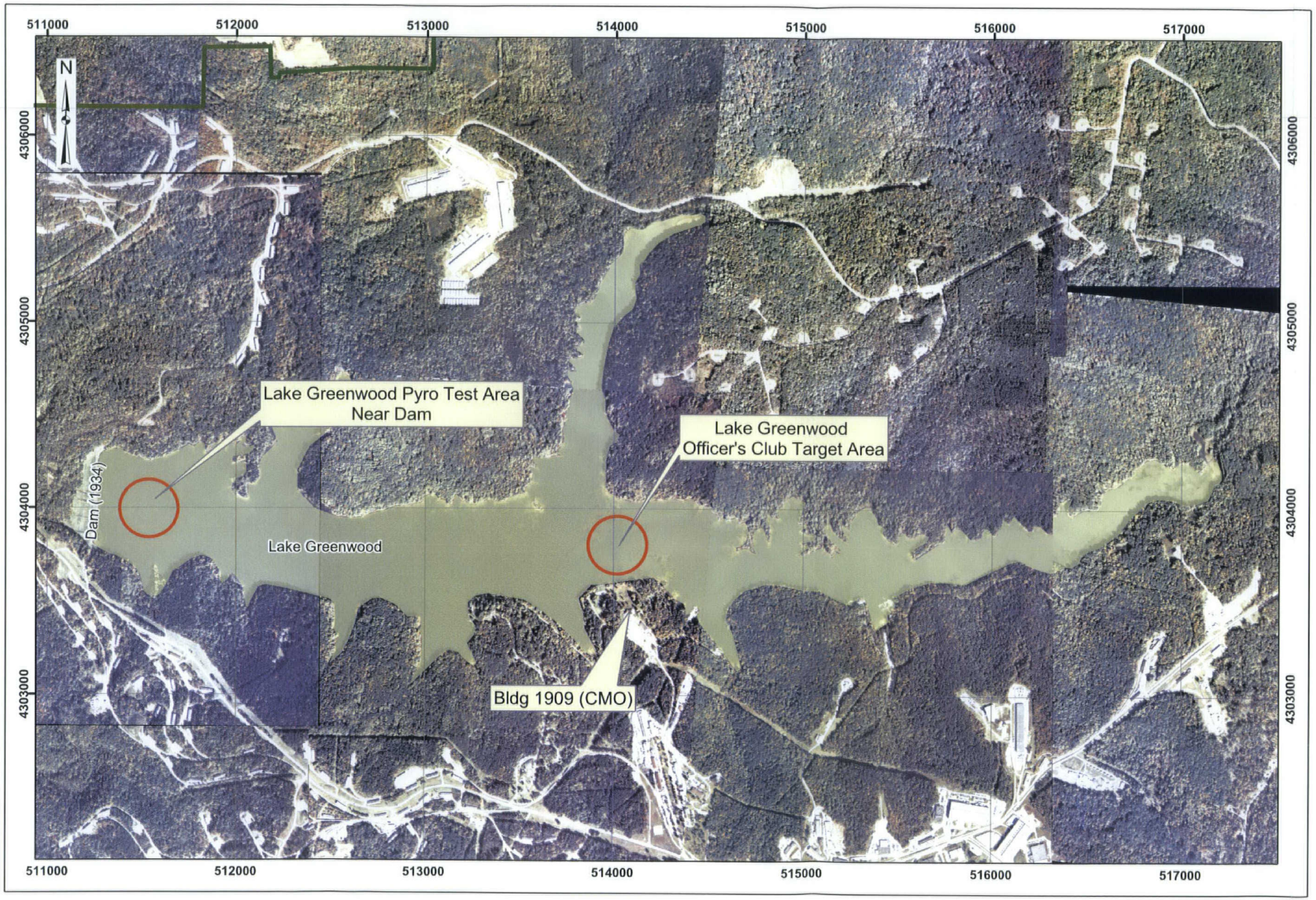

Water Area Munitions Study
NSWC Crane, Indiana

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Map 5-3
Munitions Characterization
Lake Greenwood Pyro Test Area

Legend

Installation Boundary

Lake Greenwood Pryo Test Area

MEC Presence*

Known

Suspect

* MEC Presence was determined through review of historical documentation, interviews, and visual survey.

300 0 300 600 900 Meters

Data Source: NSWC Crane, Orthophoto, 1998
NSWC Crane, GIS Data, 2003

Coordinate System: UTM Zone 16N
Datum: NAD83
Units: Meters

Contract: N62472-02-D-1300
Edition: Final Water Area Munitions Study
Date: April 2005

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NSWC Crane History
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Maps:

Electronic base map data dated 1998 was received from Tom Brent, Environmental Protection Specialist at NSWC Crane Division. No munitions related ranges or information is depicted on the maps but they establish base map references for the installation. The data layers included:

- Installation boundaries
- Installation landmarks (buildings, pads, roads)
- Topography
- Hydrology
- Environmental features (wetlands, habitat)
- Imagery (aerial photography from current and earlier time periods)

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Appendix B: Project Source Data-General

Interview Record

Installation/Range or Site: NSWC Crane, Indiana

Date/Time: March 20, 2003

Person Conducting the Interview/Title/Organization: Julie Grim, Malcolm Pirnie

Person Being Interviewed/Title/Organization: John Allen

Reason for Selecting Person to Interview (i.e., Years at Installation, Position, Previous History, etc.): Base Historian

---

Interview Notes (i.e., Range History, Ordnance Types, Land Use, Historical Records/Maps Available):

-1952 Public Works

-Oberlin & Greenwood, fired off dams; ended because employee was killed in the late 1940s or early 1950s and that was the last time used

-Captain's Pond, late 1970s, dye testing (greens) (orange) marking dye on lifevests; doesn't recall pyro testing; Jim Short planner for pyro testing in pad now part-time with SAIC (ext. 6796); Hank Webster may recall some info about pond; built in approx. 1974; never dredged

-Not familiar with work @ sedimentation pond

-Captain's Pond has never been dredged

-Conservation Dam No. 2845 was built in 1962

Interview Notes Continued:

-Off-post: Dugger lake, Camp Asbury, Plane drops into Lake Greenwood, from R&D, drift testing, video, may not have been active b/c interested in drift, late 70s, only a few passes, from Washington, IN, Hank Webster

-Boundaries: 40 acres in Davies County, no improvements, other areas to straighten fence, H 45 and H 58 sold triangle (approx. 200 acres) to Dr in early 1990s, no improvement except fence

-Crane Village, under housing office (Crane Village S.) Crane Village north, Dr. Elias bought from GSA, MOA to supply water, sewer, etc.

-Understand no testing outside boundaries

-Burial grounds for mustard, phosgene, gas, removed in 70s, repacked and sent away, SWMU, WWII items

-EOD gold course response in 2002

-14" projectile in front of building 1

-WWII, Vietnam, Korea hard to get info

Interview Notes Continued:

Interview Record

Installation/Range or Site: NSWC Crane, Indiana

Date/Time: March 19, 2003

Person Conducting the Interview/Title/Organization: Molly Howard, Malcolm Pirnie

Person Being Interviewed/Title/Organization: Mr. Phil Keith

Reason for Selecting Person to Interview (i.e., Years at Installation, Position, Previous History, etc.): Point of Contact

---

Interview Notes (i.e., Range History, Ordnance Types, Land Use, Historical Records/Maps Available):

Lake Greenwood Pyro Test Area Near Dam

- Mr. Keith accompanied the survey team to the dam, and showed the team the length of the dam and locations where testing was said to have occurred
- Noted that items were fired from the dam into the lake, several hundred yards offshore
- Boats were also used at this location and were floated into the lake from the dam

Lake Oberlin

-Mr. Keith accompanied the team to the location of the lake and noted its use by the boy scouts

-Identified the physical features at the lake, including the dock and the areas in the lake where the testing may have occurred

Interview Notes Continued:

Dugger Lake

-Mr. Keith accompanied the team to Dugger Lake and was able to identify areas on the lake where testing may have occurred

-He also stated that the water pumped from the lake was used for local mining purposes.

IV. ENVIRONMENTAL SETTING

A. Meteorology

The NWSC is located in a temperate climate zone with an average of 44 inches of precipitation annually (Ref. 3, p.5-6). Temperatures vary widely throughout the year with a mean winter low temperature of 26 degrees farenheit and a mean summer high temperature of 89 degrees farenheit. The humidity is generally high, ranging from 40 to 90 percent (Ref. 3, p. 5-6). Winds in southwestern Indiana are generally from the south southwest at an average speed of 8.2 mph (Ref. 21, p.354).

B. Floodplain and Surface Water

The facility is characterized by well developed dendritic surface drainage (Ref. 3, p. 5-19). There are five drainage basins, consisting of seven streams, that carry surface water off site (Ref. 4, p.14). Flow within the drainage basins is generally toward the southwest. The following is a list of drainage basins and the general area that each encompasses within the site (Ref. 4, p.14).

Drainage Basin	Streams Within Basin	Site Drainage Area
Basin I	Furst Creek	Northwest Section
Basin II	Indiana Creek	Extreme Eastern Section
Basin III	Sulphur Creek Little Sulphur Creek	Eastern Section
Basin IV	Boggs Creek Turkey Creek	Central, Southcentral Sections
Basin V	Seed Tick Creek	Southwestern Section

Boggs Creek and Turkey Creek provide the primary surface drainage pathways for the facility. The facility's water supply is from Lake Greenwood in the northwest corner of the site. Lake Greenwood is an 800 acre spring fed lake that discharges to Furst Creek (Ref. 3, p.5-19). Figure 2 provides the location of the surface drainage basins at NWSC.

Sections of facility property bordering the surface drainage routes at NWSC are within the 100 year floodplain. According to NWSC's Part B Permit Application, there are no hazardous waste units located within the 100 year floodplain (Ref. 6, p.B-7).

C. Geology and Soils

The NWSC is underlain by sedimentary rocks of lower Pennsylvanian and upper Mississippian Ages. With the exception of minor outwash and lacustral deposits in the northwest corner of the facility, there are no Pleistocene glacial deposits covering the site (Ref. 19). Surface deposits at NWSC consist of recent (Holocene) and Pleistocene unconsolidated alluvial silt, sand, and gravel and residual soils developed from the underlying rock (Ref. 4, p.10).

The soils covering the NWSC belong to the Zanesville and Muskingum Soil Series (Ref. 4, p. 10). These soils are characterized as dark organic silt loams with underlying mottled tan to gray clay with varying percentages of silt and sand. Soil thickness is variable with values ranging from less than one foot to over 40 feet (Ref. 4, p. 10).

The sedimentary bedrock beneath the facility dips gently to the west southwest. The inclination of the strata reflects NWSC's location on the eastern flank of the Illinois Basin. This section of the basin is comprised of Pennsylvanian and Mississippian strata consisting of shale, sandstone, limestone, and coal (Pennsylvanian) beds. The Pennsylvanian Mansfield Formation (Racoon Creek Group) unconformably overlies the Mississippian Stephensport and West Baden Groups (Ref. 18, Plate No. 1 and p. 151) at the site.

The Mansfield Formation has two distinct vertical divisions (Ref. 18, p.86). The lower division is comprised primarily of sandstone while the upper division consists of predominantly shale and mudstone (Ref. 18, p.86). Thin bituminous coal beds are prevalent throughout the formation.

The Stephensport Group conformably overlies the older West Baden Group. The Stephensport Group has five formations of which three are limestones and two are interbedded shale/sandstone formations (Ref. 18, Plate No. 2, p.13, 52, 56, and 87). Similarly the West Baden Group consists of the alternating carbonate/clastic lithology characteristic of the Stephensport Group with one exception. There is a noticeable lack of limestone tracer beds within a southwest trending linear area of the West Baden Group. This area, that outcrops northeast of the site, is referred to as the West Baden Clastic Belt (Ref. 18, p.43). The Belt consists of sandstone with adjoining bands of silty to sandy shale within the Elivren Formation (Ref. 18, p.43).

D. Groundwater

Groundwater resources at NWSC have not been studied extensively because the facility utilizes surface waters from Lake Greenwood for human consumption, process operations, and recreation. However, the existing lithologies, occurrences of springs and seeps, and the well developed surface drainage indicate the existence of groundwater that is hydraulically connected to the surface environment.

According to a Naval Assessment and Control of Installation Pollutants (NACIP) study, the groundwater at NWSC is divided into two regimes: one associated with soil/alluvial cover and the other associated with the bedrock (Ref. 3, p.5-22). This study reports that shallow groundwater is generally transient occurring during high precipitation periods. Free water within alluvial deposits is likely to percolate into bedrock or be discharged into intermittent streams along alluvial - bedrock contacts (Ref. 3, p.5-22). Table 1 is adapted from the NACIP study, it exhibits the general water bearing properties of the alluvial deposits and bedrock at NWSC.

July 14, 1941

COPY

IN REPLY ADDRESS
THE BUREAU OF YARDS AND DOCKS
AND REFER TO No.

NT1-18/N1-13

NAVY DEPARTMENT

BUREAU OF YARDS AND DOCKS

WASHINGTON, D. C.

July 14, 1941

From: Chief of Bureau of Yards and Docks.
To: Chief of Bureau of Ordnance.

SUBJECT: U. S. Naval Ammunition Depot, Burns City, Indiana - revision of boundary lines.

Reference: (a) Bu.Ord. ltr. NT1-19(52) (Ad3b) of June 27, 1941.

Inclosure: (A) One marked photostat of a map showing boundary of N. A. D., Burns City.

1. The boundary lines of the subject depot, as they now stand, have been indicated in red on the inclosure. Approximately 43,690 acres are inclosed within this boundary. It is estimated that approximately 925 high explosive magazines can be located in the portion of this area which lies south and east of the present State highway No. 45.

2. The inclosure has also been marked with yellow crayon to show twelve separate areas lying outside the present boundaries, the purchase of which would be necessary in order to obtain the straight boundary lines desired by the Bureau of Ordnance. These areas total about 4,325 acres. It is estimated that this land would cost an average price of $25.00 per acre, or about $108,000 for the total.

3. The Bureau of Ordnance is advised that, unless a certain amount of construction is deferred, this Bureau has available only $30,000 to apply toward the purchase of this land. Comment and recommendations are requested.

/s/ A. D. HUNTER

RG 71, Bureau of Naval Prop. Case Files
Box 443, Burns City, 015-3-BC, Nav. Ammo. (2 of 2)

REPRODUCED AT THE NATIONAL ARCHIVES

7-79

INSTALLATION ASSESSMENT
OF
NAVAL WEAPONS SUPPORT CENTER,
CRANE, INDIANA
RECORD EVALUATION REPORT NO 117

March 1978

DEPARTMENT OF THE ARMY
OFFICE OF THE PROJECT MANAGER
FOR
CHEMICAL DEMILITARIZATION AND INSTALLATION RESTORATION
ABERDEEN PROVING GROUND, MARYLAND 21010

DISTRIBUTION LIMITED TO US GOVERNMENT AGENCIES ONLY; FOR PROTECTION OF PRIVILEGED INFORMATION EVALUATING ANOTHER COMMAND; MARCH 1978. OTHER REQUESTS FOR THIS DOCUMENT MUST BE REFERRED TO: COMMANDER, NAVAL WEAPONS SUPPORT CENTER, CRANE, IN 47522

STATEMENT

"The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation."

EXECUTIVE SUMMARY

I. GENERAL

A. A records search was conducted on the Naval Weapons Support Center (NWSC) at Crane, Indiana to uncover indications of contamination at the installation by chemical, biological, and radiological materials resulting from past manufacturing, testing, storage, and disposal operations, and to assess the possibility of contaminant migration beyond the installation boundaries.

B. The on-site phase of the search was performed from 19 to 23 September 1977; however, data were collected from other agency sources through 15 October 1977. In addition to the on-site search, Team members also contacted personnel at the Naval Ordnance Station, Indian Head, Maryland, and the Naval Weapons Laboratory, Dahlgren, Virginia, who were familiar with operations at NWSC.

C. The procedure followed by the Records Research Team included:

1. Acquiring all pertinent documents on NWSC from other government agencies, including:

a. Department of Defense Explosive Safety Board (DDESB).

b. US Army Environmental Hygiene Agency (USAEHA).

c. US Geological Survey (USGS).

d. Defense Documentation Center (DDC).

e. US Department of Interior Ecological Survey, Carson City, Nevada.

f. US Army Engineer Waterways Experiment Station (WES).

g. National Technical Information Service (NTIS).

h. Naval Ordnance Environmental Health Center (NOEHC).

i. Naval Sea Systems Command (NSSC).

INSTALLATION ASSESSMENT

OF

CRANE ARMY AMMUNITION ACTIVITY

NWSC CRANE, INDIANA

RECORDS EVALUATION REPORT NO. 117

APPROVED:

FRANK A. JONES, JR.
Colonel, CmlC
Project Manager for
Cml Demil and
Instl Restoration

2. Obtaining copies of all pertinent installation regulations, standing operating procedures, and other available documentation.

3. Interviewing former and present key employees.

4. Analyzing the above information.

D. This report reflects the status of NWSC as of 15 October 1977.

II. FINDINGS

A. Crane Army Ammunition Activity (CAAA) License

A license, NF(R)-36943, was granted by NWSC to the Army, effective 1 October 1977 which authorizes the use by CAAA of a significant portion of the facilities at NWSC, Crane. The license was required for the establishment of the CAAA as Single Manager of conventional ammunition with assigned responsibilites as set forth in DOD Directive 5160.65 of 26 November 1975. Facilities are to be utilized for the accomplishment of Army functions required in the procurement, production, storage, supply, demilitarization and maintenance/renovation of conventional ammunition. A copy of the subject license is included as Appendix E of this report.

B. Industrial and Production Operations

1. Production areas of the installation potentially contaminated with waste from explosive and pyrotechnic operations include the 3-inch (Rockeye) and 40mm explosive loading complexes, the booster area, mine filling areas A and B, and the old 16-inch loading and demilitarization facility, see Chapter IIA of report. Contaminants identified include TNT, RDX, tetryl, lead styphnate, Composition A and B, Explosive D, HMX, aluminum, alkaline nitrates, lead chromate, and other explosive/pyrotechnic waste products.

2. Potentially contaminated wastewaters from manufacturing and demilitarization operations are dumped initially into sumps with the overflow going directly into open ditches. Prior to the recent installation of efficient dust collectors, considerable quantities of explosive powders were vented directly into the atmosphere. The soil in the vicinity of these sites is heavily contaminated and vegetation in the area of the plant is either missing or in a state of stress (i.e., dying, stunted, discolored).

C. Testing and Firing Ranges

1. Extensive testing of explosive and pyrotechnic munitions has been conducted and is being conducted at several locations on the installation. The principal ranges include three pyrotechnic ranges, a rocket

range, a rifle range, an explosive demolition area, a small arms testing area, and an ordnance burning area. Types of munitions tested include small arms, 40mm grenades, pyrotechnic flares and smoke signaling devices, mortar, bomb and projectile ammunition, and experimental devices.

2. Unexploded ordnance (UXO) were reported at several of the ranges and the demolition pits. UXO munitions include small pyrotechnic devices, aerial dispensed devices, mortar rounds, and other naval artillery shells. At the demolition area, explosive munitions are scattered as a result of demilitarization operations. During the Team's ground tour, UXO with parachutes were observed hanging from trees.

3. Lake Greenwood, which is the source of drinking and production water at NWSC, was used from the early 1940's to the late 1960's for the testing of floating pyrotechnic devices including signaling smokes and flares. Four locations were identified at Lake Greenwood where testing was conducted.

D. Disposal Operations

1. Two landfills are presently active at the installation; they are the sanitary landfill and the McComish Gorge landfill. The sanitary landfill began operations in 1971, replacing the old open burning pit as a means of disposing of daily refuse. This landfill has a leaching problem and the installation is attempting to rectify the problem by constructing a pond to hold the leachate. The McComish Gorge landfill is utilized for timbers and other large items not suitable for the main sanitary landfill. Personnel interviewed by the Team indicated that a potential exists for both landfills to be contaminated by waste materials.

2. Contaminated waste from installation activities is disposed of by burial or burning at various locations on the installation. Disposal areas include a chemical agent burial ground (1947), an ordnance burning area used since 1965, an old pyrotechnic burning pit used from the early 1940's to 1970, and a pit where approximately 50,000 pounds of smoke dyes were buried in 1969. Some of these dyes (auramine hydrochloride, yellow dye) are reported to be carcinogenic in the lastest Register of Toxic Chemical Substance published by National Institute for Occupational Safety and Health.

3. The chemical agent burial ground is located in the southeast quarter of the NWSC. Several hundred pounds of mustard agent and several pounds of radioactive thorium were buried here in 1947. One of the mustard pits was excavated in 1974 and several bombs were found to contain live mustard agent. The bombs were sealed by an Army Technical Escort Team and stored. Total number of pits is not known and a

project is being conducted by the installation to determine if migration of mustard agent is occurring. The thorium was removed from the site in 1974 and shipped to an AEC (DOE) site for storage. The site was then surveyed and certified free of radioactive contamination by the Material and Safety Department of NWSC, Crane.

E. Storage Operations

1. There are approximately 2300 storage magazines at NWSC. Materials stored within these structures include explosive and pyrotechnic powders, explosive and pyrotechnic munitions ranging from small arms to large bombs and naval projectiles, anti-riot munitions, initiators, fuzes, munition components, and subassemblies.

2. Approximately 2808 chemical agent identification kits, which contain small quantities of various chemical agents in ampules, are stored in magazines. These kits are scheduled to be moved to another site for demilitarization.

F. Biological Agent Operations

Biological Warfare agents and weapons were never developed, manufactured, tested or stored at the installation.

G. Radiological Operations

Radiological materials and weapons were never developed, manufactured, or tested on the installation. The installation is licensed to use small quantities of radiological materials for biological tracers (carbon 14), lead detection (krypton 85), radiography (cobalt 60), iridium 192, and nickel 63. Weapons equipped with Promethium-147 sights are stored at NWSC.

H. Water and Water Quality

1. The installation is drained by several surface water drainageways. The central portion of the installation is drained by Boggs and Turkey Creeks; the eastern portion by Sulphur Creek; and the northern and western portions by Furst and Culpepper Creeks.

2. A water quality monitoring program is conducted by the installation at six locations within the Boggs, Turkey, Furst, and Culpepper Creeks drainage areas. However, no water quality monitoring is conducted on the waterways that exit the installation's eastern boundary. The six monitoring locations are in the northern and central areas of the installation. No

B. Current Manufacturing Operations

A potential exists for contamination from current manufacturing operations to exit the installation via unmonitored surface and subsurface waters. Of particular concern is explosive waste (Red Water) from the Rockeye operation which is dumped into Sulphur Creek. This creek is one of several creeks in the eastern and southern areas of the installation not monitored under the installation's water quality program. In addition, NWSC is exceeding discharge limits imposed by NPDES permits.

C. Lake Greenwood

Since Lake Greenwood is not monitored by the installation for the presence of explosive or pyrotechnic waste materials, a potential exists for the lake to be contaminated by those waste materials.

D. Chemical Agent Burial Ground

An unknown quantity of mustard munitions is still buried at the Chemical Agent Burial Ground. The area is fenced, however, the exact location and number of burial pits is not known. Based on location of the burial ground, contaminant migration beyond installation boundaries is considered remote.

E. Burial of Pyrotechnic Dyes

An estimated 50,000 pounds of pyrotechnic smoke is buried at the Ordnance Burning Ground. During periods of heavy rain, colored materials seep from the filled pits. Since the dyes included carcinogenic materials, a potential exists for them to migrate via surface and subsurface waters.

F. Water Monitoring Program

The installation's present water monitoring program does not include analysis for explosive waste materials nor does it monitor all streams exiting the installation.

monitoring is done on Boggs Creek in the southern portion of the installation; neither are the waters impounded by Boggs Dam monitored. At the time of the Team's visit (September 1977), available water quality data for the six monitoring locations indicated that the installation is having difficulty in complying with EPA discharge permits. (See Chapter IE1a of report).

3. Lake Greenwood is monitored intermittently by the installation. The water quality data provided by the installation, and collected in 1970, indicate that the lake water was potable. No current analysis was available to the team for explosive manufacturing wastes such as TNT and RDX. Due to the lake's location in the northern section of the installation, only limited amounts of wastewaters from the manufacturing areas reach the lake via drainageways and creeks. The State Health Department conducts a water quality program that includes Lake Greenwood; however, analyses are not conducted for potential pyrotechnic and explosive contaminants.

4. Big Sulphur Creek, which drains the Rockeye manufacturing area, exits the installation to the east and receives wastewaters that are heavily contaminated by explosive manufacturing wastes including red water (TNT). The Records Search Team, during its ground tour, tracked the wastewaters for over a mile and the red color was visually detectable over the whole distance. Little Sulphur Creek drains the ordnance burning area where an estimated 25 tons of pyrotechnic dyes are buried. No water monitoring is conducted in this area.

5. Data on subsurface waters (groundwater) is limited. The installation has data from five wells which indicate groundwater depths of between 141 to 313 feet. Only limited water quality data are available on four of these wells and consist of a 1970 report that addresses alkalinity, pH, and hardness. General regional dip of the bedrock is approximately 20 feet per mile to the west-southwest.

III. CONCLUSIONS

A. Past Explosive Operations

Several areas of the installation (including the explosive and pyrotechnic areas, burial and burning sites, landfills, and test ranges) are suspected of being contaminated with toxic and hazardous materials. No firm conclusions can be drawn regarding migration of contaminants from past manufacturing, demilitarization, and disposal operations because of limited surface and subsurface water data.

TABLE OF CONTENTS

	Page
I. GENERAL	I-1
A. Purpose of the Assessment	I-1
B. Authority	I-1
C. Introduction	I-1
D. Summary Description of Installation	I-3
1. Location and Size	I-3
2. Area Description	I-3
3. Organization and Mission	I-6
4. History	I-8
E. Environmental	I-9
1. Water Quality	I-9
a. Surface	I-9
b. Subsurface	I-12
c. Analysis	I-12
2. Biota	I-17
a. General	I-17
b. Flora	I-18
c. Fauna	I-20
3. Geology	I-22
a. Physiography and Topography	I-22
b. Subsurface Geology	I-22
c. Soils	I-24
II. CONTAMINATION ASSESSMENT	II-1
A. Industrial Operations	II-1
1. Rockeye/3-Inch Explosive Loading Area	II-1
2. 40-Millimeter Loading Complex	II-5
3. Booster Area	II-7
4. Mine Filling Area A	II-7
5. Mine Filling Area B	II-7
6. Loading and Filling Area	II-9
7. Pyrotechnic Area	II-12
8. Old 16-Inch Loading and Demilitarization Area	II-13
9. Building 181, Clothing Change House Area	II-13
10. Transfer Depot - Building 600	II-13
11. Laundry (Building 180)	II-13
12. Small Arms Area	II-14
B. Laboratories	II-14
1. Quality Evaluation Laboratory Complex	II-14
2. Applied Science Department Complex (ASD)	II-14
3. Naval Ammunition Production Engineering Center (NAPEC)	II-15
C. Field Test Ranges	II-15
1. Pyrotechnic Test Range	II-15
2. Range 2167/Pyro Control Test Range	II-15
3. Rocket Range	II-15

	PAGE
4. Conservation Dam (Facility No. 2845)	II-17
5. Old Pyrotechnic Test Area	II-17
6. Lake Greenwood	II-17
7. Lake Oberlin	II-17
8. Rifle Range and Old Ordnance Ground	II-17
D. Burial Sites of Hazardous Materials	II-18
1. Burial Sites of Chemical and Radiological Materials	II-18
a. Chemical Burial Ground	II-18
b. Burial of Pyrotechnic Dyes	II-20
2. Burial Sites of Explosive Material	II-20
a. McComish Gorge	II-20
b. Ordnance Demolition Area	II-20
E. Storage of Toxic/Hazardous Material	II-23
F. Support Activities	II-23
1. Water Supply	II-23
2. Waste Disposal	II-23
G. Land Use Factors	II-23
1. Pesticide/Herbicide Usage	II-23
2. Sanitary Landfills	II-24
H. Geological Migration Potential	II-25
I. Environmental Indicators	II-25
1. Land Indicators	II-25
2. Waterways Indicators	II-26
III. FINDINGS	III-1
IV. CONCLUSIONS	IV-1

LIST OF FIGURES

Figure No.	Title	Page No.
I-1	Site Map, Naval Weapons Support Center, Crane, ID	I-4
I-2	Population and Distance of Towns near NWSC, Crane, ID	I-5
I-3	Naval Weapons Support Center Organization Chart	I-7
I-4	Water Supply	I-10
I-5	Surface Drainage	I-11
I-6	Water Wells	I-13
I-7	Discharge of Green Water from Naval Weapons Support Center	I-16
I-8	Geology	I-23
I-9	Boring Location	I-25
II-1	Rockeye Manufacturing Area	II-2
II-2	Red Water Discharge Point	II-2
II-3	Red Water 50 Yards Downstream	II-3
II-4	Red Water 200 Yards Downstream	II-3
II-5	Red Water 400 Yards Downstream	II-4
II-6	Red Water Approximately One-half Mile Downstream	II-4
II-7	General Development Map	II-6
II-8	Mine Filling Area "A"	II-8
II-9	Mine Filling Area "B"	II-10
II-10	Loading and Filling Area (High Explosive)	II-11
II-11	Pyrotechnic Test Range	II-16
II-12	Mustard Gas Burial Plot	II-19
II-13	Demolition Area	II-21
II-14	Demolition Area and Lake 330	II-22

LIST OF TABLES

Table No.	Title	
I-1	Water Treatment Plant Data for July 1977	I-12
II-1	Pesticide and Herbicide Usage	II-24

LIST OF APPENDIXES

Appendix	Title
A	Photographs of Naval Weapons Support Center, Crane, IN
B	Biota of Naval Weapons Support Center, Crane, IN
C	Indiana Water Quality Standards
D	Boring Logs of Naval Weapons Support Center, Crane, IN
E	License NF(R)-36943 to Crane Army Ammunition Activity
F	Green Water Report
G	Munitions Operations (1964-1977)

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I. GENERAL

A. Purpose of the Assessment

1. To search for, identify, and assess actual or potential chemical, biological, or radiological contaminant migration at Naval Weapons Support Center (NWSC)*, Crane, Indiana from available records and by interview with present and former employees.

2. To identify any immediate on-post safety hazards associated with CBR contamination and unexploded ordnance (UXO).

B. Authority

Department of the Army (DA) charter for the Project Manager for Chemical Demilitarization and Installation Restoration (PMDCIR) dated 29 April 1977.

C. Introduction

1. Pursuant to the designation of the US Army as the DOD Single Source Manager for Conventional Ammunition, and the attendant assumption of ownership and control of certain production and storage facilities formerly under the purview of the US Navy, Headquarters, US Army Armament Materiel Readiness Command (ARRCOM) requested PMCDIR to undertake a search of NWSC records.

2. Personnel from NWSC were briefed on the program prior to the start of the on-site records search. The purpose of the briefing was to outline the assessment scope and to provide guidelines to NWSC personnel for the records search.

3. Before the actual on-site review of records began, various Government agencies were contacted for documents pertinent to the records research effort. Agencies contacted included:

a. Department of Defense Explosive Safety Board (DDESB).

b. US Army Environmental Hygiene Agency (USAEHA).

c. US Geological Survey (USGS).

d. Defense Documentation Center (DDC).

e. US Army Engineer Waterways Experiment Station (WES).

*In the past the Naval Weapons Support Center was known as the Naval Ammunition Depot, Crane, Indiana.

f. National Technical Information Service (NTIS).

g. Naval Sea Systems Command (NSSC).

h. Naval Ordnance Environmental Health Center (NOEHC).

i. Naval Ordnance Station, Indian Head, Maryland (NOS).

j. Naval Facilities Engineering Command.

4. The collection of documents occurred during the period of 15 September 1977 through 15 October 1977. The following team members provided input to this report:

a. Mr. William Collins (Team Leader).

b. Mr. Norman Leibel (Ordnance Specialist).

c. Dr. Elmer Worthley (Environmentalist).

d. Mr. Harry Woods (Hydrogeologist).

e. Mr. John Bane (Chemist).

f. Mr. Reed Magness (Chemist).

g. Mr. Daniel Wenz (Chemical Engineer).

h. Mr. James Scott (PM-CDIR Representative/Chemist).

5. In addition to the review of records, interviews were conducted with more than 25 persons, including present and former employees. An aerial and a ground tour of the installation were also made. Photographs taken during the tours are included in Appendix A. Team members also contacted and interviewed personnel at Naval Ordance Station, Indian Head, Maryland and Naval Weapons Laboratory, Dahlgren, Virginia who were either former employees at NWSC or were aware of certain operations conducted there.

6. The findings and conclusions are based on the records made available to the Team at the time of the search, and the corroborated testimony of the past and present employees.

D. Summary Description of Installation

1. Location and Size

The NWSC Crane is located primarily in Martin County, Indiana, with a small area in the north, lying in Greene County and in the east, in Lawrence County (See Figure I-1). Daviess County borders the NWSC on the west. Located in southwestern Indiana, NWSC Crane lies approximately 25 miles southwest of Bloomington, Indiana, and 70 miles southwest of Indianapolis, Indiana. Figure I-2 shows the towns nearest to NWSC Crane, with their approximate populations. The NWSC is bounded on the north by State Road 45/58, on the west by US Route 231, and on the south by US Route 50/150.

The NWSC consists of 1,006 acres of improved grounds, 10,047 acres of semi-improved grounds, and 51,411 acres of unimproved grounds, a total of 62,404 acres. Included in the NWSC acreage is an 800-acre man-made lake, Lake Greenwood, constructed by the Civilian Conservation Corps.

There are approximately 2800 structures at NWSC, including 800 general purpose buildings and 2000 ammunition storage facilities.

2. Area Description

Martin County has an area of 337 square miles (215,680 acres); its county seat is Shoals. The county lies in the hilly part of Indiana, with an average elevation of 660 feet, and a height range of 425 to 860 feet. The local climate is characterized by warm and humid summers and moderately cold winters. Rainfall is fairly well distributed throughout the year, but there is usually an excess during the spring and an inadequate supply during summer.

Information on the counties surrounding or including NWSC Crane includes:

COUNTY	POPULATION	MAJOR CITIES AND TOWNS	RESOURCES	MAJOR MANUFACTURERS	RECREATIONAL FACILITIES
Martin	10,969	Loogootee, Shoals	Argriculture, Timber	Carnahan Mfg. Company; Edison, Inc.; U.S. Gypsum, National Gypsum	W. Boggs Creek Recreational Area; Patoka Reservoir; Martin County State Forest

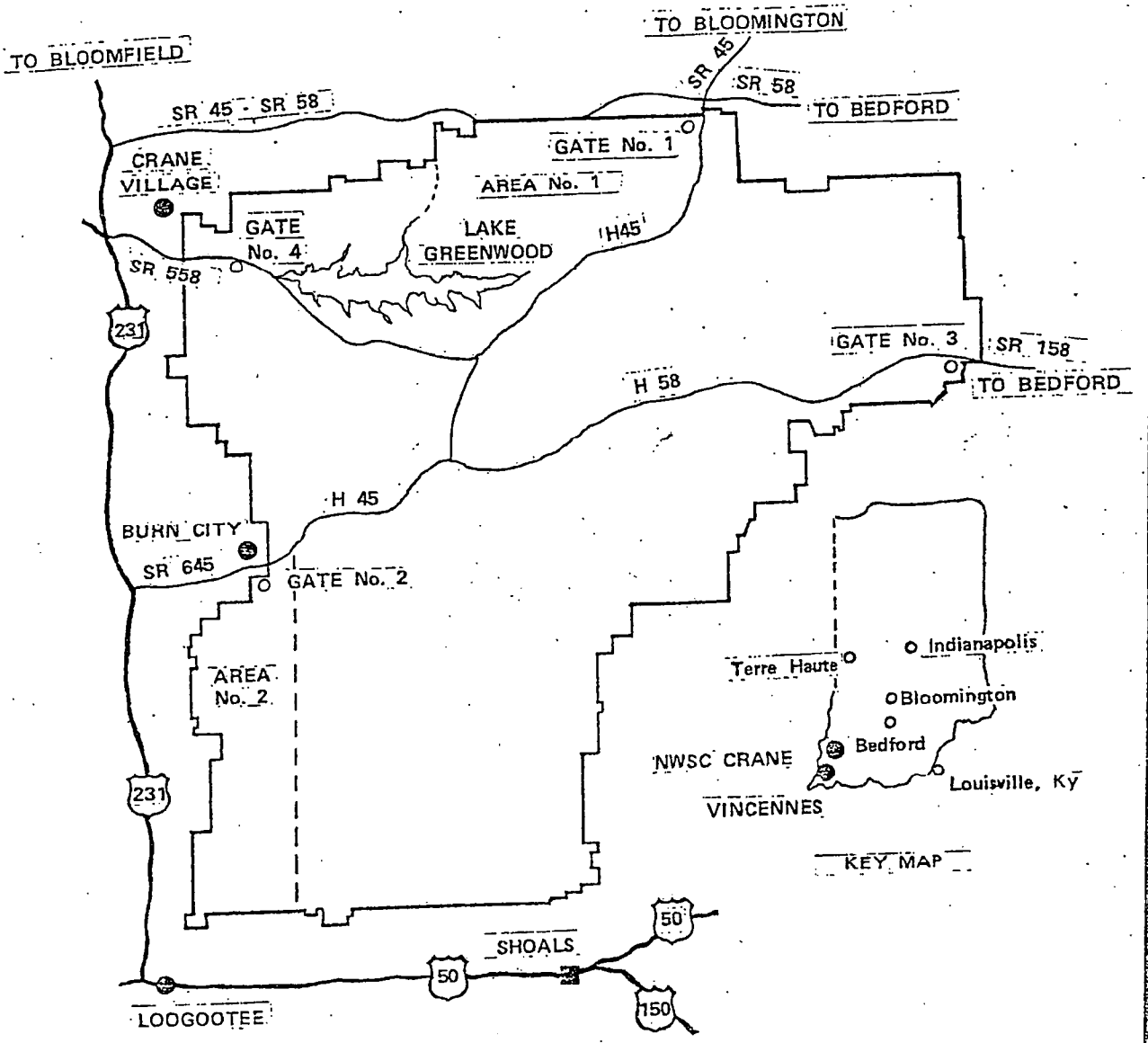

Figure I-1 SITE MAP, NAVAL WEAPONS SUPPORT CENTER, CRANE, INDIANA

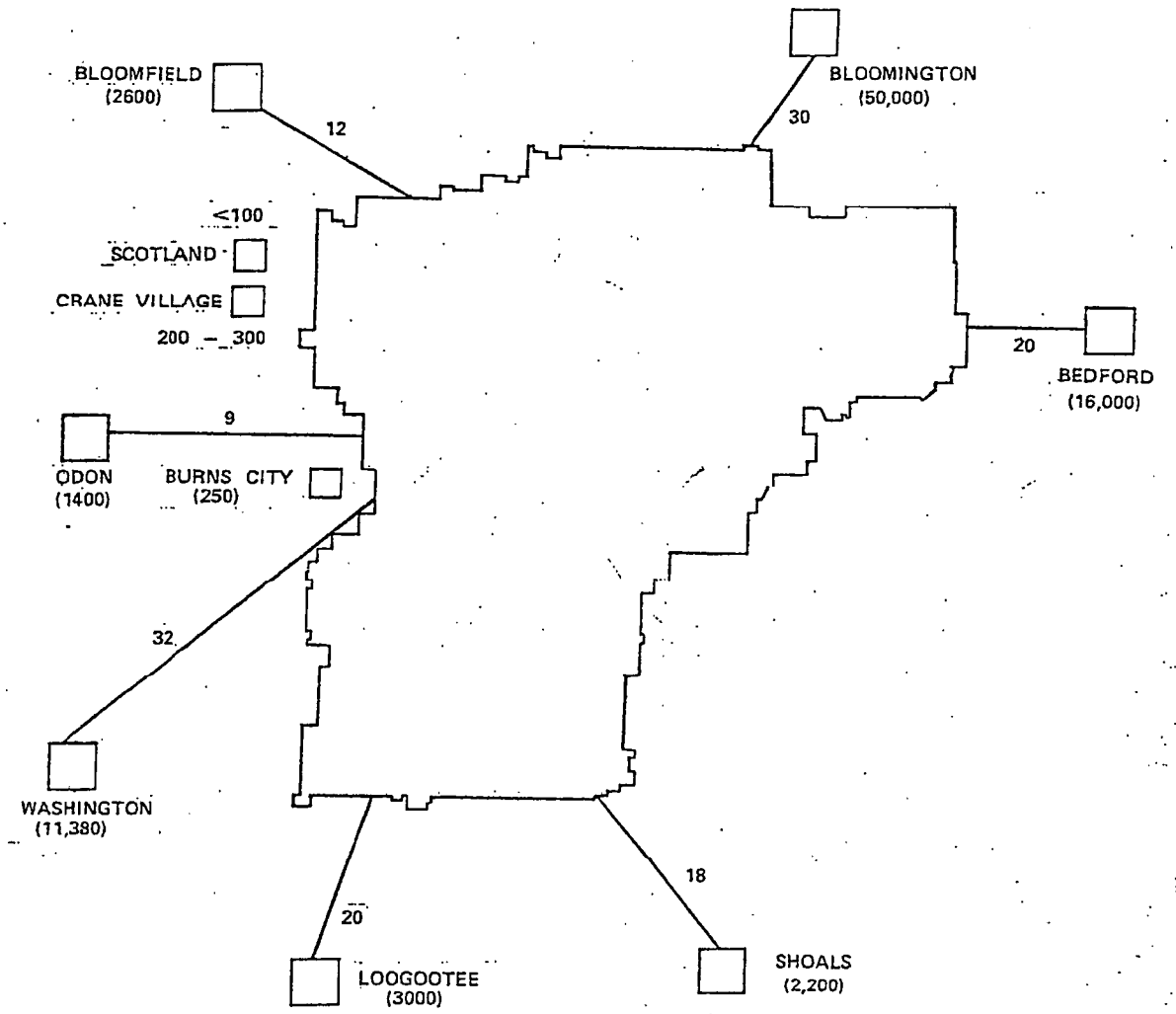

Figure I-2 POPULATION AND DISTANCE OF TOWNS NEAR NWSC, CRANE, INDIANA

COUNTY	POPULATION	MAJOR CITIES AND TOWNS	RESOURCES	MAJOR MANUFACTURERS	RECREATIONAL FACILITIES
Greene	26,894	Linton, Jasonville, Bloomfield	Coal, Agriculture	G.E. Keller Aluminum; Amax Coal Co.; Peabody Coal Co.	Lake Monroe Reservoir; Shakamak State Park; Greene-Sullivan State Forest
Lawrence	42,348	Bedford, Mitchell	Limestone, Timber	Indiana Limestone; Central Foundry Div. of G.M.; Philco-Ford; Lehigh-Portland Cement Co.; Carpenter Body Works	Wayne-Hoosier National Forest; Lake Monroe Reservoir; Springmill State Park
Daviess	26,602	Washington	Agriculture, Timber	Uniroyal Corp.	Patoka Reservoir; Santa Claus, Indiana

3. Organization and Mission

a. Mission. The original mission of NAD Crane (its name before 1975) was loading, preparing, renovating, receiving, storing, and issuing all types of ammunition to the fleet. The mission of Crane has expanded through the years to include applied science, weapons engineering, quality evaluation and engineering, maintenance and repair of military hardware, pyrotechnics, ammunition generation, industrial production equipment, support services, and quality assurance. Crane also stores a number of strategic materials, such as brass, iodine, tantalite, mica, talc, antimony, bismuth, columbite, and lead.

b. Organization. The organization of NWSC Crane, as of May 1977, is in the manual NAVWPNSUPPCENINST 5450.21D with changes dated 14 April 1976 (see Figure I-3). This organization was subject to change as of 1 October 1977, when the conventional ammunition production, renovation, quality assurance, and demilitarization functions were transferred from the Navy to the Army under the Single Manager concept for conventional ammunition procurement, production, supply, and maintenance/renovation in the

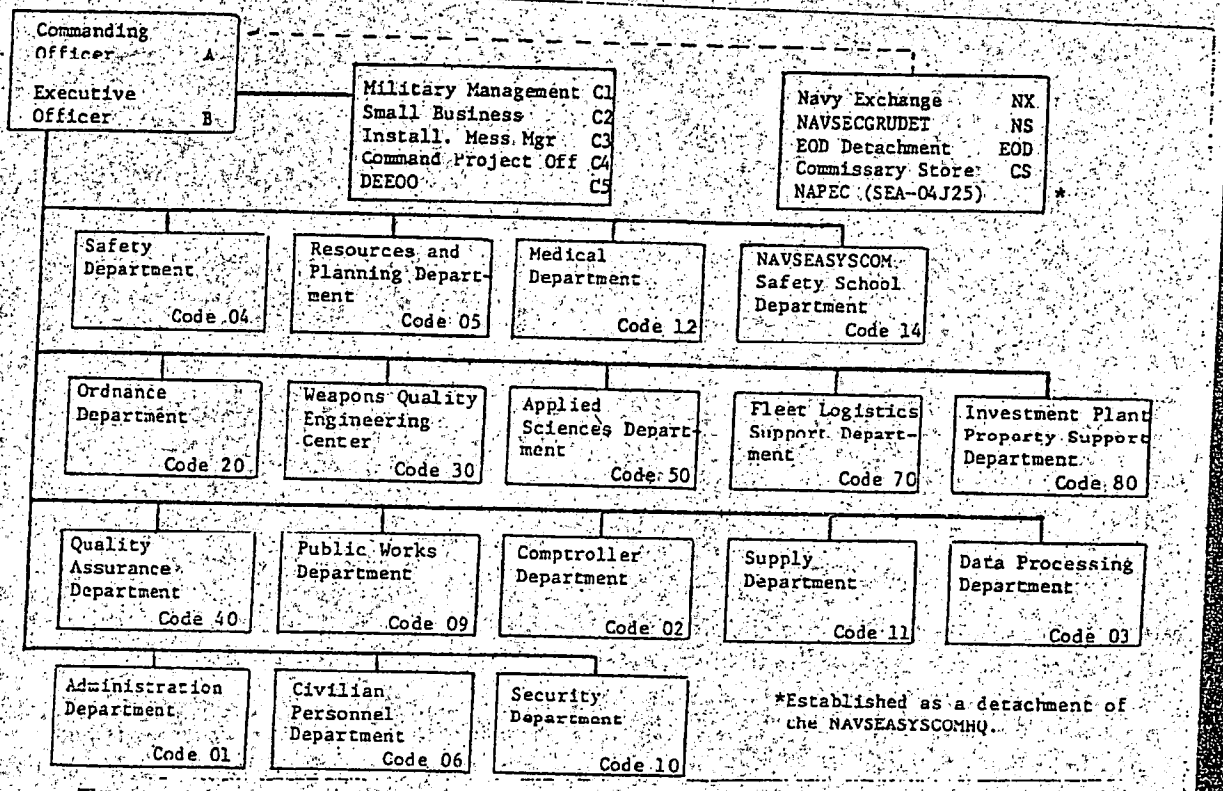

Figure I-3 NAVAL WEAPONS SUPPORT CENTER ORGANIZATIONAL CHART

Continental United States as directed by the Secretary of Defense. Installation strength as of September 1977 was 3,407 full-time personnel, civilian; 180 temporary or part-time, and 51 military. These figures apply to NWSC Crane and the Naval Ammunition Production and Engineering Center (a tenant activity). Other tenant activities account for 835 civilians and 19 military. The number of employees at Crane has varied from a high of approximately 10,000 during WWII, 4,700 during the Korean action, 7,000 during the Vietnam period, to the present level.

4. History

In 1940, Congress appropriated funds to build new inland ammunition production facilities that would be secure from enemy attack. The Naval Ammunition Depot (NAD), Burns City, Indiana, was constructed using 35,000 acres of land from the White River Land Utilization Project, a public land acquisition project begun in 1934, and 26,830 additional acres from private ownership. The depot was officially commissioned on December 1, 1941. On May 1, 1943, NAD Burns City was renamed NAD Crane.

During WWII, there were more than 112,000,000 pounds of high explosives, and 86,000,000 pounds of smokeless powder stored in the various magazines. At one time, there were also 54,000 500-pound bombs stored at NAD, as well as other types of bombs, and 5000 torpedoes. Guns, rockets, gun mounts and parts, automotive equipment, aviation, and underwater ordnance were also stored there in the mid-forties. A chemical warfare area was established at Crane early in WWII, in the high explosives area, for the purpose of unloading, storing, and servicing chemical warfare material. The first items stored were 155mm mustard shells. In January 1945, Crane became a major storage point in the Navy for chemical warfare munitions.

After WWII, thousands of carloads of equipment and materials arrived at Crane for storage, preservation, sorting, scrapping, or shipment.

Crane successfully met its purpose of providing ammunition to the Fleet during the Korean and Vietnam conflicts, reaching a high level of ordnance production in 1967-68 with approximately one million MK68 and MK82 bombs, one-half million major caliber projectiles, and one-half million MK24 flares being produced.

Over the years, the need for scientific and engineering personnel at Crane has increased, while that for laborers, helpers, and munitions workers has decreased, due to the expanded mission noted in paragraph ID3a above. On 1 July 1975, NAD Crane was renamed the Naval Weapons Support Center (NWSC) Crane, to more accurately reflect the expanded scientific and engineering functions.

E. Environmental

1. Water Quality

a. Surface. Water for the Naval Weapons Support Center (NWSC) Crane is obtained from Lake Greenwood, an 800-acre lake, situated in the northwestern portion of the NWSC (Figure I-4). Lake Greenwood is a multiple purpose reservoir that is used for recreation, flood control, and water supply. The lake has an average water depth of approximately 15 feet and is oriented in an east-west direction with a 55-foot-high compacted dam forming the western end.

Six centrifugal pumps (on the south shore of Lake Greenwood) supply raw water to the 2.1 million-gallon-a-day water treatment plant in Building 4 (Figure I-4). The water treatment consists of aeration, clarification with alum, rapid sand filtration, and chlorination. The water distribution system, consisting of 6- to 10-inch diameter lines equipped with air, electric, and hydraulic control values, is located primarily within the industrial and cantonment areas as identified by the crosshatched area in Figure I-4. Two small communities, Burns City and Crane Village, near the western boundary, purchase potable water on a fee basis from the NWSC.

The surface drainage network has formed a dendritic pattern throughout the installation. Seven creeks in four separate drainage basins carry surface water off the installation (Figure I-5). Drainage from Basin II in the northeast and southeast part of the NWSC consists of several small drainageways. The north and northwest drainage (Basin I) eventually empties into Furst Creek which flows in a westwardly direction and crosses the NWSC boundary. Rainey Hollow, Big Sulphur Creek, and Little Sulphur Creek drain the eastern sector identified as Basin III. Drainage Basin IV occupies the central portion of the installation where Boggs Creek and Turkey Creek receive the drainage from the industrial area and that portion of the cantonment area south of Roads H43 and H5. This drainage crosses the south-central boundary. Seed Tick Creek drains Basin V and exits the NWSC along the southwest boundary. All surface drainage from the NWSC empties into the East Fork of the White River south of the installation.

The NWSC maintains close coordination with the Soil Conservation Service concerning soil erosion and flood control. Ten ponds have been constructed under this program with the structures on Boggs and Seed Tick Creeks being the largest. Several small ponds and catch basins are associated with the manufacturing processes on the installation.

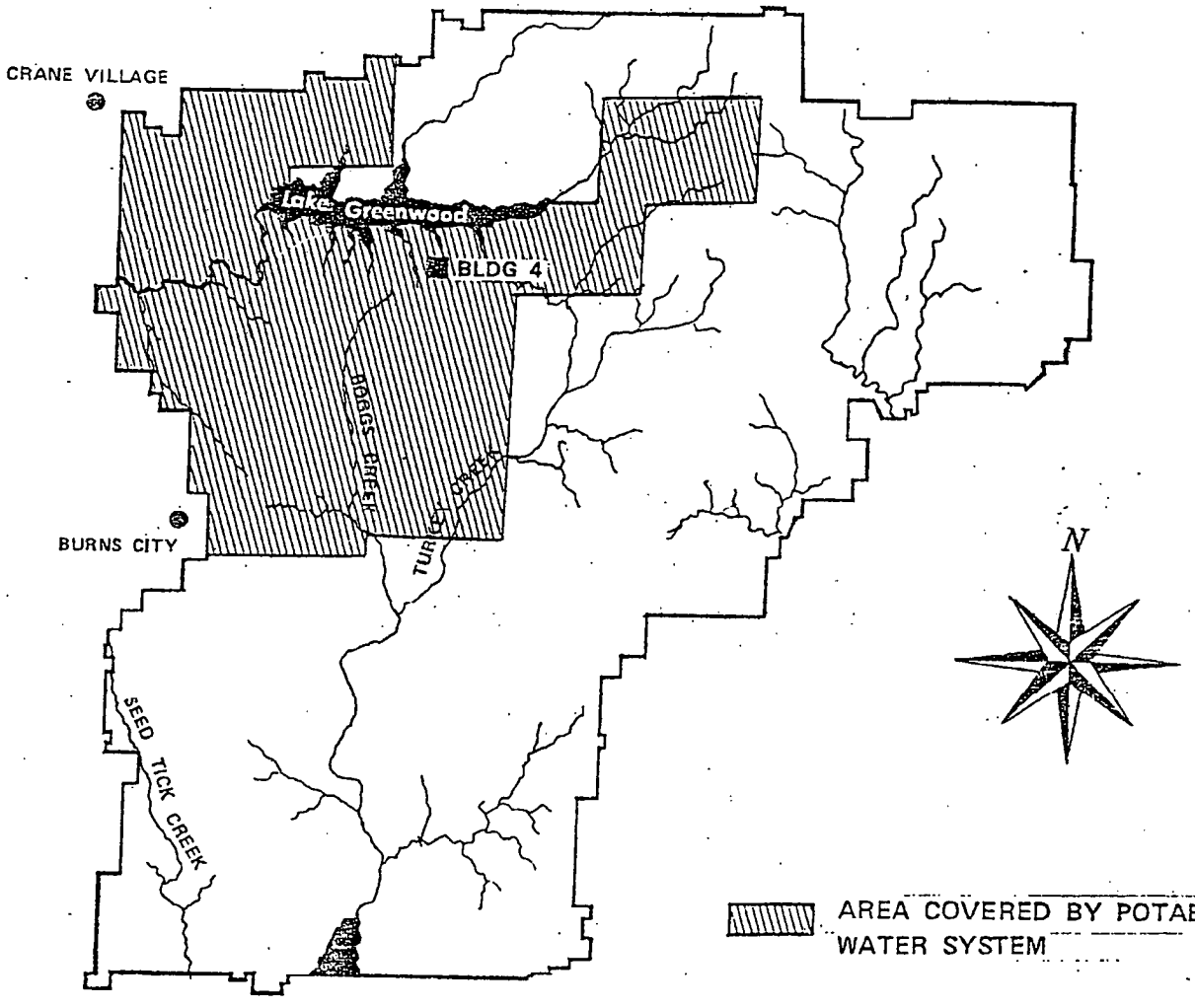

Figure I-4 WATER SUPPLY

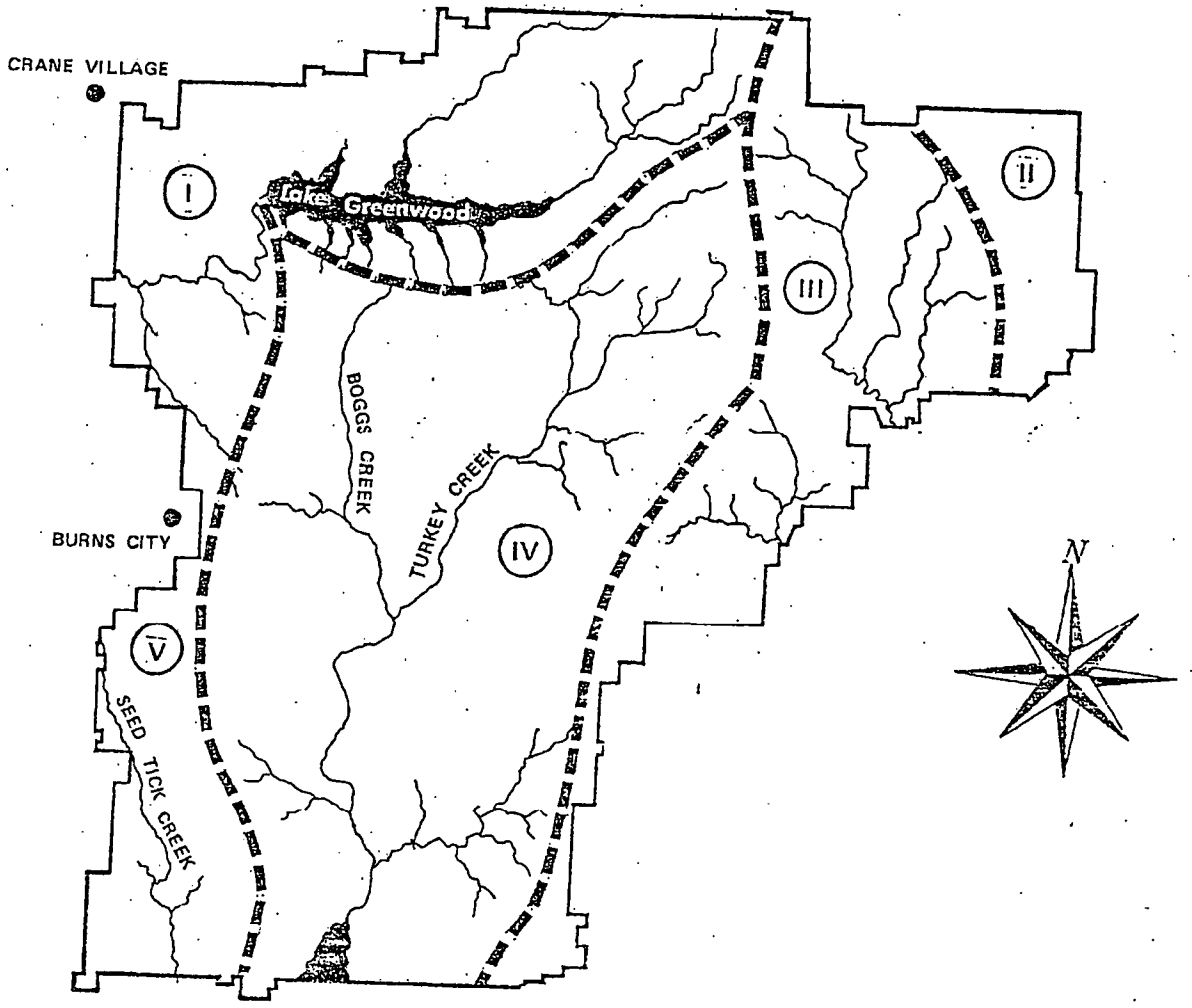

Figure I-5 SURFACE DRAINAGE

b. Subsurface. Data on groundwater conditions within the installation are extremely limited. The utilization of surface water for domestic consumption and manufacturing has precluded groundwater exploration, leaving a gap in groundwater data.

Available groundwater data are from five wells (Figure I-6) drilled in the early 1940's. No water was reported in the overburden which ranged in thickness from 0 to 26 feet. Limited water was obtained from sandstone and limestone at depths between 141 and 313 feet below the surface with the shallowest water level at 85 feet in well No. 5. The well logs are presented in Appendix D.

The regional dip of the bedrock is approximately 20 feet per mile to the west-southwest and the water level shoud conform to this general pattern.

c. Analysis. Lake Greenwood, an 800-acre lake situated in the northwest section of NWSC, supplies both potable and industrial water for the installation. The State Board of Health of Indiana analyzes four samples of water per week from NWSC and its immediate environs for compliance with State potable water standards. (See Appendix C.) Samples taken include: 1) raw water from the intake to the water treatment plant (WTP), 2) treated water from the WTP, and 3) potable water from Crane Village and Burns City which are located adjacent to the western boundary. Water from these sampling points is of good quality and currently meets the State's requirements.

Table I-1 provides a monthly report of the water treatment plant's operational data averaged over a 31-day period.

TABLE I-1. Water Treatment Plant Data for July 1977

PARAMETER	RAW WATER	TREATED WATER	UNITS
Turbidity	2.3	1.0	mg/l*
Alkalinity	12	27	mg/l
pH	6.8	8.3	
Hardness	43	76	mg/l
Chlorine		1.0 (24 tests per day)	mg/l

*milligrams per liter (mg/l)

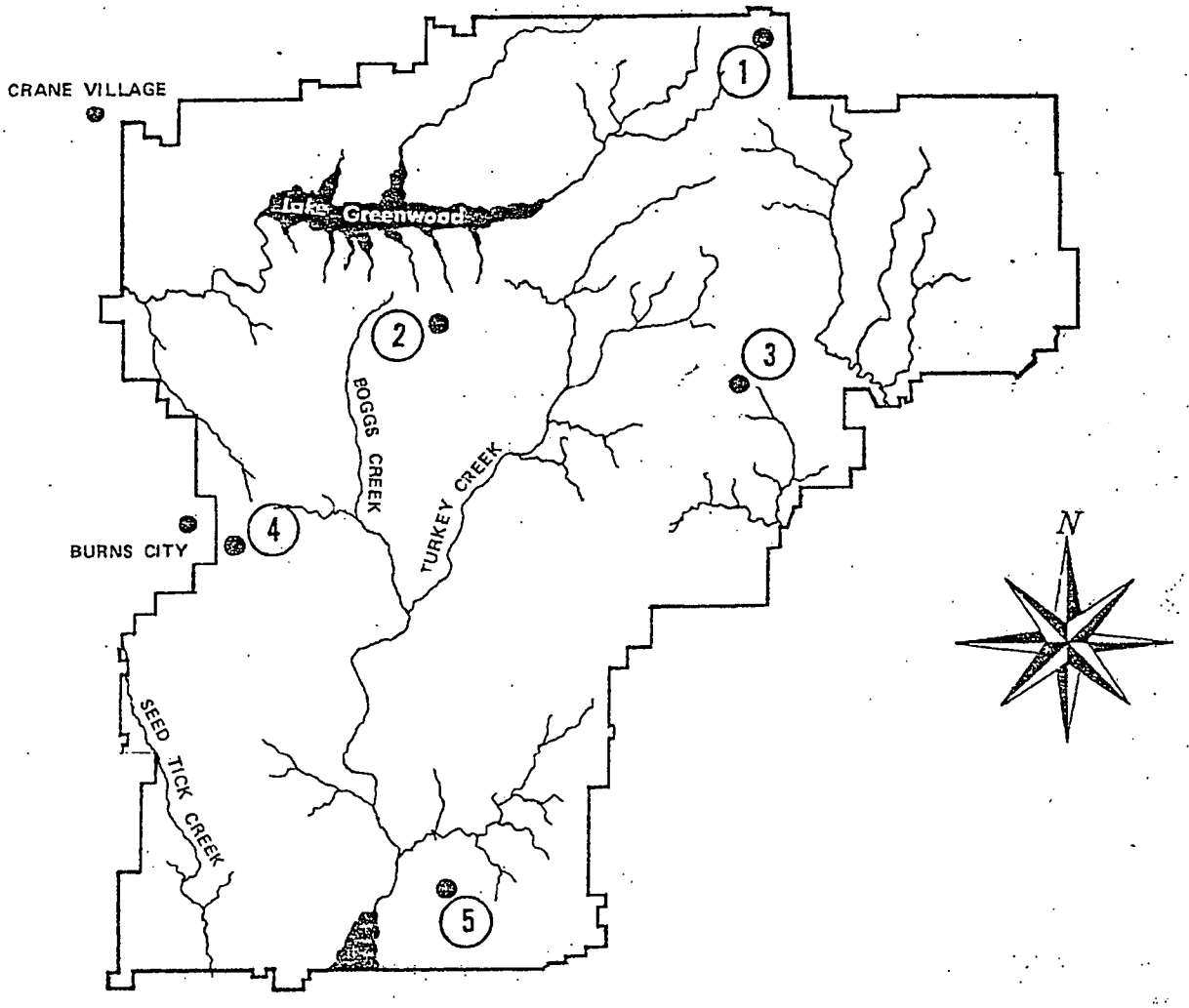

Figure I-6 WATER WELLS

Water quality at NWSC Crane has suffered in the past and continues to suffer to a lesser degree in the present both from spills and from practices of discharging untreated and/or inadequately treated sanitary and industrial wastewaters directly to the watershed. In 1960, several hundred gallons of a cyanide solution was accidently discharged to surface drainage.* The spilled solution was dammed up and chemically treated to destroy the cyanide radical; however, the metal associated with the cyanide radical still presented a potential water contamination problem. In 1970, two of the installation streams were cited as being polluted with effluent from 1) the main sewage treatment plant (STP) 2) the Rockeye bomblet loading area STP (due to inadequacies in sludge digestion and effluent disinfection, 3) the Depot laundry, and 4) the Depot Plating Shop.** The laundry discharged to an open ditch that connected into the sanitary sewage system. Laundry wastewater contaminants included phosphates, detergents, explosives, and pyrotechnics. Effluent from the Plating Shop contained concentrated slugs of metal ions (sodium, cadmium, zinc) and cyanide. Remedial action was proposed under Line Item No. P-108.

In 1971, a project (Project No. P-997) was proposed to abate water pollution associated with operation of the Case Overhaul Facility. The paint and rust stripping operations was discharging untreated wastewater containing caustic, acids, and iron oxides directly to the watershed.

Project No. P-996 (1972) was offered to provide proper disposal of wastes from Buildings 4, 7, 36, 115, 126, 130, 133, 136, 140, 146, 150, 199, 1820, 1885, 1886, 2044, 2084, 2087, 2088, and 2921. Discharges from these areas included acids, used petroleum products, chemicals, and domestic products. These wastes were being discharged to the watershed via overloaded, inadequate, or nonexistent facilities in violation of State and Federal Standards.

In 1973, the Medium Caliber Projectile Loading Facility (Building 104) was cited for the direct discharge of wastewater to the watershed (see Project No. P-130). In addition, ammonium picrate and cyclonite (RDX) dusts passed to the watershed without treatment via settling basins. Other problem sources cited that year included discharge of untreated "Rockeye" Bomblet Facility wastewater containing complexes of trinitrotoluene (TNT) and inadequacies of the septic system for disposal of sanitary wastes.

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*Memorandum, From 122H to 053D, 8 September 1977, Naval Weapons Support Center, Crane, Indiana.

**Five Year Station Plan for Naval Ammunition Depot, Crane, Indiana (FY 75-79), pg. C-1, Approved July 1974.

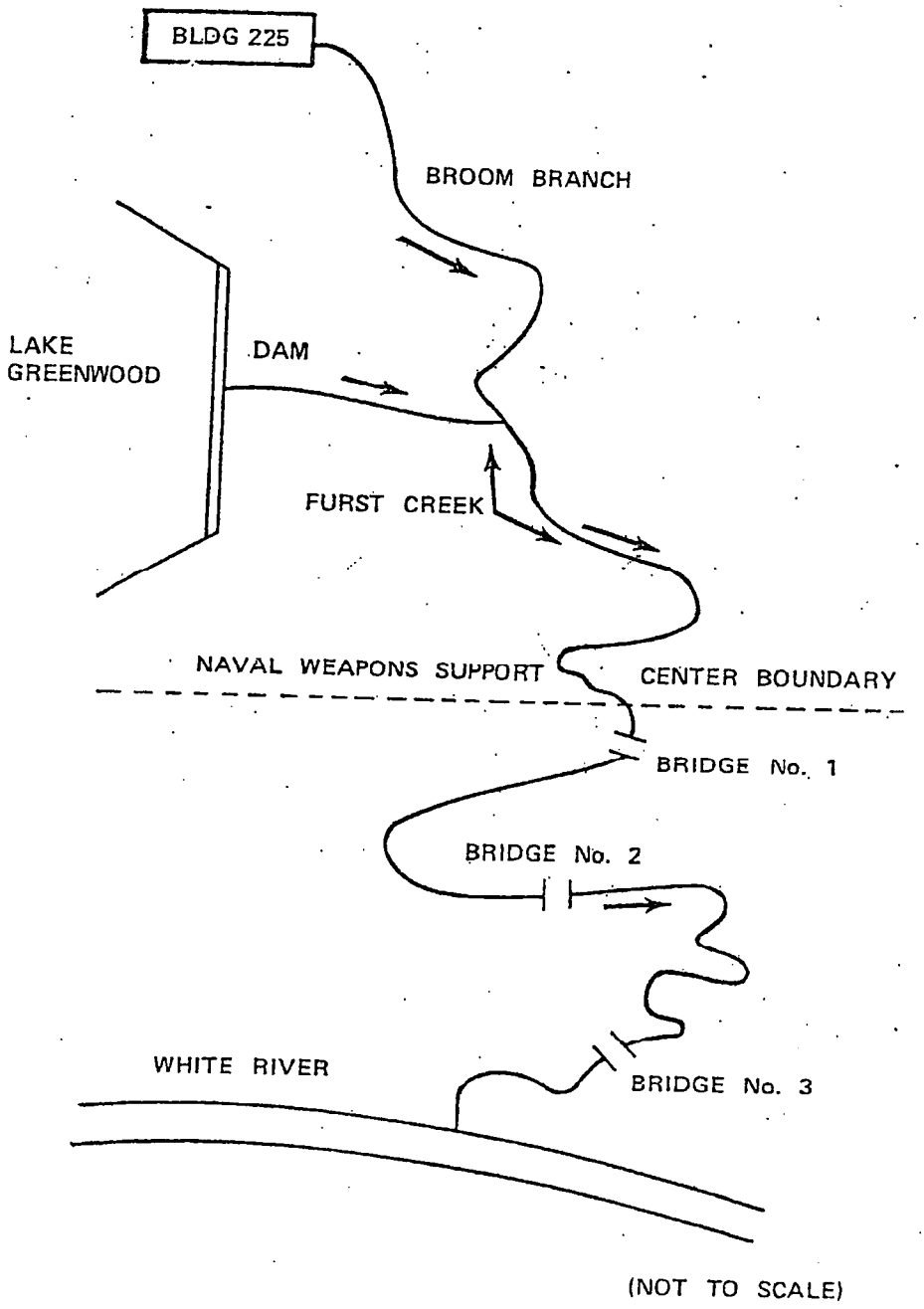

Figure I-7 DISCHARGE OF GREEN WATER FROM NAVAL WEAPONS SUPPORT CENTER

During FY75, a need was recognized (Line Item No. P-132) for the continuous monitoring of five streams flowing off the installation; the need for monitoring was due to contamination of the streams with untreated industrial wastes and with discharges from the sewage treatment system.

In 1974, the need to provide tertiary treatment capability at all four sewage treatment plants was cited. This capability was mandatory by 1977 in order to comply with Indiana Stream Pollution Control requirements.

In 1975, STP No. 1 effluent to Boggs Creek was cited as often being in violation of its NPDES Permit (Permit No. IN-0021539) for fecal coliform, residual chlorine, oil, and grease.* The effluent from STP No. 2 was often in violation of Permit No. IN-022155 for fecal coliform and STP No. 3 (Permit No. IN-0021563) lacked effluent chlorination. The operation of STP No. 4 (Permit No. IN-0021547) was satisfactory. (Project No. P-117 was designed to replace STP's No. 1 through 4 with an advanced waste treatment plant in 1977). Other problem areas included contamination of Furst Creek with heating oil from the NWSC Fuel Farm. The most severe wastewater problem discussed in the Sanitary/Environmental Survey was the industrial waste problem associated with the Metal Plating Shop, Building 1884. Activities in this shop included zinc and cadmium plating and anodizing of metals. Sodium hydroxide; sodium, cadmium and zinc cyanides; and hydrochloric acids were among the materials used. Discharge from this shop was in noncompliance with NPDES Permit No. IN-0035157.

In 1976, the burning of Building 225, a large storage building, resulted in several chemicals including pentachlorophenol and sodium fluorescein (a green dye) entering the surface drainage system. The spillage was initially contained and treated; however, the contained water was eventually allowed to flow off the installation.** (See Figure I-7).

Data obtained at the time of the Research Team's visit (19 - 23 September 1977) indicated that the installation was having difficulties during 1977 in meeting discharge limits imposed by its NPDES Permits. (See Appendix C for analyses sheets showing permit conditions and for figures showing approximate locations of outfalls.) As shown in the analyses of wastewater, all four sewage treatment plants (Outfalls 001 through 004, respectively) were in noncompliance at least once during the month of July.

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*Sanitary/Environmental Survey for Naval Weapons Support Center, Crane, Indiana.

**Memorandum, From 303 to Distribution List, Subj: "Green Water" Report, 20 September 1976, NWSC, Crane, Indiana.

Sewage treatment plant (STP) No. 1 failed requirements for total suspended solids (TSS), fecal coliform and chlorine residual, STP No. 2 failed requirements for fecal coliform and chlorine residual, and STP's No. 3 and 4 failed requirements for chlorine residual.

Although wastewater from the Metal Plating Shop (Discharge point 005), is currently neutralized and treated to destroy cyanide before discharge to surface waters, the effluent periodically fails to comply fully with its discharge limits. There are continuing problems with pH, TSS, cyanide, copper, iron, lead, and zinc. Discharge point 005 (Boggs Creek below its confluence with Turkey Creek) had difficulties with TSS, chromium, copper, and iron.

The new advanced sewage treatment plant was put on-stream on 16 September 1977; however, since several weeks of debugging were required before it became fully operational, analyses of its output were not available during the survey.

The present water monitoring program does not include analyses of any of the NWSC major streams at the point where each leaves installation property. It is necessary to have this data in order to determine whether contaminants are actually migrating off the installation. In the eastern part of the installation, Big Sulphur Creek drains southeast from the Rockeye manufacturing area and is contaminated with explosives manufacture wastes including complexes of TNT. Further south, Little Sulphur Creek drains southeast from the vicinity of a pyrotechnic burial site and an ordnance burning area. Boggs Creek, just below its confluence with Turkey Creek, contains heavy metals; therefore, the potential exists for these contaminants to migrate off the installation at the southern boundary. Seed Tick Creek enters the installation in the southwest and drains southeast from the general area of a sanitary landfill that currently has a leachate (of unknown composition) problem. In the northwest, Furst Creek receives drainage from the vicinity of the McComish Gorge landfill and an old open burning pit via Culpepper Branch and drains west off the installation.

2. Biota

a. General. The approximately 63,000-acre NWSC Crane occupies the northern third of Martin County, Indiana, with small extensions into adjacent Greene, Daviess, and Lawrence counties. Indiana, with an area of 36,045 square miles, is one of the north central states and lies between latitude 37°40' and 41°50'N and between longitude 84°49' and 88°2'W. The northern three-fifths of Indiana was covered with the Wisconsin ice sheet and the southern two-fifths (including the the NWSC area) was slightly affected by glaciation. This unglaciated region is characterized by steep ridges separated by a dendritic drainage pattern. Initially, valleys are trench-like, but grade into flat alluvial floodplains. Summers are hot and

humid, and winters are mild. Snow cover is light and of short duration. The frostfree period is more than 180 days. Soils are derived primarily from sandstone and are of silt-loam texture. Generally, they are acidic and low in nutrients (Ulrich et al., 1946). The average annual precipitation is about 39 inches. The average temperature is about 52 degrees with extremes as low as 20 degrees below zero and as high as 100 degrees. The average growing season is about 120 days near NWSC.

b. Flora. When the Depot was established in 1941, farming ceased. Currently, the land for the most part is in varying stages of forest succession. About three-fourths of the area has woody cover, a large part of which occupies land that was originally too steep for farming. Old fields, vestiges of past cultivation, occur on broader uplands and stream bottoms. A considerable area is maintained as openings by mowing. The major portion of this acreage consists of roadsides, perimeter firebreaks, power lines, water lines, and earth-covered storage magazines. Openings on dry upland sites contain almost pure stands of grasses (Andropogon spp) with scattered clumps of invading woody plants such as persimmon (Diospyros virginiana), sassafras (Sassafras albidum), and sumac (Rhus copallinum and R. glabra). As soil moisture improves, forbs become more prevalent.

On wetter sites, river birch (Betula nigra), willow (Salix spp), sycamore (Platanus occidentalis), and cottonwood (Populus deltoides) are common woody invaders. The dominant species of the hillside communities are hickory (Carya spp), white and black oak (Quercus spp), red maple (Acer rubrum), sugar maple (A. saccharum), tulip poplar (Liriodendron tulipifera), ash (Fraximus americana), and beech (Fagus grandifolia). About 2 percent of the area is in scattered plantings of pines (Pinus spp).

Approximately 50,395 acres of NWSC Crane are classified in the Central Hardwoods Forest of the United States. Commercial trees include black walnut, red and white oak, sugar maple, yellow poplar, white ash, beech, hickory, and sycamore. When the Navy obtained title to the lands, approximately one-half of the forested area was overcut, burned, pastured, contained undesirable species, or had little growing stock. Since the beginning of the Navy Forest Management Program in 1963, much of the depleted land has been restored and many young healthy stands of timber can be found on the installation (See Appendix B).

An estimate 959,820 board feet of hardwood sawtimber have been harvested during the last three years. The timber was sold by competitive bid and returned nearly $67,000 to the Government. The timber was marked under the direction of professional foresters who prepared environmental impact assessments to allow proper review of possible environmental problems.

Timber stand improvement operations were conducted on 800 acres. Most of these operations were to remove unmerchantable, diseased, cull, or stunted trees left remaining after a timber harvest. Removal of these trees allows growing room for new trees and helps perpetuate a young healthy forest.

Insect and disease problems are minor and the main protection is furnished by the young diversified forest being produced by present silvicultural practices. Careful inspection of timber harvesting operations helps to keep logging damages to the residual stand to a minimum and reduces the common but costly insect and rot damages associated with logging. Crane natural resource personnel keep abreast of potential insect and disease problems by reviewing current reports and literature from Federal, State, and professional sources.

The diversified and extremely interesting biological resources of this area owe their origin and character in part to the variety of habitats produced by present climate, soils, and topography. The diversity of habitats is evident when one considers that with the possible exception of marsh and agricultural habitats, Crane has an excellent interspersion of all other habitat types of the region. Crane's central position on the continent has also resulted in the converging here of floral elements traceable to origins in other direction. For a listing of flora including trees and plants see Appendix B and Bibliography references 12 and 56.

The Biology Survey Committee, Indiana Academy of Sciences, has prepared a list of 485 species of rare plants in Indiana. A county breakdown of these species may be obtained from the Department of Biology, University of Notre Dame.

Although a complete list of rare plant species is not available for NWSC, the following plants in need of conservation have been recorded from the base:

Showy Orchis
Lesser Fringed Orchis
Ginseng (This species is dug for commercial sale).
Nodding Trillium
Large White Trillium
Yellow Trillium
Sessile Trillium
Twinleaf (Suspected as being present on NWSC (found nearby))
Sullivantia Sullvantii (Ohionis)
Asplenium penvatifidum
Asplenium trichomanes
Vittaria lineata "herb-wagneri"

c. Fauna. The mobility of animals generally, except in some of the lower orders and specialized forms, tends to create wider distribution patterns and fewer specialized ecological limitations than is the case with the plant base upon which animal life depends. Thus, there are few really distinctive zoological resources. However, the representation of the aboriginal fauna, with the exception of such major mammals as black bear and mountain lion, is surprisingly complete. There is a great variety and abundance of bird and mammal life, and the prosepct for perpetuating and improving this situation is very good.

White-tailed deer are abundant throughout the area. It is interesting to note that deer were exterminated from Indiana by 1900, due to unrestricted hunting and the clearing of the land for farming. Crane's present herd of 3,000 to 4,000 deer has grown from a stocking of 12 deer in 1942 by the Indiana Department of Natural Resources. A controlled hunt is held annually to help maintain a healthy herd.

Another animal that had to be reintroduced to Indiana is the beaver. While sightings of beaver are rare, the many dams and lodges constructed by beaver are easy to find. Several of the beaver dams provide water for the only natural resident duck, the wood duck, on the installation.

Small mammals such as opossums, raccons, cottontail rabbits, and red and gray foxes can be seen frequently. Carnivores that are seen less frequently include the long-tailed weasel, striped skunk, mink, and coyote.

Larger rodents which are commonly seen are the muskrat, woodchuck,* gray squirrel, fox squirrel, and eastern chipmunk. Woodchucks are especially abundant and conspicuous along roadsides and on storage magazines. One rodent that is rarely seen, since it is almost entirely nocturnal, is the flying squirrel.

Lying along the Mississippi Valley flyway of waterfowl and shore birds, the installation receives seasonal influxes of numerous species in these categories. In the inlet on Lake Greenwood between the Commissioned Officers Mess and the Housing Area, a resident free-flying flock of Canada geese and mallard ducks is maintained. The nucleus of this flock was released in 1974. During the winter months, a bubbler system maintains open ice-free water and food is provided for the birds. It is not unusual to see over 500 birds in this inlet during extremely cold weather. Other migrating waterfowl which have been seen include the ringnecked ducks, lesser scaups, hooded mergansers, black ducks, redheads, common mergansers, bufflehead, and common loons.

*Often referred to as a groundhog.

Game birds at the installation include wild turkey, ruffed grouse, bobwhite quail, and woodcock. The wild turkey was reintroduced to the installation in 1974 and many sightings of this noble bird have since been made. Restocking efforts have also been successful with the ruffed grouse and several makes are heard each spring when they "drum" the air with rapidly beating wings in an attempt to attract a female.

Raptors that rest on the installation include the red-tailed hawk, redshouldered hawk, broad-winged hawk, sparrow hawk, Cooper's hawk, sharp-shinned hawk, great horned owl, barred owl, screech owl, and turkey vulture. From 50 to 100 turkey vultures live on the installation from late February through November. The hills and valleys provide good physical conditions for thermal updrafts in which the turkey vultures enjoy soaring in lazy circles.

Fall and winter raptorial visitors to the installation include the roughlegged hawk, marsh hawk, short-eared owl, long-eared owl, saw-whet owl, bald eagle, and golden eagle. This is probably the only place in the state where two species of eagles can be seen with any regularity. The primary foods of hawks and owls are the small animals of the woods, fields, and roadsides; and where cover is sufficient, these predators have only a minor impact on populations of game animals. These raptors are all protected by state and federal laws.

Many other species of birds can be found on the installation. The following checklist is by no means complete; however, it does give a good indication of the types of birds present:

American coot	Killdeer	Herring gull
Rock dove	Mourning dove	Belted kingfisher
Common flicker	Hairy woodpecker	Red-bellied woodpecker
Yellow-bellied sapsucker	Downy woodpecker	Horned lark
Blue jay	Common crow	Carolina chickadee
Tufted Titmouse	Brown creeper	White-breasted nuthatch
Red-breasted nuthatch	Winter wren	Carolina wren
Mockingbird	American rober	Eastern bluebird
Golden-crowned kinglet	Ceder waxwing	Starling
House sparrow	Cardinal	American goldfinch
Rufous-sided towhee	Dark-eyed junco	Tree sparrow
Field sparrow	Whip-poor-will	Purple martin
Red-winged blackbird	Swamp sparrow	White-throated sparrow
Song sparrow	Great blue heron	Ruby-throated hummingbird
Yellow-breasted chat	Common grackle	

There is a good variety of land reptile life including the box turtle, several lizards, and a number of species of snakes. Poisonous land snakes are represented by copperheads and rattlesnakes. Nonpoisonous land and water snakes are fairly common.

Quite a few species of frogs and salamanders inhabit the installation. Bullfrogs can be heard nightly during the summer months. Toads are common and several species of water turtles are present.

The aquatic life of the lakes, ponds, and streams is interesting. Many invertebrate forms occur. Crayfish are abundant and freshwater mussels can be found in some locations. Fish life is represented by the following species:

Golden shiner	Yellow perch	Bluegill sunfish
Redear sunfish	Warmouth	Walleye pike
Channel catfish	Largemouth bass	White crappie
Spotted sucker	White bass	Yellow bullhead
Carp	Brown bullhead	Longear sunfish
Black crappie		

3. Geology

a. Physiography and Topography. The NWSC lies in the Mitchell Plain section of the Interior Low Plateau Province. The topography consists of flat to gently undulating surfaces dissected by numerous drainageways, with ranges in elevation from 470 to 860 feet above mean sea level (msl). Bounding inclines along the streams have slopes that approach 20 degrees and rise up to 150 feet above the valley floor. The bounding inclines of the smaller drainageways are V-shaped while the larger drainageways occupy floodplains up to 2000 feet wide.

b. Subsurface Geology. The NWSC is underlain by geologic rock formations of lower Pennsylvanian and upper Mississippian age. Figure I-8 indicates the areal distribution of three units with unit 1 representing the Raccoon Creek group (Pennsylvanian) and units 2 and 3 representing the Stephensport group (Mississippian). The Illinoian glacial drift overlies the rocks in the northwest sector of the installation; however, this unit is not mapped in Figure I-8.

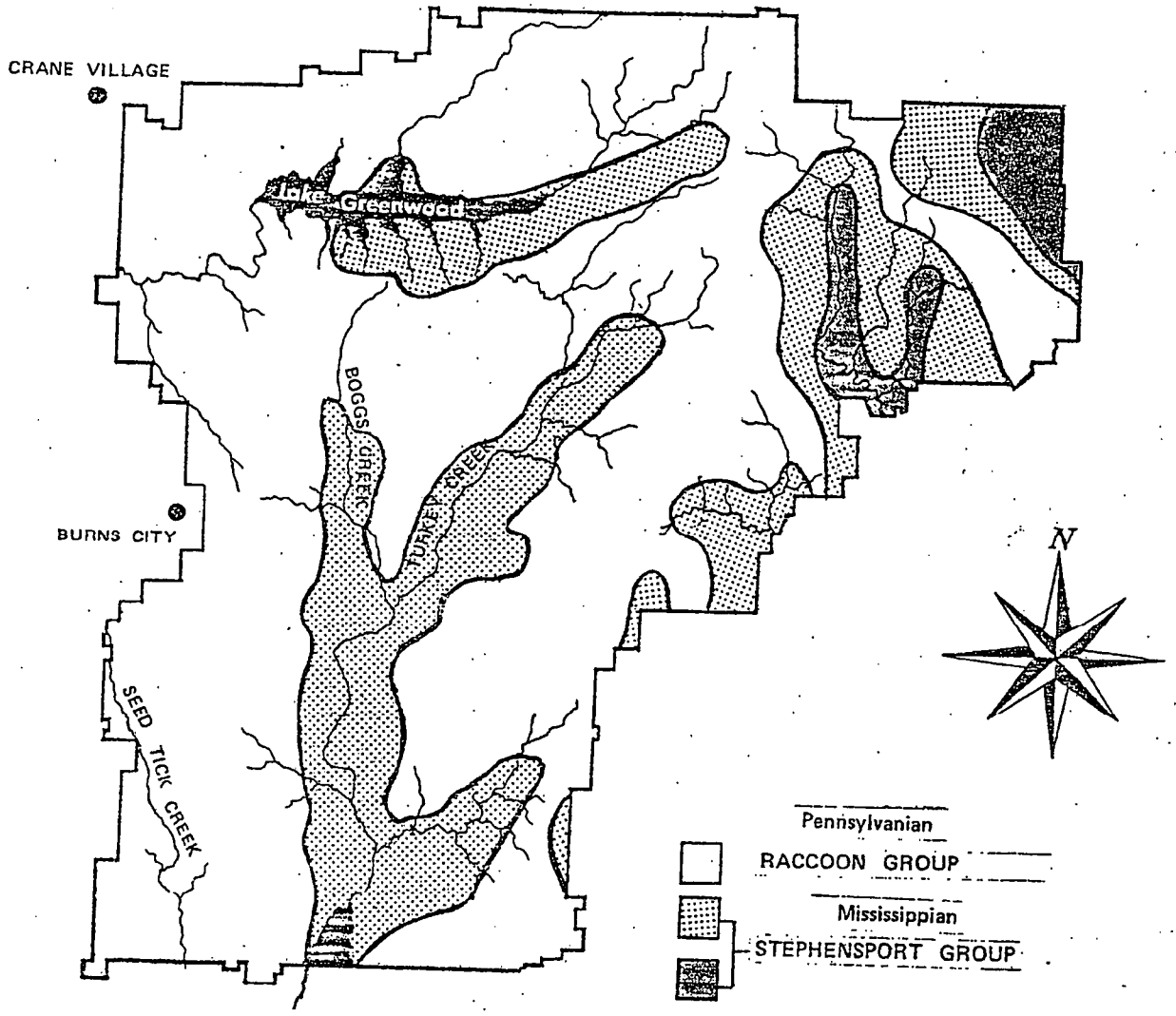


Figure I-8 GEOLOGY

Characteristics of the three mapped units are very similar and consist of gray to tan, fine to coarse-grained sandstone and limestone interbedded with seams of dark gray shale, clay, and light gray siltstone and mudstone. The total thickness fo the three units ranges between 350 and 475 feet.

c. Soils. From the boring logs, the major soil type is a 2- to 3-inch-thick surface layer of brown to tan organic clay loam underlain by clay intermixed with silts and sand. The United States Department of Agriculture identifies three-fourths of Martin County (which includes the NWSC) as the Zanesville and Muskingum soil series. These series are identified as a dark brown organic silt loam at the surface, underlain by 48 inches of mottled tan, gray, and yellow clay with varying percentages of sand and silt. Occasionally, a clay hardpan occurs between 25 and 32 inches below the surface.

Subsurface exploration at the sanitary landfill included observation wells, auger, and splitspoon borings. Data from seven observation wells indicate that clay occurs from the surface to a maximum depth of 19 feet. Sand rock, assumed to be sandstone, is at depths between 5 and 19 feet. Data from 15 auger holes show clay to sandy clay down to a maximum depth of 10.5 feet with the top of sandstone ranging from 4.5 feet to just beyond 10.5 feet. Data from splitspoon borings B50 through B52 provide a more detailed description of the soil above the sandstone that was reached at 16.6 feet. The top 2 feet consist of dark brown soft inorganic silt grading to dark yellow in color and becoming sandy down to approximately 3 to 5 feet. The next 2 feet are dark yellowish brown, dry, hard lean clay. This clay zone is absent in the data from boring B51. The remainder of the overburden is a light brown, mottled gray hard silty sand with scattered sandstone fragments.

Ten borings at the compactor site identified 14 to 18 feet of light brown to yellow silt and sand with an occasional zone of lean clay overlying sandstone. Data from six auger holes show 8.5 to 10.5 feet of red, blue-gray clay over shale.

One boring at Trinity Springs (some two miles east of the southeast boundary in the floodplain of Indian Creek) presented 13 feet of gray clay, 72 feet of gray silty clay, and 5 feet of brown silty, sandy clay. No rock was encountered in this hole.

The location of the above borings are shown in Figure I-9 and the drilling logs are presented in Appendix E.

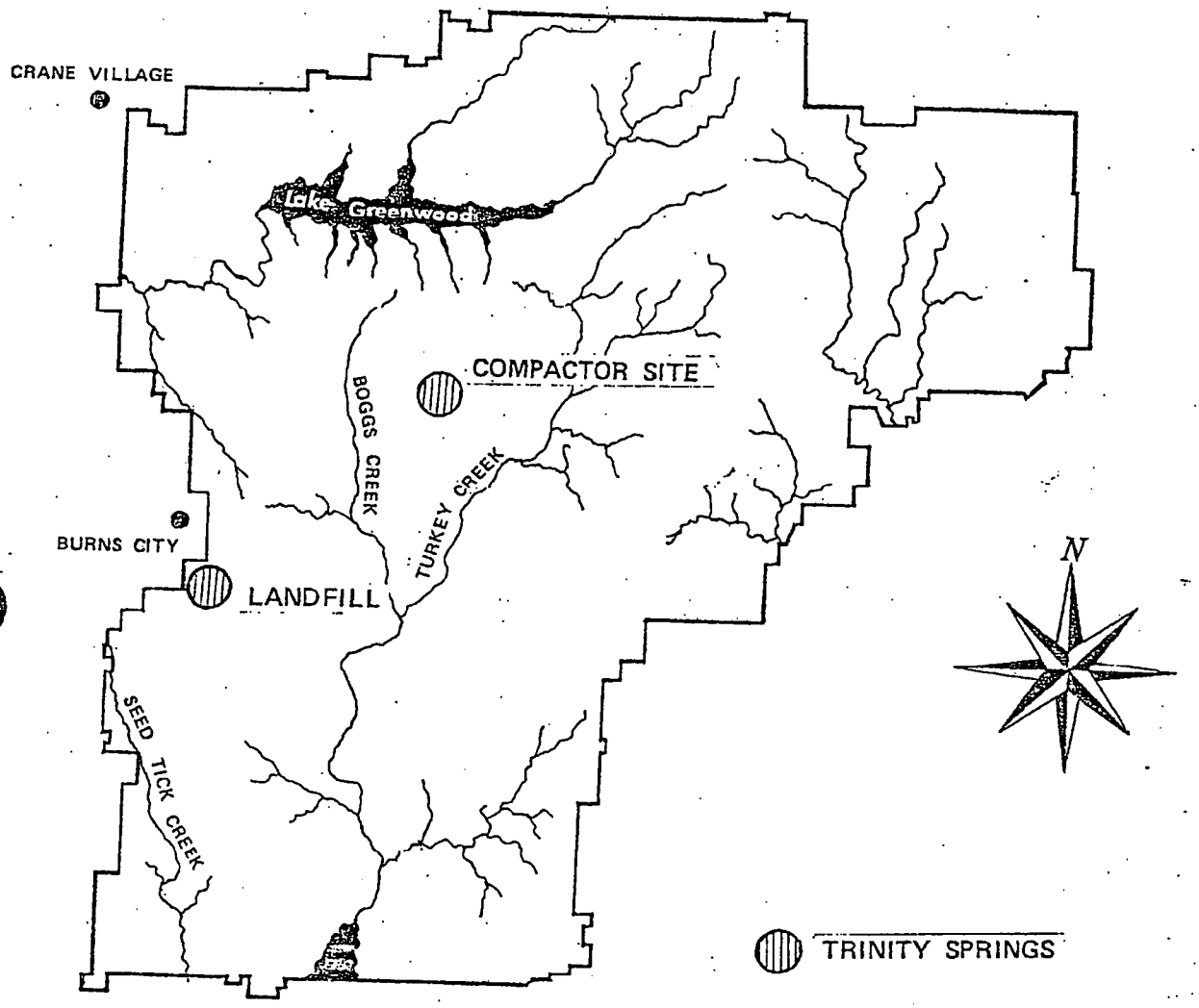


Figure I-9 BORING LOCATION

II. CONTAMINATION ASSESSMENT

A. Industrial Operations

The major source of industrial contamination at NWSC is from contaminated wastewater from the filling and demilitarization operations. Much of the present and practically all past (prior to 1970's) operations discharged contaminated wastewaters directly into the nearby ditches and streams or into sump pits or settling ponds that overflow directly into the streams. Most of the contaminants identified are explosives or explosive related chemicals carried by the wastewater into the nearby ditches and streams. These contaminants included RDX, tetryl, Composition A, B&D, TNT, HMX, aluminum, lead chromate and alkaline nitrates. Each industrial area is discussed below.

Large quantities of ammunition have been loaded and demilitarized at NWSC in the past (see Appendix G). These figures show that large quantities of explosives have been handled at NWSC. Due to the manner in which wastewater has been handled, a high potential exists in the industrial areas for contamination of nearby ground, ditches, and streams with explosives and associated chemicals.

1. Rockeye/3-Inch Explosive Loading Area

This area is located in the northeastern portion of the installation and is presently a cast loading line for the Rockeye Rocket. Figure II-1 is an aerial view of the complex. Records indicate that many thousands of 3-inch munitions were filled in this area during WW II, and the Korean and Vietnam conflicts. At present, TNT is the principal contaminant in the area; however, records indicate that large quantities of RDX, HBX, and Composition B munitions were handled in the area. The primary cause of contamination in this area is a result of wastewater discharge and run-off from the filling operation. Wastewater from the tray and bomblet washing areas runs into sumps. The drills used in this operation are water-cooled with recirculating water and the slush is gathered daily and also placed into the sumps. The sumps are periodically pumped and the residue is sent to the burning ground for disposal. It should be noted that once the sumps are filled, the excess wastewater drains directly into the drainageways and, (depending upon which side of the complex the sump pits are located) eventually to Sulphur or Boggs Creeks water beds.

All explosives spilled on the floor are collected and sent to the burning ground for disposal while the cleaning water from the floors runs directly into the sumps. All of these factors contribute to the contamination of the drainageways leading from this complex. The new milcon project to control this contamination is scheduled for operation in January 1978 and should greatly reduce furture contamination.

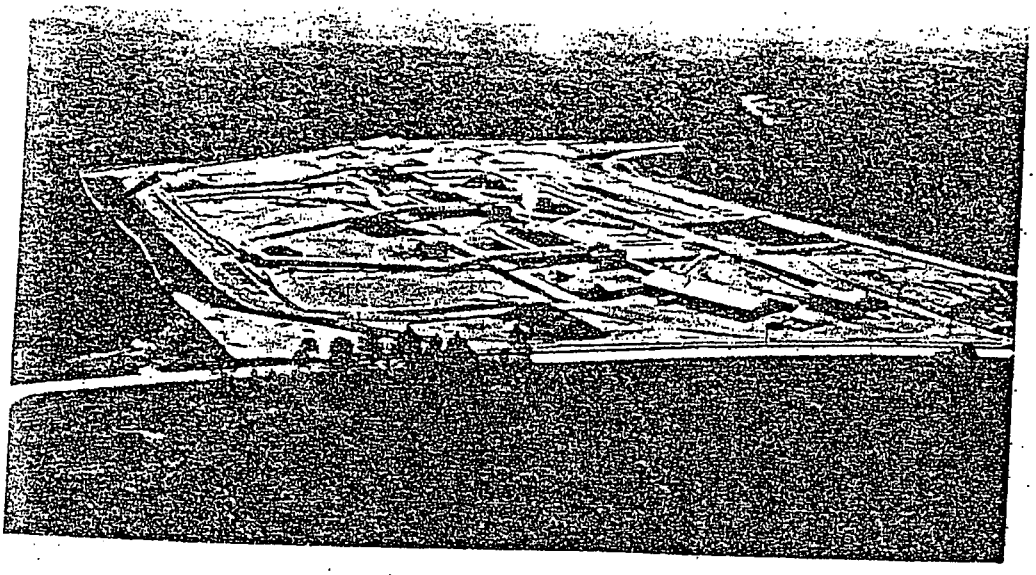


FIGURE II–1 ROCKEYE MANUFACTURING AREA, NWSC, CRANE, INDIANA (ARROW INDICATES POINT OF DISCHARGE OF RED WATER THROUGH FENCE AROUND ROCKEYE AREA)

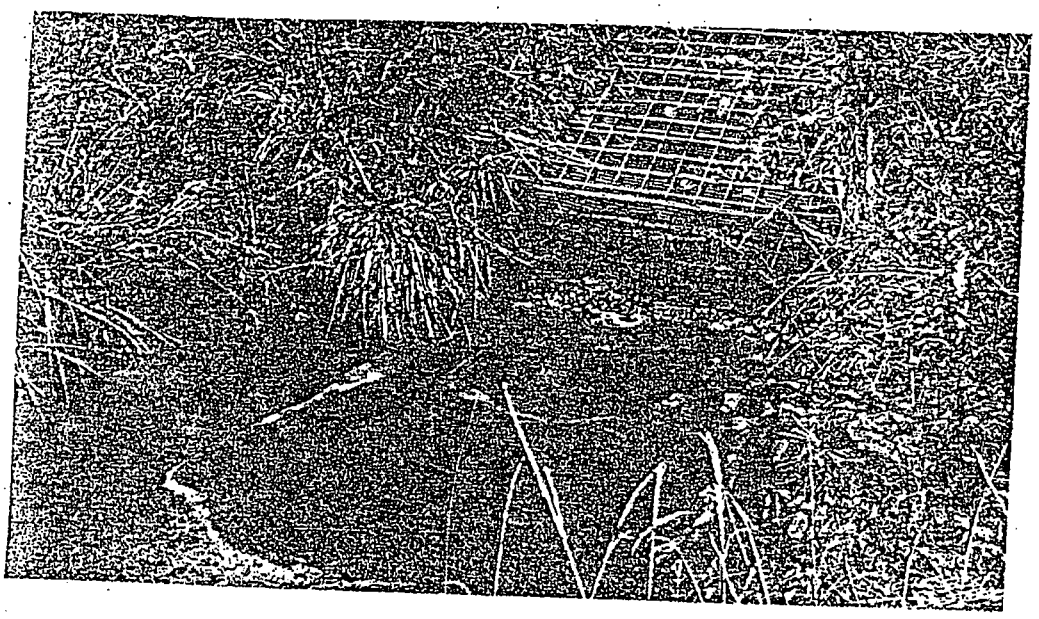


FIGURE II–2 RED WATER DISCHARGE POINT AT FENCE SURROUNDING THE ROCKEYE AREA

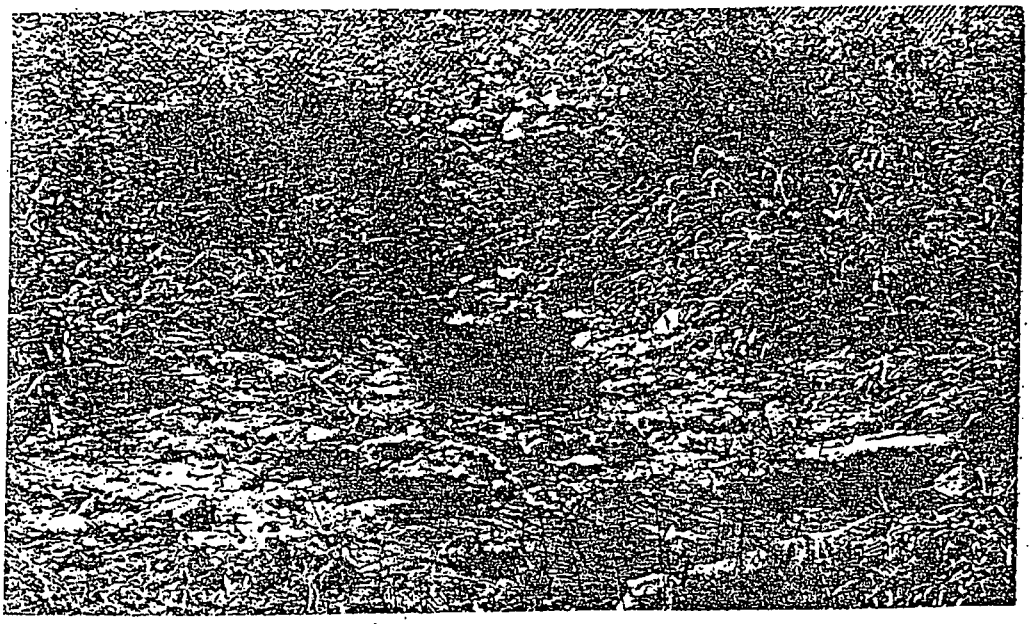


FIGURE II–3 RED WATER 50 YARDS DOWNSTREAM FROM ROCKEYE FENCE

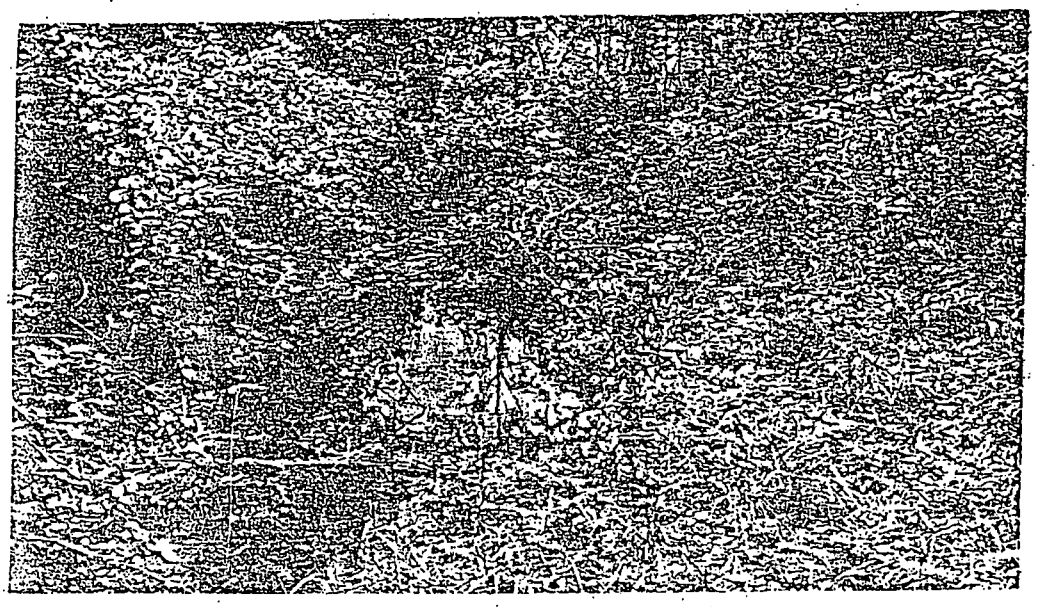


FIGURE II–4 RED WATER 200 YARDS DOWNSTREAM FROM ROCKEYE FENCE

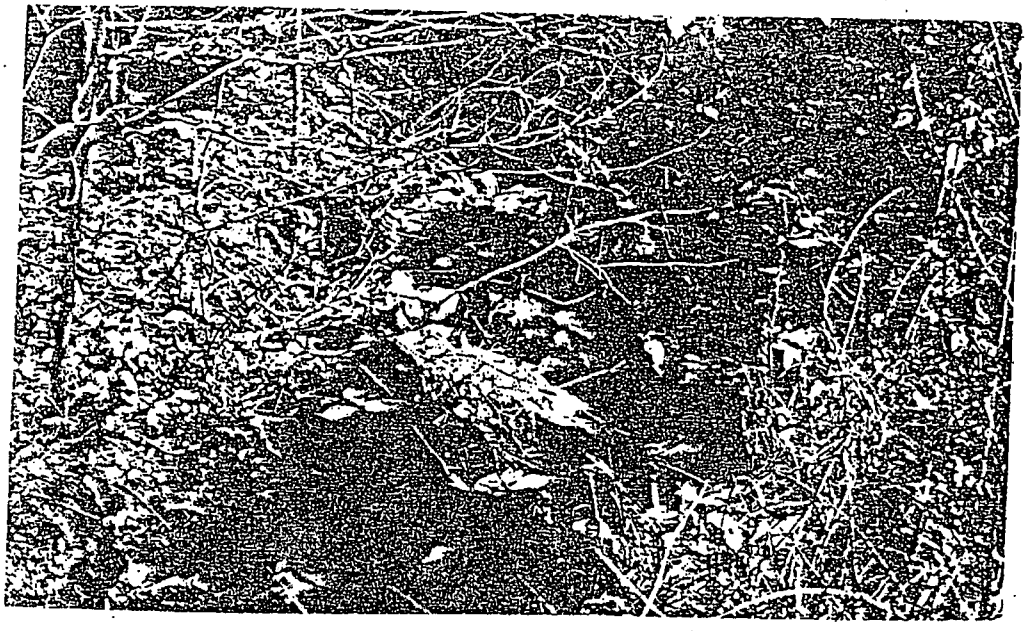


FIGURE II–5 RED WATER 400 YARDS DOWNSTREAM FROM ROCKEYE FENCE

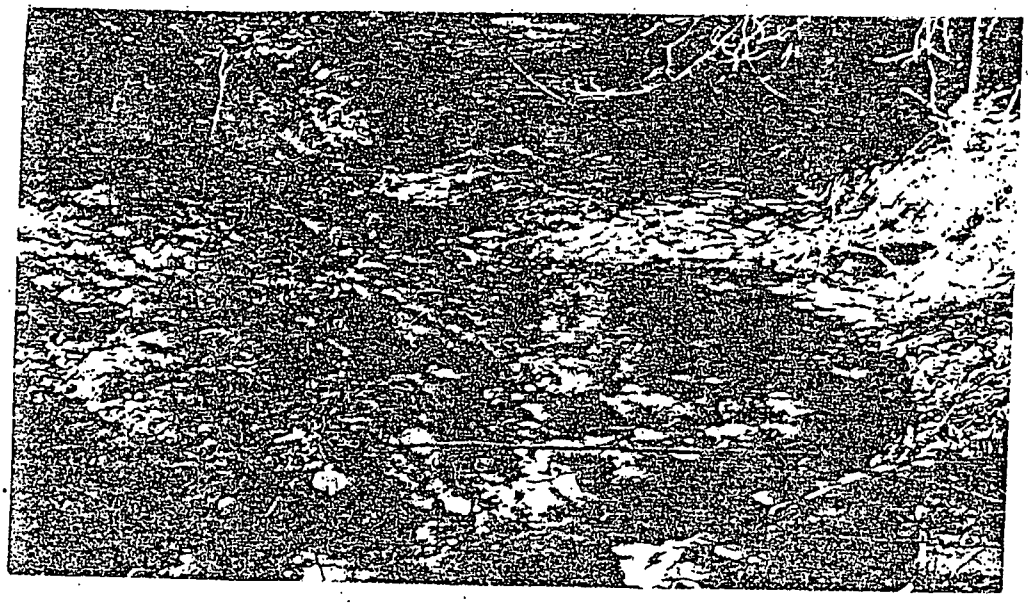


FIGURE II–6 RED WATER APPROXIMATELY ONE-HALF MILE DOWNSTREAM FROM ROCKEYE FENCE

Red water, indicative of TNT contamination, was observed by team members in the surface water drainage ditches on the northeastern side of the complex. This wastewater drainageway was followed by team members and red water was observed where the stream enters Sulphur Creek approximately 2 1/2 to 3 miles from its source. Although no water sampling and analysis of Sulphur Creek could be found in the records, concentrations of 150 to 200 parts per million (ppm) of TNT were reported in water samples taken in the drainageways near the complex. The vivid red color of the water shown in Figures II-2 through II-6 indicates a significantly high concentration of TNT in the stream even at the point of entering Sulphur Creek. It would be expected that this situation would become more critical as the workload increases and additional shifts are added. This complex presently employs a single shift of approximately 100 employees; however, as many as three full shifts have been employed in the past during peak times of national emergencies.

2. 40-Millimeter Loading Complex

The 40-Millimeter (mm) Loading Complex is located at map coordinates Q-31 (Figure II-7)*. All reported loading and demilitarization operations are confined to Building 146. This complex has been used for cast loading munitions with TNT, RDX, and HBX explosives along with the demilitarization of such ammunition as: 20mm, 30 and 50 cal munitions, shotgun shells, fuzes, detonators, boosters, tracers, flares, and various types of smoke munitions.

The major contamination in this area is from the demilitarization of 5-inch munitions filled with Composition A. One interviewee reported that numerous Army ammunition and rockets were demilitarized in this complex during the mid-fifties; this demilitarization was said to be a steamout procedure of TNT and Composition B filled items. The present demilitarization activity is reported to be intermittent in nature with overall total of approximately 300 projectiles being washed out over the last 2 to 3 years. At present, 5-inch munitions loaded with Composition A are being washed out with 9,000 to 10,000 psi water after 5 pounds of material is contour drilled out and sold. The remaining material (3 to 3 1/2 pounds per round) is washed out into a hopper and taken to the burning ground for destruction. The water is filtered and sent to the sumps where it is cooled and recycled. This recycling system has been in use for the last 2 to 3 years; however, prior to this, all water went directly into the sewer that drained into the Boggs Creek watershed. The extensive prior use of this complex has contaminated the area with explosives especially from the steam demilitarization facility and with residual contamination from the demilitarization furnaces.

*All map coordinates will be identified on Figure II-7.

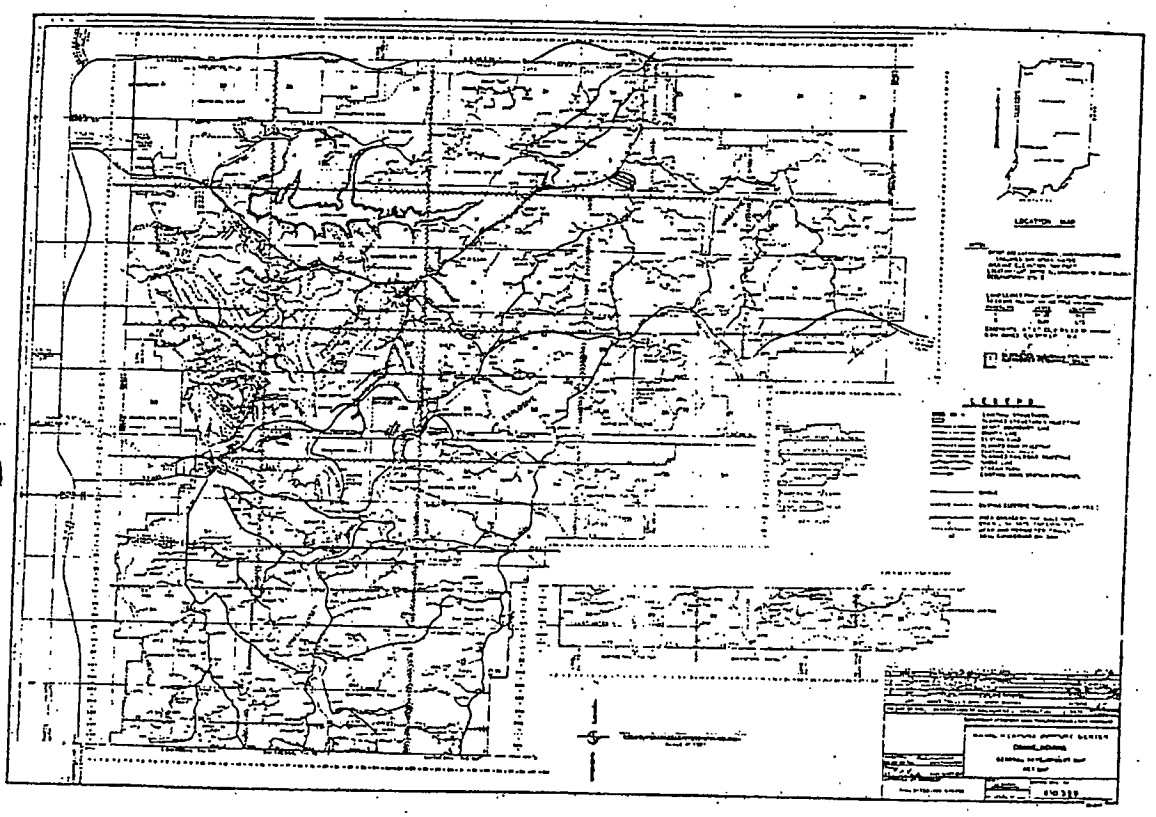


Figure II-7 GENERAL DEVELOPMENT MAP, NAVAL WEAPONS SUPPORT CENTER
(KEY MAP) NAVFAC DWG No. 610328

3. Booster Area

The Booster Area is located at map coordinates W-26. This complex is presently used to load initiating devices with tetryl, lead azide, and lead stephnate; however, in the past, large quantities of booster devices were loaded with TNT and tetryl. Each building in the area has a sump and all screening and rinse waters go to the sump. All sumps are treated to neutralize the materials and any overflow of the sumps enters into an earthen dammed holding basin. The operation is well controlled and little contamination is permitted due to the sensitive nature of the explosives. No contaminated material enters the sewer from the assembly rooms, and all collections are sent to the burning ground and destroyed.

4. Mine Filling Area A

Mine Filling Area A is located at map coordinates E-24 and is a cast loading area (Figure II-8). This area has been extensively used in the past, with TNT and RDX as the most significant contaminants from past operations. The major sources of past contamination were from the wastewater disposal and the exhaust ventilation systems. Explosive contamination through the exhaust ventilation system has been measured at approximately 40,000 pounds per year. In discussions of the procedure with employees, it was reported that during peak filling periods, the roof of the building near the exhaust ventilation system had to be hosed down to prevent the buildup of explosive material on the roof. This material was washed off the roof onto the surrounding ground and into the ditches that lead into Turkey Creek and eventually into Boggs Creek which drains off the installation. In addition, the hot water-steam demilitarization facility at Building 160 also contributed to the explosive wastewater contamination. It was reported that 120mm rounds loaded with Composition B were steamed out in Building 160 as recently as 6 months ago. This operation was used on cast loaded explosives such as Composition B, TNT, HBX, tritonal, etc, but not on the highly soluble explosives such as amatol and ammonium picrate. Most of the explosives reclaimed by this operation were reported to have been sold or sent to the burning ground; however, some of the TNT was reported to have been reused. This area has new pollution control equipment installed for both the wastewater and the exhaust ventilation system, but the plant has not been operated since its installation.

5. Mine Filling Area B

This area is similar to Mine Filling Area A except that it has larger kettles. Explosives loaded in this area within the last 10 to 12 years included Composition B, H6, and tritonal. The line was operated at full production during the 1967 through 1973 time frames; however, it has not been in operation since that time. The Fill Line was built during the

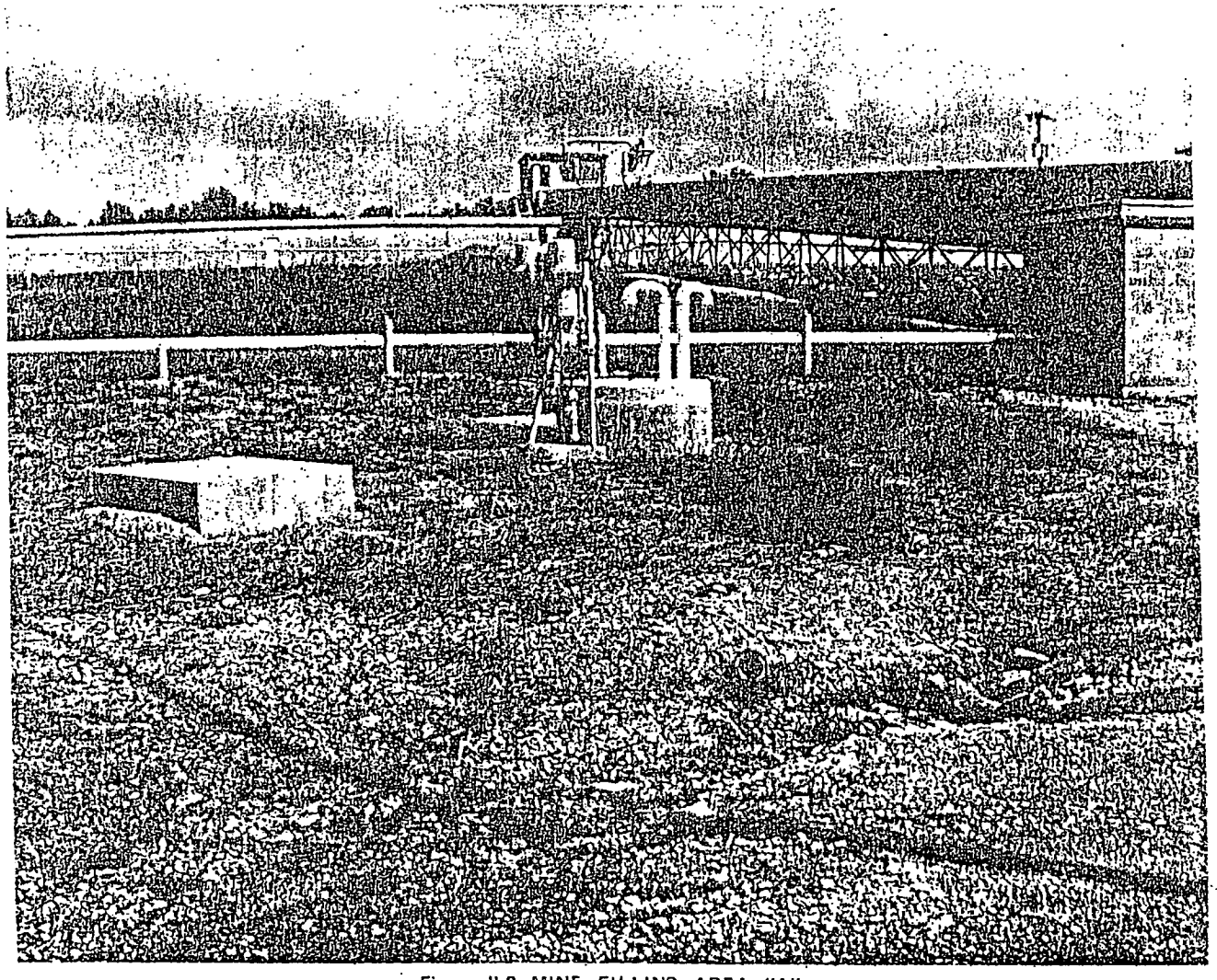


Figure II-8 MINE FILLING AREA "A"

WW II era and large quantities of TNT and possibly some Composition B explosives were reported loaded during that time frame. It was also reported that spin stabilized rocket heads were loaded in this area during the latter part of WW II. During the Korean War, the area was used to load MK53 and MK54 aerial depth bombs with TNT and HBX. Also, it was reported that during the 1950's this area was used to load large quantities of depth charges of the ash can type with TNT and to load MK25 and MK39 mine casings with HBX.

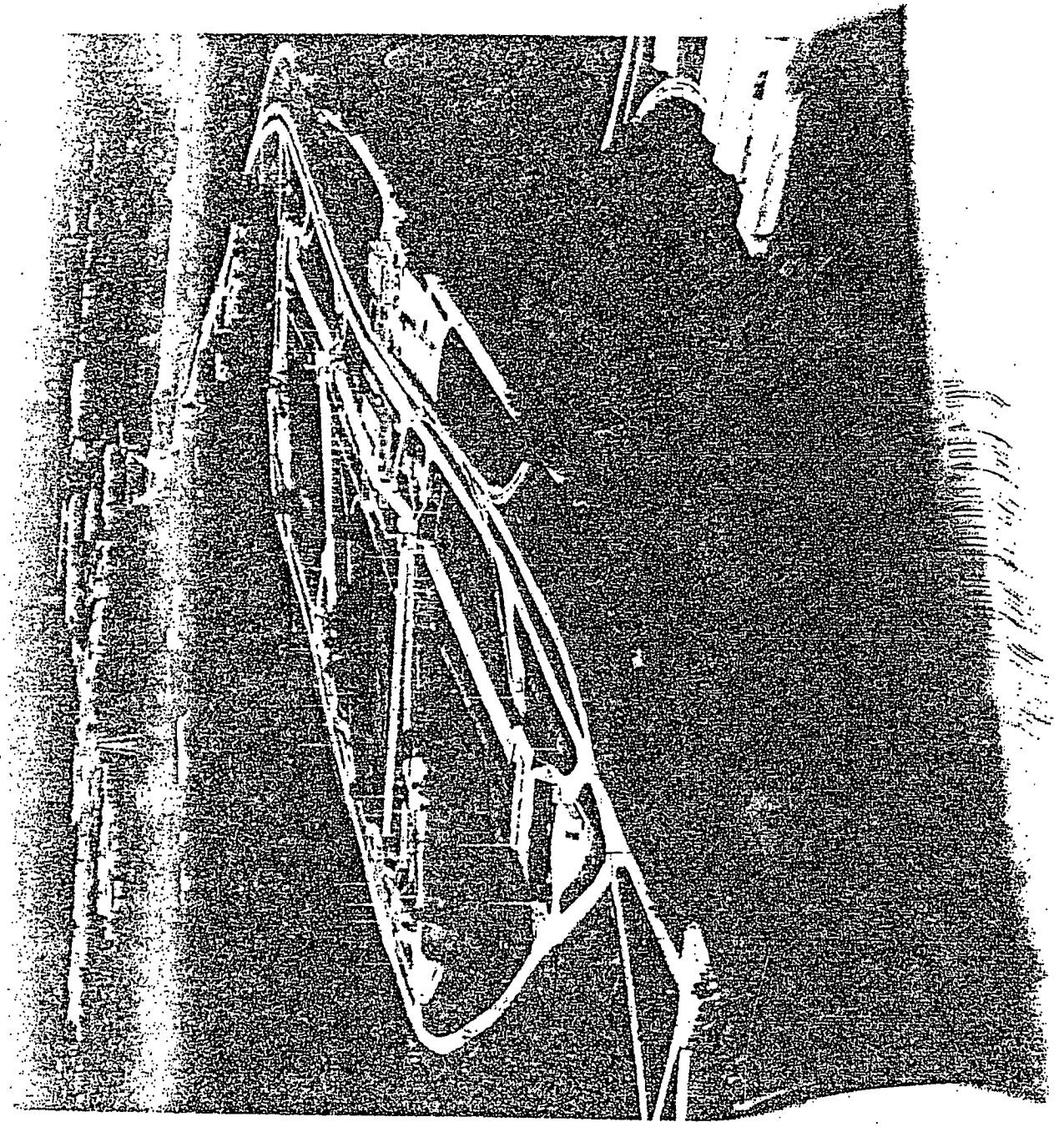
Minol was reported to have been loaded into some rounds during the Vietnam period. It was also reported that H6 was loaded into 250, 500, 1000, and 2000 pound bombs during the 1958-1960 time frame. In addition, Building 160 was reported to have been used for downloading, washout/steam out of bombs and mines from 120mm up to 1000 pounds in size.

There were reports that large quantities of TNT, Composition B, HBX-1. HBX-3, and H6 were treated in the sumps in this area. In addition, explosive contamination through the exhaust ventilation system similar to the Mine Fill Area A was also reported. This was estimated to be 40,000 pounds of explosive per year when in full operation.

Operations over the last 20 to 30 years permitted the excess water from the sumps to flow directly into the ditches that eventually flowed into the Boggs Creek watershed. Thus, the entire ground area and particularly the ditches leading from Mine Fill Area B are considered heavily contaminated with explosives as a result of these extensive past operations (See Figure II-9).

6. Loading and Filling Area

The Loading and Filling Area is located at map coordinates EE-17, Figure II-10. This area was built in 1942 and 1943 and has been in use since that time. Large quantities of ammunition were loaded in this area. Contamination from past operations would probably be from explosives such as Composition A and Explosive D (ammonium picrate), and from various acids and caustic materials used in the area. The most contaminated area would be around Building 104 where most of the past loading and washout was conducted. The Explosive D is highly soluble in water, and over the years large quantities have been discharged into the nearby stream that leads into Boggs Creek. The Explosive D is washed out with hot water until saturated, then sent to holding tanks to cool. The explosive is crystalized out, collected, and sent to the burning ground. The water is then reheated and recycled. This process continues for approximately 1 week; then the water is sent to the sump pits and the system is recharged with a new supply of fresh water. It is estimated that 20,000,000 pounds of Explosive D and 10,000,000 pounds of Composition A have been processed through this area since its start. Practically all the Composition A operation has been a



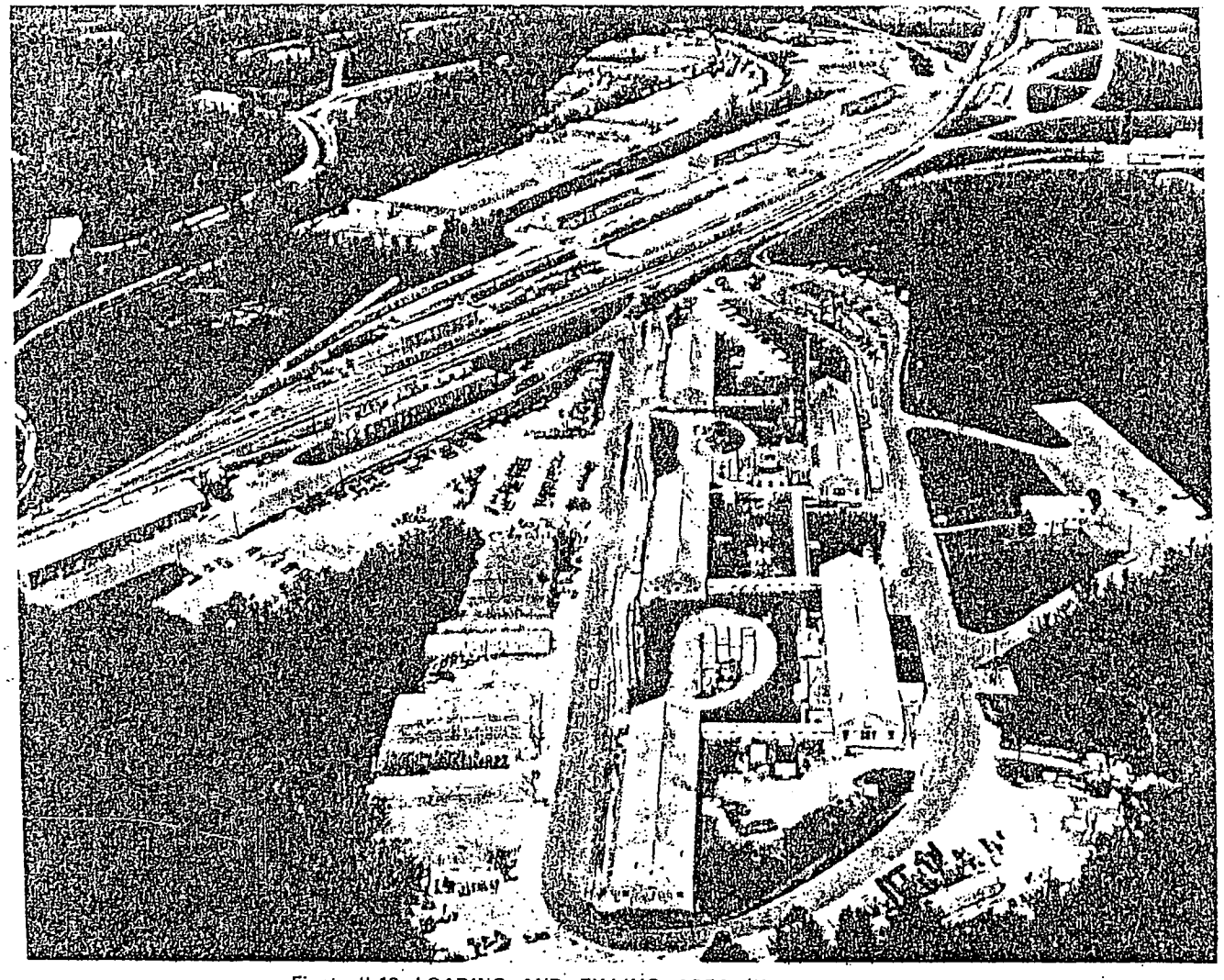


Figure II-10 LOADING AND FILLING AREA (HIGH EXPLOSIVE)

loading process while the Composition D operation is estimated to have been 75 percent loading and the remaining 25 percent demilitarization.

One other contamination spot of concern in the Loading and Filling Area is in the vicinity of old Building 225. A fire destroyed this building and its contents on 13 July 1976. This building was reportedly used for storage of large quantities of paints, solvents, dyes, inks, wood preservatives, etc. Over 600,000 gallons of water were estimated to have been pumped on to the blaze and pollutants were reportedly found in downstream samples of water. Details of this fire and subsequent activities are in the "Green Water" Report dated 20 September 1976 (See Appendix F). Building 225 has since been razed and the area reportedly cleaned; however, as a result of the large quantity of chemicals stored in the building, it would be expected that the general area in and around where Building 225 stood would continue to have residue from the building contents. The surface water in this area drains to the west and into the Furst Creek watershed. Reports have been made of small amounts of dye leaching from the nearby railroad bed during periods of heavy rains, but no toxic results could be identified.

7. Pyrotechnic Area

The Pyrotechnic Area is located at map coordinates U-24. The buildings in this area use sump pits in collecting waste and washdown water. Red phosphorus is considered the most significant contaminant in the area. Other possible contaminants identified are chlorates, dyes, oxidizers, and fuels for flares and smoke munitions. All waste and wash water reportedly drains into the respective building sump pits which are periodically pumped out into tank trucks and taken to the burning ground. All overflow of these sumps pits drains into the Boggs Creek watershed. Also within this area is a plating shop that utilizes heavy metals, caustics, acids, and cyanides. Records of past operations indicate that a cyanide neutralization treatment facility has been utilized at least, the last 12 years. However, it is expected that significant heavy metal contamination (zinc, cadmium) has been experienced from wastewater being discharged into an open ditch that drains into Boggs Creek. The acids and casutic wastes are mixed before sewering and are reported to be neutralized; however, no tests or samples are made to support this.

With the Pyrotechnic Area, there are also two old burning areas that were used many years ago. One is located behind Building 126; the other is located across Highway 5. Wastes from past activities of many years ago could still be leaching into the pits from these areas; however, neither burning area has been used for over 6 years and contamination would not be expected to be significant.

8. Old 16-Inch Loading and Demilitarization Area

This area is located at map coordinates HH-13. These facilities have not been used for 16-inch loading and demilitarization for 12 to 15 years. When this facility was in operation, large quantities of Explosive D (ammonium picrate) were loaded and washed out and heavy explosive contamination would be expected; however, due to the high solubility of Explosive D, there is little likelihood that extensive contamination of this material remains in the area. These facilities have since been converted to a pyrotechnic assembly area and little contamination would be expected from the operation.

9. Building 181, Clothing Change House Area

This area is located at map coordinates JJJ-22. Many years ago, this building was used as a chemical warfare agent decontamination building, but has not been used as such for more than 12 to 15 years. The EOD Team is presently using this area for sawing bombs into sections, etc. There was a report that CW agents (probably mustard) were burned nearby; however, this could not be confirmed by any formal documentation or by anyone interviewed at the installation. Most of the decontamination equipments (tanks, exhaust hoods, charcoal filters, etc.) have been removed from the building and little hazard from past contamination would be expected.

10. Transfer Depot - Building 600

This facility is located at map coordinates FF-27. This is where the trucks used to transport bulk explosives to and from storage were cleaned. The trucks were backed up to a pit and the truck beds were hosed down to remove any explosive contamination. Over the years, significant amounts of explosives have been washed into the pit and allowed to accumulate. No estimate of actual amount could be obtained during the records search; however, due to the large quantities moved in this manner in the past, it would be expected that the amount of waste material would be significant. Portions of the explosives have probably leached out and into Turkey Creek which flows nearby.

11. Laundry (Building 180)

The Laundry is located at map coordinates T-22. This is an industrial laundry and is used primarily to launder clothing worn by explosives and pyrotechnic workers. The primary contaminant identified is phosphates. This contaminant is a result of applying fire retardant to the clothing in the laundering process. Other contaminants identified are

detergents, ammonia, explosives, and solid matter. Prior to 1973, the wastewater from this operation was directly discharged into an open ditch that drains into Boggs Creek. This procedure was in operation from the early WW II era to 1973; since 1973, the wastewater has washed into the sanitary sewage system. Thus, this area is not considered to be a seriously contaminated area.

12. Small Arms Area

The Small Arms Area is located at map cordinates G-18. This facility is mainly a packaging and preservation operation. It has a metal coating facility that uses caustics, phosphates, and acids; however, no significant contamination was identified in the records search.

B. Laboratories

1. Quality Evaluation Laboratory Complex

This complex is located at map coordinates R-29. Building 2044 of this complex is probably the most likely building to have caused contamination in the past. Located within this building is a laboratory (lab) complex that includes a chemistry lab, a physic lab, a microbiological lab, a metallurgy lab, an X-ray facility, a photographic lab, a model machine shop, and a testing area for explosives.

In the past, the building wastes were discharged into septic tanks and absorption fields. These areas were apparently overloaded, as seepage onto the ground surface was reported in documents reviewed by the team, (Pollution Control Program 1971). Pollutants identified were formaldehyde, Elon, hydroquinone, sodium sulfate, sodium sulfite, borax, and bleach. The drainage from this area is into Turkey Creek which drains into Boggs Creek near the center of the installation. The building wastes are presently connected to the sewer line. This action is considered to correct the on-going operation of the building; however, the past pollutants remain in the absorption field.

2. Applied Science Department Complex (ASD)

This complex is located at map coordinates GG-14. This area has been used primarily for research and development of pyrotechnics. Past operations sent chemicals directly into the stream that flows into Boggs Creek. Explosives and magnesium oxide are the heaviest pollutants in this area. In addition, it was reported that dyes, some of which are carcinogenic, and chemical waste in support of the research and development (R&D) laboratory have been discharged into the stream. Since the quantities used

for R&D are much less than the quantities used in the nearby Loading and Filling Area (see paragraph II.A.6 above), it is concluded that this laboratory complex is not a major contributor of pollutants in the area.

3. Naval Ammunition Production Engineering Center (NAPEC)

This complex is located at map coordinates G-18. This is a research and development (R&D) tenant activity responsible for providing engineering support for naval ammunition. This R&D group is an organizational element of the Naval Sea Systems Command. The R&D effort includes producibility studies, design modifications, development of imporved production methods, processes and line layouts, development of Technical Data Packages for porduction, preparation of quality acceptance procedures, production facilities and equipment design, and investigation and correction of malfunctions. Little contamination as a result of this R&D effort could be identified.

C. Field Test Ranges

1. Pyrotechnic Test Range

This test area is located at map coordinates VV-18, and Figure II-11. Tests performed in the area are functional tests on flares, signals, and other marking devices. A drop test tower is also located in the area, but should not be a major contributor to contamination. Most of the contamination would be a result of pyrotechnic testing. Chlorates, dyes, oxidizers, fuels, and other by-products of flares and smokes could be in the area; however, no tests have been made to document contamination even though Boggs Creek flows through the middle of this test range.

2. Range 2167/Pyro Control Test Range

This range is located at map coordinates CC-24. This range is used for quality assurance testing of pyrotechnic devices. Trees in the area are dying; however, the reason in unknown. It is believed to result from the pesticide control program, but no data could be supplied to support this. Lead chromate contamination was also identified on the surface of the ground and was reported to be a result of testing of the Mark 1-3 flare. It was reported that more than 100 of these flares have been tested to date.

3. Rocket Range

This range is located at map coordinates KKK-18. It was reported that 7.2 Rockets were tested at this range during the early to mid 1960's. These rockets were reportedly dummy loaded and little hazard

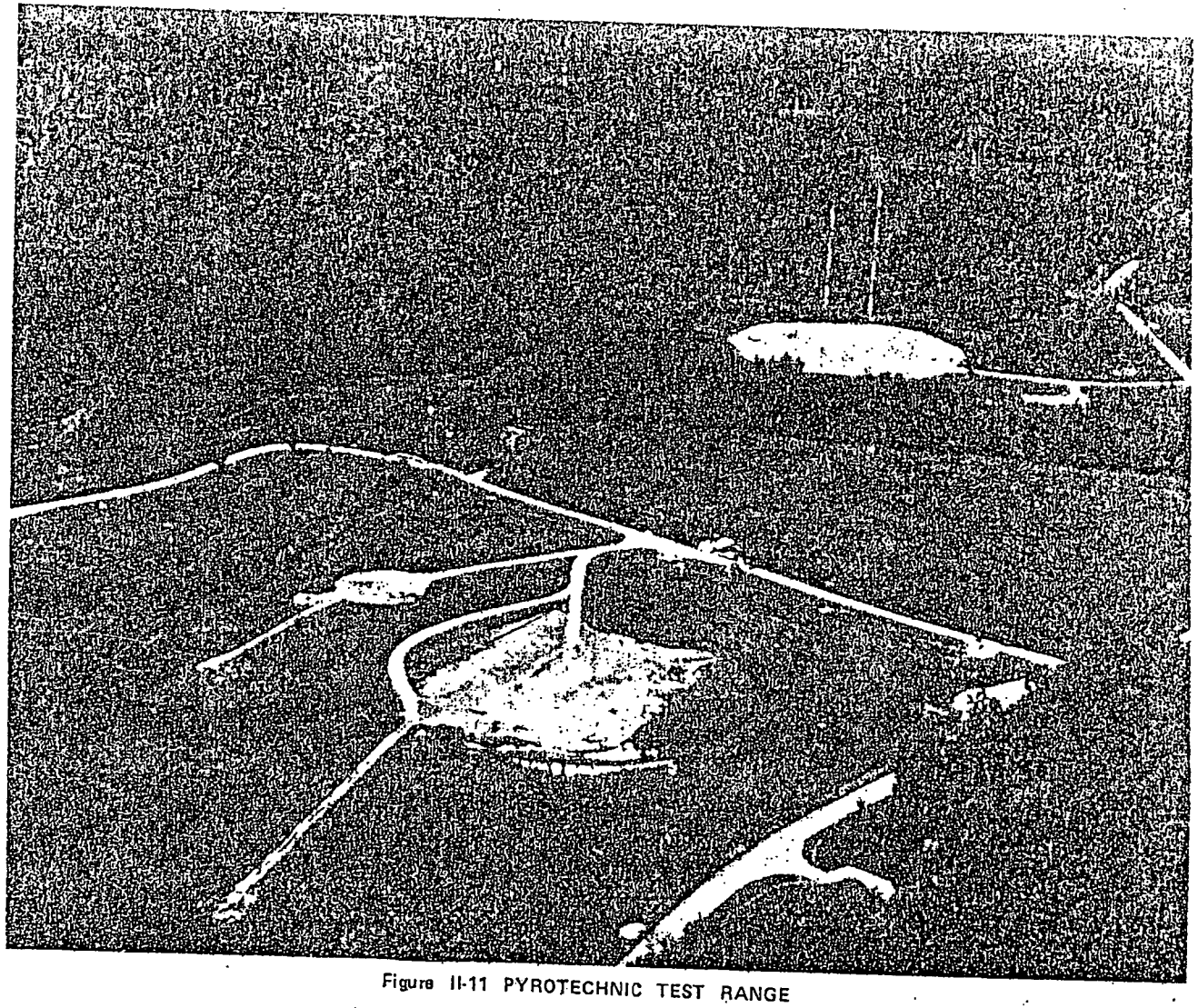


Figure II-11 PYROTECHNIC TEST RANGE

would be associated with them. Very little documentation of this test range was in the records; however, it was reported that a few rounds had been found as a result of excavations at the range. This range has not been heavily used in recent years and contamination is considered to be minimal.

4. Conservation Dam (Facility No. 2845)

This test area is located at map coordinates ZZ-18 near the intersection of Highways 161 and 30. This conservation pond was reportedly used in the past for testing floating type pyrotechnics. No documentation could be found to support this; and as nearly as could be determined, only limited testing was performed. Little contaminaiton could be expected from past operations.

5. Old Pyrotechnic Test Area

This area is located at map coordinates S-26. Until about 6 years ago, this area was heavily used to function test flares, firing devices, and smoke markers. Contamination would be similar to that at the Pyrotechnic Test Ranges. No testing has been conducted at this site for approximately 6 years; however, there is a potential for pyrotechnic by-products remaining in the area. Most likely, contaminants are chlorate dyes, oxidizers, and fuels from the functioning of flares and smoke devices.

6. Lake Greenwood

This is an 800-acre lake located in the northwestern portion of the center. As many as four sites were reported as test sites for floating type makers and flares in the past (see Figure II-7). It was reported by interviews that the MK-25 and MK-72 were tested in this area during the 1950 through 1960 time frame. Also, it was reported that mine location markers were tested on the lake up to the 1968 through 1969 time frame. Little or no contamination is suspected as a result of these tests.

7. Lake Oberlin

This lake is located at map coordinates L-10. It was reported that this lake was used in the mid-to-late 1950's for testing submarine floatation flares. No documentation could be found to confirm this report; however, little contamination would be expected as a result of these tests.

8. Rifle Range and Old Ordnance Ground

This range is located at map coordinates GG-24. Little documentation could be found on testing at this area; however, interviewees

did state that the area had been utilized for bomb cook-off testing. It was reported that black powder had been destroyed in this area over the past 6 to 8 months. In addition, it was reported that a nearby area on the jeep trail was used as a demolition area prior to 1946. contaminants in these areas would be from explosive residues and their by-products. Turkey Creek flows nearby this area; however, no evidence of contamination from this area could be documented, therefore the extent of contamination cannot be determined.

D. Burial Sites of Hazardous Materials

A review of available records and interviews with present and former employees indicate that biological materials have never been buried on NWSC. The records do, however, indicate the burial of chemical, radiological, and explosive materials in the past.

1. Burial Sites of Chemical and Radiological Materials

a. Chemical Burial Ground. The location of the chemical burial ground is at map coordinates FFF-29. Details of the burial plot are in P.W. Sketch 238 dated 2-24-72 (see Figure II-12). It was reported that several hundred pounds of mustard agent and several pounds of pyrotechnic mixtures containing radioactive thorium were disposed of at this burial ground in the mid-1950's.

The radioactive thorium was excavated and removed in May 1974 and the surrounding soil has been certified free of radioactive contamination. The records indicate that the material was disposed of by the AEC at a licensed disposal point. During the excavation, one mustard site was excavated and three rounds containing mustard agent were found; one round was complete while the other two has apparently been emptied and the containers and other material thrown into the hole. The Army Technical Escort Team at Edgewood Arsenal was called in and the rounds were sealed and stored. The records indicate that at least five additional sites are located within the confines of the burial ground (Figure II-12); these sites are suspected of containing unknown amounts of mustard agent. As nearly as could be determined from the records and in interviews with present and former employees involved with the burial, the burial operations were also handled by Technical Escort personnel from Edgewood Arsenal. Rounds were taken to Building 600 where the good rounds were loaded and shipped to Ogden, Utah and the leaking containers were taken to the burial ground, emptied into holes 12 feet deep and covered with a heavy lime slurry. The containers were then thrown into the holes and covered with soil. Since one round was in complete state when found during the excavation in 1974, the possibility exists that other complete rounds could be in the remaining burial sites.

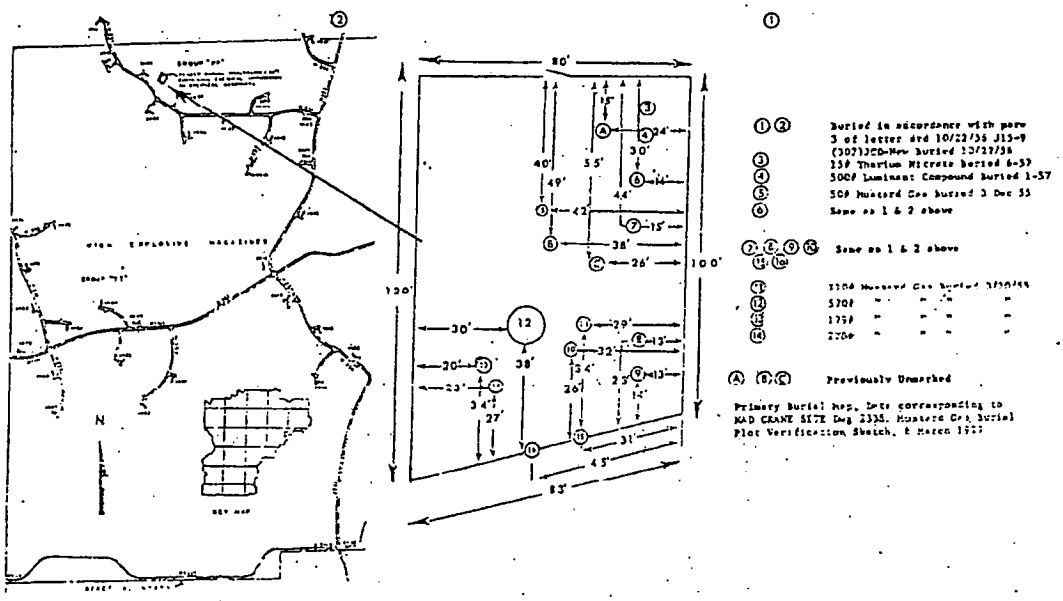


Figure II-12 MUSTARD GAS BURIAL PLOT

No records could be found on any water analysis in this area, either on surface or subsurface. However, because of the manner in which the agent was buried, there is a good possibility that mustard agents or their by-products could be getting into the surrounding waters via surface or subsurface.

b. Burial of Pyrotechnic Dyes. This burial site is located in the Ordnance Burning Area at map coordinates AA-47. This site was reportedly used from the 1940's until 1969 for the disposal of scrap material. This material was dumped into open trenches. During interviews with several employees, there were verbal reports of dyes overflowing from the pits during periods of rain. Some of these dyes are considered carcinogenic but no data could be found to support any contamination as a result of this operation. The pits were filled with soil in 1972; however, colored material seeps from this area at times of heavy rains. There is the possibility of contamination by these dye materials, but since no data is available, the extent of contamination cannot be determined without further tests.

2. Burial Sites of Explosive Material

a. McComish Gorge. This gorge was reportedly used for disposal of construction and odd type materials. Documentation of what was dumped into the gorge could not be found; however, during an interview, one past employee reported that "all-kinds of material including possible live rounds" were dumped into the gorge. The material identified by the past employee included tree stumps, concrete-filled practice 7.2 projectile warheads, and other material not acceptable for landfill or ordnance burning and demolition areas. Contamination from this gorge is not considered to be serious; however, due to the lack of knowledge of exactly what was dumped into the gorge, the gorge should be considered as a possible hazardous area.

b. Ordnance Demolition Area. This area is located at map coordinates GG-21. Although there is little old documentation on quantities and types of munitions detonated, this facility has been used extensively for many years and is presently active approximately 4 months out of the year. During the active period, approximately 20 shots per day are fired and the limit per detonation is 500 pounds. Unexploded ordnance (UXO) was reportedly found within the range area. Also, it was reported that sometime during the 1950's, insulation contaminated with Explosive D was buried in the demolition area. No documentation on just where it was buried could be found. In addition, FS smoke mixture was reportedly disposed of by being included with the explosives. The major contamination in this area would probably be from UXO's. Water samples from Pond 333 which is located nearby and receives the area's surface runoff has shown contamination from explosives. Figures II-13 and II-14 are views of the demolition area.

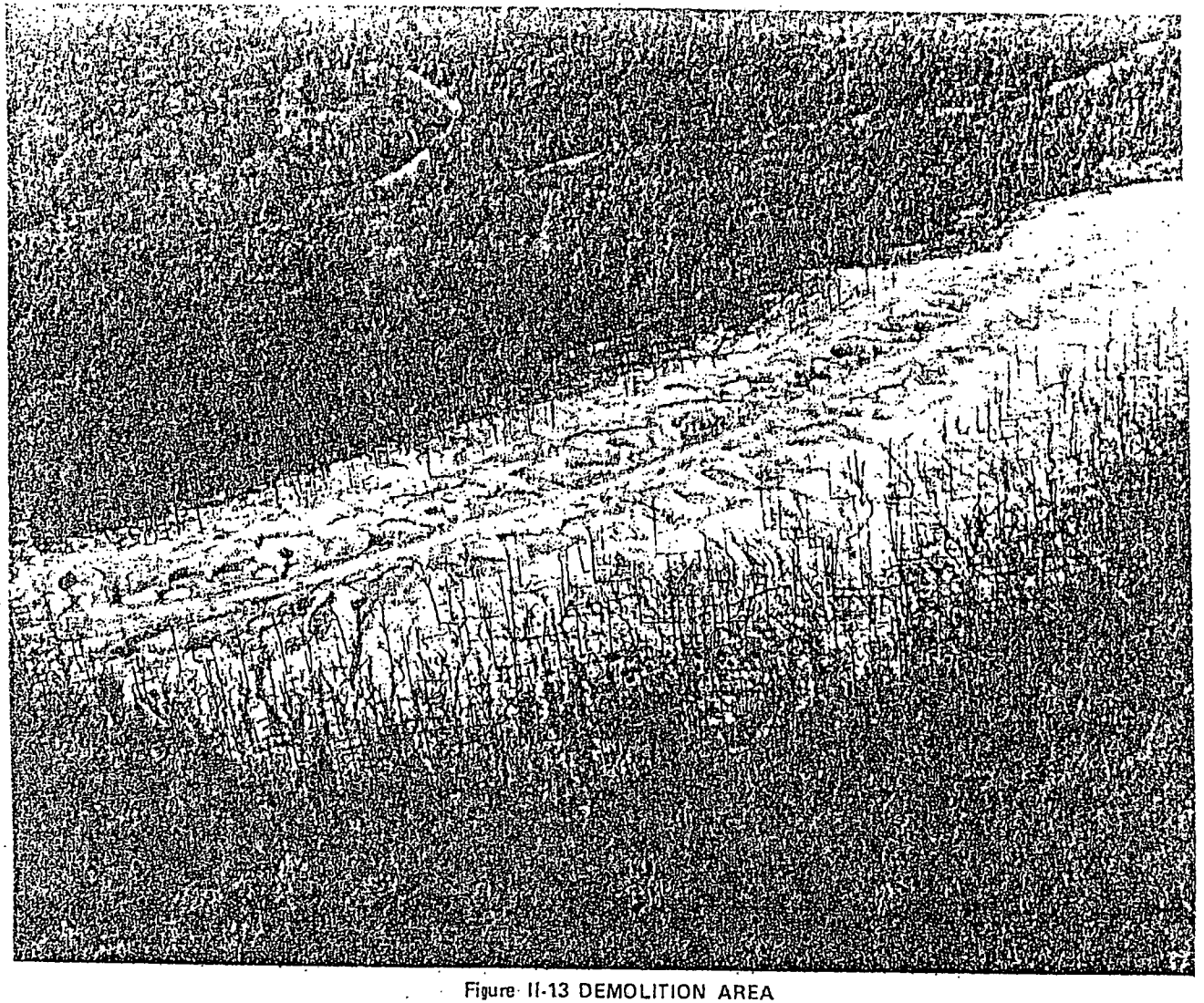


Figure II-13 DEMOLITION AREA

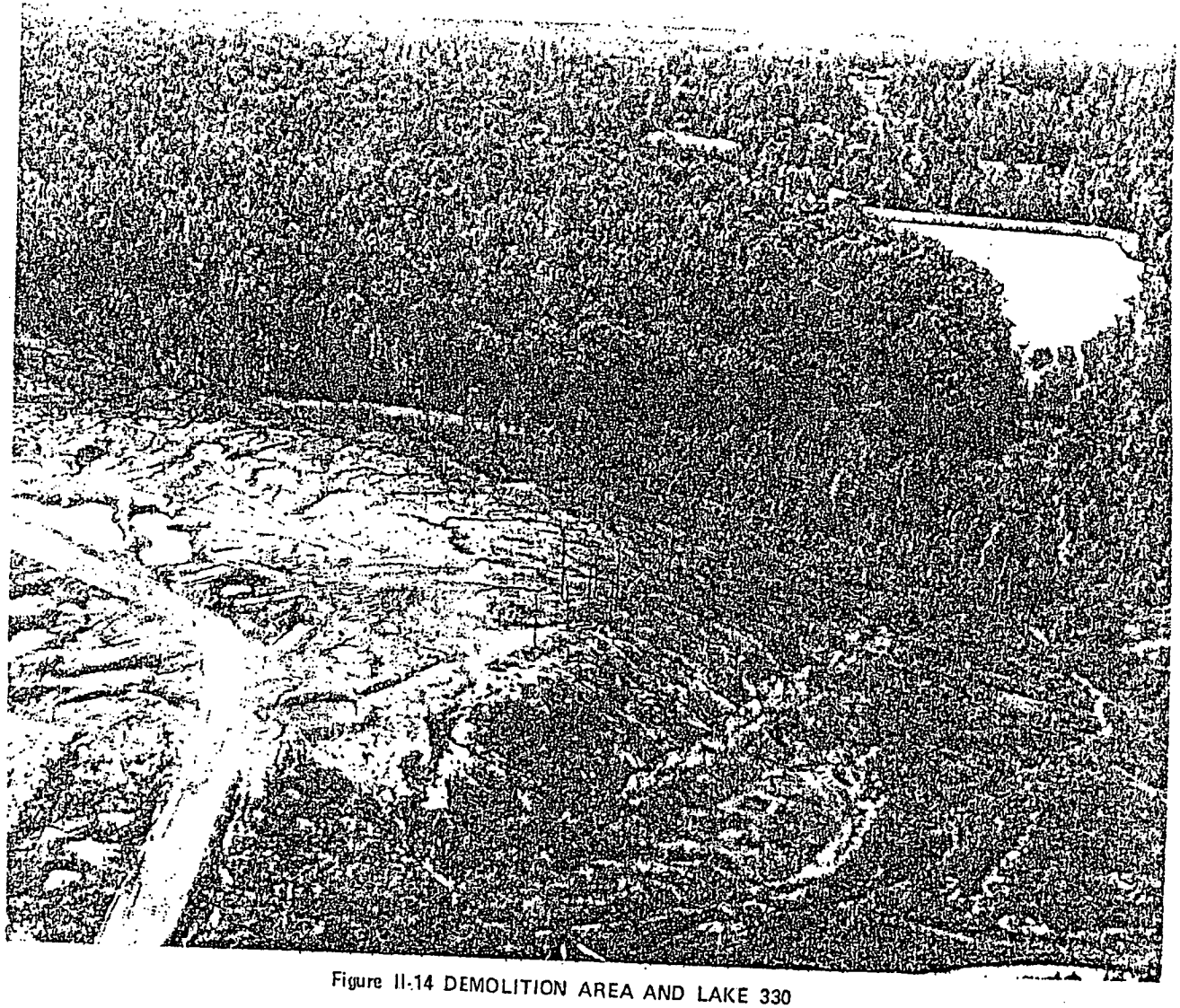


Figure II-14 DEMOLITION AREA AND LAKE 330

E. Storage of Toxic/Hazardous Material

Large quantities of explosives, explosive loaded ordnance items, red phosphorous, pyrotechnic, and riot control agents are stored in more than 2300 storage magazines at NWSC. A listing of these materials is available on computer printout. There is little probability of major contamination from this storage operation. There are no toxic chemical munitions stored at NWSC, however, there are 2808 obsolete War Gas Identification Sets on record being stored in several magazines.

F. Support Activities

1. Water Supply

Sufficient water is provided by Lake Greenwood for all phases of operations and activities of the NWSC. Although surface runoff from industrial areas and storage areas empties into the lake, this runoff is not believed to be transporting contaminants. No groundwater data associated with the lake is available.

2. Waste Disposal

The primary and secondary treatment process of the sanitary sewage adheres to all regulations pertaining to effluent treatment prior to discharging it into Boggs Creek. Previously, three small sanitary sewage plants were in the system but these plants are presently being used primarily as aeration basins and lift stations associated with the main plant near Boggs Creek.

Drainage from industrial operations is carried to the treatment plant or is discharged into open ditches. Red colored water leaving the eastern perimeter of the Rockeye Plant is discharged into a tributary of Sulphur Creek which eventually leaves the installation.

G. Land Use Factors

1. Pesticide/Herbicide Usage

A wide variety of pesticides and herbicides is used at the installation to control pests. Table II-1 shows usage of pesticides and herbicides for the period 1 August 1976 through 31 August 1977.

TABLE II-1. Pesticide and Herbicide Usage
(1 August 1976 Through 31 August 1977)

TRADE NAME	FORM	AMOUNT USED
Carbaryl	Suspension	5320 gallons
Malathion	Emulsion	2 gallons
Chlordane	Emulsion	139 gallons
Pentaur	Solution	208 gallons
Bendomyl	Suspension	247 gallons
Dyrene	Suspension	82 gallons
Methyl Bromide	Liquid	72 pounds
Promethone/2,4,5-T	Emulsion	7815 gallons
Bromacil/Dinron/2,4,5-T	Suspension	6440 gallons
MBC	Powder	2992 pounds
Bnomyls	Suspension	100 gallons
Baygon	Emulsion	60 gallons
Diazinon	Emulsion	17 gallons
Dursban	Emulsion	25 gallons
Pyrethrum	Aerosol	58 pounds
Pyrethrum	Solution	25 gallons

2. Sanitary Landfills

Prior to 1971, two landfill areas in the northwest sector were used for solid waste disposal. One was for lumber, old trees, and rubble from construction operations. The other was the depository for daily refuse which was burned. Both locations are inactive and are covered with soil.

Operation of the present landfill began in 1971, utilizing the trench method. As a trench is filled with refuse, it is compacted and then covered with impervious soil and seeded. Certain areas have been designated as "hot beds" which contain toxic or contaminated waste. As waste is placed in these trenches, a neutralizing agent is added before the placement of the soil cover. The quantity of contaminated waste placed in this area has been very small.

Surface seepage has been detected from the landfill area. A drainage system (similar to a storm drainage system, with manholes) has been completed to collect this seepage in a basin where the leachate can be analyzed. Monitoring wells have been placed around the perimeter of the landfill to monitor the subsurface in respect to leachate migration.

H. Geological Migration Potential

Present day technology and restraints placed on manufacturing processes utilizing contaminated agents have reduced the possiblity of contamination leaving a military installation either by surface or subsurface means. Prior to these practices, it was likely that some surface migration of contaminants reached the boundary and even migrated beyond the boundary. The most susceptible area for contaminant migration was east of the Rockeye Plant where the red water was allowed to be discharged into natural drainageways. The amount of residue that has settled out in pockets and slack water areas of the drainageways has not been determined nor has it been determined what effect flushing action by intense rainfall would have in moving the residue further downstream or even off the installation.

From the available subsurface soil data, the NWSC is underlain by a silty to sandy clay that ranges in thickness from a few inches to 26 feet. Because the soil thickness is determined by the topography, the valley bottoms of the larger creeks could contain clays in excess of the 26-foot depth. No permeability for inogganic silts and mixtures of sand, silt, and clay ranges from 10^{-3} to 10^{-7} cm/sec. These values represent movement rates of 3 to 0.0003 feet per day, respectively. The lower range of 10^{-3} cm/sec is for a homogenous sand and silt that is found in the subsurface. The controlling factor in respect to fluid movement is the presence of clay zones that would retard the movement considerably.

I. Environmental Indicators

1. Land Indicators

Plants along the streams near the Bomb and Mine Filling Area do not seem adversely affected by TNT spillage, but in the immediate vicinity

of the plant, the ground vegetation is strongly affected and is either depauperate or missing (with patches of bare ground). The TNT spillage seems to be deep; perhaps 1 to 3 feet of the top soil is apparently heavily contaminated.

2. Waterways Indicators

Small streams in the immediate vicinity of the Bomb and Mine Filling Area A are apparently contaminated to a great degree by the explosive waste spillage. The streams and ditches show a pink color and although the larger aquatic flowering plant vegetation does not seem affected by the explosive wastes, the animal life (e.g., insects, snails, amphibians, fish) is not present, indicating very heavy pollution.

III. FINDINGS

A. Crane Army Ammunition Activity (CAAA) License

A license, NF(R)-36943, was granted by NWSC to the Army, effective 1 October 1977 which authorizes the use by CAAA of a significant portion of the facilities at NWSC, Crane. The license was required for the establishment of the CAAA as Single Manager of conventional ammunition with assigned responsibilites as set forth in DOD Directive 5160.65 of 26 November 1975. Facilities are to be utilized for the accomplishment of Army functions required in the procurement, production, storage, supply, demilitarization and maintenance/renovation of conventional ammunition. A copy of the subject license is included as Appendix F of this report.

B. Industrial and Production Operations

1. Production areas of the installation potentially contaminated with waste from explosive and pyrotechnic operations include the 3-inch (Rockeye) and 40mm explosive loading complexes, the booster area, mine filling areas A and B, and the old 16-inch loading and demilitarization facility, see Chapter IIA of report. Contaminants identified include TNT, RDX, tetryl, lead styphnate, Composition A and B, Explosive D, HMX, aluminum, alkaline nitrates, lead chromate, and other explosive/pyrotechnic waste products.

2. Potentially contaminated wastewaters from manufacturing and demilitarization operations are dumped initially into sumps with the overflow going directly into open ditches. Prior to the recent installation of efficient dust collectors, considerable quantities of explosive powders were vented directly into the atmosphere. The soil in the vicinity of these sites is heavily contaminated and vegetation in the area of the plant is either missing or in a state of stress (i.e., dying, stunted, discolored).

C. Testing and Firing Ranges

1. Extensive testing of explosive and pyrotechnic munitions has been conducted and is being conducted at several locations on the installation. The principal ranges include three pyrotechnic ranges, a rocket range, a rifle range, an explosive demolition area, a small arms testing area, and an ordnance burning area. Types of munitions tested include small arms, 40mm grenades, pyrotechnic flares and smoke signaling devices, mortar, bomb and projectile ammunition, and experimental devices.

2. Unexploded ordnance (UXO) were reported at several of the ranges and the demolition pits. UXO munitions include small pyrotechnic devices, aerial dispensed devices, mortar rounds, and other naval artillery shells. At the demolition area, explosive munitions are scattered as a result of demilitarization operations. During the Team's ground tour, UXO with parachutes were observed hanging from trees.

3. Lake Greenwood, which is the source of drinking and production water at NWSC, was used from the early 1940's to the late 1960's for the testing of floating pyrotechnic devices including signaling smokes and flares. Four locations were identified at Lake Greenwood where testing was conducted.

D. Disposal Operations

1. Two landfills are presently active at the installation; they are the sanitary landfill and the McComish Gorge landfill. The sanitary landfill began operations in 1971, replacing the old open burning pit as a means of disposing of daily refuse. This landfill has a leaching problem and the installation is attempting to rectify the problem by constructing a pond to hold the leachate. The McComish Gorge landfill is utilized for timbers and other large items not suitable for the main sanitary landfill. Personnel interviewed by the Team indicated that a potential exists for both landfills to be contaminated by waste materials.

2. Contaminated waste from installation activities is disposed of by burial or burning at various locations on the installation. Disposal areas include a chemical agent burial ground (1947), an ordnance burning area used since 1965, an old pyrotechnic burning pit used from the early 1940's to 1970, and a pit where approximately 50,000 pounds of smoke dyes were buried in 1969. Some of these dyes (auramine hydrochloride, yellow dye) are reported to be carcinogenic in the lastest Register of Toxic Chemical Substance published by National Institute for Occupational Safety and Health.

3. The chemical agent burial ground is located in the southeast quarter of the NWSC. Several hundred pounds of mustard agent and several pounds of radioactive thorium were buried here in 1947. One of the mustard pits was excavated in 1974 and several bombs were found to contain live mustard agent. The bombs were sealed by an Army Technical Escort Team and stored. Total number of pits is not known and a project is being conducted by the installation to determine if migration of mustard agent is occurring. The thorium was removed from the site in 1974 and shipped to an AEC (DOE) site for storage. The site was then surveyed and certified free of radioactive contamination by the Material and Safety Department of NWSC, Crane.

E. Storage Operations

1. There are approximately 2300 storage magazines at NWSC. Materials stored within these structures include explosive and pyrotechnic powders, explosive and pyrotechnic munitions ranging from small arms to large bombs and naval projectiles, anti-riot munitions, initiators, fuzes, munition components, and subassemblies.

2. Approximately 2808 chemical agent identification kits, which contain small quantities of various chemical agents in ampules, are stored in magazines. These kits are scheduled to be moved to another site for demilitarization.

F. Biological Agent Operations

Biological Warfare agents and weapons were never developed, manufactured, tested or stored at the installation.

G. Radiological Operations

Radiological materials and weapons were developed, manufactured, or tested on the installation. The installation is licensed to use small quantities of radiological materials for biological tracers (carbon 14), lead detection (krypton 85), radiography (cobalt 60), iridium 192, and nickel 63. Weapons equipped with Promethium-147 sights are stored at NWSC.

H. Water and Water Quality

1. The installation is drained by several surface water drainageways. The central portion of the installation is drained by Boggs and Turkey Creeks; the eastern portion by Sulphur Creek; and the northern and western portions by Furst and Culpepper Creeks.

2. A water quality monitoring program is conducted by the installation at six locations within the Boggs, Turkey, Furst, and Culpepper Creek drainage areas. However, no water quality monitoring is conducted on the waterways that exit the installation's eastern boundary. The six monitor locations are in the northern and central areas of the installation. No monitoring is done on Boggs Creek in the southern portion of the installation; neither are the waters impounded by Boggs Dam monitored. At the time of Team's visit (September 1977), available water quality data for the six monitoring locations indicated that the installation is having difficulty complying with EPA discharge permits. (See Chapter IEla of report).

3. Lake Greenwood is monitored intermittently by the installation. The water quality data provided by the installation, and collected in 1970, indicate that the lake water was potable. No current analysis was available to the team for explosive manufacturing wastes such as TNT and RDX. Due to the lake's location in the northern section of the installation, only limited amounts of wastewaters from the manufacturing areas reach the lake via drainageways and creeks. The State Health Department conducts a water quality program that includes Lake Greenwood; however, analyses are not conducted for potential pyrotechnic and explosive contaminants.

4. Big Sulphur Creek, which drains the Rockeye manufacturing area, exits the installation to the east and receives wastewaters that are heavily contaminated by explosive manufacturing wastes including red water (TNT). The Records Search Team, during its ground tour, tracked the wastewaters for over a mile and the red color was visually detectable over the whole distance. Little Sulphur Creek drains the ordnance burning area where an estimated 25 tons of pyrotechnic dyes are buried. No water monitoring is conducted in this area.

5. Data on subsurface waters (groundwater) is limited. The installation has data from five wells which indicate groundwater depths of between 141 to 313 feet. Only limited water quality data are available on four of these wells and consist of a 1970 report that addresses alkalinity, pH, and hardness. General regional dip of the bedrock is approximately 20 feet per mile to the west-southwest.

IV. CONCLUSIONS

A. Past Explosive Operations

Several areas of the installation (including the explosive and pyrotechnic areas, burial and burning sites, landfills, and test ranges) are suspected of being contaminated with toxic and hazardous materials. No firm conclusions can be drawn regarding migration of contaminants from past manufacturing, demilitarization, and disposal operations because of limited surface and subsurface water data.

B. Current Manufacturing Operations

A potential exists for contamination from current manufacturing operations to exit the installation via unmonitored surface and subsurface waters. Of particular concern is explosive waste (Red Water) from the Rockeye operation which is dumped into Sulphur Creek. This creek is one of several creeks in the eastern and southern areas of the installation not monitored under the installation's water quality program. In addition, NWSC is exceeding discharge limits imposed by NPDES permits.

C. Lake Greenwood

Since Lake Greenwood is not monitored by the installation for the presence of explosive or pyrotechnic waste materials, a potential exists for the lake to be contaminated by those waste materials.

D. Chemical Agent Burial Ground

An unknown quantity of mustard munitions is still buried at the Chemical Agent Burial Ground. The area is fenced, however, the exact location and number of burial pits is not known. Based on location of the burial ground, contaminant migration beyond installation boundaries is considered remote.

E. Burial of Pyrotechnic Dyes

An estimated 50,000 pounds of pyrotechnic smoke is buried at the Ordnance Burning Ground. During periods of heavy rain, colored materials seep from the filled pits. Since the dyes remain buried a potential exists for them to migrate via surface and subsurface waters.

F. Water Monitoring Program

The installation's present water monitoring program does not include analysis for explosive waste materials nor does it monitor all streams exiting the installation.

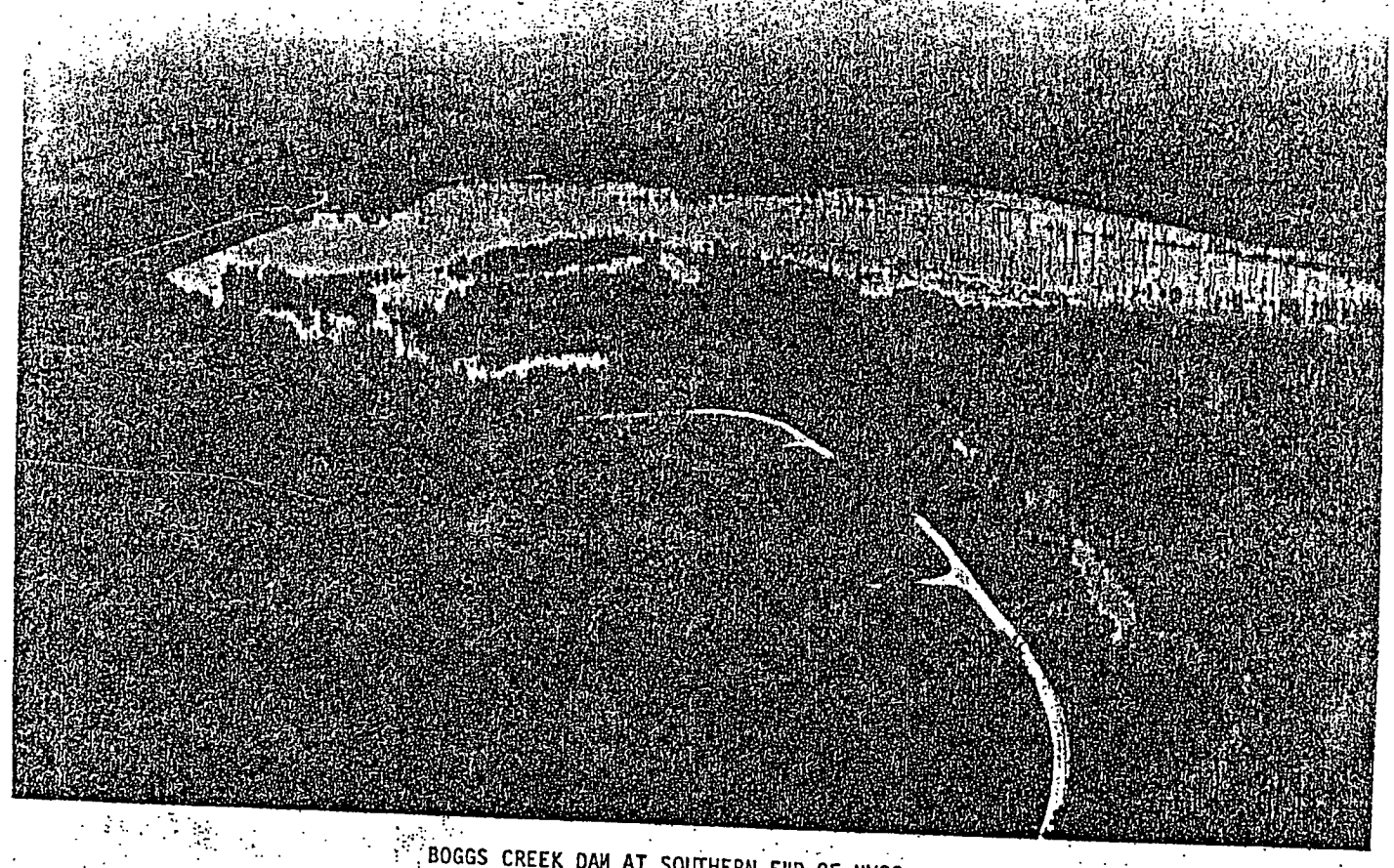
APPENDIX A

PHOTOGRAPHS

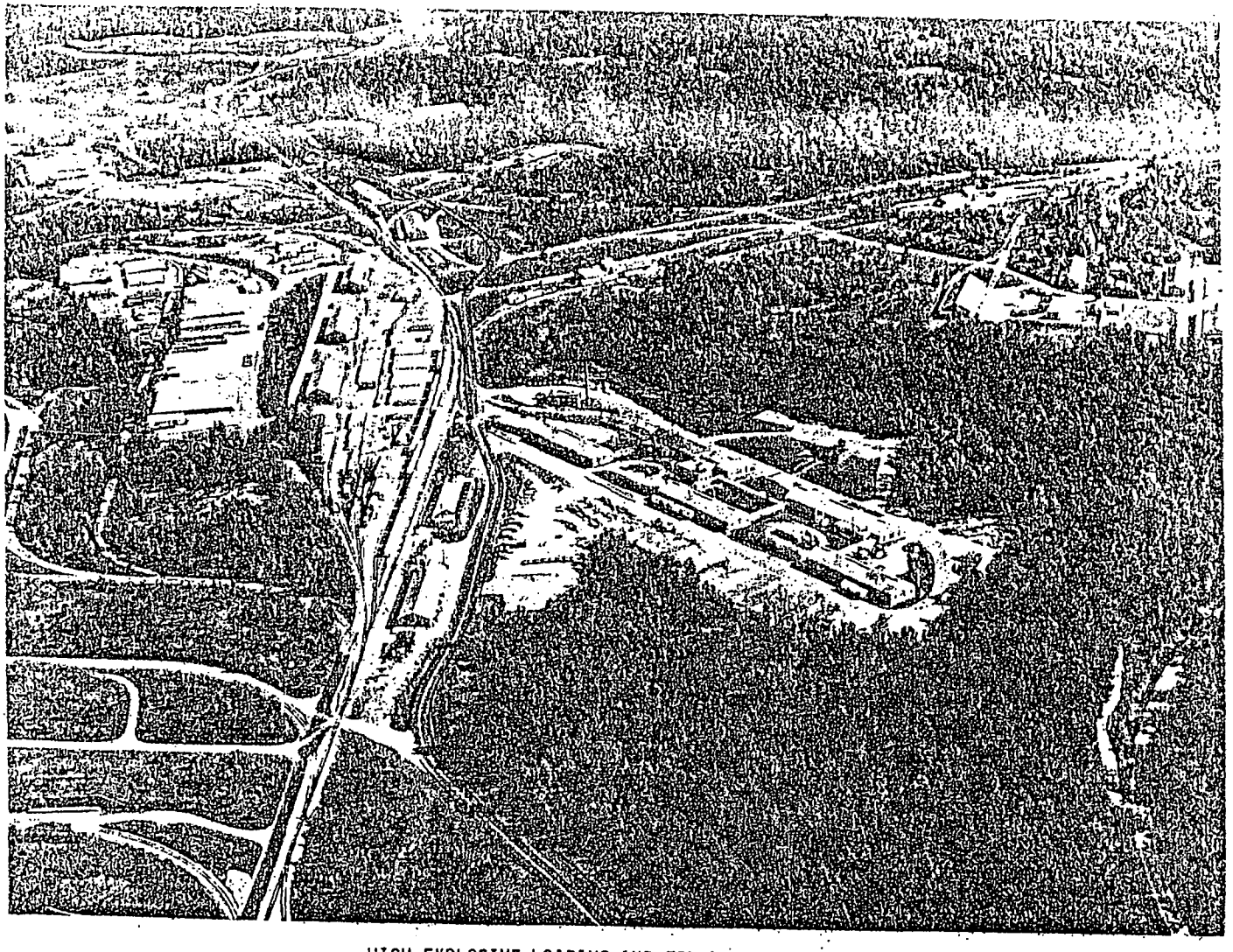
OF

NAVAL WEAPONS SUPPORT CENTER

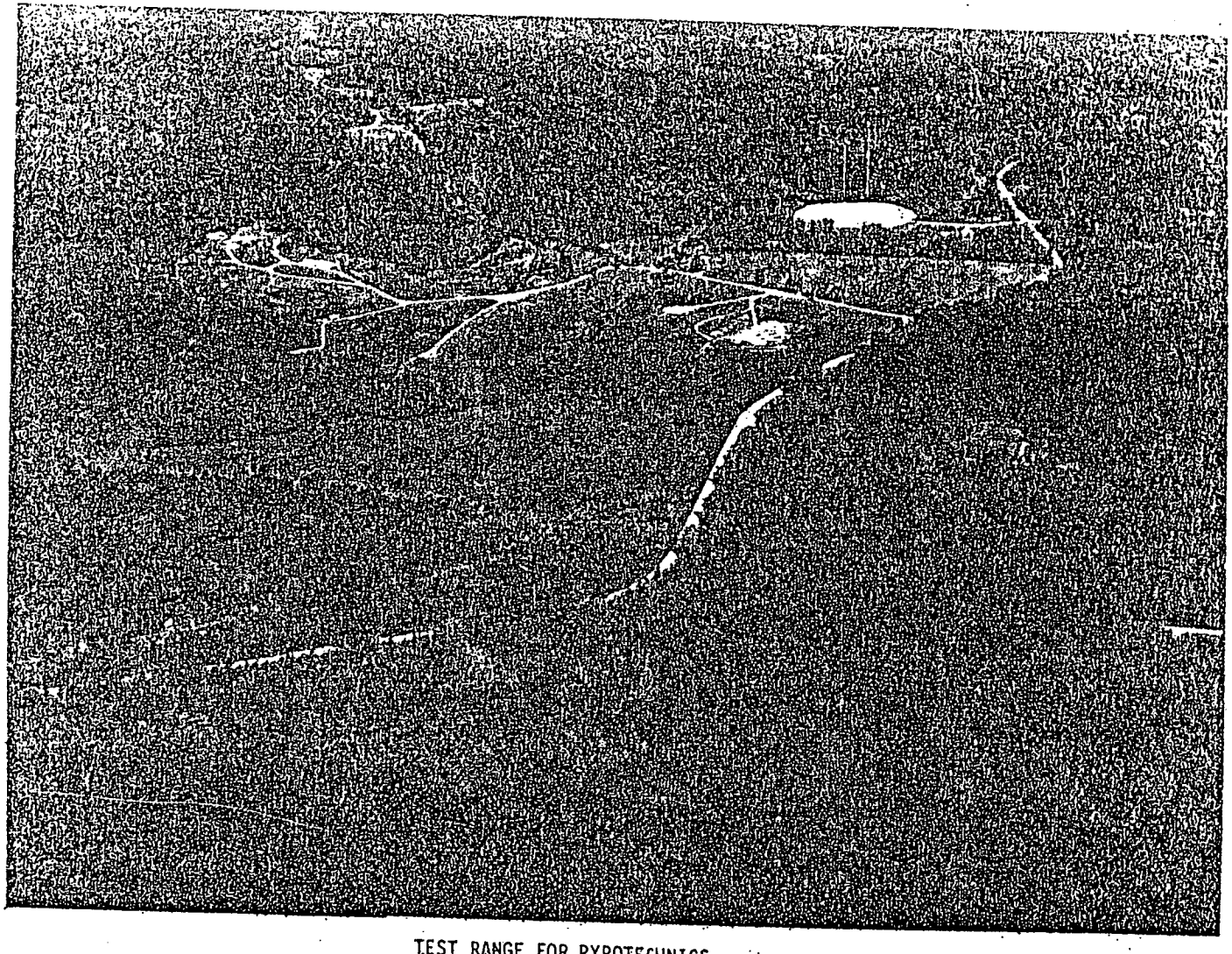
CRANE, INDIANA



BOGGS CREEK DAM AT SOUTHERN END OF NWSC



HIGH EXPLOSIVE LOADING AND FILLING AREA



TEST RANGE FOR PYROTECHNICS

APPENDIX G

OPERATIONS

WEAPONS SUPPO

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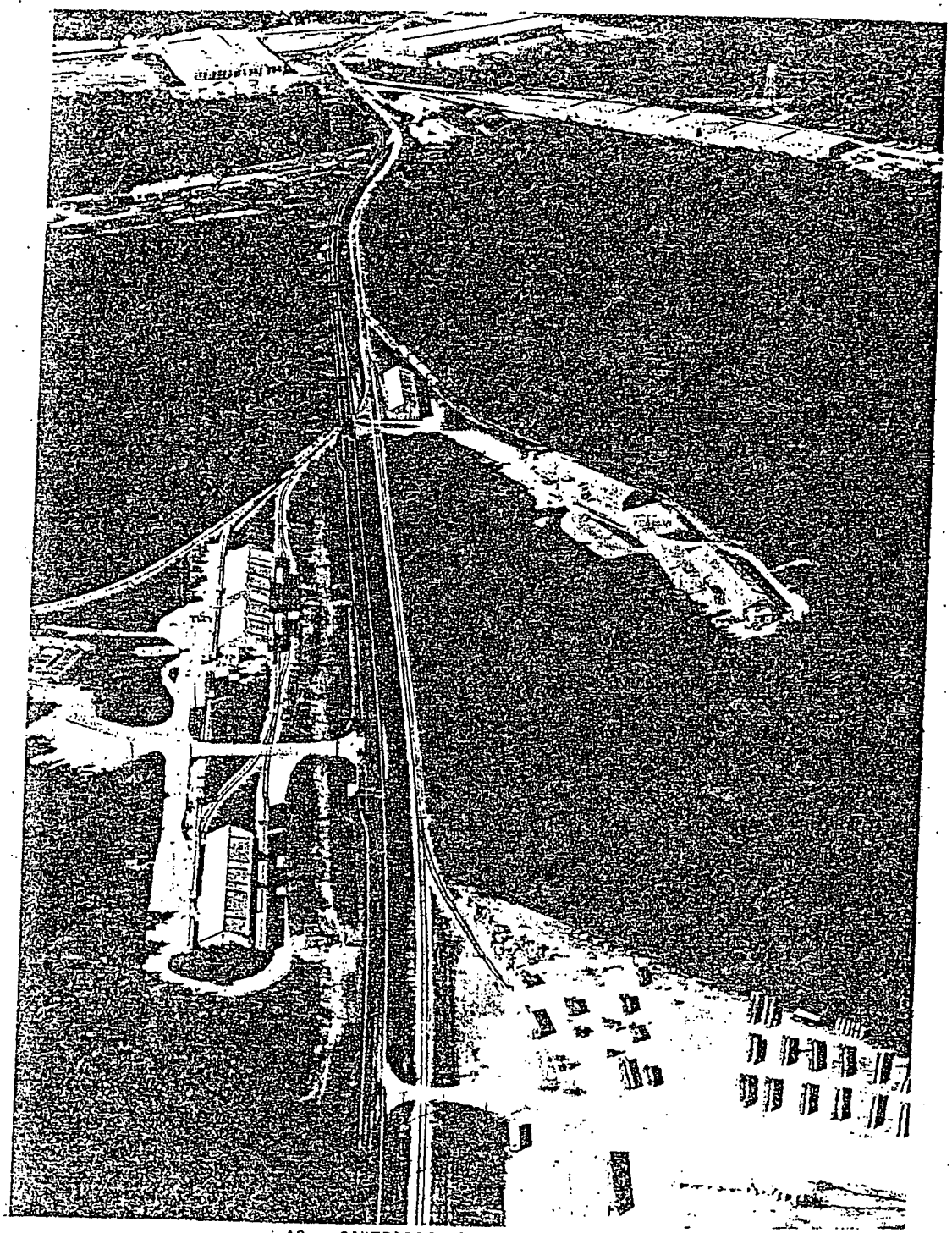
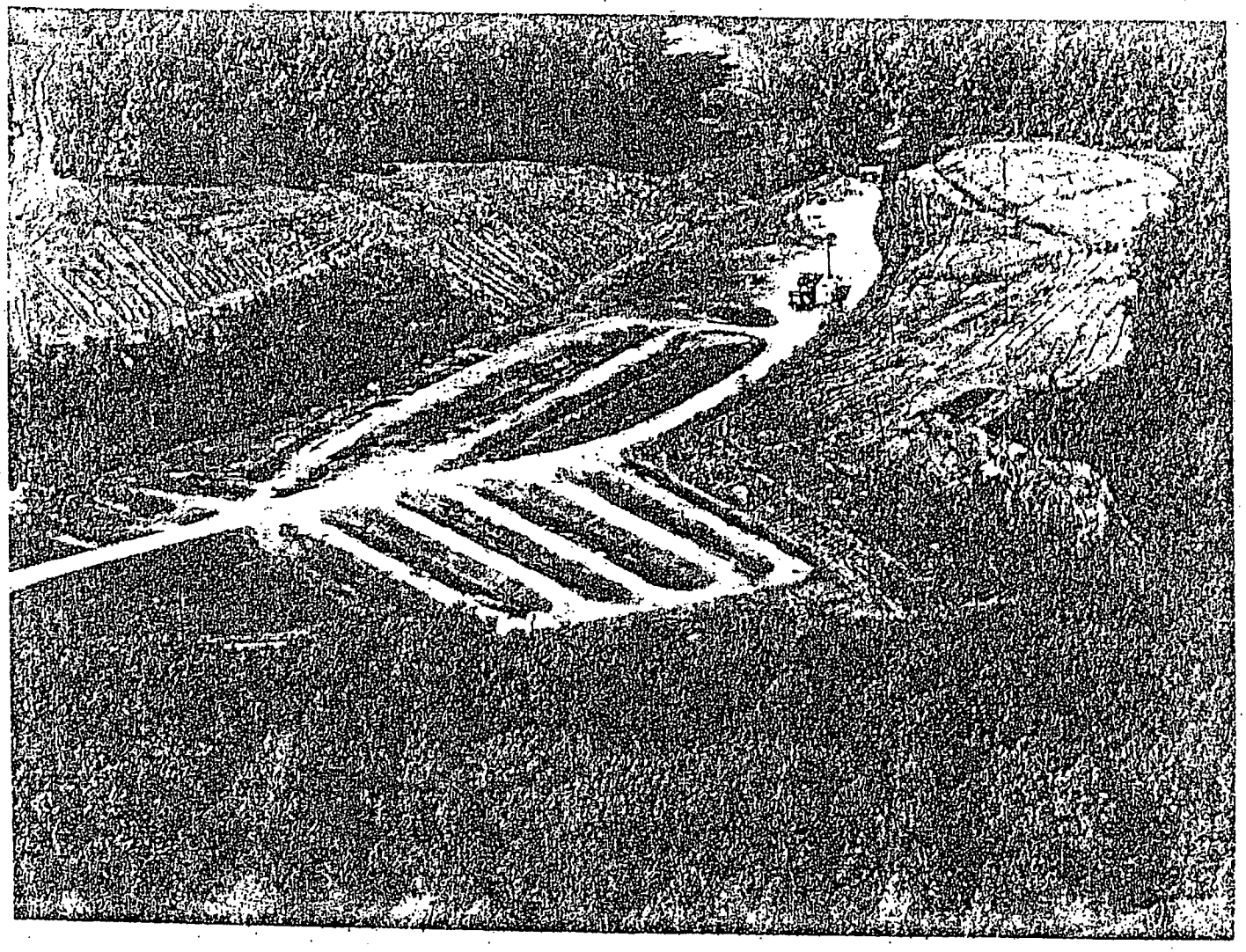
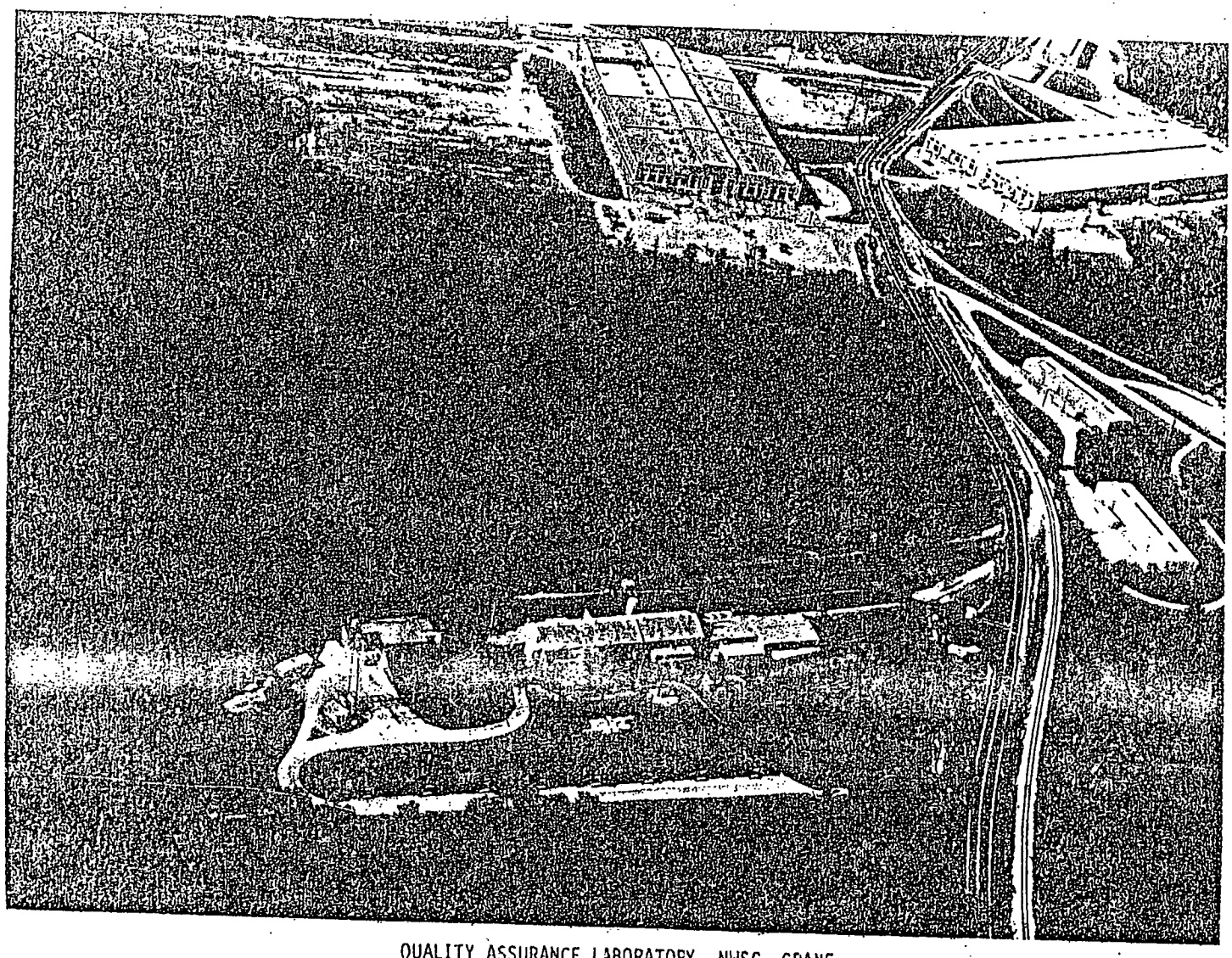


40mm CARTRIDGE LOADING AREA



BURNING GROUND AT NAVAL WEAPONS SUPPORT CENTER, CRANE



QUALITY ASSURANCE LABORATORY, NWSC, CRANE

APPENDIX B

BIOTA

OF

NAVAL WEAPONS SUPPORT CENTER

CRANE, INDIANA

PARTIAL LIST OF TREES AT NWSC

Black Ash
White Ash
Large-toothed Aspen
Baldcyrpess
Basswood
Deech
River Birch
Blackgum
Boxelder
Ohio Buckeye
Butternut
Balck Cherry
Balck Maple
Red Maple
Sugar Maple
Yellow Poplar
Black Oak
Chestnut Oak
Chinquapin Oak
Pin Oak
Red Oak
Scarlet Oak
Shingle Oak
Cottonwood

American Elm
Red Elm
Hackberry
Bitternut Hickory
Monhernut Hickory
Pignut Hickory
Shagbank Hickory
Shellbark Hickory
Honeylocust
Black Locust
White Oak
Austrian Pine
Jack Pine
Pitch Pine
Scotch Pine
Shortleaf Pine
Virginia Pine
White Pine
Yellow Poplar
Sweetgum
Black Walnut

Amphibians and Reptiles of US Naval Weapons
Support Center Crane, Indiana

Species known to occur, i.e. seen or heard

SALAMANDERS

Eastern Newt	Notophthalmus viridescens
Redbacked	Plethodon cinereus
Two-lined	Eurycea bislineata

FROGS AND TOADS

Fowlers toad	Bufo woodhousei fowleri
Chorus frog	Psuedacris triseriata
Cricket frog	Acris crepitans
Spring peeper	Hyla crucifer
Grey treefrog	Hyla versicolor
Leopard frog (southern)	Rana pipiens sphenocephola
Bullfrog	Rana catesbliana
Green frog	Rana clamitans

TURTLES

Spring softshell	Trionyx s. spinifer
Snapping turtle	Chelydra serpentina
Box turtle (eastern)	Terrapene carolina
Painted turtle	Chrepemys picta

LIZARDS

Five lined shink	Eumeces fasciatus
Fence lizard	Sceloporus undulatus
Ground shink	Scincella laterale

SNAKES

Garter snake (eastern)	Thamnophis sirtalis
Banded watersnake	Natrix sipedon
Dekays snake	Storeria dekayi
Black racer	Coluber constrictor priapus
Black rat snake	Elaphe obsoleta
Milk snake (eastern)	Lampropeltis doliata triangulum
Rough green snake	Opheodrys aestivus
Hognose (eastern)	Heterodon platyrhinos
Copperhead	Aghistrodon contortrix

Species believed to occur

SALAMANDERS	
Waterdog	Necturus maculosus
Tiger	Ambystoma tigrinum
Spotted	Ambystoma maculatum
Marbled	Ambystoma opacum
Jefferson's	Ambystoma jeffersonianum
Bluespotted	Ambystoma laterale
Small-mouthed	Ambystoma texanum
Slimy	Plethodon glutinosus
Zigzag	Plethodon dorsalis
Cave*	Eurycea lucifuga
FROGS AND TOADS	
American toad	Bufo americanus
TURTLES	
Musk turtle	Sternotherus odoratus
Redeared	Pseudymys scripta elegans
Map	Graptemys geographica
LIZARDS	
Broad-headed shink	Eumeces laticeps
SNAKES	
Ribbon snake	Thamnophis sauritus
Kirtlands	Natrix kirtlandi
Red-bellied	Storeria occipitomaculata
Earth	Virginia valeriae
Black kingsnake	Lampropeltis getulus niger
Ring-neck	Diadophis punctatus edwardsi
Worm	Carphophis amoena
Crowned	Tantilla coronata
Timber rattlesnake*	Crotalus h. horridus

* indicates unconfirmed report

APPENDIX C

INDIANA WATER QUALITY STANDARDS

OF

NAVAL WEAPONS SUPPORT CENTER

CRANE, INDIANA

COPY OF DOCUMENT CAN BE OBTAINED FROM:
NAVAL WEAPONS SUPPORT CENTER,
CRANE, INDIANA 47522

APPENDIX D

BORING LOGS

OF

NAVAL WEAPONS SUPPORT CENTER

CRANE, INDIANA

COPY OF DOCUMENT CAN BE OBTAINED FROM:
NAVAL WEAPONS SUPPORT CENTER
CRANE, INDIANA 47522

APPENDIX E

LICENSE NF(R)-36943

TO

CRANE ARMY AMMUNITION ACTIVITY (CAAA)

DEPARTMENT OF THE NAVY
NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
PHILADELPHIA, PENNSYLVANIA 19112

TELEPHONE NO.
Area Code 215
755-4845

Code 2415.1
11011/R9-LIC-IN
CRANE-36943

12 OCT 1977

From: Commanding Officer, Northern Division, Naval Facilities Engineering Command
To: District Engineer, Omaha District, Corps of Engineers, Omaha, NE 68102

Subj: NWSC Crane, IN; License NF(R)-36943 to Crane Army Ammunition Activity (CAAA) covering the use of real property

Encl: (1) Subject license, less/exhibits (fully executed cy)

1. Enclosure (1) has been executed on behalf of the Department of the Navy and is forwarded for your records. The exhibits to enclosure (1) were furnished earlier under separate cover by NWSC Crane.

2. The subject license which became effective for operations on 1 October 1977, authorizes the use by CAAA of a significant portion of the facilities at NWSC Crane. It implements the requirement for the establishment of CAAA as single manager of conventional ammunition with assigned responsibilities as set forth in DOD Directive 5160.65 of 26 November 1975.

3. All future correspondence pertaining to said license should refer to number NF(R)-36943.

Copy to: w/encl
NAVFACENGCOMHQ (CODE 205)
NAVSEASYSCOM (SEA-04J)
ARRCOM (DARSAR-ISF-R) ROCK ISLAND, IL 61201
NWSC (CODE 09CC) CRANE, IN
CAAA CRANE, IN

LICENSE FOR USE OF REAL PROPERTY BY OTHER FEDERAL AGENCIES
NAVFAC Form 11011/30(6-75)

THIS LICENSE TO USE THE U. S. GOVERNMENT PROPERTY HEREIN DESCRIBED IS ISSUED BY THE DEPARTMENT OF THE NAVY TO THE LICENSEE NAMED BELOW FOR THE PURPOSE HEREIN SPECIFIED UPON THE TERMS AND CONDITIONS SET FORTH BELOW AND THE GENERAL PROVISIONS ON THE REVERSE SIDE HEREOF. BY THE EXECUTION HEREOF THE LICENSEE AGREES TO COMPLY WITH ALL SUCH TERMS, CONDITIONS AND GENERAL PROVISIONS.

(Refer to Bulbuds Instructions 11011.18 and any succeeding changes)

LICENSE NUMBER: NF (R)-36-43

1. NAVAL ACTIVITY *(Property Location)*
Naval Weapons Support Center
Crane, Indiana 47522

2. DATES COVERED *(Inclusive)*
FROM 1 October 1977 TO Indefinite

3. DESCRIPTION OF PROPERTY *(Include room and building number when appropriate)*
Licensee shall have exclusive use of the buildings, areas and facilities delineated with legend on NAVFAC Drawings 571668 through 571679, and 718751 through 718762, marked Exhibit "A"; as tabulated and described in the listing of buildings and structures, marked Exhibit "B"; attached hereto and made a part hereof. Logistical and administrative support will be provided in accordance with the specific provisions of the separate support agreement (DD Form 1144).

4. PURPOSE OF LICENSE *(Include specific use, and specific areas and if to be used in incurring partition costs)*
License is required for the establishment of the Crane Army Ammunition Activity as Single Manager of conventional ammunition with assigned responsibilities as set forth in DOD Directive 5160.65 of 26 November 1975, Subj: Single Manager Assignment for Conventional Ammunition. Facilities are to be utilized for the accomplishment of Army functions required in the procurement, production, storage, supply, demilitarization, and maintenance/renovation of conventional ammunition.

5. LICENSOR
DEPARTMENT OF THE NAVY

5a. LOCAL REPRESENTATIVE—DEPT OF NAVY OFFICIAL *(Name and address)*
Commanding Officer
Naval Weapons Support Center
Crane, IN

6. LICENSEE *(Name and address, zip, full agency designation)*
District Engineer,
US Army Engineer District, Omaha
7410 USPO and Courthouse
215 North 17th Street
Omaha, Nebraska 68102

6a. LOCAL REPRESENTATIVE OF LICENSEE *(Name and address)*
Commander
Crane Army Ammunition Activity
Crane, IN

7. GENERAL PROVISIONS *(See Reverse Side)*
(see attached)

8. EXECUTION OF LICENSE

FOR	BY NAME AND TITLE (Typed)	SIGNATURE	DATE
DEPARTMENT OF THE NAVY	PAUL SNYDER Director, Real Estate Division Northern Division, Naval Facilities Engineering Command	Paul Snyder	12 OCT 1977
LICENSEE	KENNETH W. CHELF Chief, Real Estate Division Omaha District, Corps of Engineers	Kenneth W. Chelf	7 OCT 1977

General Provisions on reverse of NAVFAC Form 11011/30(6-75) are hereby deleted and the following is substituted in lieu thereof:

7. GENERAL PROVISIONS:

a. The intent of the general provisions contained herein is to establish policies, procedures, authority and responsibilities for administrative and logistical support; and the operation and/or utilization of all facilities licensed hereunder. Definitions of terms as used in establishing these General Provisions are as follows:

(1) "Licensor" means Commander, Naval Facilities Engineering Command for the Department of the Navy, under the direction of the Chief of Naval Operations and the Chief of Naval Material; or as said authority and responsibility, redelegated as appropriate, to either Northern Division, Naval Facilities Engineering Command or the Commanding Officer, Naval Weapons Support Center, Crane.

(2) "Licensee" means District Engineer, US Army Engineer District, Omaha, 7410 USPO and Courthouse, 215 North 17th Street, Omaha, Nebraska 68102, under the direction of the Chief of Engineers, Department of the Army, or as said authority and responsibility, redelegated as appropriate, to either Headquarters, U. S. Army Armament Materials Readiness Command or Commander, Crane Army Ammunition Activity.

(3) "NWSC" means Commanding Officer, Naval Weapons Support Center, Crane; and as used in these General Provisions, is to be considered synonymous with the terms "host" or "provider."

(4) "CAAA" means Commander, Crane Army Ammunition Activity; and as used in these General Provisions, is to be considered synonymous with the terms "tenant" or receiver."

(5) "ISSA" means Interservice Support Agreement as executed on DD Form 1144, Support Agreement and in accordance with SECNAVINST 7020.4C/AR 37-19/AFR 172-3 of 27 December 1974. The Support Agreement is not a part of this real estate instrument, but is a separate document prescribing the respective services and support to be provided by the Naval Weapons Support Center, Crane and the establishment of procedures, policies, and costs for financial reimbursement by the Crane Army Ammunition Activity.

b. The Licensor hereby grants the Licensee exclusive permission to use the facilities specified in Exhibits "A" and "B" together with the necessary rights of ingress or egress.

c. The use and occupation of said premises will be under the general supervision of the Crane Army Ammunition Activity (CAAA) which shall have immediate jurisdiction over the premises, subject to such rules and regulations as may be prescribed by the Licensor.

d. This License shall be effective during the period stated in Item 2, or until it is terminated by mutual consent.

Enclosure (1)

e. This License shall be reviewed at least annually by each party to evaluate its effectiveness and determine need for modification.

f. This License is subject to modification or termination as mutually agreed in accordance with the following:

(1) Request for modification will be furnished by one party to the other by written notice at least 60 days prior to effective date such modification is desired. Changes in custody of individual buildings and structures as determined necessary to improve effectiveness of operations and/or security by mutual consent of NWSC and CAAA shall be accomplished by the following procedures. The original NAVFAC drawing in Exhibit "A" will be replaced by a revised drawing depicting the custody change of the facility. The buildings and structures listing, marked Exhibit "B", will be revised either by pen and ink changes or by replacing the individual page where required. Approved changes to Exhibits "A" and "B" shall be forwarded to all parties concerned prior to the first week of each quarter of the fiscal year. All modifications to this license shall be effected by the aforesaid Northern Division.

(2) Notification of the intention of either party to terminate this License prior to the date set forth in Item 2 will be in the form of a written notice submitted to the other party at least 180 days in advance of the proposed date of termination. In the event of mobilization or other emergency, this License will remain in force subject to termination upon mutual agreement.

g. This License shall be neither assignable nor transferable by the Licensee. Permits granting use and occupancy of one or more buildings and structures specified in Exhibits "A" and "B" may be issued by the Licensee, however, in accordance with the following:

(1) Notification by the Licensee of the intention to issue a Permit for use and occupancy of specific property contained within this License to another Government or non-Government agency will be in the form of a written request submitted to the Licensor for approval at least 60 days prior to the effective date of the Permit.

(2) Upon approval by the Licensor, utilization of the property conveyed by Permit shall be restricted to specific functions as required to support the accomplishment of the task assignments and mission of the Licensee.

(3) CAAA will assume full responsibility for the performance of the Permittee and compliance with established policies and regulations for utilizing real property controlled by the Department of the Navy, and including specific rules and regulations as set forth by NWSC. CAAA will be responsible for any loss of or damage to Government property, and for death, injury or property damage resulting from property use or functions performed under the Permit.

(4) Issuance of said Permit shall be for a specific period of occupancy not to exceed, in any event, the term of this License. The Permit shall provide for restriction on capital investments by the

Permittee that could be construed as a reliance on the continuing use of the property. The Permit shall be revocable without prior notice to the Permittee.

(5) Any such permit shall specifically be made subject to the terms and conditions of this License.

h. Protection and Maintenance; Support Services

CAAA shall be responsible for the protection and maintenance (including long-term maintenance) of the licensed premises and facilities in good order. NWSC shall provide the support service required by CAAA necessary to accomplish its assigned tasks. Cyclical maintenance and repairs will be provided as required, and at a level equivalent to and comparable with NWSC's program for its own needs. NWSC shall continue the established level of maintenance in accordance with Chapter 6, titled "Uniform Maintenance Levels for Public Works and Public Utilities" of NAVFAC MO-322, Volume 1, Inspection for Maintenance of Public Works and Public Utilities; and as based on the maintenance levels established by the Department of Defense for military activities within CONUS. Such support services which shall be furnished on a reimbursable basis in accordance with the ISSA, shall consist of the following:

(1) Utilities - heat, electrical power and lighting, water, sewage, telephone and other communication capabilities.

(2) Maintenance and Repair Services - Maintenance and repair of all structures and facilities, railroads, highways, and roads licensed hereunder and/or utilized by or directly in support of CAAA, e.g., for access, as well as all grounds, maintenance, mowing and snow removal. Cost of maintenance and repair of highways, roads, and railroads utilized "exclusively" by and/or for CAAA will be reimbursed 100%; other such facilities used jointly with NWSC shall be reimbursed on a prorata share established by the Licensor and Licensee during the annual review of the existing license. Consultation between NWSC and CAAA on maintenance and repair programs shall be held far enough in advance to provide adequate budgeting and planning. NWSC shall also coordinate the scheduling of maintenance and repair items to preclude unnecessary adverse impact on the accomplishment of assigned tasks by the CAAA. In addition to the reimbursement of all costs for maintaining the standard level of maintenance and repair, costs of all maintenance and repair, above the standard level of the Licensor, which would not otherwise be accomplished by NWSC and which CAAA specifically requests in connection with its occupancy hereunder shall be reimbursed to NWSC in accordance with the established rates set forth in the ISSA.

(3) Equipment - Including but not limited to rail and highway transportation and materials handling Equipment.

(4) Pollution Control and Abatement Energy Conservation - The established Pollution Control Program and Energy Conservation Program shall remain the responsibility of the Licensor for management, compliance, and implementation, except for the operation of individual facilities by the Licensee. The CAAA is responsible for ensuring all personnel assigned comply with the established policies and regulations for energy conservation and pollution control. Cost for operation and maintenance of pollution control or abatement and energy conservation equipment shall be reimbursed by CAAA in accordance with the provisions set forth in the ISSA.

(5) Other Assistance and Support Services - All other necessary administrative assistance and logistical support services, in addition to those individually identified above shall be provided by NWSC on a reimbursable basis as specifically delineated in the ISSA. The Licensee shall be responsible for financing the performance of all functions within the mission and tasks assignments of CAAA which are not specifically enumerated in the ISSA. CAAA shall obtain the necessary funding for new facilities and operating support requirements as required for expanded or new mission assignments identified subsequent to licensing.

(6) Fire Protection and Security - CAAA shall be responsible for compliance by all personnel assigned to CAAA as well as by any Permittees, with all fire, safety and security regulations promulgated by NWSC.

NOTE: The furnishing of support services as provided for in this paragraph 7h is contingent upon the availability to NWSC of necessary utilities, equipment and other resources and upon the ability of NWSC to obtain the necessary personnel complement to carry out its assigned support functions. CAAA will provide written program requirements as far into the future as is practical so that the NWSC can project support requirements for budget submissions. Continued review of programs by both parties shall be required to ensure that the mutual interest of both are served. In addition to advising NAVSEASYSCOM when NWSC cannot adequately support CAAA as in accordance with paragraph G (Policy) 1 of DOD manual 4000.19M, NWSC shall also provide written notice to CAAA when it lacks, or will potentially lack, the capability to satisfactorily perform or provide the support functions as delineated in the ISSA.

i. Alterations and New Facilities - Any additions to, or alterations of, the premises or facilities which the Licensee shall consider necessary or desirable in connection with its use and occupancy shall be made only with the prior approval and written consent of the Licensor and solely at the cost and expense of the Licensee. Costs of all new construction, alterations and improvements shall be reimbursed to the Licensor in accordance with the established rates as set forth in the ISSA. Upon revocation, expiration or surrender of this license, and to the extent directed by the Licensor, the Licensee shall remove all alterations, additions, betterments and improvements made or installed, and restore the premises or facilities to the same or as good condition as existed on the date of entry under this License, reasonable wear and tear excepted.

APPENDIX F

"GREEN WATER" REPORT

20 September 1976

COPY OF DOCUMENT CAN BE OBTAINED FROM:
NAVAL WEAPONS SUPPORT CENTER,
CRANE, INDIANA 47522

Request for site approvals shall be in accordance with the policies and regulations of the Licensor and site approvals shall be obtained for all facilities regardless of size or type funding utilized, as follows:

(1) For any new building or structure whether permanent, semi-permanent, temporary, portable or relocatable;

(2) Any addition to an existing facility;

(3) A rehabilitation of an existing facility;

(4) Replacement of a facility at the same site;

(5) Redesignation of the use of an existing facility when the change is not compatible with the previously approved land use, and

(6) Relocation of an existing building or structure.

Siting and/or location of any facility for CAAA will conform to the master plan of NWSC Crane, or as agreed upon for the proposed location and/or changes by both parties. Standards of design and construction shall conform with criteria and directives of both Army and Navy. Any conflict will be resolved by the construction agencies of both services. Particular interest is imperative for projects generating or requiring changes to electromagnetic or explosive quantity/distance requirements. NWSC shall be responsible for requesting and obtaining site approval of proposed facilities required by CAAA. The CAAA shall provide notification of proposed new construction and/or alterations far enough in advance to ensure adequate time is available for NWSC to obtain the required site approval. Quantity/distance requirements generated by hazardous material shall be determined in accordance with OPNAVINST 8020.8F, Subject: Responsibilities of Naval Commands with respect to the Department of Defense Explosive Safety Board (DDESB); and NAVFACINST 8020.2A, Subj: Site Approvals for Ammunition Facilities. The proposed revision of established quantity/ distance requirements or the establishment of new requirements shall be mutually reviewed and approved by both parties prior to the submission of an official request to DDESB for approval.

Real property accounting will be in accordance with existing procedures under the cognizance of the Licensor. New facilities constructed by the Licensee and existing facilities licensed hereunder, and subsequent improvements thereto, will, accordingly, be carried on the Navy Department's Real Property Inventory.

j. Naval Facilities Engineering Command - Cognizance of Contracts - All contracts for new construction, including Military Construction projects, alterations, improvements, maintenance, repairs, equipment, installations, and support services for facilities, utilities and grounds as licensed hereunder shall be administered by Naval Facilities Engineering Command.

k. Natural Resources Management - for all land areas impacted by the location of all facilities licensed hereunder shall remain the responsibility of NWSC; including soil, water, forests and woodlands, fish and wildlife, grasslands, landscaping, outdoor recreation, and conservation and beautification. CAAA shall comply with the intent of the established natural resources management programs, including:

(1) Long Range Soil and Water Conservation Management Plan

(2) Boggs Creek Watershed Project

(3) Long Term Forest Management Plan

(4) Fish and Wildlife Management Program

NWSC shall coordinate the scheduling of work in support of the natural resources program to preclude unnecessary impact on the accomplishment of assigned tasks by CAAA

l. NWSC shall consult with CAAA prior to the implementation of new policies or regulations affecting the utilization of all facilities licensed hereunder.

Bill Cosmente

C9231-JBA:cn
11010
7 AUG 1975

From: Commanding Officer, Naval Weapons Support Center, Crane, Indiana
To: Environmental Quality Office, AMSAR-ISE, Rock Island, Illinois
(Attn: Mr. Ted Nash)

Subj: Environmental Impact Assessments for Open Burning/Detonation of Waste Munition/Propellant

Ref: (a) CSLNAVSEASYSCOM msg 042314Z of 5 Aug 1975

Encl: (1) Open-air Detonating of Excess/Obsolete Ordnance Items
(2) Open Burning of Waste Propellant, Explosive, and Pyrotechnic Materials
(3) Air Pollution Control Measures for Demil Furnace Operations

1. Enclosures (1), (2), and (3) are forwarded in accordance with reference (a).

N. L. CERVENKA
By direction

Copy to:
CSLNAVSEASYSCOM (SEA-9V12E)

Bill Cosimano

ENVIRONMENTAL IMPACT ASSESSMENT

SUBMITTING DOD COMPONENT: Department of the Navy

INSTALLATION: U. S. Naval Ammunition Depot, Crane, Indiana

PROJECT TITLE: Open-air Detonating of Excess/Obsolete Ordnance Items

Date of Submission: 15 May 1973

1. Project description:

a. Necessary disposal of excess, obsolete, and dangerous ordnance items is accomplished by controlled open-air detonation. Items detonated include bombs, rockets, projectiles, boosters, fuzes, and miscellaneous explosive articles of many kinds.

b. This operation is done at a specially developed site, located about 2.5 miles inside the nearest boundary, which is the West side of NAD Crane. Utilizing pits, barricades, and other blast-muffling features, the explosives are batched into permissible quantities and detonated by highly trained specialists.

c. Attachment (1) is a detailed listing of all types and quantities of ordnance materials burned and detonated by NAD Crane during calendar year 1972. Approximately 45% of these materials were disposed of by open-air detonation.

2. Probable environmental impact:

a. Plant and animal life: NAD Crane is located on approximately 63,000 acres of land in South Central Indiana. Topography within the station varies from gently rolling land to rugged wooded hills. Approximately 56,000 acres are classified in the Central Hardwood Forest of the United States. Lake Greenwood, 800 acres in size, is the source of water for industrial use, and has been made available for fishing, boating, and

ENCLOSURE (1)

skiing. In addition, numerous small ponds and two flood water control dams have been built. Plants, insects, reptiles, and wildlife of all types typical of Southern Indiana are numerous on station. Eagles, otter, and bobcats are the only rare or endangered species currently on station, and none are threatened by this action.

b. Natural resources: There are no known oil or mineral deposits within the vicinity of the action; nor are there any archeological or historic sites.

c. Pollution aspects: Disposal of these materials by open-air detonation results in scattering scrap metals within the confines of the controlled area, a problem which is easily solved by collection, salvage, and further disposal.

(1) The detonation also results in several types of both gaseous and particulate emissions into the atmosphere. Elements released consist mainly of nitrogen (N), oxygen (O), carbon (C), and hydrogen (H). Some materials may have other toxic or damaging elements, such as lead (Pb), mercury (Hg), magnesium (Mg), sulfur (S), aluminum (Al), phosphorous (P), potassium (K), and silver (Ag). Quantities of these latter elements range from small to non-existent, depending on type of item or material being detonated.

(2) The operation also results in considerable noise pollution, generated by the seismic and sonic energy released by the detonation.

d. Regulatory aspects: While it is recognized that these air emissions from open detonation are undesirable, they are currently exempt from state air emission standards. Indiana Air Pollution Code APC 2 advises that disposal of explosives by burning in remote locations is not in violation until feasible non-polluting methods can be developed (see paragraph 4 for progress in this area).

OECO INFO CENTER

DEPARTMENT OF THE NAVY
NAVAL WEAPONS SUPPORT CENTER
CRANE, INDIANA 47522-5000

IN REPLY REFER TO:
5090/H10.0
0924

ACTIVITY FILES

8 OCT 1987

Mr. Tim Miller
Indiana Department of Environmental Management
Solid and Hazardous Waste Management
105 S. Meridian St.
Indianapolis, IN 46225-6015

Dear Mr. Miller,

Enclosed for your review is the Interim Draft Report for the Geology and Hydrology Study being done at the Ammunition Burning Grounds. This report presents findings of work done prior to September 4, 1987. We are continuing with the study so the Interim report is subject to change with new findings. Any findings or data collected from work done after the aforementioned date will be presented in a Final Report which will be submitted at a later date.

NAVWPNSUPPCEN Crane point of contact is Mr. Jim Hunsicker, Code 0924, telephone 812-854-3114, zip code 47522-5009.

Sincerely,

J. D. FARIS
Manager, Engineering Division
Public Works Department
By direction of the
Commanding Officer

Encl:
(1) Interim Draft Report & Drawings of Geology & Hydrology of the Ammunition Burning Grounds

Copy to:
Northern Division, Naval Facilities Engineering Command (Code 14)
Naval Sea Systems Command (SEA-06G112E) (w/o encl)
U.S. Environmental Protection Agency, Region V (Marty Hamper)

Letter of Transmittal for Interim Draft Report: Geology and Hydrology of the Ammunition Burning Ground, Crane Naval Weapons Support Center.

16 Sep 1987

From: USAEWES GR-GS
P.O. Box 631
Vicksburg, Mississippi 39180-0631

To: Mr. Jim Hunsicker
Crane Naval Weapons Support Center
Crane, Indiana 47522-5009
Code 0924, Bldg 2516

Dear Jim,

Enclosed is the interim draft of Richard Hunt's report for the ABG. The draft is complete except for well installation diagrams and some of the discussion of cross sections. Richard is sending me the rest of the text and diagrams soon but we have enough now to submit the interim draft. We will continue to review the draft internally at WES to prepare it for the final report, which will also contain conclusions and recommedations. There are currently 8 figures included with the text and 20 oversize plates enclosed as bluelines. You might want to have Richard make you more copies of the plates from his originals. We will obtain a cost/time estimate from our Reports section for preparation of the final report here at WES and get back with you on that soon.

Look over the draft and if you have questions, comments or suggestions get back with us and we'll work them out. Thanks.

James H. May

James H. May
Chief, Site Char. Unit
WESGR-GS

INTERIM DRAFT REPORT
Geology and Hydrology of the Ammunition Burning Ground,
Crane Naval Weapons Support Center

I. INTRODUCTION

Background. A ground water monitoring program was established in 1981 at the Ammunition Burning Grounds (ABG) treatment site at the Naval Weapons Support Center (NWSC), Crane, Indiana. The monitoring program was initiated to keep NWSC, Crane in compliance with 40 CFR 265 Subpart F, which requires ground water monitoring by managers of hazardous waste in surface impoundments and/or waste piles. Results of the monitoring program suggested the presence of ground-water contamination at the ABG. A background well was found to be contaminated with explosive. Other wells showed evidence of contamination as determined by statistical analyses of results of indicator parameters. Subsequently, after notifying the State and Region V Environmental Protection Agency (EPA) of the findings, a Ground Water Assessment Plan was prepared (NWSC, 1986). This report presents the results of a detailed hydrogeologic and geologic study of the ABG conducted in 1986-87.

Scope. The main objective of the study was to identify and define the factors that influence and control the flow of ground water into and out of the ABG. Once the controlling factors have been identified the potential areas and routes of contaminant migration can be closely monitored and compared with ground-water conditions around the ABG.

The scope of work included the emplacing of several continuous core borings which were fitted with well screens. During the drilling program the field data were evaluated and updated continuously. Geologic cross sections were prepared and kept current with each additional boring. Field mapping, literature surveys, and interviews with personnel from the Indiana State Geological Survey were conducted in conjunction with the drilling program. The location of each new boring was selected to offer the greatest information using the previous borings as a guide. The boring locations and time of drilling were planned so that the work would not interfere with the ongoing ABG activities.

As the site investigations progressed, the accumulating hydrogeologic data indicated a need to include the area surrounding the ABG as a general part of the overall study. Springs issuing both north and south of the ABG are hydraulically connected to ground water at the ABG. Several borings have been drilled to the north and south of ABG in order to trace pertinent

WORKING DRAFT

hydrogeologic relationships associated with the ground-water flow pattern at the ABG. A line of monitoring wells is currently being installed across the Little Sulphur Creek valley at the NWSC boundary as a part of the overall ABG ground-water/contamination investigation.

Study Area Location. The NWSC, Crane, is located in Southwest Indiana approximately 75 miles southwest of Indianapolis and 71 miles northwest of Louisville, Kentucky (Figure 1). The NWSC occupies 62,463 acres or approximately 100 square miles of the northern portion of Martin County and small portions of neighboring Greene, Daviess, and Lawrence Counties. Surrounding towns that are within 30 minutes or less driving time from the NWSC include Bloomington, Bedford, Bloomfield, and Washington.

The Ammunition Burning Grounds (ABG) study area lies in the eastern part of the NWSC (Figure 2).

II. REGIONAL GEOLOGY AND HYDROLOGY

Regional Geology. Indiana lies in the midwestern region of the United States where stresses within the earth's crust have been relatively mild throughout geologic time. The deformation that has occurred has produced structural arches and basins of regional proportions where the sedimentary rocks are gently tilted and faulting has been minimal. The major structural provinces of the region are shown in relationship to the state of Indiana in Figure 3. The boundaries of the Geologic Provinces lying in the state of Indiana are shown in relationship to county locations and the general location of the NWSC in Figure 4. The Kankakee and Cincinnati arches join and extend diagonally across Indiana from the southeast to the northwest. The combined arches form a structural divide from which sedimentary rocks dip northeast into the Michigan Basin and southwest into the Illinois Basin. The sedimentary rocks were deposited in cyclic seas that fluctuated across the region during a time span ranging between 280 and 500 million years ago. Geologic time periods extending from the Pennsylvanian through the Cambrian in descending order by age, or nearly all of the Paleozoic Era, are represented in the sedimentary sequence underlying the region. Total accumulations of the sedimentary rocks range from 3500 ft across the arches to in excess of 13,000 ft near the center of the Illinois Basin. Surface rocks are older and thinner across the arches and become progressively thicker and deeper in the subsurface as the strata dip into the basins. Consequently, the surface rocks become progressively younger in a direction outward from the arches toward the basins. In Indiana,

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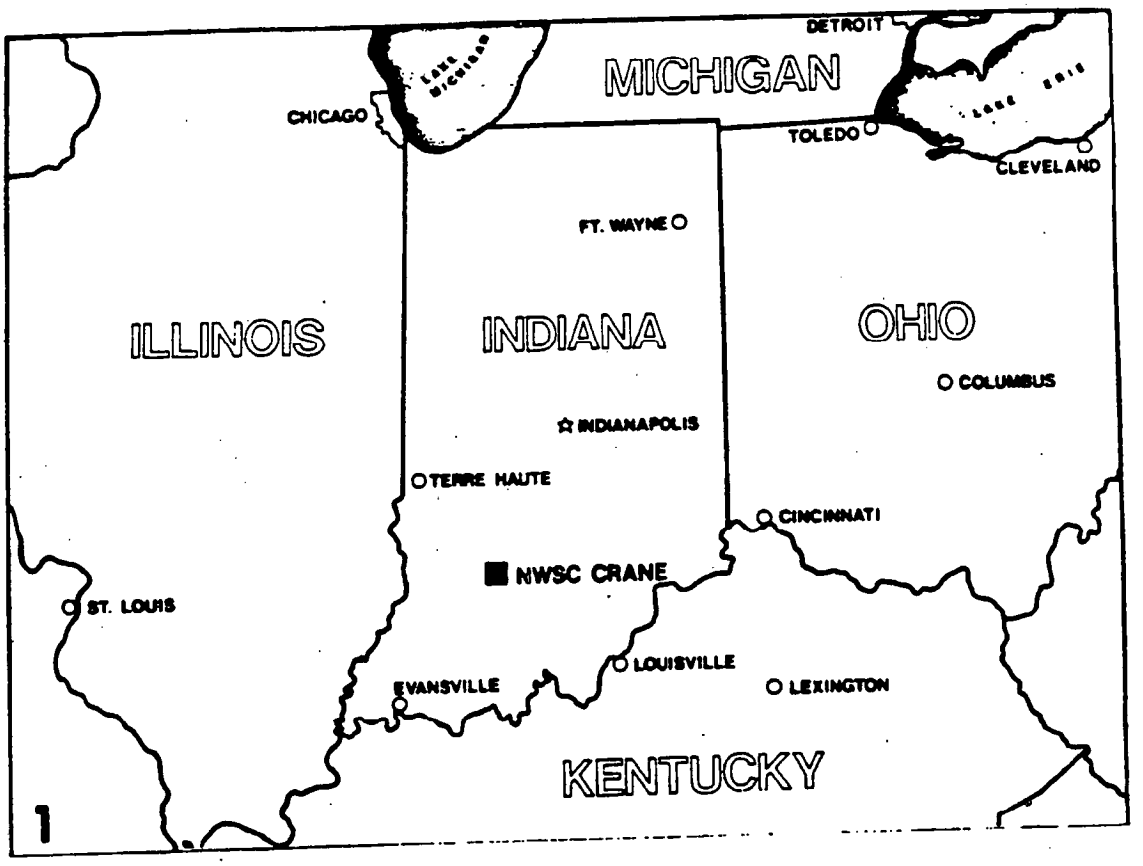

Figure 1. Location of Crane Naval Weapons Support Center (NWSC).

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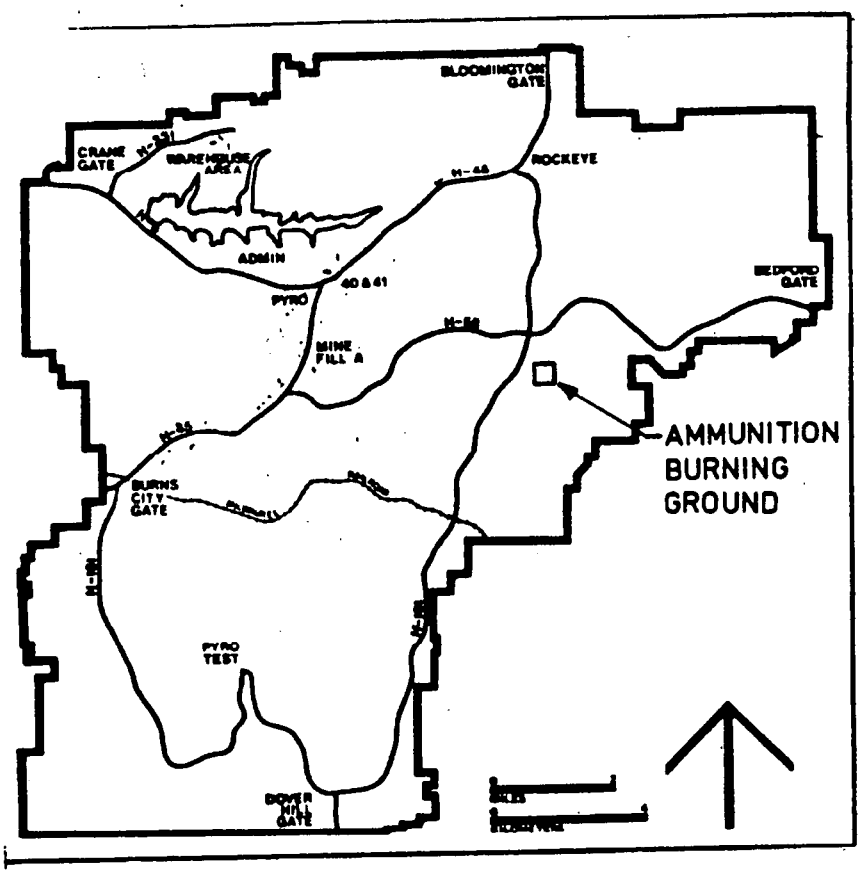

Figure 2. Location of Ammunition Burning Ground, Crane NWSC.

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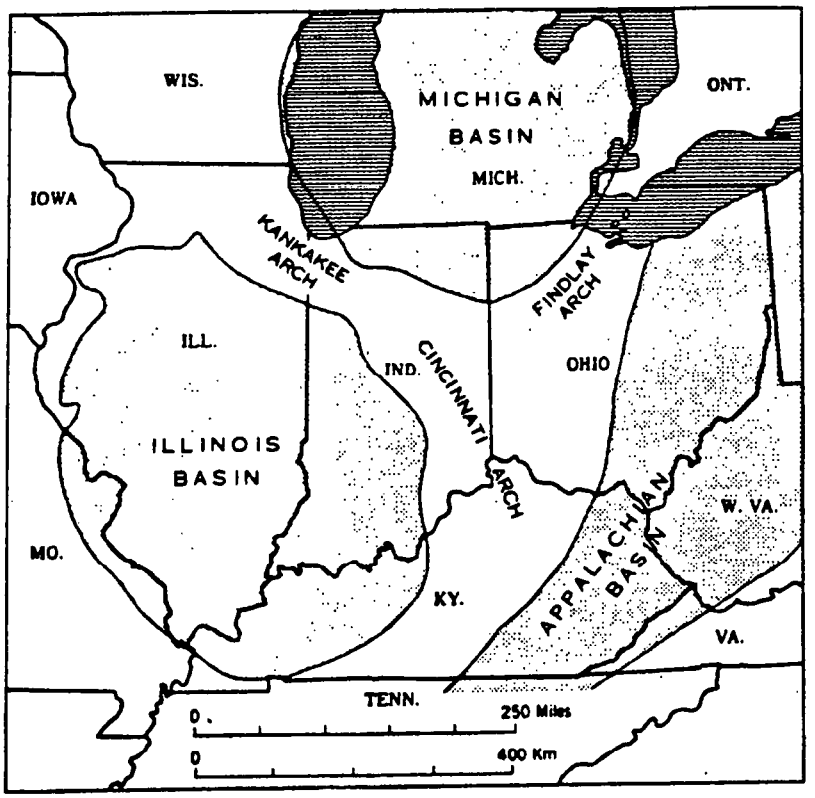

Figure 3. Major structural provinces of midwestern U.S.

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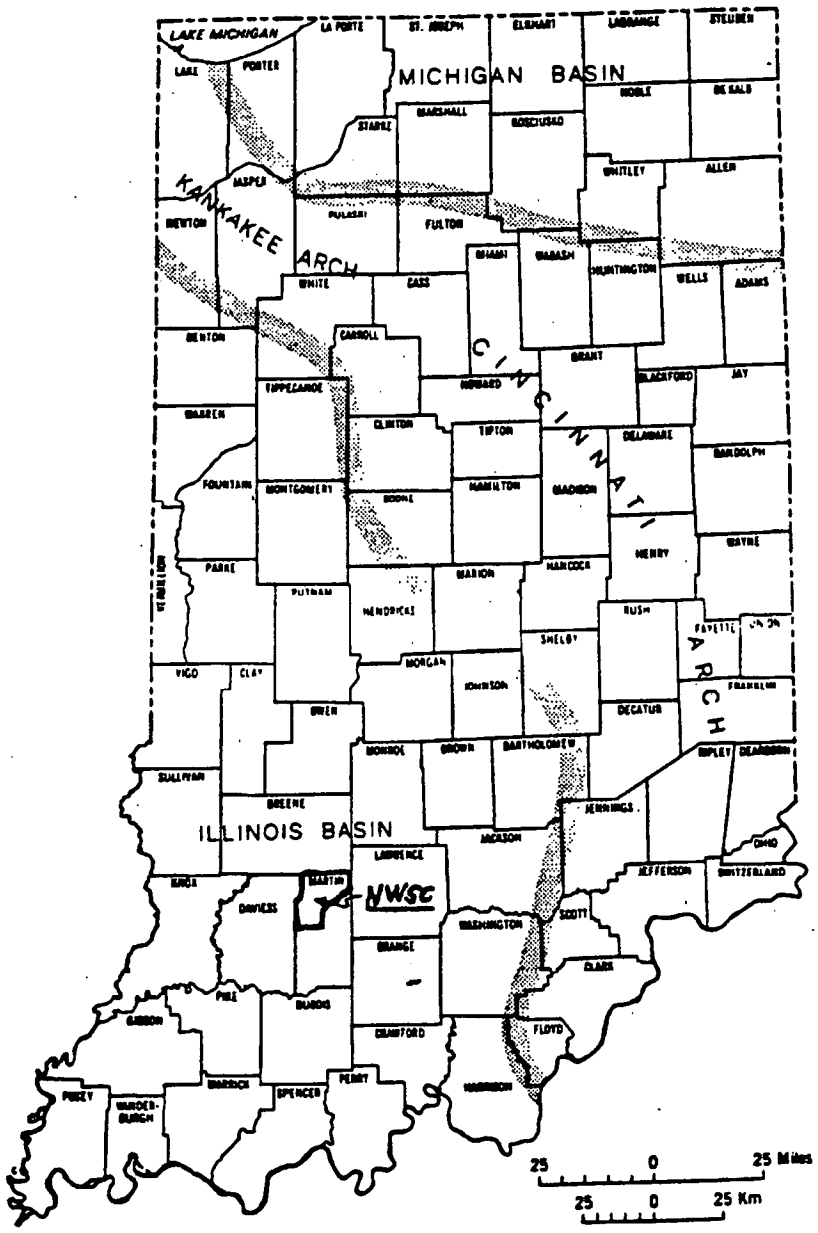

Figure 4. Boundaries of geologic provinces in Indiana.

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the youngest sedimentary rocks associated with the regional geologic structural features are Pennsylvanian in age. The absence of younger strata implies that Indiana has remained above sea level for the past 280 million years or that younger strata have been subsequently removed by erosion.

The NWSC lies in the eastern edge of the Illinois Basin where the underlying sedimentary rocks dip west-southwest at approximately 50 ft per mile. The surface rocks underlying the NWSC are in the Lower Pennsylvanian and Upper Mississippian geologic time periods. A generalized stratigraphic column at the NWSC is presented in Figure 5. Mississippian rocks of the Chester series are extensively exposed in the valley walls and hollows along the eastern portions of the NWSC and in the lower zones of deeper valleys toward the west; Pennsylvanian rocks of the Pottsville series cap most of the hills and ridges along the eastern side of the NWSC and become the predominant surface rocks toward the west boundary of the NWSC. The stratigraphic units in the Pottsville series consist of interfingered sandstones, shales, claystones, and clastic siltstones, with occasional, relatively thin interbeds of coal that were deposited in multicyclic seas and swamps. The stratigraphic units in the Chester series consist of alternating and repetitive sequences of limestones, shales, and sandstones that were deposited in shallow seas. Several hundred feet of continuous limestone, Middle Mississippian in age, underlie the Chester rocks but remain in the subsurface at the NWSC. The contact between the Mississippian and the Pennsylvanian rocks is an unconformity where erosional processes extending over a long period of time removed upper portions of the Chester series prior to Pottsville deposition. Local relief along the unconformity may be as much as 150 ft in some areas.

No faults have been mapped in the NWSC general area. The closest mapped major fault, known as the Mt. Carmel fault, trends NW-SE and passes approximately 20 miles east of the NWSC.

Regional Physiography. Figure 6 presents the physiographic divisions of the state of Indiana, the limits of Pleistocene glaciation and the location of the NWSC. The NWSC lies in an unglaciated area of the Crawford Upland, a rugged dissected plateau bound on the east by the Mitchell Plain and on the west by the Wabash Lowland. The Mitchell Plain is a low dissected limestone plateau characterized by sinkhole topography and other karst features. The boundary between the Crawford Upland and the Mitchell Plain is called the Chester Escarpment, a highly irregular east-facing cuesta escarpment. The escarpment trends northwest-southeast and passes just east of the NWSC. The face of the escarpment is somewhat obscured by elongated upland spurs and upland outliers

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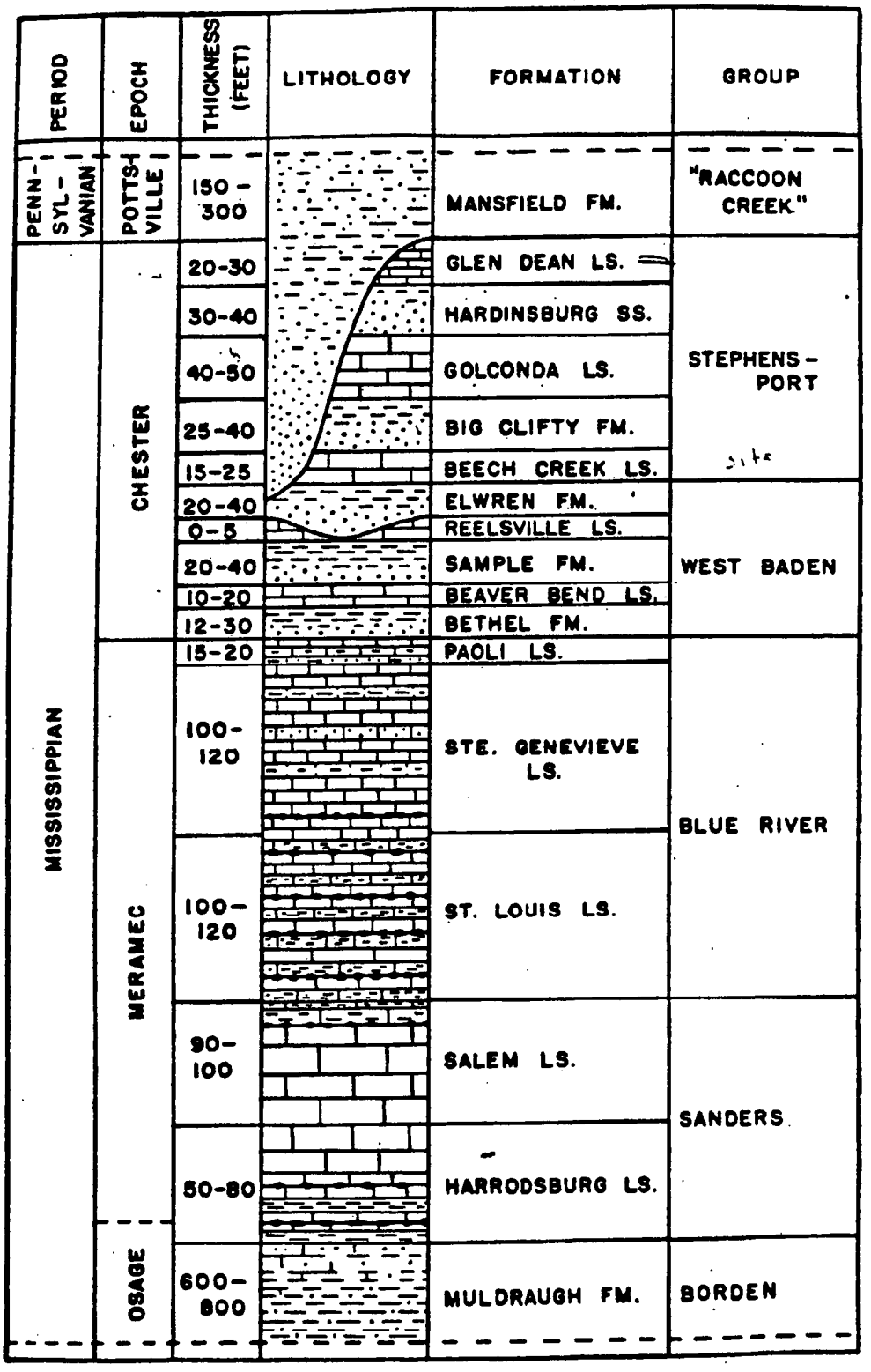

Figure 5. Stratigraphic column for rock units encountered at TMI.

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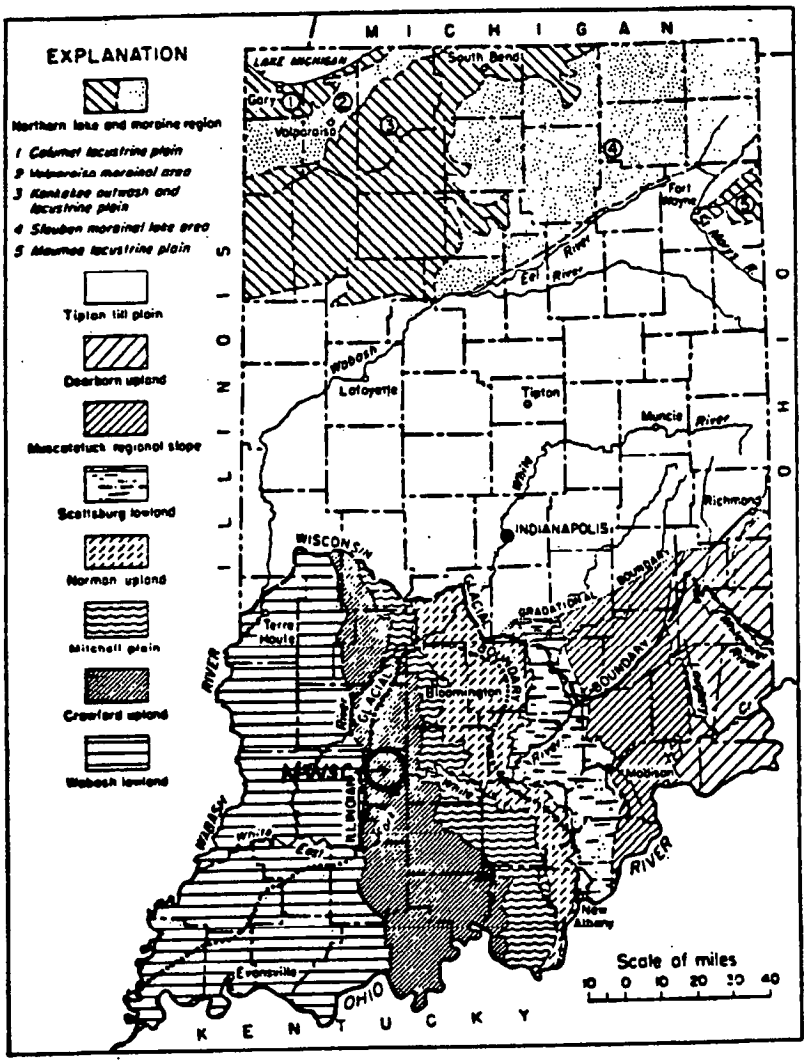

Figure 6. Physiographic divisions of the State of Indiana.

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along with karst valley re-entrants that extend into the uplands for several miles. Numerous springs, cavern passages and caves occur along the escarpment and in the eastern part of the Crawford Upland. Some of these solution features are found in the eastern portion of the NWSC. The Crawford Upland grades into the Wabash Lowland near the western NWSC boundary. Elevations on the Crawford Upland at the NWSC range from less than 500 ft msl to greater than 850 ft msl. Relief on the upland varies from about 100 ft to 350 ft, with higher elevations and greater relief occurring generally in the eastern part of the NWSC. Surface drainage in the upland is to the south and southwest.

Regional Drainage. The surface drainage along major streams in Indiana is shown in Figure 7. With the exception of the extreme northeast corner of Indiana, all the surface drainage is to the southwest and south. Approximately two-thirds of the state drains into the Wabash River which in turn empties into the Ohio River. Surface drainage at the NWSC eventually flows into the White River and thence to the Wabash to the southwest. The major drainage at the NWSC is divided into five basins as shown in Figure 8. The ABG site is located in Basin III, near the headwaters of Little Sulphur Creek.

Regional ground-water trends. Ground water in the unglaciated southwest portion of Indiana in general is contained in joint openings of limestone and sandstone aquifers. In the area of the Crawford uplands (Figure 6), the aquifer zones are more or less isolated from each other vertically by interlayered shale beds which act as aquicludes. Ground water enters the aquifer zones through outcrops and flows by gravity down the dip of the strata. Because the regional dip of the strata is to the southwest, the large scale flow pattern of ground water in each aquifer zone is also to the southwest. Locally, however, the regional ground water flow pattern may become more complex due to changes in hydrogeologic conditions. Local variations in the stratigraphic dip, and incisions into the aquifer zones by surface drainage can produce anomalies in the regional ground water trends. Local folding and flattening of the strata that occurred during regional uplift have altered ground water flow patterns relative to local changes in dip of the strata. Numerous springs and seeps issue from the aquifer zones in areas of valley incision, and locally complicate ground-water flow patterns. Ground water issuing from springs in higher aquifer zones becomes surface water that has the potential for re-entering the ground water system of a lower aquifer exposed downstream.

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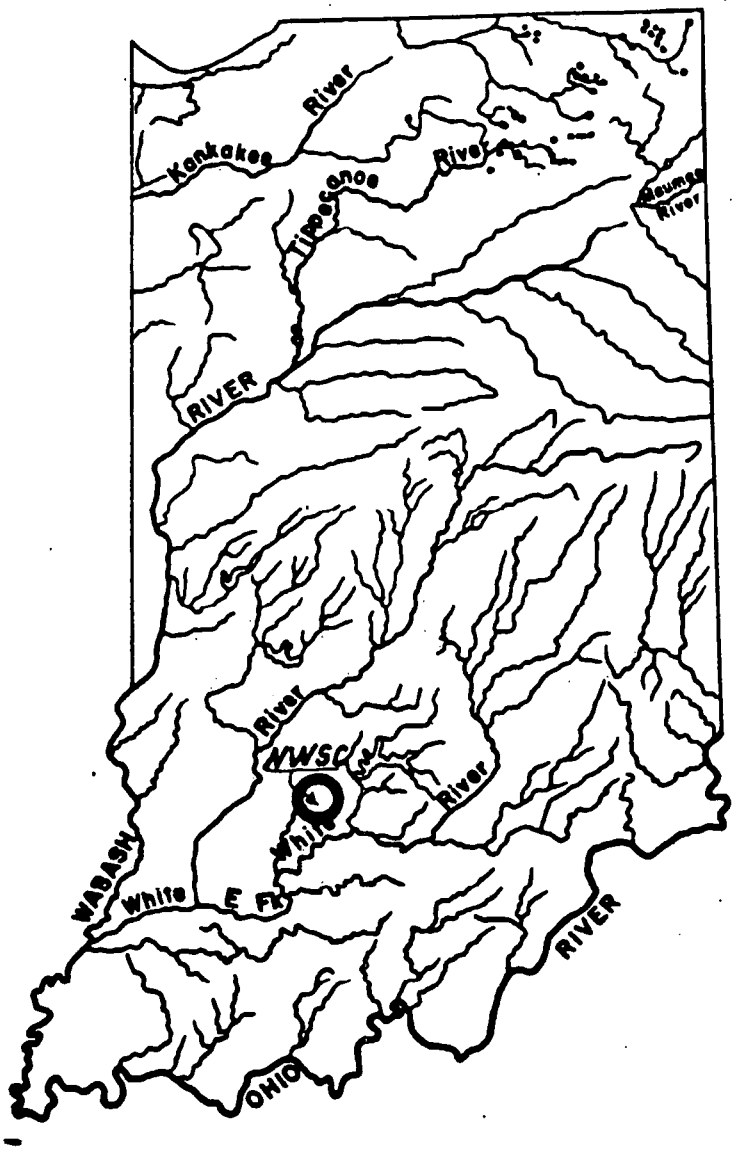

Figure 7. The stream system in Indiana.

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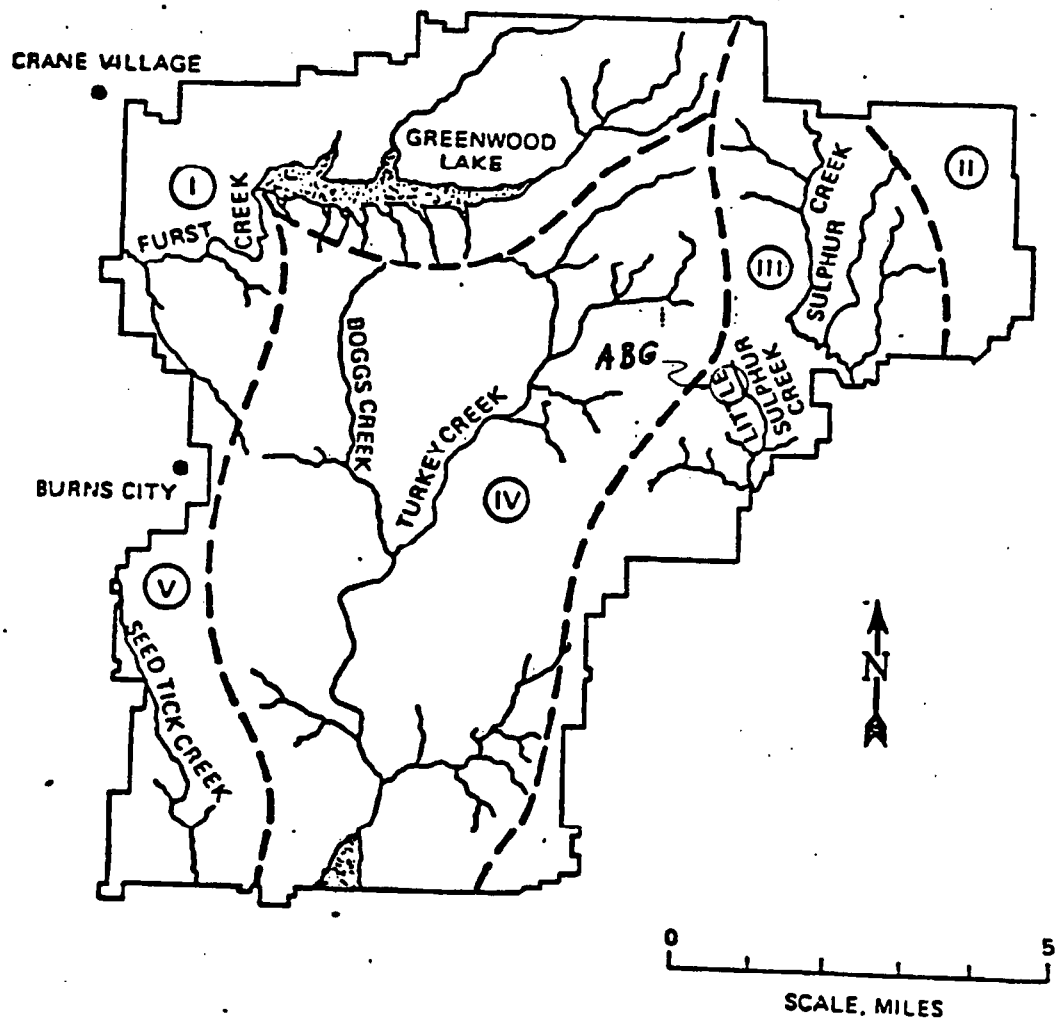

Figure 8. Surface drainage at the NWSC, Crane, IN.

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III. SUMMARY OF PREVIOUS HYDROGEOLOGIC STUDIES

Past drilling programs at the ABG produced a large number of roller rock bit borings which were drilled with air. Consequently, the only samples available were as cuttings. Determining stratigraphic breaks and lithologic conditions based on drilling characteristics and cuttings at best was difficult and somewhat of an educated guess. Well screens were set in each of the borings based on the first encounter with water, but without reliable data to correlate the stratigraphically controlled ground water occurrences between borings. One of the main objectives of the earlier studies was to aid in verifying and identifying any contaminants that might have entered the ground-water system at the ABG. The objective was accomplished and certain contaminants were found to be present in the ground water at several boring locations. In fact, two of the supposed background wells, one located at the west end of the ABG, and the other at the northwest end, showed contamination. With this in mind, the line of compliance at the east end of the ABG became questionable, and the need for further investigations arose. Also, several borings located in the eastern zone of the ABG encountered large cavities the presence of which has initiated additional investigations to determine the relationship of the cavities to the ground-water flow system out of the ABG area.

IV. ABG INVESTIGATIONS

Preliminary surveys

Prior to the start of drilling operations, literature and field surveys were conducted to establish background data on the geology of the area. The results of the pre-drilling surveys showed that the analysis of the stratigraphy presented in earlier reports on the ABG was in error. The stratigraphic units identified in earlier reports were out of sequence by one formation (too high) in descending order of occurrence. In other words, the formation labeled Hardinsburg in earlier reports is actually the Big Clifty formation and the Golconda limestone is actually the Beech Creek Limestone (Figure 5).

Boring logs of two producing water wells at the ABG, one installed in 1941 and the other in 1968, were reviewed and discussed with personnel from the Indiana State Geological Survey. The aquifer supplying these wells was determined to be the Beaver Bend limestone. Drinking water at the ABG is supplied by one of these wells. The Bethel Formation underlies the Beaver Bend

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and is relatively impervious. The boring logs indicated that the formations between the Beech Creek limestone and the Beaver Bend limestone contained thick, low permeability shale beds. The boring log data and the discussions with the State Survey indicate that these shale formations would serve as aquicludes to prevent ground-water interconnection between the two limestone formations. Personnel from the State Survey also advised that there was a possibility of encountering sulfides in the ground water contained in the limestone below the Bethel formation. Based on the above data, it was decided prior to the beginning of the drilling operations that the Beaver Bend would be the lowest ground-water zone of investigation and that only a few widely spaced verification wells were necessary in the Beaver Bend.

Boring program

A total of 54 borings have been completed as part of the ABG subsurface investigations. A plan of borings at the ABG site is presented in Plate 2. Boring locations outside the ABG site are shown in Plate 12. A summary of boring data is presented in Table _. The borings include 25 core borings, 11 roller rock-bit borings, and 18 splitspoon soil sample borings. Monitoring well screens were set in 42 of the borings. Twelve of the splitspoon borings were used to obtain soil samples of the ABG valley fill material and were backfilled after completion. The remaining six split-spoon sample borings are located along the NWSC boundary in Little Sulphur Creek alluvium. Well screens were set at the base of the alluvium in these six borings. Three additional split-spoon borings are planned to complete the closure across Little Sulphur Creek Valley in this area.

Well screens were set in all of the 25 core borings and 11 roller rock bit borings. Five (5) of the core borings extended through the Beaver Bend limestone and bottomed in the Bethel formation; twenty-nine of the core and rock bit borings extended through the Beech Creek limestone and bottomed in the Elwren formation; seven of the borings extended through the Golconda/Haney limestone and bottomed in the Big Clifty, Indian Spring shale member.

The borings drilled with a roller rock bit were located near deeper borings in which core samples had been obtained and in which the stratigraphy had been established. Detailed field logs were made for each of the core borings and are included as Appendix A (not included in this draft). The well screens were set in each of the borings at depths determined by the aquifer to be investigated. Each well screen was set in a separate boring with as many as three (3) wells located within 5 ft of each other at a few of the boring "clusters." Detailed well screen placement data are included at the backs of

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each boring log in Appendix A. The boring "clusters" correspond to the core boring numbers, i.e., WES-3-C1-86 through WES-3-C25-86. Where more than one well screen is set at a particular "cluster," there is a detailed well screen placement sheet included at the backs of the appropriate boring logs for each of the wells set at each of the multiple well sites. The well numbers at the multiple well sites correspond to the following example: WES-3-C1-86 (core boring and deepest well screen); WES-3-C1P2-86 (roller rock bit boring and middle well screen); WES-3-C1P3-86 (roller rock bit boring and upper well screen).

The first boring, WES-3-C1-86 was initially started with a 4x5-1/2-in. diamond core barrel, but required three separate set-ups and an HQ wireline core barrel rigging to complete. In the first set-up the core barrel was hung and lost along with approximately 30 ft of drill stem at a depth of about 70 ft. A new 4x5-1/2-in. core barrel was used to continue coring to a depth of approximately 114 ft in a second set-up offset 5 ft from the first, before it was also lost. A third boring, offset an additional 5 ft, was finally completed to the required depth using an HQ wireline core barrel. The third boring is numbered WES-3-C1-86 and includes the well screen set in the lower aquifer. Since the second boring had penetrated through the middle aquifer, a well screen was set in it, but the well includes the lost core barrel at the bottom. The first boring was grouted to the surface. The remaining core borings throughout the drilling program were completed with the HQ wireline rigging.

The deep core boring, WES-3-C8-86 was found to be plugged by grout (?) in the riser pipe. A second deep boring, WES-3-C8A-86, located approximately 40 ft east of the original site, was drilled with a rock bit and a well screen was set as a replacement data point. The surface evidence of WES-3-C8-86 was destroyed and the well was grouted to the surface.

Three additional core borings with well screen emplacements are planned as part of the ABG ground-water studies. These core borings are in addition to the three splitspoon borings mentioned earlier that are to be located in Little Sulphur Creek Valley alluvium. One of the core borings will be between existing borings WES-3-C5-86 and WES-3-C6-86; one between WES-3-C7-86 and WES-3-C13-86; and one is to be located farther north of WES-3-C9-86, in line with Mt. Spring.

Drilling and Well Installation Procedures.

Drilling. Prior to the start of drilling and between set-ups at each of the boring sites thereafter, the drill rig and drilling tools were steam-cleaned

WORKING DRAFT

or in a few instances flushed with clean water. After set-up, the soil zones in each of the core borings were sampled with a 7-in. diameter folding auger down to refusal. If the depth was less than approximately 11 ft (the depth needed to start coring with the HQ wireline core barrel) then a 2-ft long NX core barrel was used to sample to 11 ft. All the remaining core samples below 11 ft were taken with the HQ wireline system with the exception of boring WES-3-C1-86, as discussed earlier under the heading "Boring Program." The core samples were placed, in order of removal, into plywood boxes for future reference, and detailed geologic logs were prepared.

The drill cuttings were removed by circulating clean water in a steel mud pan sealed around the boring top. Most of the water used in drilling was obtained from a hydrant located in the heavy equipment shops area at the NWSC. At the beginning a small portion of the drilling water was obtained from the well located near the center of the ABG, which is supplied by the Beaver Bend aquifer. This well had been checked previously and is supposedly free of any contamination. Another well located near the ABG office shack is supplying drinking water from the same aquifer.

During drilling operations the mud pan was cleaned and refilled with new water whenever conditions became necessary. In most borings the drilling water was lost in the more porous and jointed aquifer zones. When water loss occurred, the mud pan was replenished with a continuous flow of clean water. Where more than one aquifer zone was penetrated in a particular boring, the upper zone or zones were sealed off before advancing the boring deeper. PVC casing was grouted 3 to 5 ft into the relatively impervious shale beds that underlie each aquifer and allowed to set, generally overnight. The procedure used in casing the higher aquifers was to set 6" diameter casing in the upper zone, followed by 4" diameter casing in the middle zone. The 4" casing was grouted up through the previously set 6" casing. Where there was no upper aquifer, the 6" casing was used to seal off surface soils. In all borings where drilling water had been lost in the aquifer zones, the water circulation returned after the casing was set. In most of the borings the circulation was again lost in the next lower aquifer zone.

After completion of each boring a bailer was attached to the drill cable hoist and the drilling fluids were bailed out until the water became relatively clear. Usually the bailing operation lasted 1 to 2 hours using a 2-1/2-in. diameter, 10 ft long bailer. In most borings the water flow into the boring was adequate to maintain a regulated steady pace of bailing. In a few borings, the aquifer was tighter and there were slight delays in bailing

WORKING DRAFT

operations to allow the inflow of additional water. After the bailing operations, monitoring well screens and riser pipes were installed in each boring.

Monitoring well installation. A system of 2-in. diameter Teflon and PVC pipe was used to install the monitoring wells. The screens are all made from Teflon, having three vertical columns of horizontal slots .020-inch wide and spaced approximately 1/4-in. apart. The riser pipe consists of Teflon extended upward to a point approximately 5 ft above the previously measured water level in each aquifer zone. The upper portion of the riser pipe consists of PVC extending from the Teflon connection to approximately 2.5 ft above the ground surface. The bottoms of each well screen have non-slotted Teflon traps extending 1 ft below the screens. All screens in the middle and lower aquifer zones are 10 ft in length. Screens in the upper aquifer are 5 ft in length. The top of each well has a vented PVC cap. The riser pipe is protected at the surface by outside 3-in. diameter steel pipes with lockable caps and are grouted 3-1/2 ft inside the 4-in. and 6-in. diameter PVC surface casing. A typical well installation is shown graphically in Figure __(not included in this draft). A summary of all well installations is presented in Table __(not included in this draft). In the first two or three wells, which were installed prior to the establishment of the above system of well placement, the PVC pipe extends below the aquifer water level.

Once the pipe system was installed in the boring, the screened section and the total aquifer zone were packed with a siliceous coarse sand-pea gravel filter material. The filter material was poured in from the top slowly by hand and checked for depth periodically with a tape measure. The bottoms of all the screens were placed at or near the base of the particular aquifer being tested. The bottom of each boring extends 1 to 3 ft into the shale beds below the aquifer zones. The filter pack was brought up to the next higher shale zone in order to obtain a good seal above the aquifer. In the lower aquifer the filter pack averages between 15 and 20 ft thick. In the middle aquifer the filter pack averages about 60 ft thick. In the upper aquifer the filter pack averages 10 to 12 ft thick. A thickness ranging from 3 to 5 ft of bentonite pellets was poured in from the top to secure a seal above the filter pack in each well. The bentonite was allowed to set 30 minutes to 1 hour for swelling time, and the well was grouted to the surface above the bentonite. The grout consisted of a cement-bentonite mixture and was pumped in from the bottom through a 3/4-in diameter pipe.

Well development. Initially, the first 12-15 wells were developed by pumping compressed air through a filtered hose system placed at the bottom of the

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screens, forcing water out at the riser tops. The blowing operations were alternated with periods of surging in the screened intervals. The surge tool consisted of an 18-in. long, 1-1/4-in. diameter stainless steel rod with rubber washers attached at each end. The washers were cut slightly smaller than the inside diameter of the well pipe. The surge tool was lowered into the well with 1/8-in. diameter stainless steel cable and pulled briskly up and down in the slotted zones to create a pumping/pushing action. The processes were repeated for several hours in each well or until the water forced out at the top became relatively clear. The time involved usually required an entire day, especially in wells where the recovery rate was slower.

As experience was gained over a period of time it became apparent that even though the inline filters were changed periodically, a certain amount of oil was escaping into the wells. The use of compressed air for well development was terminated.

The new procedure for developing the remaining wells was simply to bail out the water, alternating with periods of surging. The same stainless steel cable used for surging was used to lower and raise a 1-1/8-in. diameter, 5 ft long stainless steel bailer. In order to speed up operations and ease muscle strain, a frame was constructed on a small trailer in conjunction with a portable wireline winch to run the tools in and out of the wells. The time for development was about the same as when using air. The wells were bailed until the water became clear. The developing tools were flushed with clean water between each well setup.

Physiography and Geology of the ABG.

Physiography. A topographic map that includes the total study area and shows the ABG site location is presented in Plate 1. The map was prepared by connecting the Indian Springs and Williams, USGS 7-1/2 min. quadrangles and photographically enlarging them to a scale of 1 in. = 1,000 ft. The topography of the study area is relatively rugged, consisting of a series of steep sided, narrow ridges and valleys. The topography is a product of erosional incision into gently dipping strata of varying resistance. A major drainage divide extends southwest-northeast through the area and is followed by NWSC Road 161. East of the divide approximately 2/3 of the area drains to the south through Little Sulphur and Sulphur Creeks. West of the divide the remaining portion of the area eventually drains into Turkey Creek, which lies farther to the west. The entrance valleys show strong east-west, southwest, and southeast trends. The overall drainage pattern is a reflection of joints in the bedrock. Joints having strikes similar to the drainage trends were

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measured at a number of outcrops. Elevations across the area range from about 480 ft MSL in the lower drainage valleys to a maximum of 845 ft MSL along the major drainage divide.

The ABG site lies across the northern reaches of the Little Sulphur Creek Valley. The site is approximately 2,000 ft long by 500 ft wide with the long axis oriented east-west. A detailed topographic map of the ABG site, with a contour interval of 1 ft, is presented in Plate 2. Elevations in the valley portion of the site range from 620 ft MSL at the western end to 580 ft MSL at the eastern end. Elevations on ridges bordering the site range from 720 to 810 ft MSL. Surface drainage flows into the site from the west and northwest, and flows out of the site to the east. At the east end of the site Little Sulphur Creek turns south and continues off the NWSC boundary, 1-1/2 miles south of the ABG site. The Little Sulphur Creek eventually joins Sulphur Creek which in turn empties into Indian Creek, approximately 5-1/2 miles south of the ABG site.

Geology.

Surface geology. The general distribution of surface rocks within the study area is shown on the geologic map presented in Plate 3. The geologic map was prepared as an overlay to the topographic map of Plate 1. Data to construct the geololgic map was obtained from "Preliminary Coal Map No. 11, Distribution, Structure, and Mined Areas of Colals in Martin County, Indiana", by Harold C. Hutchinson. The outcrop pattern on the geologic map reflects continuing headward erosion of drainage in the area, and is representative of the surface geomorphology. Younger Pennsylvaninan sediments of the Raccoon Creek Group cap the ridges, and progressively older Mississippian sediments of the Stephensport and West Baden Groups are exposed downward into the valleys. The contact between the Pennsylvanian and Mississippian sediments is an unconforminty, marked by evidence of an extended period of surface erosion prior to Raccoon Creek deposition.

The area geologic map (Plate 3) includes structural contours on top of the Beech Creek limestone. The Beech Creek is the basal formation of the Stephensport Group and is used as a datum for stratigraphic correlations throughout southwestern Indiana. The structure contours show that the regional dip of strata underlying the study area is to the southwest at approximately 50 ft per mile. Where the Beech Creek has been removed by valley down cutting, the structure contours are shown dashed. The general configuration of the Beech Creek structure contours was obtained from data available in Bulletin No. 12, Indiana Dept of Conservation, 1958, entitled "The Meramec-

WORKING DRAFT

Chester and Intra-Chester Boundaries and Associated Strata in Indiana", by T.G. Perry and Ned M. Smith. The structure contours as shown in Plate 3 are modified from the original trends in Bulletin No. 12 from elevation data on the Beech Creek that were obtained from borings and outcrops during the ABG investigation.

A lineament shown on the area geologic map (Plate 3) crosses through the approximate center of the ABG site in a northeast direction. The lineament was transferred directly from the "Geological Lineament Map of the 10 x 20 Vincennes Quadrangle, Indiana, Illinois." The Vincennes Lineament Map was prepared from remote imagery under contract for the Indiana Geological Survey. Very few field checks were made for verification. The lineaments are believed to represent joints or other fractures in the bedrock and in most cases they agree with mapped joint orientations. A brief survey of local panchromatic aerial photos did not reveal evidence of the lineament through the ABG, nor was there any apparent offset of the strata in borings located to either side of the lineament position. The significance of the lineament remains uncertain at this time. Interpretive data may be gained from additional borings that are currently being drilled farther away on either side of the lineament. Ground-water data from borings to date do not indicate any hydraulic connection along the proposed lineament between the vertically separated aquifers at the ABG site.

A larger scale, detailed geologic map of the ABG site, constructed from boring data and outcrop examinations is presented as Plate 4. The site geologic map (Plate 4) defines the surface formations that underlie the general area of the ABG disposal activities. The Mansfield formation of the Raccoon Creek Group occupies the higher elevations at the ABG. In the order of increasing geologic age, the Hardinsburg, Golconda/Haney, and the Big Clifty formations of the Stephensport Group occupy the lower valley slopes and valley floor. The Hardinsburg and portions of the Golconda/Haney formations have been thinned by pre-Mansfield erosion at the Pennsylvanian-Mississippian unconformity. The Big Clifty formation is divided into two map units: the upper Indian Springs shale member and the lower sandstone member.

In the eastern area of the ABG, a number of borings, drilled during several previous study phases, encountered large cavities in the contact zone between the Big Clifty sandstone and the underlying Beech Creek limestone. The area of cavity development is shown cross-hatched on the site geologic map (Plate 4). The geologic development and hydrogeologic significance of the cavities are discussed later in this report.

WORKING DRAFT

The surface formations in the ABG valley floor area are covered by a blanket of alluvial and colluvial soils ranging from less than 1 ft to approximately 15 ft in thickness. The soils predominantly consist of yellow-brown and tan firm silty to sandy clay, with occasional to numerous weathered sandstone fragments, cobbles and pebbles. No zones considered to be permeable were encountered in the alluvial materials. Thin residual and colluvial silty clay, generally less than 5 ft thick, covers large areas of the ABG valley slopes. These soils have continually been reworked by dozers during maintenance operations at the ABG (large areas of the valley floor have also been reworked). Windows of underlying rock are exposed at scattered locations around the valley slopes.

Stratigraphy. The geologic formations encountered by borings in the study area are described in the following paragraphs, in descending order of geologic age (youngest units first).

a. **Raccoon Creek Group**

Mansfield formation. The Mansfield formation caps the hills and ridges in the study area and varies from 0 to 65 ft thick in the core borings. The formation consists of interfingered fine to medium grained, cross-bedded, friable, and oxidized sandstones; thinly bedded laminated shale and sandstone; thinly bedded to massive carbonaceous shale; massive claystone; clastic siltstone; and occasional thin seams of coal. The various beds tend to lense out rapidly in a lateral direction.

b. **Stephensport Group**

(1) Hardinsburg formation. The Hardinsburg is in contact with the Pennsylvanian-Mississippian unconformity and is missing or greatly thinned in many borings. The thickness varies from 0 to about 14 ft. The formation consists of olive to dark gray, thinly bedded, carbonaceous shale.

(2) Golconda/Haney formation. Several years ago the name for this formation was changed from the Golconda to the Haney. However, to insure easy cross reference to earlier reports both names are used in this report. The formation is in contact with the Pennsylvanian-Mississippian unconformity in several borings. The thickness varies from a few feet to about 14 ft. The formation consists of gray-brown, medium to coarsely crystalline, fossiliferous limestone in beds ranging from 2 to 14 ft thick, with interbeds or zones of dark gray shaley limestone encountered in several borings. A 1-1/2 to 2 ft thick shale bed occurs near the middle of the formation in most borings.

(3) Big Clifty formation. The Big Clifty formation is divided into

WORKING DRAFT

two distinctly different lithologic members. The upper member is known as the Indian Spring shale and consists of a 20 ft thick bed of dark gray, thinly bedded, platey to fissile, carbonaceous shale that is fossiliferous locally. The lower 3 to 4 ft of shale is generally massive, olive to olive gray and tan, and oxidized in contact with the underlying sandstone. The Indian Spring serves as an aquiclude at the base of the Golconda/Haney aquifer zone. The lower member of the Big Clifty formation consists of 40 ft of yellow to olive tan, massive, rippled, very fine, well sorted, friable sandstone that is cut by numerous intersecting joints.

(4) Beech Creek formation. The Beech Creek consists of fossiliferous, very hard and dense limestone that ranges from 18 to 22 ft thick except in areas where downward solutioning has removed the upper portions. In the upper one third to one half of the formation the limestone is light to medium gray brown, medium to coarsely crystalline and has occasional stylolites. In the lower zone the limestone is dark gray, fine to medium crystalline and contains occasional to numerous wavy shaley partings. Generally, the lower few inches of limestone contain rounded shale inclusions from the underlying Elwren shale. The limestone has numerous intersecting joints. The Beech Creek limestone and the overlying Big Clify sandstone together represent the middle aquifer zone at the ABG site.

c. **West Baden Group**

(1) Elwren formation. The Elwren averages 20 ft thick and consists of massive to thinly bedded, dark gray-green relatively impervious shale with interzones of red-brown claystone. The Elwren serves as an effective aquiclude at the base of the Beech Creek limestone.

(2) Reelsville formation. The Reelsville averages 10 ft in thickness. The formation consists of an upper 1 to 3 ft of hard sandy limestone that grades laterally into calcareous sandstone; a middle zone of massive to thinly bedded dark gray to gray-green shale; and a lower 1 to 3 ft zone of fine grained sandstone that is locally calcareous.

(3) Sample formation. The Sample formation ranges from 40 to 45 ft thick and consists of dark gray to black, thinly bedded, platey to fissile shale with occasional thin to thick beds of light gray, fine grained, massive, friable sandstone. The sandstone beds generally occur in the lower zone. Approximately 1-1/2 miles north of the ABG site an outcrop of the Sample formation consists of sandstone in a 25 to 30 ft section.

(4) Beaver Bend formation. The Beaver Bend ranges from 10 to 12 ft thick and consists of medium gray-brown, medium to coarsely crystalline, fos-

WORKING DRAFT

siliferous, very hard and dense limestone that is occasionally oolitic. The formation has numerous intersecting joints.

(5) Bethel formation. Only five wells bottomed in the upper portion of the Bethel formation. The zone penetrated consisted of black thinly bedded shale with occasional light gray sandstone lenses and light gray sandstone with shale lenses.

Analysis of geologic cross sections. The controlling geologic and hydrogeologic factors underlying the ABG site and interrelated portions of the total study area are graphically portrayed in a total of thirteen geologic cross sections (Plates 6-11 and 13-16). The cross sections were constructed primarily from boring data, but in some cases include data from outcrop examination. Ground-water profiles and the stratigraphic positions of well screens are included on the sections. Borings shown on the cross sections as having 2 or 3 well screens located in different stratigraphic horizons represent well cluster sites, where more than one ground water zone was encountered. The well screens at the cluster sites are numbered beside the boring to correspond to ground-water levels shown on the cross sections.

The exploratory drilling program has continued to provide additional boring data since the construction of the cross sections. The later borings have not been included on the sections. However, preliminary analysis implies that the new data will only complement the existing sections.

The geologic cross sections are divided into two interrelated sets or groups. The first group of cross sections represents the geologic-hydrogeologic conditions underlying the ABG site. The second group of cross sections is at a smaller scale than the first and represents the geologic-hydrogeologic conditions related to and extending beyond the ABG site, including springs. A plan of the ABG site geologic cross sections (AA' through II') is presented as Plate 5. The geologic cross sections AA' through II'are presented as Plates 6 through 11, respectively. A plan of the area geologic cross sections (JJ' through MM') is presented as Plate 12. The geologic cross sections JJ' through MM' are shown in Plates 13 through 16.

The general geologic characteristics associated with each of the cross sections are discussed in the following paragraphs. The geological development of the solution cavern passages that are shown on many of the cross sections will be discussed in detail in a separate section following the discussion of cross sections. Detailed ground-water data analysis is presented under the next major heading (Hydrogeology) and will make reference to the geologic cross sections.

WORKING DRAFT

A composite of geologic cross sections AA'through DD' (Plate 6) was constructed to present a panoramic encompassing view through borings located around the perimeter of the ABG site. The individual sections can be viewed separately, but are connected to show the continuity of the geologic conditions underlying the site in all directions. The composite section begins at boring C16, runs clockwise around the outer portion of the ABG site and concludes at C16. The individual sections are views looking north, east, south, and west from a point located in the center of the ABG. The geomorphology of the ABG valley floor, in relationship to elevations and stratigraphic horizons, is shown in the north, east and west views (sections AA', BB' and DD', resp.). The highest elevation and stratigraphic horizon in the ABG valley floor region lie in the west view. The corresponding lowest zones lie in the east view.

The well screens shown on the cross sections are in the Golconda/Haney, Beech Creek, and Beaver Bend limestones, representing the three ground-water zones encountered at the ABG site in descending order. The ground-water profile shown for the Golconda/Haney is somewhat misleading in the perimeter section (Plate 6). Actually, all of the ground water in this upper zone at the ABG has a flow potential downward into the ABG valley, and eventually into the middle ground water zone through the Big Clifty sandstone outcrop area (more discussion under Hydrogeology, below). The effective drawdown of the middle ground water profile occurring in the area of solution cavities and shown in section BB' (Plate 6) is obvious. Four of the five deep borings that extended into the Beaver Bend limestone are included on the perimeter section (Plate 6). Well screens in the lower ground-water zone revealed a horizontal piezometric surface at an elevation slightly higher than 512 ft MSL. The highest and lowest elevations on the middle ground water profile are approximately 558 ft and 545 ft (MSL), respectively.

Geologic cross section EE' (Plate 7) runs from west to east along the ABG valley floor, beginning with boring C1 and concluding with boring C5. The alluvial thickness ranges from about 4 to 12 ft, and averages between 5 and 7 ft thick. The section shows how the upper and middle ground-water zones are hydraulically connected through the Big Clifty sandstone outcrop area. The middle ground water profile drops rapidly in elevation to the east (between borings C3 and C11) as the influence of ground water outflow through the solution passages is approached. The headward advancement of the solution passages underlying the eastern ABG valley floor ends between borings C11 and C12.

WORKING DRAFT

(Discussions of sections FF' through MM' are not included in this draft but will be presented later).

Solution cavern passages. The current hydrogeological investigations being conducted in the ABG study area indicate that the following modes of formation of solution cavern passages are in effect in the study area. The caverns encountered by borings in the eastern portion of the ABG have been identified as part of a complex solution cavern passage system. The cavern passages have formed in the Beech Creek limestone in the area underlying and bordering the Little Sulphur Creek valley. The cavern system began in the lower reaches of Little Sulphur Creek and has migrated headward into the ABG as a by-product of the erosional processes that have carved out the present Little Sulphur Creek valley.

Solutioning in the Beech Creek limestone begins when the overlying Big Clifty sandstone is initially exposed to surface waters during valley incision. The Big Clifty sandstone is highly permeable and accepts nearly all of the water that comes in contact with its surface. The water seeps rapidly downward through the sandstone and into the underlying Beech Creek limestone. After entering the limestone the ground water can go no deeper because of the aquiclude formed by the underlying Elwren shale. The increasing ground water supply entering through the Big Clifty sandstone is forced to move horizontally through joints in the limestone. Cavern passages are opened along the joints and at the top of the limestone by solution resulting from the increasing ground-water flow. The ground water finds outlets through springs issuing from Beech Creek outcrops along the valley flanks farther downstream. The solutioning has continued to work its way headward to its present position in the ABG in conjunction with incision along the Little Sulphur Creek valley. Caverns that have developed on top of the Beech Creek limestone have resulted in the subsequent collapsing of overlying blocks and slabs of the Big Clifty sandstone. The solutioning processes as described above are illustrated in geologic cross section JJ' (Plate 13), which extends along the Little Sulphur Creek valley from above the ABG to the NWSC south boundary. The solution features can be seen in an outcrop in the east valley wall just south of spring "C".

Solution caverns have developed in the Beech Creek along other drainage ways both north and south of the ABG, where favorable stratigraphic conditions have evolved similar to those along Little Sulphur Creek. One of these drainage ways, of great importance in the ABG studies, lies along Johnson Hollow, located south-southwest of the ABG (Plate 1). Solution caverns in the

WORKING DRAFT

Beech Creek along Johnson Hollow are believed to be connected to those in the Little Sulphur Creek valley in the area near the south boundary of the NWSC. The relationship of the solution features in Johnson Hollow and the west end of the ABG is illustrated in geologic cross section KK' (Plate 14). The relationship between the Little Sulphur Creek valley and Johnson Hollow is shown in geologic cross section MM' (Plate 16). Solution caverns along Little Sulphur Creek and Johnson Hollow are the controlling conduits for the greater part of ground water flow from the middle ground water zone at the ABG.

Springs issuing from the base of the Beech Creek limestone north at the ABG (Mt. Springs and springs "D", "E" and "F", Plate 12), are part of cavernous systems, but are not believed to be connected to the solution systems south of the ABG. The relationship of Mt. Springs to the ABG is shown in geologic cross section LL' (Plate 15). At this point in the ABG studies, there is still a possibility that Mt. Springs may in some way be influencing the ground water conditions in the middle aquifer at the ABG.

Hydrogeology of the ABG.

Three separate and progressively deeper zones of ground water were identified by borings at the ABG site. The lower ground water zone is in the Beaver Bend limestone; the middle ground water zone is in the Beech Creek limestone and the overlying Big Clifty sandstone; and the upper ground water zone is in the Golconda/Haney limestone. The relative positions of the three aquifer zones can be seen on the geologic cross sections. The ground water in each zone is primarily contained in rock joints, with the storage capacities and flow rates dependent on the joint frequency, size of openings, and interconnection of openings.

Lower ground water zone. Ground water in the Beaver Bend limestone is confined by the overlying and underlying aquicludes, the Sample and Bethel shales, respectively. The Beaver Bend aquifer produces piezometric levels in monitoring wells that range from 50 to 60 ft above the top of the aquifer, or 33 to 47 ft below ground-water levels in the middle zone. Five monitoring wells were set in the Beaver Bend aquifer. The wells were located at the north, south, east, and west ends of the ABG site, with one well located near the center of the site. Water levels measured in the wells over a period of time showed that the piezometric surface of the Beaver Bend aquifer remains about horizontal at approximately 512 ft msl. The depth to the piezometric surface below the ABG valley floor ranges from approximately 112 ft at the west end to 70 ft at the east end.

Recharge into the lower aquifer is from areas of Beaver Bend outcrops

WORKING DRAFT

located in Sulphur Creek and other favorable drainage valleys, lying updip to the north and northeast of the ABG site. Examples of surface drainage in contact with the Beaver Bend are presented in geologic cross sections LL' and MM' (Plates 15 and 16, resp.).

It is doubtful that any significant connection exists between ground water in the middle and lower aquifers at the ABG site. Totaling the combined thickness of the Sample, Reelsville and Elwren formations, approximately 70 feet of predominantly impervious shales separate the two aquifers and provide an effective aquiclude. The non-connection between the two aquifers is emphasized by the difference in ground water surface (piezometric) elevations and the contrasting surface geometries. Another preliminary indicator of non-connection was evidenced by measurements made in the wells following a period of heavy rain. Most of the wells in the middle aquifer showed higher readings, ranging from 0.2 to 0.5 ft above previous readings. In contrast, the ground water levels in the lower aquifer remained about the same as previous measurements.

Middle ground water zone.

a. General analysis. The middle aquifer is partially open to surface water infiltration within the ABG; has hydraulic connection through solution caverns to springs south of the ABG (and possibly north, also); and is the most likely aquifer to receive and transport contaminants from the ABG disposal activities. The greater part of the study effort was applied toward defining the hydrogeologic parameters surrounding the middle aquifer. The middle aquifer includes the Beech Creek limestone and the Big Clifty sandstone, which are hydraulically connected and total 60 ft in thickness. The Elwren shale formation underlies the Beech Creek and provides an aquiclude at the aquifer base. The surface of the Elwren aquiclude under the ABG is defined by one-ft contours from boring data (Plate 17). The Elwren surface has local irregularities, but the general dip of the surface is from northeast to southwest, consistent with the regional stratigraphic dip trends. Elevations on the Elwren surface range from 539 ft, MSL, in the northeast area of the ABG, to 520 ft MSL in the southwest area.

A total of 22 monitoring wells has been set to date in the middle aquifer during the course of this study. Seventeen of the wells are within the ABG site, three wells are to the north of the site and two wells are to the south of the site. Contours on the middle aquifer at the ABG site were constructed from water levels measured in the monitoring wells on April 1, 1987 and on June 25, 1987. The resulting ground water maps are shown in

WORKING DRAFT

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WORKING DRAFT

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WORKING DRAFT

Plates 18 and 19, resp. Additional data from wells set after April 1 are included on the June map. The June map also includes an overlay of ground water contours on the upper aquifer where data were made available in the western part of the ABG (discussed below).

The ground water trends in the middle aquifer are nearly identical on each map, and show a complex multi-directional flow pattern. Ground water enters the ABG from the north-northeast, flowing downdip through joints and along bedding planes in the Beech Creek limestone. The zone of ground water entry into the ABG lies between borings C7 and C13. (Boring C26 has since been drilled near the mid-point between these borings and will probably represent the background well at the ABG site). Recharge into the middle aquifer apparently originates from updip, to the northeast and north of the ABG site. Surface waters enter through outcrops of Big Clifty sandstone and Beech Creek limestone lying in favorable areas west of Sulphur Creek and along drainage ways flowing into Sulphur Creek north of the ABG. Recharge into the middle aquifer also occurs within the ABG through the Big Clifty sandstone area shown in Plate 4. The high zone on the middle ground water surface at the ABG lies slightly above an elevation of 558.5 ft msl. The high zone encompasses borings C3, C9, C13 and C26, and covers the central and north-central portions of the ABG. The 558.5 ft contour defines the high on the ground water maps.

Ground water in the eastern half of the ABG is flowing rapidly out of the middle aquifer through the cavern passage system along Little Sulphur Creek. Ground water from the middle aquifer in the western half of the ABG flows at a slower rate out to the south and southwest, following the stratigraphic dip. There is a slight component of flow, indicated by the ground water contours on the middle aquifer surface, to the northeast from the northwestern portion of the site.

b. Detailed analysis. Where erosion has not intervened, the top of the Big Clifty-Beech Creek aquifer zone is protected from direct downward seeping water from the upper aquifer by the Indian Springs, a 20 ft thick shale aquiclude. The areas that are underlain by all or part of the Indian Springs shale lie along the valley slopes and in the northwestern and western valley floor regions (Plate 4). In the central and eastern regions of the ABG valley floor, erosion has progressed below the Indian Springs and exposed a large area of the Big Clifty sandstone. The sandstone is highly permeable and is capable of taking most of the water that comes in contact with its surface. The clayey nature of the relatively thin valley alluvium that blankets the sandstone retards the downward flow of surface water, but does not appear to

WORKING DRAFT

hold water for any great length of time. Once the water reaches the top of the sandstone, it seeps rapidly downward until it reaches the ground-water level in the middle aquifer. Ground water seeping from the upper (Golconda/Haney) aquifer into the ABG valley flows down the eroded slopes of the Indian Springs shale at the base of the alluvium and into the Big Clifty sandstone similarly to surface water conditions.

Surface water enters the Big Clifty sandstone outcrop area from two sources within the ABG. One source is from rainfall. The other source is from two creek branches that flow into the ABG from the west and the northwest and represent the headwaters of Little Sulphur Creek. The branch water is derived from ground water in sandstones and possibly from coal seams in the higher Pennsylvanian strata, and from seeps out of the Golconda/Haney limestone. The branches join near the center of the ABG and the flow continues out the east end of the site, then south down Little Sulphur Creek valley. During drier periods and in light to moderate rains, all of the surface water in the branches becomes ground water in the middle aquifer through the Big Clifty sandstone within the ABG. During wetter periods and heavier rainfall, a large part of the branch water enters the ground-water system within the ABG, and the remainder flows out the east end of the site. All of the surface water that exits the ABG eventually becomes ground water through an outcrop of Big Clifty sandstone located in the creek bed approximately 300 ft south of the ABG. The one exception is during periods of very heavy rain, when water flows freely along the creek bed for short periods of time. Normally, the Little Sulphur Creek bed remains free of water flow until a point is reached downstream where the valley downcutting has progessed to the top of the Elwren shale. The Elwren shale is reached approximately 3/4 mile south of the ABG near Spring "C" (Plate 12). Spring "C" issues a moderate volume of ground water from the base of the Beech Creek limestone, and starts a new source of surface water flowing down Little Sulphur Creek. The creek bed remains in the Elwren shale past the south boundary of the NWSC, which lies approximately 1-1/2 miles south of the ABG. Springs "A" and "B" (Plate 12) issue additional waters from the Beech Creek limestone to the surface flow before the creek crosses the NWSC boundary. A number of springs are reported to issue from the Beech Creek along the Little Sulphur Creek valley flanks south of the NWSC boundary. Groundwater is also seeping from the Beech Creek into the Valley alluvium below the surface.

The ground water that is issuing from the springs and seeps along Little Sulphur Creek is hydraulically connected through the solution cavern passage

WORKING DRAFT

system to the middle ground water zone at the ABG. The hydrogeologic relationships in the above statement are illustrated in geologic cross section JJ' (Plate 13). The ground water in the middle aquifer in the eastern half of the ABG flows practically unrestricted out through the cavern passage system.

Evidence of the rapid transfer of surface waters through the solution cavern ground water system was observed during two periods of heavy rainfall. The observations were made at springs "C" and "A", where shortly following the rainfall the volume of outflow had greatly increased above normal. The larger volume of water issuing from the springs had turned murky and light grayish tan in color. In each case, by the next day the springs had cleared up and returned to their normal flow. Seasonal changes in rainfall also produce a gradual increase and decrease in the total volume of outflow from the springs. However, the springs never seem to run dry.

The system of solution cavern passages that has developed in Johnson Hollow is interrelated to the cavern system along Little Sulphur Creek valley. The two cavern systems intersect at the junction of Johnson hollow and Little Sulphur valley, near the south boundary of the NWSC. Ground water flowing southwest out of the middle aquifer in the western half of the ABG is gradually pulled south-southeast, toward conduits in the solution cavern system along Johnson Hollow. Geologic cross section KK' (Plate 14), includes two borings (C24 and C25) in Johnson Hollow and shows the drawdown on the middle aquifer water surface induced by the free flow provided along the solution passages in Johnson Hollow.

The ABG south valley wall projects southward and becomes a broad high ridge that is bounded on the west by Johnson Hollow and on the east by the Little Sulphur valley (Plate 1). The ridge terminates as a nose at the junction of Johnson Hollow and the Little Sulphur valley. The Beech Creek limestone has been breached at the base of the ridge, around the nose and up both drainage valleys for a considerable distance. Geologic cross section MM' (Plate 16) cuts the ridge normal to its axis and shows the isolation of the middle aquifer zone between the two valleys, caused by the breaching. The cross section also shows that the flow component from Johnson Hollow at boring C___ is toward Little Sulphur Creek at Spring "C". The only active springs issuing from the Beech Creek at the base of the ridge are spring "B" at the end of the nose, and spring "A", located near the nose on the Little Sulphur Valley side. Geologic cross section LL' (Plate 15) extends along the axis of the ridge from the ABG to below spring "B". Section LL'illustrates the potential lowering effects on the middle aquifer induced by the breaching of the

WORKING DRAFT

Beech Creek aquifer base.

South of the ridge nose and just inside the NWSC boundary, an alignment of nine alluvial wells was installed across the valley as part of the ABG study. (The details concerning these wells have not been finalized for reporting at this time, but will be included in the final report.) The nine borings revealed an abundance of ground water contained in gravelly sands in the lower half to two-thirds of the alluvial valley fill. The alluvial fill ranges from 10 to 15 ft thick and is resting on the Elwren shale. The source of the alluvial ground water is from seeps out of the basal Beech Creek limestone below the alluvial surface. A large portion of the seepage water originates from the zone bounded by Johnson Hollow and the Little Sulphur valley. As stated earlier, there is no ground water in the valley alluvium at the ABG.

In order to illustrate the middle aquifer flow pattern beyond the ABG, a ground-water contour map was constructed as an overlay to the area topographic map (Plate 1). The map was constructed from data points at the ABG; the two borings in Johnson Hollow; one boring at the NWSC south boundary; and surveyed elevations at springs "A", "B" and "C". The ground water map has a 5-ft contour interval and is presented as Plate 20. The flow pattern shown on the map implies that all or nearly all of the ground water in the middle aquifer at the ABG eventually flows out through the Little Sulphur Creek valley, either as surface water issued from springs or as ground water in the alluvium. The above statement applies both to ground water flowing rapidly out the eastern half of the ABG, and to ground water flowing more slowly out the western half of the site.

Approximately one mile north of the ABG site, Mt. Spring (Plate 12) issues a large volume of water from the base of the Beech Creek and starts a major branch flow which empties into Sulphur Creek. There is evidence (not conclusive) that Mt. Spring may be hydraulically connected to ground water in the northwest portion of the ABG as shown on geologic cross section LL' (Plate 15). Mt. Spring appears to be flowing at an elevation that is 3 to 5 ft below the higher water levels of the middle aquifer at the ABG. The elevation at Mt. Springs was estimated from contours on the topographic map. Beech Creek springs "D", "E", and "F", lying north-northeast of the ABG, also flow into Sulphur Creek, but appear from topographic map elevations to be slightly higher then ground-water levels in the ABG. A survey is planned to determine the true elevations of each of the northerly springs.

WORKING DRAFT

Upper ground water zone. The upper ground water zone at the ABG is in the Golconda/Haney limestone and is underlain by the Indian Springs shale aquiclude. The aquifer is opened or breached in the ABG valley slopes, and underlies the extreme western portion of the valley floor. Six monitoring wells were installed in the upper aquifer at the west end of the ABG and one well at the C8 boring site. Contours were constructed on the upper ground water surface at the west end of the ABG and are shown as an overlay to the contour map of the middle aquifer in Plate 19. The western end of the ABG is the lowest zone in relation to the stratigraphic dip at the ABG. If ground water were to be exiting from the ABG through the upper aquifer, it should be occurring in the western zone. Instead, the ground water contours show that ground water from the upper aquifer is actually flowing into the ABG. The available evidence supports the observation that any ground water seeping from the upper aquifer within the ABG eventually ends up in the middle aquifer zone. There is no evidence that possible contaminants entering the upper aquifer would exit the ABG other than through the middle ground water system.

WORKING DRAFT

INDIANA DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WATER

WATER RESOURCE AVAILABILITY REPORTS FOR INDIANA

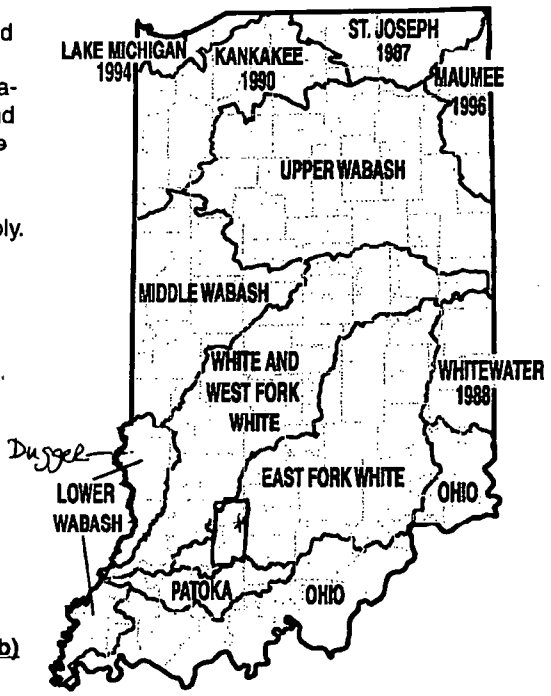
Although Indiana is a water-rich state, few reports have summarized the state's water resource on a regional basis. Perhaps the most comprehensive treatment of Indiana's water resource can be found in a series of reports published by the Indiana Department of Resources, Division of Water. In these studies, the division summarizes the amount, location, and characteristics of surface water and ground water for regional river basins **(figure 1)**. By comparing the supply potential of surface-water and ground-water systems with current and projected water use, the division can identify areas of potential water-use conflicts and areas of underutilized water supply.

Topics covered in the basin study reports include:

- Socioeconomic setting
- Geological framework
- Climatic features
- Surface-water hydrology and quality
- Ground-water hydrology and quality
- Current and projected water use
- Potential for water use conflicts

Of the twelve regional river basins shown in **(figure 1)**, five have been completed. They include the **St. Joseph(file size 831kb), Whitewater(file size 1,020kb), Kankakee(file size 1,649kb), Lake Michigan(file size 1,991kb),** and **Maumee(file size 1,918kb)** River basins. Work is presently underway on the White and West Fork White River basin. To view an executive summary of a given report, please select from the above list.

Figure 1. Indiana Water Management Basins



ACTIVITY FILES

CULTURAL RESOURCES SURVEY

Crane Division
Naval Surface Warfare Center

Crane, Indiana

June 1992

Northern Division Naval Facilities Engineering Command

4.0 ARCHAEOLOGICAL AND BUILDING SURVEYS

HIGHLIGHTS

The archaeological survey revealed 19 historic and prehistoric sites, or possible sites. The buildings survey revealed six sites that are eligible for listing on the National Register of Historic Places.

4.1 ARCHAEOLOGICAL SURVEY

The archaeological investigations were designed to sample the range of environmental settings at Crane and test the validity of predictive models developed for adjoining areas at Crane.

The existing site location model was provided as part of the *Overview Survey Report, Naval Weapons Support Center, Crane, Indiana*, prepared by Greenhorne and O'Mara Inc. October 1990. In that model areas with high potential for prehistoric archaeological sites are upland rises overlooking streams, heads of drainages or swales, and rockshelters. Areas of low potential are steep slopes without rock shelters or overhangs. Areas that had undergone intensive construction were identified has having little or no potential for archaeological resources. Local information used to assess the predictive site model was obtained from the SHPO, the Hoosier National Forest, Crane, and the Hoosier National Forest overview prepared by the Glenn A. Black Laboratory of Archeology (Sieber et al. 1989).

Data on historic settlement was obtained from Crane personnel and from maps and local histories reviewed at county government offices and local libraries. Early Soil Conservation Service maps were also examined. Modern topographic maps were reviewed for cultural features and for landforms. The site predictive model was modified, incorporating this research. The revised model adds low terraces, floodplain rises (knolls, levees, etc.), and floodplains inside stream bends and at stream confluences to the inventory of highly likely locations for prehistoric sites. For historic sites, it was assumed that agricultural settlements would not be found on the limited tillable land, which would have been required for crops. On the other hand, it was assumed that the camps of those involved in exploiting specific resources (e.g., loggers, or bog iron or early drift miners) would be found convenient to work places.

Sites for 60 shovel pits were selected using USGS topography maps, to test the revised model. In selecting locations, the two major considerations were presence of a "desirable" topographic feature and easy road access. Test locations were submitted to the Navy for review and provided to the SHPO as a professional courtesy. Several locations proved to be in unsafe areas, or areas where special escorts were required. Alternative sites were selected.

For the broadest coverage, the testing program was designed to test for presence/absence of cultural material in one pit at each shovel site. Some evidence was found that cultural resources are present and not rare at Crane. Cultural resources were found in 13 (23 percent) of 60 test pits. The high success rate was significant, especially since just one shovel pit was made at each location.

A total of 19 historic and prehistoric sites or possible sites were recorded on state survey forms. Of these, 13 were found by shovel testing; one discovered in the field at a previously unselected location; and the remainder identified by Crane personnel. The methodology of testing was simple. The field team walked to the approximate location selected, chose a reasonable place for a shovel test, and dug an irregular hole through the "C" soil horizon. The walls of the pit were inspected, then fill was broken up and sifted back into the pit by hand.

A summary of tested areas is included in Appendix B.

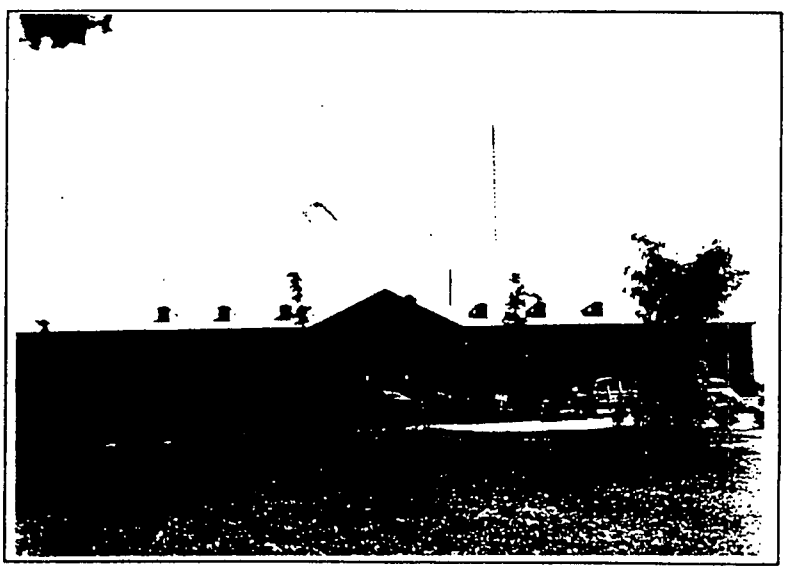
4.2 BUILDING SURVEY

4.2.1 Purpose of the Survey

The building survey evaluated all buildings, structures, and sites for eligibility for the National Register of Historic Places. The survey was conducted by direct observation of the developed areas, comparing the types and quality of buildings, structures, and site areas at Crane. The intention was to apply the National Register criteria, in conjunction with functional data and records of modifications made to many of the facilities. The building survey will be used as a source of information for facilities planning decisions and for the ongoing facilities management program at Crane.

The architectural survey began by identifying the existing structures that were conducted during or before 1946, based upon review of *Document P-164, Detailed Inventory of Naval Shore Facilities*, 30 September 1990. The architectural team photographed each building (or building type, if repetitive.) Using the photographs, plans, and observations, the buildings were evaluated for architectural significance and integrity. Archival research established the original uses and appearances of the buildings and aided in the determination and evaluation of the historical significance of each structure or group of structures within the context of naval history in general and within the context of the history of this installation. The National Register evaluation criteria were used to evaluate each building and district.

There are no previously identified historic resources on the site and no buildings or structures are listed in local or state inventories or the National Register of Historic Places. The following architectural and engineering resources were identified during the survey as eligible for listing on the National Register as individual resources or as contributing elements to a historic district.



Building 13

Pump House

Crane

On a national level, Crane is considered historically significant as the primary ammunition depot for the east coast requirements of the U. S. Navy, in its role in the storage, manufacturing, and development of munitions. The site structures and plan are considered to have architectural and engineering significance relating to the WPA-constructed recreation structures remaining from the state forest and park occupation, the early farmhouses remaining before state and federal ownership of the site, and the design of the site, buildings, and structures by the architectural and engineering firm of Russell B. Moore Company.

District A: Industrial/Administrative Area

This district consists of the grouping of buildings originally planned for the core of the area labeled "industrial area." The district is potentially eligible under criteria A and C as containing the earliest buildings constructed at the facility, for the site plan of the area, and for the design of the buildings. The buildings are assembled along an open green, and share architectural style and detailing: they form a cohesive group.

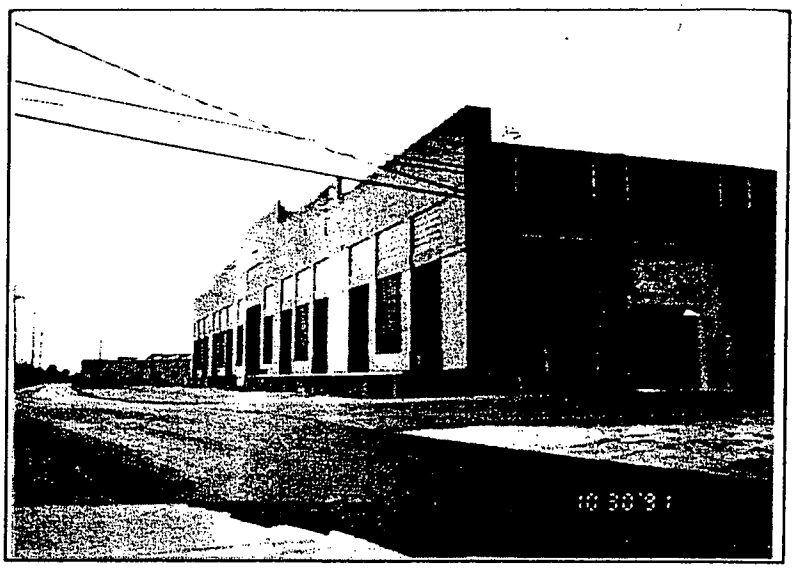
The potential district includes all of the buildings and structures of the original industrial area, the open space between the buildings, and the open space surrounding the area that constitutes the "viewshed" of the area. The viewshed area typically includes all land between the site and the next ridgeline. It is clear from the original site plan that the original barracks (Building 13) was sited on the highest land point of the industrial area and oriented to take advantage of the views the topography offered.

District B: Residential Area

This district consists of the original single-family detached housing constructed on the site. Designed by Russell B. Moore Co., Architects and Engineers, the houses were intended to be consistent with the 1938 WPA residence constructed for the park ranger. The 23 houses and 13 garages/outbuildings are of stone and wood construction, masterfully sited to take advantage of the topography, to provide views of the lake and woodland and to provide privacy. The proposed district is eligible under criterion A for its association with the development of Crane and under criterion C for the siting and design of the buildings and as the work of the R.B. Moore firm. The district includes the residences and outbuildings, the open space between the buildings, and the viewsheds from the houses; the views of Lake Greenwood are particularly critical.

WPA Construction

As part of the White River Land Utilization Project, the WPA undertook construction of recreational facilities for the planned state park. Several of these structures remain and have been maintained by the Navy as part of Crane's recreation areas along the banks of Lake Greenwood. Although primarily wood frame and log construction,



Building 40

the buildings have stone foundations and substantial stone fireplaces and chimneys. In addition to the buildings, several stone culverts were noted along highway H-438, and are considered significant.The buildings are considered eligible under criterion A for their association with the WPA program and under criterion C for their architectural design.

Bridges

Several bridges on site are considered eligible for listing on the National Register. The bridges are Navy- and WPA-built, and include wood, concrete, and stone construction. Those bridges constructed by the Navy were designed by R.B. Moore and represent the work of the firm. Not all bridges were accessible during the on-site survey. It is therefore possible that additional, eligible bridges may exist. The bridges presently identified are significant under criterion A for their association with the development of the site and criterion C for their design and engineering.

Individual Industrial Buildings

In addition to the buildings included in district A, Buildings 34, 36, 37, 38, and 40 appear to meet National Register criteria. The buildings were part of the facility as originally planned, before its scope expanded after Pearl Harbor. The buildings are the same in design and detailing as the buildings in district A. The buildings are eligible under criterion A for their association with the development of the site by the Navy and under criterion C for their design, construction materials, and construction methodology and for technological improvements in the storage of ordnance.

Farmhouses

Two individual farmhouses have been identified as eligible. Both farmhouses were remodeled by the Navy and continue in use as housing. The farmhouses are eligible under criterion A for their association with farming in Indiana, association with the White River Land Utilization Project, and association with the development of Crane as a ammunition depot. The farmhouses may also be eligible under criterion C for use of materials and style characteristics of rural residential construction in Indiana.

Detailed descriptions of the engineering and architectural development of the Crane site appear in Appendix C. More detailed descriptions of the National Register criteria and application of those criteria to the Crane site also appear in Appendix C. Appendix D summarizes legislation and regulation relevant to construction and preservation at Crane.

December 21, 1940

NT1-13/A1
NBS:SA

Burns City

December 21, 1940

From: Officer-in-Charge of Construction
Naval Ammunition Depot
Burns City, Indiana

To : Chief of the Bureau of Yards and Docks

Subject: Proposed Development Plan For Station

Enclosure (A) Marked Tax Map.

1. Enclosure (A) has been marked to show the proposed general layout for development of this station. This layout is, of course, very general as yet, as only a small part of the area has been surveyed. However, considerable thought has been given to the location of the personnel and industrial areas, and the general location of high explosive and other type magazines. The location of the star shell loading plant and mine filling plant will require further study.

2. Figures on the enclosed area are as follows:

	Acres	Sq. Miles
Total area proposed	30,576	47.7
Area already owned (Dept. of Agriculture)	18,210	28.5
Area under option (Dept. of Agriculture)	1,388	2.2
Area to acquire (including land optioned as well as that which has not).	12,366	19.3

3. The area shown will provide for the following types and numbers of buildings.

Projectile magazines	75
Smokeless powder magazines	65
Fixed ammunition magazines	15
Inert storage buildings	25
pyrotechnic magazines	15
High explosive magazines	413
Star shell loading plant	1 sq. mile
Mine and bomb filling plant	3400 ft. x 1000 ft.

RG 71, Bu Docks
Naval Prop. Case Files
Box 443, Burns City
115-2-B, Nav. Ammo. (2 of 2)

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4. In determining the number of smokeless powder and other types of buildings which must be served by railroad the terrain is assumed to be 50% usable (hence the exagerated spacing on the enclosure). This is due to the extremely rough nature of the topography and the difficulty of constructing railroad tracks with their low limits of grades and curves. For the high explosive magazines which are served by highway with steeper allowable grades, the land is assumed to be 75% usable.

5. Attention is invited to the large area which is necessary to acquire, 18,000 acres. The acquisition of these scattered tracts is a project of some magnitude and it is recommended that the Officer-in-Charge be authorized to obtain options, or that a representative of the Judge Advocate Generals office be sent out to do this. Enough area is already owned by the government for the contractor to do considerable work so that the acquisition of additional area is not something which is urgent enough to accomplish within the next few days but that area north of the Chicago, Milwaukee, and St. Paul Railroad tracks should be acquired within the next six weeks.

6. That area south of the railroad tracks which contains most of the high explosive area should be acquired as soon as possible giving due consideration to economy and time for the present land owners to settle themselves in other locations. If this area is not acquired now the value of the land will be enhanced by the Depot development, and in addition the owners will probably construct improvements in the form of housing, gasoline stations, cheap restraunts, etc. which will be of no value to the government but which it would have to pay for. There are only a few scattered houses and no towns in the proposed area. Blankenship, which shows as a town, contains only 4 or 5 houses and a dilapidated store.

7. The District Attorney advises that in this location it is his experience that negotiation is more satisfactory to all concerned and much more economical than condemnation. If the area north of the tracks can be acquired by negotiation within the next few weeks or so it could be done by this method, otherwise condemnation will be necessary. The area south of the tracks can be acquired largely by negotiation.

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8. The average price paid by the Department of Agriculture for the land already acquired was $8.00 per acre. Figures are not yet available on the option price which has been obtained by the same department. The area which has not yet been acquired is the best land in the area and will probably cost more to obtain than the above figure. At an estimate cost of $20.00 per acre, the total land yet to acquire would cost approximately $250,000.

9. Attention is invited to the personnel and industrial areas shown on the enclosure. It is desirable to separate such activities from the explosive area, and the location shown on the lake is a beautiful area and well suited for recreational facilities of the personnel. It is proposed to start work in this area and a tentative layout will be forwarded for approval within the next few days. In this connection it is requested that complete sets of plans be forwarded for similar buildings at Hawthorne.

10. To sum up the following is requested:

1. Approval of the area selected. It is assumed that the Bureau will require a delineation of the boundary line in order to transfer that part of the area owned by the Department of Agriculture.
2. Permission to obtain options.
3. Approval of the personnel and industrial areas.
4. Plans of personnel and industrial buildings at Hawthorne.

W. B. Short.

REPRODUCED AT THE NATIONAL ARCHIVES

NAVY ASSESSMENT AND CONTROL OF INSTALLATION POLLUTANTS:

INITIAL ASSESSMENT STUDY
of
Naval Weapons Support Center
Crane, Indiana
UIC: N00164

May 1983

Prepared by:

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6.1.10.3 Building 600, Transfer Depot

At this munitions transfer depot, an open storage and trailer parking area to the southwest contains a hose and truck washout facility. Explosives-carrying vehicles are hosed down in this area. The 1979 study gave the following values for soil samples taken in the vicinity of the washrack.

	TNT, ppm	RDX, ppm	HMX, ppm
Soil (surface)	6.0	2	3.0
Soil (surface)	2.8	1,032	12.4
Soil (1-ft. depth)	1.7	418	60.0

6.1.10.4 Conservation Dam No. 2845

This conservation pond, located south of the Pyrotechnic Test Area, was reportedly used for testing floating-type pyrotechnics in the past. Only limited testing was conducted, and the potential contamination is minimal.

6.1.10.5 Old Phyrotechnic Test Area

This test area, inactive since the ~~early~~ 1970s, is located on the north side of Highway H-5 northeast of Building 2940. Extensively used for testing flares, ignition devices, and smoke markers, the area has small potential for significant contamination.

2930?

6.1.10.6 Lake Greenwood

Some four sites were reported as past test areas for floating-type markers and flares on this 800-acre lake. Also reported was testing of MK25 and MK72 flares in the 1950s, as well as the testing of mine location markers in the late 1960s. The testing of bombs in the lake during World War II is documented, but could not be substantiated as to type, quantity, or whether the rounds were live or inert.

archive letter @ bomb

6.1.10.7 Miscellaneous Summary

The comparatively low volume of operations throughout these miscellaneous facilities results in low potential for contamination. The high concentrations from soil samples near Building 181 and the washrack near Building 600 are localized. Soil samples taken some distance from the facilities give contaminant levels below 1.0 ppm.

6.1.11 Explosives Operating Building

The following subparagraphs list buildings that have housed significant explosives operations, e.g., black powder, smokeless powder, and explosives compositions. The present building title is listed, with the past title or function, along with ordnance material handled, enclosed in parentheses.

Partial List of Rare Plants at NWSC Crane
(Not listed as threatened or endangered)

Showy Orchis	Sessile Trillium
Lesser Fringed Orchis	Twinleaf
Ginseng	Sullivantia sullvantii
Nodding Trillium	Asplenium penvatifidum
Large White Trillium	Asplenium trechomanes
Yellow Trillium	Vittaria lineata

Major Tree Species at NWSC Crane

Black Ash	American Elm
White Ash	Red Elm
Large-toothed Aspen	Hackberry
Baldcypress	Bitternut Hickory
Basswood	Monhernut Hickory
Beech	Pignut Hickory
River Birch	Shagbark Hickory
Boxelder	Honeylocust
Ohio Buckeye	Black Locust
Butternut	White Oak
Black Cherry	Austrian Pine
Black Maple	Jack Pine
Red Maple	Pitch Pine
Sugar Maple	Scotch Pine
Yellow Poplar	Shortleaf Pine
Black Oak	Virginia Pine
Chestnut Oak	White Pine
Chinquapin Oak	Yellow Poplar
Pin Oak	Sweetgum
Red Oak	Black Walnut
Scarlet Oak	Sycamore
Shingle Oak	Willow
Cottonwood	

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Partial List of Fauna at NWSC Crane (Continued)

Other Birds (Continued)

Winter wren
American robin
Cedar waxwing
Cardinal
Dark-eyed junco
Whippoorwill
Swamp sparrow
Great blue heron
Herring gull
Belted kingfisher
Red-bellied woodpecker
Horned lark
Carolina chickadee
White-breasted nuthatch
Carolina wren
Eastern bluebird
Starling
American goldfinch
Tree sparrow
Purple martin
White-throated sparrow
Ruby-throated hummingbird

Salamanders

Eastern newt
Redbacked salamander
Two-lined salamander

Frogs and Toads

Fowlers toad
Chorus frog
Cricket frog
Spring frog
Grey tree frog
Leopard frog
Bull frog
Green frog

Turtles

Spring softshell turtle
Snapping turtle
Box turtle
Painted turtle

Lizards

Five lined skink
Fence lizard
Ground skink

Snakes

Garter snake
Banded water snake
Dekays snake
Black racer
Black rat snake
Milk snake
Rough green snake
Hognose snake
Copper head
Rattle snake

Aquatic Animals

Crayfish
Freshwater mussels
Golden shiner
Redear sunfish
Channel catfish
Spotted sucker
Carp
Yellow perch
Warmouth
Largemouth bass
White bass
Brown bullhead
Bluegill sunfish
Walleye pike
White crappie
Yellow bullhead
Longear sunfish

Partial List of Fauna at NWSC Crane

Reintroduced Mammals

- White-tailed deer
- Beaver

Small Mammals

- Opossum
- Mice
- Raccoon
- Cottontail rabbit
- Red fox
- Gray fox
- Long-tailed weasel
- Striped skunk
- Mink
- Coyote

Larger Rodents

- Muskrat
- Woodchuck (Groundhog)
- Gray squirrel
- Fox squirrel
- Eastern chipmunk
- Flying squirrel

Water Fowl and Shore Birds

- Canada goose
- Mallard duck
- Ringnecked duck
- Lesser scaup
- Hooded mergansers
- Black duck
- Redhead
- Common merganser
- Bufflehead
- Common loon

Game Birds

- Wild turkey
- Ruffed grouse
- Bobwhite quail
- Woodcock

Raptors that Rest on Center

- Red tailed hawk
- Red-shouldered hawk
- Broad-winged hawk
- Sparrow hawk
- Coopers hawk
- Sharp-shinned hawk
- Great horned owl
- Barred owl
- Screech owl
- Turkey vulture

Fall and Winter Raptor Visitors

- Rough legged hawk
- Marsh hawk
- Short-eared owl
- Long-eared owl
- Saw whet owl
- Bald eagle
- Golden eagle

Other Birds

- American coot
- Rock dove
- Common flicker
- Yellow-bellied sapsucker
- Blue jay
- Tufted titmouse
- Red-breasted nuthatch
- Mockingbird
- Golden-crowned kinglet
- House sparrow
- Rufous-sided towhee
- Field sparrow
- Red-winged blackbird
- Song sparrow
- Killdeer
- Mourning dove
- Hairy woodpecker
- Downy woodpecker
- Common crow
- Brown creeper

Received Jul-08-2003 10:41am From-3174690030 To-MALCOLM PIRNIE WASHI Page 004

List of Pyrotechnic Items Produced

Title

Signal, Illumination, Marine, Mk 2 Mod 0.....
Signal, Smoke, Marine, Mk 2 Mods 0.....
Signal, Illumination, Aircraft, AN-M37A2 Thru AN-M42A2; AN-43A2 thru AN-M45A2 AN-M53A2 thru AN-M58A2.....
Signal, Smoke, Ground, M62, M64 and M65.....
Signal, Smoke and Illumination, Marine, Mk 13 Mod 0.....
* Signal, Smoke and Illumination, Marine, Mk 38 Mod 0.....
Signal, Illumination, Ground, Green, M125A1.....
Signal, Smoke, Ground, M128A1 and M129A1...
Signal, Hand Fired, Mk 80 Mods 0 and 1.....
Signal, Illumination, Aircraft, Mk 6 Mod 0.....
Signal, Smoke, Aircraft, Mk 7 Mod 0.....
Fuse, Warning, Railroad M72
Cartridge, Signal, Mk 130, Mk 138, Mk 139, and Mk 140 Mods 0.....
Cartridge, Signal, Mk 121, Mk 122, and Mk 123 Mods.
Flare, Aircraft, Parachute, Mk 5 Mods.....
Flare, Aircraft, Parachute, Mk 6 Mods 3 thru 6.....
Projectile Load, Illuminating, Mk 7 Mod 0.....
Flare, Aircraft, Parachute, Mk 24 Mods 2, 2A, 3 and 4
Projectile Load, Illuminating Mk 4 Mods.....

Title

Projectile Load, Illuminating Mk 9 Mods 0 and 1.....
* Projectile Load, Illuminating Mk 11 Mod 0.....
Projectile Load, Illuminating Mk 12 Mod.....
Flare, Surface, High Altitude, Parachute Mk 20.....
Cartridge, 81MM Illuminating M301A2.....
Flare, Surface M49
Grenade, Hand Illuminating Mk 1 Mods 2 and 3.....
* Flare, Aircraft, Parachute Mk 45 Mod 0.....
Warhead, 5.0 Inch Rocket, Illuminating Mk 33 Mod 1
* Marker, Location, Marine Mk 2 Mods 0 and 1.....
Signal, Smoke and Illuminating, Aircraft Mk 5 Mods 3 and 4...
Signal, Smoke and Illumination, Aircraft Mk 6 Mod 3.....
Marker, Location, Marine Mk 7 Mods 2 and 3.....
Marker, Location, Marine Mk 9 Mod 0.....
* Marker, Location, Marine Mk 25 Mods 0, 1, 2 and 3
* Marker, Location, Marine Mk 58 Mod 0.....
* Signal, Smoke, Aircraft Mk 89 Mod 0.....
Signal, Illumination, Marine, Mk 3 Mods 1, 2 and 3.....
Signal, Smoke and Illumination, Marine Mks 51, 52, and 53 Mods
Marker, Location, Marine, Mk 26 Mod 0 and Marker Location, Submarine,... Mk 75 Mod 0.....

(Continued)

*Major items produced

List of Pyrotechnic Items Produced (Continued)

Title

Signal, Smoke, Marine (Submarine) Mk 2 Mods 0, 1 and 2.....
* Marker, Location, Submarine Mks 21, 22, 23, 24, 76, 77, 78 and 79 Mods 0.....
* Signal, Smoke and Illuminating, Marine Mks 66, 67 and 68..... Mods 0.....
Signal, Illumination, Marine Mks 41, 45 and 46 Mods 0..
* Marker, Location, Marine, Mk 28 Mod 0 and Marker, Location, Submarine, Mk 80 Mod 0.....
False Target, Submarine Mk 2 Mod 0.....
Marker, Location, Marine AN-Mk 1 Mods 0 and 1..
* Marker, Location, Marine, Mk 1 Mods 2 (Green) and 3 (Yellow).....
Marker, Location, Marine Mk 8 Mod 0.....
Bomb, Photoflash M120 and M120A1.....
Cartridge, Photoflash M112A1 Series.....
Cartridge, Photoflash M123A1 Series.....
Cartridge, Signal, Practice Bomb Mk 4 Mods 3 and 4...
Cartridge, Signal, Practice Bomb, Mk 111 Mod 0.....
* Marker, Location, Marine Mk 38 Mod 0.....
Signal Assembly Mk 25 Mod 2
Unit, Color Burst Mk 7 Mod 0.....
Signal Assembly Mks 39, 40, 43 and 44 Mod 0.....
Signal, Smoke and Illumination, Marine Mk 55 Mod 0.....
Signal, Flash, Guided Missile Mk 33 Mods 0 and 1.....
Signal, Flash, Guided Missile Mk 37 Mod 1.....
Signal, Flash, Guided Missile Mk 42 Mod 0.....
Unit, Color Burst Mk 1, Mk 2 Mods 0.....

Title

Unit, Color Burst Mk 3 Mods 0 and 1.....
Unit, Color Burst Mk 5 Mod 0.....
Unit, Color Burst Mk 6 Mod 0.....
Marker Kit, Location Mk 19 Mod 0.....
Projector, Marker Mk 23 Mod 0.....
Signal, Float, Torpedo Mk 21 Mod 1.....
* Flare, Target, Mk 28.....
Flare, Guided Missile Mk 21 Mod 0.....
Tracer Mk 21 Mod 0.....
Flare, Guided Missile Mk 27 Mod 0.....
Tracking Device, Smoke, Mk 1 Mod 0.....
Flare, Guided Missile Mk 25 Mod 0.....
* Flare, Decoy, Mk 42, Mk 43, Mk 46 and Mk 47 Mod 0....
Flare, Guided Missile Mk 23 Mod 0.....
Simulator, Detonation, Explosive Mk 2.....
Simulator, Booby Trap, Flash M117.....
Simulator, Booby Trap, Illuminating M118...
Simulator, Booby Trap, Whistling M119.....
Simulator, Projectile, Air Burst M74A1.....
Simulator, Projectile, Ground Burst M115A2.....
Smoke Pot, HC, Mk 3 Mod 0....
Grenade, Hand, Smoke, WP, M15.....
Smoke Pot M6.....
Cartridge, Igniter, Turbo-Jet Engine Mk 243 Mod 2.....
Flare, Ground, Parachute XM-184.....
Light, Chemical, Aerosol Mk 11 Mod 0.....
* Marker, Location, Chemical, Mk 46 Mod 0.....

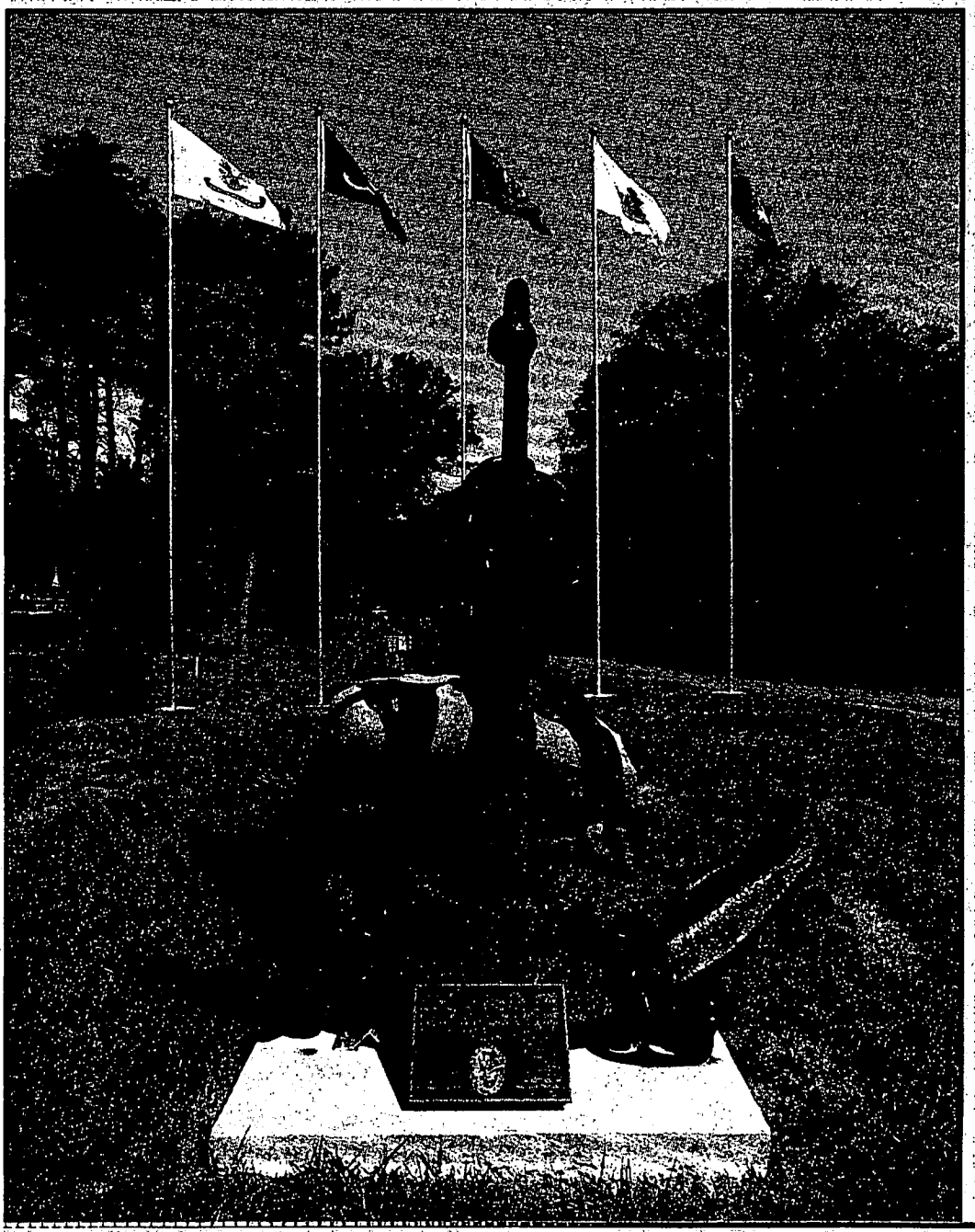
*Major items produced

A GOOD NEIGHBOR:

THE FIRST FIFTY YEARS AT CRANE

1941–1991

BY ROBERT L. REID AND THOMAS E. RODGERS



Crane Division
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Crane, Indiana

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REMARKS:

Harnessing the Power of Technology for the Warfighter

/

MONTHLY REPORT OF OPERATION
WATER TREATMENT PLANT

Report for NAVSURFWARCENDIV BLDG 4 CRANE, INDIANA for the Month of JUNE 20 3
Water Works Name

I.D.E.M. Field Rep. SHAWN FLANNIGHAN

Signed [signature] Title Utilities System Leader

Public Water Supply I.D. No. 5251003 Certification Number 17923

PHYSICAL AND CHEMICAL DATA*

Date	Turbidity		Alkalinity		pH		Hardness		Iron		Manganese		Phosphate	Fluoride
	Raw	Finished	Raw	Finished	Raw	Finished	Raw	Finished	Raw	Finished	Raw	Finished	Finished	Finished
1	4.20	0.14	19	17	7.00	7.20	25	23						0.66
2	2.90	0.14	20	18	6.80	7.80	23	23						0.88
3	2.80	0.12	17	17	6.90	7.70	22	21						0.83
4	3.00	0.11	14	15	6.80	7.70	23	23						0.96
5	2.60	0.11	19	18	6.80	7.80	22	21						0.85
6	2.40	0.10	20	19	7.10	7.80	23	22						0.80
7	2.30	0.11	18	17	6.00	7.60	22	21						0.85
8	2.30	0.13	19	18	7.00	7.50	23	22						0.93
9	2.20	0.10	19	17	7.00	7.40	23	22						0.86
10	2.10	0.10	19	17	7.10	7.80	23	21						0.97
11	2.40	0.10	20	19	7.00	7.50	23	22						0.98
12	2.10	0.14	19	18	7.00	7.60	23	23						0.09
13	2.50	0.13	14	16	6.90	7.50	24	24						0.97
14	28.70	0.12	16	18	7.10	7.80	23	23						0.97
15	9.00	0.18	17	19	6.80	7.30	25	24						0.88
16	4.50	0.14	16	10	6.90	7.50	24	24						1.03
17	3.70	0.18	19	18	6.80	7.70	23	23						0.00
18	3.80	0.19	20	19	6.90	7.80	23	24						1.02
19	3.30	0.13	19	18	6.80	7.90	23	22						0.80
20	3.40	0.11	20	19	7.00	7.80	24	23						0.85
21	3.70	0.10	20	18	7.00	7.00	23	22						0.93
22	3.10	0.12	19	18	7.00	7.90	24	23						0.87
23	2.90	0.19	20	19	7.10	0.00	23	22						0.76
24	2.80	0.14	19	17	6.90	7.70	22	21						0.87
25	2.80	0.14	20	19	7.00	7.60	23	22						0.88
26	2.30	0.14	21	20	7.10	7.60	23	22						0.91
27	2.60	0.17	24	21	7.00	8.00	22	23						0.03
28	3.20	0.20	23	22	7.10	8.70	22	24						0.70
29	2.00	0.14	21	22	7.00	7.20	22	23						0.28
30	3.00	0.46	22	23	6.90	6.80	23	24						0.86
31														

*All parameters are to be expressed in mg/l except pH and turbidity

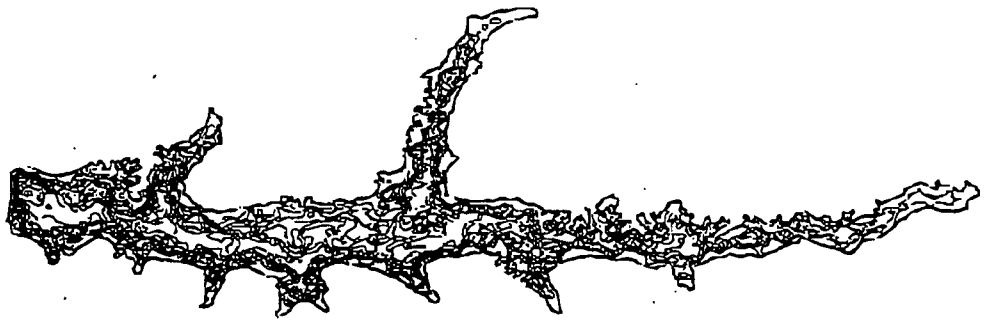
avg = avg = avg = avg = avg =

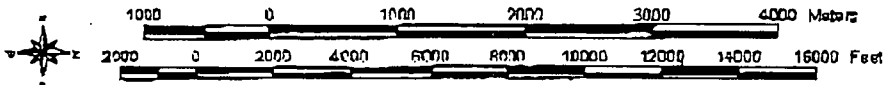
Raw samples are taken at our water treatment plant - prior to treatment. These ~~Fluoride analysis~~ represent Lake Greenwood water.

Enclosure (1)

2

-FINAL-
Lake Greenwood Diagnostic Study





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Bloomington, Indiana University

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Box 28
Bloomfield, Indiana

July 2001

1993). The total nitrogen : total phosphorus ratio measured in August in Lake Greenwood was 3 : 1. Thus, at the time of sampling, Lake Greenwood was nitrogen limited – a rare occurrence in Indiana lakes. The primary sources of nitrogen to lakes are runoff and biological fixation. Many blue-green algae are nitrogen fixers (convert N_2 into inorganic nitrogen) and this can be an important source of nitrogen to many lakes. Lake Greenwood's plankton population was only 32% blue-greens.

Summary. From the data collected, we can conclude that Lake Greenwood is a rather unproductive lake with regards to algae and essential algal nutrients. The trophic state of the lake hasn't changed much since the only other comprehensive assessment of the lake in 1996. The Indiana TSI score for both assessments was only 7. There were differences in score distribution between the two assessments, however. In 1996, the samples were taken during an algae bloom and TSI points were assigned to algal density and poorer light transmission. In 2000, algal densities were very low but TSI points were assigned for higher total phosphorus concentrations.

Higher phosphorus concentrations in Lake Greenwood are troubling as additional phosphorus can stimulate increased algal growth in phosphorus-limited lakes. However, because Lake Greenwood was nitrogen-limited at the time of sampling, this additional phosphorus did not stimulate algal production. Higher hypolimnetic ammonia concentrations in the 1996 assessment drove the mean total nitrogen : total phosphorus ratio to 17.8 : 1, which indicated phosphorus limitation at that time.

Our working model for Lake Greenwood is that the lake isn't overly productive. The products of that productivity are consumed largely by decomposers before they can build up in the sediments. The higher algal productivity in 1996 resulted in increased hypolimnetic ammonia concentrations, the primary by-product of bacterial decomposition. A consequence of this heterotrophic process, oxygen is consumed. However, despite the anoxia, no phosphorus was released from the sediments.

Our concern is that increased nitrogen can flip Lake Greenwood to a phosphorus-limited system with a resulting increase in algal production. The long-term consequences of this is decreased transparency, increased anoxia, and build-up of organic matter in the sediments.

AQUATIC PLANT SURVEY AND SHORELINE ANALYSIS

Methods

On August 16, 2000, we conducted a survey of rooted vegetation and shoreline erosion in Lake Greenwood by slowly traversing the entire shoreline area of the lake in our sampling boat. Vegetation stands were identified and noted on enlarged maps of the lake. When needed, plant samples were collected with a double-tined rake for identification in the boat. Plant identifications were made using Fink (1994), Borman et al. (1997) and Nichols (1999). Eroded shoreline areas were marked on separate maps.

Results

A map showing the overall vegetation of the entire lake is shown in Figure 17. More detailed maps of the western, middle, and eastern sections of Lake Greenwood are shown in Figures 18-20. Areal coverage of rooted aquatic plants is given in Table 9. Overall, rooted vegetation covered nearly 260 acres or about 32% of the lake's surface area.

The most abundant rooted plant in Lake Greenwood is Eurasian watermilfoil (*Myriophyllum spicatum*). This species occurs throughout the lake, especially in shallow coves. Large stands of the plant also occur on shallow, offshore bars in the east and central sections of the reservoir. Eurasian watermilfoil is an invasive species that is probably the number one nuisance plant species in midwestern lakes. It can grow in depths greater than 4m, shows no substrate preference, and is not turbidity tolerant (Nichols 1999). It forms a dense surface canopy that effectively blocks out light to shorter native species. Milfoil can spread by small fragments cut by motorboats or wind shearing.

Fragrant water lily (*Nymphaea odorata*) is the next most abundant rooted plant in the lake. The median depth of water in which this plant grows is one meter. It shows no substrate or turbidity preference (Nichols 1999).

For the most part, the shoreline of Lake Greenwood is stable. Areas of shoreline erosion are indicated in Figures 18-20. Our best estimate is that there is less than 600 feet of eroded shoreline needing stabilization. Most individual areas observed were relatively short sections (30 feet) and 3 to 6 feet high. However, several areas on the south side of the lake west of the marina (Figure 19-20) have eroded banks exceeding 10 feet in height.

Discussion

Diverse, moderately dense stands of aquatic plants are desirable in a lake's littoral zone. Emergent aquatic plant communities protect the shoreline from erosion by dampening the force of waves and stabilizing shoreline soils. Vegetation can also provide screening for the lakeshore resident or user and buffer noise from motorboats. Many species of aquatic plants, such as the fragrant water lily and pickerelweed, are aesthetically pleasing because they have showy flowers or interesting shapes. Aquatic vegetation also provides fish habitat and spawning sites, waterfowl cover and food, and habitat for aquatic insects. For example, sedges (*Carex* spp.) become spawning beds for northern pike in spring, wild rice beds (*Zizania aquatica*) attract shorebirds in summer, and wild celery (*Vallisneria americana*) develops tubers that attract canvasbacks in fall and is one of the finest fish food and cover plants (Engel, 1988). Table 10 lists positive attributes of some aquatic plant species.

Non-native plants often do not have these positive attributes and can be overly aggressive in crowding out native species. The dense upper canopy that Eurasian watermilfoil produces is known to crowd out native species. The fact that this species now accounts for more than 64% of the rooted aquatic plant stands in Lake Greenwood is evidence of this.

TABLE 9. Lake Greenwood Littoral Vegetation.

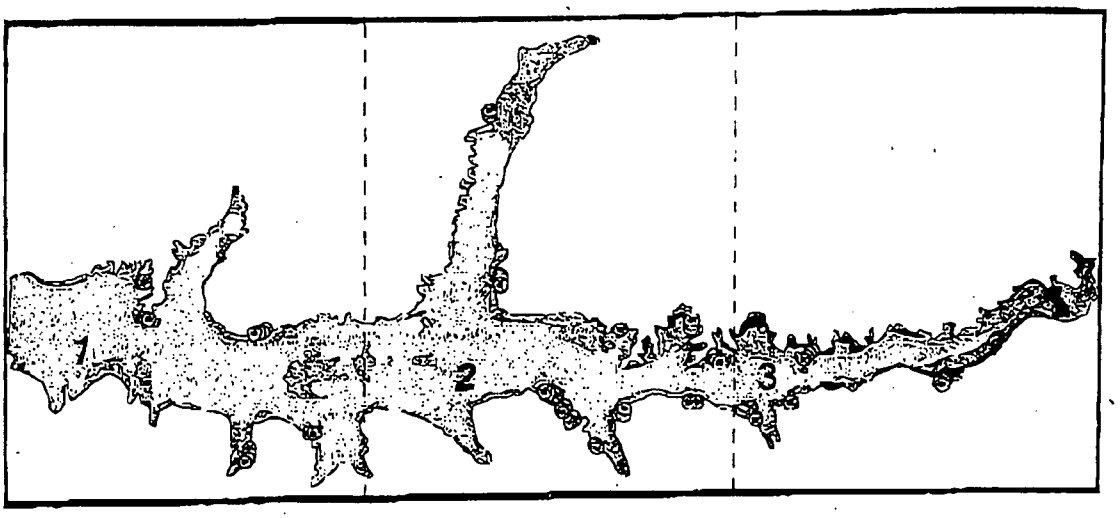
Vegetation Type	Area m^2	Area (acres)	%
American waterwillow	43,379	10.71	4.12
Rushes	2,013	0.50	0.19
Eurasian watermiltoil	679,478	167.83	64.58
Sedges	2,024	0.50	0.19
Slender naiad	74,798	18.48	7.11
Rushes/Sedges (50/50)	7,699	1.90	0.73
Water-thread pondweed	181	0.04	0.02
E. watermilfoil/Slender naiad (50/50)	12,627	3.12	1.20
Spatterdock	57,561	14.22	5.47
Fragrant water lily	14,0281	34.65	13.33
Vallisneria	15,994	3.95	1.52
Chara	4,612	1.14	0.44
Broad-leaf cattail	11,151	2.75	1.06
American pondweed	402	0.10	0.04
TOTAL	1,052,200	259.89	100

TABLE 10. Attributes of a Vegetated Shoreline Buffer

POSITIVE ATTRIBUTES	RECOMMENDED PLANT TYPES
Shoreline erosion control	Grasses, emergents
Wave dampening	Emergents
Screening	Emergents, shrubs
Shade	Trees
Noise buffer	Emergents, shrubs
Aesthetics	Pretty flower or plant form
Fish cover	Submergents, floating leaved
Fish spawning	Varies
Animal cover	Emergents, shrubs
Animal nest sites	Varies
Animal food	Varies
Macroinvertebrate habitat	Submergents

Source: Klessig and Jones (1986)

Figure 17. Lake Greenwood Littoral Vegetation & Shoreline Erosion



0.5 0 0.5 1 1.5 2 Miles

1000 0 1000 2000 3000 Meters

N

1 *Map #1 - Detail of littoral vegetation & shoreline erosion.*

2 *Map #2 - Detail of littoral vegetation & shoreline erosion*

3 *Map #3 - Detail of littoral vegetation & shoreline erosion*

Shoreline Erosion

Lake Greenwood Littoral Vegetation

- American Waterwillow
- Eurasian Water-milfoil
- Brittle Naiad
- E. Water-milfoil/Brittle Naiad (50/50)
- Fragrant Water-lily
- Spatterdock
- Vallisneria
- Water-thread Pondweed
- American Pondweed
- Chara
- Rushes
- Sedges
- Rushes/Sedges (50/50)
- Broad-leaf Cattail
- Open Water

Sources

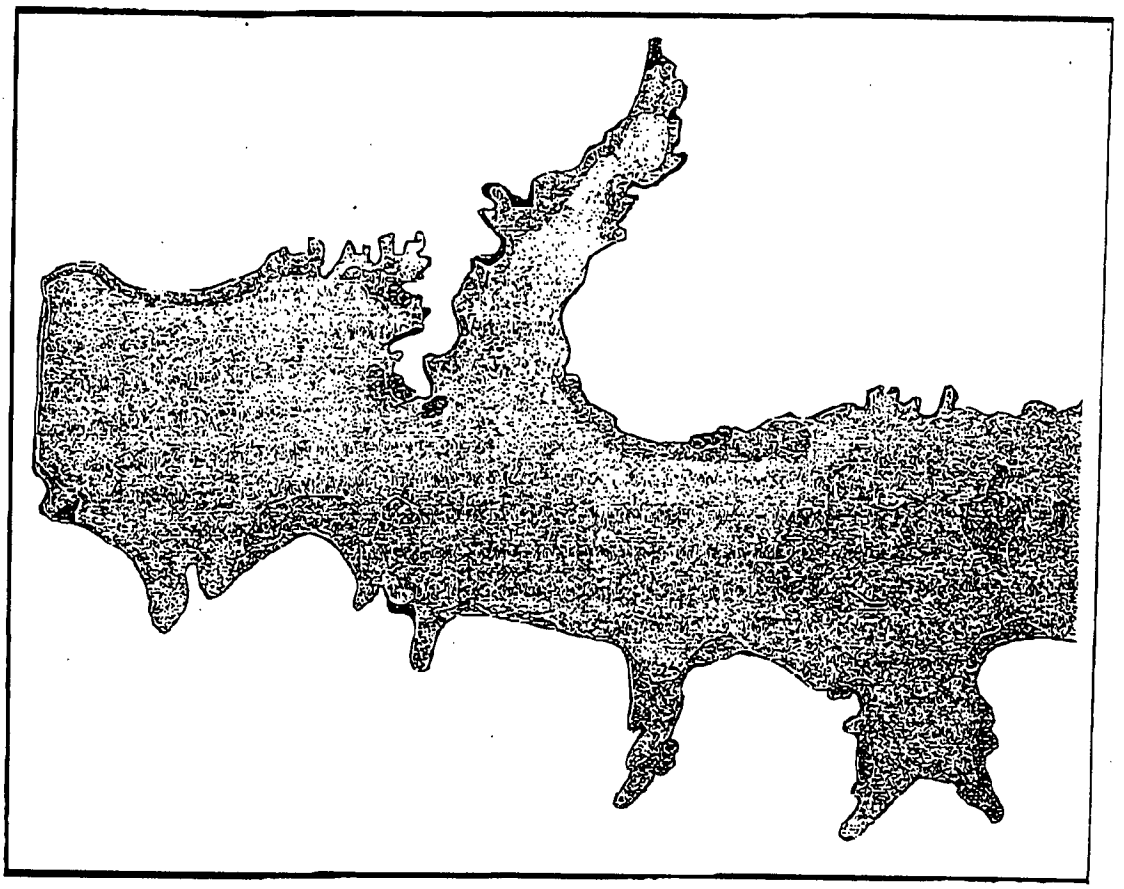
By: Melissa Clark
Date: 10-10-00

Lake Greenwood Shoreline boundary from NWI: U.S. Fish & Wildlife Service, National Wetlands Inventory (NWI). Dates range from Feb. 1971 to Dec. 1992.

Littoral Vegetation Data collected on 08-16-00, By Bill Jones, Melissa Clark, & Sara Peel.

Shoreline Erosion Data collected on 08-16-00, By Bill Jones.

Figure 18. Lake Greenwood Littoral Vegetation & Shoreline Erosion #1



N

500 0 500 1000 Meters

0.5 0 0.5 Miles

● Shoreline Erosion

Lake Greenwood Littoral Vegetation

- American Water-willow
- Eurasian Water-milfoil
- Brittle Naiad
- E. Water-milfoil/Brittle Naiad (50/50)
- Fragrant Water-lily
- Spatterdock
- Vallisneria
- Water-thread Pondweed
- American Pondweed
- Chara
- Rushes
- Sedges
- Rushes/Sedges (50/50)
- Broad-leaf Cattail
- Open Water

Sources

By: Melissa Clark
Date: 10-18-00

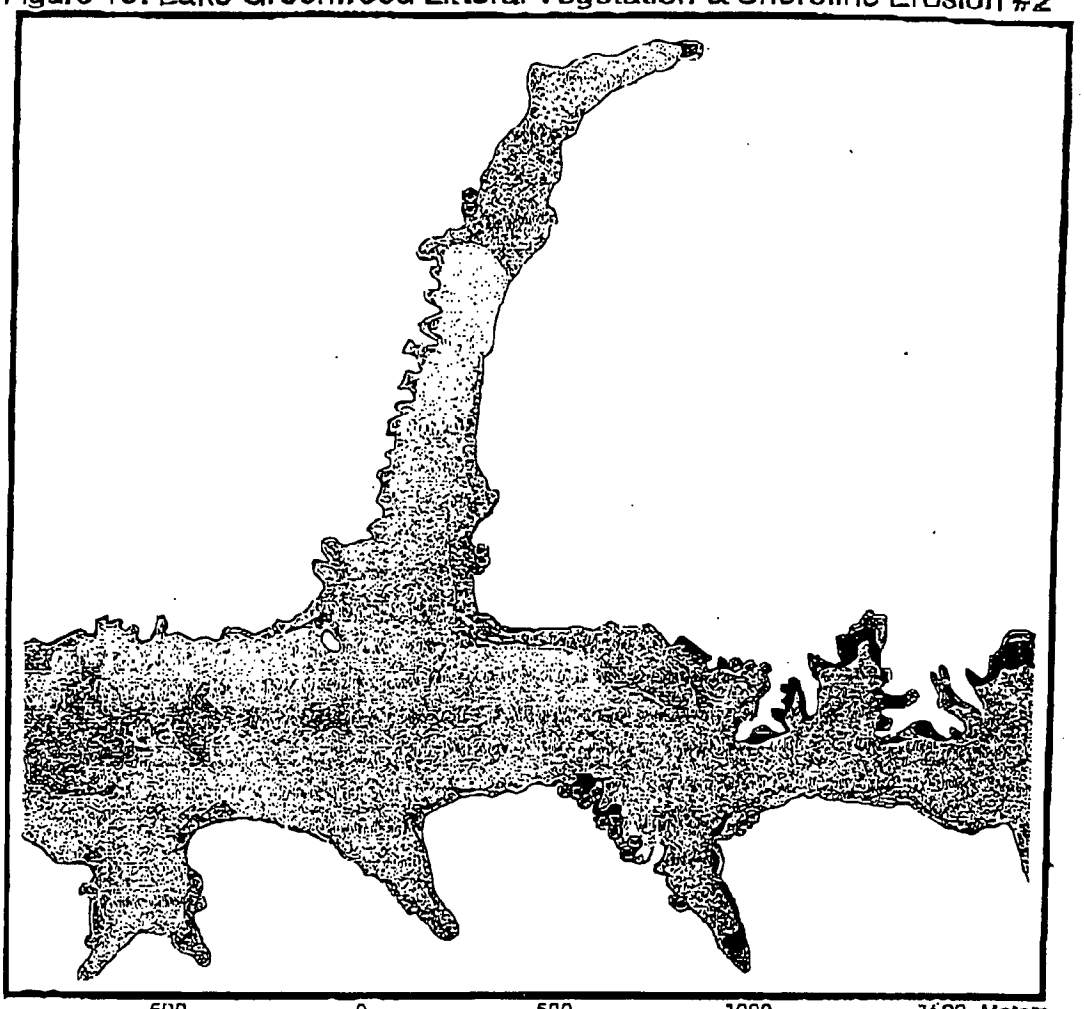
Lake Greenwood Shoreline boundary from NWI: U.S. Fish & Wildlife Service, National Wetlands Inventory (NWI), Dates range from Feb. 1971 to Dec. 1992.

Littoral Vegetation Data collected on 08-16-00, By Bill Jones, Melissa Clark, & Sara Peel.

Shoreline Erosion Data collected on 08-16-00, By Bill Jones.

8

Figure 19. Lake Greenwood Littoral Vegetation & Shoreline Erosion #2



500 0 500 1000 1500 Meters

0.5 0 0.5 Miles

N

Shoreline Erosion

Lake Greenwood Littoral Vegetation

- American Waterwillow
- Eurasian Water-milfoil
- Brittle Naiad
- E. water-milfoil/Brittle Naiad (50/50)
- Fragrant Water-lily
- Spatterdock
- Vallisneria
- Water-thread Pondweed
- American Pondweed
- Chara
- Rushes
- Sedges
- Rushes/Sedges (50/50)
- Broad-leaf Cattail
- Open Water

Sources

By: Melissa Clark
Date: 10-18-00

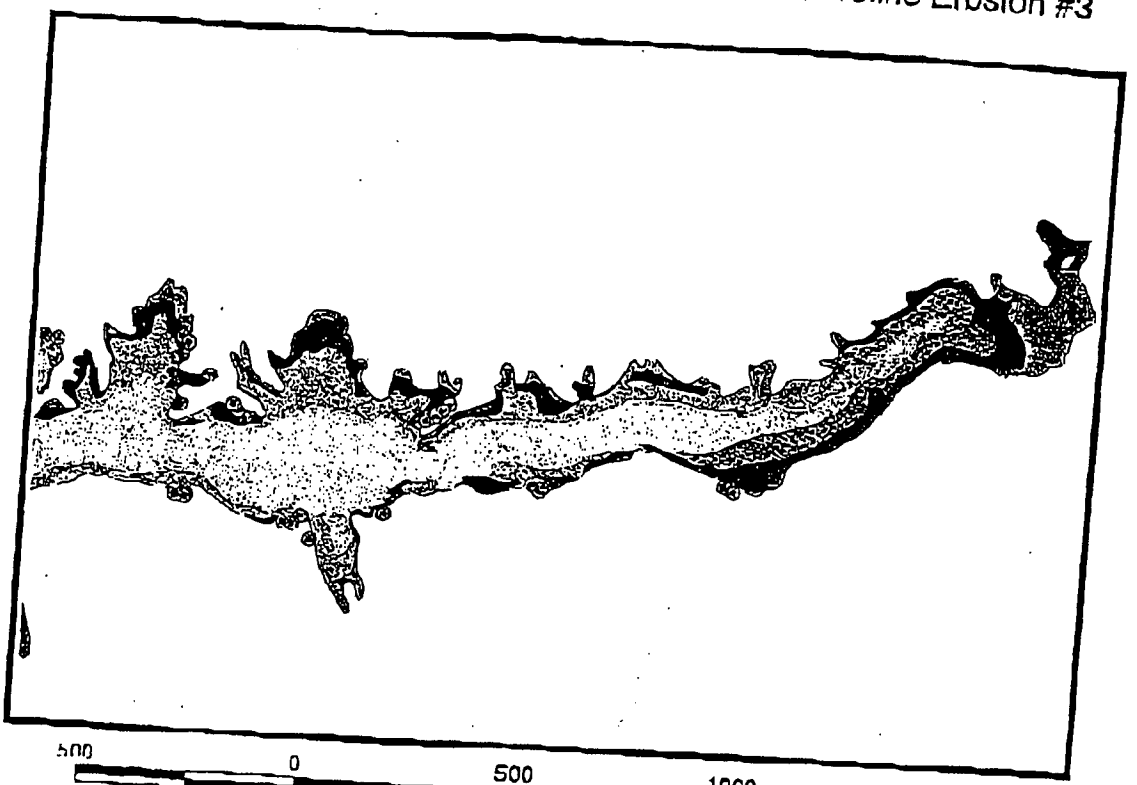
Lake Greenwood Shoreline boundary from NWI: U.S. Fish & Wildlife Service, National Wetlands Inventory (NWI), Dates range from Feb. 1971 to Dec. 1982.

Littoral Vegetation Data collected on 08-16-00, By Bill Jones, Melissa Clark, & Sara Peel.

Shoreline Erosion Data collected on 08-16-00, By Bill Jones.

9

Figure 20. Lake Greenwood Littoral Vegetation & Shoreline Erosion #3



500 0 500 1000 1500 Meters

0.5 0 0.5 Miles

N

Shoreline Erosion

Lake Greenwood Littoral Vegetation

- American Waterwillow
- Eurasian Water-milfoil
- Brittle Naiad
- E. Watermilfoil/Brittle Niad (50/50)
- Fragrant Water-lily
- Spatterdock
- Vallisneria
- Water-thread Pondweed
- American Pondweed
- Chara
- Rushes
- Sedges
- Rushes/Sedges (50/50)
- Broad-leaf Cattail
- Open water

Sources

By: Melissa Clark
Date: 10-18-00

Lake Greenwood Shoreline boundary from NWI: U.S. Fish & Wildlife Service. National Wetlands Inventory (NWI). Dates range from Feb. 1971 to Dec. 1992.

Littoral Vegetation Data collected on 08-16 00, By Bill Jones, Melissa Clark, & Sara Peal.

Shoreline Erosion Data collected on 08-16-00, By Bill Jones.

LAKE SEDIMENTS

Methods

Surficial sediment samples were collected from Lake Greenwood at four different sites along the length of the lake (Figure 14). The samples were collected using an Ekman dredge, then transferred into glass jars and kept in a cooler filled with ice.

In the laboratory, the following was determined for each sample: particle size distribution, percent organic matter, total phosphorus and total Kjeldahl nitrogen. Particle size was determined using hydrometers according to ASTM methods. Organic matter content of the dried sediment samples was determined by weight loss following ashing in a muffle furnace at 550^{0}C for four hours. Total phosphorus and total Kjeldahl nitrogen was determined following cupric sulfate digestion on an Alpkem FLOW Solution Autoanalyzer Model 3570.

Particle Size

The particle size distribution of a sediment sample defines the percentage amounts of the different size ranges in the sediment (by dry weight). The common classification of sedimentary particles was devised by C.K. Wentworth in 1922 according to the following (Twenhofel, 1950):

Name of Particles	Dimensions, mm
Boulder	256 or above
Cobble	64 to 256
Pebble	4 to 64
Granule	2 to 4
Very coarse sand grain	1 to 2
Coarse sand grain	0.5 to 1
Medium sand grain	0.25 to 0.5
Fine sand grain	0.125 to 0.25
Very fine sand grain	0.0625 to 0.125
Silt particle	3.9×10^{-3} to 0.0625
Clay particle	Smaller than 3.9×10^{-3}

Lake Greenwood's sediments have a relatively large percentage of sand-sized particles (Table 11). This is likely due to the primary parent material of local soils – sandstone and shale. Since clay is only a minor component of the local soils, there is less clay in the sediments compared to sand or silt. Nevertheless clay still ranges between 17% and 24% in the sediments of the lake. Fine clay particles have a very slow settling rate and thus, stay in suspension in the water column for a long time. It takes very little energy from water movements to overcome the low density of these particles to prevent their settling. For example, a coarse clay with a settling rate of 0.0015 cm/sec, would take 11.7 days to settle through five feet of absolutely calm, undisturbed water.

TABLE 11. Textural Analysis of Lake Greenwood Sediment - 8/16/00.

Sample	% Sand	% Clay	% Silt
1	59.2	21.4	19.4
2	69.2	16.8	14.0
3	41.2	23.8	35.0
4	38.2	18.4	43.4

Often in long reservoirs having a single major inlet, the largest soil particles drop out initially because it takes more energy to keep them suspended. As the water moves through the lake, losing energy along the way, finer particles drop out. This creates a gradient of larger to smaller particles from the inlet to the outlet. However, we observed little pattern such as this in particle size in Lake Greenwood sediments. Apparently the various small side channels along the lake deliver enough sand- and silt-sized particles to maintain relative homogeneity in particle size along the lake.

Organic Matter

The percentage of organic matter content in lake sediments can be an indicator of organic production in the lake. It also reflects organic matter inputs from watershed runoff. In 'healthy' lakes not suffering from excessive productivity, organic matter is sufficiently decomposed in the water column and at the sediments that it does not accumulate in the sediments. In over productive lakes, more organic matter is produced than can be handled by the heterotrophic organisms and organic matter accumulates. Hasler (1969) termed such lakes as 'physiologically senile", in that they produce more food than they can consume.

The organic matter content of Lake Greenwood sediments is shown in Table 12. Concentrations range from 9% at Site 1 near the dam/outlet to 5.2% at Site 4 near the inlet. In hypereutrophic Cedar Lake, Indiana, organic matter content of surficial sediments ranged from 17-20% (Rehelberger et al. 1984). The organic matter content of Monroe Reservoir sediments ranged from only 2.1-3.5 % (Jones et al. 1997). Lake sediments generally have a higher organic matter content than do reservoir sediments. In a study of sediments from six lakes and four reservoirs in Indiana, the mean organic matter content of lake sediments was 10.1% while that of reservoir sediments was 1.9 % (Orme and Nelson 1979). This may be due to the generally greater flushing rate of reservoirs, which can keep sediments better oxidized, can wash out particulates before they have time to settle out, and can dilute organic sediments with mineral materials from watershed erosion.

The high (for reservoirs) organic content of Lake Greenwood's sediments and the gradient from the dam to the inlet can be explained by the potential sources of organic matter. Although algal productivity is relatively low in Lake Greenwood, there is a significant amount of rooted aquatic vegetation present. The senescence of these plants each fall is an important source of organic matter, nitrogen and phosphorus to the lake. We would also expect that significant organic material loading to the lake would derive from runoff from the steep, forested slopes of the watershed. Such terrestrial organic matter tends to be more resistant to

TABLE 12. Organic Content of Lake Greenwood Sediment – 8/16/00.

Sample	%
1	9.0%
2	5.6%
3	6.5%
4	5.2%
4 dup	5.2%

decomposition than internally produced (autochthonous) sources of organic matter. Thus, this resistant organic matter can build up in the sediments and the fine organic matter can move with the water flow down the lake to the outlet.

Nitrogen and Phosphorus

Sediment-bound nutrients represent a potential pool of nutrients that can, under certain circumstances, be released back into the water column to nourish algae. Unfortunately, there are no guidelines for assessing the amounts of nutrients in lake sediments.

Nitrogen and phosphorus concentrations in Lake Greenwood sediment samples are shown in Table 13. These concentrations are consistent with those measured in other Indiana lake and reservoir sediments. For example, Orme and Nelson (1979) report mean total phosphorus and total nitrogen concentrations in lake sediments as 0.71 mg/g and 6.89 mg/g respectively and 0.72 mg/g and 1.77 mg/g respectively in reservoir sediments. The phosphorus concentrations we found in Lake Greenwood's sediments are somewhat lower than these other values while the nitrogen levels are somewhat higher. Leaves and other allochthonous sources are relatively nitrogen-rich and phosphorus-poor so we might expect higher nitrogen and lower phosphorus concentrations in Lake Greenwood sediments due to these materials.

There is an apparent gradient of higher to lower sediment nitrogen concentrations as one goes from the outlet east toward the inlet. Since nitrogen is strongly coupled with organic matter, and sediment organic matter concentrations followed a similar trend, these results are consistent.

TABLE 13. Nutrient Content of Lake Greenwood Sediments – 8/16/00.

Sample	Phosphorus (mg/g)	Nitrogen (mg/g)
1	0.081	10.509
1 dup	0.098	-
2	0.517	5.545
3	0.134	6.069
3 dup	-	5.990
4	0.123	4.596
4 dup	0.123	4.721

United States
Department of
Agriculture

Soil
Conservation
Service

In cooperation with
United States Department of
Agriculture, Forest Service;
Purdue University
Agricultural Experiment
Station; and Indiana
Department of Natural
Resources, Soil and Water
Conservation Committee

Soil Survey of Martin County, Indiana

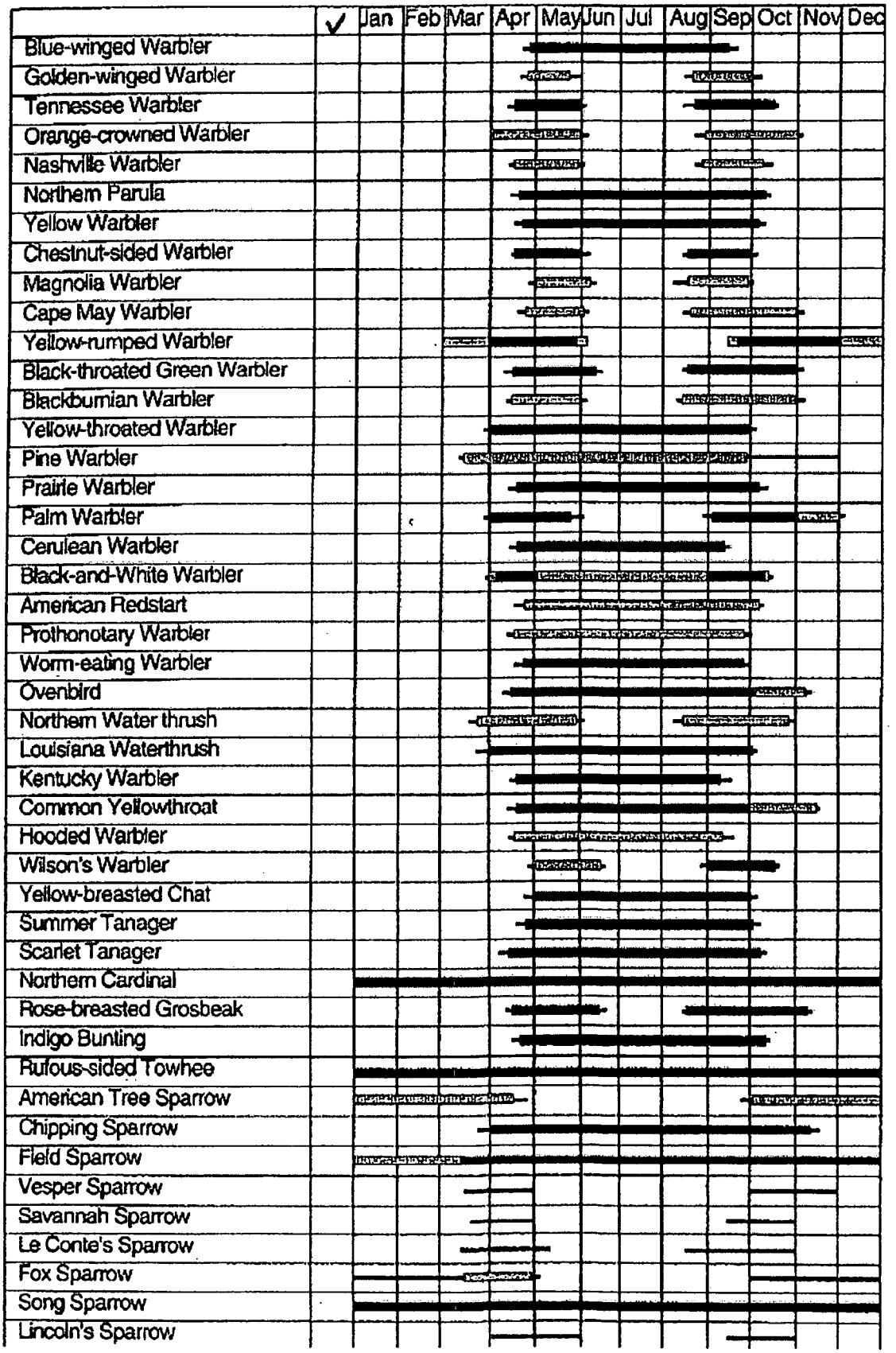
CHECK LIST OF BIRDS
CRANE DIVISION
NAVAL SURFACE WARFARE CENTER

BIRDS OF CRANE DIVISION

DATE:_____
NOTES:_____

	✓	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red-throated Loon													
Common Loon													
Pied-billed Grebe													
Horned Grebe													
American Bittern													
Great Blue Heron													
Great Egret													
Little Blue Heron													
Green Heron													
Yellow-crowned Night-Heron													
Sandhill Crane													
Snow Goose													
Canada Goose													
Wood Duck													
Green-winged Teal													
American Black Duck													
Mallard													
Northern Pintail													
Blue-winged Teal													
Northern Shoveler													
Gadwall													
American Wigeon													
Canvasback													
Redhead													
Ring-necked Duck													
Greater Scaup													
Lesser Scaup													
King Eider													
Common Goldeneye													
Bufflehead													
Hooded Merganser													
Common Merganser													
Red-breasted Merganser													
Ruddy Duck													
Turkey Vulture													
Osprey													
Bald Eagle													
Northern Harrier													
Sharp-shinned Hawk													
Cooper's Hawk													
Red-shouldered Hawk													
Broad-winged Hawk													
Red-tailed Hawk													
Rough-legged Hawk													
Golden Eagle													
American Kestrel													

	✓	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ring-billed Gull													
Herring Gull													
Rock Dove													
Mourning Dove													
Black-billed Cuckoo													
Yellow-billed Cuckoo													
Eastern Screech-Owl													
Great Horned Owl													
Barred Owl													
Long-eared Owl													
Northern Saw-whet Owl													
Common Nighthawk													
Chuck-will's-widow													
Whip-poor-will													
Chimney Swift													
Ruby-throated Hummingbird													
Belted Kingfisher													
Red-headed Woodpecker													
Red-bellied Woodpecker													
Yellow-bellied Sapsucker													
Downy Woodpecker													
Hairy Woodpecker													
Northern Flicker													
Pileated Woodpecker													
Eastern Wood-Pewee													
Acadian Flycatcher													
Willow Flycatcher													
Least Flycatcher													
Eastern Phoebe													
Great Crested Flycatcher													
Eastern Kingbird													
Horned Lark													
Purple Martin													
Tree Swallow													
No. Rough-winged Swallow													
Cliff Swallow													
Barn Swallow													
Blue Jay													
American Crow													
Carolina Chickadee													
Tufted Titmouse													
Red-breasted Nuthatch													
White-breasted Nuthatch													
Brown Creeper													
Carolina Wren													


✓
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Blue-winged Warbler
Golden-winged Warbler
Tennessee Warbler
Orange-crowned Warbler
Nashville Warbler
Northern Parula
Yellow Warbler
Chestnut-sided Warbler
Magnolia Warbler
Cape May Warbler
Yellow-rumped Warbler
Black-throated Green Warbler
Blackburnian Warbler
Yellow-throated Warbler
Pine Warbler
Prairie Warbler
Palm Warbler
Cerulean Warbler
Black-and-White Warbler
American Redstart
Prothonotary Warbler
Worm-eating Warbler
Ovenbird
Northern Water thrush
Louisiana Waterthrush
Kentucky Warbler
Common Yellowthroat
Hooded Warbler
Wilson's Warbler
Yellow-breasted Chat
Summer Tanager
Scarlet Tanager
Northern Cardinal
Rose-breasted Grosbeak
Indigo Bunting
Rufous-sided Towhee
American Tree Sparrow
Chipping Sparrow
Field Sparrow
Vesper Sparrow
Savannah Sparrow
Le Conte's Sparrow
Fox Sparrow
Song Sparrow
Lincoln's Sparrow

NAVY NATURAL RESOURCES AND LAND MANAGEMENT PROGRAM

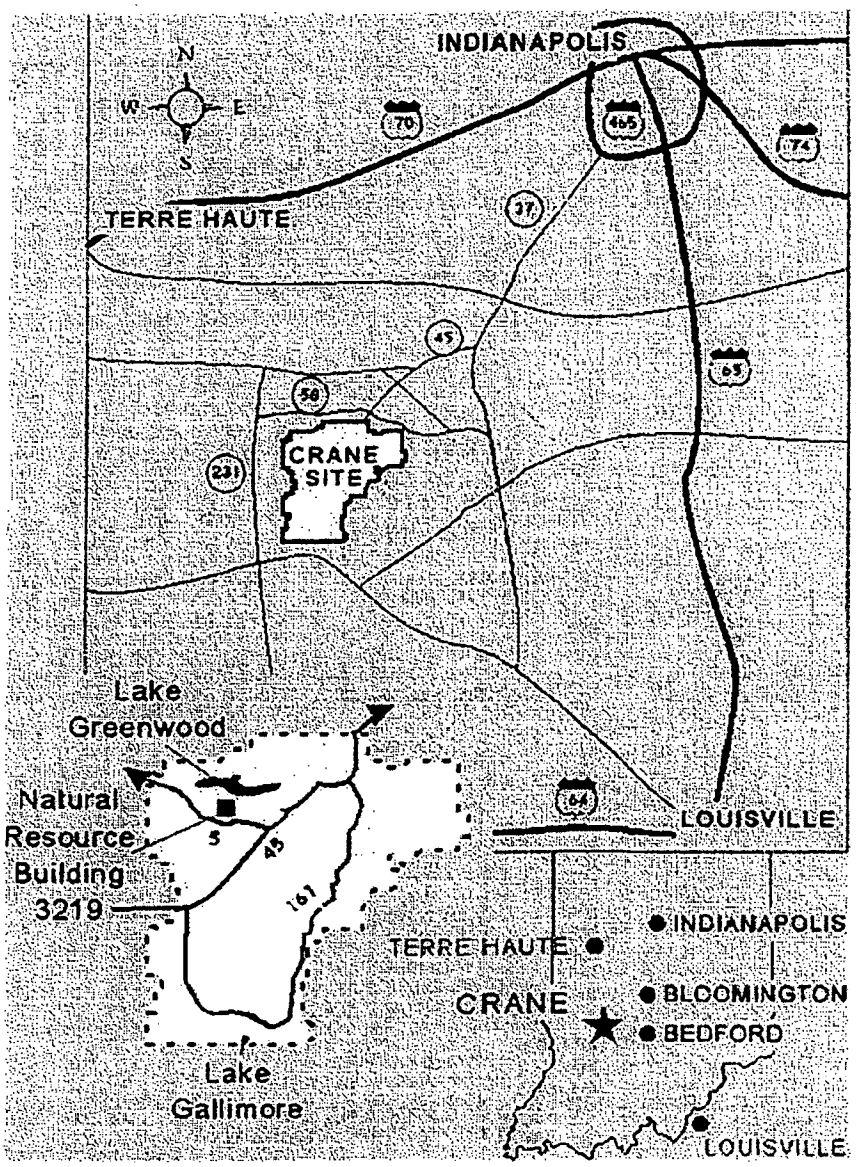
The Navy and Marine Corps manage more than four million acres worldwide. Much of this land is located in sensitive wetlands along valuable coastlines, some of the most ecologically significant areas in the world. The location of these real estate holdings makes it imperative that the various military missions are planned and executed in harmony with the environment. It is a Department of the Navy goal to promote an environmental protection ethic within the Navy workforce.

The Department of the Navy supports numerous partnerships with other Federal, State, local and private resource groups to promote such programs as the North American Waterfowl Management Plan, Neotropical Migratory Bird Conservation, Wetlands P rotection and Enhancement, and Watchable Wildlife.

To succeed in its mission, and to earn public confidence, the Navy must emphasize natural resources stewardship in every aspect of its land use. It does. Come see for yourself and discover our resources.

WILD TURKEYS

NAVAL SURFACE WARFARE CENTER
CRANE, INDIANA



Crane Division's military mission is to provide engineering and industrial base support of Naval weapons systems. Crane Division manages this site, Crane, Indiana, as well as facilities in Louisville, Kentucky. Quality, responsive support of weapons subsystems, equipments and components is provided, as assigned by the Commander, Naval Surface Warfare Center.

Crane site comprises 62,609 acres, of which nearly 49,000 are forested. Oak-hickory, upland mixed hardwood, bottomland hardwood, and pine are the existing forest types. 3,262 acres of wetlands have been identifies, including Lake Greenwood and the extensive marshes of Lake Gallimore. Diversity of the land and successful integration of natural resource management with military mission has resulted in excellent wildlife habitat.

This list was compiled and documented by Dr. Harmon P. Weeks, Jr., Purdue University, who has conducted field studies of birds at Crane Division for over 20 years.

Military mission requirements preclude access by the general public except on special days or with special permission. Please contact the Natural Resources Manager, Mr. Lynn Andrews, (812)854-1165, for information.

The U.S. Navy and the National Fish and Wildlife Foundation are cooperating on an international program to promote conservation of neotropical migratory birds. For more information, call U.S. Navy at (703) 325-0427 or NFWF at (202) 857-0166.

Back to Contents

Appendix C: Project Source Data – Site Specific

Interview Record

Installation/Range or Site: NSWC Crane, Indiana

Date/Time: March 19, 2003

Person Conducting the Interview/Title/Organization: Julie Grim, Malcolm Pirnie

Person Being Interviewed/Title/Organization: Dr. Bernie Douda

Reason for Selecting Person to Interview (i.e., Years at Installation, Position, Previous History, etc.): Dr. Bernie Douda

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Interview Notes (i.e., Range History, Ordnance Types, Land Use, Historical Records/Maps Available):

Lake Greenwood Pyro Test Area Near Dam

-was used in the 50s and 60s

-this site was the major area until pyro areas was set up started with star sell, towards the end of WWII and during Korean

-Fly over and drop into Lake Greenwood, late 70s/early 80s one time thing, 3-4 passes aircraft out of Washington, IN

-Off part where the club is; testing for burning time, green markers, channel into deeper water towards the dam

-At the dam, deepest spot on the lake (35 ft) –kind of hole trying to develop underwater, trying to develop underwater illuminating flare suspended from cables from boat wires ≈ 6-12 tests

-illuminating material, sodium nitrate, burning magnesium, binders CO-CO_2

-Red phosphorus flares

-All recovered hardware back on the boat (all of it was tethered)-green markers

-Occurred during the late 50s early 60s—mid 1950s testing performed finished testing in 1958

-Captain's Pond-late 70s, marking dyes testing, July 13, 1977 bldg 225 was burnt, dye storage and all was lost, dye entered the water shed, contained in bladders

-Pond constructed in 1974, never been dredged

-40 acres in Daves County, Forest Creek, no improvements

-No construction, tried to straighten perimeter fence

-200 +, sold to a doctor early 90s no addition construction

-Area across highway-never fences

-Crane Village, under housing officer (S.) separate utility, Dr. Alias purchased from GSA (all utilities provided by Crane)

-Nothing constructed outside boundary fences

-Oberlin was the original Lake prior to Lake Greenwood, was constructed by boy scouts in the late 60s

-Burial grounds-mustard gas, dug up the containers and removed in the late 1970s/80s replaced and hauled away, GW are currently there

-EOD found something in golf course, Bldg 1 experimental projectile

Interview Notes Continued:

Lake Oberlin-near Crane gate

-Fired out of signaling pistol (like a flare gun)

-Fluorescene dye put on water when person was overboard to test the dye device

-Fired onto the pond (to prevent fire)-you could see the slick

-Currently a boy scout site as of the late 1950s

Dr. Douda mentioned Junior Flick as a possible resource. He did not provide contact information for Mr. Flick.

He also mentioned Jim Short, who was with the army, only works part time (SAIC) ext. 6796, as a possible resource for information about Lake Greenwood and Lake Oberlin.

Interview Record

Installation/Range or Site: NSWC Crane, Indiana

Date/Time: March 19, 2003

Person Conducting the Interview/Title/Organization: Denise Tegtmeyer, Malcolm Pirnie

Person Being Interviewed/Title/Organization: Linda Stoll

Reason for Selecting Person to Interview (i.e., Years at Installation, Position, Previous History, etc.): Explosive Safety Office

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Interview Notes (i.e., Range History, Ordnance Types, Land Use, Historical Records/Maps Available):

-Greenwood Dam: July 4, 1962 there was a pyro demo, Bernie, Dr. Hubble 20 years, 407 pyro gray, #2350 building

-H-333 little testing in 1970s

-No other areas

-Dale Groh is a contractor now, bldg 122, Linda's predecessor, ext. 3601, worked here in the 1960s

MALCOLM PIRNIE

Fisheries Biologist reports on Monroe and Crane's Lake Greenwood

by Don Jordan
From the *Hoosier Times 2/18/01*

After 16 years as the Avoca district fisheries biologist for the Indiana Div. of Fish and Wildlife, nobody has ever known Lake Monroe's fishery better than Steve Andrews who now manages fish and wildlife at Crane.

"I really enjoyed managing Lake Monroe and figuring that fishery out. It was definitely a challenge. I enjoyed developing the predator stocking program there," said Andrews in a recent interview from his new office at Crane.

"Monroe is probably one of the more complex and dynamic fisheries in the state. Nobody will every fully understand what is going on out there. We may be got a hold of some of the basic interactions...the ones you notice," said the biologist who conducted a dozen fisheries surveys of various types at Monroe. "There has been a gradual improvement in the crappie fishing over the last 10 years or so."

The average size of Monroe crappie has increased over the past 10 years. It is possible to catch nice 11 and 12 inch crappie at Monroe now, but they are very hard to locate and are usually in deeper water than most anglers try at Monroe. The presence of larger crappie in Monroe is probably directly related to Andrews' stockings of wiper and walleye, and the pressure those predators exert on Monroe's volatile gizzard shad population.

Monroe's gizzard shad population accounts for nearly one-third of the entire fishery. This population explosion was one reason Andrews stocked wiper and walleye. The results are noticeable, but so are environmental factors at Monroe.

"One of the things I noticed is the increasing development at the lake, and in particular, all the small coves now have a group boat pier in them. Development was noticeable. Also, there has been a noticeable increase in fishing for largemouth bass and particularly in tournament fishing. . The number of boats on the lake has increased to the point that I only go to Monroe during the week" he continued.

"I think tournament fishermen are pretty good at regulating themselves Catch and release fishing has been a main factor that has kept the bass fishing good. I would say Monroe is in the top 20 bass lakes in the state. The numbers of larger bass are still relatively good compared to a lot of lakes," said the Bedford resident.

Lake Monroe's future? Here's what Andrews said: "I don't know that anybody ever

figured out the entire fish population there, but Monroe will probably continue to (be similar to) what it has been for the next 10 to 20 years, and there may be a gradual decline due to aging of the lake. People at Monroe are fortunate that so much of that watershed is protected from development. Predator stocking can at least convert shad into usable fishing opportunities."

LAKE GREENWOOD

Andrews new territory may not be as overwhelming as Monroe's 100,000-acre fishery, but Lake Greenwood inside the Crane reservation is home to nesting bald eagles and is one of the most beautiful and interesting bodies of water in southern Indiana. Andrews is already working on improving or at least holding the line on the fishery there.

Lake Greenwood covers 800 acres and is open to the public in the Crane's public fishing and boating program. Any U.S. citizen can fish Greenwood by purchasing either a $15 annual pass or a $2 daily pass.

"Greenwood is primarily warm water fishery: largemouth bass, bluegill, redear, crappie, channel catfish. It is unusual in that it has a reproducing white bass population, and it doesn't have gizzard shad as a forage bass. White bass are apparently spawning in the lake somewhere," explained the 45-year-old biologist.

He is attempting to get walleye established in Greenwood. The species was introduced last year in the "first modern day stocking" of walleye.

As many local anglers familiar with Greenwood will remember, a large variety of species was stocked at the impoundment over 20 years ago. Northern pike and walleye were among them, but, as Andrews explained, "they never did contribute anything to the fishery."

You may find walleye in Greenwood soon, however. There were two stockings in 2000, he said. One dose of 27,000 1- and 2-inch fingerlings went into Greenwood last June, and 900 "advanced" fingerlings, 6- to 8-inches long were stocked in October.

"Survival of those (June) fingerlings was very limited, if at all. Survival was relatively good for the October advanced fingerlings. The Indiana DNR did a fall shocking survey. They had a catch rate of 6.5 per hour. There standard for a successful stocking is 7 per hour. I have had at least one report of walleye being caught last fall, but we do have a few yellow perch in the lake, in the 6- to 10-inch range that might look like walleye. We do plan to stock walleye for at least the next two years," he said.

Unlike Monroe where walleye were intended to help control gizzard shad, there are no gizzard shad in Greenwood, so far...knock on wood. Andrews said there was a gizzard shad "scare" in the early 90s. A 12- to 15-inch slot limit for largemouth was imposed then, mainly in response to gizzard shad showing up in a survey. The shad have not reappeared, but the slot limit is coming back at Greenwood.

U.S. Fish and Wildlife biologists conducted a fishery survey on Greenwood last summer, and the outcome of that survey has stimulated some tinkering.

"We had a fish management meeting a week ago between federal and state biologists. We agreed to a slot limit for Greenwood this year. The goal is to increase the harvest of smaller bass," he added.

Andrews described Greenwood's fishery, overall, as being in "good condition, especially the panfish and channel catfish. Largemouth bass are good in numbers, but there aren't many legal fish." The slot limit, he hopes, will increase the number of larger bass and decrease the number of small ones.

Here's Andrews summary of other discoveries from the summer, 2000 Greenwood survey:

*Bluegill: "Bluegill were nice size, 9.5 to 10 inch maximum, average about 7.5 inches, and abundant. There was concern that smaller bluegill were not as abundant as they should be. That might be related to the high density bass population. Out of 111 bluegill (in the survey), 31 were 8 inches or larger. So, over a fourth of the bluegill were large ones. There were some big redear in the survey. The biggest was 10 inches."

*Crappie: "The crappie fishery was average. Most fish were in the 9- to 10-inch range. There are both white and black crappie in Greenwood.

*Channel Catfish: The average was in the 2.5- to 3-lb. range. They have established a reproducing population in Greenwood and that is kind of unusual. Typically you see catfish reproduction controlled by bass predation, but Greenwood apparently has some other forage opportunity for bass that is different. There is a large population of shiners. That may be what they are eating. There is also a fairly large population of spotted suckers and white suckers.

Crane also offers reserved public deer hunts in the season, and there is a group campground for scouts and the like at one of the military reserve's other, smaller lakes; however, Greenwood is the only spot open to general public use. Crane is not open to the public for spring wild turkey hunting.

The Crane website address is: http://www.crane.navy.mil

You can contact Don Jordan on the internet by browsing to http://realindy.com and clicking the email link there.

-30-

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Inverness, Florida

April 4, 1946

NT1-18 (PLg)

4 APR 1946

My dear Mr. Johnson:

Your letter of 1 April 1946 enclosing the letter of Milton Matter, Director, Indiana Department of Conservation, concerning the possibility of some plan whereby Lake Greenwood at the Naval Ammunition Depot, Crane, Indiana might be made available for public recreation has been received.

Any plan which would make the facilities of this lake open to the public is considered unfeasible from the standpoints of safety, security, and sanitation.

Lake Greenwood is almost entirely surrounded by processing buildings, storage warehouses, or magazines containing high explosives. Permitting the public access to this area would seriously affect the security of the installation and result in a greatly increased fire hazard, as well as endangering the lives of the people.

Further, the use of the lake by the public for recreational purposes would result in the contamination of the water. The water of this lake, besides being utilized in the preparation of components used in the loading and assembly of gun ammunition and high explosives, is the source of potable water supply for the Naval Ammunition Depot.

I regret that the Navy must take this stand concerning the public use of Lake Greenwood but no other course appears open.

Sincerely yours,

G. F. HUSSEY, Jr.
Vice Admiral, U. S. Navy
Chief of the Bureau of Ordnance

Honorable Noble J. Johnson
House of Representatives
Washington, D. C.

G. F. Hussey Jr. (signed)

G40346 0048

Copy to: Ep17 (Capt. Granat); Adlb

RG 74, Bu Ord
Corr. + Proc. 1946
Box 381, NT1-18

DECLASSIFIED
Authority NND 913566
By AB NARA Date 3/13/06

January 27, 1942

U. S. NAVAL AMMUNITION DEPOT
Burns City, Indiana

NT1-18/N1
EGO:wck

January 27, 1942

MEMORANDUM:

Subject: Conference regarding Naval possession of Lake Greenwood. Acquisition of additional land from Department of Agriculture.

Reference: (a) SecNav ltr L11-10/EA(410424) of 5 Nov. 1941, Ord. file NT1-18(AD3c)

1. After numerous postponements a conference was finally held on this date at this Depot, regarding the ultimate disposition of Lake Greenwood and having a bearing on the acquisition of additional land from the Department of Agriculture.

2. By reference (a) the Secretary of the Navy requested the Secretary of Agriculture to arrange for ceding to the Navy certain lands held by the Department of Agriculture. In other correspondence the Department of Agriculture advised that the area in 9 sections in the northeast corner of Martin County would be ceded and the Navy could proceed with the utilization of this area. The ceding of the area immediately north of Lake Greenwood and extending to the northern boundary of Martin County was tentatively agreed to, but final action deferred until after a conference had been held to acquaint the State Department of Conservation, the public, and other interested parties, with the Navy's need to expand to the north and to close Lake Greenwood to public access.

3. At 11:00 a.m. on this date an informal and preliminary meeting was held at which were present the following: From Indiana State Department of Conservation:-Mr. H. A. Barnhart, Director; Mr. Paul Yost, State Forester; Mr. Addison Beavers, attorney; and, later in the day, Mr. Wagner, publicity agent. From U. S. Department of Agriculture:-Mr. J. H. Price, Regional Forester, Milwaukee; Mr. Murray Bruner, in charge of State cooperation under Regional Forester; and Mr. R. H. Grabow, Hoosier Forest Supervison of Bedford, Indiana. From the naval ammunition depot; Inspector of Ordnance in Charge; Executive Officer, Lieutenant Commander T. E. Kelly; Officer in Charge of Construction, Lieutenant Commander W. B. Short; Medical Officer, Lieutenant Commander L. F. Farrell; and Security Officer, Lieutenant Schwarg, USNR.

4. The possibility of the Depot cooperating with the State Department of Conservation and the U. S. Forest Service in reforestation, game control, forest fire observation, and use of the depot as a wild game refuge was discussed and it appeared quite

Filed - Ruane

RG 71, Bureau
Naval Prop. Case Files
Box 451, Burns City
Transfer Dept Ag (1952)

feasible to work out some cooperative plan. Those present were then taken on a short trip around the Depot area.

5. At 2:00 p.m. the before-mentioned group met with numerous newspaper men representing various papers of the state and numerous members of various conservation clubs interested in Lake Greenwood from a fishing standpoint. Captain Oberlin stated the conference was called to acquaint the public of the Navy's military needs in this area. He stated the Depot's policy was to employ mainly local people and to make the Depot an object of pride both of the locality and the state. He explained the fact that Burns City was one of many sites considered and that the availability of the lake as a source of water supply was one feature that influenced the final decision to locate the Depot here, with the result that nearly a million dollars per month was being distributed as wages in this locality. He then asked Mr. Price to preside.

6. Mr. Price clearly outlined the conditions under which the Department of Agriculture had acquired land now included in the Depot, the Department's arrangements with the State Department of Conservation regarding its use of this land and the land's subsequent transfer to the Navy. He then asked Mr. Barnhart to present the views of the Department of Conservation, as well as of the members of the various conservation clubs.

7. Mr. Barnhart mentioned the advice he had received from Washington that it was the Government's intention to consider recreation an essential national function and to continue, in conjunction with the States, the development of recreational areas. He called attention to the lack of lakes for recreational purposes in southern Indiana as compared with the northern part of the state, and reviewed what the State had done to develop the area now occupied by the Depot as a recreational center for this part of the State. He expressed the willingness of all to go along as might be necessary in the national interests, but hoped that some means might be found to allow fishermen continued access to the lake. In short, he very ably presented the viewpoint of those interested in conservation and in fishing, while at the same time, recognized that personal interest or interests of those he represented, should not stand in the way of the Navy's needs.

8. The Depot personnel then outlined the Navy's problems. Dr. Farrell explained the use of lake water for drinking purposes, the incident objections to use of the lake for swimming or fishing purposes, and succinctly covered the actuality by saying the body of water had changed from a lake to a reservoir. Lieutenant Schwarz explained the necessity of protecting the lake intake to our water system and the difficulty of such protection if people were allowed on the lake or had access to the lake shore. Captain Oberlin outlined the probable need for expansion of Depot area to accomodate an increase in number of

magazines, the inability of expansion to the southeast by reason of the possibility of the Shoals Flood Control Project under study by the War Department, which, if it became an actuality, would flood about 30 square miles of territory and create a lake alongside of which Lake Greenwood would be only a mill pond. He stated that therefore, expansion would logically take place to the north, as far into Greene County as the new route of Highway 45 and to the west into Daviess County. He pointed out the desirability to always have on hand a little more area than was actually needed, in order to permit the Bureau of Ordnance to continue existing practice of finding some new need and then deciding there was room for it at Burns City and accordingly filling that need by additional expansion of activities here.

9. Captain Oberlin outlined the possibility of using Lake Greenwood in testing out bomb sights by dropping of water bombs and perhaps even of studying bomb design and trajectory at a later date, pointing out the danger to any one from falling bombs and the unenviable position in which the Depot authorities would find themselves, should a civilian not connected with the Depot accidentally be hit by one of these bombs.

10. Questions were asked by those present about various factors in which Lake Greenwood was involved, including the possibility of allowing the public access to the lake after the present war was over. Those present were advised that, unless the present war was terminated successfully, there would probably be little interest in the lake, and in any case that was a question that would have to be answered by those in charge when the time came. The conference adjourned with a practically unanimous expression of sentiment that the Navy's needs were logical and the Navy was warranted in closing the lake, and that all present could be counted upon to further the Depot's interests in every way possible.

11. In closing, it might be noted that the press notices regarding the conference were uniformly favorable and friendly. This summary of the conference is necessarily incomplete and sketchy but gives a general idea of what took place.

E. G. Oberlin,
Captain, USN,
Inspector of Ordnance
In Charge

Copy to
BuOrd
BuY&D
Mr. Barnhart
Mr. Price
Chief of Division of State Forest Service,
Department of Agriculture

Bernie Donda Interview
Re: Lake Greenwood Testing (Pyro)
Carl Lohkamp - N-333 found ~~tests~~
P such commercial test

Lake Greenwood
Any cleanup done?

How large an area?

→ Bernie Donda

1. RP signals - MLM developmental improvements to MK 6 wt. = 4X NEW MK 5 or MK
Doing improvements to formula MK 5-Mod 4, MK 7-Mod 2, MK 8-Mod 3
Tested in Lake Greenwood in mid-50's 54-58
ignited the markers and timed the burn.
Generally - a dozen or so units tested per test
Bodies (wooden) were recovered
From cliffs - straight out then left toward dam 200-300 yds.

middle of town for E.C. Rooks

6 tests/summer X 2

2. Underwater illuminating flare - experimental
Mg, $NaNO_3$, Polyester binder
About 6 tests total around 1958
in a metal container
ignited from the boat
At deep spot near dam ≈ 30' depth
All parts were recovered

Rooks Term = 7/50 - 6/54
Harney's Term = 6/54 - 9/57

812-854-3420

Lake Greenwood

Keith Phillip A CNIN
From: Keith Phillip A CNIN
Sent: Friday, November 03, 2000 3:40 PM
To: McCahill Sherry M NOSA
Subject: RANGE SURVEY

Sherry,
I lucked out - Tom happened to call in so I asked him about the B-143 Drop Test range to clear up the inconsistency in answers for sections, VI.A vs. VI. E.

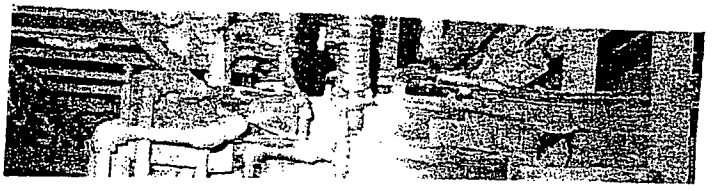
The answer for VI.A was marked NO because there was never an investigation done on the B-143 drop site range. VI.E. was marked YES because Tom thought we could investigate the B-143 drop site range when the RFI for SWMU 18/13 is undertaken. SWMU 18/13 is designated as Load and Fill Area Buildings and is in the same general area as the B-143 drop site range. The Load and Fill Area Buildings were identified in the IAS report.

I turned-up a copy of the IAS report and read the descriptions for the Pond 330/333 and Conservation Dam No. 2845, also Lake Greenwood. I believe Pond 330/333 is the sedimentation pond to capture sediment from the NW corner of our Demolition Range. Apparently the Conservation Dam No. 2845 was used for limited testing but none of the folks I talked to when we were collecting info for the Range Survey ever mentioned it as a test location.

I had collected some information on Lake Greenwood - it was used from about 1954-1958 during two summers to test Marine Location Markers (MK5-4, MK7-2, MK6-3). About a dozen markers were tested each time and they tested about six time each of the two summers. The markers had wooden bodies and were recovered. Around 1958 there were about six experimental underwater illuminating flares tested - they contained Mg, $NaNO_3$, and polyester binder - and all parts were recovered. They loaded the items into a boat and put them over the side to test them. The test location was about 200-300 yards off-shore at a deep spot (~30 ft.) near the dam. Bernie Douda, a Senior Engineer in the Code 40 pyro group provided the information. His number is 812-854-3420.

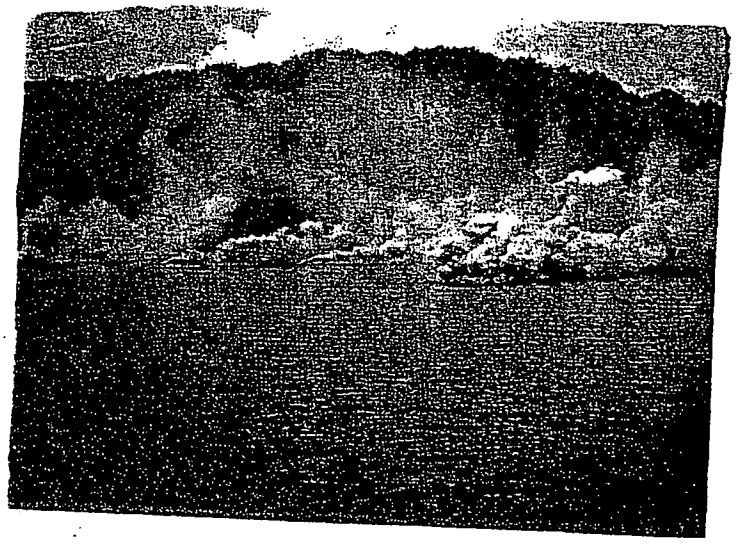
None of these locations meet your definition of military range because they were never specifically designated and set aside for range use. Conservation Dam No. 2845 has always been open to employees for fishing and Lake Greenwood has always been used for recreational purposes as well as our drinking water supply.

Hope this helps.
Phil



Lake Greenwood
"4 pits were located where pyrotechnics testing were conducted during the 1940s thru 1960's."

Records Research on-site survey by OESO + the Army Records Research



Pollution Control Program
1971

prepared by
Naval Ammunition Depot, Crane, Indiana

OESO FILES

Appendix D: Ordnance Technical Data Sheets

Ordnance Technical Data Sheet
MK 6 Mod 3 Signal

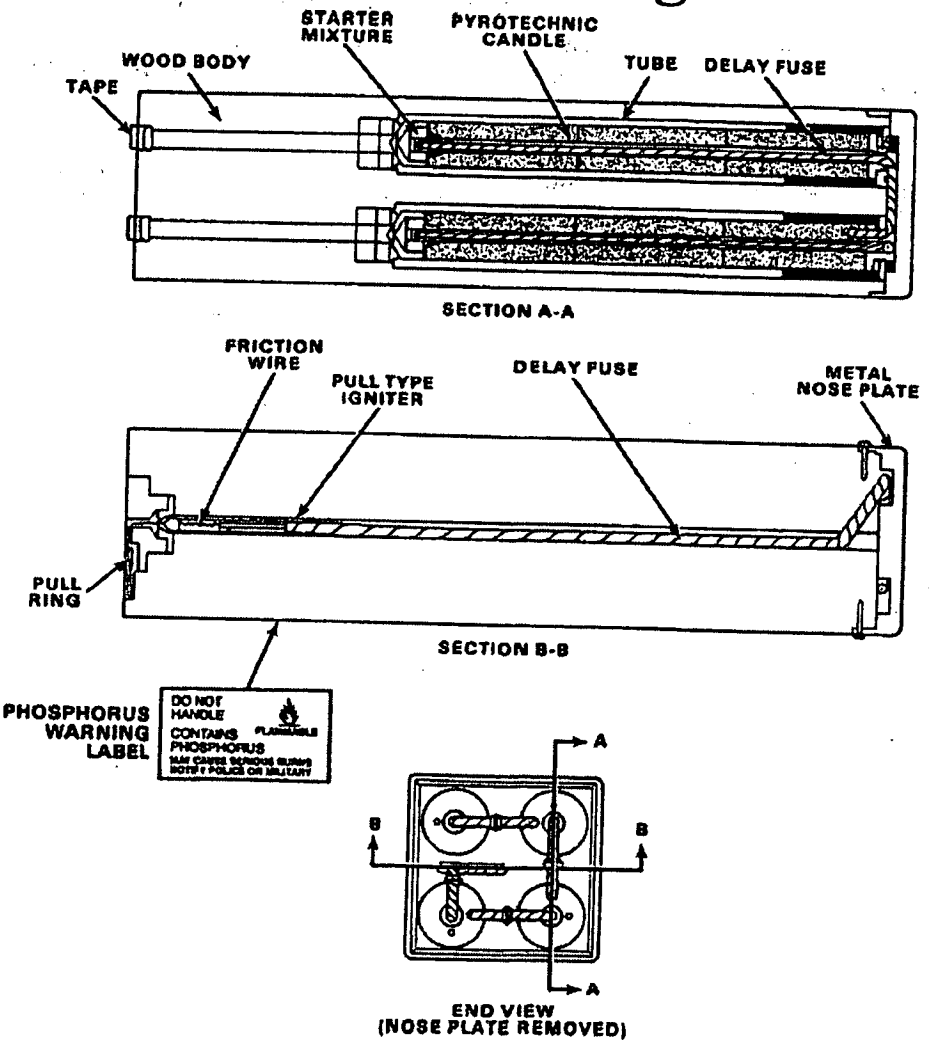


Figure 11-2.1 Aircraft Smoke and Illumination Signal Mk 6 Mod 3

Nomenclature:	MK 6 Mod 3 Aircraft Smoke and Illumination Signal
Ordnance Family:	Pyrotechnic/Smoke
DODIC:	L525
Filler:	Red phosphorus composition
Filler weight:	4 pounds 1 ounce
Item weight:	5.806 kg (12.8 Lbs)
Diameter:	128.5 mm (5.06 inches square)
Length:	517.14 mm (20.36 in)
Fuze:	Friction

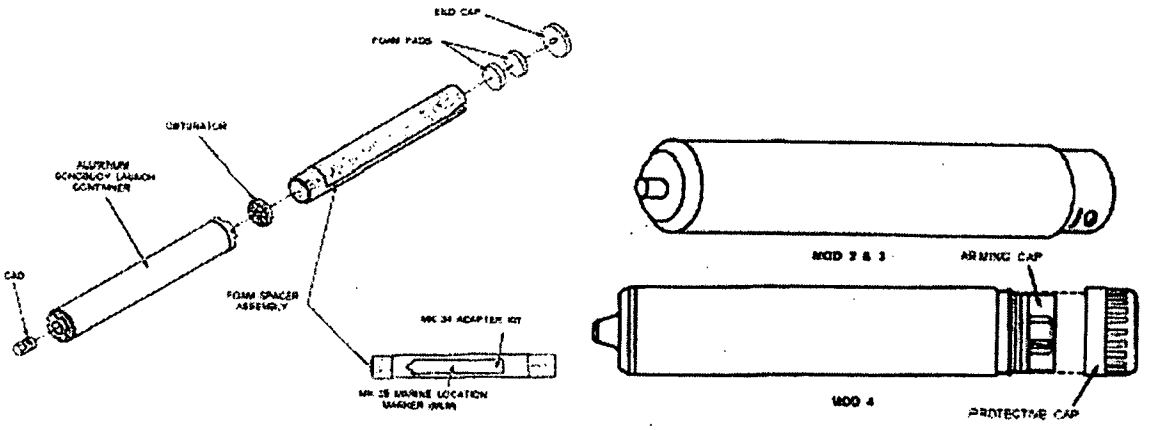
Usage: This pyrotechnic device is launched from surface craft only to produce a day or night floating reference point. One of its principal particular uses is as a man-overboard marker.

Description: This device consists of a rectangular-shaped, wooden body (20.36 inches long and 5.06 inches square) with a flat, die-cast metal plate affixed to one end to protect it from water impact damage and to maintain it in the correct floating attitude. There are four flame and smoke emission holes in the opposite end, each capped and sealed with tape. The pull wire ring, also at the emission end, is likewise covered with tape.

This device has a direct-firing ignition system. Ignition results from a quick pull on the pull ring in a direction perpendicular to the end of the signal. The pull ring is pulled by hand, and the device is thrown into the water immediately. The pull wire ignites a 90 second delay fuse which ignites the quickmatch at the top of the first of four candles. The quickmatch ignites the first candle starting mix which, in turn, initiates burning of that candle. Expanding gases of combustion force the cap and tape from the emission hole, allowing smoke and flame to be emitted. When the first candle is nearly burned out, a transfer fuse carries the ignition to the quickmatch of the next candle in series. This process continues until all four candles have burned. Yellow flame and gray-white smoke are produced for a minimum of 40 minutes.

Reference: NAVSEA SWO050-AB-MMA-010, NAVAIR 11-15-7

Ordnance Technical Data Sheet
MK 25 Marine Marker



Nomenclature:	MK 25 Marine Marker
Ordnance Family:	Pyrotechnic/Smoke
DODIC:	
Filler:	Red Phosphorous pyrotechnic composition
Filler weight:	
Item weight:	1.678 kg (3.7 Lbs)
Diameter:	72.33 mm (2.9 in)
Length:	469.9 mm (18.5 in)
Fuze:	Saltwater activated battery

Usage: The MK 25 marine location marker is launched from aircraft or surface craft. They provide day or night reference points for marking the course of enemy submarines in antisubmarine warfare operations. The MK 25 is suitable for any type of sea-surface reference point marking that calls for both smoke and flame for a period of 10 to 20 minutes.

Description: Consists of a cylindrical outer tube about 18.5 inches long and 2.9 inches in diameter. A valve assembly is fitted into the projecting chimney at the marker's nose end. The smoke and flame are emitted from this opening. At the opposite end is a heavier aluminum base assembly to which the outer tube is crimped. Within the base assembly is a Mk 72 Mod 0 seawater-activated battery (two batteries in the Mod 2). The battery is shielded from water contact by two plugs fitted into 1/2-inch holes on two opposite sides of the base assembly. The words SAFE and ARMED are stamped into the base rim. A black rubber G-ring circles the base assembly approximately 1/4 inch from the crimp, which holds the outer case.

Reference: ORDATA Online, NAVSEA SWO050-AB-MMA-010, NAVAIR 11-15-7