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Report On January 1993 Biomonitoring for Site 8 - Nitroglycerin Plant Office Indian Head Division Naval Surface Warfare Center

Indian Head, Maryland

Northern Division
Naval Facilities Engineering Command

Contract Number N62472-90-D-1298
Contract Task Order 0064

April 1993

Halliburton NUS
CORPORATION

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REPORT ON
JANUARY 1993 BIOMONITORING
FOR
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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1.0 INTRODUCTION

The Northern Division of the Naval Facilities Engineering Command has issued Contract Task Order Number 0064 (CTO 64) to Halliburton NUS Corporation (Halliburton NUS), under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-90-D-1298. CTO 64 is for environmental investigative work at the Navy Installation Restoration Program Site 8--Nitroglycerin Plant Office (Installation Restoration Site 8)--at the Indian Head Division, Naval Surface Warfare Center (NSWC) in Indian Head, Maryland. NSWC is part of the Chesapeake Division (CHESDIV) of the Naval Facilities Engineering Command. CTO 64 consists of tasks to: (1) investigate the extent of mercury contamination in the sediment, soils, and surface water of Installation Restoration Site 8 and environs to support interim removal action if necessary, and (2) develop and implement a Biomonitoring Program to assess the extent of mercury contamination in the biota of Site 8 and evaluate the potential ecological impacts of any interim removal action.

Halliburton NUS developed a Biomonitoring Program for Site 8 that was presented to CHESDIV in a site-specific Biomonitoring Plan (Halliburton NUS, 1992a). The plan outlined procedures for conducting quarterly biomonitoring at Site 8 through two distinct phases: Phase I and Phase II. The plan was designed so that it could be modified (particularly during Phase I) in order to achieve the overall objective of the Biomonitoring Program. During Phase I, which consisted of preliminary (U.S. Fish & Wildlife Service) sampling in July 1992 and two regular quarterly sampling events (October 1992 and January 1993), sample collection and analytical techniques were established and subsequently modified to better suit actual site conditions. Phase II is scheduled to begin with the April 1993 sampling round and is scheduled to last through January 1995; a decision regarding additional biomonitoring will be made after review of Phase II Biomonitoring Results.

This report presents the results of the January 1993 round of biomonitoring, which was performed in accordance with the approved Biomonitoring Plan (Halliburton NUS, 1992a). This second quarterly round of biomonitoring concludes Phase I. Information obtained in Phase I will be used both to characterize Site 8 biota and further refine the Biomonitoring Program in subsequent (Phase II) rounds.

1.1 BACKGROUND

For approximately 20 years, mercury was inadvertently released in small amounts from sink and floor drains in Building 766 of the Site 8 - Nitroglycerin Plant Office (NPO). The Building 766 sink and floor drains emptied into a storm drain system that discharged into a small (unnamed) stream that flows south and east for approximately 1/4 mile, enters a cattail marsh/pond, then empties into Mattawoman Creek. Previous investigations have determined that sediment and surface water of the stream, marsh, and pond contain elevated concentrations of mercury (ABB-ES, 1992a; ABB-ES, 1992b). The actual quantity of mercury that was released is unknown; however, it has been estimated that between 200 and 500 pounds of mercury were released to the environment from the Site 8-NPO (ABB-ES, 1992a).

In August 1992, Halliburton NUS Corporation began sampling and analysis work to investigate the extent of mercury contamination in the soils, sediment, and surface water of Site 8 in accordance with an approved Abbreviated Field Sampling Plan (Halliburton NUS, 1992b). The results of that sampling and analysis indicated that sediments in the upper section of the stream (near Building 766) were contaminated with mercury concentrations greater than 25 mg/kg. Mercury concentrations in the upper stream section ranged from nondetectable (lower than detection limits) to 671 mg/kg. Sediments in the pond/marsh area had mercury concentrations ranging from nondetectable to 13.8 mg/kg. Background mercury concentrations (i.e., mercury levels in sediment and soil samples from the general vicinity of Site 8 but outside of the impacted stream corridor) ranged from nondetectable to 0.34 mg/kg.

The Biomonitoring Program developed by Halliburton NUS was designed to be carried out in the marsh/pond area of Site 8 only. Because the velocity of the stream is reduced as it widens and flows into the marsh/pond, the pond is a natural sediment trap, holding silt, detritus, and organic matter from upstream. Unlike the stream, which is subject to extreme fluctuations in temperature, flow, and turbidity, the marsh/pond support an abundant growth of aquatic vegetation as well as a variety of planktonic organisms, aquatic insects, fish, reptiles, amphibians, wading birds, and waterfowl (personal observation, P. R. Moore, (Halliburton NUS). Thus the potential for contaminant (specifically mercury) exposure and bioaccumulation is considered to be higher in the marsh/pond, and the biomonitoring effort focuses on this area.

1.2 SITE DESCRIPTION

The study site (Site 8 pond/marsh) lies within the main (northern) NSWC area. Site 8 discharges into Mattawoman Creek via a 6-foot-diameter culvert running under Noble Road. A beaver pond on the Stump Neck Annex of NSWC, approximately 3 miles southeast of the study site and 1/2 mile northwest of Alexandria Church, was used as a control site in October 1992 (Control Site 1). An additional control site in Mattawoman Creek approximately 3 miles east of the NSWC, just upstream of the Maryland Highway 225 Bridge, was added for the January 1993 sampling round (Control Site 2). The locations of Site 8 and the Control Site 1 are shown on Figure 1-1.

The beaver pond control site is located on an unnamed tributary of the Chicamuxen Creek, the drainage to the south of Mattawoman Creek. This beaver pond was chosen as a control site because it offers security (access to the area is restricted and controlled by NSWC) and reasonably approximates the study site in terms of water chemistry, water level, topography, and resident plants and animals. The "upper" Mattawoman control site was selected because it appeared to offer better fish habitat than the beaver pond control site and was in the same drainage basin as the Site 8 stream and pond. Both the Mattawoman and the Chicamuxen are tributaries of the Potomac River.

Because the beaver pond control site is approximately 2 miles upstream from Chicamuxen Creek and approximately 3 miles upstream from the Potomac River, it has not been impacted by mercury contamination from Site 8. Any pollutants (e.g., mercury) in its water, sediments, and biota are presumed to be from atmospheric or geologic sources rather than Site 8. The upper Mattawoman Creek control site, which is approximately 4 miles upstream of the Site 8 outfall and 3 miles east of the NSWC boundary, should not be affected to any significant degree by NSWC operations.

Until recently (spring of 1992), the Site 8 pond/marsh was approximately 4 to 5 feet deep, the water level maintained by a beaver dam located just upstream of the culvert that runs under Noble Road and drains the pond/marsh. The beaver dam was removed in the spring of 1992 and normal pool was lowered approximately 3 to 4 feet. During the October 1992 and January 1993 rounds of biomonitoring, the water level in the study site was generally 1 to 2 feet deep. A weir designed to regulate flow from the study site and maintain the water level in the pond at a "normal" depth of 2 to 3 feet is to be installed on the upstream end of the Noble Road culvert some time in 1993.

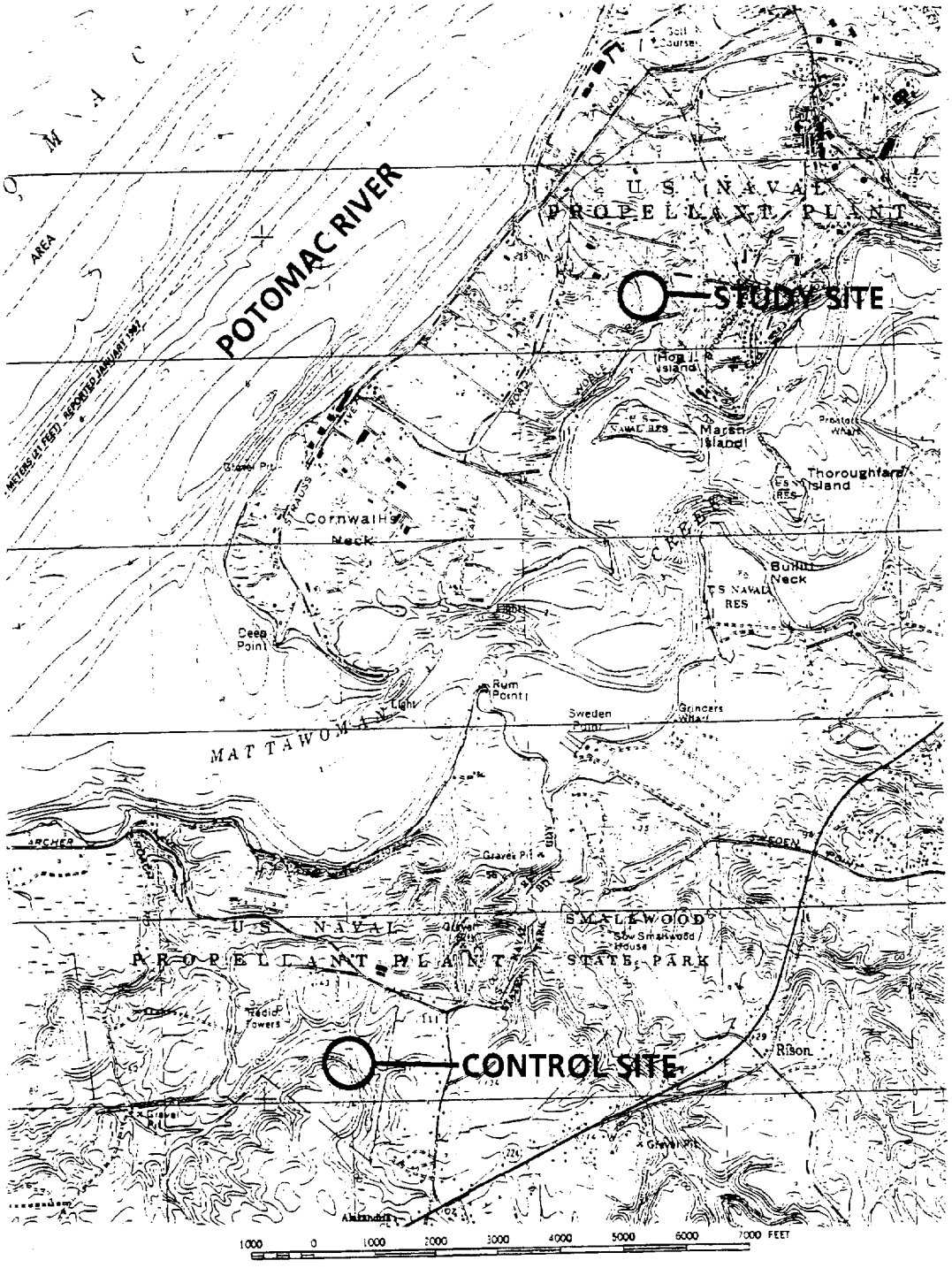


FIGURE 1-1
LOCATION MAP
SITE 8 AND CONTROL SITE 1
BIOMONITORING PROGRAM
INSTALLATION RESTORATION PROGRAM
SITE 8 - NITROGLYCERIN PLANT OFFICE

HALLIBURTON NUS
Environmental Corporation

Source: 7.5 Minute USGS Quad Indian Head, MD-VA 1966 Photo Revised 1978

1.3 OBJECTIVE

The primary objectives of the Biomonitoring Program are to assess the impact of mercury contamination at Site 8 has had on the biota of the Site 8 pond/marsh and to evaluate potential environmental impacts of any interim removal action. The October 1992 and January 1993 rounds of biomonitoring were intended to establish baseline conditions at Site 8 and provide information to refine and improve methods employed in subsequent phases of biomonitoring.

2.0 SAMPLING LOCATIONS AND METHODS

Field sampling for the January 1993 round of biomonitoring was conducted on January 27 and 28, 1993. Field sampling was performed by Coastal Environmental Services, Inc. (CES), a subcontractor to Halliburton NUS. Halliburton NUS personnel were also present to assist CES with sampling and evaluate several possible new control sites.

As previously noted, because a weir had not been installed, the actual depth of the Site 8 pond was approximately 1 to 2 feet when sampling was conducted. Field sampling was performed at six transects in the main area of the pond/marsh (Transects 1 through 6) and at a location on the north side of Atkins Road Extension (Transect 10). The Site 8 sampling locations are shown on Figure 2-1. During the October 1992 and January 1993 rounds of biomonitoring, the pond system consisted of a 1 to 2-foot-deep pool extending north from the base of the Noble Road embankment (encompassing Transects 1, 2, and 3); a narrower section of water extending north another 400 to 500 feet (containing Transects 4 and 5); and a small stream flowing through the old lake bed (Transects 6 and 7). Transect 10, which under normal circumstances is a marsh with standing water just upstream of the pond, was, at the time of the October and January sampling, a small stream flowing into the pond.

The following ecological components were sampled in January 1993:

- Water Quality
- Periphyton
- Benthic Macroinvertebrates
- Fish

2.1 WATER QUALITY MEASUREMENTS

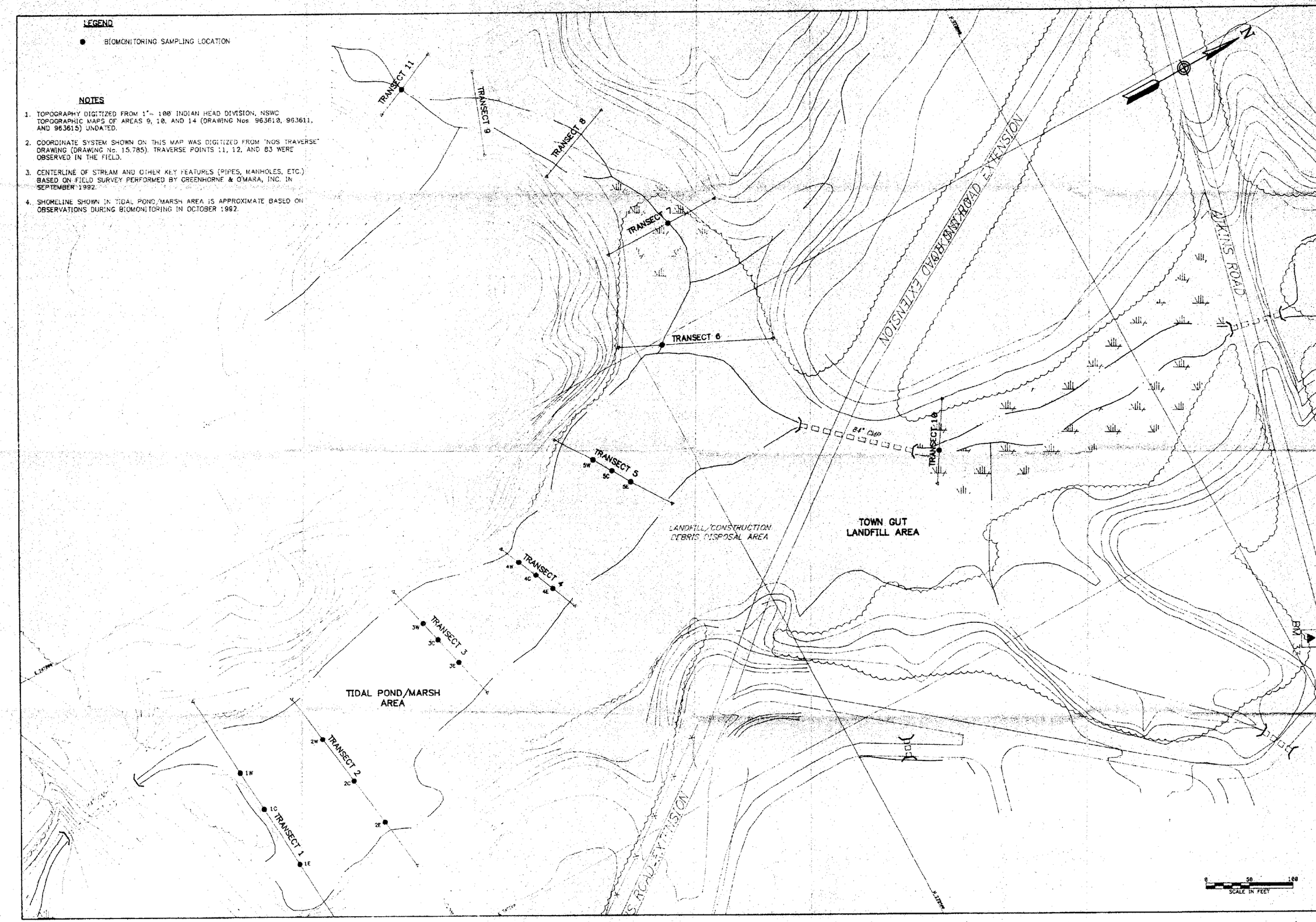
Water temperature, dissolved oxygen (DO), pH, and conductivity measurements were taken in the field with a Hydrolab Surveyor II only at a mid-depth because water was <1.0 meter deep at all transects. Conductivity, rather than salinity, was monitored because preliminary field measurements indicated that the pond was freshwater, with salinities <1.0 part per thousand (ppt) at all transects. Grab samples of water for hardness and total organic carbon (TOC) were taken at the surface and shipped to Halliburton NUS' Pittsburgh laboratory for analysis.

LEGEND

● BIOMONITORING SAMPLING LOCATION

NOTES

1. TOPOGRAPHY DIGITIZED FROM 1" = 100' INDIAN HEAD DIVISION, NSWC TOPOGRAPHIC MAPS OF AREAS 9, 10, AND 14 (DRAWING Nos. 963610, 963611, AND 963615) UNDATED.
2. COORDINATE SYSTEM SHOWN ON THIS MAP WAS DIGITIZED FROM "NOS TRAVERSE" DRAWING (DRAWING No. 15,785). TRAVERSE POINTS 11, 12, AND 83 WERE OBSERVED IN THE FIELD.
3. CENTERLINE OF STREAM AND OTHER KEY FEATURES (PIPES, MANHOLES, ETC.) BASED ON FIELD SURVEY PERFORMED BY GREENHORNE & O'MARA, INC. IN SEPTEMBER 1992.
4. SHORELINE SHOWN IN TIDAL POND/MARSH AREA IS APPROXIMATE BASED ON OBSERVATIONS DURING BIOMONITORING IN OCTOBER 1992.



REV.	DESCRIPTION	PREP BY	DATE	APPRVD

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON NAVY YARD — WASHINGTON, D.C.

CHESAPEAKE DIVISION

INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
SITE B – NITROGLYCERIN PLANT OFFICE
JANUARY 1993 – BIOMONITORING SAMPLING LOCATIONS

ISSUED: APRIL 15, 1993 — NORFOLK, VA

SEAL AREA

SAT TO: DATE

CODE I.D. NO. 86001
SCALE: AS SHOWN
SPEC. NO. 84 – NA
CONSTRN. CONTR. NO.: NA
NAVFAC DRAWING NO.: NA
SHEET 1 OF 1
SIZE: D
DIS. SH. NO.: FIGURE 2-1

0032I01X
Box 2
FIG. 2-1

2.2 PERIPHYTON SAMPLING

Periphyton was sampled with an artificial substrate device similar to that described in Standard Methods for Analysis of Water and Wastewater (APHA, 1985). This device employs glass slides in a frame supported by styrofoam floats. Two sets of periphyton samplers, each containing 8 slides (a total of 16 slides), were placed at each sampling location. After 14 days the samplers were retrieved and transported to the laboratory for analysis.

Three randomly selected slides from each array were analyzed for ash-free dry weight, three were analyzed for chlorophyll-a, and three were examined for species composition and abundance. One slide from each periphyton sampler was preserved and archived, in the event that additional analysis or verification of periphyton identification is required. Any remaining slides collected at a given sampling location were discarded.

2.3 BENTHIC MACROINVERTEBRATE SAMPLING

Benthic macroinvertebrates were sampled with a Petite Ponar grab sampler. Samples were sieved in the field, preserved, and transported to the laboratory for identification and enumeration. Standard methods described in APHA (1985) and Lind (1979) for collecting and counting benthic macroinvertebrates were employed.

2.4 FISH SAMPLING

2.4.1 Fish Survey

No systematic fish surveys were conducted at the study sites in January 1993. Previous surveys (Halliburton NUS, 1993) indicated that fish species diversity and abundance were very low at all sites and that electro-fishing samples revealed little about community structure. In the October 1992 biomonitoring event, two species, *Gambusia affinis* (mosquitsfish) and *Fundulus heteroclitus* (mummichog), comprised approximately 95% of all fish collected at the Site 8 pond. Attempts to collect fish from the Stump Neck beaver pond (Control Site 1) in October 1992 were unsuccessful. Although the planned fish surveys have been abandoned, a species list and notes on occurrence will be maintained for each sampling location, based

on collections made for mercury analysis. This will provide a rough measure of species diversity and abundance (i.e., "rare" or "common").

2.4.2 Fish Sampling for Mercury Residues

Fish sampling in January 1993 for analysis of mercury in tissues was conducted using a combination of electrofishing, seining, and minnow traps. Minnow traps were set at the study site and control sites, left overnight, and retrieved the next day. Target species were largemouth bass (*Micropterus salmoides*), brown bullhead (*Ameiurus nebulosus*), and the mosquitofish (*Gambusia affinis*), which were selected because they represent three distinct trophic (feeding) levels: top-of-the-food-chain predator, bottom-feeding omnivore, and surface-feeding insectivore (Halliburton NUS, 1992a). Because sampling efforts produced no largemouth bass, bluegill (*Lepomis macrochirus*) were collected from the Site 8 pond and analyzed as a surrogate in both October 1992 and January 1993.

Largely unsuccessful attempts were made to collect fish at the two control sites with a backpack electrofisher, bag seine and minnow traps. The poor electrofishing success may have been due to the low conductivity of the water (approximately 75-100 micromhos/cm) or, in the case of the beaver pond, to the inability of the sampling crew to approach fish in this small body of water without being detected. The effectiveness of the bag seine in the beaver pond was limited by the soft bottom and the abundance of stumps beaver-felled trees, and aquatic vegetation. Seining at the upper Mattawoman Creek control site, although unhindered by stumps and vegetation, produced only one fish, a creek chubsucker (*Erimyzon oblongus*). All fish collected were placed on ice and shipped to Gascoyne Laboratories, Incorporated, for analysis of mercury residues in tissue.

3.0 BIOMONITORING RESULTS AND DISCUSSION

3.1 WATER QUALITY

Water quality data are presented in Table 3-1. Water temperatures in the Site 8 pond ranged from 0.5 to 2.7°C on January 27, 1993. Water temperatures were higher at the two control sites: 2.8°C in Mattawoman Creek and 6.1°C in the Stump Neck beaver pond. Dissolved oxygen (DO) concentrations were 12.3 mg/L at both Transect 2 and Transect 5, more than adequate to support a variety of aquatic life. DO levels were lower at the two control stations, however, measuring 9.8 mg/L at the Stump Neck beaver pond and 2.8 mg/L in upper Mattawoman Creek. The very low DO concentration at the Mattawoman Creek control site is surprising considering the low water temperature (2.8°C) and the tendency of dissolved oxygen concentrations to vary inversely with temperature. It is unknown whether this low DO reading is an artifact (i.e., a malfunctioning DO meter) or the result of some oxygen-scavenging chemical or organic material (e.g., untreated sewage) being discharged to the stream. The stream was, for the most part, free of decaying leaves and vegetation on the day DO measurements were taken (personal observation, P. R. Moore, Halliburton NUS). If DO levels at this location are chronically depressed, then it may be a poor choice for a control site. Measurements of pH ranged from 6.7 to 7.1 at the Site 8 study site (Transects 2 and 5), and were slightly higher (7.3) at both control sites.

Total Organic Carbon (TOC) ranged from 3.0 to 4.0 mg/L in the Site 8 pond (four samples). Hardness (as $CaCO_3$) ranged from 37.0 to 45.0 mg/L at the same stations. There was very little variation, with up- and down-lake stations showing identical TOC values and similar total hardness values. TOC values at the two control sites were slightly higher (4.0 to 5.0 mg/L), while hardness was slightly lower (14.0 to 24.0 mg/L).

All of the measured values were unremarkable, indicative of soft water (low in dissolved ions and with a low buffering capacity) with low to moderate TOC levels (Lind, 1979; Drever, 1982). TOC and hardness values at the two Site 8 transects were little changed from October 1992.

3.2 PERIPHYTON

Periphyton (or "attached" algae) collected in January 1993 were dominated in number and biomass by the Phylum (or "Division") Baccillariophyta, or diatoms (see Attachment A, Tables A-1 through A-12). Diatoms,

TABLE 3-1

WATER QUALITY DATA - JANUARY 1993
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Station	Time (approx)	DO (mg/L)	Temp (°C)	pH	Cond (μmhos)	Mean TOC (mg/L)	Mean Total Hardness (as $CaCO_3$) (mg/L)
T-2 (downlake)	09:30	12.3	0.5	6.7	267.0	3.5	44.5
T-5 (uplake)	10:30	12.3	2.7	7.1	254.0	3.5	38.0
Mattawoman Creek Control	13:30	2.8	2.8	7.3	96.0	4.5	22.0
Stump Neck Control	14:30	9.8	6.1	7.3	74.0	5.0	16.0

ubiquitous in a wide variety of freshwater and marine habitats, are generally associated with the littoral zones of reservoirs, lakes, and ponds as well as the bottoms of streams (Whitford and Schumacher, 1973).

In January 1993, periphyton samples from Transect 1 were composed almost entirely (99.7 percent) of diatoms. *Navicula, Nitzschia*, and *Achnanthes* were the most common genera. The only non-diatom in samples was the distinctively-shaped Euglenophyte *Trachelmonas*, which is a component of plankton and periphyton communities, but is generally uncommon in both (Whitford and Schumacher, 1973). This was in sharp contrast to the October 1992 collections from Transect 1, in which Chlorophyta (green algae) were numerically dominant (53.5 percent of total collected) and made up approximately 84 percent of samples by weight.

The periphyton of Transect 2, which were not sampled in October 1992, were made up exclusively of diatoms in January. *Navicula* and *Nitzschia* were the most abundant genera, making up more than 78 percent of all periphyton collected in January at this transect. Transect 2 had the second highest density of diatoms (4,737 cells/cm^2) and the highest algal biomass (62.1 mg/m^2) of the four transects sampled.

Transect 3 collections were also dominated by *Navicula* and *Nitzschia*, which made up nearly 71 percent of all periphyton collected at this transect. Two green algae, *Scenedesmus* and *Spirogyra*, were also found at this transect in January 1993, but were present in low densities. In October 1992, Transect 3 collections were dominated by diatoms and green algae, both in density and weight. Diatoms evidenced highest densities, while green algae made up more than 70 percent of the biomass of periphyton samples. October 1992 samples from Transect 3 contained small numbers of algae from two other phyla, Euglenophyta and Cyanophyta, neither of which was collected in January. Cyanophyta, or blue-green algae, are generally regarded as indicators of eutrophication or pollution.

Periphyton density at Site 8 in January 1993 was highest at Transect 4, with 4,741 cell/cm^2. All periphyton collected at this transect were diatoms. In October 1992, diatoms were the most abundant group (66 percent of total) at Transect 4, but green algae comprised the bulk of the biomass (72 percent by weight). Transect 4 samples also contained small numbers of Euglenophyta and Cyanophyta in October 1992.

The four Site 8 transects contained a diverse assemblage of diatoms in January, with genera present that are associated with clean waters (e.g., *Cocconeis, Meridion, Pinnularia and Navicula*) as well as diatoms often used as bioindicators of stress or pollution in aquatic ecosystems (e.g., *Gomphonema* and *Nitzschia*)

(APHA, 1985). Palmer (1975) lists (*Nitzschia* and) *Navicula* among the 22 most pollution-tolerant genera of algae. It is unclear how *Navicula* can be listed as an indicator of good water quality by one authority and poor water quality by another. Given this genus's widespread distribution in freshwater, brackish, and marine environments, and the large number (more than 50) of *Navicula* species that exist world-wide, it will be necessary to determine which specie(s) of *Navicula* occur(s) at Site 8 before making any inferences about its value as a bioindicator.

Neither control site was sampled for periphyton in January 1993. In October, the periphyton of the Stump Neck beaver pond control site were dominated by diatoms and green algae. These two groups made up more than 95 percent by number and weight of attached algae collected. *Eunotia*, which Patrick (1977) describes as a genus characteristic of "bog" habitats, was common in October beaver pond samples as well as Site 8 Transects 1, 3, and 4.

Diatom populations show marked seasonal changes in species composition and abundance. Factors that affect these population shifts include solar radiation and water temperature, nutrient fluxes, precipitation and turbidity, and availability of critical trace metals and silica (critical to diatoms, which have silica cell walls, or "frustules") (Wetzel, 1975; Patrick, 1977). In temperate lakes, diatoms typically dominate phytoplankton populations in colder months (late fall and winter), and show a spring pulse or "bloom" (Cole, 1975). Periphyton show a similar annual cycle, but because attached algae are slower to respond to seasonal changes in light and water quality, peak densities lag behind those seen in lakes (Wetzel, 1975). Planktonic diatom populations tend to peak in April and May in the northern hemisphere, which periphyton diatom populations tend to peak a little later, in May or June.

Patrick (1977) lists *Asterionella, Fragilaria*, and *Synedra* as diatom genera that are common in spring algal blooms in temperate waters, and *Melosira, Cyclotella*, and *Stephanodiscus* as diatoms that dominate autumn diatom pulses. Although *Fragilaria* and *Synedra* were found in roughly half of the January samples from Site 8, they were present in low numbers. *Asterionella* was not seen in January samples. *Melosira* was found in 8 of 12 January samples, but was present in relatively low densities. Very little information on periphyton community structure in mid-winter exists in the scientific literature.

The most abundant genera for the Site 8 pond as a whole were, in descending order: *Navicula* (1681 cells/m^2), *Nitzschia* (1040 cells/m^2), *Gomphonema* (267 cells/m^2), and *Achnanthes* 163 cells/m^2). *Navicula, Nitzschia, and Gomphonema* were also the three most widely-distributed genera, with *Navicula* and *Nitzschia* present at all 12 stations (3 stations per transect), and *Gomphonema* present at 11 of

12 stations. Patrick (1977) lists *Navicula* and *Nitzschia* as genera associated with sediments, and describes *Gomphonema* as an "epilithic" genus that is often found attached to hard surfaces such as stones or wood. *Achnanthes* is an epiphytic species generally found growing on the surface or undersides of leaves of aquatic plants or filamentous algae.

3.3 BENTHIC MACROINVERTEBRATES

The Site 8 pond is typical of tidally influenced freshwater ponds in the Potomac River estuary, with rooted aquatic vegetation and a soft bottom containing large amounts of organic detritus (Maryland DNR, 1981). Table 3-2 lists densities of benthic macroinvertebrates collected at the various transects in October 1992 and January 1993.

A total of 16 macroinvertebrate taxa was collected from the pond proper (Transects 1-3) in October, with oligochaetes most abundant (36.5% to 80.0% of total). A total of 10 taxa was collected from the pond-cattail marsh transition zone (Transects 4 and 5), again with Oligochaeta most prevalent. A total of three taxa was collected from Transects 6 and 7, which represent the stream-cattail marsh transition zone.

In January 1993, 15 macroinvertebrate taxa were collected from Transects 1-3, with Oligochaeta the most common group by far (48.2 to 93.4% of total). A total of seven taxa were collected from the pond-cattail marsh transition zone (Transects 4 and 5), with Oligochaeta again dominating samples (approximately 86% at each). The surprisingly high diversity seen at "pond" transects (Transects 1, 2, and 3) is somewhat misleading, however. Six, rather than three, replicate samples were taken at Transect 1 in an effort to better define within-transect variation. This produced an inflated measure of diversity because more areas, thus more macroinvertebrates habitats, were sampled.

In October 1992, high densities of macrobenthos were found in the transition zone between the pond proper and the cattail marsh (Transects 4 and 5), which had 3,102 and 5,129 organisms per square meter, respectively. The highest densities of macrobenthos were at Transect 5, a relatively shallow, narrow area at the head of the pond, just below the confluence of the two tributary streams.

In January 1993, as in October 1992, high macroinvertebrate densities were seen at Transect 5 (3,578 organisms/m^2), but highest densities (4,846 organisms/m^2) were observed at Transect 6, which was essentially a small stream flowing through the old lake bed. The high densities at Transect 6 were largely the result of an unusually high density (4,058 /m^2) of Oligochaeta.

TABLE 3-2

BENTHIC MACROINVERTEBRATES AT SITE 8
DENSITY (NO./m²) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES AT SITE 8
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER

Taxon	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
	Oct 92	Jan 93	Oct 92	Jan 93	Oct 92	Jan 93	Oct 92	Jan 93	Oct 92	Jan 93	Oct 92	Jan 93
Hymanella sp.	32 (1.5)		--		--		211 (6.8)		--		--	
Nematoda	--		--		51 (6.1)		306 (9.9)		--		38 (4.3)	
Oligochaeta	1,097 (50.4)	878 (48.2)	472 (80.0)	615 (77.8)	306 (36.5)	962 (93.4)	1,053 (34.0)	1,000 (86.0)	4,860 (94.8)	3,058 (85.5)	804 (91.4)	4,058 (83.7)
Polychaeta	--	19 (1.0)	19 (3.2)	24 (3.0)	6 (0.8)		230 (7.4)		--		--	
Hirudinea						10 (1.0)				77 (2.2)		19 (0.4)
Asellus sp.	--	98 (5.4)	6 (1.1)	15 (1.9)	--		--		--		--	39 (0.8)
Gammarus sp.	791 (36.4)	493 (27.1)	13 (2.1)	10 (1.3)	70 (8.4)		134 (4.3)	29 (2.5)	--		--	
Ephemerella sp.		26 (1.4)										
Gomphus sp.	--	42 (2.3)	6 (1.1)	5 (0.6)	9 (1.1)	10 (1.0)	58 (1.9)	19 (1.6)	--		--	38 (0.8)
Calopteryx sp.	128 (5.9)	6 (0.3)	6 (1.1)		140 (16.7)		19 (0.6)		--		--	
Hemiptera	--		--		--		--		--		--	
Notonecta undulata		3 (0.2)		10 (1.3)								
Sialis sp.	--		--		6 (0.8)		--		--		--	
Trichoptera	--		--		6 (0.8)		--		--		--	
Dysticidae		6 (0.3)										
Diptera (adult)	--		6 (1.1)		--		--		--		--	
Diptera (larvae)	--		--	5 (0.6)	6 (0.8)		--		--	19 (0.4)	--	
Culex sp.	--		13 (2.1)		--		--		--		--	
Chironomidae	128 (5.9)	228 (12.5)	48 (8.2)	101 (12.8)	128 (15.2)	48 (4.7)	880 (28.4)	96 (8.3)	115 (2.2)	77 (2.2)	--	577 (11.9)
Helisoma sp.		6 (0.3)										
Gyraulus sp.		3 (0.2)										
Physella sp.	--	6 (0.3)	--		38 (4.5)		77 (2.5)		115 (2.2)		38 (4.3)	
Unionidae	--		--		6 (0.8)		--		--		--	
Sphaerium sp.	--	6.0 (0.3)	--	5 (0.6)	64 (7.6)		134 (4.3)	19 (1.6)	39 (0.8)	347 (9.7)	--	115 (2.4)
Totals	2,176	1,820	589	790	836	1,030	3,102	1,163	5,129	3,578	880	4,846

TABLE 3-2
BENTHIC MACROINVERTEBRATES AT SITE 8
DENSITY (NO./m²) AND RELATIVE ABUNDANCE (%) OF BENTHIC MACROINVERTEBRATES AT SITE 8
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
PAGE 2

Taxon	Transect 7		Transect 10		Transect 11		Control A		Control B	
	Oct 92	Jan 93*	Oct 92	Jan 93	Oct 92	Jan 93*	Oct 92	Jan 93*	Oct 92	Jan 93*
Hymanella sp.	--		76 (1.8)		--		--		--	
Nematoda	--		--		--		76 (9.9)		--	
Oligochaeta	172 (37.5)		4,132 (98.25)	3,178 (84.0)	76 (100.0%)		--		--	
Polychaeta	--		--		--		--		--	
Hirudinea										
Asellus sp.	--		--		--		--		--	
Gammarus sp.	--		--		--		536 (70.2)		38 (100.0)	
Ephemerella sp.										
Gomphus sp.	--		--		--		--		--	
Calopteryx sp.	--		--		--		--		--	
Hemiptera	--		--		--		76 (9.9)		--	
Notonecta undulata										
Sialis sp.	--		--		--		--		--	
Trichoptera	--		--		--		--		--	
Dysticidae										
Diptera (adult)	--		--		--		--		--	
Diptera (larvae)	--		--		--		76 (9.9)		--	
Culex sp.	--		--		--		--		--	
Chironomidae	--		--		--		--		--	
Helisoma sp.										
Gyraulus sp.										
Physella sp.	287 (62.5)		--	39 (1.0)	--		--		--	
Unionidae	--		--		--		--		--	
Corbicula sp.				19 (0.5)						
Pisidium sp.				506 (13.4)						
Sphaerium sp.	--		--	41 (1.0)	--		--		--	
Totals	459	0	4,208	3,783	76	0	764	0	38	0

* No collections made at this station in January 1993

Excluding Transect 1 (which was sampled more intensively than other stations), diversity was highest (8 taxa), in January, at Transect 2. This transect crosses the pool that lies at the base of the Noble Road embankment. All of the other transects showed low diversity, with only four to six taxa present. In October, by contrast, three transects (2, 3, and 4) contained nine or more taxa.

Groups that are indicative of good water quality, such as the odonates (dragonfly larvae) *Gomphus* and *Calopteryx* and an unspecified trichopteran (caddisfly), were found only at Transects 1-4 in October 1992, and this pattern was observed again in January. Pennak (1978) notes that dragonfly larvae are "rare" in polluted waters. Similarly, caddisflies are associated with shallow (generally lotic) freshwater habitats where there is an adequate supply of oxygen. This dependence on relatively high oxygen levels stems from the fact that respiration in caddisfly larvae is "independent of the (water) surface and atmospheric oxygen" (Wiggins, 1984).

The megalopteran (alderfly larvae) *Sialis*, a sediment-dwelling predator that feeds on insect larvae, annelids, and crustaceans, which was collected at Transect 3 in October but was not seen in January samples. A new genus, *Ephemerella* (mayfly), which is characteristically found in unpolluted waters, was found at Transect 1 in January.

In October 1992, the beaver pond control site showed a depauperate macroinvertebrate community, low in density and diversity. The amphipod *Gammarus* was the dominant organism, making up 85% of the macroinvertebrates collected. Small numbers of nematodes, dipteran larvae, and hemipterans were also present. This site was not sampled in January, but it will be sampled in future quarterly biomonitoring.

3.4 FISH DIVERSITY

Low water levels at the Site 8 study site and low conductivity at the beaver pond control site hindered fish collecting in October 1992. Four fish species were captured during the October population surveys at the Site 8 pond: *Lepomis gibbosus* (pumpkinseed), *Ameiurus nebulosus* (brown bullhead), *Fundulus heteroclitus* (mummichog), and *Gambusia affinis* (mosquitofish). No fish were collected from the Stump Neck control site. At least two more species--largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis machrochirus*)--have been collected in the past at Site 8 (letter from Robert E. Foley, U.S. Fish & Wildlife Service to Philip Moore, Halliburton NUS Corporation, dated August 11, 1992). Even if these two

additional species had been collected during the October biomonitoring effort, the fish community could only be described as low in species diversity.

The water level of the pond was lowered in the summer of 1992 when a beaver dam in its lower end was breached. A weir is planned to be installed on the upstream end of the pipe in 1993. Once the weir is installed, the water level in the pond is expected to rise approximately 2 to 3 feet, this increase in depth will inundate much of the exposed pond bed.

Installation of the weir will prevent fish (and invertebrates) from moving into the Site 8 pond from Mattawoman Creek. All recruitment of biota will be from upstream, or from the pond itself. It is unclear whether this will result in marked changes in invertebrate communities, but it appears likely that the fish community will change over time, with a fishery developing that is more typical of a freshwater stream/pond than an estuary.

In the absence of recruitment from downstream, at least one species--the mummichog, *Fundulus heteroclitus*--is expected to decrease in relative abundance. A review of published life history accounts of this species suggests that the mummichog is able to reproduce and maintain population levels in freshwater impoundments under certain circumstances, but is more likely to flourish in brackish waters (Scott and Crossman, 1973; Lee et al., 1980). It is unknown what effect the installation of the weir and the isolation of the pond will have on *Gambusia*, bluegill, and brown bullhead. Bluegill and brown bullhead are freshwater species. *Gambusia affinis* is an adaptable euryhaline species that fares equally well in fresh or brackish water, lakes, ponds, backwaters of rivers, and drainage ditches (Lee et al., 1980). Ramsey (1975) notes that *Gambusia affinis* is the only fish species in the central and southern U.S. that thrives in polluted waters.

As noted in Section 2.4.1, plans to conduct fish population studies were abandoned in January 1993 as a result of the low species diversity and scarcity of fish observed in the July (U.S. Fish & Wildlife Service) and October 1992 samples.

3.5 ANALYSIS OF MERCURY IN FISH TISSUE

Fish collected for mercury analysis in January 1993 included the mummichog (*Fundulus*), mosquitofish (*Gambusia*), bluegill (*Lepomis macrochirus*), and the creek chubsucker (*Erimyzon oblongus*) at the Site 8 pond, and *E, oblongus* at the Mattawoman Creek control site.

As previously noted, fish samples were shipped on ice to Gascoyne Laboratories, Inc. EPA Method 7471 (detection limit = 0.01 mg/kg) was used to determine the concentration of total inorganic mercury present in each sample. Analyses were performed on homogenized whole body samples, rather than on fillets. The number and total weight of fish comprising each sample and the concentration of total mercury present in each sample are summarized in Table 3-3.

No particular trends were evident from these limited data. No significant difference was demonstrated when tissue concentrations of mercury measured in a given species were compared between sites (e.g., mercury present in creek chubsucker samples collected from Mattawoman Creek Control vs. Site 8). The data also failed to demonstrate a marked difference in the concentration of mercury measured in different fish species collected at a particular sampling station (i.e., Site 8). Because mercury exhibits a tendency to biomagnify (increases in concentration at higher levels of a food chain), detection of higher concentrations of mercury in bluegill (a mid-food-chain organism) than in *Fundulus* or *Gambusia* would have been anticipated. No such pattern was observed.

The tissue concentrations of mercury measured in the samples of bluegill collected in October 1992 and January 1993 (0.02 mg/kg in both instances) are similar to concentrations reported by the USFWS for this area between 1987 and 1991 (USFWS, 1991). As noted in these reports, the levels of mercury reported for bluegill collected from Indian Head are similar to those reported for bluegill collected from other locations in Maryland and throughout the United States; comparable data were not available for bullheads or *Gambusia.* The bluegill data (1987-1992) suggest that the levels of mercury available to these organisms have remained static over the last 6 years and that mercury tissue levels in bluegill have remained within the range reported for this species from other locations throughout the state.

Eisler (1987) suggested that fish tissue levels of 0.1 mg/kg mercury (wet weight) be used as a guideline for the protection of sensitive piscivorous birds and recommended that 1.1 mg/kg serve as a guidance level for the dietary intake of piscivorous mammals.

TABLE 3-3

MERCURY CONCENTRATIONS IN FISH TISSUE
(FISH COLLECTED JANUARY 27-28, 1993)
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Fish Species	Site 8			Control (Mattawoman Creek)		
	No. Fish Analyzed	Total Weight (grams)	mg Hg/kg	No. Fish Analyzed	Total Weight (grams)	mg Hg/kg
Fundulus	8	11.3	0.02	0	N/A	N/A
Gambusia	4	1.8	0.15	0	N/A	N/A
Bluegill	6	28.9	0.02	0	N/A	N/A
Creek Chubsucker	1	65.7	0.03	1	231.4	0.03

In October, the concentration of mercury present in fish samples from Site 8 and a control site were well below these suggested guidance levels, indicating that piscivorous terrestrial species that feed in these areas are not at risk. In January 1993, however, the concentration of mercury in one species, *Gambusia*, was slightly higher (0.15 mg/kg). Unfortunately, because attempts to capture *Gambusia* were unsuccessful at both control sites, it is unknown whether this slight increase in mercury body burden in Site 8 *Gambusia* is significant or whether it is a function of the small sample size (N=4) producing a sample mean that is not truly representative of the population mean. Mercury levels in *Gambusia* from Site 8 and control sites will be followed closely over the course of this investigation.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

These Phase I findings suggest that the Site 8 marsh/pond system has relatively simple community structure. The periphyton community was dominated by diatoms and green algae in October 1992 and by diatoms in January 1993. It is normal for periphyton communities to show marked seasonal changes. The benthic macroinvertebrate community is composed largely of herbivores that feed on attached algae and detritivores (such as oligochaetes) that feed on organic detritus. The two most abundant fish species (*Fundulus heteroclitus* and *Gambusia affinis*) in the Site 8 pond are omnivores that feed on plant matter, larval and adult insects, and small fish. Fish species diversity is low in the Site 8 pond and both control sites.

Concentrations of mercury in fish tissue from Site 8 in October 1992 and January 1993 revealed no clear differences between species or areas. Mercury levels in fish samples were below those suggested as a guideline for protection of sensitive piscivorous birds (0.1 mg/kg) and piscivorous mammals (1.1 mg/kg) in all cases but one, *Gambusia* samples from the Site 8 pond in January. All indications are that fish-eating birds and mammals that feed on Site 8 fish are not at risk, however.

None of these data should be regarded as conclusive. Future biomonitoring will reveal more about community structure and will yield more definitive information about levels of mercury in Site 8 biota.

4.2 RECOMMENDATIONS

Despite a number of practical and logistical problems caused by low water levels, Phase I biomonitoring was useful in that it provided data to begin establishment of baseline conditions at the study site. Based on the results of the October 1992 biomonitoring, a number of refinements were implemented. These refinements included: (1) reducing the number of replicate benthos samples taken at the study site, (2) increasing the level of resolution to which certain benthic macroinvertebrate groups are identified, (3) re-evaluating fish sampling methods employed, (4) omitting quantitative studies of fish abundance (catch-per-unit-effort) and diversity, and (5) identifying control site deficiencies.

Numerous researchers have commented on the tendency of benthic macroinvertebrates to be patchily, rather than uniformly distributed (Cummins, 1975; Wetzel, 1975). Given this patchiness and the large number of samples that would be required to discern statistically significant differences between sampling events (based on the variability observed in this preliminary study), in future rounds of biomonitoring the number of benthos samples will be reduced, and these data will be assessed qualitatively and graphically rather than quantitatively.

In the future it may be wise to increase the resolution of sample identification while reducing the number of samples. It is recommended that duplicate, rather than triplicate samples, be taken at each transect. It is also recommended that taxa such as Trichoptera and Unionidae be classified at least to the genus level, and, when practicable, to species. This should provide more information about the true diversity of the systems and, more importantly, allow a more detailed examination of pollution-tolerant and pollution-intolerant genera and species. As is, it is difficult to draw any conclusions about the relative pollution tolerance of the groups that are represented. Identification to the species level is essential for evaluations of the pollution sensitivity of many benthic organisms.

Given the ecology of the fish species present and the size and configuration of the three bodies of water, monitoring fish population parameters in the Site 8 pond and the control sites is not recommended. The fish community of Site 8 is dominated by two species, *Gambusia affinis* and *Fundulus heteroclitus*, both of which are small, schooling species. As a result, fish sampling may produce several hundred fish in a very short time (if a large school is encountered) or no fish over a longer time period. Moreover, factors totally unrelated to NSWC operations, such as rainfall, may well determine electrofishing success. For these reasons it is suggested that fish be collected for mercury analyses only, and that additional effort go into collecting adequate numbers of fish from the three targeted groups (i.e., largemouth bass, brown bullhead, and *Gambusia*). Based on fish collections in October 1992 and January 1993, it may be necessary to replace largemouth bass with bluegill as a test species, a species that is apparently more abundant than largemouth bass in the Site 8 pond.

In April 1993, there will be no "quantitative" (e.g., timed electrofishing in order to calculate catch-per-unit-effort) fish sampling. The emphasis will be on collecting sufficient numbers of fish from three groups (bass, bluegill, catfish-bullhead, and "minnow") and from three locations (Site 8 and two control sites) to allow analysis of mercury concentrations in tissues.

The subcontractor conducting fish sampling will be directed to collect fish with hoop or trap nets and large "slat" or fish traps in addition to electrofishing, seining, and collecting minnows with small minnow traps. The goal will be to collect 2 to 5 largemouth bass, 5 to 10 brown bullhead, and 10 or more *Gambusia* or *Fundulus*. It may be necessary to use bluegill as a surrogate for largemouth bass, and some other bottom feeder (*Moxostoma* or *Erimyzon*) in lieu of catfish or bullhead.

The fish and invertebrate communities in the Stump Neck control site are markedly less diverse than the study site, containing only three groups of aquatic macroinvertebrates (i.e., amphipods, nematodes, and dipterans) and small numbers of fish. This probably stems from the fact that the Stump Neck Annex beaver pond is in transition from a stream ecosystem to a pond ecosystem, is in large measure a closed system, and has not been colonized by organisms from upstream and downstream to the degree that the study site has. Because we have been unable to find a more appropriate control site within the Indian Head complex, we will continue to use the Stump Neck Annex control site and note its obvious limitations.

The October round of sampling suggested that at least one water quality parameter, salinity, may be omitted in future quarterly biomonitoring. Despite the fact that several sources (e.g., ABB-ES, 1992a) reported that the Site 8 pond was oligohaline (approximately 1 ppt salinity), all indications are that this system is a tidally influenced freshwater system. This was suggested by a definitive reference (Maryland DNR, 1981) and was confirmed by field measurements of salinity in October 1992 and January 1993. It is conceivable that under extraordinary circumstances (e.g., extreme drought coupled with extreme high tides, hurricanes) the Indian Head pond might show low levels of salinity. In future sampling it should only be necessary to measure salinity at a representative location at each site before each day's sampling and to note these data in the field logs. Once confirmed, there should be no reason to measure salinity at every station.

As expected, the water level in the Site 8 pond was low during the January 1993 biomonitoring. In spite of the logistical problems that this caused, solid information was obtained and additional sampling refinements will be made based on the results of the October and January biomonitoring. It is hoped that normal water levels will be restored by April 1993 (the next sampling period), that the entire pond can be sampled effectively, and that a more complete and representative picture of the pond ecosystem and its plant and animal communities will emerge.

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ATTACHMENT A

JANUARY 1993 PERIPHYTON SAMPLING RESULTS

TABLE A-1

TRANSECT 1W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Cyclotella*	44		0.1	
	Melosira	132		0.3	
	Meridion	44		0.1	
	Navicula	880		10.5	
	Nitzschia	132		1.0	
	Synedra	132		1.0	
TOTALS		1,364		13.0	
	BACILLARIOPHYTA	1,364	100.0	13.0	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-2

TRANSECT 1C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	672		2.6	
	Amphora	48		0.9	
	Cymbella	48		0.7	
	Eunotia	48		0.4	
	Fragilaria	96		0.2	
	Gomphonema	48		0.4	
	Melosira	48		0.1	
	Meridion	24		0.1	
	Navicula	1,560		29.2	
	Neidium	72		1.2	
	Nitzschia	624		6.2	
	Pinnularia	96		9.6	
	Surirella	24		0.9	
	Synedra	96		4.2	
EUGLENOPHYTA	*Trachelomonas*	24		1.2	
TOTALS		3,528		58.6	
	BACILLARIOPHYTA	3,504	99.3	57.4	98.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	24	0.7	1.2	2.0

TABLE A-3

TRANSECT 1E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	150		0.6	
	Amphora	30		1.2	
	Cyclotella	60		1.5	
	Coscinodiscus	30		15.0	
	Fragilaria	120		0.3	
	Gomphonema	240		2.4	
	Melosira	120		0.3	
	Navicula	1,410		15.3	
	Nitzschia	1,080		11.8	
	Pinnularia	30		18.0	
	Pleurosigma	30		2.1	
	Synedra	120		0.9	
TOTALS		3,420		69.4	
	BACILLARIOPHYTA	3,420	100.0	69.4	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-4

TRANSECT 2W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Amphora*	80		1.6	
	Cymbella	120		1.8	
	Diploneis	20		0.2	
	Eunotia	20		0.8	
	Fragilaria	40		0.1	
	Frustulia	40		1.2	
	Gomphonema	200		2.0	
	Meridion	80		0.2	
	Melosira	320		0.9	
	Navicula	1720		20.4	
	Nitzschia	740		13.9	
	Pinnularia	80		8.0	
	Pleurosigma	20		0.6	
	Synedra	20		9.0	
TOTALS		3500		60.7	
	BACILLARIOPHYTA	3500	100.0	60.7	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-5

TRANSECT 2C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	210		0.8	
	Amphora	180		3.6	
	Eunotia	60		0.6	
	Fragilaria	240		0.7	
	Gomphonema	240		2.4	
	Neidium	30		1.5	
	Navicula	1,260		15.0	
	Nitzschia	1,110		9.6	
	Pinnularia	60		6.0	
TOTALS		3,390		40.2	
	BACILLARIOPHYTA	3,390	100.0	40.2	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-6

TRANSECT 2E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	180		0.7	
	Cocconeis	60		0.2	
	Coscinodiscus	30		2.1	
	Fragilaria	180		0.5	
	Gomphonema	300		3.0	
	Melosira	150		0.4	
	Navicula	3,720		37.2	
	Nitzschia	2,610		23.3	
	Pinnularia	60		6.0	
	Stauroneis	30		12.0	
TOTALS		7,320		85.4	
	BACILLARIOPHYTA	7,320	100.0	85.4	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-7

TRANSECT 3W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	60		0.2	
	Amphora	30		0.6	
	Cymbella	30		0.4	
	Diatoma	30		0.1	
	Fragilaria	60		0.1	
	Gomphonema	240		2.4	
	Navicula	1,050		11.7	
	Nitzschia	630		5.0	
TOTALS		2,130		20.5	
	BACILLARIOPHYTA	2,130	100.0	20.5	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-8

TRANSECT 3C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Amphora*	180		3.6	
	Cocconeis	60		0.6	
	Cymbella	60		0.9	
	Diploneis	30		1.5	
	Eunotia	120		1.2	
	Gomphonema	300		3.0	
	Melosira	60		0.1	
	Meridion	60		0.1	
	Navicula	1,740		19.8	
	Neidium	120		2.1	
	Nitzschia	1,020		9.7	
	Pinnularia	180		18.0	
CHLOROPHYTA	*Scenedesmus*	240		0.2	
	Spirogyra	120		24.0	
TOTALS		4,290		84.8	
	BACILLARIOPHYTA	3,930	91.6	60.6	71.5
	CHLOROPHYTA	360	8.4	24.2	28.5
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-9

TRANSECT 3E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	120		0.4	
	Amphora	60		1.2	
	Cyclotella	30		0.7	
	Eunotia	90		0.9	
	Gomphonema	270		2.7	
	Navicula	1020		10.2	
	Nitzschia	810		7.2	
	Pinnularia	60		6.0	
TOTALS		2,460		29.3	
	BACILLARIOPHYTA	2,460	100.0	29.3	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-10

TRANSECT 4W
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Amphora*	192		3.8	
	Coscinodiscus	32		9.6	
	Cymbella	64		0.9	
	Eunotia	32		0.3	
	Fragilaria	192		0.5	
	Gomphonema	192		1.9	
	Melosira	64		0.1	
	Navicula	2144		21.4	
	Nitzschia	1120		8.9	
	Pinnularia	128		12.8	
	Stauroneis	32		0.6	
TOTALS		4192		60.8	
	BACILLARIOPHYTA	4192	100.0	60.8	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-11

TRANSECT 4C
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	320		0.7	
	Amphora	64		1.2	
	Fragilaria	96		0.2	
	Gomphonema	32		0.3	
	Navicula	672		6.7	
	Nitzschia	384		3.0	
	Pleurosigma	32		1.0	
TOTALS		1,600		13.1	
	BACILLARIOPHYTA	1,600	100.0	13.1	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

TABLE A-12

TRANSECT 4E
PERIPHYTON SAMPLING RESULTS
SITE 8 - NITROGLYCERIN PLANT OFFICE
INDIAN HEAD DIVISION, NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

Taxon		January 1993			
		Density (cells/cm^2)	Relative Abundance (%)	Weight (mg/m^2)	Relative Weight (%)
BACILLARIOPHYTA	*Achnanthes*	240		0.9	
	Amphora	120		2.4	
	Cyclotella	60		1.5	
	Cymbella	90		1.3	
	Eunotia	180		1.8	
	Fragilaria	480		1.4	
	Frustulia	60		7.2	
	Gomphonema	1,140		11.4	
	Melosira	540		1.6	
	Navicula	3,000		34.8	
	Neidium	60		1.0	
	Nitzschia	2,220		24.2	
	Pinnularia	150		15.0	
	Pleurosigma	60		4.2	
	Surirella	30		1.2	
TOTALS		8,430		109.9	
	BACILLARIOPHYTA	8,430	100.0	109.9	100.0
	CHLOROPHYTA	0		0	
	CHRYSOPHYTA	0		0	
	EUGLENOPHYTA	0		0	

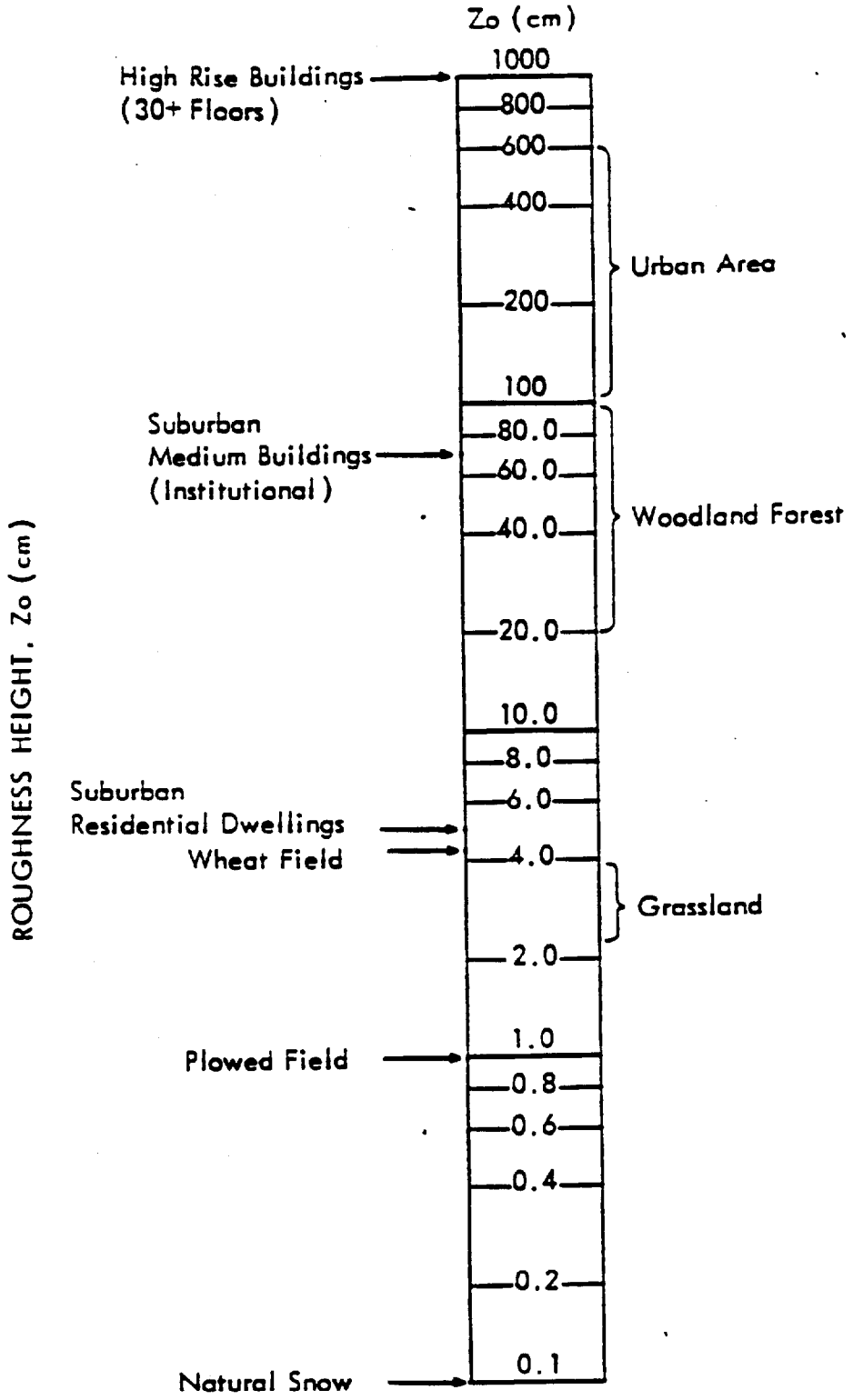

Figure 3-6. Roughness Heights for Various Surfaces (Cowherd and Guenther, 1976)

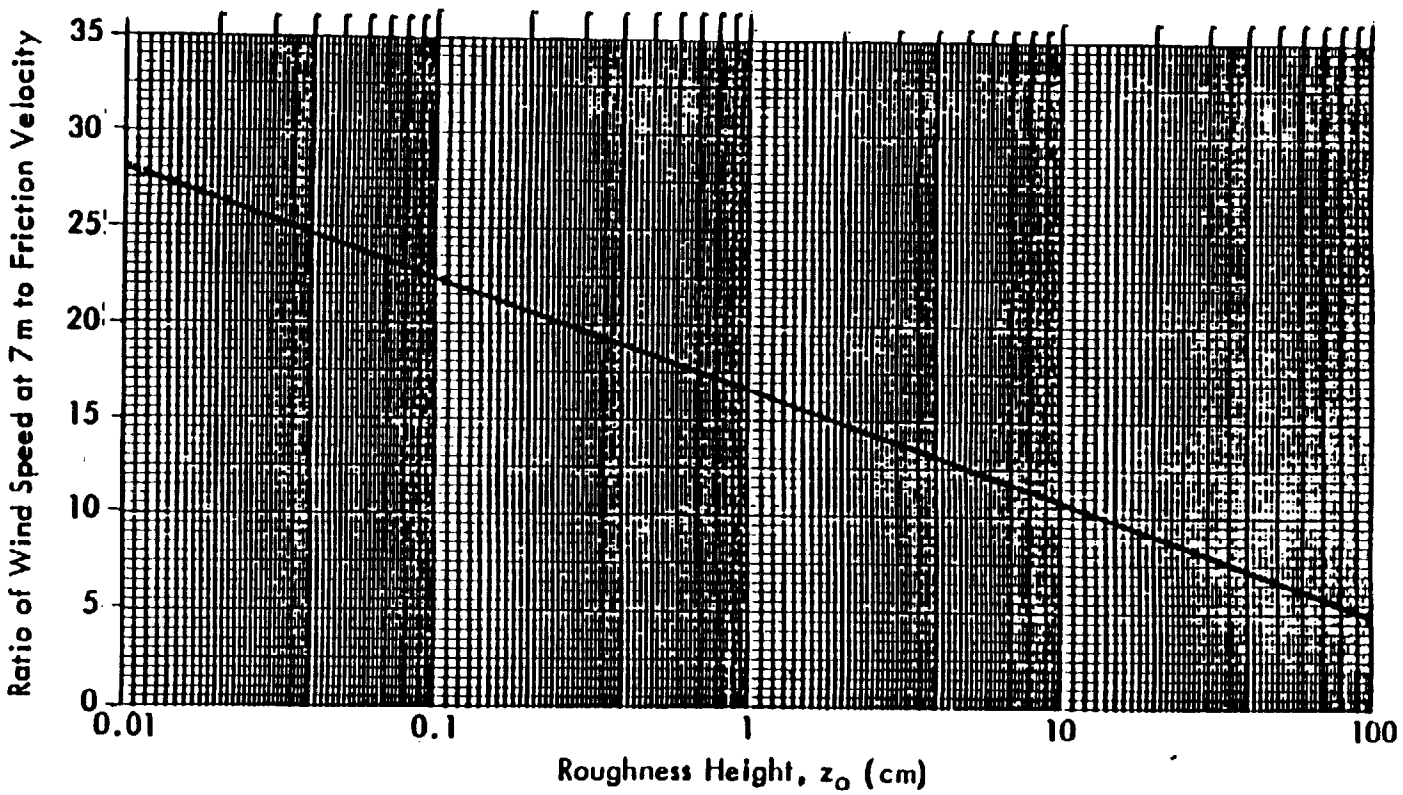

Figure 4-1. Ratio of wind speed at 7 m to friction velocity as a function of roughness height.

REGION 7 FINE GRID SOURCE SIZE 10M X 10M

WIND EROSION

DIR	RANGE (M) 200	300	400	500
N	3.680	1.805	1.091	0.735
NE	3.391	1.626	0.970	0.648
E	4.622	2.192	1.301	0.866
SE	5.454	2.610	1.555	1.039
S	4.151	2.000	1.198	0.802
SW	2.686	1.285	0.766	0.511
W	1.358	0.640	0.377	0.250
NW	0.668	0.305	0.177	0.116

Q_E = SCALING FACTOR = _____ (UNITS)

MECHANICAL RESUSPENSION

DIR	RANGE (M) 200	300	400	500
N	43.224	22.172	13.633	9.279
NE	41.792	21.160	12.891	8.725
E	39.522	19.843	12.040	8.124
SE	29.911	14.844	8.948	6.014
S	40.962	20.833	12.744	8.645
SW	34.257	17.154	10.389	7.005
W	26.682	13.384	8.117	5.473
NW	16.752	8.328	5.017	3.369

Q_M = SCALING FACTOR = _____ (UNITS)

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NO. 0454R	
SUBJECT CALCULATION OF FUGITIVE DUST EMISSION RATES			
BASED ON COWHERD, et al., September 1984.		DRAWING NUMBER	
BY NORMAN STRAUB	CHECKED BY KMS	APPROVED BY	DATE 04/01/94

PURPOSE:

Estimate fugitive dust emission rates using model developed by the Exposure Assessment Group of the U.S. EPA's Office of Research and Development. The model used provides "order of magnitude" estimates of respirable dust concentrations (< 10 μm) due to wind erosion and mechanical resuspension.

ASSUMPTIONS:

- Fugitive dusts are assumed to be generated from limited and unlimited sources of respirable particles. The greatest generation rates are used as a conservative estimate of the emission rate.
- Meteorological data for Norfolk, Virginia used for the site, located at Indian Head, Maryland.
- Receptor exposed to dusts originating only from wind erosion. Mechanical resuspension and agitation not considered.
- Fugitive dusts are assumed to be ingested (as sputum) at a rate of 62.5% and absorbed through the lungs at a rate of 12.5% relative to the rate of material inhaled (Schaum, 1984)

RELEVANT EQUATIONS:

- Emission rate of respirable contaminant particles (R_{10})

$$R_{10} = \alpha \, E_{10} \, A$$

Where: R_{10} = Emission rate of contaminant as respirable particle (mg/hr)
α = Mass fraction of contaminant in soil (unitless)
E^{10} = Respirable particulate (<10μm) emission rate (mg/m^2-hr)
A = Source areal extent (m^2)

- Emission rate from surface with limited erosion potential (E_{10})

$$E_{10} = 0.83 \frac{f \; P(u^+) \; (1-V)}{\left(\frac{PE}{50}\right)^2}$$

Where: E_{10} = Respirable particulate (<10μm) emission rate (mg/m^2-hr)
f = Frequency of disturbance (events/month)
$P(u^+)$ = Observed fastest mile windspeed (m/sec)
V = Fraction of vegetated cover (unitless)
PE = Thornthwaite's Evaporative Index (obtained from Figure 4-2)

CALCULATION WORKSHEET Order No. 19116 (01-91) PAGE ____ OF ____

CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF FUGITIVE DUST EMISSION RATES			
BASED ON COWHERD, et al., September 1984.		DRAWING NUMBER	
BY 245	CHECKED BY KHS	APPROVED BY	DATE 04/01/94

- Erosion threshold windspeed (u_t)

$$u(z) = \left(\frac{u_*}{0.4}\right) \ln \left(\frac{z}{z_0}\right)$$

Where: u(z) = Windspeed at height z (m/sec)
u. = Threshold friction velocity (m/sec)
z = Height above surface (cm)
z_0 = Roughness height (cm)

The value for u. is determined from a site survey as the windspeed at the ground surface which results in erosion of the surface. The height above the surface (z) is the height from which windspeed data is obtained (typically from a 7 m high weather station). The roughness height (z_0) is obtained from Figure 3-6.

SAMPLE CALCULATION:

For Norfolk, Virginia, a mean annual windspeed of 4.7 m/sec and a fastest mile windspeed of 21.3 m/sec is reported. From an assumed mode particle size of 1 mm, a value of u. = 0.65 m/sec is obtained from Figure 3-4. Also, from Figure 3-6 a roughness height (z_0) of 1 cm is obtained for a bare field.

- Erosion threshold windspeed (u_t)

$$u(z) = \left(\frac{u_*}{0.4}\right) \ln \left(\frac{z}{z_0}\right)$$

Substituting;

$$u(z) = \left(\frac{0.65\ m/sec}{0.4}\right) \ln \left(\frac{700\ cm}{1\ cm}\right)$$

$$u_t = 10.6\ m/sec$$

- Emission rate from surface with limited erosion potential (E_{10})

$$E_{10} = 0.83\ \frac{f\ P(u^*)\ (1-V)}{\left(\frac{PE}{50}\right)^2}$$

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF FUGITIVE DUST EMISSION RATES			
BASED ON COWHERD, et al., September 1984.		DRAWING NUMBER	
BY JHS	CHECKED BY KMR	APPROVED BY	DATE 04/01/94

and

$$P(u^+) = 6.7\ (u^+ - u(z))$$

Where: u^+ = Fastest wind speed (m/sec)

$$E_{10} = 0.83\ \frac{(\frac{50}{12})\ [(6.7)\ (21.3\ m/sec - 10.6\ m/sec)]\ (1-0)}{(\frac{111}{50})^2}$$

$$E_{10} = 50.3\ mg/m^2\text{-}hr$$

- Emission rate for Site 5:

Based on an area that is 1100 feet (335 m) long and 100 feet (31 m) wide an area of 10,385 m^2 is obtained. Under worst case conditions, limited reservior, the following emission rate can be expected from the site:

$$R_{10} = (50.3\ mg/m^2\text{-}hr)\ (10{,}385\ m^2)\ (10^{-6}\ Kg/mg) = 0.522\ Kg_{soil}\ /\ hour$$

- Dispersional modeling

Indian Head, MD is located in Climatic Zone 7 (from Figure 4-5). Therefore, the value P_R which corresponds is P_R = 0.296. This allows the calculation of the annual scaling factor and respirable concentration of dust.

Annual Scaling Factor Q

$$Q_l = \frac{R_{10}}{P_R} = \frac{0.522\ Kg_{soil}/hr}{0.296}\ x\ \frac{1\ hr}{3600\ sec}\ x\ \frac{1000\ gm}{1\ kg}$$

$$Q_l = 0.490\ gm/sec$$

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER	
SUBJECT CALCULATION OF FUGITIVE DUST EMISSION RATES			
BASED ON COWHERD, et al., September 1984.		DRAWING NUMBER	
BY	CHECKED BY	APPROVED BY	DATE 04/01/94

Respirable concentration (X)

$$X = Q_i f_i = (0.490\ gm/sec)\ (5.454 \frac{\mu g\ sec}{gm\ m^3}) = 2.67\ \mu g/m^3$$

NSWC INDIAN HEAD - CTO 157 - SITE 5 1454

CALCULATION OF FUGITIVE DUST EMISSION RATES

COWHERD, et al., September 1984.

REFERENCES:

Cowherd, C., Muleski G.E., Englehart, P.J., Gillette, D.A., Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites. Midwest Research Institute, Kansas City, Missouri, 68440. September, 1984.

Schaum, J., 1984. Risk Analysis of TCDD Contaminated Soil. EPA/540/8-84/031.

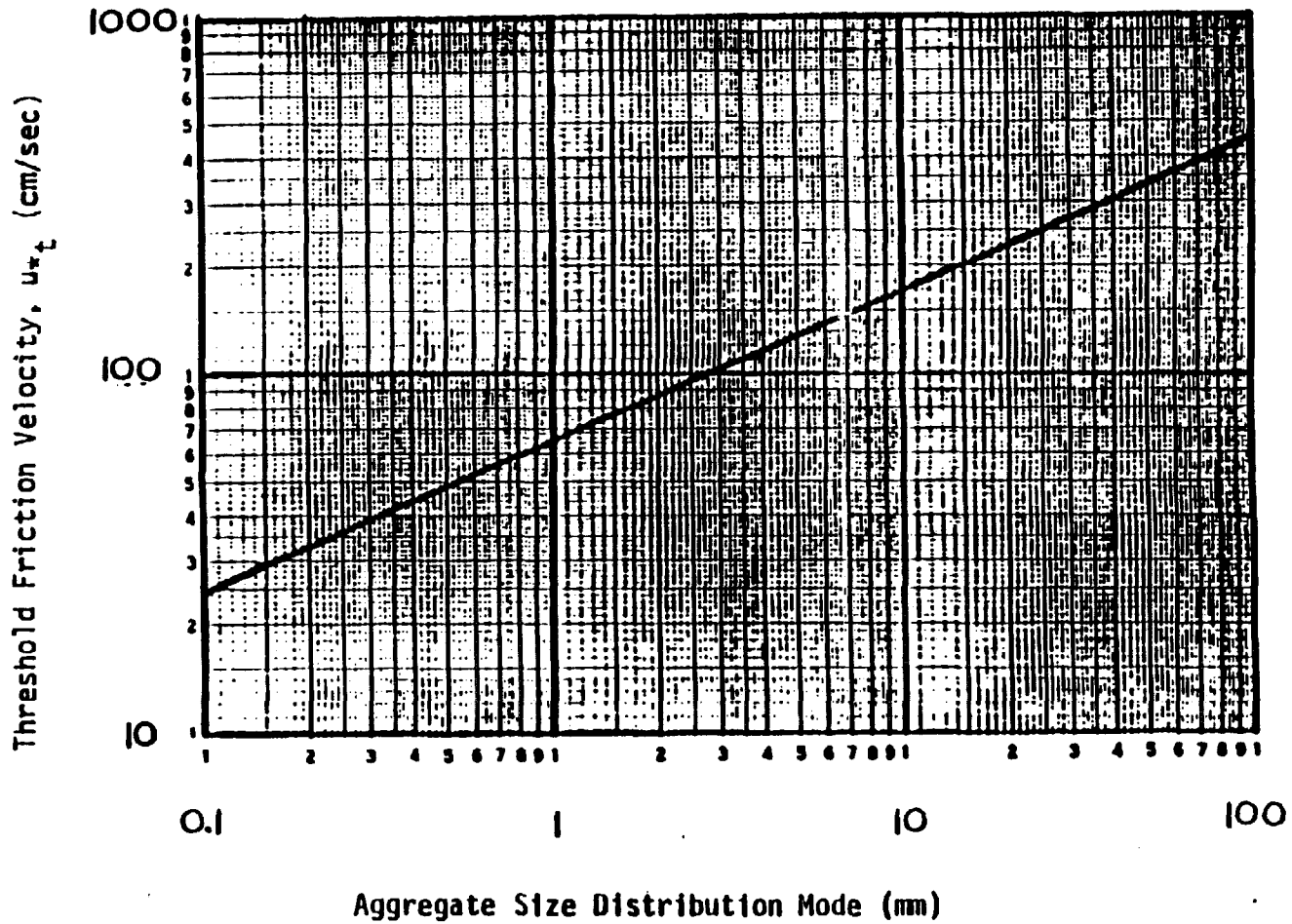

Figure 3-4. Relationship of Threshold Friction Velocity to Size Distribution Mode

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS			
BASED ON USEPA, RAGS (Part B), December 1991.		DRAWING NUMBER	
BY NORMAN STRAUB	CHECKED BY	APPROVED BY	DATE 04-01-94

PURPOSE:

Calculate site-specific risk-based preliminary remediation goals for soil exposure by adult maintenance receptors via incidental ingestion exposure route.

ASSUMPTIONS:

- Ingestion from all outdoor activities are considered.
- Receptors exposed under maintenance conditions.

RELEVANT EQUATIONS:

- Risk-based Preliminary Remediation Goal

For noncarcinogens:

$$C_{soil}\ (mg/Kg) = \frac{THI \times RfD \times BW \times AT \times 365}{IR_{soil} \times EF \times ED \times CF}$$

Where:
- C_{soil} = Chemical-specific PRG concentration in soil (mg/Kg)
- THI = Target Hazard Index (unitless)
- RfD = Chemical-specific reference dose (mg/Kg-day)
- BW = Receptor body weight (Kg)
- ED = Exposure duration (yr)
- 365 = Conversion factor (days/yr)
- IR_{soil} = Soil ingestion rate (mg/day)
- EF = Exposure frequency (days/yr)
- CF = Conversion factor (10^{-6} Kg/mg)
- AT = Averaging time = ED (yr)

For carcinogens:

$$C_{soil}\ (mg/Kg) = \frac{TR \times BW \times AT \times 365}{CSF \times IR_{soil} \times EF \times ED \times CF}$$

Where:
- C_{soil} = Chemical-specific PRG concentration in soil (mg/Kg)
- TR = Target cancer risk (unitless)
- BW = Receptor body weight (Kg)
- LT = Receptor lifetime (yr)
- 365 = Conversion factor (days/yr)
- CSF = Chemical-specific cancer slope factor $(mg/Kg\text{-}day)^{-1}$
- IR_{soil} = Soil ingestion rate (mg/day)
- EF = Exposure frequency (days/yr)
- ED = Exposure duration (yr)
- CF = Conversion factor (10^{-6} Kg/mg)

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS			
BASED ON USEPA, RAGS (Part B), December 1991.		DRAWING NUMBER	
BY	CHECKED BY	APPROVED BY	DATE 04/01/94

SAMPLE CALCULATION:

For silver at Site 5, a reference dose of 5×10^{-3} mg/Kg-day is reported. The following maintenance receptor exposure input parameters are used. No carcinogenic effects are reported for silver.

Parameter	Value	Units	Source/Rationale
THI	1.0	unitless	Target hazard index of unity
RfD	5×10^{-3}	mg/Kg-day	IRIS, December 1993
IR	50	mg/day	USEPA, March 25, 1991
ED	25	years	USEPA, March 25, 1991
EF	50	days/yr	Estimate based on weekly maintenance
BW	70	Kg	USEPA, March 25, 1991

- Noncarcinogenic PRG for silver

For noncarcinogens:

$$C_{soil}\ (mg/Kg) = \frac{THI \times RfD \times BW \times ED \times 365}{IR_{soil} \times EF \times ED \times CF}$$

Substituting;

$$C_{soil}\ (mg/Kg) = \frac{(1.0)\ (5 \times 10^{-3} mg/Kg\text{-}day)\ (70\ Kg)\ (25\ yrs)\ (365\ days/yr)}{(50\ mg/day)\ (50\ days/yr)\ (25\ yrs)\ (10^{-6}\ Kg/mg)}$$

$$C_{soil} = 51100\ mg/Kg$$

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS			
BASED ON USEPA, RAGS (Part B), December 1991.		DRAWING NUMBER	
BY	CHECKED BY	APPROVED BY	DATE 04/01/94

SAMPLE CALCULATION:

For silver at Site 5, a reference dose of 5 x 10^{-3} mg/Kg-day is reported. The following maintenance receptor exposure input parameters are used. No carcinogenic effects are reported for silver.

Parameter	Value	Units	Source/Rationale
THI	1.0	unitless	Target hazard index of unity
RfD	1 x 10^{-3}	mg/Kg-day	Oral RfD (5 x 10^{-3} mg/kg-day; IRIS, December 1993) adjusted for absorption (ABS = 20%).
SA	5000	cm^2/event	Estimate based on 95th %-ile adult male trunk and arms
AF	1.0	mg/cm^2	USEPA, January 1992
ABS	0.01	fraction	Estimate based on toxicity profile
ED	30	years	USEPA, March 25, 1991
EF	50	events/yr	Estimate based on weekly maintenance
BW	70	Kg	USEPA, March 25, 1991

- Noncarcinogenic PRG for silver

For noncarcinogens:

$$C_{soil}\ (mg/Kg) = \frac{THI \times RfD \times BW \times ED \times 365}{SA \times AF \times ABS \times EF \times ED \times CF}$$

Substituting;

$$C_{soil}\ (mg/Kg) = \frac{(1.0)\ (1 \times 10^{-3} mg/Kg\text{-}day)\ (70\ Kg)\ (25\ yrs)\ (365\ days/yr)}{(5000\ cm^2/event)\ (1.0\ mg/cm^2)\ (0.01)\ (50\ events/yr)\ (25\ yrs)\ (10^{-6}\ Kg/mg)}$$

$$C_{soil} = 102200\ mg/Kg$$

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS			
BASED ON USEPA, RAGS (Part B), December 1991.		DRAWING NUMBER	
BY	CHECKED BY	APPROVED BY	DATE 04/01/94

REFERENCES:

USEPA, January 1992. Dermal Exposure Assessment: Principles and Applications. Interim. EPA/600/8-91/011B. Office of Research and Development, Washington, D.C., 20460.

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Integrated Risk Information System (IRIS), On Line. December, 1993.

USEPA, December 1989. Risk Assessment Guidance for Superfund - Volume I. Human Health Evaluation Manual Part A. EPA/540/1-89/002.

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CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS			
BASED ON USEPA, RAGS (Part B), December 1991.		DRAWING NUMBER	
BY TAS	CHECKED BY KMB	APPROVED BY	DATE 04/01/94

REFERENCES:

USEPA, December 1991. Risk Assessment Guidance for Superfund - Volume I. Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals). Interim. OSWER Directive 9285.7-01B. Office of Emergency and Remedial Response, Washington, D.C., 20460.

USEPA, March 25, 1991. Risk Assessment Guidance for Superfund - Volume I. Human Health Evaluation Manual Supplemental Guidance - "Standard Default Exposure Factors". Interim Final. OSWER Directive 9285.6-03. Office of Emergency and Remedial Response, Washington, D.C., 20460.

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USEPA, December 1989. Risk Assessment Guidance for Superfund - Volume I, Human Health Evaluation Manual Part A. EPA/540/1-89/002.

CALCULATION WORKSHEET Order No. 19116 (01-91)

CLIENT NSWC INDIAN HEAD - CTO 157 - SITE 5		JOB NUMBER 1454	
SUBJECT CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS			
BASED ON USEPA. RAGS (Part B), December 1991.		DRAWING NUMBER	
BY NORMAN STRAUB	CHECKED BY	APPROVED BY	DATE 04/01/94

PURPOSE:

Calculate site-specific risk-based preliminary remediation goals for soil exposure by adult maintenance receptors via dermal contact exposure route.

ASSUMPTIONS:

- Dermal uptake from all outdoor activities are considered.
- Receptors exposed under maintenance conditions.

RELEVANT EQUATIONS:

- Risk-based Preliminary Remediation Goal

For noncarcinogens:

$$C_{soil}\ (mg/Kg) = \frac{THI \times RfD \times BW \times AT \times 365}{SA \times AF \times ABS \times EF \times ED \times CF}$$

Where:
- C_{soil} = Chemical-specific PRG concentration in soil (mg/Kg)
- THI = Target Hazard Index (unitless)
- RfD = Chemical-specific reference dose (mg/Kg-day)
- BW = Receptor body weight (Kg)
- ED = Exposure duration (yr)
- 365 = Conversion factor (days/yr)
- SA = Receptor skin surface area (cm^2)
- AF = Soil-to skin adherence factor (mg/cm^2)
- ABS = Fraction of contaminant absorbed through skin
- EF = Exposure frequency (days/yr)
- CF = Conversion factor (10^{-6} Kg/mg)
- AT = Averaging time = ED (yr)

For carcinogens:

$$C_{soil}\ (mg/Kg) = \frac{TR \times BW \times AT \times 365}{CSF \times SA \times AF \times ABS \times EF \times ED \times CF}$$

Where:
- C_{soil} = Chemical-specific PRG concentration in soil (mg/Kg)
- TR = Target cancer risk (unitless)
- BW = Receptor body weight (Kg)
- AT = Receptor lifetime (yr)
- 365 = Conversion factor (days/yr)
- CSF = Chemical-specific cancer slope factor $(mg/Kg\text{-}day)^{-1}$
- SA = Receptor skin surface area (cm^2)
- AF = Soil-to skin adherence factor (mg/cm^2)
- ABS = Fraction of contaminant absorbed through skin
- EF = Exposure frequency (days/yr)
- ED = Exposure duration (yr)
- CF = Conversion factor (10^{-6} Kg/mg)

CLIENT	JOB NUMBER
NSWC INDIAN HEAD - CTO 157 - SITE 5	1454
SUBJECT	
CALCULATION OF SOIL PRELIMINARY REMEDIATION GOALS FOR INHALATION	
BASED ON	DRAWING NUMBER
USEPA RAGS (Part B) December 1991	

BY	CHECKED BY	APPROVED BY	DATE
NORMAN STRAUB	KMB		04/01/94

PURPOSE:

Calculate site-specific risk-based preliminary remediation goals for soil exposure by adult maintenance receptors via inhalation of fugitive dust exposure route.

ASSUMPTIONS:

- Inhalation of outdoor air considered.
- Receptors exposed under maintenance conditions.

RELEVANT EQUATIONS:

- Risk-based Preliminary Remediation Goal

For noncarcinogens:

$$C_{air}\ (mg/m^3) = THI \times \left(\frac{RfD_{inh} \times BW \times AT \times 365}{0.125 \times InhR \times F_i \times EF \times ED} + \frac{RfD_{ing} \times BW \times AT \times 365}{0.625 \times InhR \times F_i \times EF \times ED}\right)$$

Where:

C_{air}	=	Chemical-specific PRG concentration in air (mg/m^3)
THI	=	Target Hazard Index (unitless)
RfD_{inh}	=	Chemical-specific inhalation reference dose (mg/Kg-day)
RfD_{ing}	=	Chemical-specific oral reference dose (mg/Kg-day)
BW	=	Receptor body weight (Kg)
ED	=	Exposure duration (yr)
365	=	Conversion factor (days/yr)
InhR	=	Inhalation rate (m^3/day)
F_i	=	Fraction of time spent at site (unitless)
EF	=	Exposure frequency (days/yr)
AT	=	Averaging time = ED (yr)

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For carcinogens:

$$C_{air}\ (mg/m^3) = TR \times \left(\frac{BW \times AT \times 365}{0.125 \times CSF_{inh} \times InhR \times F_i \times EF \times ED} + \frac{BW \times AT \times 365}{0.625 \times CSF_{ing} \times InhR \times F_i \times EF}\right)$$

Where: C_{air} = Chemical-specific PRG concentration in air (mg/m^3)
TR = Target cancer risk (unitless)
BW = Receptor body weight (Kg)
AT = Receptor lifetime (yr)
365 = Conversion factor (days/yr)
CSF_{inh} = Chemical-specific inhalation cancer slope factor $(mg/Kg\text{-}day)^{-1}$
CSF_{ing} = Chemical-specific oral cancer slope factor $(mg/Kg\text{-}day)^{-1}$
InhR = Inhalation rate (m^3/day)
F_i = Fraction of time spent at site (unitless)
EF = Exposure frequency (days/yr)
ED = Exposure duration (yr)

- Calculation of soil PRG

$$C_{soil}\ (mg/Kg) = \frac{C_{air}}{(x)(CF)}$$

Where: C_{soil} = Chemical-specific PRG concentration in soil (mg/Kg)
x = Respirable soil emissions concentration (mg/m^3)
CF = Conversion factor (10^{-6} Kg/mg)

SAMPLE CALCULATION:

For silver at Site 5, a reference dose of 5×10^{-3} mg/Kg-day is reported. The following maintenance receptor exposure input parameters are used. No inhalation reference dose or carcinogenic effects are reported for silver.

Parameter	Value	Units	Source/Rationale
THI	1.0	unitless	Target hazard index of unity
RfD	5×10^{-3}	mg/Kg-day	IRIS, December 1993
InhR	20	m^3/day	USEPA, March 25, 1991
F_i	0.33	unitless	8 hour working day
EF	50	days/yr	Estimate based on weekly maintenance
ED	25	years	USEPA, March 25, 1991
BW	70	Kg	USEPA, March 25, 1991

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- Noncarcinogenic PRG for silver

For noncarcinogens:

$$C_{air}\ (mg/m^3) = THI \times \left(\frac{RfD_{inh} \times BW \times ED \times 365}{0.125 \times InhR \times F_i \times EF \times ED} + \frac{RfD_{ing} \times BW \times ED \times 365}{0.625 \times InhR \times F_i \times EF \times ED}\right)$$

$$C_{air}\ (mg/m^3) = (1.0) \times \left(\frac{(5 \times 10^{-3}\ mg/Kg\text{-}day) \times (70\ Kg) \times (25\ yr) \times (365\ day/yr)}{0.625 \times (20\ m^3/day) \times (0.33) \times (50\ day/yr) \times (25\ yr)}\right)$$

$$C_{air} = 0.619\ mg/m^3$$

- Soil PRG for silver

$$C_{soil}\ (mg/Kg) = \frac{0.619\ mg/m^3}{(2.67 \times 10^{-3}\ mg/m^3)\ (10^{-6}\ Kg/mg)} = 232{,}000{,}000\ mg/Kg$$

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REFERENCES:

USEPA, December 1991. Risk Assessment Guidance for Superfund - Volume I. Human Health Evaluation Manual (Part B. Development of Risk-based Preliminary Remediation Goals). Interim. OSWER Directive 9285.7-01B. Office of Emergency and Remedial Response, Washington, D.C., 20460.

USEPA. March 25, 1991. Risk Assessment Guidance for Superfund - Volume I. Human Health Evaluation Manual Supplemental Guidance - "Standard Default Exposure Factors". Interim Final. OSWER Directive 9285.6-03. Office of Emergency and Remedial Response, Washington, D.C., 20460.

Integrated Risk Information System (IRIS), On Line. December, 1993.

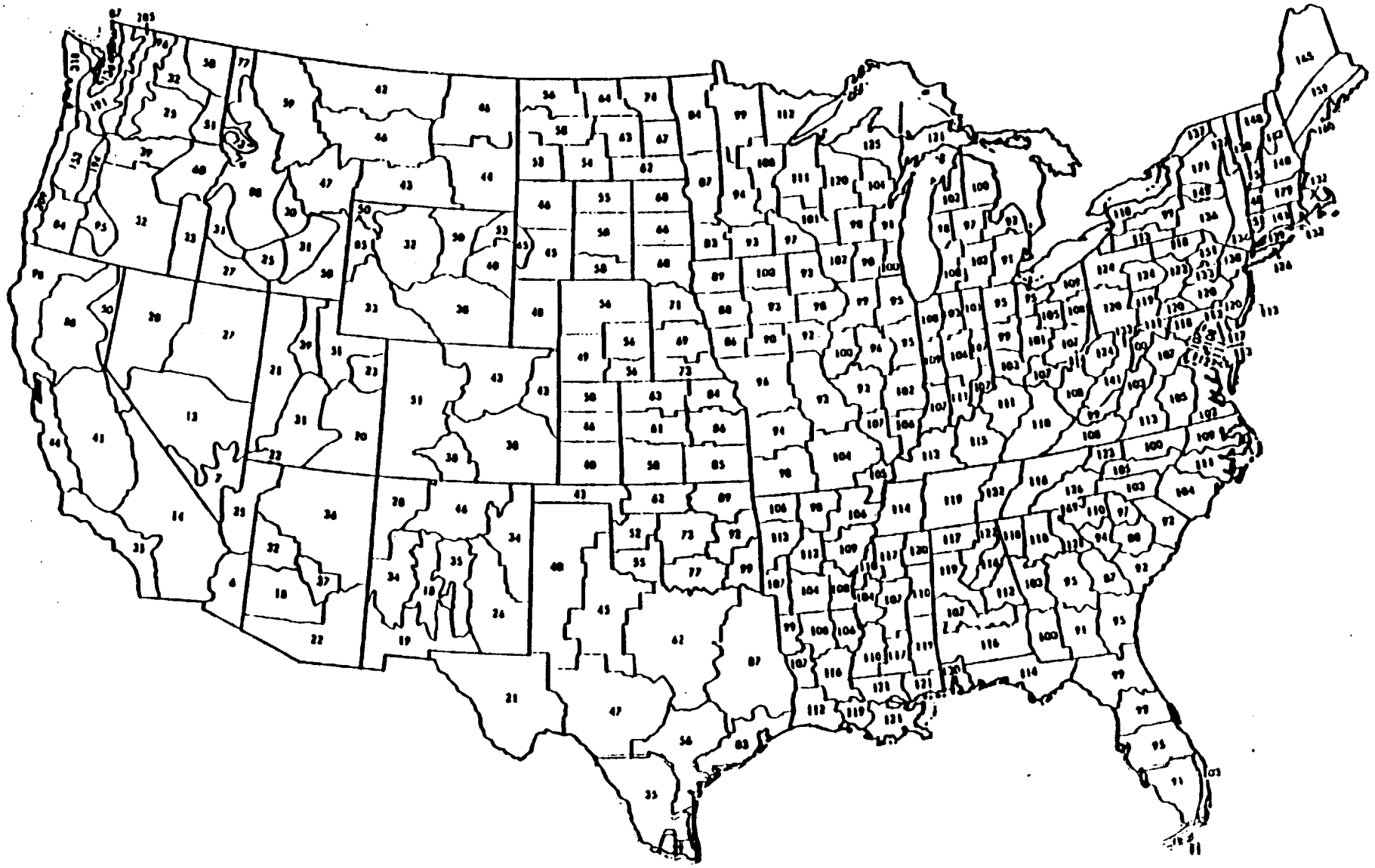

Figure 4-2. Map of P-E Index for State Climatic Divisions

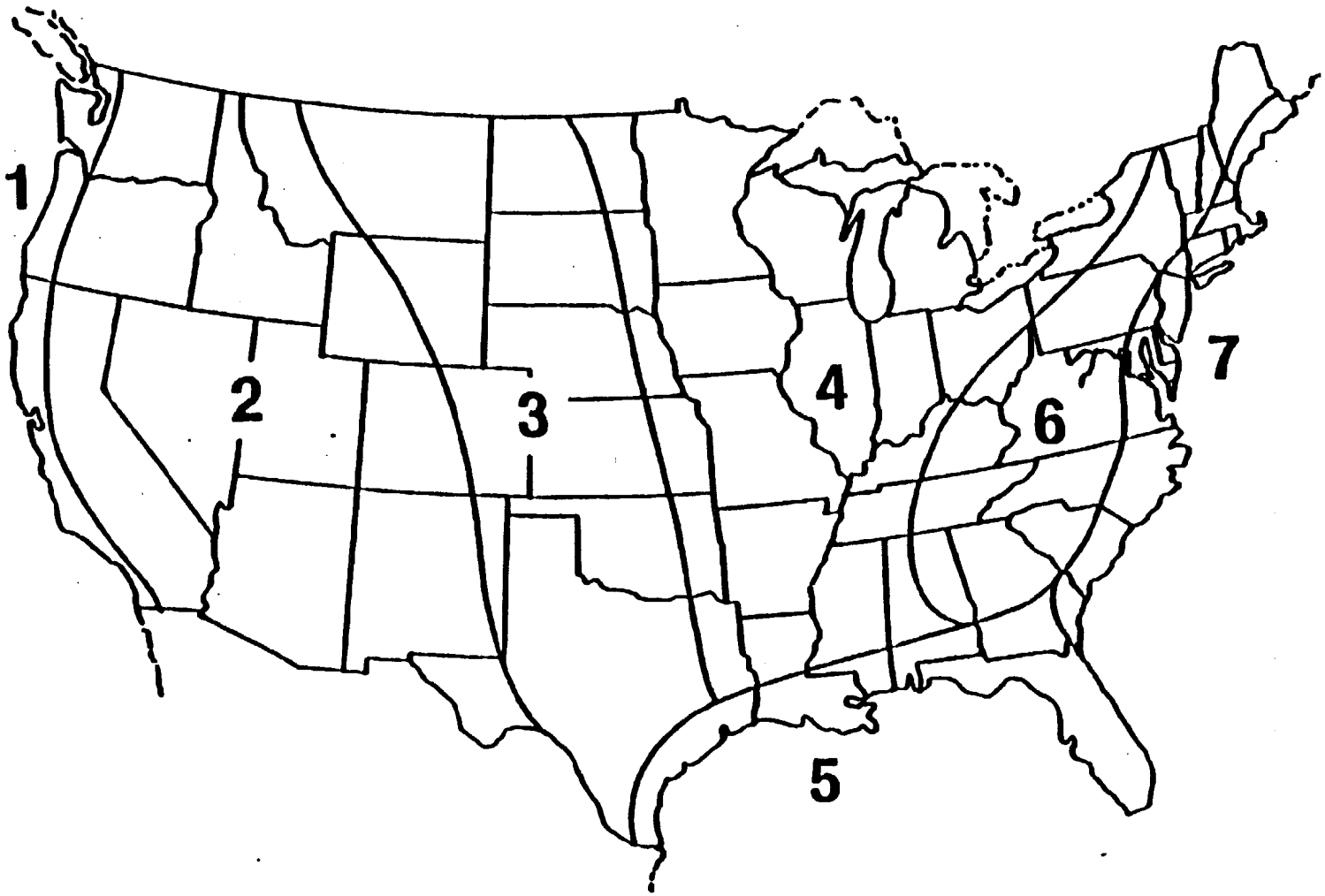

Figure 4-5. Climatic Region