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HISTORICAL RADIOLOGICAL ASSESSMENT

NAVAL SUBMARINE BASE
NEW LONDON

VOLUME I

NAVAL NUCLEAR PROPULSION PROGRAM

1954 - 1993

HISTORICAL RADIOLOGICAL ASSESSMENT

NAVAL SUBMARINE BASE
NEW LONDON

Volume I

NAVAL NUCLEAR PROPULSION PROGRAM

1954 - 1993

RADIOLOGICAL CONTROLS OFFICE
PORTSMOUTH NAVAL SHIPYARD
PORTSMOUTH, NH 03804-5000

NOVEMBER 1997

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1.0 Executive Summary

1.1 Purpose

This Historical Radiological Assessment (HRA) has been prepared by Portsmouth Naval Shipyard for Naval Submarine Base, New London (Subase) pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA). The purpose of this HRA is to catalog and present over 38 years of radiological environmental data within the framework of the CERCLA process and within the pathway scoring protocol of the revised Hazard Ranking System (HRS).

Volume I of this HRA addresses radioactivity associated with the Naval Nuclear Propulsion Program (NNPP). Volume II addresses general radioactive material (G-RAM), including all non-NNPP applications of radioactivity (both Radiological Affairs Support Program (RASP) material and site-related medical applications). Different branches of the Navy are responsible for these categories of radioactivity, and different historical practices have applied.

1.2 Background

Subase was first authorized to accomplish NNPP work in 1959. The first work of this nature was performed in USS SKATE (SSN 578) upon arrival at Pier 10 on September 4, 1959. This was the first use of Pier 10 by a nuclear-powered submarine following the May 25, 1959 acceptance of the new pier. Prior to this time, the Thames River channel and Subase berths were not deep enough to accept the 28 foot draft of the nuclear-powered submarines nor were Subase piers equipped with all the support services required by a nuclear-powered submarine. Prior to this time, nuclear-powered submarines were occasionally towed to the base for short duration periods in the floating drydock . During these drydockings, work such as reballasting and hull cleaning, inspection, and painting was performed. USS NAUTILUS (SSN 571) was the first nuclear-powered submarine to be placed in drydock at Subase, arriving on January 25, 1955 and departing on February 11, 1955.

The project to allow nuclear-powered submarines ready access to Subase was begun in June 1958. This project included dredging the river channel and the Pier 10 berthing area, dismantling the wooden Pier 10, and constructing a new steel and concrete Pier 10. The dredging was completed in October 1958. The next phase of renovation to accommodate nuclear-powered submarines was completed on March 24, 1961, with the dedication of reconstructed Piers 12 and 13. Modification of the YFN-685 barge to service nuclear-powered submarines began in September 1961. This barge was designated as the Radiological Repair Support Barge, YRRS-4, and was placed into service in March 1962. Since then, Subase has conducted routine and emergent Intermediate Maintenance Activity level maintenance, alterations, repairs, and testing on nearly every type and class of nuclear-powered submarine.

Beginning in 1954, before any nuclear work was performed or a nuclear-powered ship was berthed at the base, a baseline study of the radiological environment of NNPP activities on the Thames River was conducted. Radiological environmental monitoring has continued through the present. Results are forwarded to the NNPP headquarters which, since 1967, has published an annual report with distribution to other Federal Agencies, States, Congress, and the public.

Independent surveys of the river have been an integral part of this program since its inception. These independent verifications have been consistent with NNPP and Subase results and conclusions.

1.3 Findings

Of all the radiological data collected by the Navy, the Public Health Service (PHS), and the Environmental Protection Agency (EPA), the only radioactivity attributable to Naval nuclear propulsion plants in the vicinity of the base are trace levels of cobalt-60 within river bottom sediments, and in some non-edible aquatic species at locations adjacent to piers where nuclear-powered ships have been moored. This radioactivity is attributable to pre-1972 discharges of processed radioactive liquids, as discussed in annual reports issued by the NNPP. The small concentrations of cobalt-60, less than 0.1 pCi/g dry weight, measured in samples of kelp, sea lettuce, and sea cucumber, may be due to sediment adhering to the surface of these biota samples (Reference 1).

Even though NNPP release limits were well below federal requirements, the NNPP had eliminated these discharges by Program activities by about mid-1972. Since 1973, no radioactivity has been intentionally released by Subase. This has been confirmed by the findings and conclusions of the PHS and EPA surveys performed in 1966, 1972, and 1989. No detectable radioactivity attributed to Naval nuclear propulsion plant work was found in any river water, drinking water, or edible sea food samples collected during all three of these surveys.

1.4 Conclusions

This HRA concludes that: (a) the berthing of and work on nuclear-powered ships at Subase has had no adverse effect on the human population or the environment of the region; (b) the trace levels of cobalt-60 found within river bottom sediments do not require remediation, due to the low levels detected and due to the environmental harm that would occur during removal of bottom material by extensive dredging; and (c) independent reviews by the PHS and EPA are consistent with these conclusions. Subase concludes that no additional characterization and no remedial actions are necessary as a result of NNPP activities at the base.

2.0 Introduction

2.1 Background

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 established a process whereby past private sector disposal sites were scored for environmental contamination, and remedial action initiated where warranted. Federal facilities were not included within CERCLA; however, under Executive Order 12316 of August 20, 1981, the President directed the Department of Defense (DOD) to conduct similar evaluations of their installations.

By the mid-1980's, most DOD facilities had been evaluated. These Initial Assessment Studies were conducted for Naval shipyards and operating bases where nuclear-powered ships were maintained and berthed. The Naval Submarine Base New London (Subase) Initial Assessment Study (IAS), Reference 2, was completed in 1983.

During 1986, DOD realigned its programs to be more consistent with those of the Environmental Protection Agency (EPA) in the private sector. Initial Assessment Studies paralleled the Preliminary Assessments and Site Inspections of CERCLA. Confirmation Studies paralleled the Remedial Investigation and Feasibility Studies of CERCLA.

The Superfund Amendments and Reauthorization Act (SARA) of 1986 required that Federal agencies comply in the same manner and extent as private entities and allowed Federal activities to be placed on the National Priorities List (NPL). Executive Order 12580 of January 23, 1987 gave additional jurisdiction to the EPA for Federal facilities on the NPL.

SARA also directed the EPA to revise its Hazard Ranking System (HRS) used to score sites undergoing the CERCLA process. This was completed and the revised HRS was published in the Federal Register in December 1990.

The EPA scored Subase under the original Hazard Ranking System. Data collected during the 1983 IAS, Reference 2, was used in this scoring. The 1983 IAS and the HRS scoring did not include consideration of any past releases of radioactivity associated with NNPP work since the emphasis during those efforts was on industrial and chemical pollutants. Due to past chemical disposal and control practices, EPA proposed Subase for listing on the NPL in 1989. Subase was listed on the NPL on August 30, 1991.

2.2 Purpose

This Historical Radiological Assessment (HRA) was produced to provide a comprehensive review and assessment of the impact of radiological operations at Subase. This assessment is organized in a format similar to the standard Preliminary Assessment (PA) protocol used by the EPA within the CERCLA process. This format was chosen as a vehicle that is in common use and is easily understood.

Environmental radiological data collected for Subase is cataloged and presented within the pathway evaluation protocol of the PA. Additional environmental data collected by the Public Health Service and the EPA and their independent conclusions are included in the relevant sections of this assessment.

Section 8 of this assessment addresses each pathway along with the salient data results contained in previous sections and evaluates estimates of radiological impact to the public and to the environment from Subase operations.

This assessment is historical in that the regulatory and policy changes that have occurred during the evolution of the NNPP are included as an explanatory supplement to the analytical results.

2.3 Methods

2.3.1 Counting Terminology

"Gross gamma" spectrometry systems used for counting environmental samples are currently calibrated to respond to gamma energies between 0.1 MeV and 2.1 MeV, and thus detect a combined total of all radionuclides with gamma energies between 0.1 and 2.1 MeV. (The gross gamma energy range for counting systems used from 1964 through 1974 was between 0.6 and 1.6 MeV). Similarly, "cobalt-60 energy range" gamma spectrometry is used to identify total gamma radioactivity in the range of 1.1 to 1.4 MeV. Where activity in this range is above 1 pCi/g, radionuclide-specific gamma spectroscopy analysis is performed to determine whether cobalt-60 is present or whether all the activity is due to other (natural or fallout-related) radionuclides. For some analyses (e.g., modern environmental monitoring sediment, water, and biota samples), radionuclide-specific gamma spectroscopy analysis is performed regardless of measured gamma levels.

Spectrometry detectors, whether sodium iodide or germanium, have conversion efficiencies which vary as a function of the incident gamma energy. This means that in order to determine the amount of a given radionuclide in a sample, the efficiency of the detector for that specific radionuclide would have to be determined using a known source of that radionuclide. Alternatively, a source containing known quantities of several radionuclides with gamma energies ranging from about 0.15 MeV to about 2.0 MeV can be used to construct an efficiency curve for the detector.

A simpler approach is to assign the efficiency for a particular radionuclide to all energies between the upper and lower limits of the region of interest. For the NNPP, cobalt-60 is the most predominant radionuclide and has the most restrictive concentration limit in air and water of all the radionuclides identified in Naval reactor plants. If all of the radionuclides with gammas occurring within a given band of energies are quantified by using the efficiency of the most limiting radionuclide, the resulting calculated quantity will conservatively overestimate the actual radioactivity for the radionuclide of concern.

Gross gamma, cobalt-60 equivalent is the quantity of all radioactivity in the gamma energy range of interest (0.1-2.1 MeV) calculated using the efficiency value of cobalt-60. Cobalt-60 energy range radioactivity is calculated using the cobalt-60 efficiency for all energies between 1.1 MeV and 1.4 MeV.

Natural background radionuclides generally have only one gamma per disintegration, of lower energy than cobalt-60's two gamma's (potassium-40 is an exception). Hence, actual background radioactivity is likely higher than measured and reported by this procedure. This is acceptable since background radioactivity is not of concern in these "gross gamma" and "cobalt-60 energy range" measurements. (This is also the basis for the term "cobalt-60 equivalent activity," since instruments are calibrated for pure cobalt-60 activity.)

When radionuclide-specific gamma spectroscopy analyses are performed, germanium detectors are used. "Actual cobalt-60 radioactivity" or "specific cobalt-60" is the amount of cobalt-60 only, based on the counts in the 1.33 MeV photopeak and the efficiency of the detector at that photopeak using a known cobalt-60 source in a geometry equivalent to that of the sample.

2.3.2 The Investigatory Process

The pathways, targets, and potential release mechanisms described in this HRA were used to guide the process of selecting the information to be reviewed in preparing this assessment. During the course of the investigation, they were used to gauge the adequacy of the historical record of radiological work at Subase.

Information descriptive of the base was in large measure taken from recent Navy Installation Restoration documents. Navy and Subase correspondence and history files were reviewed to ensure all potential source terms of radioactivity were identified. Navy and Subase historical records were reviewed to ensure that an accurate account is presented of past requirements and practices.

All available records related to release, monitoring, and waste disposal were reviewed to determine: where radiological work was performed; what the environmental impact of radiological operations has been; and the history of radioactive waste disposal. Records were reviewed to determine if any inadvertent releases of radioactivity to the environment were not immediately remediated. Records of areas formerly used for radiological work were reviewed to determine whether all such areas have been appropriately released from radiological controls in accordance with all applicable requirements. A more detailed discussion of the specific types of records reviewed, and the results of that review, are contained in Section 5.

2.3.3 Interviews

Interviews with employees, retirees, local officials, and citizens were conducted during preparation of Reference 2 (1983 IAS) and in the course of developing the Community Relations Plan (Reference 3). For the 1983 IAS, the contractor invited employees (via base newspaper announcements) to participate in interviews. The subject of past practices associated with the three former (non-radioactive) disposal sites on base was emphasized in these interviews. Radioactivity was not raised as a concern in these interviews.

Two issues regarding radioactivity were raised as concerns in the Community Relations Plan interviews: how radioactive material from the submarines was disposed of, and whether additional sampling for radioactivity would be conducted. The former was addressed in the Community Relations Plan report: radioactive waste associated with Naval nuclear propulsion plants has never been buried at Subase, and EPA survey results verify that Program practices have been successful in ensuring that there is no radioactivity associated with the Naval Nuclear Propulsion Program at or near Subase that requires remediation. The latter is addressed in Section 8, where it is noted that additional radioactivity analyses will be performed as part of the Phase II Remedial Investigation.

To confirm that past practices at the base were in keeping with local and headquarters instructions, the Navy considered interviewing people who were assigned to NNPP radiological work at Subase in the early years of nuclear power operations. All such work is currently performed by active duty military personnel assigned to the Naval Submarine Support Facility (NSSF) at Subase. Prior to the NSSF formation as a separate command in 1974, the radiological work currently performed by NSSF was performed by persons

assigned to certain Divisions within the Repair Department of Subase. Examination of radiation exposure records and interviews with employees confirm that, as late as the mid-1960's, all NNPP radiological work was performed by active duty military personnel (with the exception of a single Planner/Estimator who was monitored for occupational exposure to radiation only to perform shipcheck inspections).

The Subase Human Resources Office has minimal information for past civilian employees of Subase and its associated tenant commands. These employee records number in the tens of thousands, and do not document employment history below the department level. Thus, the records do not identify persons who might be knowledgeable about past NNPP work. Military personnel files are not maintained at the base after the individual leaves. Radiation exposure records could be examined to identify which military personnel were monitored for exposure at the base in a given year. However, attempting to locate persons today on the basis of old military records would be an arduous task with an uncertain outcome, and this effort has not been undertaken for this assessment. The Navy does interview key personnel assigned to NNPP radiological work during the annual audits discussed in Section 4.5.

2.3.4 **Units**

Units used throughout this report include: pCi/100 cm^2 (picocurie per 100 centimeters squared), pCi/g (picocurie per gram), kcpm (thousand counts per minute), μCi/ml (microcurie per milliliter), Ci/yr (curie per year), mrem/hr (millirem per hour), and μR/hr (microroentgen per hour). A further explanation of a particular unit can be found in the glossary.

3.0 Site Description

3.1 Site Name and Location

Naval Submarine Base New London
Groton, Connecticut 06349
CERCLIS ID # CTD980906515

Naval Submarine Base New London (Subase), including all tenant activities under its cognizance, is located in Southeastern Connecticut within the towns of Ledyard and Groton. The base is situated on the east bank of the Thames River approximately six miles north of Long Island Sound.

The main base is centered at 41° 24' 00" North latitude and 72° 05' 15" West longitude. The main base is bounded to the east by Connecticut Route 12, to the south by Crystal Lake Road, and to the West by the Thames River. The northern border is a low ridge that trends approximately east-southeast from the river to Baldwin Hill. Figure 3.1 is a portion of four spliced 7.5 minute U.S. Geological Survey (USGS) maps for the Uncasville, New London, Niantic, and Montville Quadrangles. Subase is clearly designated. Circles of 1/4, 1/2, 1, 2, 3, and 4 mile radii are shown. Figure 3.2 is a portion of the 1x2 degree USGS state map of Connecticut. State parks, forests, and fish and wildlife areas are designated. A 4 mile radius circle and the 15 mile downstream arc are shown. Figure 3.3 is a vicinity map of the base. Figure 3.3 is taken from Reference 4, the 1992 Phase I Remedial Investigation report prepared in support of the ongoing Installation Restoration study at Subase. Figures 3.4 (a)-(h) are historical aerial photographs of the base. Figure 3.5 is a drawing of the base identifying building numbers, pier and berth designations, etc.

3.2 Site History

3.2.1 Type of Site (References 2 and 4)

Subase serves as an operating and support base for Naval submarines. The base, along with its tenant activities, provides: intermediate level maintenance, alterations, repairs, and testing on U.S. Navy submarines; home porting of submarines and their crews; training for submarine personnel; medical care; and research and training in the field of submarine medicine.

The base, including all the non-contiguous areas, encompasses 1,412 acres of land. The main base consists of 547 acres of land and associated buildings while the remaining areas are used for housing and community support. The base has almost 1,400 structures and buildings with over 5.8 million square feet of floor space in use. Included are several piers with capability of providing adequate berthing and support for 21 SSN submarines plus numerous other assigned craft. There are 16.5 miles of paved roads, over 185,000 square yards of parking lots and sidewalks, 13 tennis courts and athletic fields, and a 9-hole golf course on the base. Five Navy housing developments also lie within one and one-half miles of the base.

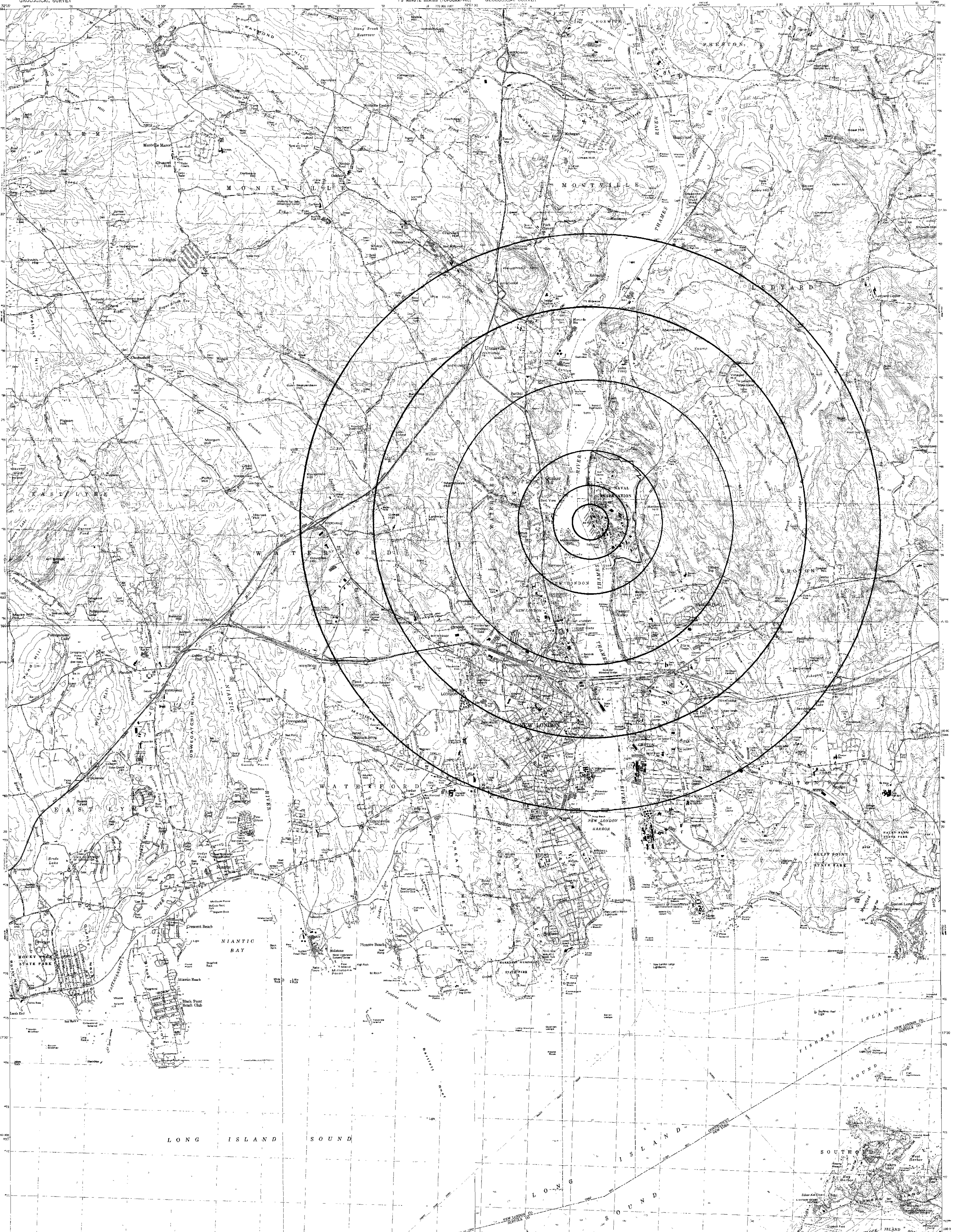
Figure 3.1
Radii of circles are
1/4, 1/2, 1, 2, 3, and 4 miles

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MONTVILLE QUADRANGLE
CONNECTICUT–NEW LONDON CO
7.5 MINUTE SERIES (TOPOGRAPHIC)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

UNCASVILLE QUADRANGLE
CONNECTICUT–NEW LONDON CO
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey in cooperation with Connecticut Department of Environmental Protection

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 2.7 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U S GEOLOGICAL SURVEY DENVER COLORADO 80225 OR RESTON VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
Primary highway, hard surface — Light duty road, hard or improved surface
Secondary highway, hard surface — Unimproved road
Interstate Route — U S Route — State Route

NIANTIC, CONN – N Y
41072-C2-TF-024
1983
DMA 6566 I SW–SERIES V816

NEW LONDON, CONN – N Y
41072-C1-TF-024
1984
DMA 6566 I SE–SERIES V816

0638110IX

Figure 3.2

4 mile radius and 15 downstream miles arc

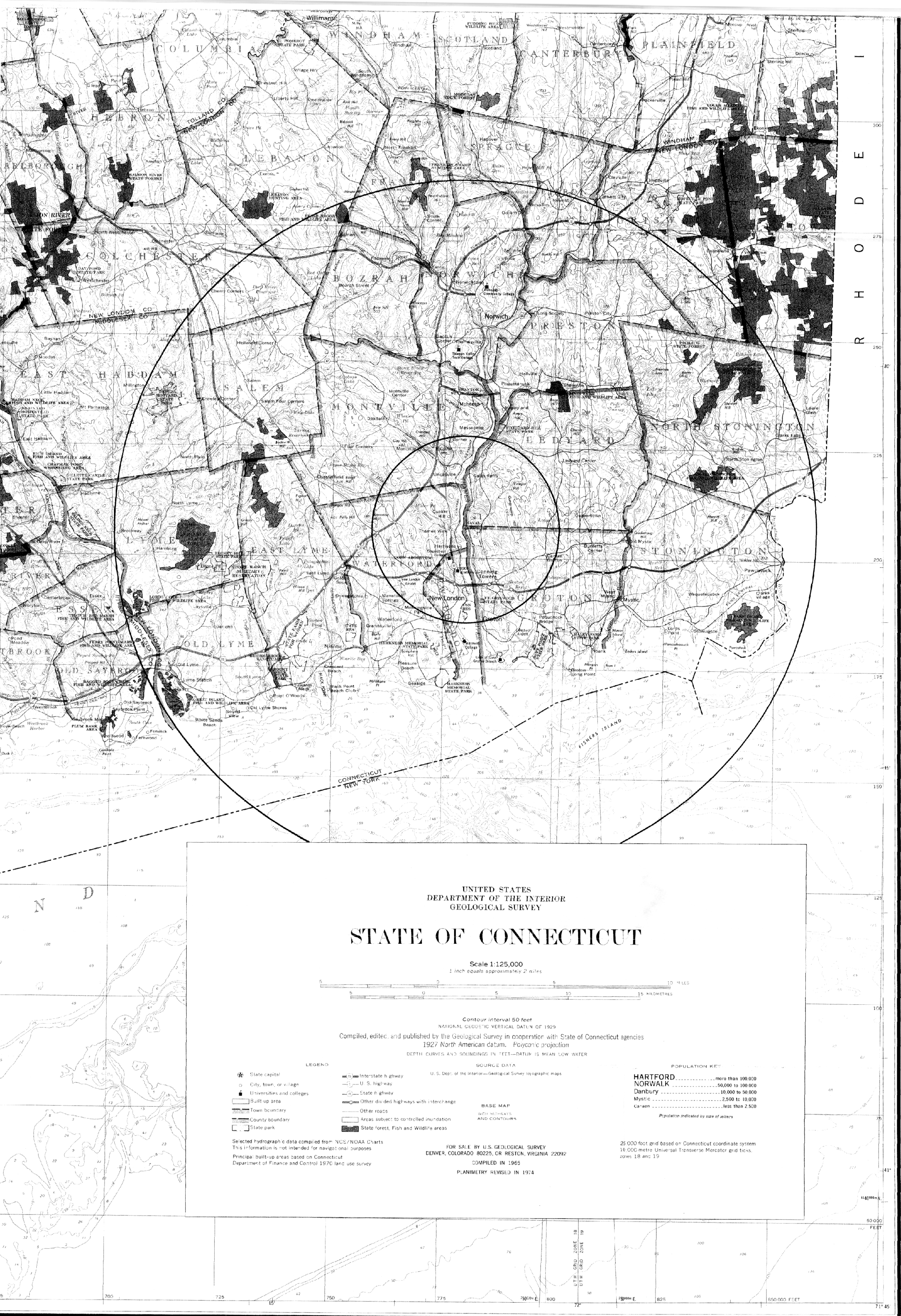

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
STATE OF CONNECTICUT
Scale 1:125,000
1 inch equals approximately 2 miles
10 MILES
15 KILOMETRES
Contour interval 50 feet
NATIONAL GEODETIC VERTICAL DATUM OF 1929
Compiled, edited, and published by the Geological Survey in cooperation with State of Connecticut agencies
1927 North American datum. Polyconic projection
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
LEGEND
State capital
City, town, or village
Universities and colleges
Built-up area
Town boundary
County boundary
State park
Interstate highway
U. S. highway
State highway
Other divided highways with interchange
Other roads
Areas subject to controlled inundation
State forest, Fish and Wildlife areas
Selected hydrographic data compiled from NOS/NOAA Charts
This information is not intended for navigational purposes
Principal built-up areas based on Connecticut
Department of Finance and Control 1970 land use survey
SOURCE DATA
U. S. Dept. of the Interior—Geological Survey topographic maps
BASE MAP
WITH HIGHWAYS
AND CONTOURS
FOR SALE BY U.S. GEOLOGICAL SURVEY
DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
COMPILED IN 1965
PLANIMETRY REVISED IN 1974
POPULATION KEY
HARTFORD more than 100,000
NORWALK 50,000 to 100,000
Danbury 10,000 to 50,000
Mystic 2,500 to 10,000
Canaan less than 2,500
Population indicated by size of letters
25,000 foot grid based on Connecticut coordinate system
10,000-metre Universal Transverse Mercator grid ticks, zones 18 and 19
RHODE I
COLUMBIA
HEBRON
LEBANON
COLCHESTER
EAST HADDAM
SALEM
MONTVILLE
BOZRAH
NORWICH
PRESTON
LEDYARD
NORTH STONINGTON
STONINGTON
GROTON
WATERFORD
EAST LYME
LYME
OLD LYME
WINDHAM
SCOTLAND
CANTERBURY
PLAINFIELD
SPRAGUE
ESSEX
OLD SAYBROOK
Norwich
New London
Groton
Mystic
Willimantic
CONNECTICUT
NEW YORK
FISHERS ISLAND
NEW LONDON CO
MIDDLESEX CO
TOLLAND CO
WINDHAM CO
UTM GRID ZONE 18
UTM GRID ZONE 19
50,000 FEET
650,000 FEET
72°
71° 45'
41°

Figure 3.3

INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT	SOURCE: Marshall Penn-York Co. Inc. N 0 1 2 SCALE OF MILES	SITE VICINITY ATLANTIC ENVIRONMENTAL SERVICES, INC.

Figure 3.4 (a) 1944-1945

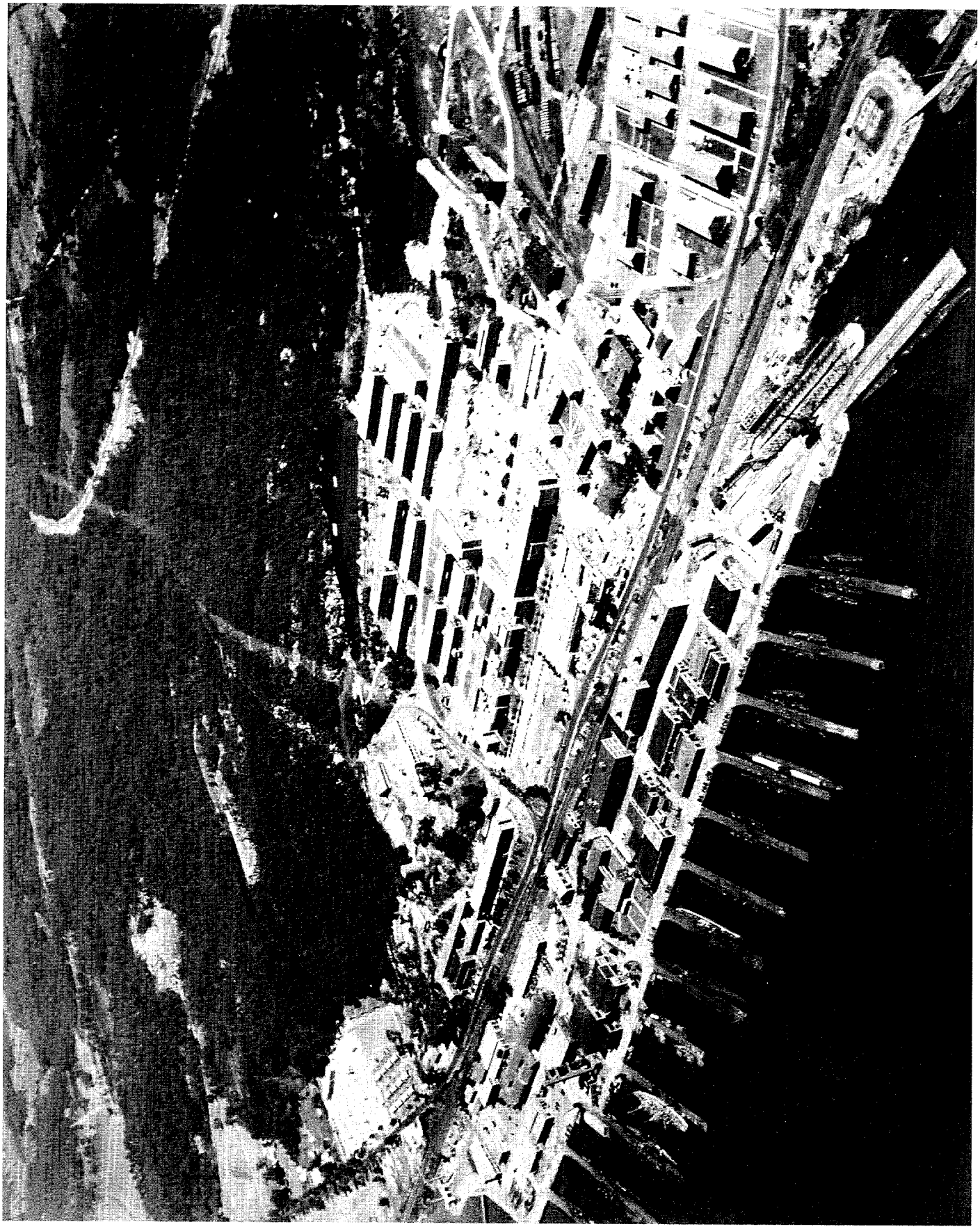


Figure 3.4 (b) 1946-1947

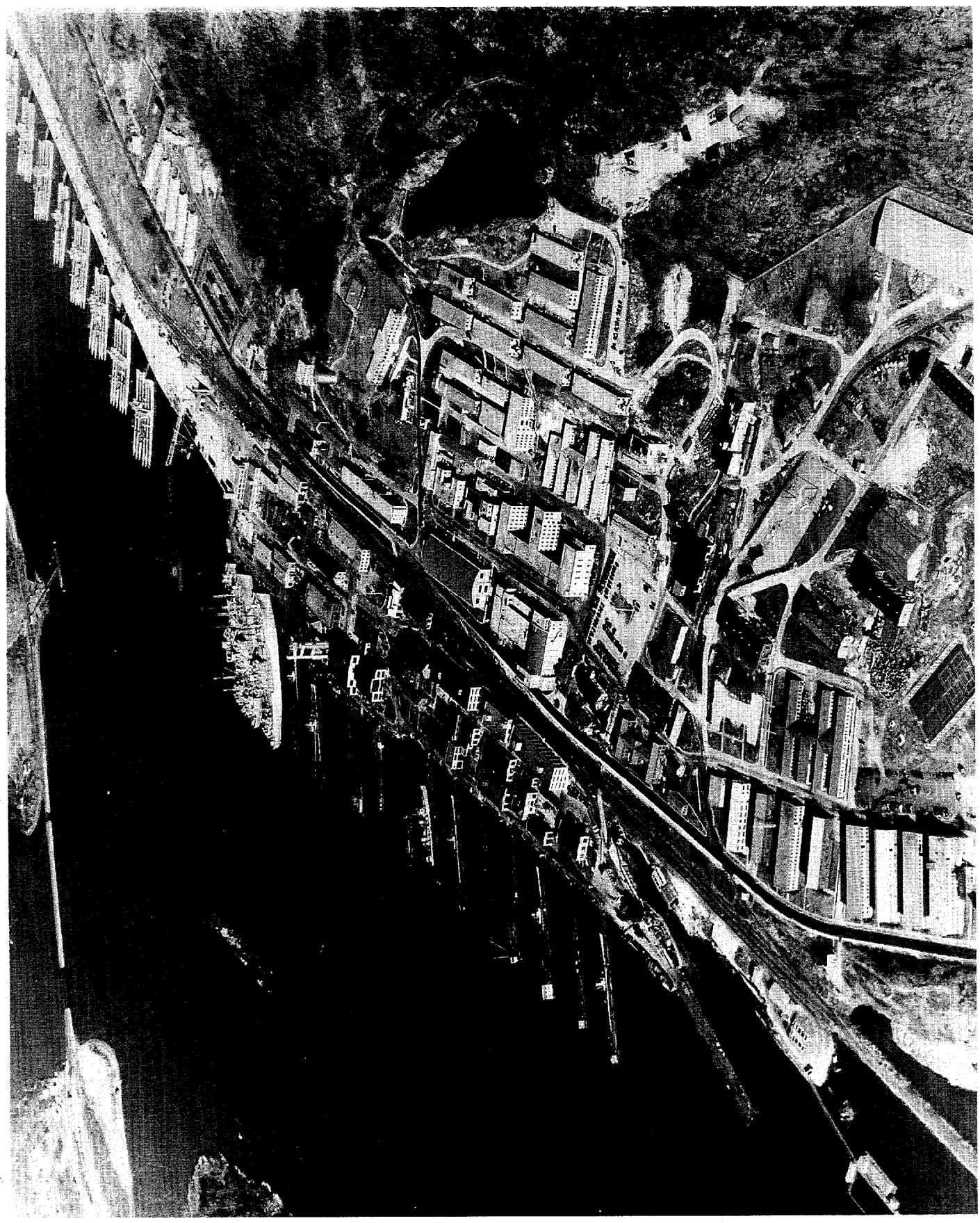


Figure 3.4 (c) 1950's

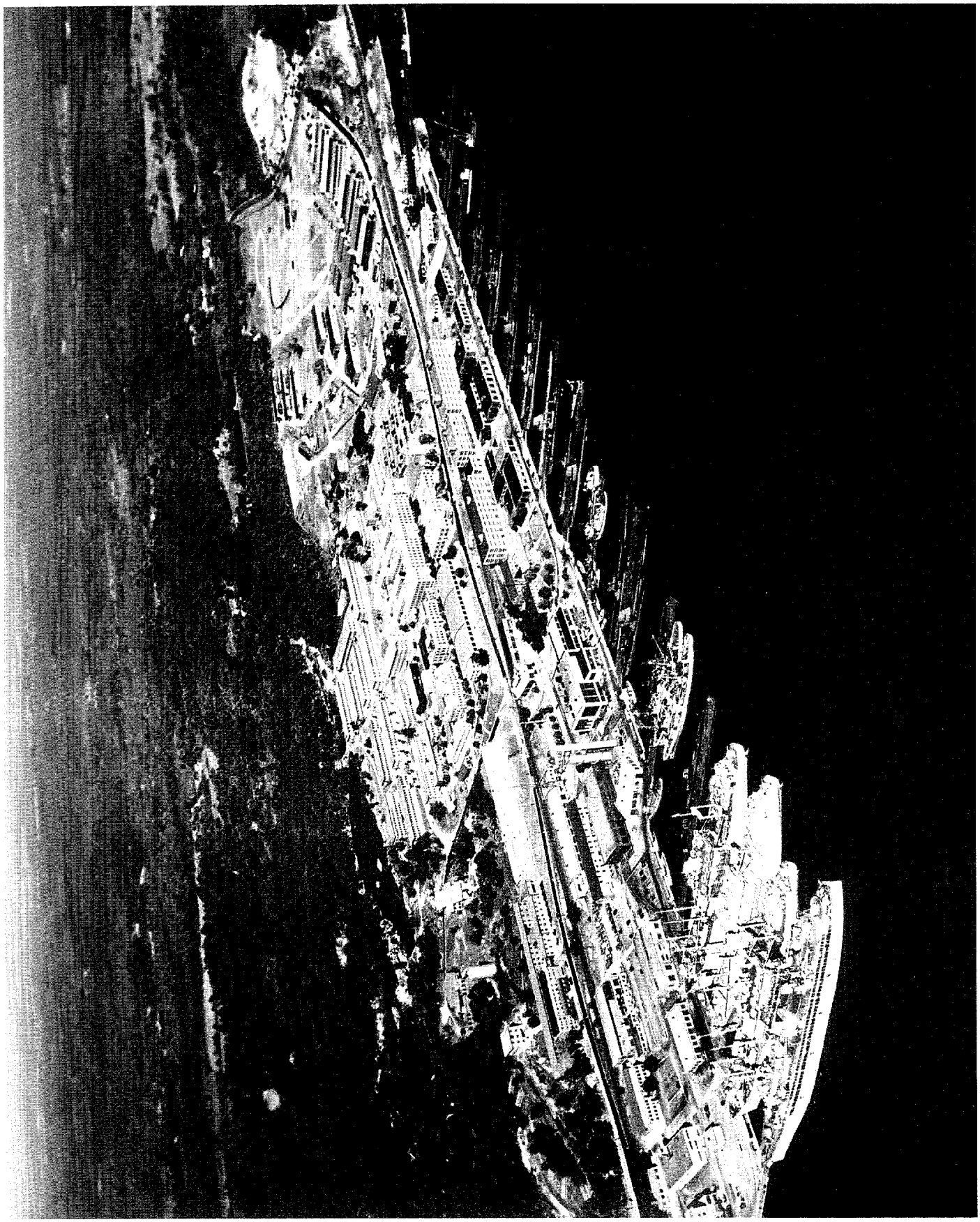


Figure 3.4 (d) 1961-1962

Figure 3.4 (e) 1983

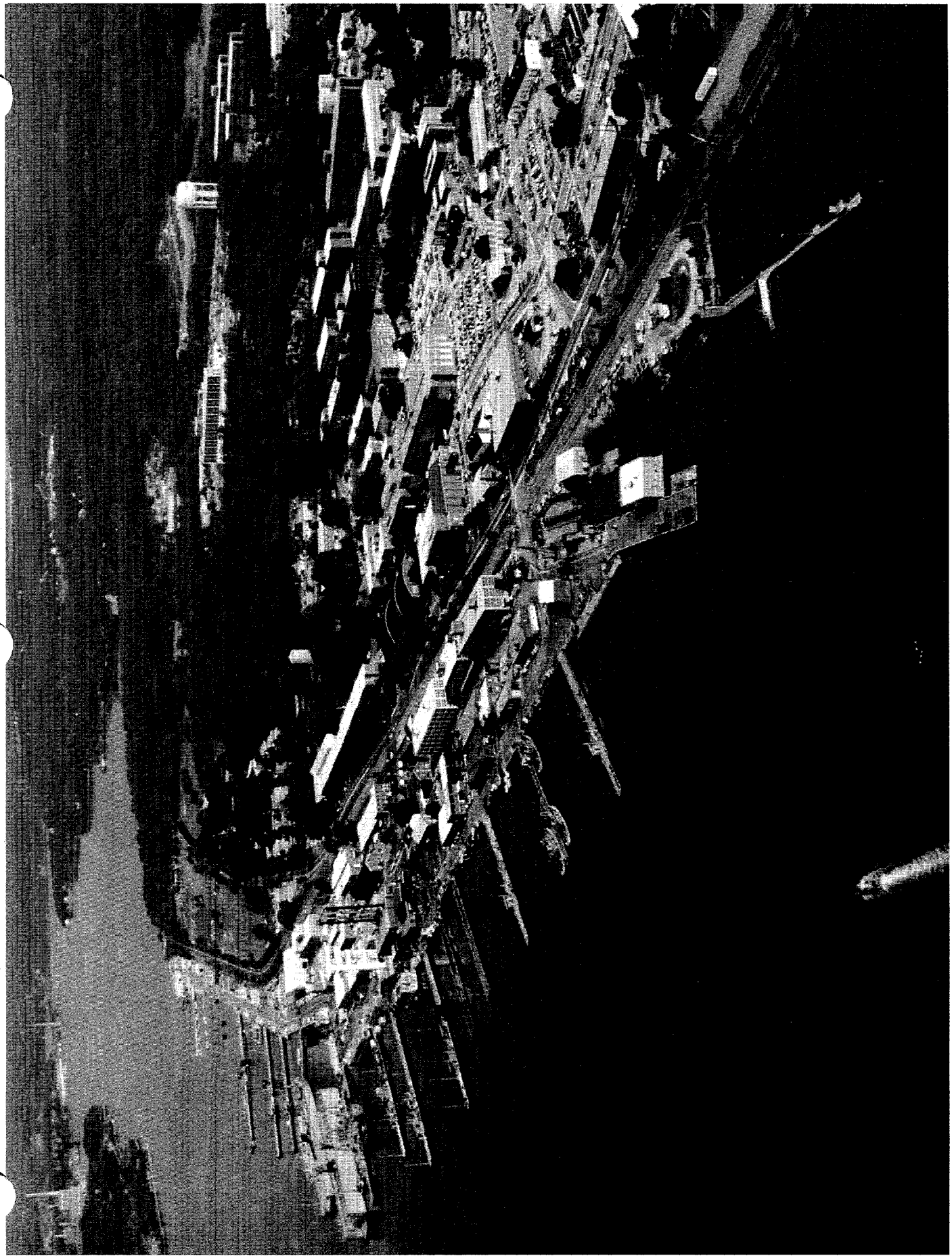


Figure 3.4 (f) 1985

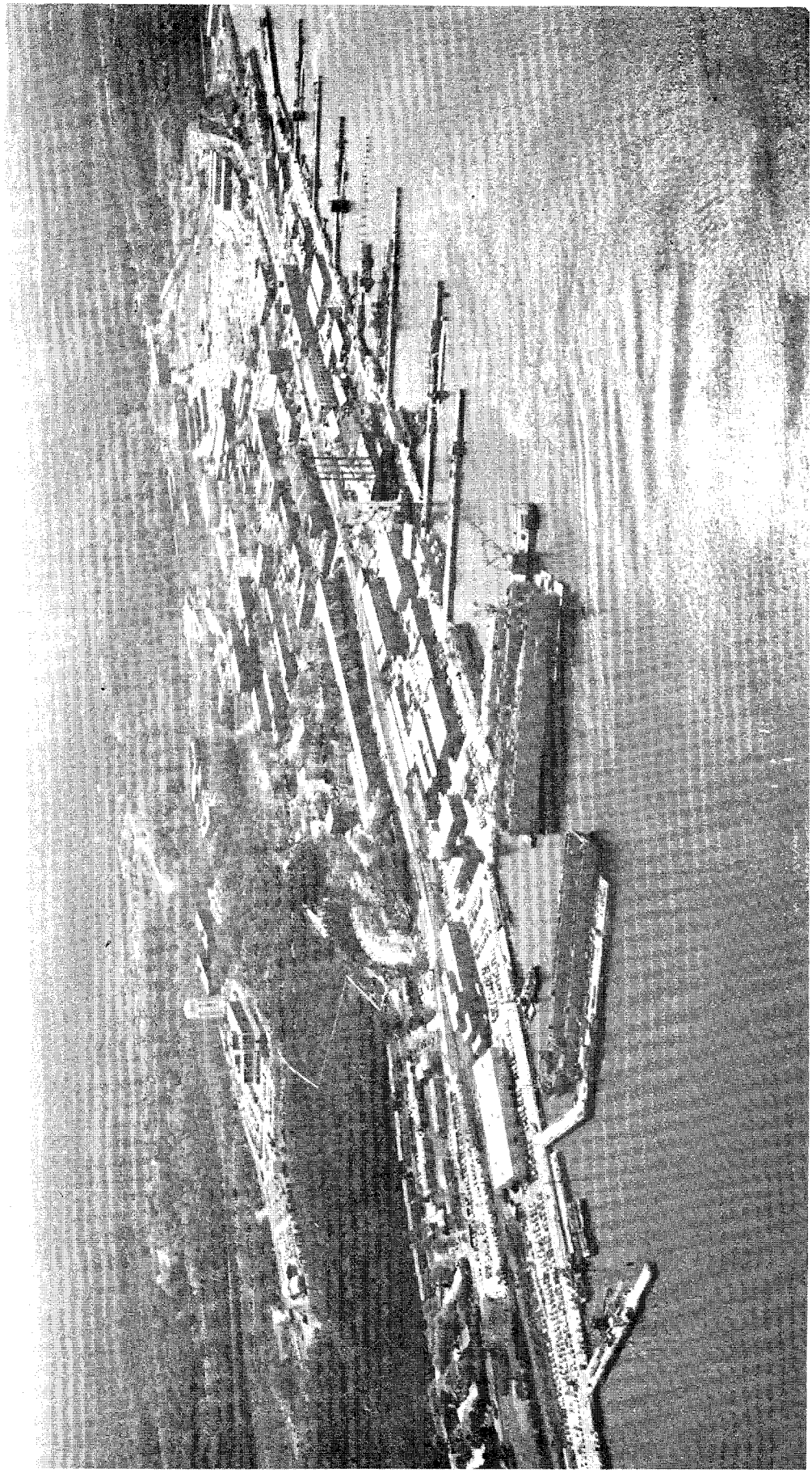


Figure 3.4 (g) July 1993

Figure 3.4 (h) July 1993

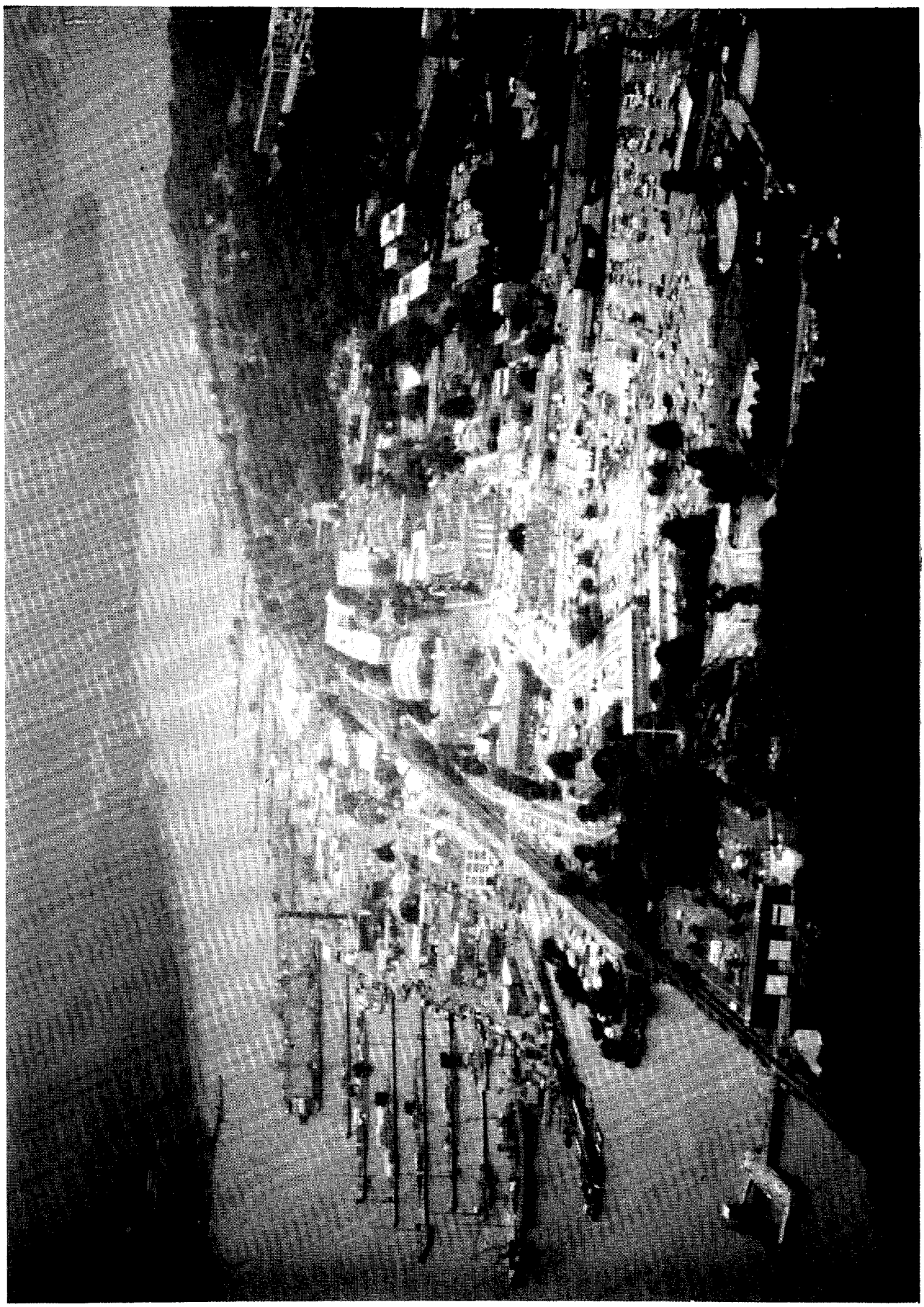
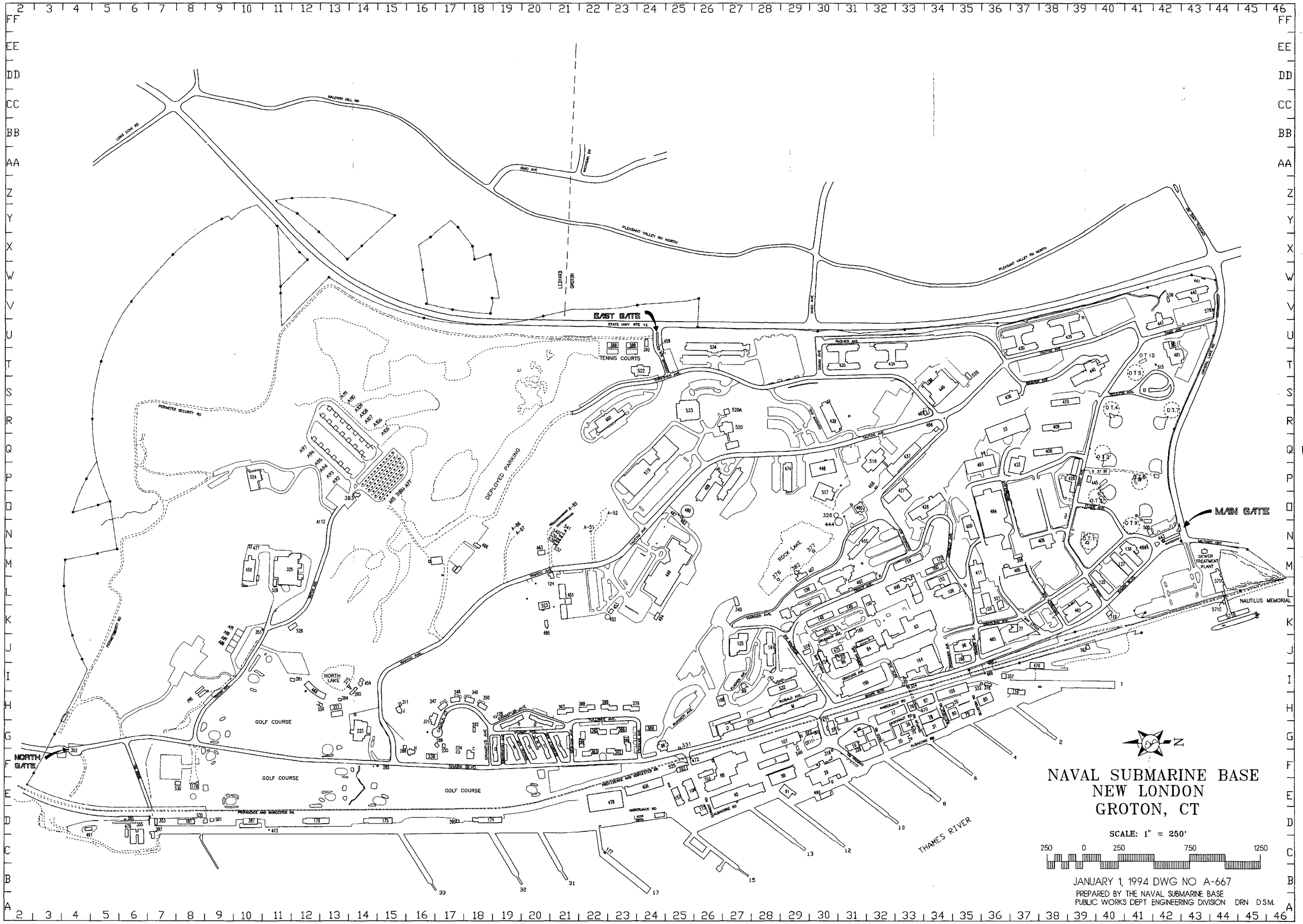


Figure 3.5

Naval Submarine Base
New London


NAVAL SUBMARINE BASE
NEW LONDON
GROTON, CT
SCALE: 1" = 250'
250 0 250 750 1250
JANUARY 1, 1994 DWG NO A-667
PREPARED BY THE NAVAL SUBMARINE BASE
PUBLIC WORKS DEPT ENGINEERING DIVISION DRN DSM
EAST GATE
MAIN GATE
NORTH GATE
STATE HWY RTE 12
TENNIS COURTS
DEPLOYED PARKING
GOLF COURSE
GOLF COURSE
GOLF COURSE
NORTH LAKE
ROCK LAKE
THAMES RIVER
NAUTILUS MEMORIAL
SEWER TREATMENT PLANT
PERIMETER SECURITY RD
PERIMETER SECURITY RD
LONG COVE RD
BALDWIN HILL RD
OHIO AVE
MICHIGAN DR
PLEASANT VALLEY RD NORTH
PLEASANT VALLEY RD NORTH
LEEWARD
GROTON
CENTRAL LAKE RD
CENTRAL LAKE RD
RASHER AVE
TAUTOG AVE
TARPON AVE
SHARK BLVD
PROVIDENCE AND WORCESTER RR
AMBERJACK RD
ALBACORE RD
MILITARY WAY
BOBALO AVE
GRAMPUS AVE
TULLIBEE AVE
HARDER AVE
ROOK AVE
GRAYLING AVE
DRUM AVE
PUFFER AVE
SEAWOLF AVE
SKATE BLVD
A112
A-51
A-52
A-85
A-86
A-87
A97
A96
A95
A94
A93
A92
A91
A90
A89
A88
A87
A86
A85
A85 THRU A97
OT 1
OT 2
OT 3
OT 4
OT 5
OT 7
OT 9
OT 10
S 27 ST
N

06381103X

3.2.2 **Navy Ownership History**

In 1867, the state of Connecticut donated to the Navy 112 acres on the east bank of the Thames River above the town of Groton. There was no Naval activity on this donated property until July of 1868 when the facility was officially designated a Navy Yard. The site was used to moor small craft and obsolete warships and as a coaling station for the Atlantic Fleet. At this time, two brick buildings were constructed, including Building One (which remains standing today) and a "T" shaped pier. By 1881 the yard consisted of five or six structures, but because of little use it served only as a coaling station for the Atlantic Fleet's small craft.

The facility remained relatively inactive for the next few years and was designated to be disposed of by the Naval Appropriations Bill submitted to Congress in 1912. Only a last minute speech saved the site from being closed. In 1915, the Monitor Ozark, a floating raft with guns, acting as a tending vessel, arrived at the Navy Yard with four submarines which made up the fledgling submarine service. Other tenders and submarines soon followed, and in 1916 permanent status came to the facility when the Navy Department designated it a submarine base. The Naval Submarine Base, New London became the nation's first continental submarine base.

During World War 1, facilities at the base were greatly expanded. Between October 1917 and October 1918, eighty-one buildings were either completed or under construction, six piers were added, and the old "T" shaped pier was removed. In 1917, the Submarine School was established and 10,000 officers and enlisted personnel were trained for submarine service. In 1918, the Submarine Medical Center was established as a dispensary. Following World War I, Subase continued its submarine services, and the Submarine School's curriculum was expanded.

During World War II, the base had to service a submarine fleet which was undergoing unprecedented growth. From 1935 to 1945, the base expanded from 112 acres to 497 acres and from 86 to 270 buildings.

The Submarine Medical Research Laboratory was organized in 1942 as a Medical Research Department within the base Medical Department.

Following World War II, Subase continued to expand. The Medical Research Department was established as a separate activity and designated the Medical Research Laboratory in 1946. Its mission was to select personnel for the Submarine School, instruct hospital corpsmen attending the Submarine School, and undertake research. In May of 1955, the dispensary was redesignated as a Station Hospital. The Medical Research Laboratory and the Station Hospital were disestablished in June of 1964 to form the Submarine Medical Center. Separate commands were again established in 1974 for the Naval Hospital, Groton, and the Naval Submarine Medical Research Laboratory.

The status of the Submarine School was changed from an activity to a command in June of 1968 and became the largest single tenant on the base. In February of 1974, the Naval Submarine Support Facility was established, encompassing the former departmental areas of submarine repair, operations, and weapons. In February of 1975, the Naval Undersea Medical Institute was established as a separate command. Today, the base consists of over 300 buildings and more than 547 acres of land.

3.2.3 Site Activities

Subase is a large industrial complex capable of providing a wide range of industrial, manufacturing, and technological processes required for maintaining and repairing the modern high technology warships of the U.S. Navy. Other major activities include training of submarine personnel, providing home port services to 21 submarines and their crews, and training in submarine medicine.

In the specific case of Naval Nuclear Propulsion Program work, which is the focus of Volume I of this HRA, all of the engineering disciplines, trade skills, quality assurance inspectors, and radiological control personnel are available to accomplish electrical and mechanical service to nuclear propulsion plants. These range from simple valve repairs to complex nuclear ship alterations. A few of the typical services performed are listed below:

- Minor valve repair
- Major valve overhaul or replacement
- Piping system repair or alteration
- Calibration of mechanical and electrical measuring instruments
- Motor and generator overhaul
- Repair and calibration of electrical equipment
- Test and inspection of components and systems
- Off-hull resin discharges

Numerous activities support this work such as engineering, planning, supply, radiological controls, quality assurance, machine shops, and administrative groups required to plan and execute tasks as complex as maintaining a nuclear-powered warship.

3.3 Site Description

3.3.1 Site Land Use (References 2 and 4)

The physical features of the base are discussed above and shown in Figure 3.5. Subase provides a base command for Naval submarine activities. Additionally, the base includes housing for Navy personnel and their families, submarine training facilities, military offices, medical facilities, and facilities designated for the maintenance, repair, and testing of submarines. More than 85 percent of the base surface area is covered by buildings, other structures, and pavement. The base is divided internally into a Controlled Industrial Area (Lower Base) and a non-industrial area (Upper Base). The Providence and Worcester Railroad operates a branch line that runs completely through the main part of the base parallel to Shark Boulevard, separating the Upper and Lower Bases.

All of the piers, barges, floating drydocks, and work facilities accomplishing Naval Nuclear Propulsion Program work are within the Controlled Industrial Area (Lower Base). Radioactive material shipments traverse the non-industrial area but are stored within the Controlled Industrial Area. As a result of this division, the non-industrial area of the base is not considered a potential source of NNPP radioactivity entering the environment.

Since most of the work that is accomplished on the reactor plant is done onboard the ship, Subase facilities dedicated to radiological work are relatively small. The primary radiological work facilities are contained within the Radiological Controls Barge, YRR-14. The YRR-14 replaced the Radiological Repair Support Barge, YRRS-4, in March 1981. The YRRS-4 (formerly the YFN-685) was placed into service as the Radiological Repair Support Facility at Subase in March 1962. Prior to September 1975, a portion of the YRRS-4 was used for radioactive material storage. The YRRS-4 was removed from Subase subsequent to being released from radiological controls in 1984.

A portion of Building 91 is designated as a radioactive material storage area. A portion of Building 174 was used for long term storage of radioactive material from September 1975 to September 1982. Building 174 was released from radiological controls in 1982 after being replaced by Building 91 for use as the radioactive material storage area.

The remaining buildings in the Controlled Industrial Area are shop areas, warehouses, and administrative areas that do not contain radiological material associated with the Naval Nuclear Propulsion Program. Open paved areas are used for storage of non-nuclear materials and large equipment associated with ship repair functions.

Other functions which occupy significant portions of the Lower Base are the administrative facilities for Submarine Squadron Two, Submarine Development Squadron Twelve, Naval Submarine Support Facility, and the Supply Department's warehouse, shipping, and receiving facilities. The Utilities Department, including the main power plant, also occupies Lower Base space. The north end of the Lower Base is narrow and contains less land than the southern end. The northern end is used by the Defense Reutilization and Marketing Office, and by maintenance, production, and administrative activities.

The Upper Base consists of three general sections. The northern section, predominantly undeveloped and natural land, contains the Weapons Department, torpedo shops, and ammunition storage bunkers.

The middle section contains both developed and undisturbed land. The Naval Submarine Medical Research Laboratory, the Naval Undersea Medical Institute, and the Naval Hospital, Building 449, are located in the middle section. Community facilities, which include the Rock Lake recreation area, golf course, and all tennis courts, use a few acres of land in this area. The area also contains troop housing, indoor community facilities, training, and family housing.

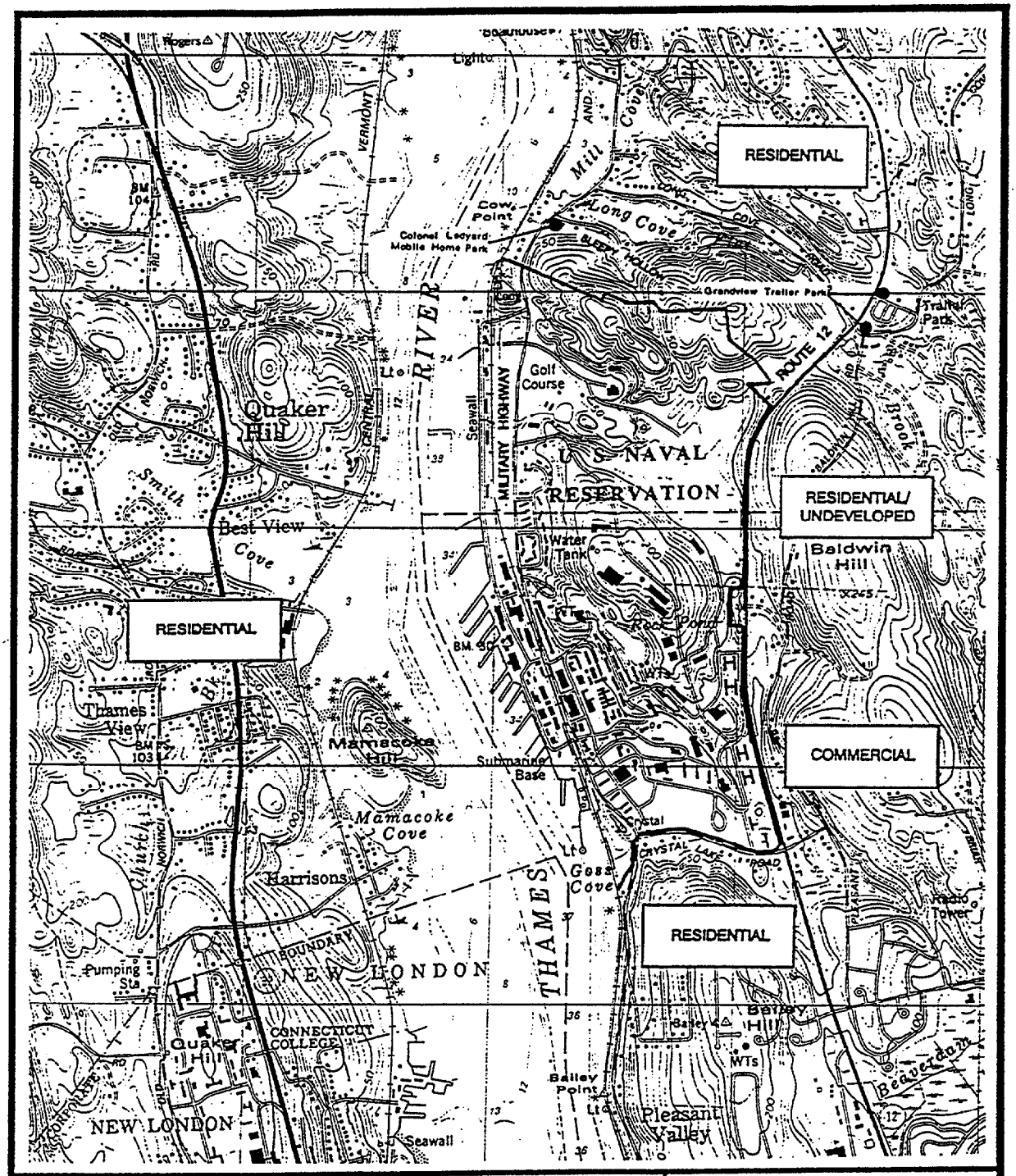
The southern portion of the Upper Base has three dominant land uses: troop housing, training, and community facilities. Each of these involve many structures. Collectively, these three activities occupy half of the southern section of the Upper Base. Other functions conducted in this area include: administration for Subase and forces afloat; Submarine Group Two administrative facilities; supply and storage warehouses; maintenance, production and administrative facilities for the Public Works Department; and Exterior Community Facilities, in the form of baseball fields. The underground fuel farm is located in this section. Also located here are Interior Community Facilities which include the gymnasium, theater, bowling alley, Navy Exchange, and Commissary. The land adjacent to Goss Cove and the Thames River in the southwest corner of the Upper Base is the site of the Nautilus Memorial and the Submarine Force Library and Museum, the Navy's repository of submarine-related artifacts and information concerning the Submarine Force.

3.3.2 Demography & Adjacent Land Use (Reference 4)

Land use adjacent to the site is generally residential or commercial. Adjacent land use is shown on Figure 3.6, taken from Reference 4. Residential development along Military Highway, Sleepy Hollow, Long Cove Road, and Pinelock Drive borders the site to the north and extends north into the Gales Ferry section of Ledyard. Property along Route 12 to the east of the site consists of widely spaced private homes, housing for Navy personnel (Trident Park), and open, wooded land. Farther south on Route 12, development is mixed commercial and residential, and includes a church, automobile sales and repair facilities, convenience stores, restaurants, and a gas station. Private residences and an automobile service station are located along the south side of Crystal Lake Road. Farther south is housing for Navy personnel (Conning Towers, Polaris Park, and Dolphin Gardens).

At the time of the 1990 census, approximately 1.66 million persons resided within the 50-mile radius from the base, with 172,820 within 10 miles and 6,272 within 1 mile of the base. Table 3-1 shows the estimated 1990 populations of the towns surrounding the base.

Figure 3.6



INSTALLATION RESTORATION STUDY

NAVAL SUBMARINE BASE - NEW LONDON

GROTON, CT

SOURCE: Uncasville, Ct.
U.S.G.S. Topographic Map 1984

● Active Water Supply Well

N

0 1000 2000'

SCALE

AREA LAND USE

ATLANTIC ENVIRONMENTAL SERVICES, INC.

Table 3-1
1990 Population of Towns Surrounding
Naval Submarine Base New London

URBAN TOWNS:	Population
Groton	45,144
New London	28,540
Norwich	37,931
	111,075
SUBURBAN TOWNS:	
Colchester	10,930
East Lyme	15,340
Griswold	10,384
Ledyard	*14,913
Lisbon	3,970
Montville	16,673
Preston	5,006
Sprague	3,008
Stonington	16,919
Waterford	17,930
	114,893
RURAL TOWNS:	
Bozrah	2,297
Franklin	1,810
North Stonington	4,884
Salem	3,310
Voluntown	2,113
	14,414
REGIONAL TOTALS	240,382

*Exclusive of military personnel

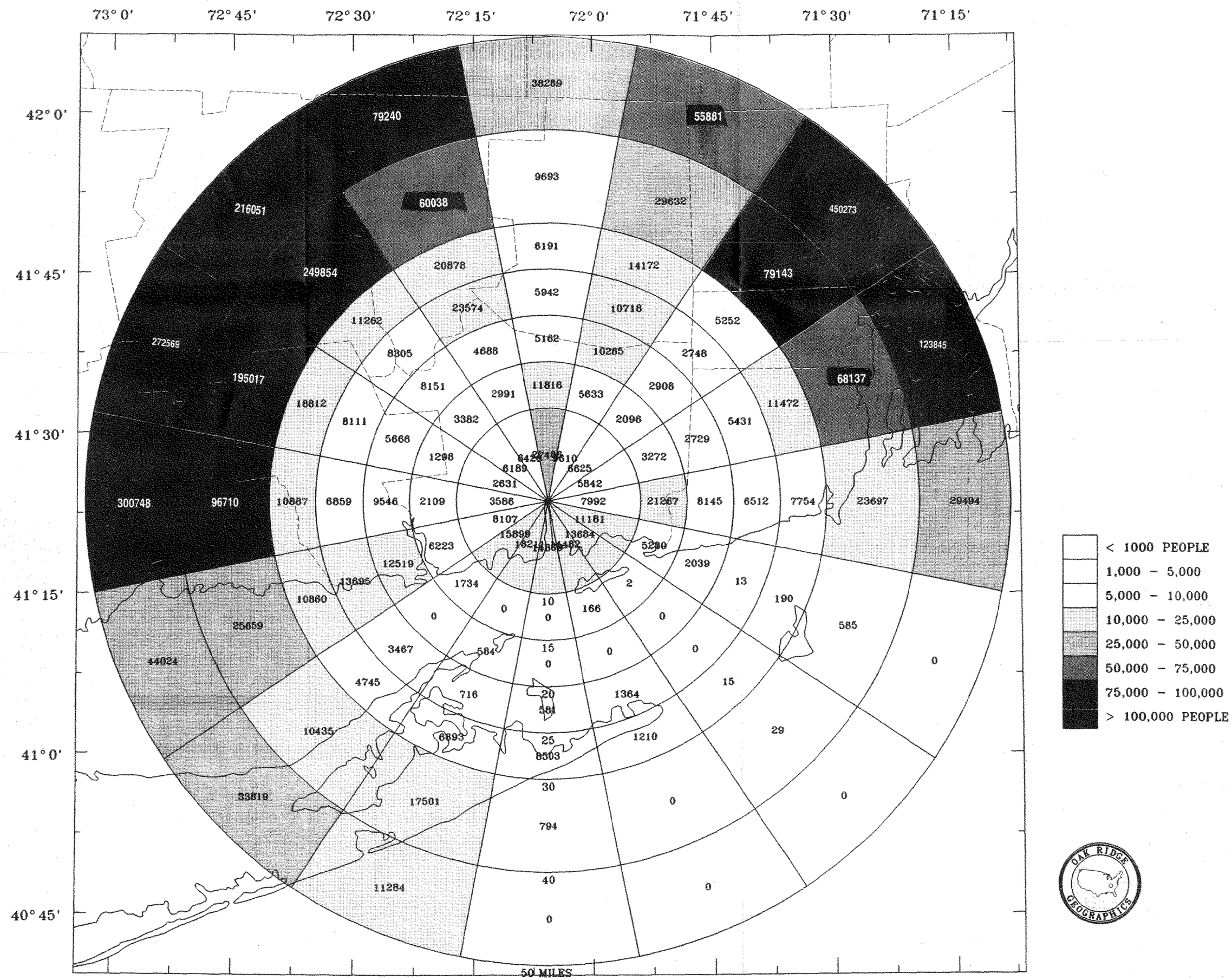
Figures 3.7 and 3.8 are computer generated constructs of 7.5 minute maps with the population by standard zone and sector divisions overlain. A zone is a 22.5 degree arc with Zone "A" centered on geographic north and Zones B, etc., increasing clockwise. A sector is a one-mile, five mile, or ten mile annular segment. Population data is based on the 1990 census data.

Additional population data based on current occupancy (1996) at the Subase was obtained to determine one-quarter and one-half mile radius (as shown on Figure 3.1) population estimates. Within the one-quarter mile radius there are approximately 320 permanent residents and a total population of approximately 3500, when Subase workers are included. For the one-half mile radius there is a total population of approximately 7500 of which approximately 1650 are permanent residents.

Figure 3.7

Population
50 miles

1990 Regional Population - SUBASENL
POPULATION COUNT BY SECTORS AND ANNULI - SUBASE - NEW LONDON
1990 Census



Prepared by Geographic Data Systems Group of CAD

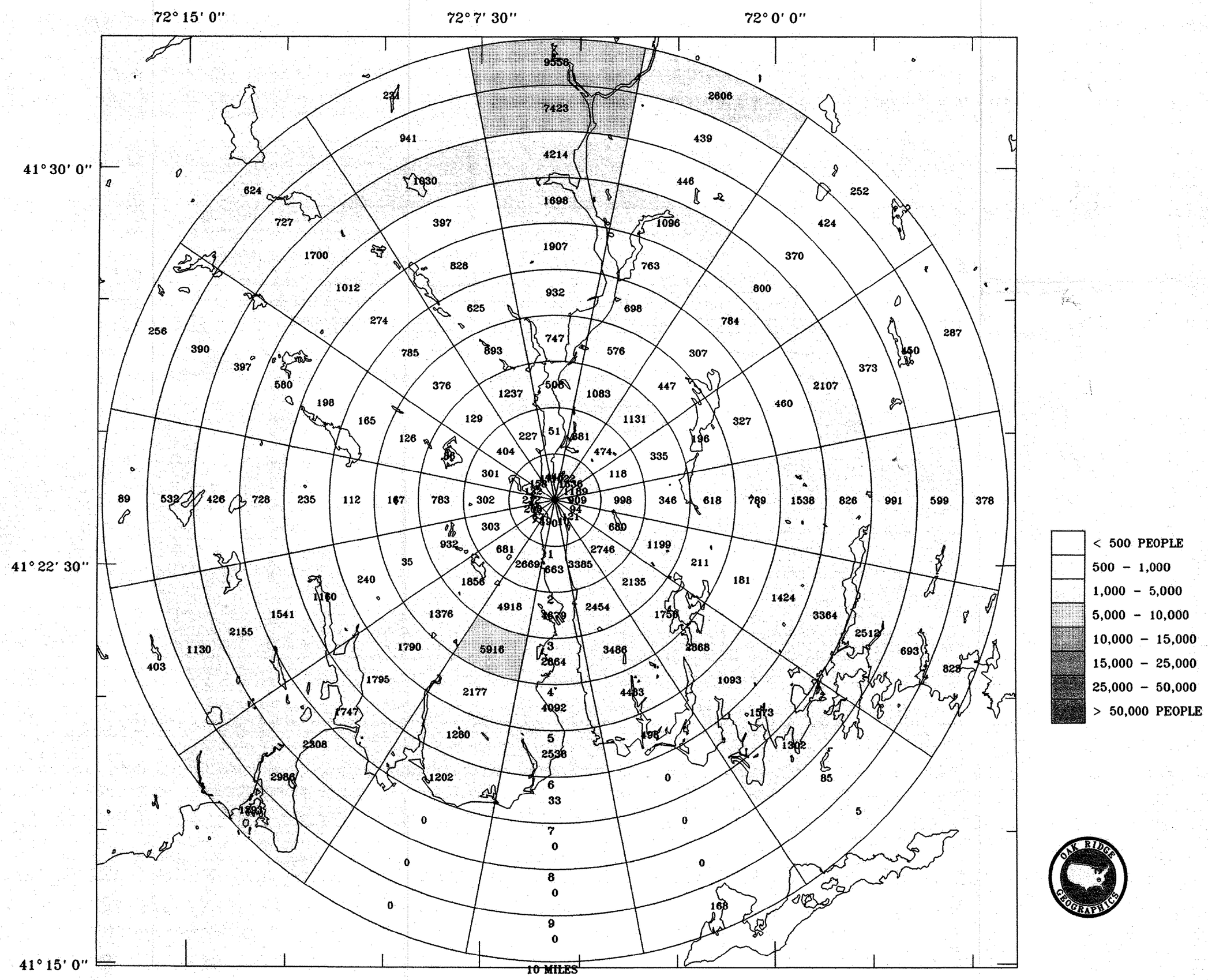
2-16-94

06381104X

Figure 3.8

Population
10 miles

1990 Local Population - SUBASENL
POPULATION COUNT BY SECTORS AND ANNULI - SUBASE - NEW LONDON
1990 Census



Prepared by Geographic Data Systems Group of CAD

2-16-94

06381105X

Several communities are located within one mile of the base. Three neighborhoods in the Town of Groton lie adjacent to or within Subase. The neighborhood boundaries are described below:

North West - The community is located adjacent to the base on the east side of Route 12 from the Groton - Ledyard town line to Walker Hill Road on the south. The neighborhood extends east to the Ledyard Reservoir.

Pleasant Valley - The Pleasant Valley Neighborhood borders the south boundary of the base. On the east it is bounded by Connecticut Route 12 and on the west by the Thames River. The southern boundary of Pleasant Valley is Grove Street and Walker Hill Road.

Naval Submarine Base New London is considered a neighborhood in Groton although portions of it are located in Ledyard.

The Gales Ferry section of Ledyard is located adjacent to Subase to the north.

3.3.3 **Physical Characteristics**

This section describes the geology, seismology, and geohydrology of the region around the base as they relate to infiltration of contaminants into ground waters, mobility and transport via the ground water, and confining features that inhibit area-wide distribution of introduced potential contaminants. The transport and distribution of materials in the local ground water is, in part, a function of the local and regional geological morphology and stratigraphy.

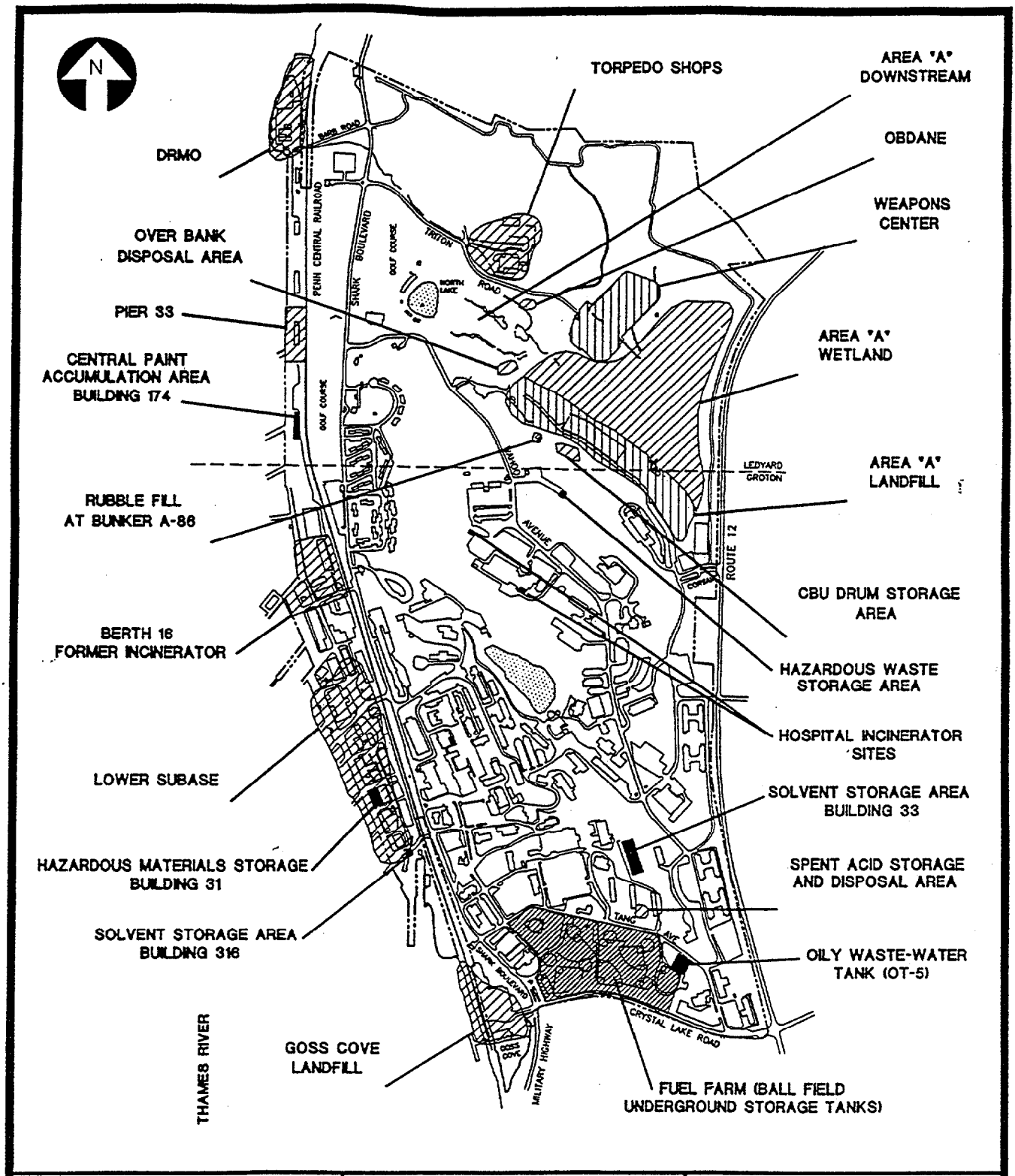
3.3.3.1 **Topography (References 2 and 4)**

The land around the base is a series of low bedrock ridges that trend generally north-south. Lowlands between the ridges are commonly wetlands and poorly-drained stream valleys. The Thames River adjacent to the west of the base is flanked by glacially-derived terrace deposits and more recent flood plain deposits.

The topography of the base (Figure 3.6, taken from Reference 4) is dominated by bedrock ridges in the northern portions of the base as well as an offsite ridge that is located adjacent to the east of the base. The low lying area between these ridges slopes to the west. The eastern portion of this area is a wetland which drains through an earthen dike into an area that is thirty to forty feet below the elevation of the wetland.

The topography in several areas of the base has been altered by landfilling and quarrying. The low lying area that is now the Area A Wetland was filled in in 1958 with dredged sediments from the Thames River. The capitalized site names in this section are Installation Restoration (IR) study sites at Subase (Figure 3.9, taken from Reference 3). Area A is divided into four subareas: Area A Wetland, Area A Landfill, Area A Over Bank Disposal Area, and Area A Downstream. Boring information indicates that the thickness of dredge spoil is approximately 10 to 15 feet on the north section of the Area A Wetland and approximately 35 feet on the south portion of the Area A Wetland adjacent to the Area A Landfill.

Figure 3.9



INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT	0 600 1200 GRAPHIC SCALE IN FEET	INSTALLATION RESTORATION STUDY SITES ATLANTIC ENVIRONMENTAL SERVICES, INC.

All materials generated by base operations that were not salvageable were incinerated, and the residues were disposed of on top of the dredge spoils in the Area A Landfill, from 1958 to 1963 when the base incinerator ceased operating. All non-salvageable materials (e.g., scrap wood, metal, paper, asphalt) generated by base operations from 1963 to 1973 were disposed of in the Area A Landfill. Thickness of refuse material in the Area A Landfill is estimated to be 10 to 20 feet. The Area A Landfill was closed in 1973. After closure, a concrete pad was constructed in the southwest portion of the Area A Landfill, for above ground storage of industrial wastes.

The Defense Reutilization and Marketing Office (DRMO) site was used as a landfill from 1950 to 1969. The materials which were burned and landfilled included construction materials, combustible scrap (e.g., wood pallets, tires, old furniture), and other non-salvageable waste items. These materials were piled together at the north shoreline of what is now the DRMO site and burned. The residue was pushed to the shoreline and partially covered. Fill material in the northern portion of the DRMO site extends from the surface to between 5 and 20 feet below grade. In the eastern and southern portions of the site, fill is absent or less than 5 feet thick.

Incinerator ash and inert rubble (e.g., cinders, metal, brick, glass) were disposed of at the Goss Cove Landfill from 1946 to 1958, in what was then the northern portion of Goss Cove. It is not known what other materials may have been disposed of in the landfill. Several large compressed gas cylinders were uncovered during the excavation of a utility trench in the parking area north of the Nautilus Museum building. Depth of fill material is between 15 and 20 feet on the west side of the Goss Cove site and 10 feet or less on the east side of the site. Fill material lies directly on top of river sediments in most cases.

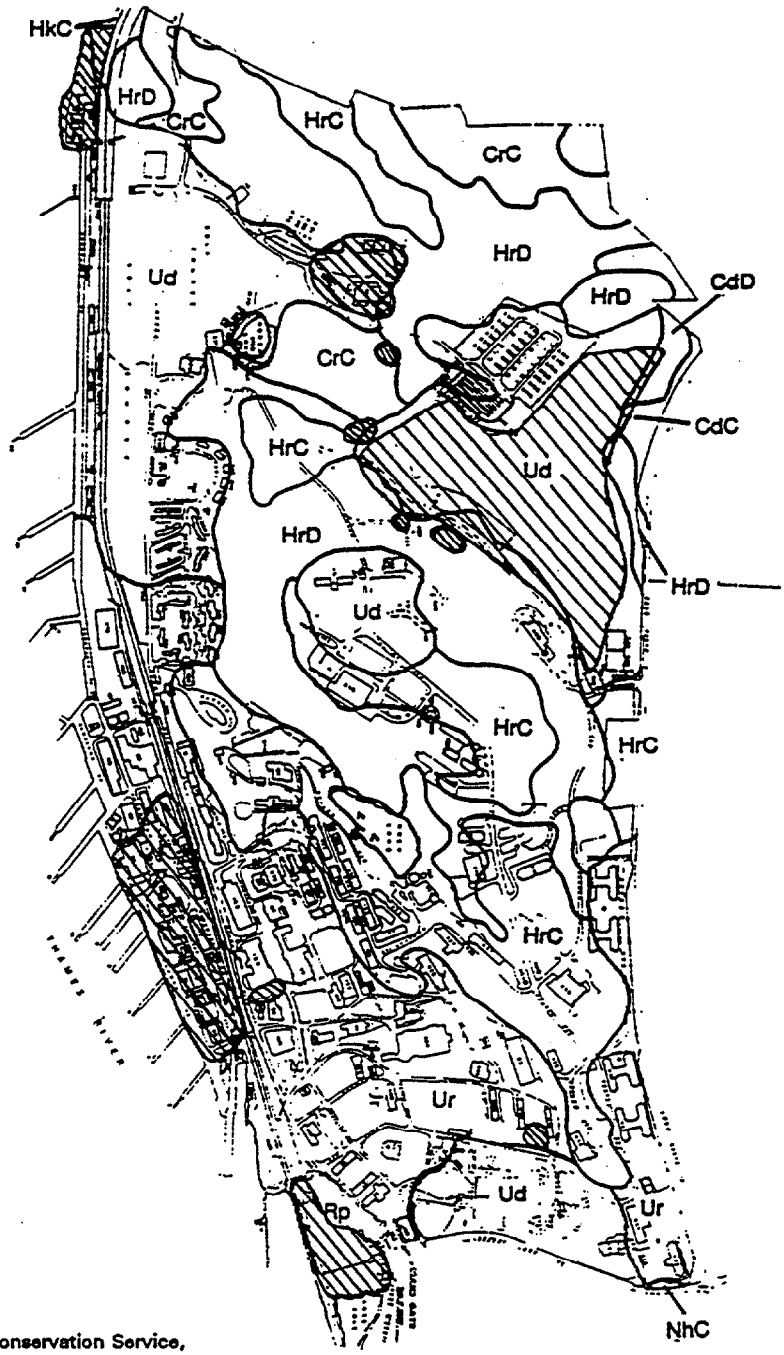
The Lower Base is built primarily on fill material. The original pier was constructed on a parcel of land that protruded into the Thames River. As more buildings and piers were added, fill material was also added. The fill consists of clean sand and gravel, and lies directly on top of river sediments in most cases. Fill is thickest (20 feet) on the west side of the Lower Base adjacent to the quay wall and thins to the east.

The present site of the Torpedo Shops was once a rock quarry. A large lake, Crystal Lake, was located in the southernmost portion of the base adjacent to Crystal Lake Road. It was filled sometime after 1938.

3.3.3.2 **Soils (Reference 4)**

Figure 3.10 is a soils map of the base prepared by the U.S. Department of Agriculture's Soil Conservation Service and taken from Reference 4. In general, soils at the base have moderate to moderately rapid permeability according to the Soil Conservation Service information. Available water capacity is moderate to low, and runoff is rapid or very rapid. The pH is strongly to moderately acidic. Erosion hazard is severe. A detailed description of each type of soil at the base is given in Reference 4. Permeability is categorized between moderately rapid and very rapid among soils at the base and classified in Reference 4 as Canton and Charlton, Hinckley Sandy Loam, Narragansett Silt Loam, and Udorthents-Urban Land. Soils within the Thames River drainage area would likely be characterized predominantly as medium-textured soils.

Figure 3.10



SOURCE: Soil Conservation Service, U.S. Department of Agriculture

INSTALLATION RESTORATION STUDY

NAVAL SUBMARINE BASE - NEW LONDON

GROTON, CT

LEGEND

CdC - Canton and Charlton, 3-15% slopes
CdD - Canton and Charlton, 15-35% slopes
CrC - Charlton-Hollis, 3-15% slopes
HrC - Hollis-Charlton Rock, 3-15% slopes
HrD - Hollis-Charlton Rock, 15-45% slopes
HkC - Hinkley Sandy Loam, 3-15% slopes
NhC - Narragansett Silt Loam, 3-15% slopes
Rp - Rock Outcrop-Hollis, 3-45% slopes
Ud - Udorthents-Urban Land, 0-15% slopes
Ur - Urban Land, surface covered by pavements or structures

SOILS MAP

ATLANTIC ENVIRONMENTAL SERVICES, INC.

3.3.3.3 **Surficial Geology (Reference 4)**

Figure 3.11, taken from Reference 4, shows the surficial geology of Subase. Most of the surficial deposits onsite are unconsolidated glacial materials deposited during the Pleistocene Age. The remainder of the surficial deposits are the products of post-glacial geological processes and man-made modifications.

The glacial deposits are divided into two types; nonstratified drift (also known as till or ground moraine) and stratified drift (also known as outwash). Nonstratified drift was deposited in direct contact with the glaciers. Stratified drift was deposited by meltwater streams from a near or distant ice mass.

Most of the bedrock onsite is mantled by a thin layer of till which consists of a dense heterogeneous mixture of clay, silt, sand, and rock fragments ranging in size from cobbles to boulders. The majority of the material is unstratified but locally contains small pockets or lenses of stratified sand and gravel. Till is exposed on most of the upland surface and underlies outwash materials in the valleys. It varies considerably in thickness and in some places is absent, but averages less than ten feet thick. The till is thickest on the north slopes of hills and thin to absent on the summit and south sides. Till on the base consists of either locally fissile bouldery sand and gravel, or a fissile bouldery silt and clay.

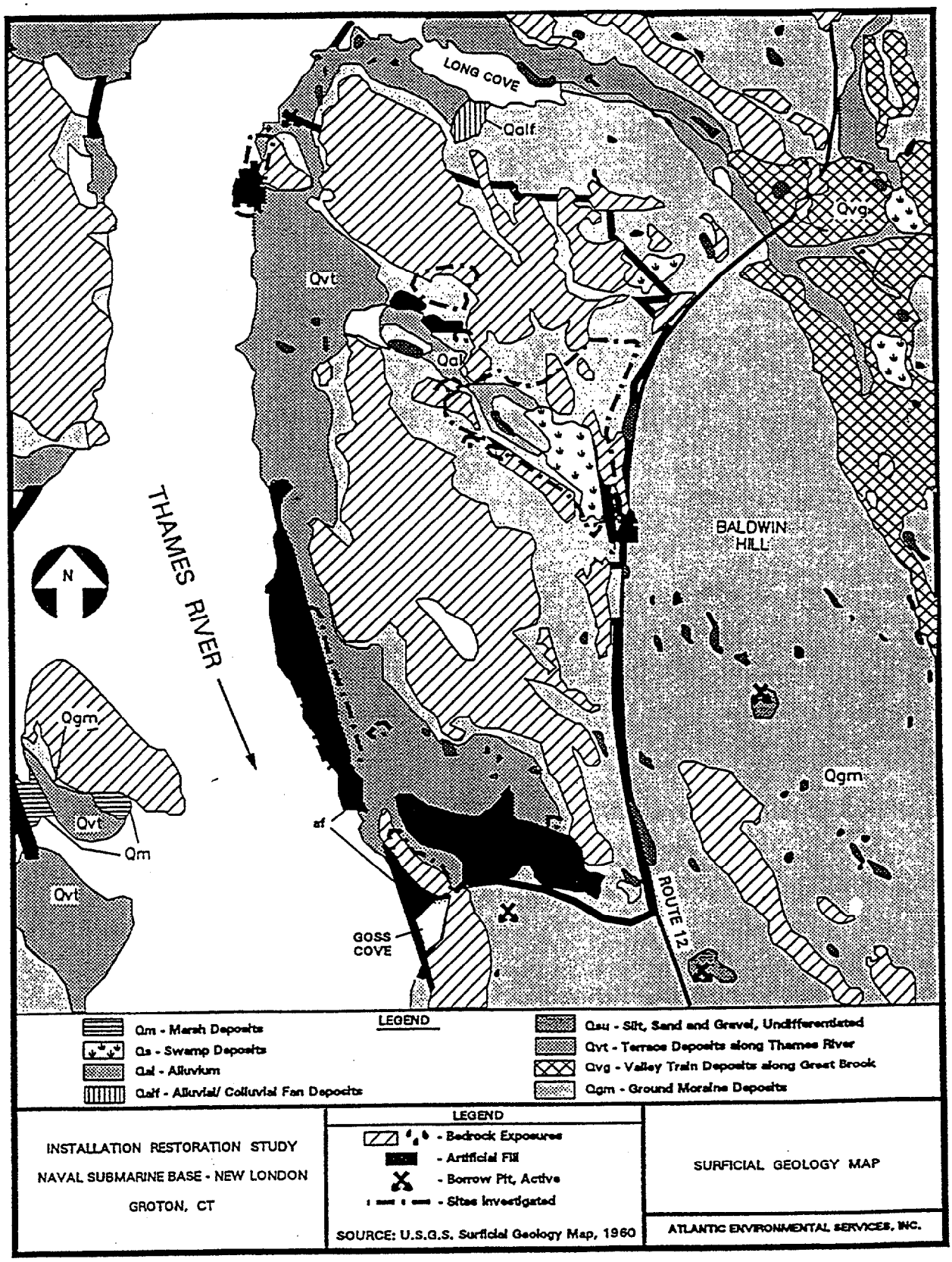
Stratified drift is stratified silt, sand, and gravel that was deposited by glacial meltwater. As the ice melted and local base levels of streams were lowered, the stratified deposits were left as ridges, mounds, terraces, and pitted valley floors. At the base, stratified drift is shown as terrace deposits of the Thames River and is mapped in the western portion of the site, at the southwestern end of the base adjacent to the former location of Crystal Lake, and beneath such sites as the southern portion of DRMO, the Area A Downstream, and portions of the Lower Base. The Spent Acid Storage and Disposal Area is located on the contact between stratified drift and the limit of artificial fill in the southeastern part of the site.

The northwestern end of the Area A Wetland, as well as the Over Bank Disposal Area (OBDA) and the Area A Downstream, is mapped as Quaternary Alluvium. Quaternary alluvium consists of recently deposited sand, silt, and gravel in flood plains.

Artificial fill is mapped in the areas of Goss Cove Landfill, DRMO, the majority of the Lower Base, and the southernmost portion of the base (former location of Crystal Lake).

Extensive bedrock outcrops are mapped and observed throughout the base at or adjacent to all sites except the Lower Base. There are no karst features (terrain, formations, or aquifers) at the base or within New London County.

Figure 3.11


LONG COVE
Qalf
Qvg
Qvt
Qal
THAMES RIVER
N
BALDWIN HILL
Qgm
Qvt
Qm
Qvt
af
GOSS COVE
ROUTE 12
Qgm
LEGEND
Qm - Marsh Deposits
Qs - Swamp Deposits
Qal - Alluvium
Qalf - Alluvial/ Colluvial Fan Deposits
Qsu - Silt, Sand and Gravel, Undifferentiated
Qvt - Terrace Deposits along Thames River
Qvg - Valley Train Deposits along Great Brook
Qgm - Ground Moraine Deposits
INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT
LEGEND
- Bedrock Exposures
- Artificial Fill
- Borrow Pit, Active
- Sites Investigated
SOURCE: U.S.G.S. Surficial Geology Map, 1960
SURFICIAL GEOLOGY MAP
ATLANTIC ENVIRONMENTAL SERVICES, INC.

3.3.3.4 **Bedrock Geology (Reference 4)**

Subase is situated in the Eastern Uplands region of Connecticut, an area that is characterized by irregular hilly areas with many swamps, exposed bedrock, and poorly drained, uneven valleys. The Eastern Uplands can be divided into two geological terrains according to their origins - the Avalonian Terrane which originated from continental crust, and the Iapetus Terrane which originated from oceanic crust. The Avalonian Terrane is considered to be the remnant of a relatively small continental land mass that collided with the North American continent in the late Permian Period (approximately 250 million years ago). The Iapetus Terrane is composed of sediments from the ocean that lay between the Avalonian continent and the North American continent, and were intensely deformed prior to and during the collision. The northern portion of eastern Connecticut is part of the Iapetus Terrane. The southeastern-most portion of Connecticut, including the base, consists of intensely deformed rocks that make up the Avalonian Terrane. A major east-west trending fault, the Honey Hill Fault, separates the two terrains approximately six miles north of the base. Avalonian rocks, including the bedrock at the base, consist of metamorphosed sedimentary and igneous rocks. There are no Holocene age faults, salt domes, underground mines, or caves at the base.

Bedrock at the base can be divided into three age groups: Pre-Silurian, Pre-Pennsylvanian, and Pennsylvanian (or younger). The local bedrock contains a complex series of folds, faults, anticlines and synclines. Figure 3.12 shows the bedrock geology of the base and Figure 3.13 presents a generalized geologic cross-section of the site area. Reference 4 discusses the area geology in detail. Figures 3.12 and 3.13 are taken from Reference 4.

Figure 3.12

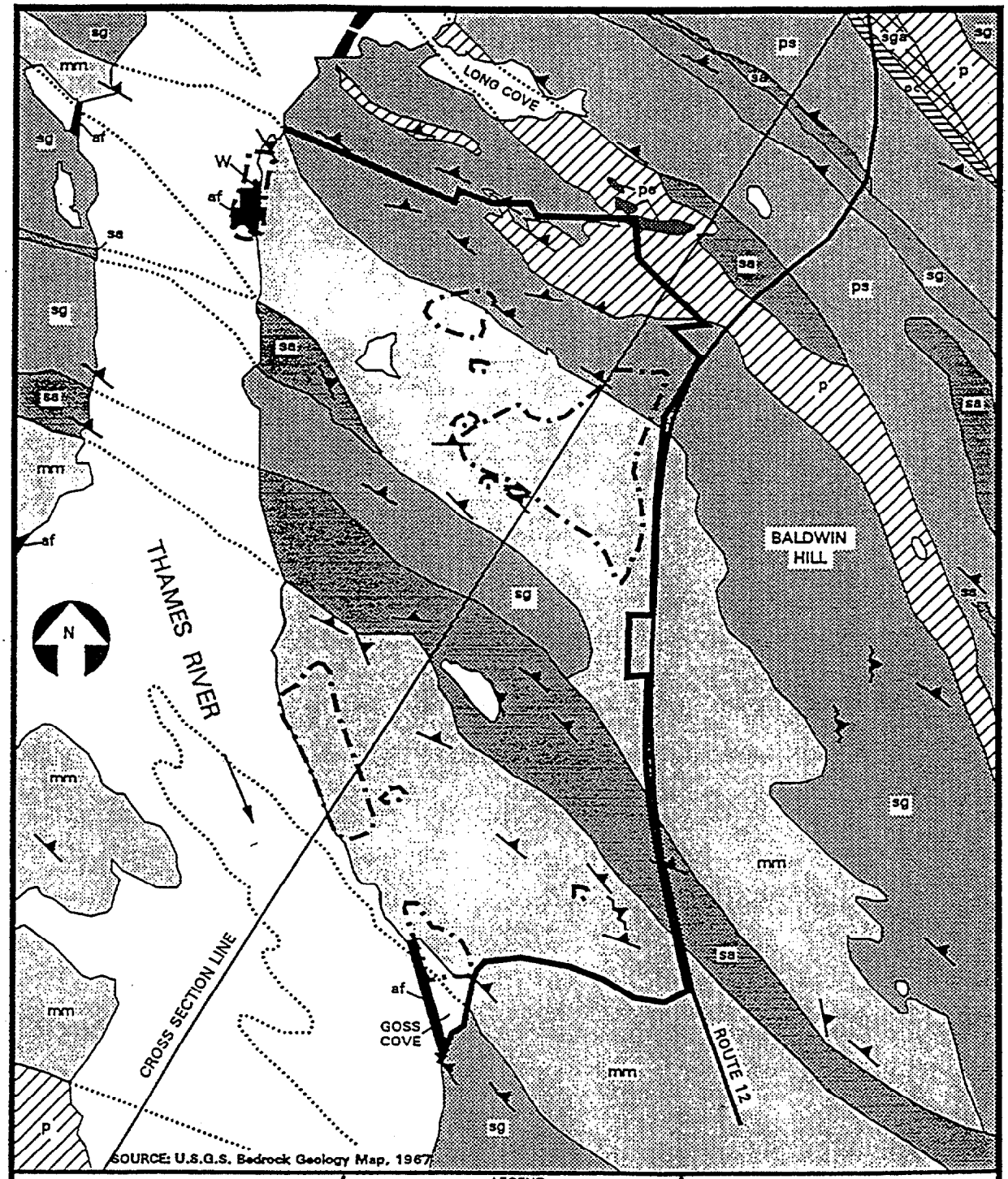
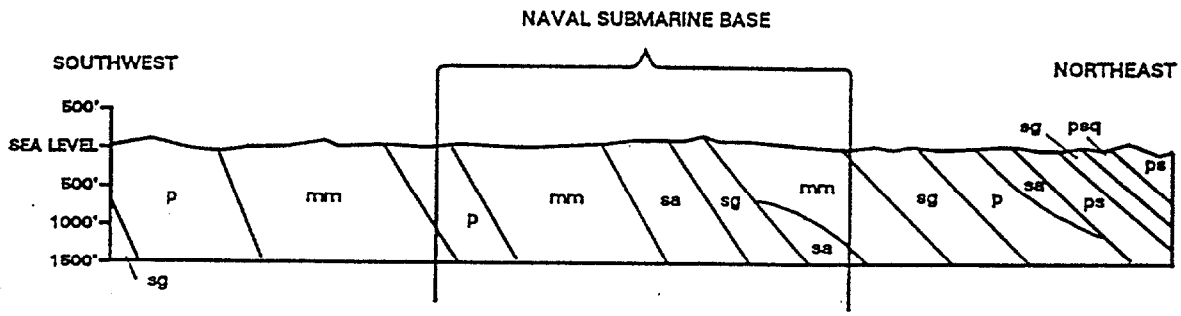

LONG COVE
THAMES RIVER
BALDWIN HILL
GOSS COVE
CROSS SECTION LINE
ROUTE 12
N
W
sg
mm
af
sa
ps
sga
p
pc
SOURCE: U.S.G.S. Bedrock Geology Map, 1967
INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT
LEGEND
- mm
- sa
- p
- ps
- pc
- sga
- sg
- af
- pc
w - Westerly Granite
- Sites Investigated
Strike & Dip of Mineral Foliation
- Inclined
- Gently Folded
BEDROCK GEOLOGY MAP
ATLANTIC ENVIRONMENTAL SERVICES, INC.

Figure 3.13



Legend

Alaskite gneiss

sa - orange-pink to light-grey, fine to medium-grained, equigranular gneissic granite composed of about equal amounts of quartz, microcline and albite to sodic oligoclase, and about 1 percent magnetite or as much as 2 percent magnetite and biotite.

Granite gneiss

sg - orange-pink to light-grey, medium-grained, gneissic biotite granite, main constituents quartz - microcline oligoclase with 2-7 percent biotite and iron oxides. Locally contains muscovite and garnet; somewhat uneven in mineral distribution. Foliation typically marked by parallelism of alternate flat lenses of quartz and feldspars, and parallelism of biotite flakes. Biotite tends to be concentrated on surfaces between lenses. Some masses have slightly coarser grained streaks rich in orange-pink microcline in finer grained grey quartz-microcline-plagioclase rock. Locally mafic-poor similar to biotitic phases of the alaskite gneiss (sob).

Mamacoke Formation

mm - indistinctly layered light- to dark-grey, biotite-, quartz-feldspar gneiss and minor hornblende-biotite-quartz-feldspar gneiss; locally granitoid and migmatic. Thin layers of amphibolite and quartzite. Biotite flakes typically small and mostly evenly distributed.

Plainfield Formation

p - dark-green hornblende-biotite-quartz-plagioclase gneiss, in part diopsidic; dark biotite-quartz-plagioclase gneiss with variable amounts of microcline; garnet-biotite-quartz-feldspar schist and gneiss; amphibolite; light-grey sugary textured biotite-feldspar-quartz gneiss; thin grey quartzite, rare thick white quartzite.

pc - calc-silicate quartzite and gneiss.

pa - garnet-sillimanite-biotite-quartz-feldspar schist and gneiss; garnet-biotite-quartz-feldspar gneiss; biotite-quartz-feldspar gneiss; minor biotite-quartz-andesine gneiss with diopside and colorless amphibole; thin-bedded quartzite, locally pyritic.

psq - thick- to thin-bedded, white or tan, to light-grey, rarely greenish quartzite; thin-bedded micaceous quartzite, locally graphitic; thin interlayers of garnet and sillimanite-bearing schist and gneiss.

INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT	LEGEND SOURCE: U.S.G.S. Bedrock Geology Map, 1967 N	BEDROCK GEOLOGY CROSS-SECTION LINE ATLANTIC ENVIRONMENTAL SERVICES, INC.

3.3.3.5 **Ground Water Sources and Uses (References 2, 4, and 5)**

Aquifer of Concern. Ground water is readily available in the southeastern portion of Connecticut where the base is located. While the base and most of the areas within the township of Groton receive their potable water from surface water supplies, areas north and northeast of the base, in the township of Ledyard, are dependent upon ground water for their potable water. Ground water in the area can be obtained from three aquifers: the stratified glacial outwash deposits; glacial till; and the bedrock aquifer. No confining layer is present between the overburden (i.e., glacial outwash and glacial till) and bed rock aquifers. Interconnection of the aquifers has been demonstrated by review of Installation Restoration study performance logs for wells located within three miles of the base. The combined unconsolidated overburden/aquifer is considered of concern. Regional water supply resources, including major aquifers, are shown on Figure 3.14.

Glacial Outwash Aquifers. The glacial outwash (stratified drift) deposits consists of gravel, sand, silt, and clay which have been sorted by glacial meltwater streams. These outwash deposits can be divided on a hydrologic basis into two water bearing units. There is a coarse-grained unit which is capable of yielding large quantities of water (up to several hundred gallons per minute) and a fine grained unit (Thames River terrace deposits) which generally yields less than 20 gallons per minute. The coarse grained unit consists predominantly of medium sand or coarser material, whereas the fine grained unit consists predominantly of fine sand, silt, and clay.

These glacial outwash deposits are the most productive ground water sources in the area. In most areas, the glacial outwash material is underlain by till, but in some instances it is underlain by bedrock. In isolated areas till may be underlain by outwash deposits. Glacial outwash areas are common in valley and lowland areas, but they are scarce or absent on hillsides and upland areas.

Wells completed in the coarse grained outwash material have yields which average 85 gallons per minute, with yields in excess of 880 gallons per minute reported. Permeability ranges from 250 to 4,000 gallons per day per square foot, with averages of 1,500 gallons per day per square foot. Thicknesses range from 1 to 120 feet throughout the area.

The lower portions of the base, which are on a terrace of the Thames River, have fine grained glacial outwash deposits. Yields of wells in this material average about 11 gallons per minute, with maximum recorded yields of around 20 gallons per minute. The permeability of these fine grained outwash deposits is about 300 gallons per day per square foot. Mapped thicknesses of stratified drift range from 10 feet along the banks of the Thames River to a maximum depth of 80 feet at the former location of Crystal Lake in the southwestern portion of the base.

In the coarse-grained glacial outwash, drilled wells which are properly screened provide the best yields. However, dug wells are the most practical in the fine grained outwash material such as that which occurs in the lower portions of the base. These wells are shallower than drilled wells, but the large diameter of dug wells enable them to serve as storage tanks. A four-foot diameter dug well holds about 94 gallons per foot of depth. These dug wells can supply sufficient quantities for domestic uses if periods of pumping do not exceed the quantity of water in storage.

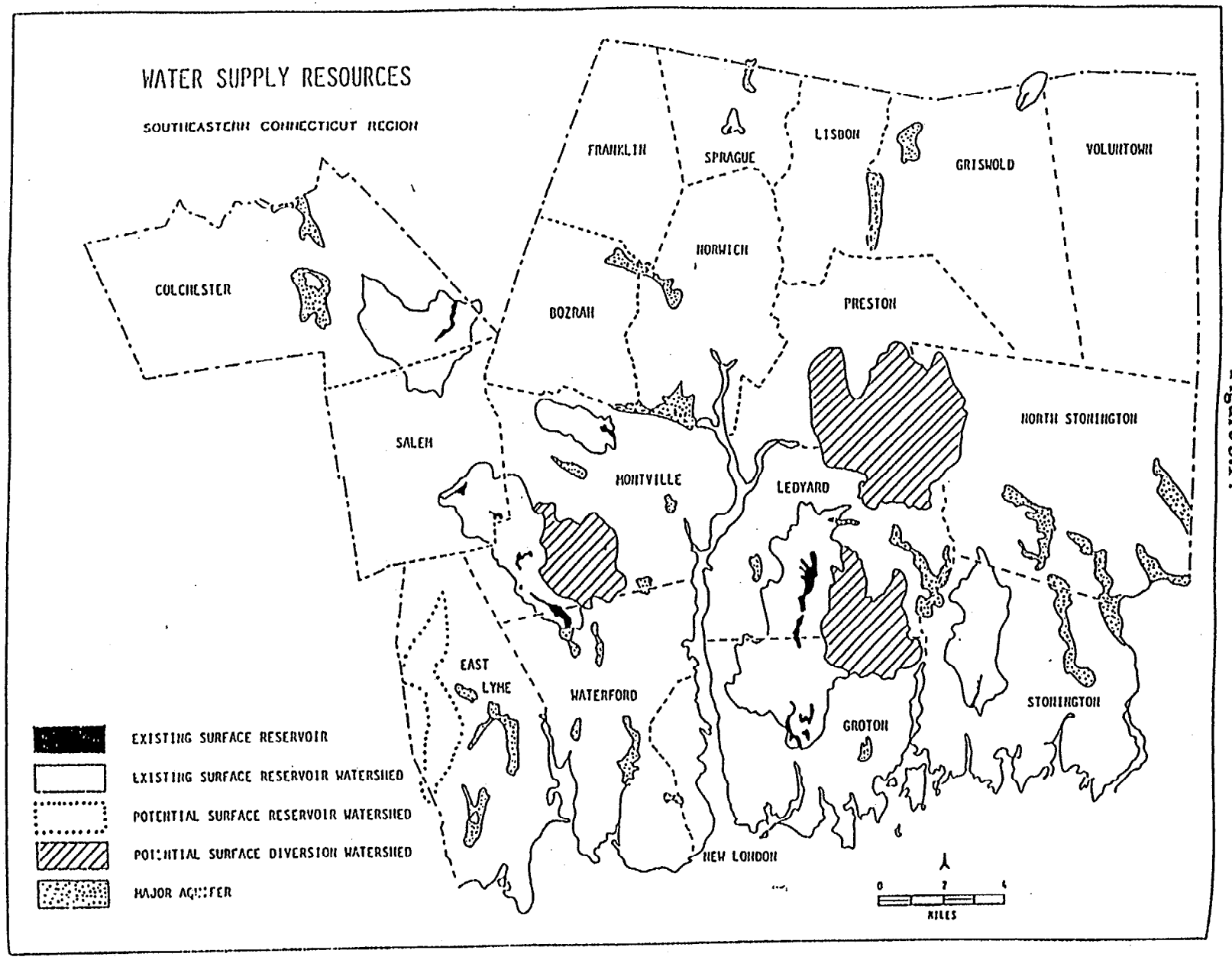


Figure 3.14

Source: Recommended Regional Development Plan, Southeastern Connecticut Regional Planning Agency, January 1987

Glacial Till Aquifer. The till is a poorly sorted, non-stratified, unconsolidated deposit of boulders, cobbles, gravel, sand, silt, and clay laid down directly by the glaciers. Till covers the bedrock almost everywhere in the area, and it occurs just below the soil on most hillsides, hilltops, and upland areas except where the bedrock is exposed.

Permeability measurements of the till range from 0.2 gallons per day per square foot for compact silty till to about 120 gallons per day per square foot for loose sandy till. Wells completed in till rarely yield more than a few hundred gallons per day, even to wells of large diameter. During periods of drought, wells completed in till are likely to be inadequate even for small domestic use. Till ranges in thickness from less than a foot near bedrock outcrops to some 110 feet, but is usually less than 40 feet.

Bedrock Aquifer. The bedrock underlying the area is a hard, dense, crystalline rock, including a variety of igneous and metamorphic types. The bedrock is fractured to a depth of several hundred feet, and it is along these cracks that most groundwater moves. Vertical joints, which are common in the area, may be connected by horizontal tension joints which are roughly parallel to the configuration of the bedrock surface. These horizontal joints are more common in granite and related igneous rocks. The abundance, width, and continuity of the joints vary widely from place to place. The joints become narrower and scarcer with depth so that the probability of encountering significant quantities of water at depths greater than 200 to 300 feet from the top of the bedrock is slight.

Even with fracturing, the permeability of the bedrock is very low, with an average of about 2 gallons per day per square foot. Despite its low permeability, bedrock wells yield small but dependable supplies of water. Bedrock wells in the site vicinity yield between 1 and 65 gallons per minute, with an average yield of 14 gallons per minute. The yield from bedrock wells varies depending upon the thickness of the saturated bedrock penetrated, the surface topography, the size and distribution of water-bearing fractures, and the type of overburden. Drilling to depths greater than around 300 feet seldom increases the yields but does increase the well's storage capacity. In general, the greatest well yields occur in valleys where bedrock is highly fractured and is overlain by over 50 feet of stratified drift.

Aquifer Depth. Ground water throughout the base is relatively shallow, generally being less than 10 feet below the surface. In the lower portions of the base, which are on the Thames River terrace, ground water is often less than 5 feet below the surface. The ground water is deepest on the hills which occur in the upper portions of the base. The Area A Landfill is in an area that was previously traversed by a stream. Here, the water table is at or above the ground surface.

Aquifer Summary. In the Subase HRS scoring document, Reference 5, EPA concluded the following regarding aquifers: "The general layering sequence of the aquifers is that the glacial outwash overlies the till units (including the terrace deposits) which in turn, overlies the bedrock. In areas where bedrock outcrops are predominant, such as the Subase, it is possible that bedrock fractures are open at the surface. While the extent of the bedrock fractures is not known, it is possible that fractures could be hydraulically connected to fractures supplying groundwater to nearby

residential bedrock wells in South Ledyard. It is unlikely that any other outwash aquifers, containing residential wells, are directly connected to surficial deposits at the Subase."

The geographic focus of Volume I of this HRA is Lower Base since, as described in Section 3.3.1, Naval Nuclear Propulsion Program (NNPP) work is limited to this area. Therefore, within the base, only the Lower Base is considered a potential source of NNPP radioactivity entering the environment. According to Reference 4, there are no bedrock outcrops at Lower Base, and no bedrock was encountered at Lower Base during the Installation Restoration (IR) study Phase I installation of monitoring wells and test borings. All of the IR monitoring wells at Lower Base draw water from the "overburden" (i.e., glacial outwash) aquifer. With no bedrock outcrops at the surface, and with no bedrock having been found beneath Lower Base, only the near-surface glacial outwash aquifer need be considered, and the question raised in Reference 5 regarding possible interconnection between glacial and bedrock aquifers does not apply to Lower Base.

Ground Water Flow in the vicinity of Subase (Reference 4)

Ground water flow from the near-surface glacial aquifers generally trends from east to west, and all of this ground water eventually drains to the Thames River. Ground water flow from the bedrock aquifer is being evaluated as part of the ongoing IR study.

At Lower Base, ground water flows west toward the Thames River during low tide. At high tide, ground water flows east from the river in the western portion of Lower Base, and flows west towards the river in the eastern portions of Lower Base. According to Reference 4, it is likely that this reversal of ground water flow direction at Lower Base during high tide does not extend farther than 300 feet inland from the Thames River.

Ground Water Quality (Reference 4)

The chemical quality of the ground water in southeastern Connecticut is generally good for most uses. The crystalline bedrock and glacial material are composed of minerals which are only slightly soluble in water, and the dissolved solids are correspondingly low. Most ground water has a dissolved solids concentration of less than 200 parts per million and a hardness of less than 120 parts per million, making the ground water soft or moderately hard. Iron and manganese cause taste, odor, and discoloration problems throughout southeastern Connecticut.

Salt water intrusion can be a problem in wells completed close to the Thames river and where overpumping has occurred. Each of the these types of aquifers is vulnerable to salt water intrusion, but wells in the stratified drift are most vulnerable to this problem. The high permeability of the stratified drift results in a relatively shallow but wide cone of depression, and during prolonged pumping this cone may intersect with estuary waters. Dug wells close to the estuary also may be subjected to salt water contamination resulting from flooding during hurricanes.

The State of Connecticut Department of Environmental Protection (CTDEP) has classified the ground waters beneath the central and southern portions of the base as GB/GA. A classification of GB/GA indicates that the ground water may not be suitable for direct human consumption without

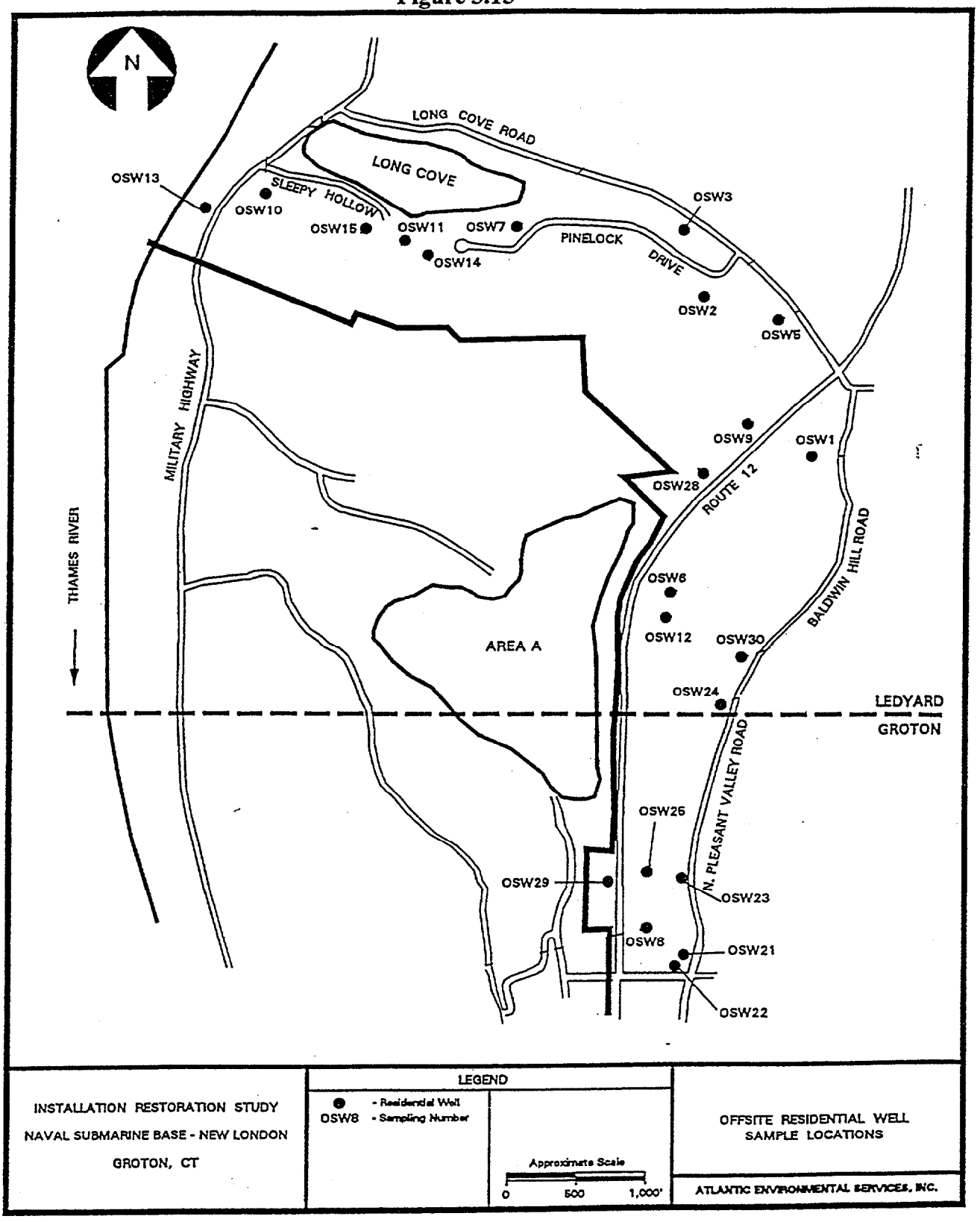
treatment due to waste discharges, spills, chemical leaks, or land use impacts. GB/GA waters may be useful for industrial process waters or cooling waters. The State's goal is to restore the water to drinking water quality (GA).

The ground water beneath the north portion of the base is classified by CTDEP as GA. Installation Restoration (IR) sites included on the north portion of the base include the DRMO, and the Area A Landfill plus adjacent sites. There are localized areas of chemical contamination within these IR sites that may not meet the GA classification. The GA classification signifies ground waters presumed suitable for direct human consumption without the need for treatment. The CTDEP's goal is to maintain drinking water quality.

Uses. The ground water at the base is not presently being used. There are several irrigation wells onsite at the golf course which have not been used for several years.

The majority of residences in Ledyard use private wells. The only local public water supply system in Ledyard is fed by wells and serves the Highland section, in the northeast corner of the town. The Southeastern Connecticut Water Authority operates a series of public water supply wells which serve the Tower, Ferry View, and Riverside neighborhoods of Gales Ferry north of the base. Homes on Route 12 adjacent to the northeast portion of the base have individual onsite drinking water wells, as do homes north of the base on Sleepy Hollow, Long Cove Road, and Military Highway. Two trailer parks near the base have wells classified as public water supply wells. The Colonel Ledyard Mobile Home Park, located on Sleepy Hollow adjacent to the North Gate has a well that supplies between 15 and 20 families. The Grandview Trailer Park, located at the intersection of Long Cove Road and Route 12, has two water supply wells. The public water supply well locations nearest to the base are shown as filled-in circles on Figure 3.6. The private drinking water well locations adjacent to the base are shown on Figure 3.15, taken from Reference 4.

Figure 3.15


N
LONG COVE ROAD
LONG COVE
SLEEPY HOLLOW
OSW13
OSW10
OSW15
OSW11
OSW7
OSW14
PINELOCK
DRIVE
OSW3
OSW2
OSW5
MILITARY HIGHWAY
THAMES RIVER
OSW9
OSW1
OSW28
ROUTE 12
BALDWIN HILL ROAD
OSW6
OSW12
OSW30
AREA A
OSW24
LEDYARD
GROTON
N. PLEASANT VALLEY ROAD
OSW26
OSW29
OSW23
OSW8
OSW21
OSW22
INSTALLATION RESTORATION STUDY
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CT
LEGEND
- Residential Well
OSW8 - Sampling Number
Approximate Scale
0
500
1,000'
OFFSITE RESIDENTIAL WELL
SAMPLE LOCATIONS
ATLANTIC ENVIRONMENTAL SERVICES, INC.

Subase Supply. The city of Groton has been supplying potable water to Subase since the 1940s. The primary source of the Groton water supply is reservoirs which are supplemented with wells. The water supplies are located within the Poquonock River Watershed, located east of the base, which is not within the base watershed.

Regional Supply. Surrounding the Thames River watershed are six lakes and reservoirs which are used as public water supply sources for the surrounding cities. The approximate radial distances of these water bodies to Subase and the communities served are contained in Table 3-2.

Table 3-2
Surface Water Bodies Used for Public Water Supply Sources

Water Body	Approximate Distance from Subase (miles)	City Served
Ledyard Reservoir	2	Groton
Morgan Pond Reservoir	3	Groton
Groton Reservoir	3	Groton
Lake Konomoc	4	Waterford/New London
Fairy Lake	9	Salem/Montville
Bond Reservoir	9	Salem/Montville

NOTE: These impoundments are the primary regional public water sources. Groton operates several wells adjacent to the Groton Reservoir during periods of drought.

3.3.3.6 **Surface Water Sources and Uses (References 1, 2, 4, and 5)**

General. Subase is located within the Thames River Watershed. The Thames River and its tributaries drain approximately 1,400 square miles of eastern Connecticut, western Rhode Island, and south central Massachusetts. The Thames River estuary is tidal, and extends from Long Island Sound north 16 miles to Norwich. The Thames discharges into Long Island Sound approximately six miles downstream (south) of the base.

Surface water from the base drains west toward the Thames River via streams and storm sewers. Figure 3.16, taken from Reference 4, shows site drainage basins. The offsite portion of these watersheds includes a sparsely developed residential area located to the east along Route 12 and an area with limited commercial development located north of the intersection of Crystal Lake Road and Route 12.

Onsite drainage includes several streams and ponds. These water courses discharge to the Thames River through discharge points located at the DRMO, on the Lower Base north of Pier 33, and at Goss Cove.

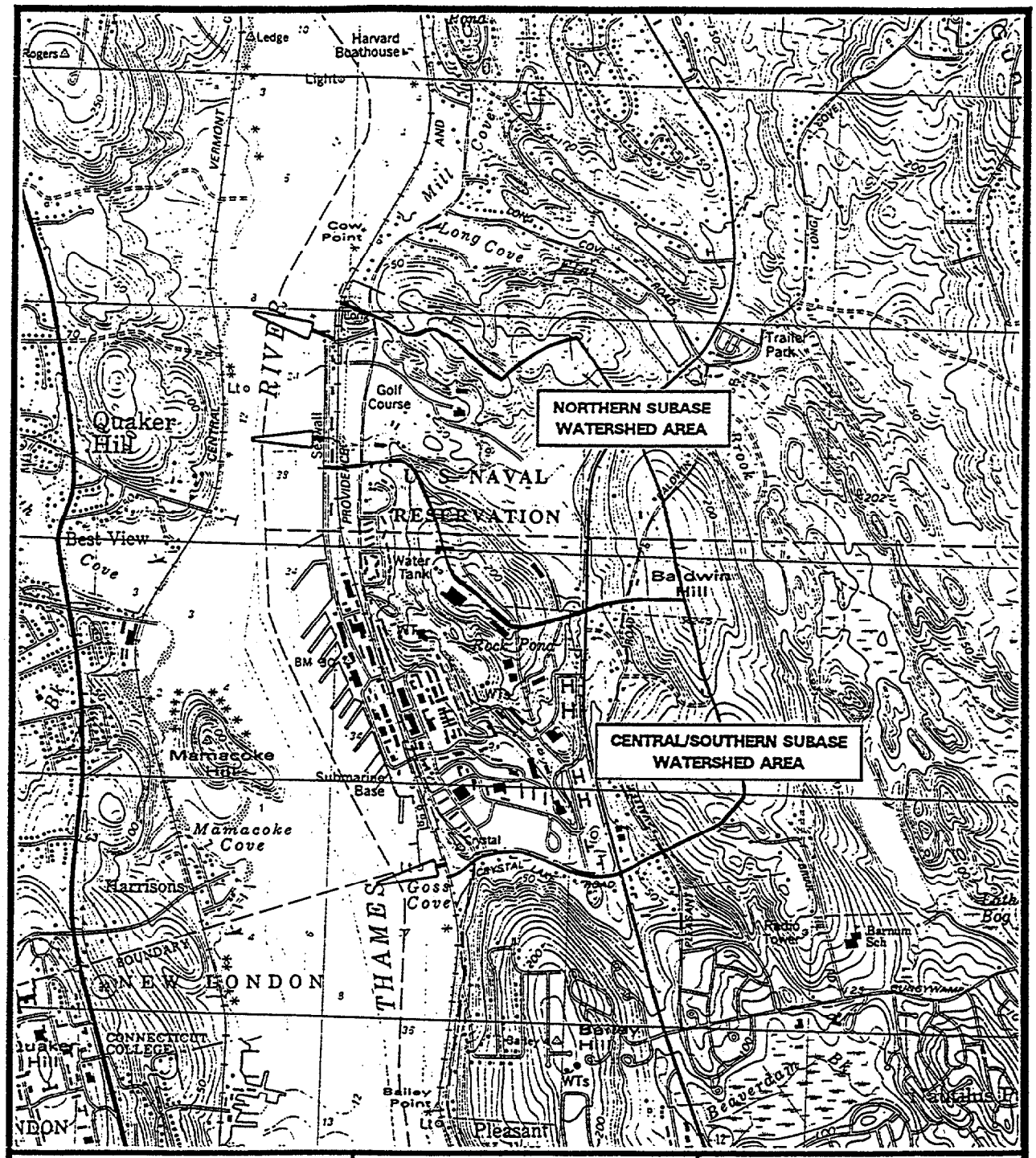
The volume of fresh water entering the Thames River estuary is very small compared to the volume of sea water within the estuary. In the vicinity of the base, the river width varies from about 1500 feet (DRMO, portions of Lower Base) to about 3000 feet (Goss Cove). The estimated average freshwater flow rate in the Thames River (including the vicinity of the base) is 1300 cubic feet per second.

The Thames River estuary seems to exhibit a two-layered flow, with a net inward bottom current and a net outward surface current. The rivers flowing into the Thames provide a continual input of water which determines the downstream flow rate. This downstream flow rate is important in the exchange of water out of the river and into Long Island Sound. The average non-tidal downstream flow rate for the Thames from Subase seaward is about 0.43 feet per second.

Tides are semi-diurnal in the Thames River with a mean range of 2.6 feet at New London. The average tidal current is about 1 foot per second in the area of the base.

The bottom sediment in the vicinity of the base is characterized in Reference 1 as being mainly mud, gravel, and sand. Because of minor silting, occasional maintenance dredging is required in the channel and in the areas adjacent to Subase piers.

Figure 3.16



INSTALLATION RESTORATION STUDY NAVAL SUBMARINE BASE - NEW LONDON GROTON, CT	LEGEND SOURCE: U.S.G.S. Topographic Map, 1984 Uncasville, Ct. N Major Surface Water Discharge Points	WATERSHED AREAS IN THE VICINITY OF NSB-NLON ATLANTIC ENVIRONMENTAL SERVICES, INC.

A wide range of salinity values occur in the Thames from the mouth of the river up to Norwich. Moving up the river, salinity values become lower as freshwater is more prevalent. At any given location, salinity values also vary between surface waters and bottom waters, with more freshwater in the surface layers and more salt water in the lower layers. During periods of low freshwater inflow, low level brine is detectable north of Norwich. When high freshwater inflow volumes occur, the effects of stream discharge become significant, and at low tide the limit of saltwater intrusion may be pushed several kilometers downstream of Norwich. Stratification in the northern two thirds of the river can be great depending on freshwater inflow. At times, the bottom saline waters become nearly depleted of dissolved oxygen. However, the portion of the river adjacent to the base is less likely to be stratified due to the greater input of water from Long Island Sound in this area.

Quality. (Reference 4) The State of Connecticut Department of Environmental Protection (CTDEP) has classified the Thames River water quality in the vicinity of the base as SC, with the goal of improving the water quality to Class SB. The SC classification designates the water as being suitable for: marine fish, shellfish, and wildlife habitat; certain aquaculture operations; recreational uses; industrial and other legitimate use. (It indicates the waters presently are not meeting Class SB water quality criteria or are not supporting one or more designated uses due to pollution.) Class SB water is suitable for swimming and harvesting of shellfish and is desirable to promote the restoration of an anadromous fishery.

Uses. No commercial fishing occurs in the Thames River above the I-95 bridge for any fish species. Some commercial harvesting of lobsters does occur north of the I-95 bridge. There are commercial relay beds for oysters and clams along the western shoreline immediately upstream and downstream of the base. Relay beds are areas where shellfish are grown for 5-6 years prior to retrieval and transplantation to purge beds outside of the Thames River. Purge beds are areas of relatively pristine water quality where the shellfish are allowed to shunt contaminants prior to final harvesting for commercial markets. Within 3 miles downstream of the base, there is a commercial fishery for eels. A large portion of the river, including Subase waterfront, is permanently closed to commercial shellfishing. Recreational shellfish harvesting is allowed but is strictly regulated by CTDEP. Recreational sport fishing is allowed. The river also provides a habitat for wildlife.

Sensitive Environments. No coastal wetlands exist within 2 miles of the base. One fresh-water wetland is within 1 mile of Subase. This freshwater wetland is approximately 25 acres and is located in the northeast section of the base. The Area A Landfill is within the wetland and drainage area. Critical habitats for endangered species do not exist within 1 mile of the base.

Population Served. The Thames River is saline/brackish and would not meet drinking water standards. Thus, there are no drinking water supply intakes in the Thames River. There is no land irrigated by surface waters with intakes downstream of the base or upstream to the limit of salt water intrusion. Intakes at the University of Connecticut - Avery Point are used to support aquaculture research. Therefore, no human population is served by surface waters with intakes downstream of the base or upstream to the limit of salt water intrusion.

3.3.3.7 Seismology

Seismic risk maps published by the U. S. Coast and Geodetic Survey place the vicinity of the Subase in risk zone 1, indicating an expectancy of only minor damage due to earthquakes. No major faults underlie the Thames River region and the region is considered aseismic.

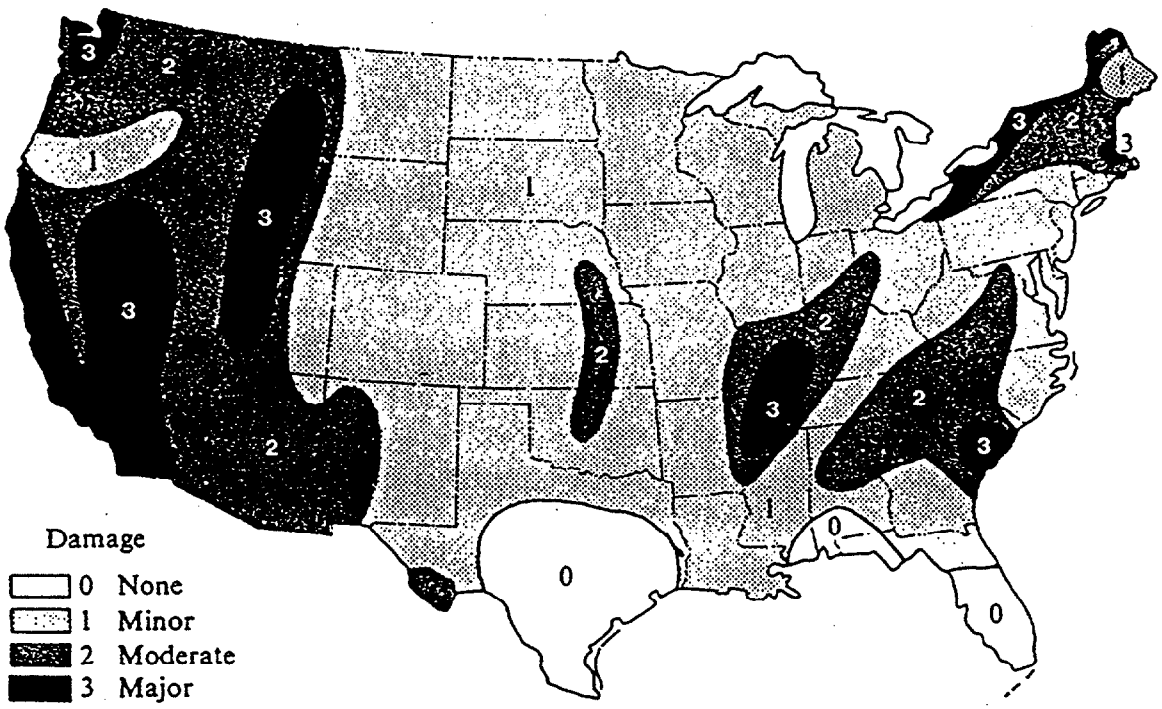


Figure 3.17 Seismic risk map for conterminous U. S. The map divides the U. S. into four zones: Zone 0, areas with no reasonable expectancy of earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, where major destructive earthquakes may occur.

Reference: Robert J. Foster, "Physical Geology," Charles E. Merrill Publishing Company, Second Edition, 1975

3.3.4 **Climatology (References 2 and 4)**

Southeastern Connecticut has a variable climate that is defined by both continental and maritime air masses, and modified by its proximity to the Atlantic Ocean. The ocean tends to modify temperatures, making winters somewhat warmer and summers cooler than areas more inland. Winters are moderately cold in the area, and summers are generally mild. The region lies in the path of prevailing westerlies and cyclonic disturbances that cross the country from the west or southwest toward the east and northeast. The prevailing winds are southwesterly in the summer and northwesterly in the winter. The average wind speed is around ten miles per hour. The region is exposed to occasional storms that travel up the Atlantic coast. Storms in the region are laden with moisture from the ocean; in addition, some storms are tropical and occasional storms are of hurricane intensity. These storms are heavily laden with moisture and can result in substantial tidal damages.

According to data from New London, Connecticut, the average annual temperature is approximately 50°F. Average monthly temperatures vary from 58-72°F in July and August to 23-30°F in January and February. The average growing season is from about the middle of April through the middle of October. Subzero temperatures seldom occur and are confined to December, January, and February. Temperatures in excess of 100°F seldom occur and are limited to June, July, and August. Temperature extremes for the area are - 13°F and 104°F.

Precipitation averages approximately 44 inches per year as measured at New London over an 81-year interval. Precipitation ranges from 32 to 65 inches per year. Southeastern Connecticut is characterized by frequent but short periods of precipitation. Measurable precipitation occurs about one day out of every three, and is fairly evenly distributed throughout the year although the greatest amount of precipitation occurs in the months of March and August with the least in June and September. Thunderstorms are responsible for much of the rainfall from May through August. These thunderstorms can be very intense but are generally of short duration. Snowfall varies considerably from year to year, with most snowfall occurring in January, February, and March. Evaporation averages approximately 23 inches per year.

Relative humidity in the area averages 55 percent in midafternoon and 75 percent at dawn. Lowest relative humidities occur in April and the highest in September. Climatological data for the Subase area are extensively characterized on a monthly basis in Table 5.3-1 of Reference 2.

Most of the Lower Base below the railroad trackage is located within the 100-year floodplain. The 100 year line is at 12.4 feet Mean Low Water (MLW) or 11.0 feet Mean Sea Level (MSL). The 500 year line is at 15.4 feet MLW or 14.0 feet MSL. Floodplain areas are shown on Figure 3.18.

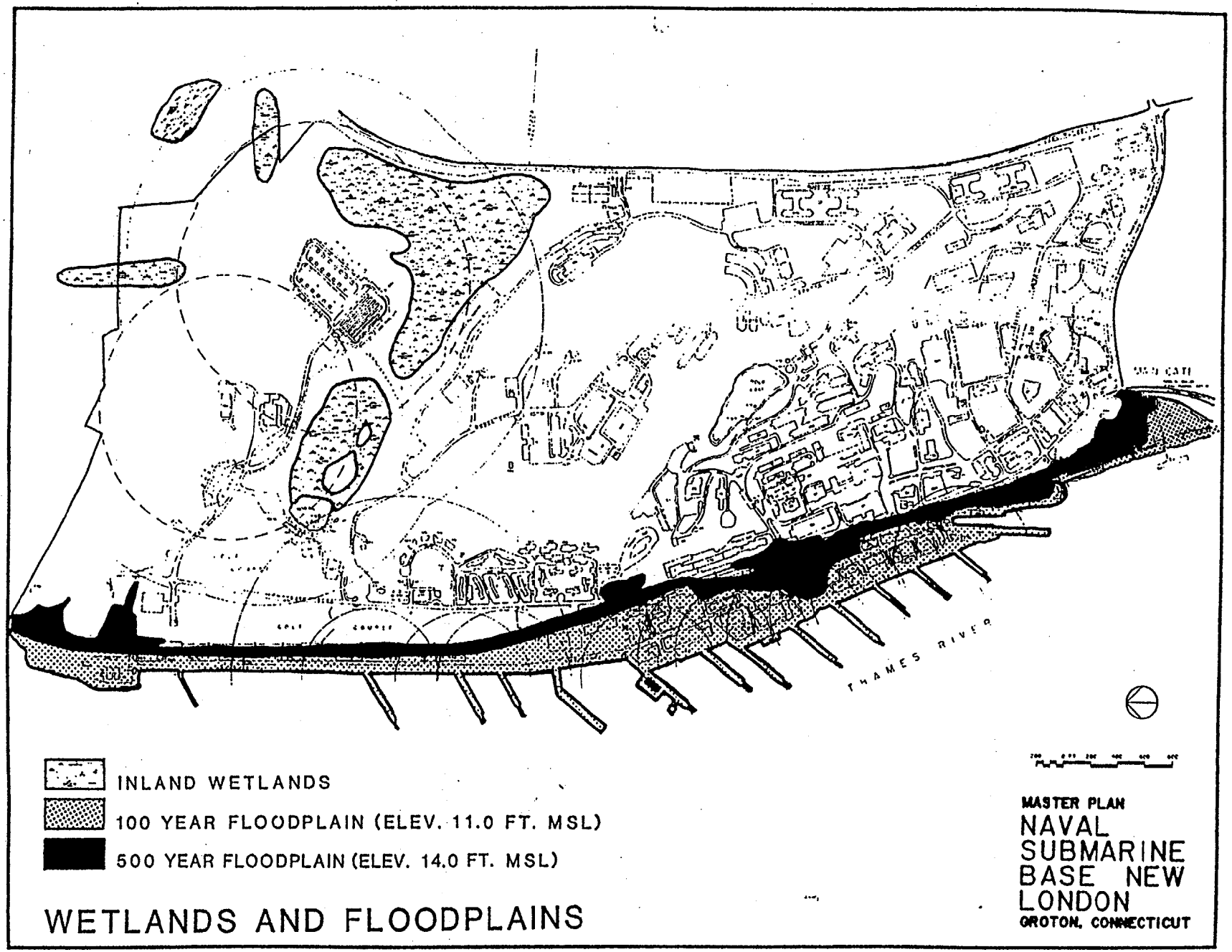

THAMES RIVER
INLAND WETLANDS
100 YEAR FLOODPLAIN (ELEV. 11.0 FT. MSL)
500 YEAR FLOODPLAIN (ELEV. 14.0 FT. MSL)
WETLANDS AND FLOODPLAINS
MASTER PLAN
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT

Figure 3.18

4.0 Description of Operations

4.1 Background on Navy Organizational Activities

4.1.1 Naval Facilities Engineering Command (NAVFAC)

NAVFAC is responsible for taking the lead in negotiating Federal Facilities Agreements (FFAs) with EPA regional offices and states.

4.1.2 Naval Nuclear Propulsion Program

The Naval Nuclear Propulsion Program is a joint Department of Energy (DOE)/ Department of the Navy program comprised of military and civilian personnel who design, build, operate, maintain, and oversee operation of Naval nuclear-powered ships and associated support facilities. The Program has a broad reach, maintaining responsibility for all aspects of Naval nuclear propulsion plants (including control of radiation and radioactivity) from cradle to grave. It is completely separate from the rest of the Navy and DOE activities that deal with radioactivity. Program responsibilities are delineated in Presidential Executive Order 12344 of February 1, 1982, and enacted as permanent law by Public Law 98-525 of October 19, 1984 (42 U.S.C. 7158).
Program elements include:

* The Navy's nuclear-powered warships;
* Research and development laboratories;
* Contractors responsible for the design, procurement, and construction of propulsion plant equipment;
* Shipyards that construct, overhaul, and service the propulsion plants of nuclear-powered vessels;
* Navy nuclear support facilities and tenders;
* Nuclear power schools and Naval Reactors training facilities; and
* The Naval Nuclear Propulsion Program headquarters organization and field offices.

Admiral H. G. Rickover developed the Naval Nuclear Propulsion Program at the end of World War II, with a commitment to technical excellence and an organization staffed by experienced professionals dedicated to designing, building, and operating Naval nuclear propulsion plants safely and in a manner that protects people and the environment. Executive Order 12344 and Public Law 98-525 capture the concepts and principles central to the Program's accomplishments.

Dealing with radioactive materials and ionizing radiation safely and responsibly has been an integral part of the NNPP from the beginning. It was recognized that the usefulness of nuclear-powered warships would be seriously hampered if operational restrictions were necessary because of radiological concerns. Therefore, the reactor plants were designed and continue to be operated such that the radiological impact on people and the environment is minimized. The NNPP established limits for releases to the environment which were well below limits applied to operation of commercial nuclear power plants. NNPP policy has been to control radioactivity such that radiological environmental impact is insignificant compared to natural radioactivity levels in the environment. From the start of the Naval Nuclear Propulsion Program, the policy has been to reduce to the minimum practicable the amounts of radioactivity released into the environment.

4.2 Radioactivity from Naval Nuclear Propulsion Plants

Naval nuclear propulsion plants differ from commercial power generating reactors in several important ways with respect to potential environmental impact. They are considerably smaller both in physical size and power output. To assure safe operation in close proximity to operating crews under possible high shock loading of battle conditions, the reactor plants are much more durable. Leakage of fission products into the cooling system, or leakage of the cooling system, are not compatible with ship operation and are not tolerated. Over 40 years experience with Naval nuclear propulsion plants has shown that fission products are contained in the fuel elements. This characteristic significantly reduces the potential for radiological environmental impact.

In the shipboard reactors, pressurized (non-boiling) water circulating through the reactor core picks up the heat of nuclear reaction. The reactor cooling water circulates through a closed piping system to heat exchangers which transfer the heat to water in a secondary steam system isolated from the primary cooling water. The secondary system water is turned into steam, which is then used as the source of power for the propulsion plant as well as for auxiliary machinery. Releases from the shipboard reactors occur primarily when reactor cooling water expands as a result of being heated up to operating temperature; this coolant passes through a purification system ion exchange resin bed prior to being transferred from the ship.

While fission products produced in the fuel, including iodine and the fission gases krypton and xenon, are retained within the fuel elements, it is true that trace quantities of naturally occurring uranium impurities in the surface of reactor structural materials release small amounts of fission products to the reactor coolant. The concentrations of fission products and the volumes of reactor coolant released are so low, however, that the total radioactivity attributed to long-lived fission product radionuclides comprises only a small fraction of the total long-lived gamma radioactivity releases discussed elsewhere in this section of this report.

The primary mechanism by which environmental releases of NNPP radioactivity occur include: (1) inadvertent releases of small volumes of liquids (or pre-1972 historical releases) to the river, as discussed in Section 5.1.1; (2) inadvertent releases of small amounts of liquid or solid material (or, very rarely, gases), as listed in Section 5.1.3;

(3) the particulate output from HEPA-filtered air exhausts at work areas, as discussed in Section 5.1.2; and (4) the release of trace quantities of fission product gasses and carbon-14 gaseous products from primary coolant which has been depressurized (including that which is removed from ships for processing into controlled pure water, as discussed in Section 5.1.1.1). Note that ships are prohibited from discharging reactor cooling water overboard in the vicinity of shore; hence, shipboard reactor operations are not considered a significant potential source of environmental contamination.

4.2.1 Cobalt-60

The principal source of radioactivity in liquid effluents or encountered during maintenance work is trace amounts of corrosion and wear products from reactor plant metal surfaces in contact with reactor cooling water. Radionuclides with half-lives of approximately one day or greater in these corrosion and wear products include tungsten-187, chromium-51, hafnium-181, iron-59, iron-55, nickel-63, niobium-95, zirconium-95, tantalum-182, manganese-54, cobalt-58, and cobalt-60. The most predominant of these is cobalt-60, which has a 5.3 year half-life. Cobalt-60 also has the most restrictive concentration limits, as listed in Reference 6. Therefore, cobalt-60 is the primary radionuclide of interest for Naval nuclear propulsion plants.

4.2.2 Tritium

Small amounts of tritium are formed in reactor coolant systems as a result of neutron interaction with the approximately 0.015 percent of naturally occurring deuterium present in water, and as a result of certain other nuclear reactions. Although tritium has a 12.3 year half-life, the radiation produced is of such low energy (weak beta; no gamma) that the Reference 6 radioactivity concentration limit for tritium is at least one hundred times higher than for cobalt-60. This tritium is in the oxide form (i.e., water) and is chemically indistinguishable from normal water; therefore, it does not concentrate in marine life or collect on sediment as do other radionuclides.

Tritium is naturally present in the environment because it is generated by cosmic radiation in the upper atmosphere. Reference 7 estimates the natural production rate of tritium would produce a global equilibrium inventory of between 28 million and 70 million curies. Table 3.3 of Reference 7 shows that 65 percent of the global inventory occurs in oceanic waters. These values yield an oceanic inventory of about 18 million to 45 million curies. Because of this naturally occurring tritium, much larger releases of tritium than are conceivable from Naval nuclear reactors would be required to make a measurable change in the background tritium concentration.

The total amount of tritium released annually from all U.S. Naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 200 curies. Most of this has been into the ocean greater than twelve miles from shore. The total tritium released annually from the entire nuclear Navy is less than single electrical generating nuclear power stations typically release each year. Total tritium released annually into harbors within twelve miles of shore is less than one curie. Appendix B of Reference 7 reports an estimated dose due to natural tritium in the environment of between 1.0 μrem/yr and 1.5 μrem/yr. In comparison to the millions of curies naturally occurring

in the oceans, the 200 curies of tritium per year released from nuclear ships is insignificant to both the global inventory and to the annual dose due to the environmental tritium. Therefore, tritium has not been combined with the data on other radionuclides in other sections of this report.

4.2.3 Carbon-14

Carbon-14 is also formed in small quantities in reactor coolant systems as a result of neutron interactions with nitrogen and oxygen. This carbon is in the form of a gas, primarily methane and ethane, although some insoluble carbonates may be present; following reprocessing of reactor coolant (to make controlled pure water), it is possible some carbon-14 has been converted to carbon dioxide. Carbon-14 decays with a half-life of 5,730 years; however, only low energy beta radiation is emitted as a result of this decay process. As a result, the Reference 6 radioactivity concentration limit for carbon-14 in its chemical form in air is sixty times higher than for cobalt-60.

Carbon-14 occurs naturally in the environment. It is generated from cosmic radiation interactions with nitrogen and oxygen in the upper atmosphere and oxidized to form carbon dioxide. Appendix B of Reference 7 states that "weapons testing has essentially doubled the atmospheric inventory of carbon-14 present from natural sources." Carbon-14 is chemically indistinguishable from other isotopes of carbon. The carbon dioxide diffuses and convects throughout the atmosphere and enters the earth's carbon cycle (i.e., achieving equilibrium concentrations in all living organisms; this is what permits "carbon dating" of deceased organisms, since carbon-14 in dead matter decays and is not replenished).

The earth's carbon-14 inventory is estimated to be about two hundred and fifty million curies. The total amount of carbon-14 released annually from the operation of all U.S. Naval nuclear-powered ships and their supporting tenders, bases, and shipyards has been less than 100 curies, most of which is released at sea beyond twelve miles from shore. Since the inventory of naturally occurring carbon-14 is millions of curies, releases from Naval nuclear reactors do not result in a measurable change in the background concentration of carbon-14.

Typical annual releases of carbon-14 at Subase are about 1 curie per year, virtually all as a gas. This is much less than the approximately 7 curies per year discharged by the typical commercial nuclear power plant per Reference 8. These gaseous releases are dispersed in the atmosphere and are not concentrated in the environment. Calculations using the EPA COMPLY computer code indicate that the resulting dose is less than 1 mrem per year. Furthermore, studies around a large civilian nuclear power plant showed no measurable carbon-14 in downwind foliage (Reference 9). For these reasons, carbon-14 is not judged a remediation concern, and carbon-14 data has not been combined with the data on other radionuclides in other sections of this report.

4.3 Type of Activities

Navy facilities authorized to perform radioactive work associated with Naval nuclear propulsion plants perform a wide range of maintenance, repair, and upgrading activities.

Some facilities also refuel reactor plants (not done at Subase). Refueling involves removal of spent fuel into special shipping containers and installation of new fuel. No work on or processing of fuel is performed at these facilities. Radioactive materials encountered during reactor plant work include reactor coolant that is processed and reused, reactor plant components (including removed and/or unusable components), tools and equipment used to perform the work, reusable (laundered) contamination control clothing, and contamination control waste products such as plastic bags, tape, plastic bottles, and impervious fabrics.

Trade skills required for reactor plant work are the same as for typical shipyard operations. Machinists, pipefitters, shipfitters, welders, sheet metal workers, electricians, painters, fabric workers, and riggers perform the work. Work is directed by engineers and monitored by inspectors and radiological control technicians. At Subase, the majority of the NNPP-related work is performed by active duty military personnel assigned to the Naval Submarine Support Facility (NSSF). The primary differences from other work are the extremely high quality standards and the interaction with radiation and radioactive materials. For example, it is common to train personnel on uncontaminated mockups prior to performing work on contaminated systems, to minimize exposure and help preclude errors.

4.4 Control of Radioactivity

A major objective in the performance of Naval nuclear propulsion plant work is avoiding the potential for releases of low level radioactivity into the environment. From the beginning of the NNPP, radiological work has been performed under strict controls to preclude the spread of contamination, by containing radioactivity at the source to the smallest practicable area or volume. Facilities where work on radioactive materials is performed are specifically designed to contain radioactivity. Design criteria include impervious walls, easily decontaminated surfaces, absence of floor drains, and ventilation systems with High Efficiency Particulate Air (HEPA) filtered exhausts to maintain a negative pressure in work areas. The HEPA filters are 99.97% efficient at removing 0.3 micron particles. To ensure proper operation, HEPA filters in radiological ventilation systems are tested in place, both after installation and periodically thereafter. The filtered exhausts are monitored with an Environmental Monitoring System; results of this monitoring are discussed in Section 5.

In addition, most work on radioactive materials is performed inside Contamination Containment Areas inside these facilities with all the same features as the building. This provides double isolation of radioactivity from the environment. In the event of a loss of containment (e.g., a liquid spill or a puncture in a containment), immediate action is taken to isolate and correct the problem, and to sample/survey to verify complete recovery.

Radioactive material in storage areas is packaged to contain any loose radioactive contamination and is surveyed prior to transfer by radiological control personnel to ensure the outside of the packaging is not contaminated. Radioactive material storage areas are surveyed for loose radioactive contamination periodically by radiological control personnel.

When in use, radiological work areas within the Radiological Controls Barge, YRR-14, are designated as radiologically controlled areas. These areas are physically separated from the rest of the barge. Access to the barge is restricted. Access to the radiologically controlled area for both personnel and material is via a control point manned by radiological control personnel. Personnel and material exiting a radiologically controlled area are surveyed for radioactive contamination with beta-gamma friskers.

All areas within a radiologically controlled area are maintained less than 450 pCi/100 cm^2 (by swipe analysis), except for those areas designated and specially controlled as Controlled Surface Contamination Areas. Controlled surface contamination areas are maintained at or near 450 pCi/100 cm^2 even during work on contaminated items. Radiologically controlled areas and controlled surface contamination areas are surveyed frequently by radiological control personnel to ensure that radioactive contamination levels are held below NNPP limits.

The NNPP controls radioactivity at the source by using the concept of total containment. This policy minimizes the spread of radioactive contamination to adjacent surfaces and to personnel. Engineered ventilation systems containing HEPA filters, drapes, glovebags, and tents are utilized to accomplish this goal. Any personnel, instructional, or equipment errors that result in even a minor spread of contamination halt the work until the cause is determined and corrective action is taken. This policy and its successful application allow most radiological work to be performed without personal protective clothing or respirators. In addition to permitting work to be accomplished more efficiently, the number and extent of radiological areas requiring release is minimized.

Radioactive materials are either maintained within controlled areas, or are attended or physically secured at all times. Movement of radioactive materials outside controlled areas requires a strict accountability system. All movements are verified by an individual other than the one performing the move.

Routine radiological surveys in and around facilities where work on radioactive materials is performed confirm that controls are effective. Corrective actions are taken immediately in the unusual event that surveys identify unexpected radioactivity. Inadvertent releases are cleaned up immediately (within hours if practicable), and a critique is held to identify and correct the cause of the problem. Detectable radioactivity in uncontrolled areas is not permitted.

The basic policies covering control of radioactivity have not been changed since the beginning of the NNPP. There has been continuous upgrading based on over 40 years of experience. An example of this is development of processing methods to make radioactive liquids reusable as reactor coolant. Other examples of upgrading include improved work facilities, development of improved contamination containment area designs, solid radioactive waste volume reduction, improved radiological analysis of environmental samples, and the extensive use of engineered ventilation systems. Upgraded monitoring methods have not detected problems with the basic control methods which have been used from the beginning of the Program.

4.5 Regulatory Oversight

NNPP radiological controls at Subase are overseen by Naval Nuclear Propulsion Program headquarters. As the NNPP's representative, nuclear-trained personnel on the Fleet Commander (CINCLANTFLT) and Type Commander (SUBLANT) staffs perform annual on-site audits of all Subase nuclear work practices, including radiological controls, worker training, quality control, and compliance with work procedures and headquarters requirements. Similar on-site audits are occasionally performed by NNPP headquarters as overchecks. These on-site reviews are performed in support of the NNPP authorization for Subase handling of NNPP radiological materials.

Regulatory interface regarding mixed (radiological and hazardous) waste is addressed in Section 5.3.

5.0 Policies and Results

5.1 Policies and Records Related to Environmental Release of Radioactivity

5.1.1 Liquid Discharges

5.1.1.1 Policy

General

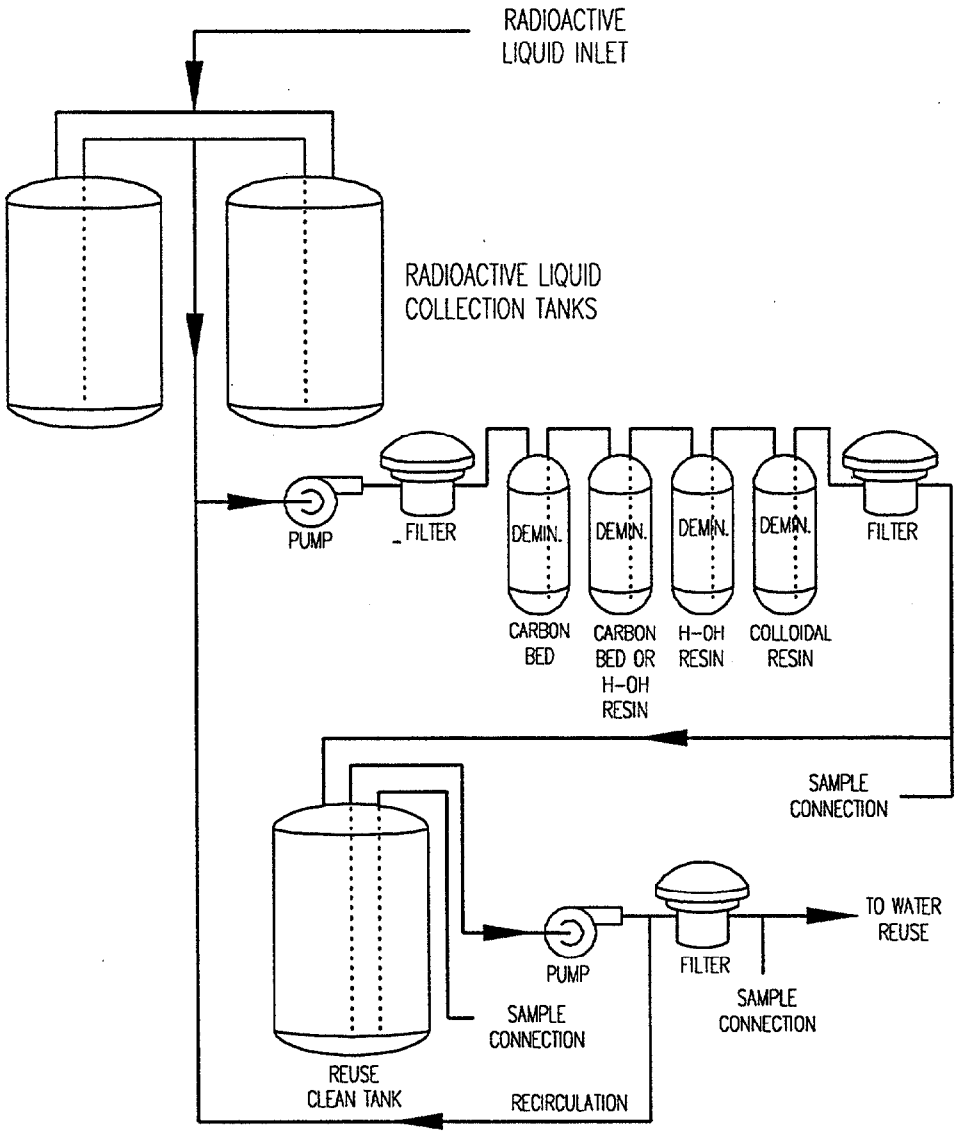
As stated in Reference 10, the policy of the NNPP is to minimize the amount of radioactivity released to the environment, particularly within twelve miles of shore (e.g., including into harbors). This policy is consistent with applicable recommendations issued by the Federal Radiation Council (incorporated into the Environmental Protection Agency in 1970), U.S. Nuclear Regulatory Commission, National Council on Radiation Protection and Measurements, International Commission on Radiological Protection, International Atomic Energy Agency, and National Academy of Sciences--National Research Council. To implement this policy of minimizing releases, the NNPP has issued standard instructions defining radioactive release limits and procedures to be used by U.S. Naval nuclear-powered ships and their support facilities. These instructions were reviewed by the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, and the U.S. Environmental Protection Agency.

The policies and procedures instituted by about 1972 remain in place through the present. The total amount of long-lived (half-life greater than one day) gamma radioactivity released into harbors and seas within twelve miles of shore by the entire Naval Nuclear Propulsion Program has been less than 0.002 curie during each of the last twenty-two years. This total is for releases from U.S. Naval nuclear-powered ships and from the supporting shipyards, tenders, and submarine bases, including releases at operating bases and home ports in the U.S. and overseas and all other U.S. and foreign ports which were visited by Naval nuclear-powered ships. This activity level is conservatively reported as if it consisted entirely of cobalt-60, which is the predominant long-lived gamma radionuclide and also has the most stringent concentration limits.

Processing and Reuse of Radioactive Liquids

Radioactive liquids at Subase are collected in stainless steel tanks and processed through a processing system to remove most of the radioactivity (exclusive of tritium) prior to collection in a clean tank for reuse. Figure 5.1 shows a simplified block diagram of the liquid processing system which consists of particulate filters, activated carbon bed filters, mixed hydrogen hydroxyl resin, and colloid removal resin beds. This type of processing system has been developed and used successfully to produce high quality water containing very low radioactivity levels. The NNPP refers to this as "Controlled Pure Water" (CPW).

Figure 5.1
Simplified Diagram of Typical Radioactive Liquid Processing System



Even after processing to approximately 10^{-8} μCi/ml, reactor coolant is not discharged into the harbor. Rather, it is reused to the maximum extent practical, with excess volume returned to ships for eventual discharge well at sea. To put this in perspective, the Safe Drinking Water Act of 1974 standards established in Title 40 Code of Federal Regulations Part 141 (40 CFR 141) specify that the annual dose equivalent to the total body or any internal organ shall not be greater than 4 millirem/year from man-made radionuclides in drinking water based on continuous consumption. If water containing cobalt-60 at a level of 3×10^{-6} μCi/ml were consumed continuously for a year, the total effective dose equivalent to the individual would equal 50 mrem. This value is derived from Reference 6. On this basis, the NNPP limit of 6×10^{-8} μCi/ml cobalt-60 for processed water is conservative, and discharge of such water at sea has negligible environmental impact.

Policy Details

Standardized NNPP instructions concerning discharges of radioactive liquids from nuclear-powered ships were first issued in 1958. In 1960, all of the prior instructions were consolidated and incorporated into a technical manual for use by all submarine bases in their radiological control programs.

The basic criteria for release limits set in 1958 was that disposal of radioactive liquids should not increase the average concentrations of radionuclides in the surrounding environment by more than one-tenth of the maximum permissible concentrations for continuous exposure listed in National Bureau of Standards Handbook 52, Reference 11.

Measurements showed a dilution of over 100,000 for reactor coolant discharged from a ship. Credit for dilution was reduced to a factor of 1000 to be conservative. By setting the coolant discharge concentration limit at 100 times the Handbook 52 value for specific radionuclides listed, and taking credit for a 1000-fold dilution, the one-tenth criteria was met.

In January 1960, the NNPP release criteria was revised to be one-tenth of the limit of National Bureau of Standards Handbook 69, Reference 12. The Handbook 69 values were subsequently incorporated into Reference 6. 10 CFR 20 continues to serve as the commercial nuclear industry basis for radioactive effluents in air or water through the present. The standard instructions, which were reissued in 1964 for submarine bases, were based on the limits of 10 CFR 20, to ensure consistency with commercial standards where practical.

Between 1958 and May 1961, shore activities were allowed to dilute radioactive liquids to less than 3×10^{-5} μCi/ml prior to discharge. In May 1961, the Program required that radioactive liquids be treated by filtration and ion exchangers to minimize the dilution required to attain the 3×10^{-5} μCi/ml limit. In January 1966, requirements were modified to prefer additional treatment to attain the allowable concentrations in lieu of dilution.

In addition to the concentration limits discussed above, other limits and conditions were required, including total activity per year, total activity per shift, tidal conditions at the time of discharge, total gallons discharged, and proper authorizations. These NNPP limits and conditions were more conservative than any other agency's regulations at this time.

The tritium (hydrogen-3) concentration in both reactor coolant and controlled pure water is the same, at about $2x10^{-3}$ μCi/ml or less. This is below the 10 CFR 20 sanitary sewer release criteria for tritium which the Nuclear Regulatory Commission uses for sites it regulates. Any such water which entered the river would be rapidly diluted and become indistinguishable from background tritium levels, as discussed in Section 4.2.2. If any small volume spilled on land and went undetected, it would be quickly washed into the river (e.g., by rainwater, or possibly by entering the shallow ground water system which discharges into the river as discussed in Section 3.3.3.5). No environmental mechanism to concentrate this radionuclide exists.

During 1970, shore activities were directed to acquire the capability to collect, process, and reuse reactor cooling water. In June of 1972, the Program regulations directed that discharges of processed liquids could only be made with specific approval of Naval Nuclear Propulsion Program headquarters.

5.1.1.2 **Liquid Discharges and Records**

Subase performed its first NNPP maintenance in September 1959. Liquids were processed and discharged to the river as described above. Since 1973, Subase has not intentionally discharged any liquids to the river and has not requested permission to do so.

Although none of the original discharge permits remain, each year from 1963 through 1972 the data concerning volume and total radioactivity from the discharge permits were summed and the values reported annually to NNPP headquarters by Subase. These values for discharges to the Thames River by all NNPP facilities (not just Subase) are shown in Table 5-1.

As shown in Table 5-1, the highest annual activity discharged by all NNPP facilities to the Thames River was 1.93 curies in 1964. 2.27 curies were discharged for 1961-62, but records are not available to separate this amount into yearly totals; this total is about the amount of naturally occurring radioactivity in a cube if sea water 200 yards on a side (Reference 13). For the entire NNPP, annual discharges within 12 miles of land prior to 1973 ranged from 1 to 10 curies; total NNPP discharges (including at sea) have been 0.4 Ci/yr since about 1975 (less than 0.002 curie within 12 miles of land). Compared to the discharges from other nuclear programs and activities and to the millions of curies occurring naturally in the oceans, even the pre-1973 amount of radioactivity is small. Table 5-2 shows 1990 radioactivity discharges from commercial nuclear power plants, in comparison to the NNPP total within 12 miles of land. (Table 5-2 includes all radionuclides with a half-life of greater than 8 days).

Table 5-1
Radioactive Liquid Waste Released to the Thames River From All NNPP Facilities 1955-1993

Year	Volume (Thousand Gallons)	Activity (Curies)
1955	5. (a)	0.323
1956	6.2 (a)	0.420
1957	3.7 (b)	0.217
1958	12 (b)	0.938
1959	(c)	(c)
1960	(c)	(c)
1961/1962	(c)	2.27
1963	101	1.69
1964	201	1.93
1965	828	1.29
1966	1,274	0.025
1967	606	0.011
1968	469	0.006
1969	615	0.006
1970	359	0.004
1971	258	<0.001
1972	151	<0.001
1973	<1	<0.001
1974	<1	<0.001
1975	<1	<0.001
1976	<1	<0.001
1977	<1	<0.001
1978	<1	<0.001
1979	<1	<0.001
1980	<1	<0.001
1981	<1	<0.001
1982	<1	<0.001
1983	<1	<0.001
1984	<1	<0.001
1985	<1	<0.001
1986	<1	<0.001
1987	<1	<0.001
1988	<1	<0.001
1989	<1	<0.001
1990	<1	<0.001
1991	<1	<0.001
1992	<1	<0.001
1993	<1	<0.001

Note: Activity is reported as cobalt-60 equivalent. Refer to Section 2.3 for a discussion of counting terminology. Tritium and carbon-14 are excluded. Data since 1958 are totals, attributed to all NNPP facilities along the Thames River. Limited Subase data available indicate that Subase contributed a small fraction of these totals.

(a) USS NAUTILUS discharges to New London Harbor
(b) USS NAUTILUS and USS SKATE discharges to New London Harbor
(c) Records not available

Table 5-2
ENVIRONMENTAL RELEASES (Curies)
ON LAND OR WITHIN TERRITORIAL WATERS
Naval[1] vs. Civilian[2] Reactors

AIRBORNE

PEACH BOTTOM 2 & 3	11200	
OCONEE 1, 2 & 3	8840	
CRYSTAL RIVER 3	7310	
SEQUOYAH 1 & 2	6070	
WATERFORD 3	5730	
BIG ROCK POINT 1	5550	
VERMONT YANKEE 1	5070	
MONTICELLO	2960	
MILLSTONE 2	2890	
INDIAN POINT 1 & 2	2230	
SAN ONOFRE 1	1800	
HADDAM NECK	1460	
BRAIDWOOD 1	1420	
JAMES A. FITZPATRICK	1350	
BYRON 1 & 2	1240	
PALO VERDE 3	1200	
SAN ONOFRE 2 & 3	1160	
BRUNSWICK 1 & 2	1120	
EDWIN I. HATCH 1 & 2	1100	
DAVIS - BESSE 1	1090	
RIVER BEND 1	1030	
BRAIDWOOD 2	1020	
WOLF CREEK 1	999	
NORTH ANNA 1 & 2	952	
MAINE YANKEE	946	
PILGRIM 1	907	
COMANCHE PEAK 1	906	
CALLAWAY 1	902	
WNP - 2	890	
HOPE CREEK 1	830	
SUMMER 1	751	
OYSTER CREEK 1	735	
PALO VERDE 1	708	
ARKANSAS ONE 1	700	
TURKEY POINT 3	688	
LASALLE 1 & 2	687	
PALO VERDE 2	676	
CALVERT CLIFFS 1 & 2	672	
THREE MILE ISLAND 1	666	
INDIAN POINT 3	626	
ST. LUCIE 1	619	
HARRIS 1	596	
R. E. GINNA	595	
TURKEY POINT 4	592	
ST. LUCIE 2	534	
CATAWBA 1	533	
CATAWBA 2	533	
MCGUIRE 1	518	
MCGUIRE 2	518	
FORT CALHOUN 1	459	
SURRY 1 & 2	451	
SALEM 1	313	
MILLSTONE 3	211	
TROJAN	206	
ARKANSAS ONE 2	189	
DONALD C. COOK 1 & 2	188	
VOGTLE 1 & 2	188	
COOPER	187	
SOUTH TEXAS 1	172	
NINE MILE POINT 2	163	
FERMI 2	161	
SALEM 2	149	
GRAND GULF 1	136	
PALISADES	121	
MILLSTONE 1	117	
YANKEE ROWE 1	113	
ZION 1 & 2	110	
SOUTH TEXAS 2	109	
SEABROOK 1	107	
JOSEPH M. FARLEY 1	87	
PERRY 1	84	
PRAIRIE ISLAND 1 & 2	83	
BEAVER VALLEY 1 & 2	82	
QUAD - CITIES 1 & 2	80	
SUSQUEHANNA 1 & 2	72	
DIABLO CANYON 1 & 2	56	
DUANE ARNOLD	46	← NAVAL
JOSEPH M. FARLEY 2	34	REACTORS
LIMERICK 1 & 2	34	<50
DRESDEN 2 & 3	20	
CLINTON 1	11	
POINT BEACH 1 & 2	8	
H. B. ROBINSON 2	7	
KEWAUNEE	2	
RANCHO SECO 1	0.2	
BROWNS FERRY 1, 2 & 3	N/D	
DRESDEN 1	N/D	
FORT ST. VRAIN	N/D	
HUMBOLDT BAY 3	N/D	
LACROSSE	N/D	
NINE MILE POINT 1	N/D	
SHOREHAM 1	N/D	
THREE MILE ISLAND 2	N/D	

LIQUID (less tritium)

MILLSTONE 2	8.76	
SOUTH TEXAS 1	7.09	
SOUTH TEXAS 2	5.72	
SURRY 1 & 2	4.60	
SALEM 2	3.14	
OCONEE 1, 2 & 3	3.11	
SALEM 1	3.00	
DIABLO CANYON 1 & 2	2.80	
HADDAM NECK	2.69	
ZION 1	2.65	
BEAVER VALLEY 1 & 2	2.55	
MILLSTONE 3	2.47	
ARKANSAS ONE 1	2.36	
BRAIDWOOD 1	2.13	
BRAIDWOOD 2	2.13	
COOPER	2.04	
MCGUIRE 1	2.00	
MCGUIRE 2	2.00	
DONALD C. COOK 1 & 2	1.61	
HOPE CREEK 1	1.49	
CALVERT CLIFFS 1 & 2	1.42	
SEQUOYAH 1 & 2	1.22	
BYRON 1 & 2	1.18	
INDIAN POINT 1 & 2	1.06	
VOGTLE 1 & 2	1.01	
CATAWBA 1	0.978	
CATAWBA 2	0.978	
ZION 2	0.926	
ST. LUCIA 1	0.827	
FORT CALHOUN 1	0.805	
ST. LUCIE 2	0.768	
RIVER BEND 1	0.737	
HARRIS 1	0.731	
WATERFORD 3	0.730	
DRESDEN 1, 2 & 3	0.712	
NORTH ANNA 1 & 2	0.675	
GRAND GULF 1	0.645	
CRYSTAL RIVER 3	0.619	
PERRY 1	0.610	
BRUNSWICK 1 & 2	0.457	
SAN ONOFRE 1	0.403	
H. B. ROBINSON 2	0.360	
SUMMER 1	0.356	
LIMERICK 1 & 2	0.343	
WOLF CREEK 1	0.315	
INDIAN POINT 3	0.309	
BROWNS FERRY 1, 2 & 3	0.302	
EDWIN I. HATCH 1 & 2	0.301	
ARKANSAS ONE 2	0.252	
FERMI 2	0.218	
KEWAUNEE	0.206	
SAN ONOFRE 2 & 3	0.202	
MAINE YANKEE	0.187	
R. E. GINNA	0.150	
TROJAN	0.144	
DAVIS - BESSE 1	0.141	
TURKEY POINT 3	0.141	
TURKEY POINT 4	0.140	
MILLSTONE 1	0.139	
SUSQUEHANNA 1 & 2	0.134	
PRAIRIE ISLAND 1 & 2	0.130	
QUAD - CITIES 1 & 2	0.113	
JOSEPH M. FARLEY 2	0.083	
JOSEPH M. FARLEY 1	0.075	
LACROSSE	0.069	
NINE MILE POINT 2	0.063	
CALLAWAY 1	0.039	
BIG ROCK POINT 1	0.036	
JAMES A. FITZPATRICK	0.027	
CLINTON 1	0.025	
LASALLE 1 & 2	0.025	
THREE MILE ISLAND 1	0.024	
PILGRIM 1	0.016	
WNP - 2	0.015	
PEACH BOTTOM 2 & 3	0.014	
COMANCHE PEAK 1	0.012	
POINT BEACH 1 & 2	0.012	
PALISADES	0.008	
HUMBOLDT BAY 3	0.006	
YANKEE ROWE 1	0.004	
SEABROOK 1	0.002	← NAVAL
NINE MILE POINT 1	0.00195	REACTORS
RANCHO SECO 1	0.00021	<0.002
THREE MILE ISLAND 2	0.00018	
FORT ST. VRAIN	0.00008	
OYSTER CREEK 1	0.00007	
DUANE ARNOLD	N/D	
MONTICELLO	N/D	
PALO VERDE 1	N/D	
PALO VERDE 2	N/D	
PALO VERDE 3	N/D	
SHOREHAM 1	N/D	
VERMONT YANKEE 1	N/D	

1. Naval reactors include 4 land based prototypes and over 120 ships. Total Program releases are comparable to commercial reactor releases listed above.
2. Source: U. S. Nuclear Regulatory Commission report NUREG/CR - 2907, Vol. 11, October 1993

From 1973 through 1993, all NNPP facilities on the Thames River (including Subase) reported total annual discharges (i.e., inadvertent discharges to the harbor) of less than 1000 gallons and less than 0.001 curie. This volume primarily originates from disconnecting underwater joints between facility collection facilities and nuclear submarines. These lines are blown down prior to disconnection, but some residual water remains at low points in hard piping. Since the disconnection is made by divers, there is no way to measure the amount of water residual in the hard piping connected to the ship. The 1000 gallons is a very conservative volume. In most years, the volume actually released is much less than 1000 gallons. The "less than 0.001 curie" reported is based on a total discharge of 1000 gallons, and is also very conservative.

These volumes do not include rare spills of controlled pure water, due to the very low levels of activity in such water as discussed above. These spills did not affect the "less than 0.001 curie" reported.

5.1.2 Air Exhausted From Radiological Facilities

Since nuclear work began at Subase, radiological work facility exhaust systems have been equipped with High Efficiency Particulate Air (HEPA) filters and have been monitored for radioactivity.

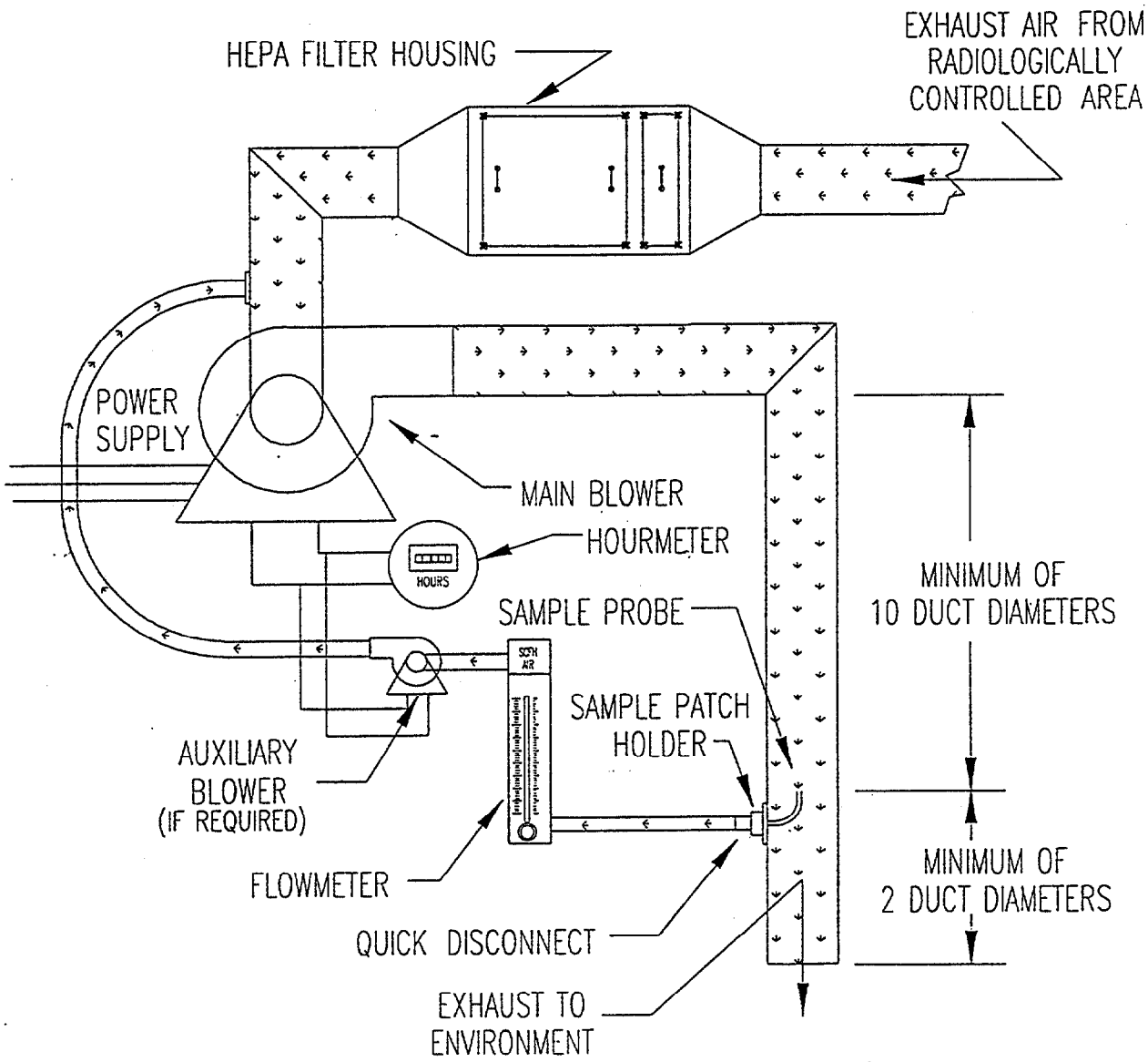
Beginning in 1970, Subase documented the results of monitoring air exhausted from radiological work facilities. From 1970 until 1978, a fixed-filter continuous air particulate detector was installed to detect air at concentrations of 1×10^{-9} μCi/ml, the regulatory limit for occupational exposure.

In 1978, a more sensitive system for air exhaust analysis was required to be in service at submarine bases. This Environmental Monitoring System, consisting of a vacuum pump, filter holder, differential pressure gauges, totalizing hourmeter, and connecting tubing, was installed at the HEPA filter exhausting to the environment from the Radiological Controls Barge. A similar unit has been monitoring air exhausted from the NAUTILUS since her arrival at Goss Cove in 1986. A simplified diagram of this system is shown in Figure 5.2. At the same time, the analysis procedure was revised to require a minimum detectable activity (MDA) of less than 2×10^{-14} μCi/ml. Actual MDAs have generally been lower than this, and most analysis results are "less than MDA." The low exhaust air radioactivity concentrations shown in Table 5-3 are expected to have existed since the beginning of NNPP work, since HEPA filtering policies have not been changed.

Sampling probe location is determined by obtaining a velocity profile across the duct. A uniform velocity distribution indicates turbulent flow, assuring adequate mixing and entrainment of particulates to permit single point sampling. If the velocity profile did not permit single point sampling (laminar flow), an array of sampling probes could be located in accordance with ANSI N13.1-69. All NNPP systems are configured to permit single point sampling (turbulent flow).

The sampling probe inlet velocity is adjusted to provide isokinetic flow. This assures that a representative sample will be obtained.

Figure 5.2
Simplified Diagram of Environmental Monitoring System



The systems are checked weekly to verify the flow rate is within specification and the differential pressure across the filter is within prescribed limits. At a minimum, the sampling filter must be changed annually. In practice, much more frequent changes are required due to dust loading of the filter.

Table 5-3 summarizes the results of air exhaust monitoring. In each year, the activity of air exhausted from radiological facilities has contained less total radioactivity than the naturally occurring radioactivity in an equal amount of air from the environment.

Table 5-3
Airborne Particulate Radioactivity in Air Exhausted From Radiological Facilities vs. Background Radioactivity in Air Naval Submarine Base New London

Year	Average Facility Exhaust Air Activity Concentration µCi/ml	Total Airborne Radioactivity Discharged From Facilities µCi/yr	Background Air Activity Concentration µCi/ml (a)	Total Activity If Background Air Had Been Discharged µCi/yr
1993	2.8×10^{-15}	0.27	2.5×10^{-14}	2.4
1992	2.9×10^{-15}	0.26	2.5×10^{-14}	2.2
1991	3.3×10^{-15}	0.27	2.7×10^{-14}	2.2
1990	3.3×10^{-15}	0.12	2.7×10^{-14}	1.0
1989	3.5×10^{-15}	0.16	2.6×10^{-14}	1.2
1988	3.4×10^{-15}	0.25	2.6×10^{-14}	1.9
1987	3.3×10^{-15}	0.28	2.6×10^{-14}	2.2
1986	3.5×10^{-15}	0.30	4.0×10^{-14}	3.4
1985	(b)	(b)	2.6×10^{-14}	(b)
1984	(b)	(b)	2.8×10^{-14}	(b)
1983	3.2×10^{-15}	0.49	2.6×10^{-14}	4.0

Note: Exhaust air activity monitoring began in 1960 based on results of installed air particle detectors. Numerical data was not reported until 1978. HEPA filtering procedures were identical in earlier years, so exhaust air radioactivity levels are expected to have been about the same prior to 1986. Actual exhaust air concentrations are expected to have been lower than reported here, since most analysis results were below detectability and MDA values were included in each year's average for "less than MDA" results.

(a) Measured at Portsmouth Naval Shipyard. Closest sensitive analysis available.
(b) Data not available.
(c) 1982 and earlier data not available.

These data verify that Subase air exhausts are about an order of magnitude cleaner than the air in the environment, from a radiological perspective.

EPA regulations for radionuclide emissions from non-DOE Federal facilities, including from Navy facilities, are contained in Title 40, Code of Federal Regulations, Part 61 (40 CFR 61) Subpart I. The 40 CFR 61 regulations specify more complex radionuclide emissions measurement systems than the NNPP requires for radiological work.

Since 1991, the NNPP and the EPA have been working together to reach agreement on alternate measurement procedures for NNPP work. In 1993, the NNPP submitted a draft agreement to the EPA and formally applied for EPA approval, on an interim basis, for alternate procedures for the measurement and estimation of radionuclide emissions. The agreement called for a two year interim period during which a series of special testing will be performed. These tests will provide additional data on airborne radionuclide releases and are intended to provide the EPA with sufficient information to approve the simplified alternate procedures on a permanent basis. In February 1994, the EPA granted interim approval of alternate procedures for estimation of radionuclide emissions.

One aspect of the interim agreement with the EPA concerns consistency of Program exhaust monitoring systems with the American National Standards Institute (ANSI) standard invoked by the EPA regulations. Some of the special tests in the two year test program are intended to quantify the difference, if any, between Program sampling systems and ANSI standard sampling systems and determine whether it is necessary to install ANSI standard sampling systems in Program exhausts.

As part of the 40 CFR 61 regulations, activities are required to report emissions unless the amounts released are less than 10 percent of the standards. To assist activities in assessing their facilities, the EPA has provided a computer code called COMPLY. Portsmouth Naval Shipyard has run this program using Subase site-specific parameters required for Level 4 analysis using COMPLY. For 1993, the COMPLY results are less than 10 percent of the standards, and Subase is exempt from the requirements for reporting in accordance with 40 CFR 61.

The NESHAPS 40 CFR 61 calculations demonstrate an exposure level to on-site residents (and hence the general public) of less than 1 mrem/yr, including the contributions from trace levels of fission product gases and gaseous carbon-14 products as discussed in Sections 4.2 and 4.2.3. Noble gasses such as isotopes of argon, krypton, or xenon do not accumulate in the environment and are therefore not a potential candidate for site remediation. Also, even if radioiodines had ever been released in significant quantities (which they haven't been), they would not constitute a potential remediation issue due to their short half-lives. Finally, while carbon-14 is incorporated into all living organisms as discussed in Section 4.2.3, it does not "bioaccumulate" in the sense that it does not concentrate in any particular organs or organisms.

5.1.3 Reports of Inadvertent Releases

Naval Nuclear Propulsion Program regulations require that formal reports be submitted to headquarters by activities when inadvertent releases of radioactivity to uncontrolled areas, to

personnel, or to the environment occur. These "incident reports" have been required since the inception of the program. Tenant commands at Subase have listings dating back to 1968.

An extensive search for archive copies of incident reports was conducted. A total of twenty-seven (27) reports were related to potential radioactivity releases to the environment. A comprehensive review of all available detailed records was performed for this HRA. Table 5-4 summarizes data obtained during these reviews. These reviews verified that the affected areas were surveyed and sampled as required by regulations and that the areas were properly released from radiological controls. The release criteria for surface contamination are less than 450 pCi/100 cm^2 by swipe analysis as discussed in Section 4.4, and less than 450 pCi /20 cm^2 scanning probe. The release criteria for soil/concrete at a spill site was formerly less than 30 pCi/g; several years ago it was reduced to less than 1 pCi/g cobalt-60 unless NNPP headquarters approves otherwise on a case basis. No such exceptions apply at Subase. Using NNPP sampling and analysis procedures, these surface and soil release criteria are at the limit of detectability above background.

The review of past incident reports also verified that any radioactive liquids lost to the environment were accounted for and included in the annual discharge reports to the Naval Nuclear Propulsion Program.

That no significant radioactivity was left on the ground as a result of past releases, documented or otherwise, is confirmed by the results of aerial monitoring conducted by EG & G and discussed elsewhere in this HRA. That no radioactivity has accumulated in river water or edible aquatic species is confirmed by survey results reported elsewhere in this HRA. Some radioactivity did accumulate in Thames River bottom sediment as a result of the previously discussed discharges of radioactive liquid. Reference 1 addresses this subject, with the EPA concluding that "radioactive decay and sedimentation is naturally reducing cobalt-60 levels in surface sediments and that no significant releases of cobalt-60 have occurred in recent years."

Table 5-4
Summary of Reports of Potential
Radioactivity Releases to The Environment

Date	Location	Volume	Activity
1-7-75	Piers 12/13 quay wall	n/a	n/a
Summary: Unexpected liquid spill onboard barge while decontaminating piping. All liquid was contained within the barge. A low-level airborne release was detected in the work area.			
Response: Ventilation was secured. Piping was re-bagged. Surveys of path of travel, and all subsequent air samples, were < minimum detectable. Procedures were revised.			

Date	Location	Volume	Activity
7-21-75	Pier 15 South	n/a	n/a
Summary: Inadvertent discharge from a ship.			
Response: Immediate surveys of river water were < minimum detectable. Surveys of river sediment were comparable to previous environmental monitoring results.			

Date	Location	Volume	Activity
9-4-75	Unknown pier	n/a	4500 pCi/frisk
Summary: Dry spill from shipping cask cover to asphalt while preparing to transfer resin catch tank from shielded shipping cask.			
Response: Isolated all potentially contaminated areas, replaced cover. Normal corrective actions for the spill (containment, clean-up, surveys, and personnel training) were taken. After decontamination with absorbants, tape, and strippable paint, all asphalt surveyed < minimum detectable. An area inside a building was designated for future stowage and testing of casks and catch tanks.			

Date	Location	Volume	Activity
3-31-78	Piers 12/13 quay wall	n/a	n/a
Summary: Accountability loss of a radioactive compensated ion chamber while awaiting shipment to a refurbishment facility.			
Response: An extensive search was conducted of all radioactive material storage areas and surrounding spaces, all radioactive material containers packed but not yet shipped, and underwater areas around the location. Investigation concluded the chamber was inadvertently disposed of as radioactive waste. Separate security storage for items requiring turn-in was established.			

Date	Location	Volume	Activity
5-21-82	Unknown pier	500 ml	None
Summary: While preparing for a hydrostatic test, potentially radioactive liquid sprayed from a defective adapter onto the pier.			
Response: High point valve was shut to stop the spill. All actions for a spill were carried out. Spill water, air, and area swipes surveyed < minimum detectable. All similar adapters were examined.			

Table 5-4 (continued)
Summary of Reports of Potential Radioactivity Releases to The Environment

Date	Location	Volume	Activity
5-11-83	Piers 12/13 quay wall	particle	4 μCi
Summary: Temporary holding tank of barge sewage system contaminated with a small amount of radioactivity; the radioactivity was traceable to a single particle.			
Response: Tank was bypassed and contents collected. Tank water and tank internal surfaces surveyed < minimum detectable. Radioactive particle was segregated from tank sludge. All sanitary surveyed system piping and accessible fixtures frisked < minimum detectable. Chemistry room sink modified to prevent inadvertent addition of radioactive material.			

Date	Location	Volume	Activity
4-8-84	Piers 12/13 quay wall	500 ml	0.019 μCi
Summary: Water spilled from portable effluent tank demineralizer head flange to drip pan; 500 ml went to river.			
Response: Spill was secured. All actions for a spill were carried out. River water surveyed < minimum detectable. Surveys of river sediment were comparable to previous environmental monitoring results. Defective gasket was replaced. All similar gaskets were examined.			

Date	Location	Volume	Activity
5-31-85	Bldg. 478	n/a	0.0275 μCi
Summary: A removed tool bag and tool roll were improperly surveyed. A later survey discovered a total of 22,050 pCi of fixed contamination in four localized areas of the bag and roll.			
Response: Contaminated material was contained and moved to a controlled area. Comprehensive surveys were performed inside and outside the ship, work barge, shop, and locker where the bag/roll had been placed, and all potential walkways. No contamination was detected. Subsequent surveys of all NNPP areas within Subase discovered a total of 5,400 pCi of fixed contamination in four other areas. This contaminated material was contained and moved to a controlled area.			

Date	Location	Volume	Activity
6-6-85	Bldg. 175 / Ship's trailer near Bldg. 456	n/a	n/a
Summary: A contaminated vent fitting was discovered outside of radiologically controlled areas (file drawer in ship's trailer near Bldg. 456). The fitting had originally been in Bldg. 175 (ship's warehouse). All required surveys of Bldg. 175 and the trailer had been conducted for the past three years.			
Response: The fitting was bagged and moved to a controlled area. Surveys of all non-radiological work areas of the ship, ship's trailer, and Bldg. 175 were performed. No other radioactive material was found. It could not be determined when the fitting was first placed in Bldg. 175 or where it originated from.			

Table 5-4 (continued)
Summary of Reports of Potential Radioactivity Releases to The Environment

Date	Location	Volume	Activity
3-9-86	Bldg. 40	n/a	n/a
Summary: Improperly surveyed test equipment pieces were discovered outside of radiological work areas.			
Response: All contaminated pieces were bagged and moved to a controlled area. Comprehensive surveys of the shop area and of all potential walkways from the shop to ships revealed no further radioactive material.			

Date	Location	Volume	Activity
3-27-86	Unknown pier	n/a	n/a
Summary: Low level airborne radioactivity was detected onboard a ship during welding on piping to a differential pressure cell. No work site ventilation was employed since no airborne radioactivity was expected.			
Response: All airborne casualty actions were taken. Comprehensive surveys of the worksite and of the exit path revealed no contamination beyond controlled areas. Air samples in adjacent areas were < minimum detectable.			

Date	Location	Volume	Activity
4-7-86	Bldg. 40	n/a	n/a
Summary: Improperly surveyed test equipment was discovered outside of radiological work areas.			
Response: Contaminated item was bagged and moved to a controlled area. Comprehensive surveys of the shop area, including similar test equipment, and of all potential walkways revealed no further radioactive material.			

Date	Location	Volume	Activity
10-21-86	Piers 12/13 quay wall	n/a	18,000 pCi/100cm^2
Summary: Contamination above limits discovered on three sets of laundered anti-contamination clothing (in the Response Van).			
Response: Contaminated clothing was bagged and moved to a controlled area. All previously laundered cloth anti-contamination clothing was controlled while 100% survey performed. All clothing which surveyed above limits was disposed of as radioactive waste. Comprehensive surveys of clothing storage area revealed no loose surface contamination. Contamination was apparently due to poor laundering by the vendor. Procedure revised to survey larger percentage of laundered clothing upon receipt from vendor.			

Date	Location	Volume	Activity
1-8-87	Bldg. 40	n/a	2025 pCi/frisk
Summary: Improperly surveyed test rig pieces were discovered outside of radiological work areas during routine monthly survey. Contamination levels were up to 2025 pCi/frisk.			
Response: Radioactive material was bagged and moved to a controlled area. Complete survey of all equipment in this shop and of all other areas where similar equipment might be stored revealed no further radioactive material.			

Table 5-4 (continued)
Summary of Reports of Potential Radioactivity Releases to The Environment

Date	Location	Volume	Activity
8-28-87	Pier 12	500 ml	0.0023 μCi
Summary: Inadvertent spill past a flange to the river while pressurizing an installed effluent collection system.			
Response: Spill was secured. Immediate samples of river water at spill location as well as upstream and downstream were < minimum detectable. All actions for a spill were carried out.			

Date	Location	Volume	Activity
10-12-88	Piers 12/13 quay wall	n/a	1800 pCi/frisk
Summary: Improperly surveyed containment material removed as non-radioactive material from portable effluent collection tank on Pier 12 to a non-radiological area on the barge. Material was subsequently discovered to be contaminated up to 1800 pCi/frisk.			
Response: Contaminated material was contained and controlled. All actions for a spill were carried out. Comprehensive surveys of barge, tank on Pier 12, and of all walkways between tank and barge revealed no further radioactive material.			

Date	Location	Volume	Activity
12-17-88	Pier 25	1 gallon	0.0002 μCi
Summary:. This was a release of controlled pure water.			
Response: No action required (Note (c)).			

Date	Location	Volume	Activity
3-21-89	Pier 15 - Piers 12 /13 quay wall	n/a	12,600 pCi/100 cm^2
Summary: Improperly surveyed material was discovered outside of radiological work areas.			
Response: Material was contained and removed to a controlled area. All actions for a spill were carried out. Comprehensive surveys of route from Pier 15 to barge revealed no further radioactive material.			

Date	Location	Volume	Activity
10-20-89	Various	n/a	27,000 pCi/frisk
Summary: Improper work practices resulted in personnel with contaminated clothing/skin leaving a controlled area.			
Response: Contaminated clothing was controlled and removed to a controlled area. Comprehensive surveys of all potential walkways, involved personnel, pertinent bunking areas and vehicles, and one affected ship revealed no further radioactive material.			

Table 5-4 (continued)
Summary of Reports of Potential
Radioactivity Releases to The Environment

Date	Location	Volume	Activity
12-12-89	Bldg. 456	n/a	1350 pCi/frisk
Summary: Loose surface contamination was discovered on a portable survey instrument upon receipt at the RADIAC Calibration Laboratory. Contamination was localized and fixed in label glue residue.			
Response: Contamination was contained and removed to a controlled area. All actions for a spill were carried out. Comprehensive surveys of barge, personnel, Calibration Laboratory, and instrument transfer routes revealed no further radioactive material. Origin of contamination could not be determined.			

Date	Location	Volume	Activity
3-11-90	Piers 12/13 quay wall	5 gallons	0.001 μCi
Summary: This was a release of controlled pure water.			
Response: No action required (Note (c)).			

Date	Location	Volume	Activity
7-29-90	Pier 32 South	2 gallons	0.003 μCi
Summary: This was a release of controlled pure water.			
Response: No action required (Note (c)).			

Date	Location	Volume	Activity
10-9-90	Bldg. 91 - Piers 12/13 quay wall	n/a	1800 pCi/100 cm^2
Summary: Improper work practices resulted in contaminated clothing being transported outside of radiologically controlled areas.			
Response: Contaminated clothing was contained and removed to a controlled area. All actions for a spill were carried out. Source of contamination was contained and removed to a controlled area. Comprehensive surveys of Bldg. 91, portable effluent tank house, and all walkways revealed no further radioactive material.			

Date	Location	Volume	Activity
4-24-91	Piers 12/13 quay wall	10 gallons	0.002 μCi
Summary: This was a release of controlled pure water.			
Response: No action required (Note (c)).			

Table 5-4 (continued)
Summary of Reports of Potential Radioactivity Releases to The Environment

Date	Location	Volume	Activity
7-18-91	Piers 12/13 quay wall	3 gallons	0.0003 μCi
Summary: This was release of controlled pure water.			
Response: No action required (Note (c)).			

Date	Location	Volume	Activity
11-13-91	Pier 12	250 ml	0.0021 μCi
Summary: Liquid inadvertently spilled to river from improperly positioned and inadequately drained effluent transfer hose.			
Response: Spill was secured. Contaminated hose was contained and moved to a controlled area. All actions for a spill were carried out. Comprehensive surveys revealed no further radioactive material. No detectable contamination was present on any of the materials involved in spill recovery actions; activity estimate based on analysis of liquid remaining in the hose.			

Date	Location	Volume	Activity
1-8-92	Piers 12/13 quay wall	n/a	367 pCi
Summary: Incorrect criterion was applied to release of 16 lagging samples based on gamma spectroscopy analysis. Samples had been released if Co-60 energy range activity concentration was within the gross gamma release criterion.			
Response: The lagging samples were contained and controlled. Records search indicated 16 additional samples had been improperly released in previous two years. Total Co-60 energy range activity in these 32 samples was 367 pCi. Training was accomplished and procedures were revised to prevent recurrence.			

Notes: (a) n/a - data not available.
(b) On occasion, spills also occurred onboard Naval craft, including the Radiological Controls Barge and the floating drydocks, in which no release to the environment occurred. These craft will warrant special sampling and surveying at the time they are to be released from radiological controls and/or be decommissioned.
(c) Five of the twenty-seven items above consist only of controlled pure water spills; see Section 5.1.1.1-Processing and Reuse of Radioactive Liquids. For reference purposes, this CPW is well below the Nuclear Regulatory Commission's 10 CFR 20 Appendix B unrestricted release criteria for cobalt-60 and sanitary sewer release criteria for tritium. Nevertheless, the NNPP controls this water.

5.2 Low-Level Solid Radioactive Waste Disposal

5.2.1 Policy

Solid low-level radioactive waste is generated during operation and maintenance of Naval nuclear-powered ships. This low level waste consists primarily of contaminated rags, plastic bags, paper, filters, ion exchange resin, and scrap materials. To maintain accountability, strict controls over these materials are implemented. These controls include serialized tagging and marking, and signatures by radiologically trained personnel to document transfers of materials. Solid radioactive waste materials are packaged in strong tight containers and shielded as necessary.

From the inception of the Program, on-site disposal of radioactive solid waste has been prohibited. This policy was described in early reports such as "Radioactive Waste Disposal from U.S. Naval Nuclear Powered Ships", January 1959, Reference 14. Radioactive solid waste was shipped to disposal sites operated or authorized by the Atomic Energy Commission (AEC). In the early years of the Program, this included some AEC-authorized ocean disposal sites. Subase has not used ocean disposal. When commercially operated sites licensed by the AEC or a state under agreement with the AEC became available, Navy solid waste was sent to these sites. Currently, such waste is shipped to disposal sites licensed by the U.S. Nuclear Regulatory Commission or a State under agreement with the U.S. Nuclear Regulatory Commission.

The quantity of solid radioactive waste generated and shipped in any one year from Subase depends on the amount and type of support work performed that year.

All Subase radioactive shipments in the NNPP contain only low-level radioactivity classified under Department of Transportation regulations as low specific activity or limited quantity shipments. The predominant radionuclide associated with these shipments is cobalt-60 in the form of insoluble metallic oxide corrosion products attached to surfaces of materials inside shipping containers. Most low-level shipments are made by truck. Air transport is used no more than a few times per year for the NNPP. These air shipments involve only very low levels of radioactivity and are restricted to cargo aircraft.

The policies and practices used successfully for over 40 years in managing radioactive materials and radioactive waste continue to be used currently. Reference 10 discusses and also illustrates the overall performance of the Program since 1961 in managing radioactive waste.

Facilities continue to be prohibited from disposing of radioactive waste on site. No NNPP sites have active or inactive disposal areas for Program radioactive materials.-

Submarine bases currently have agreements with Naval Shipyards in their geographic area to assist in the packaging and disposal of Fleet radioactive waste. Portsmouth Naval Shipyard has certified the proper packaging and labeling of low level radioactive waste shipments from Subase to approved disposal sites since 1980. Prior to 1980 this was accomplished by Navy personnel at the Subase. Submarine bases have only limited storage areas for staging waste for disposal. The Program policies of minimizing waste at the point of generation and then disposing of it as soon as processing and packaging are completed continue to be applied.

5.2.2 **Records**

The annual summary of solid waste disposal is included with the annual environmental monitoring reports prepared by the Naval Nuclear Propulsion Program. Subase has archive copies of annual solid radioactive waste summary reports from 1963 through 1979. Portsmouth Naval Shipyard has archive copies of Subase solid radioactive waste shipping records since 1980. A synopsis of annual solid radioactive waste data derived from available records is contained in Table 5-5.

The summary records covering the years 1963-1979 do not indicate the ultimate disposal site. However, by regulation: all licensed carriers assumed responsibility for transport to a pre-notified, AEC(NRC)-licensed low-level radioactive waste disposal site; and all shipments required disposal site receipt documentation be sent to the originator. Since 1980, with the exception of one shipment to Richland, Washington, all solid waste through 1993 has been disposed of at Barnwell, South Carolina. These records do not include classified components disposed of at the Oak Ridge, Savannah River, or Hanford sites owned by the DOE. No spent fuel has been shipped from Subase, since no nuclear refuelings were ever performed at the base.

The existence of waste disposal records dating back to 1963 and continuing through 1993, along with the prohibition of disposing of waste on-site, provide evidence that no solid radioactive waste has been disposed of on Subase property. Adding to this evidence are the results of the aerial radiological survey conducted by EG & G and reported in Section 6.7.

Table 5-5
Summary of Solid Radioactive Waste Disposal From Naval Submarine Base New London 1963-1993

Year	Number of Shipments	Volume Cubic Feet	Contractor (a)	Disposal Site (a)
1993	2	786	TS, CN	BSC
1992	2	1045	MS	BSC
1991	3	1750	TS, MS, TFB	BSC
1990	3	1717	TS, CN	BSC
1989	4	1190	CN, TFB	BSC
1988	3	1104	TS, TFB	BSC
1987	3	1271	TS	BSC
1986	1	338	TS	BSC
1985	2	695	TS	BSC
1984	1	542	TS	BSC
1983	3	1158	TS	BSC
1982	2	598	TS	BSC
1981	2	870	SWNP, TI	RW, BSC
1980	2	1285	SWNL	BSC
1979	3	2801	SWNL, RRC	(c)
1978	(b)	1925	NECO, RS, SWNL	(c)
1977	(b)	3128	NECO, TI	(c)
1976	(b)	1621	NECO, TI	(c)
1975	(b)	1786	NECO, RRC	(c)
1974	(b)	669	NECO, TI	(c)
1973	(b)	767	NECO	(c)
1972	(b)	1161	NECO	(c)
1971	(b)	1883	NECO	(c)
1970	(b)	904	NECO	(c)
1969	(b)	926	NECO	(c)
1968	(b)	897	NECO	(c)
1967	(b)	544	NECO	(c)
1966	(b)	148	ACNC	(c)
1965	(b)	251	NECO	(c)
1964	(b)	189	NECO	(c)
1963	None	None	NA	NA

This table lists waste shipments from Naval Submarine Support Facility for 1974 to present; from Subase Repair Department for 1963 through 1973.

(a) Abbreviations used:

TS: Tri State Motor Transit Co, Joplin, MO
CN: Chem-Nuclear Systems, Inc. Barnwell, SC
MS: McGill Specialized Carriers, Marietta, GA
TFB: T.F. Boyle Transportation, Billerica, MA
SWNP: Southwest Nuclear, Pleasonton, CA
TI: Teledyne Isotopes, Westwood, NJ
SWNL: Southwest Nuclear, Louisville, KY
RRC: Radiac Research Corporation, Brooklyn, NY
NECO: Nuclear Engineering Co., Inc., Morehead, KY
RS: RAD Services, Laurel, MD
ACNC: Allied Crossroads Nuclear Corp., Dorchester, MA
BSC: Chem-Nuclear Systems, Inc., Barnwell, SC
RW: U. S. Ecology, Richland, WA

(b) Not determinable from available records

(c) Not listed on available records. However, by regulation: all licensed carriers assumed responsibility for transport to a pre-notified, AEC (NRC)-licensed low-level radioactive waste disposal site; and all shipments required disposal site receipt documentation to be sent to originator.

NA: not applicable

5.3 Mixed Waste

Mixed waste (waste which is both hazardous and contaminated with low level radioactivity) has been generated during overhaul and repair of nuclear-powered ships at some NNPP facilities. However, the nature of the work performed at Subase makes it unlikely that any mixed waste would be produced at the base. Efforts to prevent the generation of mixed waste have to date been successful, but it is possible that Subase could produce small quantities of mixed waste in the future. Any such waste would be shipped elsewhere for storage or treatment.

5.4 Release of Facilities and Equipment Previously Used for Radiological Work

NNPP regulations require that activities engaged in Naval nuclear propulsion plant work compile and maintain lists of facilities, areas, and equipment that have been used in support of radiological work. These regulations further require that extensive radiological surveys be conducted when these radiological work or storage areas will no longer be used or when the area, facility, or equipment is being released from radiological control.

Such surveys include those using a gamma scintillation meter, and beta-gamma frisk surveys. Solid material samples are analyzed with a high-purity germanium detector coupled to a multi-channel analyzer. Samples are taken in defined grids. Any radioactivity detected by surveys or samples is removed and the area resurveyed or resampled until levels comparable to background are attained. Release criteria are discussed in Sections 4.4 and 5.1.3.

Results of surveys and sample analyses are formally documented and archived. For those areas being permanently released, a written report describing the area, radiological history, surveys and sampling protocol, tabulated results, and conclusions is forwarded to NNPP headquarters.

Table 5-6 lists previous radiologically controlled facilities that have been released for unrestricted use.

Table 5-6
Previous Radiological Facilities Unconditionally Released From Radiological Controls

Facility	Radiological Use
Building 174	Radioactive Material Storage

Note: One radiological controls barge and certain portable facilities have also been released from radiological controls and removed from Subase.

Pier and wharf areas adjacent to berths where nuclear ships are moored are used to locate portable radioactive liquid waste collection tanks, and occasionally serve as temporary radioactive material storage areas. Radioactive liquid waste tanks are controlled by technical working documents approved by the Radiological Controls Officer. All temporary radioactive material storage areas require the written approval of the Radiological Controls Officer.

When a radioactive liquid waste tank is relocated or a temporary radioactive material storage area is disestablished, beta-gamma radiological surveys are performed prior to removing signs and barriers. The area must meet the Naval Nuclear Propulsion Program limits of less than 450 pCi/100cm^2 swipe sample, or less than 450 pCi/20 cm^2 scanning probe, to be released for general use. Even then, the area is included on the list of those areas requiring permanent release as described above.

Radiological equipment, including portable work and storage enclosures, are maintained under the control of radiological control personnel until permanently released as described above. In addition, if the equipment has any crevices which could trap loose surface contamination, the item must be bulk counted before release or be disposed of as solid radioactive waste.

An example of the large-scale release of prior NNPP radiological facilities occurred when the NNPP left Ingalls Shipbuilding in Pascagoula, Mississippi. From 1958 to 1980, Ingalls Shipbuilding was engaged in the construction and overhaul of Naval nuclear-powered ships. The shipyard radiological facilities which supported this work were deactivated between 1980 and 1982. Extensive radiological decommissioning surveys were performed to verify the effectiveness of deactivation. Direct radiological surveys were performed on over 274,000 square feet of building and facility surfaces. Over 11,000 samples of these surfaces as well as soil, ground cover, and concrete were taken from all areas where radioactive work was previously performed. These samples were analyzed using sensitive laboratory equipment. In addition, both the State of Mississippi and the Environment Protection Agency (Reference 15) performed overcheck surveys of the deactivated facilities. After these surveys were completed, the Ingalls facilities were released for unrestricted use.

As at Ingalls, extensive radiological decommissioning surveys were performed at Mare Island and Charleston Naval Shipyards to verify the removal of radioactive material. These shipyards were deactivated following the 1993 round of the Base Realignment and Closure (BRAC) process. At each shipyard, direct radiological surveys on over 5,000,000 square feet of building and facility surfaces and analyses of over 40,000 samples of soil, ground cover, and concrete using sensitive laboratory equipment detected no cobalt-60 other than trace concentrations in a few localized areas. Simple, proven cleanup methods were used to remediate these areas. The total amount of NNPP radioactivity removed from the environment at each shipyard was equivalent to that in a single home smoke detector (2 to 3 μCi). Both shipyards were released for unrestricted use with respect to NNPP radioactivity by the operational closure date of April 1, 1996, with state and EPA agreement.

Personnel who subsequently occupy these facilities will not receive detectable radiation exposure above natural background levels. This relatively rapid and inexpensive remediation effort was only possible due to the NNPP policy of operating its radiological facilities in a manner which does not impact the environment.

5.5 Current Radiological Facilities

Other than active radiological work and storage areas, there are no areas within Subase where radioactivity exists above natural background levels. Current NNPP radiological work and storage areas are identified in Table 5-7.

Table 5-7
Radiological Facilities Currently in Use

Facility	Radiological Use
Building 91	Radioactive Material Storage
Reactor Plant Effluent Collection System Tank # 8 House, Pier 13	Radioactive Material Storage
Reactor Plant Effluent Collection System Tank # 9 House, Pier 12	Radioactive Material Storage
Piers 10, 12, 13, 15	In-Transit Radioactive Material Storage

Note: In addition to the above shore-based areas, Naval craft (Radiological Controls Barge - typically berthed at the quay wall between Piers 12 and 13, and two floating drydocks - typically berthed at Piers 15 and 17) are used.

6.0 Environmental Monitoring Program

Radiological environmental monitoring has been conducted at Subase since the beginning of its involvement with Naval nuclear-powered ships. This monitoring consists of analyzing river sediment, water, and marine life samples for radioactivity associated with Naval nuclear propulsion plants, radiation monitoring around the perimeter of support facilities, and related monitoring. Since 1979, the sediment, water, and marine life sample analyses have been performed by a U.S. Department of Energy (DOE) laboratory. The scope and analysis methods of Subase monitoring are sensitive enough to identify environmental radioactivity from various sources, such as that due to airborne nuclear tests in past years. The DOE laboratory annually analyzes a portion of the environmental samples with equipment and procedures which result in a minimum sensitivity approximately that achieved by the EPA in their 1989 survey of the Thames River, Reference 1.

Sections 2.3.1 and 4.2.1 discuss the basis for cobalt-60 being the primary radionuclide of interest for the NNPP.

6.1 Harbor Environmental Records

Harbor environmental data consisting of sediment, water, and marine life sample analysis data are applicable to the surface water pathway.

6.1.1 Sediment Sampling

Initial sediment samples were taken in 1954 as part of a base-line study prior to beginning NNPP work on the Thames River.

The earliest published report that included sediment sampling data is contained in Reference 17. Table II of Reference 17 shows that in 1966, 349 samples were taken at NNPP facilities on the Thames River (including Subase). Two samples per quarterly sampling period were sent to the U.S. Public Health Service Southeastern Radiological Health Laboratory for independent analysis. As an additional intercomparison, some randomly selected samples were sent to a U.S. Atomic Energy Commission laboratory for analysis.

Weekly sampling was required in 1964. In 1966, Subase implemented a uniform Program environmental monitoring protocol. Sediment samples have been collected quarterly through the present.

Beginning in 1967, the NNPP has published an annual report of environmental monitoring and waste disposal throughout the Program. These reports have been made available to federal regulatory agencies, state governments, and the general public. Reference 10 is the latest in this series of reports.

Each of the annual reports contains sediment sampling data. Data for sediment sampling results reported annually by NNPP headquarters for all NNPP facilities on the Thames River are included in Table 6-1.

Site-specific sediment sampling data for Subase are available from 1979 through the present and are included in Table 6-2.

Table 6-1
Gamma Radioactivity Concentration in River Sediment Samples
All NNPP Facilities on Thames River

1970 - 1993

Year	No. of Samples with Co-60 Energy Range Activity <3 pCi/g	3-30 pCi/g	>30 pCi/g	Total bottom area with Co-60 Energy Range Activity >3 pCi/g km^2	Estimated total Co-60 Energy Range Activity in top layer of sediment Ci	Range of Specific Co-60 Activity High / Low pCi/g (a)
1993	400	0	0	0	<0.01	0.80-<0.07
1992	495	0	0	0	<0.01	0.29-<0.06
1991	528	0	0	0	<0.01	0.78-<0.04
1990	528	0	0	0	<0.01	0.32-<0.04
1989	528	0	0	0	<0.01	1.63-<0.04
1988	544	0	0	0	<0.01	
1987	528	0	0	0	<0.01	
1986	528	0	0	0	<0.01	
1985	529	1	0	0	<0.01	
1984	528	0	0	0	<0.01	
1983	510	0	0	0	0.01	
1982	533	0	0	0	0.01	
1981	530	2	0	0.001	0.01	
1980	537	3	0	0.01	0.01	
1979	547	1	1	0.01	0.01	
1978	531	13	0	0.1	0.02	
1977	537	4	0	0.1	0.02	
1976	531	12	1	0.1	0.02	
1975	529	15	0	0.1	0.02	
1974	506	15	0	0.1	0.02	
1973	384	22	0	0.1	0.02	
1972	461	40	2	0.1	0.02	
1971	461	40	2	0.1	0.02	
1970	377	86	1	0.1	0.02	

Note: (a) Reporting requirements changed in 1989 to include range of specific cobalt-60 activity.

1966 - 1969

Year	No. of Samples with Co-60 Energy Range Activity <10 pCi/ cm^2 (a)	10-100 pCi/ cm^2	>100 pCi/ cm^2	Total bottom area with Co-60 Energy Range Activity >10 pCi/cm^2 km^2	Estimated total Co-60 Energy Range Activity in top layer of sediment Ci
1969	322	130	2	0.1	0.02
1968	189	198	23	0.3	0.1
1967	108	237	50	0.3	0.2
1966	58	215	76	0.3	0.3

Note: (a) From 1966 to 1969, the standard reporting requirements were in units of μμCi/cm^2. The above table has been changed to pCi/cm^2 since μμCi and pCi are the same unit. There is no direct conversion from cm^2 to gram without knowing the number of dredge loads needed to obtain a sample. This was corrected in 1970 by reporting pCi/g.

At present, 42 samples of river sediment are taken quarterly at Subase. Sampling locations are shown on Figure 6.1. Sample locations are selected based on berthing locations of nuclear-powered ships and at points upstream and downstream of berths where tidal ebb and flood currents could deposit suspended radioactivity.

A modified 6 inch square Birge-Ekman dredge is used to obtain a sample of the top 1/2 to 1-inch of the bottom sediment. This was selected since surficial sediments are more mobile and more accessible to marine life.

Prior to 1979, collected wet sediment samples were placed in 1-quart cylindrical containers and analyzed using a sodium iodide scintillation detector. A state-of-the-art multichannel analyzer has always been used for this analysis. Since 1979, a multichannel analyzer and germanium high resolution spectroscopy system has been used, and actual cobalt-60 activities have been measured by a DOE laboratory since then, in addition to gross gamma. Collected wet sediment samples were placed in Marinelli containers to provide consistent counting geometry.

Sample collection is conducted using a standardized procedure which has been approved by the NNPP. All Program Fleet and shore-based activities conducting environmental monitoring use this method. Subase river bottom sediment samples are analyzed by a DOE laboratory. This laboratory continues to participate satisfactorily in the quality control programs sponsored by DOE and EPA.

Figure 6.1

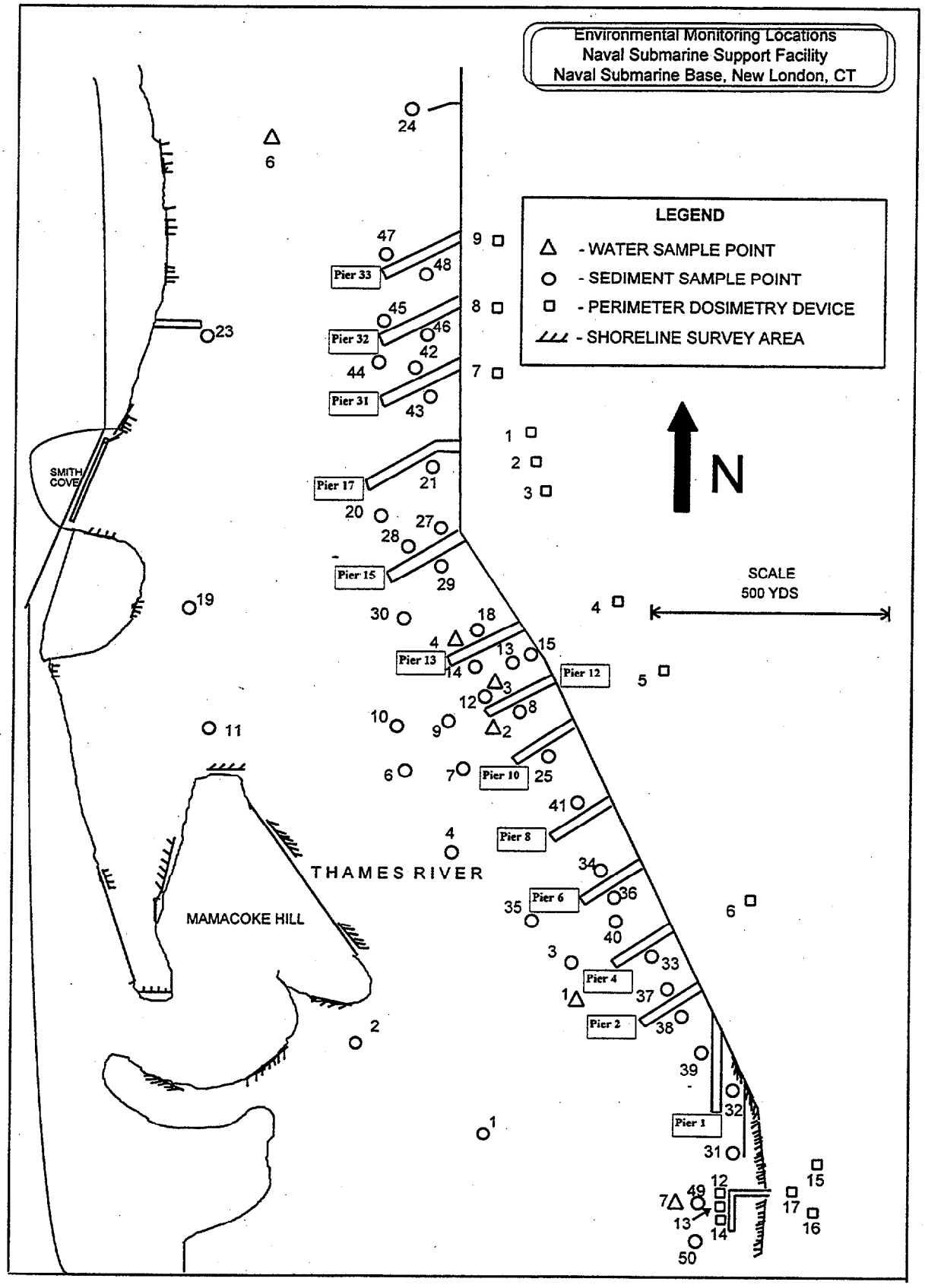

Environmental Monitoring Locations
Naval Submarine Support Facility
Naval Submarine Base, New London, CT
LEGEND
- WATER SAMPLE POINT
- SEDIMENT SAMPLE POINT
- PERIMETER DOSIMETRY DEVICE
- SHORELINE SURVEY AREA
N
SCALE
500 YDS
SMITH COVE
MAMACOKE HILL
THAMES RIVER
Pier 33
Pier 32
Pier 31
Pier 17
Pier 15
Pier 13
Pier 12
Pier 10
Pier 8
Pier 6
Pier 4
Pier 2
Pier 1

Table 6-2
Gamma Radioactivity Concentration in River Sediment Samples
Naval Submarine Base New London
1979 - 1993

		Number of Samples with Specific Cobalt-60 Activity					Gross Gamma >0.1 MeV		Specific Cobalt-60 (a)	
Year	Qtr	<MDA (b)	>MDA to 0.3 pCi/g	0.3 to 3 pCi/g	3 to 30 pCi/g	>30 pCi/g	Average pCi/g	High / Low pCi/g	(c) Average pCi/g	High/Low pCi/g
1993	4	42	0	0	0	0	1.0	1.4 - 0.9	<0.12	<0.17 - <0.06
	3	41	1	0	0	0	1.0	1.3 - 0.8	<0.12	0.20 - <0.05
	2	40	2	0	0	0	1.1	1.5 - 0.8	<0.13	<0.22 - 0.06
	1	42	0	0	0	0	1.1	1.3 - 0.9	<0.13	<0.24 - <0.06
1992	4	41	1	0	0	0	1.0	1.6 - 0.8	<0.12	<0.18 - 0.06
	3	39	3	0	0	0	1.0	1.4 - 0.8	<0.13	<0.21 - <0.06
	2	41	1	0	0	0	1.0	1.2 - 0.8	<0.14	<0.20 - <0.05
	1	41	1	0	0	0	1.1	1.5 - 0.7	<0.13	<0.25 - <0.06
1991	4	41	1	0	0	0	1.0	1.3 - 0.8	<0.13	<0.27 - <0.07
	3	43	2	0	0	0	1.0	1.3 - 0.8	<0.13	<0.23 - <0.04
	2	41	1	0	0	0	0.9	1.3 - 0.8	<0.12	<0.20 - <0.04
	1	40	2	0	0	0	1.0	1.5 - 0.8	<0.12	<0.23 - <0.05
1990	4	42	0	0	0	0	1.0	1.6 - 0.7	<0.13	<0.22 - <0.07
	3	41	0	1	0	0	1.0	1.5 - 0.8	<0.14	0.32 - <0.08
	2	42	0	0	0	0	1.0	1.3 - 0.7	<0.13	<0.20 - <0.07
	1	45	0	0	0	0	1.0	1.3 - 0.8	<0.10	<0.16 - <0.04
1989	4	44	1	0	0	0	1.0	1.4 - 0.7	<0.10	<0.17 - <0.04
	3	44	1	0	0	0	1.0	1.5 - 0.9	<0.12	<0.18 - <0.05
	2	44	1	0	0	0	1.0	1.3 - 0.8	<0.11	<0.18 - <0.07
	1	42	3	0	0	0	1.0	1.5 - 0.8	<0.11	0.19 - <0.05
1988	4	45	0	0	0	0	1.0	1.9 - 0.7	<0.10	<0.16 - <0.05
	3	44	1	0	0	0	1.0	1.4 - 0.8	<0.11	<0.17 - <0.04
	2	41	4	0	0	0	1.1	2.2 - 0.8	<0.11	<0.18 - <0.04
	1	43	2	0	0	0	1.0	1.5 - 0.7	<0.11	<0.20 - <0.05
1987	4	43	2	0	0	0	1.0	1.5 - 0.7	<0.10	<0.19 - <0.04
	3	45	0	0	0	0	1.0	1.5 - 0.8	<0.11	<0.16 - <0.05
	2	42	3	0	0	0	1.0	1.4 - 0.8	<0.10	<0.16 - <0.04
	1	44	1	0	0	0	1.2	2.1 - 0.6	<0.20	<0.24 - <0.03
1986	4	43	2	0	0	0	1.0	1.3 - 0.7	<0.20	0.24 - <0.04
	3	45	0	0	0	0	1.0	1.3 - 0.7	<0.20	<0.25 - <0.05
	2	42	3	0	0	0	0.9	1.4 - 0.7	<0.10	<0.16 - <0.06
	1	40	5	0	0	0	0.8	1.2 - 0.7	<0.20	<0.17 - <0.06
1985	4	45	0	0	0	0	1.3	1.9 - 0.9	<0.20	<0.19 - <0.03
	3	45	0	0	0	0	1.1	1.4 - 0.8	<0.20	<0.20 - <0.04
	2	43	1	1	0	0	1.0	1.4 - 0.7	<0.20	0.30 - <0.05
	1	43	0	0	0	0	1.1	1.6 - 0.9	<0.20	<0.20 - <0.05
1984	4	43	0	0	0	0	1.0	1.5 - 0.8	<0.20	<0.22 - <0.04
	3	40	3	0	0	0	1.0	1.4 - 0.9	<0.20	0.23 - <0.06
	2	41	2	0	0	0	1.0	1.3 - 0.9	<0.20	<0.28 - <0.05
	1	43	1	0	0	0	1.0	2.5 - 0.8	<0.20	<0.39 - <0.07

Table 6-2 (continued)
Gamma Radioactivity Concentration in River Sediment Samples
Naval Submarine Base New London
1979 - 1993

		Number of Samples with Specific Cobalt-60 Activity					Gross Gamma >0.1 MeV		Specific Cobalt-60 (a)	
Year	Qtr	<MDA (b)	>MDA to 0.3 pCi/g	0.3 to 3 pCi/g	3 to 30 pCi/g	>30 pCi/g	Average pCi/g	High / Low pCi/g	(c) Average pCi/g	High/Low pCi/g
1983	4	43	0	0	0	0	1.0	1.7 - 0.9	<0.20	<0.23 - <0.06
	3	43	0	0	0	0	1.1	1.7 - 0.9	<0.20	<0.21 - <0.08
	2	41	1	1	0	0	1.0	1.6 - 0.8	<0.20	.34 - <0.04
	1	43	0	0	0	0	1.0	1.8 - 0.7	<0.20	<0.19 - <0.07
1982	4	43	0	0	0	0	1.0	1.4 - 0.7	<0.20	<0.20 - <0.04
	3	43	0	0	0	0	1.1	1.3 - 0.8	<0.20	<0.25 - <0.06
	2	39	2	0	0	0	1.1	2.0 - 0.9	<0.20	0.28 - <0.04
	1	41	0	0	0	0	1.1	1.5 - 0.9	<0.20	<0.20 - <0.06
1981	4	38	2	1	0	0	1.2	2.5 - 0.8	<0.20	<0.23 - <0.05
	3	41	0	0	0	0	1.2	1.6 - 0.8	<0.20	<0.26 - <0.02
	2	40	1	0	0	0	1.1	1.6 - 0.6	<0.20	0.21 - <0.07
	1	39	1	1	0	0	1.1	1.8 - 0.9	<0.20	0.32 - <0.05
1980	4	38	2	1	0	0	1.1	2.0 - 0.8	<0.20	0.63 - <0.06
	3	37	3	1 -	0	0	1.2	1.8 - 0.9	<0.20	0.42 - <0.07
	2	38	2	1	0	0	1.1	1.8 - 0.8	<0.20	0.65 - <0.05
	1	37	4	0	0	0	1.1	1.4 - 0.8	<0.20	0.29 - <0.07
1979	4	39	2	0	0	0	1.2	1.8 - 0.9	<0.20	<0.31 - <0.05
	3	39	4	2	0	0	1.2	1.6 - 0.9	<0.20	0.42 - <0.08
	2	38	5	2	0	0	1.2	1.6 - 1.0	<0.20	0.40 - <0.11
	1	38	7	0	0	0	1.1	1.8 - 0.9	<0.20	<0.32 - 0.02

Note : (a) Values preceded by a < symbol are the Minimum Detectable Activity (MDA) for that particular analysis; the sample analysis result was less than MDA. Sample analysis results which range between the high and low values and are greater than MDA are indicated in the left columns.

(b) MDA = Minimum Detectable Activity. MDA varies from sample to sample and location to location due to statistical fluctuations. MDA for this analysis has, in general, ranged from approximately 0.10 to 0.15 pCi/g from the mid 1980's through the present and from 0.1 to 0.2 pCi/g for earlier analyses.

(c) Starting the 2nd quarter 1987, the average specific cobalt-60 concentration listed was the average value taken from the calculated concentrations (or MDA's, if no activity was present) from the sample set. Prior to this date, a more conservative value was used for the average specific cobalt-60 concentration.

A portion of the first quarter sediment samples are re-analyzed by the DOE laboratory. For this analysis, a higher efficiency, larger volume detector and very long counting times are used to provide the capability to detect extremely low concentrations of radionuclides. This analysis achieves a minimum sensitivity on the order of that reported by EPA in Reference 1, where the average background cobalt-60 activity concentration for the Thames River "upriver" sediment is reported as being 0.02 pCi/g and the minimum sensitivity is on the order of 0.01 pCi/g. Results for the re-analyzed Subase sediment samples are presented in Table 6-3 and the 1993 re-analyzed samples are compared in Table 6-4 with the routine analysis results. In each case, the 1993 re-analysis value is lower than the sensitivity of the routine analysis. These records are available for 1978 through the present.

Table 6-3
Sediment Enhanced Monitoring Results
Naval Submarine Base New London
1978 - 1993

Year	Specific Cobalt-60 Activity, pCi/g (a)								
	Location Number								
	1	2	8	11	24	28	31	32	34
1993	0.046	<0.011	0.054	<0.008	0.031	0.048	(b)	(b)	0.054
1992	0.043	<0.011	0.041	<0.009	0.031	0.036	(b)	(b)	0.039
1991	<0.009	<0.008	0.037	0.045	<0.008	0.036	0.039	0.043	0.050
1990	0.050	<0.017	0.052	<0.016	<0.019	<0.021	0.055	0.012	<0.023
1989	<0.045	<0.030	0.051	<0.040	<0.031	<0.040	0.126	<0.041	<0.038
1988	0.090	<0.033	<0.045	<0.032	<0.033	<0.042	<0.040	<0.045	<0.044
1987	<0.034	<0.030	0.071	<0.044	0.023	0.079	0.038	0.045	<0.044
1986	<0.044	<0.036	<0.047	<0.038	<0.041	<0.044	<0.046	<0.050	<0.048
1985	<0.032	<0.032	<0.042	<0.034	<0.042	<0.046	<0.037	<0.035	<0.040
1984	<0.032	0.150	<0.040	<0.033	<0.039	<0.039	0.085	<0.046	<0.037
1983	<0.012	<0.013	0.043	0.026	0.029	0.057	(b)	0.041	0.026
1982	0.092	0.079	0.060	<0.012	<0.010	0.040	(b)	0.064	0.086
1981	0.099	0.046	0.101	<0.018	0.114	0.090	(b)	0.054	0.086
1980	0.071	0.230	0.095	0.031	0.072	0.120	(b)	0.084	0.074
1979	0.075	0.056	0.132	0.063	0.235	0.114	(b)	0.132	0.086

Notes to Table 6-3

Locations are identified on Figure 6.1.
(a) The "<" indicates the minimum detectable activity for this analysis.
(b) Not sampled.

Additional Data, pCi/g
1979: No. 33, 0.090
1978: No. 35, 0.138; No. 41, 0.609

Table 6-4
Comparative Analysis
1993 Enhanced vs. Routine Sediment Analysis

1993 Data	Specific Cobalt-60 Activity, pCi/g (a)						
	Location Number						
	1	2	8	11	24	28	34
Routine	<0.170	<0.090	<0.150	<0.126	<0.132	<0.129	<0.138
Enhanced	0.046	<0.011	0.054	<0.008	0.031	0.048	0.054

Notes to Table 6-4
(a) The "<" indicates the minimum detectable activity for this analysis.

In 1966 the U.S. Public Health Service (PHS) conducted a radiological survey of the Thames River and its environs in the vicinity of all NNPP sites. This survey was repeated in 1972 and in 1989 by EPA. The results of these surveys were published in References 17, 18, and 1, respectively, in 1966, 1973, and 1991.

The 1966 PHS survey concluded that "The cobalt-60 probably constitutes no direct hazard to the general population based on the following:

"a. The activity is found only in the sediments.

"b. Samples of local, bottom-feeding marine species contained no detectable cobalt-60.

"c. The river water is polluted and shellfishing is prohibited.

"d. The river has no apparent use apart from boating and ship traffic.

"e. The contaminated portion of the river bottom has no outlet to populated areas except Long Island Sound in which dispersion and dilution of the activity would take place."

The 1972 EPA survey concluded:

"Comparison with a similar survey conducted in 1966 show(s) that cobalt-60 activity levels in sediment have decreased by an average factor of 33 due to a reduction in the amount of radioactivity discharged, radioactive decay and natural sedimentation. Analysis of samples indicative of direct pathways for human exposure lead to the conclusion that no significant radiation exposure to the public has resulted from nuclear ship operations in this area. It is concluded that the environmental surveillance routinely conducted by the Navy should be adequate to assure protection of the public from the routine nuclear ship operations.

"No evidence was found of cobalt-60 activity in areas where it was absent in the 1966 survey.

"The results of this survey indicate that nuclear powered vessel operations have not resulted in activity levels which could contribute a significant radiation exposure to the public.

"This conclusion is based on the fact that:

"a. activity is located principally in harbor sediment and not in fish or lobster,

"b. levels of radioactivity are quite low compared to the Atomic Energy Commission standards.

"c. there is no commercial fishing in the harbor, and

"d. no activity other than natural radioactivity was found in the harbor and drinking water.

"The continuation of current waste discharge practices and the Navy routine monitoring program should be sufficient to assure continued absence of significant public exposure for routine nuclear ship operations."

Reference 18 compares the 1966 data and 1972 data in Table 2. The average decrease in cobalt-60 activity concentration in the six Subase vicinity sediment locations common to the 1966 and 1972 surveys is a factor of 13. If radioactive decay were the only removal mechanism, a factor of 2.2 reduction would have been expected.

Reference 18 explains the reasons for this observed decrease in concentration (over what would be expected on the basis of radioactive decay alone) by stating, "This reduction is due largely to the effects of reducing the quantity of radioactivity discharged to the harbor, the effects of natural sedimentation in the estuary and loss by radioactive decay. Measurements made using the underwater gamma probe substantiated this reduction in activity based on the spectra obtained on the two surveys. Natural sedimentation could cause a reduction in cobalt-60 concentrations by diluting contaminated sediment with uncontaminated sediment and by covering the contaminated sediment."

The 1989 EPA survey concluded:

"1. Trace quantities of Co-60 remain in the sediment at all locations investigated; however, the concentrations have significantly decreased since the earlier two surveys and represent no radiological impact to the environment or individuals living or working in the area.

"2. Sediment samples that duplicated samples obtained in 1972 contained 8-30 times less Co-60 than the earlier samples, indicating that radioactive decay and sedimentation is naturally reducing the Co-60 levels in surface sediments and that no significant releases of Co-60 have occurred in recent years.

"3. No Co-60 was detected in any edible aquatic species.

"4. All seven sediment core samples contained low levels of Co-60. The maximum concentration observed was 0.37 pCi/g at a depth of about 18 cm, but this cannot be related to any particular occurrence and indicates the Co-60 is not the result of current operations.

"5. Water samples contained no detectable levels of radioactivity other than those occurring naturally.

"6. Gamma-ray measurements did not detect any increased radiation exposure to the public above natural background levels.

"7. Based on these surveys, current practices regarding nuclear-powered warship operations have resulted in no increase in radioactivity that would result in significant population exposure or contamination of the environment."

Reference 1 compares 1972 data with 1989 data in Table 3. Reference 1 states the following regarding the observed decrease in cobalt-60 activity concentration in sediment: "Cobalt-60 was observed in sediment samples collected during previous surveys of these facilities in 1966 and 1972. An attempt was made during this recent survey to collect some sediment samples from the same sites used in 1972. Although changes in piers and docks since the last survey, as well as conditions that existed during this survey, made this task difficult, twelve sampling sites were duplicated. The results obtained in 1989 are compared in Table 3 with measurements made in 1972. Significant decreases in the Co-60 concentration have occurred at all sites. A seven to eight fold decrease in the Co-60 concentration has occurred in sediments at the Subase, which is about the decrease that would result from radioactive decay in the 17-year period since the last survey with no subsequent Co-60 added. A greater decrease is observed to have occurred in sediments at the Electric Boat area and the State Pier (25 to 30 fold), which may be the result of sedimentation in addition to radioactive decay."

EPA concluded in Reference 1 that "Although Co-60 was observed in sediment at the Navy facilities, the concentrations present are very small, and have continued to decrease with time at a rate equal to or greater than the decay rate of Co-60. The small and decreasing quantities of Co-60 in the harbor sediments pose no radiological impact to the area."

The Navy notes that dredging could also have played a role in the observed decrease of cobalt-60 activity in the Thames River, in addition to the reasons as stated in the EPA conclusions above. Dredging is discussed in Section 6.2.

Connecticut has performed independent radiological monitoring of river water and bottom sediment since the beginning of NNPP activities along the Thames River. All state data of which the Navy is aware are consistent with Subase and EPA results for those areas where the surveys overlap.

The data collected by Subase, the Public Health Service, and the Environmental Protection Agency over the period 1954 through 1993 clearly support the conclusion that the levels of cobalt-60 detected in harbor sediment: a) contribute a negligible increase to background radioactivity levels; and b) pose no hazard to the public, either directly or via the food chain, and pose no hazard to the ecological systems of the region.

6.1.2 River Water Sampling

Beginning with the baseline data obtained in 1954, and continuing through the present, samples of water from the Thames River have been collected and analyzed. Weekly sampling was required in 1964. Quarterly sampling began in 1966. Current sampling locations are shown on Figure 6.1.

Sample locations are selected based on areas where radioactive liquids could have been discharged and at upstream and downstream locations.

From 1964 through 1965, samples were evaporated and counted for gross beta activity. Beginning in 1966, a sodium iodide scintillation detector was used to count one-liter samples in polyethylene bottles. A state-of-the-art multichannel analyzer has always been used for this

analysis. The sodium iodide detector was used to measure gross gamma activity in terms of cobalt-60 equivalent, and cobalt-60 energy range activity. Since 1979, a multichannel analyzer and germanium high resolution spectroscopy system has been used, and actual cobalt-60 activities have been measured by the DOE laboratory since then, in addition to gross gamma. Like sediment samples, a Marinelli container is used for water sample analysis.

Water samples were taken of Subase vicinity river water and of area drinking water supplies by the Public Health Service in 1966 and by the Environmental Protection Agency in 1972 and 1989. References 17, 18, and 1 report that no cobalt-60 was detected in any water sample taken during these surveys. In their 1989 survey, EPA additionally analyzed all water samples for tritium. No detectable tritium was observed in these water samples. No cobalt-60 has been detected in any water sample taken by Subase since the inception of the monitoring program. A review of both Subase gamma counting results and the series of environmental monitoring reports published annually by the Naval Nuclear Propulsion Program reveals that no cobalt-60 has ever been detected in river water samples. Quarterly data for each year is reported annually by Subase. The water sample data are not tabulated in this report since they reflect 40 years of less than minimum detectable activity concentration values.

The conclusions reached by the Navy in its annual reports are confirmed by References 17, 18, and 1. The Reference 17, 18, and 1 conclusions are quoted in Section 6.1.1.

6.1.3 Marine Life Sampling

Beginning in 1978, Program Intermediate Maintenance Activities (including Subase) conducting environmental monitoring were required to obtain marine life samples during July of each year. Samples are collected from locations in the vicinity of Subase piers where nuclear-powered ships berth. The rationale for marine life sampling is based on the local marine food chain. Local species of three broad families are collected (if available) to determine whether any bioaccumulation is occurring. The typical species collected at Subase are lobster (crustaceans), mussels (mollusks), and sea lettuce (marine plants). The collected samples are sealed in plastic containers with formaldehyde preservative. The samples are shipped to a DOE laboratory for high resolution radionuclide analysis by gamma spectroscopy. Analysis data of marine life samples taken since 1978 are shown in Table 6-5.

Table 6-5
Marine Life Monitoring Results
Naval Submarine Base New London
1978-1993

Year	Specific Cobalt-60 Activity, pCi/g (a)		
	Mollusks	Crustaceans	Marine Plants
1993	<0.008	<0.007	<0.008
1992	<0.007	<0.009	<0.008
1991	<0.008	<0.008	<0.007
1990	<0.022	<0.011	<0.013
1989	<0.025	<0.028	<0.026
1988	<0.042	<0.048	<0.030
1987	<0.051	<0.024	<0.021
1986	<0.023	<0.025	<0.023
1985	<0.024	<0.037	<0.032
1984	<0.025	<0.030	<0.024
1983	<0.014	0.115(b)	<0.011
1982	0.023(c)	<0.007	0.013(c)
1981	<0.013	<0.009	0.021(d)
1980	<0.011	<0.011	<0.009
1979	<0.009	(e)	(e)
1978	<0.011	<0.013	<0.013

Notes:
(a) Values preceded by "<" are the minimum detectable activity at the 90 percent confidence level, under the conditions of the analysis.
(b) The sample contained a relatively large amount of sediment in addition to the crustacean fragments. Since cobalt-60 is present in sediment from the area and, due to its refractory nature, is not assimilated by marine life, it was concluded that the cobalt-60 in the sample was due to its presence in the sediment portion of the sample.
(c) Although the 1982 laboratory report does not address these results, subsequent DOE laboratory reports all indicate that no NNPP radioactivity has been assimilated by marine life in the vicinity of Subase. In an interview for this HRA, a long-term DOE laboratory chemist stated that any cobalt-60 detected in Subase marine life samples has most often proven to be contained in sediment adhering to the sample and has never proven to be assimilated in the sample; in this case, the numerical values reported by the laboratory may be missing a "<" symbol.
(d) This seaweed sample was washed and recounted. A significant amount of debris, which appeared to be sediment, was removed in the washing. The results of the recount showed no detectable cobalt-60 in the washed sample, indicating that the cobalt-60 in the sample was due to sediment deposited on the surface and not from uptake by the seaweed.
(e) Sample not obtained.

During the 1989 EPA survey, samples of flounder, lobster, mussels, kelp, sea lettuce, starfish, conch, and sea cucumber were collected at various locations in the vicinity of Piers 12, 13, 31, 32, and 33. Reference 1 reports that cobalt-60 was not detected in any edible seafoods, and that the small concentrations of cobalt-60 (less than 0.1 pCi/g dry weight) measured in samples of kelp, sea lettuce, and sea cucumber taken from the vicinity of Subase may be due to sediment adhering to the surface of these biota samples.

On the basis of the data shown in Table 6-5, and the findings of the EPA survey reported in Reference 1, there has been no accumulation of cobalt-60 in edible aquatic life as a result of operation of nuclear-powered ships or work on those ships by Subase.

6.1.4 Core Sampling

Core samples of river bottom sediment in the vicinity of Subase are taken during the third calendar quarter of each year. Core sampling began in 1970 and has always been accomplished by following a detailed, Navy-approved procedure. A 3 inch diameter tube is currently used to collect core samples. Samples up to 24 inches long are obtained; at least 12 inch long samples are obtained, if practicable.

Core samples are taken to determine whether radioactivity may have accumulated below the top layer of sediment which is sampled on a routine basis. Initially, six core samples were collected annually from those locations showing the greatest cobalt-60 concentration in sediment during the previous four quarters of sediment sampling. The results of four years of monitoring showed that the distribution of cobalt-60 in the core samples varied widely and in 1973 four locations, near where nuclear-powered ships are berthed, were selected for annual core sampling in the vicinity of Subase. Core sample locations correspond to sediment sample locations shown on Figure 6.1.

The core samples are analyzed by a DOE laboratory using a high resolution gamma spectroscopy system. Since 1980, two inch long segments of each core sample have been individually analyzed for radioactivity.

Data are available for the selected locations from 1979 through the present, as shown in Tables 6-6 through 6-10. Subase core sediment data are consistent with the core sediment data reported by PHS and EPA in References 17, 18, and 1. Cobalt-60 is detectable in some Subase core sediment samples. Cobalt-60 is the only gamma-emitting radionuclide attributable to NNPP operations that is detectable in these samples.

EPA reported in Reference 1 that the 1989 survey core sample data "indicates the Co-60 is not the result of current operations" and that "Much of the cobalt-60 remaining was found at a depth of 15 cm to 20 cm in the sediment, indicating that it did not result from operations of the early 1970's." The maximum cobalt-60 activity concentration reported by EPA for 1989 Subase core sediment was 0.37 pCi/g at a depth of about 18 cm (7 inches) in the core, between Piers 13 and 15. By comparison, the maximum cobalt-60 activity concentration in 1993 Subase core sediment samples was 0.22 pCi/g at a depth of 20 inches in the core taken between Piers 13 and 12.

Subase, PHS, and EPA data verify that the cobalt-60 activity concentrations in Subase core sediment samples are very small and are decreasing at a rate equal to or greater than what would be expected by radioactive decay alone.

Notes common to Tables 6-6 through 6-10:

Core sample location numbers correspond to sediment sample location numbers shown on Figure 6.1.

Values preceded by "<" are the minimum detectable activity at the 90% confidence level, under the conditions of the analysis .

(a) 1979 segments were 4 inches long; 1980 to present were 2 inches long.

Table 6-6
Core Sample 12

	Specific Cobalt-60 Activity (pCi/g) at specified range of depth (inches)									
Year	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20
1993	<0.040	0.075	<0.037	<0.032	<0.034	<0.031	<0.029	<0.030	0.094	0.221
1992	<0.046	<0.035	<0.041	<0.031	<0.036	<0.015	<0.030	<0.048	<0.030	<0.026
1991	<0.041	<0.040	<0.035	<0.028	<0.018	<0.021	<0.023	<0.019	-	-
1990	<0.064	<0.076	<0.057	<0.051	<0.053	<0.051	<0.050	<0.050	-	-
1989	<0.259	0.933	<0.091	<0.089	<0.085	<0.093	-	-	-	-
1988	<0.073	<0.124	0.463	≤0.121	<0.088	<0.095	<0.125	-	-	-
1987	<0.113	<0.102	0.251	0.594	0.796	<0.124	<0.066	<0.060	<0.089	-
1986	<0.200	<0.154	<0.123	<0.126	<0.093	<0.170	0.605	1.24	<0.152	<0.164
1985	<0.180	<0.127	<0.116	<0.170	<0.160	<0.103	-	-	-	-
1984	<0.113	<0.157	<0.118	<0.102	<0.139	<0.124	<0.159	-	-	-
1983	<0.031	<0.039	<0.034	<0.027	<0.021	<0.033	<0.033	<0.058	<0.027	-
1982	<0.029	<0.030	0.088	0.088	0.164	0.101	0.141	0.133	-	-
1981	0.113	<0.031	<0.030	0.071	<0.029	<0.028	0.103	0.173	0.226	0.270
1980	0.080	0.066	0.101	0.223	0.208	0.139	0.085	0.191	0.128	-
1979	(a)	<0.064	-	0.404	-	0.182	-	<0.063	-	0.265

Actual final segment length
1988: 12-13 in.
1983: 16-17.5 in.
1981: 18-19 in.
1980: 16-19 in.
1979: 16-19 in.

Table 6-7
Core Sample 33

	Specific Cobalt-60 Activity (pCi/g) at specified range of depth (inches)									
Year	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20
1993	<0.033	<0.037	<0.034	<0.033	<0.031	<0.034	<0.039	<0.035	<0.031	0.022
1992	<0.056	<0.042	<0.038	<0.015	<0.030	-	-	-	-	-
1991	0.102	<0.033	<0.020	<0.021	<0.022	<0.018	<0.028	-	-	-
1990	<0.086	<0.054	0.125	<0.057	<0.053	<0.045	<0.047	<0.071	-	-
1989	<0.093	<0.116	<0.104	<0.082	<0.096	<0.067	-	-	-	-
1988	<0.071	<0.076	<0.080	<0.098	0.239	0.378	-	-	-	-
1987	<0.070	<0.092	<0.085	<0.086	<0.080	<0.099	<0.120	<0.120	-	-
1986	<0.154	<0.163	<0.139	<0.194	<0.177	<0.130	<0.134	<0.121	<0.159	<0.127
1985	<0.139	<0.165	<0.155	<0.137	<0.187	<0.162	<0.159	<0.152	<0.150	-
1984	<0.130	<0.133	<0.127	<0.131	-	-	-	-	-	-
1983	<0.030	0.092	<0.027	<0.022	<0.044	<0.030	<0.073	-	-	-
1982	<0.032	<0.041	0.083	<0.029	0.120	<0.038	0.148	-	-	-
1981	0.039	<0.022	0.084	0.130	<0.030	0.106	0.096	0.178	-	-
1980	0.138	0.061	0.121	0.102	0.110	<0.018	<0.024	-	-	-
1979	(a)	<0.046	-	<0.037	-	0.302	-	0.318	-	0.372

Additional data, pCi/g
1993: 20-22 in., <0.031; 22-24 in., <0.025; 24-25 in., <0.030
1986: 20-22 in., <0.115; 22-24 in., <0.130; 24-25 in., <0.166

Actual final segment length
1991: 12-13 in.
1990: 14-15 in.
1984: 6-8.5 in.
1983: 12-13.5 in.

Table 6-8
Core Sample 38

	Specific Cobalt-60 Activity (pCi/g) at specified range of depth (inches)									
Year	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20
1993	<0.028	<0.037	<0.026	<0.025	<0.025	<0.028	<0.036	-	-	-
1992	<0.047	<0.033	0.074	0.125	<0.015	0.057	<0.027	-	-	-
1991	<0.030	<0.032	<0.030	<0.033	<0.021	<0.022	<0.031	<0.034	-	-
1990	<0.054	<0.049	<0.043	<0.040	<0.046	<0.050	<0.054	<0.036	<0.029	-
1989	<0.103	<0.063	<0.065	<0.078	<0.096	<0.099	-	-	-	-
1988	<0.076	<0.064	<0.093	<0.067	<0.086	<0.076	-	-	-	-
1987	<0.086	<0.073	<0.067	<0.083	<0.082	<0.084	<0.082	<0.054	<0.050	-
1986	<0.142	<0.138	<0.134	<0.113	<0.094	<0.111	<0.129	<0.090	<0.121	<0.080
1985	<0.112	<0.130	<0.120	<0.121	<0.108	<0.110	0.105	<0.164	<0.129	-
1984	<0.151	<0.112	<0.138	<0.127	<0.124	-	-	-	-	-
1983	0.150	0.096	<0.030	0.131	<0.027	<0.018	<0.044	-	-	-
1982	0.094	0.070	<0.039	0.083	0.039	0.142	0.096	0.241	-	-
1981	0.057	<0.025	<0.023	<0.025	<0.025	0.114	0.074	0.145	0.155	-
1980	<0.020	0.091	<0.016	<0.022	<0.023	<0.022	0.062	0.083	-	-
1979	(a)	0.114	-	<0.041	-	0.171	-	0.144	-	-

Actual final segment length
1993: 12-13 in.
1984: 8-9.5 in.
1983: 12-13.5 in.
1982: 14-15 in.
1981: 16-17 in.

Table 6-9
Core Sample 39

	Specific Cobalt-60 Activity (pCi/g) at specified range of depth (inches)									
Year	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20
1991	<0.018	0.141	<0.036	0.043	<0.030	<0.038	<0.031	<0.027	-	-
1990	<0.075	<0.053	<0.055	<0.038	<0.046	<0.046	<0.048	<0.070	-	-
1989	<0.072	<0.072	<0.080	<0.088	<0.072	<0.100	-	-	-	-
1988	<0.090	<0.080	<0.085	<0.063	<0.071	<0.063	-	-	-	-
1987	<0.132	<0.114	<0.112	<0.113	<0.090	<0.087	-	-	-	-
1986	<0.162	<0.129	<0.124	<0.115	<0.109	<0.121	<0.104	<0.117	<0.133	0.315
1985	<0.117	<0.139	<0.133	<0.121	<0.164	<0.162	<0.167	<0.155	<0.130	-
1984	<0.168	<0.128	<0.195	<0.171	<0.190	<0.149	<0.153	<0.123	-	-
1983	<0.034	<0.026	<0.025	<0.028	<0.041	<0.029	<0.042	<0.042	0.140	-
1982	<0.028	0.136	<0.030	<0.026	<0.024	0.122	-	-	-	-
1981	<0.035	0.144	0.226	0.154	0.197	0.137	0.210	-	-	-
1980	0.188	0.134	0.273	0.200	0.151	0.182	-	-	-	-
1979	(a)	0.246	-	0.250	-	0.148	-	0.082	-	-

Actual final segment length
1990: 14-15 in.
1983: 16-17 in.
1982: 10-12.5 in.

Table 6-10
Core Sample 48

	Specific Cobalt-60 Activity (pCi/g) at specified range of depth (inches)									
Year	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20
1993	<0.032	<0.037	<0.033	<0.034	<0.045	<0.030	<0.031	<0.028	<0.033	-
1992	<0.019	<0.038	<0.036	<0.033	<0.033	<0.026	<0.029	-	-	-

6.2 Dredging Records

The history of dredging in the Thames River is extensively described in Reference 19, the 1991 Draft Environmental Impact Statement (DEIS) for Thames River Dredging at Naval Submarine Base New London, Groton CT. The following is taken essentially verbatim from Reference 19.

The history of dredging in the Thames River goes back to colonial times. Available records only trace back to 1954 in some detail, though the accuracy of some may be questionable. Most records are in the form of permits issued by the Army Corps of Engineers which list the project location, anticipated dredge quantity, and disposal area. Table 6-11 summarizes significant past dredging events in the Thames. Where available, actual scow records and dredge volumes were used; this is prevalent in data from 1977 to the present. Previous to this period, data is primarily available only from permit information.

As indicated in Table 6-11, roughly five million cubic yards of material was dredged from the Thames between 1958 and 1969. Of this total, the U.S. Navy sponsored almost 2.3 million cubic yards of dredging, the vast majority of that being the material deposited at Hempstead Farms on the west bank of the Thames River. In the period between 1970 and 1980, over 7.8 million cubic yards of material was dredged from the Thames River, with over 5.5 million cubic yards being listed as Navy dredging.

A large portion of the Navy dredging was necessary to accommodate SSN 688 Class submarines in 1975/1977, and to accommodate Trident Class submarines in 1980.

The most extensive dredging project ever undertaken in the Thames River involved the removal of approximately 3,671,927 cubic yards of material, the bulk of which (2,172,495 yards) was removed in a continuous operation which ran from July 6, 1977 to June 22, 1978. The remaining yardage, 1,499,432 yards, had been removed in Phase One of the project, between November 19, 1974 and June 30, 1975. The purpose of the dredging was to accommodate SSN 688 Class submarines.

A second project of this magnitude was undertaken in late 1979, to accommodate Trident Class submarines. Completed in two phases, one from December 12, 1979 to June 10, 1980 and the other from October 1, 1980 to January 15, 1981, this project involved the removal of 2,911,658 cubic yards of material in both channel and pier side dredging operations. The material was disposed of at the New London Off-Shore Disposal Site.

The New London Off-Shore Disposal Site has been used extensively for the disposal of dredged materials since 1955. Though records are incomplete, reasonable estimates of sediment deposition quantities can be made from available data. Estimates of annual disposal volumes are presented in Table 6-12. As can be seen in this table, almost 13 million cubic yards of dredge spoils have been deposited here in the last 35 years, for an average of almost 370,000 cubic yards per year. Peak disposal years are those associated with the SSN 688 and Trident dredging projects: 1975, 1977, and 1980.

The New London Off-Shore Disposal Site is a one square nautical mile area located approximately 2.5 miles due south of the mouth of the Thames River. It is composed almost exclusively of material dredged from the Thames River and has been a focus of the Army Corps of Engineers' Disposal Area Monitoring System (DAMOS). Sediments consist primarily of soft cohesive materials, silts, and clays, mixed with fine sands. Under the DAMOS program, the site has been continuously surveyed and monitored since 1977. Materials deposited there tend to be unaffected by ocean dynamics.

Base Command Histories indicate the following regarding Subase-related dredging:

1958 - Completed dredging 2.5 million cubic yards from Thames River channel between the Highway Bridge and Pier 20.

1974 - Thames River dredging (Phase I) to accommodate SSN 688 Class submarines begins.

1977 - Phase II of SSN 688 Class dredging begins.

PHS and EPA reports of environmental monitoring include the following dredging summaries (References 17, 18, and 1):

1965 - From April through June, removed 500,000 cubic yards while dredging the channel to 33 feet from Pier 17 to the Gold Star Memorial Bridge.

1972 - Between 1966 and 1972 surveys, dredging had been performed in an area adjacent to Pier 17 and the marine railway.

1989 - Dredging continued in the Thames during the 1980's, primarily to accommodate the greater draft of Trident Class submarines.

The 1992 Phase I Remedial Investigation (Reference 4) reports the following regarding Thames River dredge spoils pumped to the Area A Landfill (Figure 3.9):

> "The Area A Wetland abuts the north side of the landfill and is approximately 30 acres in size. The minimum wetland sediment thickness is approximately 35 feet, based on boring information. Based on the boring logs, the total volume of dredged material in the wetlands is approximately 1,170,000 cubic yards. Until the late 1950s, this portion of the site was undeveloped, wooded land.
>
> "In the late 1950s, dredge spoils from the Thames River were pumped to this area and contained within an earthen dike that extends from the Area A Landfill to the south side of the Weapons Storage Area. The dredged sediments, in combination with the elevated water table due to the damming of the stream, appear to have created this large wetland."

The 1983 Initial Assessment Study (IAS, Reference 2) reported that this landfill opened sometime before 1957. The 1992 report (Reference 4) investigated that finding and stated the following:

> "According to the IAS report, the landfill opened sometime before 1957; however, a 1957 aerial photograph shows no apparent landfilling, indicating a somewhat later startup date."

The later startup date has been confirmed by review of news accounts and Subase histories in the Submarine Force Library and Museum at the base. Dredging began in June 1958. Dredge spoils were initially deposited at Hempstead Farms on the west bank of the Thames River. The Area A dam was constructed between June and August of 1958 and subsequent dredge spoils were pumped to create the landfill, which was completed by October 1958.

Table 6-11
Past Dredging Activity
Thames River
(Table 4-2 of Reference 19)

Year	Source or Sponsor	Volume (cubic yards)
1932	U.S. Coast Guard Academy	Undetermined
1943	U.S. Coast Guard	406,565
1958	New London Harbor	129,405
	U.S. Navy - Pier 10	30,400
		159,805
1959	New London Harbor	13,570
	Thames River	133,000
	U.S. Navy - Subase	119,000
	U.S. Navy	2,000,000
		2,265,570
1960	New London Harbor	69,435
	State Pier	131,000
	U.S. Navy - Subase	118,884
		319,319
1961	Groton	27,650
	New London Harbor	2,450
	Thames River	9,360
	U.S. Navy - Subase	4,000
	Groton	108,090
		151,550
1962	New London	24,304
	Groton	12,880
	New London Harbor	67,388
		104,572
1963	New London Harbor	87,712
	Montville	2,260
		89,972
1964	Groton	11,020
	Fort Trumbell	37,750
		48,770
1965	Fort Trumbell	18,800
	New London	778,700
	New London Harbor	7,810
	Groton	19,750
		825,060
1966	Thames River	11,833
	DOW Chemical	154,500
	Smith Cove	217,875
	New London	250,500
	Groton	40,800
		675,508
1967	Electric Boat	8,225
	Groton	12,100
		20,325
1968	New London	140,000
	Groton	30,000
		170,000

Table 6-11 (continued)
Past Dredging Activity Thames River
(Table 4-2 of Reference 19)

Year	Source or Sponsor	Volume (cubic yards)
1969	Thames River	55,000
	Groton	3,000
	U.S. Navy - Subase	8,800
	New London	38,000
		104,800
1970	New London	62,400
	Groton	5,000
	Thames River	86,000
		153,400
1971	Thames River	119,325
1972	Groton	2,300
	U.S. Navy - Subase	73,000
		75,300
1975	U.S. Navy	1,508,432
1976	Amerada - Hess	7,400
1977	General Dynamics	244,000
	Amerada - Hess	26,000
	U.S. Coast Guard Academy	23,000
	U.S. Navy	1,271,695
		1,564,695
1978	U.S. Navy	900,800
	Pfizer, Inc.	2,000
	Wronowski	29,050
		931,850
1979	Pfizer	2,500
	Wronowski	9,500
	U.S. Navy - Pier 33	403,145
	General Dynamics	45,500
	Show (sic) Cove	10,800
	DOW Chemical	13,750
	U.S. Navy - Trident	184,855
		670,050
1980	U.S. Navy - Trident	1,791,705
	DOW Chemical	57,235
	U.S. Navy - Trident	905,098
	Amerada - Hess	68,090
		2,822,128
1981	U.S. Navy - Trident	30,000
	General Dynamics	21,550
		51,550
(a)	Federal RR Admin.	5,025
	General Dynamics	1,800
	U.S. Navy - State Pier	150,000
	U.S. Navy - Pier 8	110,000
		266,825
1984	Federal RR Admin.	3,350
	U.S. Navy - Nautilus	31,229
		34,579

Table 6-11 (continued)
Past Dredging Activity Thames River
(Table 4-2 of Reference 19)

Year	Source or Sponsor	Volume (cubic yards)
1985	Thames River	319,800
1986	Thames River U.S. Navy	173,000 11,400 184,000(sic)
1987	AES Thames City of New London	61,600 3,950 65,500(sic)
1988	AES Thames Thames River Shipyard	1,200 70,250 71,450
1989	Thames River Shipyard	16,700
1990	U.S. Navy - Subase Pier 17	19,533
1991- 1992	Dow Chemical	108,985
1993	U.S. Navy - Subase quay wall	2,430
	APPROXIMATE TOTAL 1943-1993	14,085,598

(a) No year(s) entered in Table 4-2 of Reference 19.
1990 - 93 Source: U.S. Army Corps of Engineers

Subase has not sampled dredge spoils or any dredge spoils disposal site for radioactivity. The amount of naturally occurring radioactivity removed from the region in the millions of cubic yards of spoil deposited at the New London Off-Shore Disposal Site, primarily potassium-40 in organic detritus, would far exceed the total upper limit gross gamma radioactivity found in sediment even if all the sediment removed from the Subase since 1958 had been deposited in one location at the New London Off-Shore Disposal Site.

The Area A Landfill has been monitored for radioactivity. During the 1992 Phase I Remedial Investigation (RI), certain groundwater samples were screened for both gross alpha and for gross beta radioactivity concentrations, in accordance with the EPA-approved work plan for Phase I ("Plan of Action," April 1989). Radionuclide-specific analyses were not part of this Phase I screening. Groundwater samples exceeding either the gross alpha applicable, relevant, or appropriate requirement (ARAR) or the gross beta ARAR during Phase I were re-analyzed for gross alpha and gross beta during Round I of Phase II, and were analyzed for radionuclide-specific content as part of Round 2 of the Phase II sampling, in accordance with the EPA-approved work plant for Phase II (both the "Work Plan" of May 1993, and the "Addendum to Work Plan" of October 1993). The only radionuclide identified during the Phase II, Round 2 analyses was naturally-occurring potassium-40. The radionuclide-specific results of the Phase II, Round 2 monitoring will be included in the final Phase II RI report.

Regarding dredge spoils, the draft Environmental Impact Statement (EIS) on SEAWOLF homeporting concluded that the radiological environmental impacts associated with sediment disposal are inconsequential. Both Navy and EPA radiological surveys support this conclusion. The latest EPA survey, documented in an EPA report (Reference 1) dated December 1991, describes the cobalt-60 as being in "trace" amounts and not posing a radiological concern to human health or the environment.

Table 6-12
Disposal Volumes of Dredge Spoils
At New London Off-Shore Disposal Site
(Table 4-3 of Reference 19)

Year	Volume (Cubic Yards)
1955	51,540
1956	14,100
1957	9,000
1958	163,805
1959	165,570
1960	323,298
1961	133,460
1962	88,656
1963	154,370
1964	159,770
1965	1,248,160
1966	734,008
1967	8,625
1968	269,000
1969	104,800
1970	156,400
1971	15,925
1972	103,400
1973	0
1974	14,500
1975	1,500,000
1976	0
1977	1,564,745
1978	931,850
1979	667,800
1980	2,871,508
1981	68,725
1982	1,975
1983	192,153
1984	290,454
1985	367,005
1986	207,900
1987	160,905
1988	110,440
1989	41,900
1990-1993	291,734
TOTAL	13,188,506

1990-1993 Source: U.S. Army Corps of Engineers

6.3 Perimeter Radiation Records

Beginning in 1966, beta-gamma film badges were posted outside of controlled radiation areas to ensure that unmonitored personnel within the Subase and the general public were not exposed to radiation levels above natural background.

In January 1970, the regulations were revised to include a group of film badges close to or at the perimeter of what is now the Controlled Industrial Area (Lower Base). This second group of film badges provided additional data that no member of the general public living or working outside the base exceeded the radiation exposure they would receive due to natural background, even if they lived or worked immediately adjacent to the base perimeter 24 hours per day.

During a trial period in 1979, both film badges and thermoluminescent dosimeters (TLDs) were posted in the same locations. The third quarter of 1979 was the first full quarter of posting TLDs. Since then, TLDs only have been posted at the perimeter of the Lower Base. Originally, six TLDs were posted at the perimeter. Since the fourth quarter of 1981, nine TLDs have been posted at the perimeter. Since the third quarter of 1985, six additional TLDs have been posted around the NAUTILUS complex perimeter at Goss Cove. Figure 6.1 shows the locations of currently posted TLDs.

A cluster of five TLDs is posted at each background location. Three background locations were used from the third quarter of 1979 through the fourth quarter of 1981. Five TLDs have been posted at each of four background locations since the first quarter of 1982. Examples of background locations include: on a wooden building over a grass surface in Norwich, on a tree over a grass and stony area in East Lyme, on a wooden post over dirt in Ledyard, and on a chain link fence over a grass surface at Avery Point. Background locations are shown on Figure 6.2.

Results of perimeter radiation monitoring are reported quarterly to the Naval Nuclear Propulsion Program. Table 6-13 lists the quarterly results of the Subase perimeter monitoring program since the use of TLDs was initiated. The results of the monitoring, as well as summary documentation in Reference 8 and its predecessors, verify that radiation exposure to the general public in occupied areas surrounding the base is indistinguishable from natural background.

Table 6-13 data shows that the actual difference between perimeter and background measurements has remained relatively constant from 1979 to 1993. However, there is an apparent increase of levels over time. This increase is due to changes in the dosimetry system with time; i.e., TLD location changes, and use of calibration standard TLDs with characteristics slightly different from the environmental TLDs (e.g., different production batches, sensitivity, or self-irradiation factor of the TLD). The consistency of increase between perimeter and background results verifies that the increase is not a result of any radiological activity at Subase.

Table A-1 of Reference 20 lists the annual total body dose due to natural sources in the vicinity of Subase as approximately 91 mrem (10.4 μR/hr): 50 mrem is due to terrestrial sources of natural radioactivity and 41 mrem is due to cosmic radiation. Reference 20 is cited extensively by the National Council on Radiation Protection and Measurements (NCRP) in Reference 7 as a continuing source of data for natural background radiation exposure estimates. This referenced estimate for natural background radiation exposure rate in the vicinity of Subase is consistent

with data in Table 6-14, which is a tabulation of values reported in References 1, 20, and 21, along with the 1993 fourth quarter Subase data. (Reference 1 reports the results of the 1989 Environmental Protection Agency survey. Table 6 and Appendix D of Reference 1 report the ranges of gamma-ray exposure rates for various locations on and near Subase. Reference 21 reports the results of the aerial radiological survey of NNPP activities on the Thames River as discussed in Section 6.7).

Figure 6.2

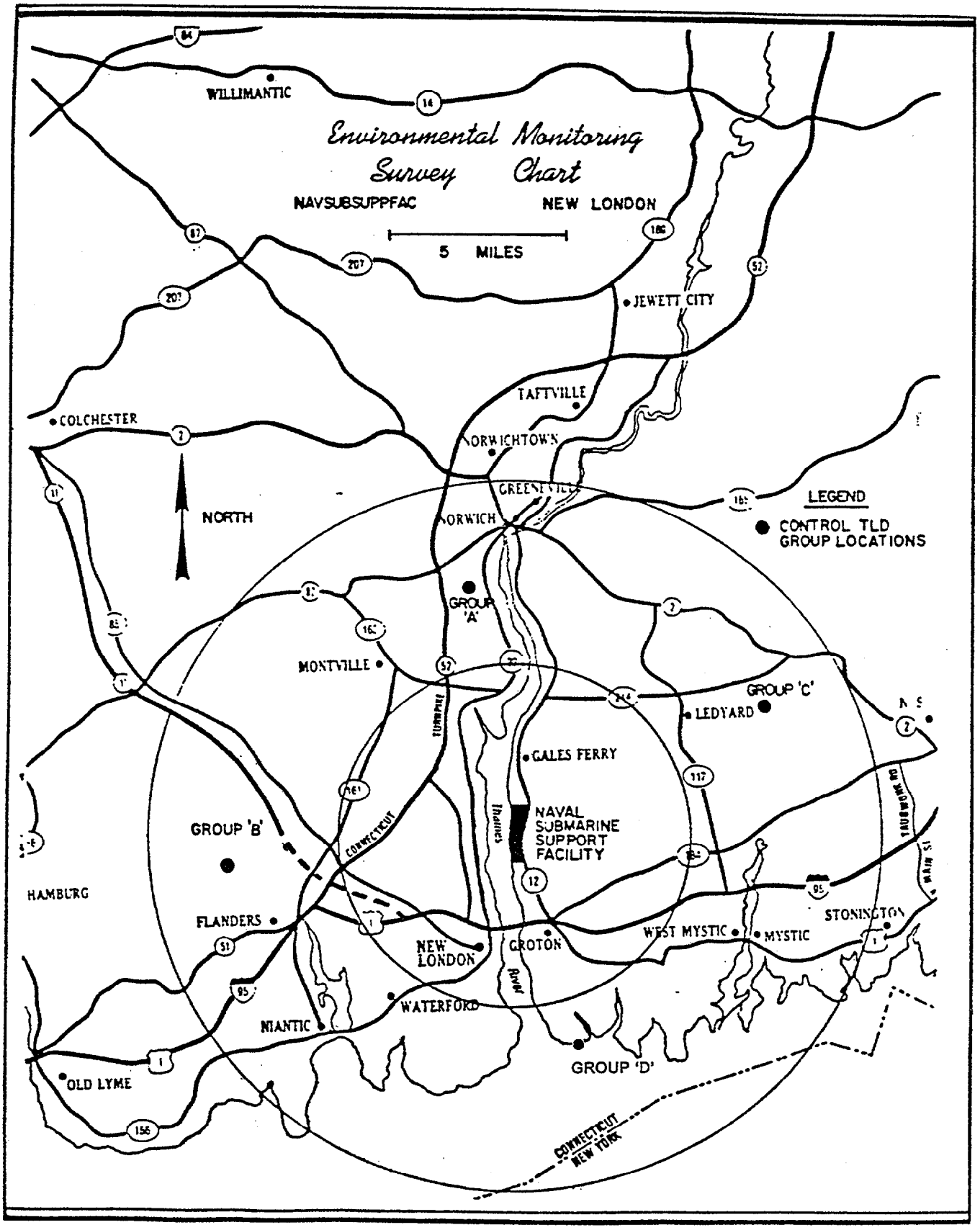

Environmental Monitoring
Survey Chart
NAVSUBSUPPFAC
NEW LONDON
5 MILES
WILLIMANTIC
JEWETT CITY
TAFTVILLE
COLCHESTER
NORWICHTOWN
GREENEVILLE
NORWICH
NORTH
LEGEND
CONTROL TLD
GROUP LOCATIONS
GROUP 'A'
MONTVILLE
GROUP 'C'
LEDYARD
GALES FERRY
NAVAL
SUBMARINE
SUPPORT
FACILITY
GROUP 'B'
HAMBURG
FLANDERS
NEW
LONDON
GROTON
WEST MYSTIC
MYSTIC
STONINGTON
WATERFORD
NIANTIC
GROUP 'D'
OLD LYME
CONNECTICUT
NEW YORK

Table 6-13
Perimeter Radiation Monitoring
Naval Submarine Base New London
1979-1993

Year	Quarter	Posting	Exposure Rate Range mrem/qtr		Average Exposure Rate mrem/qtr	
			Background	Perimeter	Background	Perimeter
1993	4	Base	20 - 40	20 - 41	30.3	31.9
		Nautilus	20 - 40	17 - 23	30.3	20.2
	3	Base	25 - 36	24 - 33	30.9	29.4
		Nautilus	25 - 36	19 - 25	30.9	21.8
	2	Base	28 - 41	27 - 36	34.6	32.6
		Nautilus	28 - 41	21 - 27	34.6	24.2
	1	Base	23 - 33	23 - 30	28.1	26.2
		Nautilus	23 - 33	18 -22	28.1	19.8
1992	4	Base	21 - 37	18 - 29	27.8	24.0
		Nautilus	21 - 37	15 - 22	27.8	18.0
	3	Base	20 - 38	19 - 34	28.7	27.7
		Nautilus	20 - 38	13 - 25	28.7	20.0
	2	Base	25 - 41	21 - 33	32.1	28.7
		Nautilus	25 - 41	17 - 28	32.1	22.2
	1	Base	18 - 35	18 - 30	25.5	24.0
		Nautilus	18 - 35	13 - 25	25.5	19.7
1991	4	Base	22 - 41	20 - 32	30.0	26.6
		Nautilus	22 - 41	15 - 24	30.0	18.2
	3	Base	21 - 41	21 - 34	29.2	27.2
		Nautilus	21 - 41	15 - 27	29.2	21.5
	2	Base	23 - 36	19 - 30	28.2	25.1
		Nautilus	23 - 36	16 - 28	28.2	20.2
	1	Base	23 - 42	23 - 37	31.0	30.0
		Nautilus	23 - 42	10 - 29	31.0	22.5
1990	4	Base	22 - 36	20 - 29	29.1	24.4
		Nautilus	22 - 36	19 - 23	29.1	20.3
	3	Base	24 - 43	22 - 36	31.5	29.4
		Nautilus	24 - 43	19 - 28	31.5	22.7
	2	Base	19 - 34	15 - 26	24.7	21.3
		Nautilus	19 - 34	12 - 16	24.7	13.8
	1	Base	23 - 32	21 - 31	25.7	26.0
		Nautilus	23 - 32	16 - 24	25.7	19.0
1989	4	Base	21 - 38	20 - 33	28.4	26.0
		Nautilus	21 - 38	13 - 20	28.4	16.5
	3	Base	21 - 33	20 - 30	26.8	24.3
		Nautilus	21 - 33	14 - 18	26.8	15.8
	2	Base	20 - 35	21 - 28	25.7	24.3
		Nautilus	20 - 35	17 - 21	25.7	19.7
	1	Base	14 - 29	18 - 25	21.6	20.7
		Nautilus	14 - 29	20 - 44	21.6	30.0

Table 6-13 (continued)
Perimeter Radiation Monitoring
Naval Submarine Base New London
1979-1993

Year	Quarter	Posting	Exposure Rate Range mrem/qtr		Average Exposure Rate mrem/qtr	
			Background	Perimeter	Background	Perimeter
1988	4	Base	19 - 34	18 - 31	25.7	24.3
		Nautilus	19 - 34	12 - 24	25.7	17.2
	3	Base	20 - 35	21 - 32	26.6	25.2
		Nautilus	20 - 35	13 - 22	26.6	17.3
	2	Base	17 - 27	16 - 26	21.8	21.3
		Nautilus	17 - 27	11 - 18	21.8	14.8
	1	Base	23 - 39	19 - 32	30.3	26.4
		Nautilus	23 - 39	16 - 19	30.3	17.8
1987	4	Base	21 - 33	25 - 34	26.7	30.1
		Nautilus	21 - 33	15 - 20	26.7	17.3
	3	Base	19 - 40	20 - 40	27.5	27.2
		Nautilus	19 - 40	12 - 20	27.5	16.8
	2	Base	24 - 43	22 - 30	25.0	25.7
		Nautilus	24 - 43	12 - 18	25.0	15.3
	1	Base	21 - 40	26 - 32	29.4	29.7
		Nautilus	21 - 40	16 - 23	29.4	19.7
1986	4	Base	17 - 31	16 - 29	22.3	22.6
		Nautilus	17 - 31	11 - 17	22.3	13.8
	3	Base	20 -35	22 - 39	27.4	28.0
		Nautilus	20 - 35	16 - 19	27.4	17.7
	2	Base	21 - 33	25 - 34	26.7	30.1
		Nautilus	21 - 33	15 - 20	26.7	17.3
	1	Base	19 - 38	19 - 29	26.3	23.8
		Nautilus	19 - 38	13 - 18	26.3	15.7
1985	4	Base	21 - 35	21 - 32	27.0	25.6
		Nautilus	21 - 35	14 - 41	27.0	23.2
	3	Base	20 - 35	20 - 27	25.6	24.3
		Nautilus(a)	20 - 35	16 - 37	25.6	22.2
	2	Base	19 - 32	19 - 27	25.2	24.2
	1	Base	19 - 33	19 - 27	25.1	23.7
1984	4	Base	20 - 37	19 - 30	25.8	23.9
	3	Base	(b)	(b)	(b)	(b)
	2	Base	19 - 36	19 - 43	26.4	25.4
	1	Base	19 - 32	19 - 27	24.5	22.7

Table 6-13 (continued)
Perimeter Radiation Monitoring
Naval Submarine Base New London
1979-1993

Year	Quarter	Posting	Exposure Rate Range mrem/qtr		Average Exposure Rate mrem/qtr	
			Background	Perimeter	Background	Perimeter
1983	4	Base	20 - 44	20 - 29	27.2	23.9
	3	Base	(b)	(b)	(b)	(b)
	2	Base	22 - 39	21 - 31	28.8	26.0
	1	Base	20 - 39	20 - 27	29.5	23.6
1982	4	Base	14 - 25 (c)	19 - 27	19.7 (c)	22.6
	3	Base	15 - 30	20 - 27	20.2	23.2
	2	Base	14 - 26	19 - 29	19.2	23.9
	1	Base	15 - 32	19 - 25	20.1	22.1
1981	4	Base	14 - 22 (d)	20 - 29	17.4 (d)	24.4
	3	Base	16 - 22	19 - 27 (e)	17.6	23.0 (e)
	2	Base	13 - 42	20 - 26	19.1	22.4
	1	Base	13 - 19	16 - 23	16.3	20.0
1980	4	Base	15 - 45	19 - 24	19.7	22.0
	3	Base	17 - 22	21 - 27	19.9	24.3
	2	Base	11 - 18	14 - 22	14.9	17.3
	1	Base	15 - 22	18 - 25	18.5	21.4
1979	4	Base	19 - 22	20 - 26	20.3	23.9
	3	Base	18 - 23	21 - 28	20.6	24.4

(a) Nautilus arrived at Subase in July 1985 and berthed at Goss Cove in October 1985.
(b) Data not available.
(c) Group B data not available.
(d) Three groups of five background TLDs each at about 7 miles west , 6 miles northeast, and 8 miles northwest of Subase from 3rd qtr 1979 through 4th qtr 1981; four groups of five each, at about 8 miles west, 7 miles north, 8 miles eastnortheast, and 5 miles south from 1st qtr 1982 through the present.
(e) Six perimeter TLDs from 3rd qtr 1979 through 3rd qtr 1981; nine perimeter TLDs around Subase from 4th qtr 1981 through the present.

Table 6-14
Perimeter Radiation Monitoring Comparison
Naval Submarine Base New London

Year	Survey		Ref.	Exposure Rate Range μR/hr	Average Perimeter Exposure Rate μR/hr
1993 4th Quarter	Subase Quarterly Monitoring Data:		N/A		
	Background	Subase		9.2 - 18.3	13.8
		Nautilus		9.2 - 18.3	13.8
	Perimeter	Subase		9.2 - 18.8	14.6
		Nautilus		7.8 - 10.5	9.2
1989	US EPA Radiological Survey		1		
	Background			3 - 12	Not reported
	Perimeter	Subase		3.2 - 19	Not reported
		Nautilus		7 - 11	Not reported
1982	EG&G Aerial Radiological Survey		21	5 - 16	9 - 12
1972	US EPA		20	Not reported	10.4

EPA concluded in Reference 1 (regarding Subase) that "Gamma-ray measurements did not detect any increased radiation exposure to the public above natural background levels." This conclusion is consistent with the Navy findings reported annually for the past 28 years in Reference 16 and successive reports through Reference 10.

6.4 Shoreline Monitoring Records

Subase has conducted gamma radiation surveys of selected shore areas uncovered at low tide since 1966. The purpose of this monitoring is to determine if any radioactivity has washed ashore. These surveys are conducted during the second and fourth quarters of the year. Areas are selected based on the likelihood of suspended radioactivity being deposited by tidal currents upstream and downstream of nuclear ship berthing areas. Two or more background readings are taken at least thirty feet from the high water line at each survey location.

Table 6-15 summarizes the available results of these surveys. A PRM-5N/SPA-3 gamma scintillation survey meter is used. Surveys are taken at waist level and Subase examines any reading that exceeds twice background. These examinations have always concluded that the source of the elevation above background was naturally-occurring radioactivity (e.g., granite outcropppings). This instrument is calibrated to permit distinguishing between natural and non-naturally occurring radioactivity; it is not calibrated for the direct conversion of count rate data to natural background radiation dose rates.

Table 6-15
Shoreline Radiation Monitoring
Naval Submarine Base New London
1983-1993

Year	Average Background Count Rate kcpm	Average Shoreline Count Rate kcpm	Shoreline Count Rate Range kcpm
1993	7.2	6.1	1.0-12
1992	6.5	5.9	2.0-12
1991	6.0	5.7	1.8-13
1990	5.6	5.3	1.8-11
1989	5.3	5.4	1.9-16
1988	5.1	6.1	1.9-15
1987	5.0	6.0	2.0-10
1986	5.0	6.0	3.0-20
1985	(a)	(a)	(a)
1984	(a)	(a)	(a)
1983	7.2	7.3	2.0-14

(a) Data not available.

The selected shorelines for 1993 are shown on Figure 6.1. These areas are readily accessible for monitoring by Subase. The data of Table 6-15 show that there has been no measurable increase in radioactivity along monitored shorelines.

The Environmental Protection Agency conducted surveys in 1989 along shorelines within Subase and along public shorelines. The results are listed in Table 6 of Reference 1. On the basis of this survey, EPA concluded that "The slightly elevated measurements (at some locations, e.g., Subase Golf Course) over those taken along the shoreline are attributed to natural terrestrial radiation or areas where rock high in granite content was used as fill."

6.5 Drydock Sampling Records

6.5.1 Drydock Sampling

The floating drydocks at Subase are surveyed annually due to the potential to release radioactivity into the drainage and pumping systems.

Radiation surveys are performed using a gamma scintillation survey instrument (PRM-5N/SPA-3). The gamma radiation measurements are taken 1/2" from the drydock floor surface at intervals of 20-40 feet. Additional readings are taken on contact with the drydock walls. The results are listed in Table 6-16. The general radiation levels ranged from 0.43 to 6.2 kcpm while levels adjacent to the drydock walls ranged from 0.43 to 7.3 kcpm. In comparison, land perimeter measurements reported in Section 6.4 ranged from 1.0 to 20 kcpm.

The results show that NNPP activities have had no measurable effect on normal background radiation levels.

Table 6-16
General Gamma Radiation Levels
Floating Drydocks
Naval Submarine Base New London
1990-1993

Year	Area	General Areas kcpm	Adjacent to Walls kcpm
1993	ARDM-4		
	Basin	0.60-0.95	0.55-1.1
	Port Wing Wall	na	1.1-1.2
	Stbd Wing Wall	na	1.1-1.2
	ARD-5		
	Basin	0.95-1.0	0.90-1.1
	Port Wing Wall	na	1.0-1.1
	Stbd Wing Wall	na	1.1-1.2
1992	ARDM-4		
	Basin	0.45-1.5	0.45-0.80
	Port Wing Wall	na	0.50-1.5
	Stbd Wing Wall	na	0.80-1.5
	ARD-5		
	Basin	1.5-2.5	0.85-3.0
	Port Wing Wall	na	0.65-1.0
	Stbd Wing Wall	na	0.63-0.88
1991	ARDM-4		
	Basin	0.43-2.4	0.43-2.0
	Port Wing Wall	na	0.80-1.1
	Stbd Wing Wall	na	1.0-1.6
	ARD-5		
	Basin	1.5-3.0	0.70-3.3
	Port Wing Wall	na	0.65-5.8 (a)
	Stbd Wing Wall	na	1.5-7.3 (a)
1990	ARDM-4	(b)	(b)
	ARD-5		
	Basin	1.0-6.2 (c)	0.69-4.4 (c)
	Port Wing Wall	na	(b)
	Stbd Wing Wall	na	(b)

Notes: These are floating drydocks; radiation level readings are typically lower than land-based (such as in Table 6-15) due to greater concentrations of naturally occurring radionuclides in soil and rocks than in the water surrounding the floating drydocks.

na Not applicable; in wing walls, readings adjacent to walls are also general area readings.

(a) A review of available data indicated no known basis for the elevated readings

(b) Data not available.

(c) Elevated readings were due to naturally occurring radioactivity in a large grouping of concrete blocks.

Composite samples of the accumulated sediment from the floating drydock drainage systems are analyzed for gross gamma (0.1 to 2.1 MeV) activity and for cobalt-60 energy range (1.1 to 1.4 MeV) activity. The available average gross gamma activity and average cobalt-60 energy range activity results are included in Table 6-17. Radionuclide analysis of all samples was performed, but results were not recorded in 1991. All of the radionuclides encountered in the analyses of the drainage system samples since 1992 were naturally occurring (i.e., naturally occurring gamma radiation is detected in the 1.1-1.4 MeV "cobalt-60 energy range," as well as in the wider 0.1-2.1 MeV range).

Table 6-17
Drydock Sediment Samples
Naval Submarine Base New London
1991-1993

Year	Number of Samples	Average Gross Gamma Activity Concentration pCi/g (a)	Average Co-60 Energy Range Gamma Activity Concentration pCi/g
1993	23	2.2 (1.8 Avg MDA)	1.3 (1.2 Avg MDA)
1992	26	3.1 (1.9 Avg MDA)	< 1.5 (1.5 Avg MDA)
1991	6 (b)	2.9 (2.5 Avg MDA)	2.6 (2.1 Avg MDA)

Notes: (a) The samples were analyzed for average gross gamma activity over the energy range from 0.1 to 2.1 MeV. The elevated activity was due to naturally occurring radionuclides.
(b) One drydock had recently been overhauled, and had insufficient amounts of drainage system sediment for analysis.
MDA: Minimum detectable activity.
<: Less than minimum detectable activity.

6.5.2 Conclusions

No measurable cobalt-60 has been found in any drydock drainage system sample. This demonstrates that procedures are effective in preventing radioactivity associated with work on Naval nuclear propulsion plants from contaminating the river via drydock drains.

6.6 Routine Radiological Surveys

To ensure proper posting of radiation areas, gamma surveys are performed weekly in occupied radiological areas, including on piers and in drydocks where nuclear ships have been. Monthly surveys are performed on any potentially contaminated ducts, piping, or hoses in use. Surveys are performed quarterly in locked, unoccupied areas.

To ensure no environmental release of contamination, surveys for loose surface contamination are conducted either each shift, daily, or weekly, depending on the work site and potential for release.

Searches are also conducted each month to identify any radioactive material (RAM) outside radiologically controlled areas. Building searches using a beta-gamma frisker and a gamma scintillation survey instrument are performed in areas and buildings where no radioactive work is performed or radioactive material is stored. These searches are conducted on a revolving basis such that all parts of the Controlled Industrial Area (Lower Base) associated with the Naval Submarine Support Facility are surveyed every year. These surveys frequently find radioluminescent dials from old watches and naturally occurring radioactivity in building materials. There are two cases of NNPP radioactivity being found since this RAM survey program started in 1971. In both cases the RAM was controlled, and comprehensive surveys performed at the locations found no spread of radioactive material.

6.7 Aerial Radiological Survey

The Aerial Measuring Systems (AMS) program is managed by the Remote Sensing Laboratory in Las Vegas, Nevada, operated for the Department of Energy by EG & G. Since 1958, hundreds of baseline radiation surveys have been performed as part of the AMS program. EG & G aerial surveys of Department of Energy sites and radioactive waste disposal sites have demonstrated that the AMS can readily detect areas with surface contamination due to liquid or airborne releases and areas with buried radioactive waste.

In 1982, an aerial monitoring survey was performed over the Groton, Connecticut area. The 10 mile by 11 mile survey area was centered in the northern part of Groton. The helicopter used for the survey flew at an altitude of 400 feet and all readings were extrapolated into data results at 1 meter above ground level. The results of the survey are shown in Figure 6.3, and are reported as radiation exposure rates in microroentgen per hour (μR/hr). The radiation exposure rates reported include terrestrial gamma radiation measured throughout the survey area and an estimated 3.7 μR/hr cosmic ray contribution to the radiation exposure rate. The survey report, Reference 21, states "The background exposure rates ranged from 5 to 16 microroentgens per hour, which is normal for the coastal plains bordering the Atlantic Ocean." With the exception of Rock Lake, all of Subase is in the 9-12 μR/hr range, as are all the land areas bordering the Thames River. Reference 21 also states, "Other than Millstone Nuclear Power Station, no other man-made source of radiation was detected within the survey area."

After the aerial phase survey was completed, ground-based (one meter height) radiation measurements were taken at selected locations to corroborate the aerial measurements. Four locations were chosen in the survey area. Soil samples were also taken at the four locations, and radiation levels were projected from radionuclide analysis. These ground-based and soil measurements, and a comparison with the aerial data, are given in Table 6-18. These data confirm the aerial survey results.

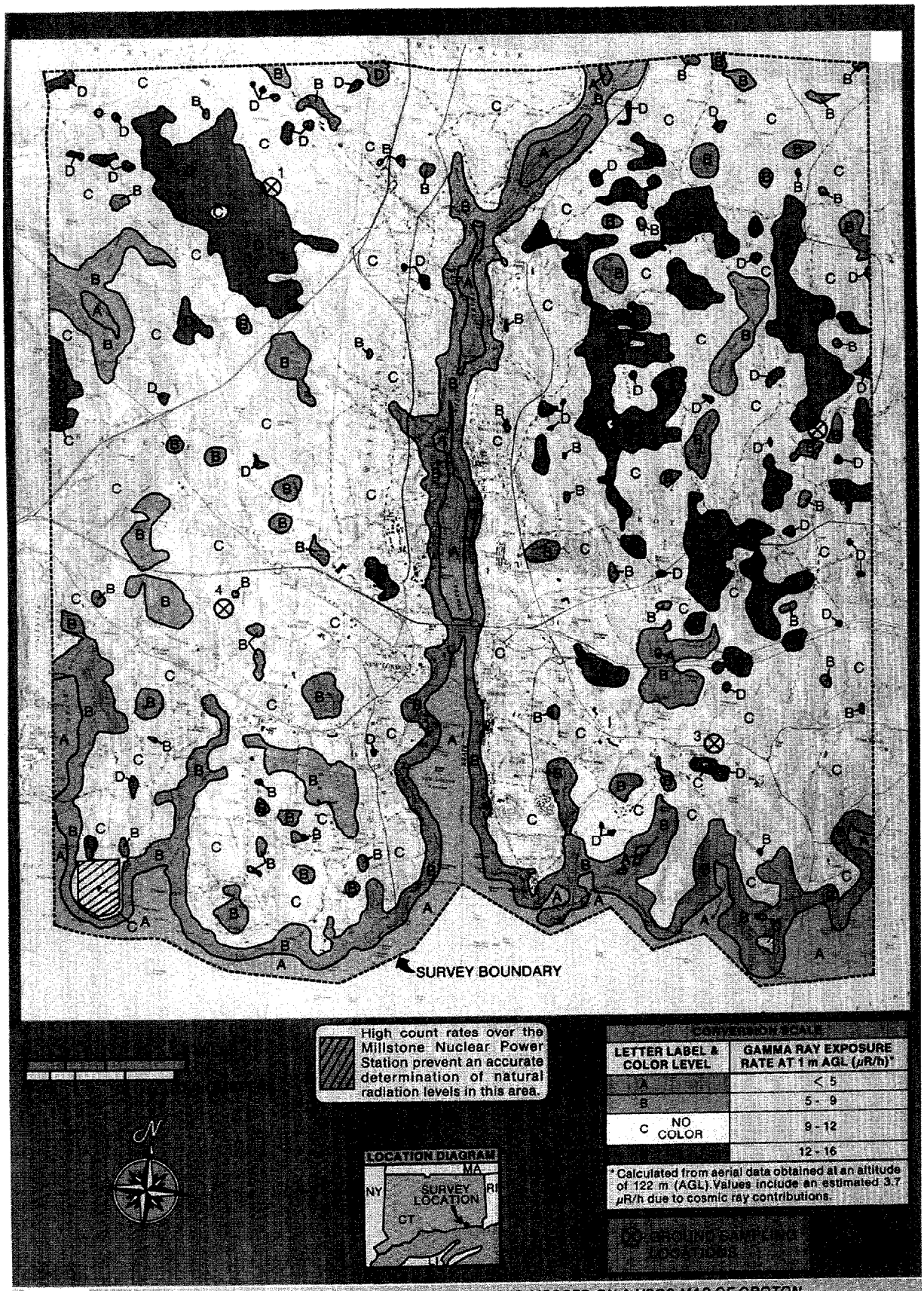
Table 6-18
Comparison of Aerial and Ground-Based Results

Site Number	Exposure Rate (μR/hr at 1 meter)		
	Ground Survey Results		Aerial Survey Results (b)
	Ion Chamber (a)	Soil Analysis Estimate (b)	
1	12.1	11.6	9-12
2	12.3	11.4	9-12
3	11.3	10.9	9-12
4	10.0	9.9	9-12

Notes: (a) Pressurized ion chamber. Similar EG&G surveys for other NNPP sites report this as a Reuter-Stokes Model RSS-111. Includes exposure rate contribution from radon.
(b) Includes an estimated cosmic ray contribution of 3.7 μR/hr.

The radiation levels of Subase property are no different than those found in the survey areas remote from any base activities. This survey is credible independent evidence that there are no locations within Subase, other than active facilities, where significant radioactivity is present.

Figure 6.3
Aerial Radiological Survey Results



NATURAL RADIATION EXPOSURE RATE CONTOURS SUPERIMPOSED ON A USGS MAP OF GROTON, CONNECTICUT AND THE SURROUNDING AREA

7.0 Residual Radioactivity

Of all the environmental radioactivity data collected, analyzed, and reported by Subase since 1954, by the U.S. Public Health Service (PHS) in 1966, and by the U.S. Environmental Protection Agency (EPA) in 1972 and 1989, the only radioactivity remaining in the environment attributable to NNPP work at Subase is trace amounts of cobalt-60 found in sediment and core samples from the Thames River. With respect to biota samples in the vicinity of the base, EPA states in Reference 1 that these "small concentrations of Co-60, less than 0.1 pCi/g dry weight . . may be due to sediment adhering to the surface of these (non-edible) biota species."

The highest reported Subase surface sediment or core sample activity in the past three years was less than 0.3 pCi/g. The highest activity reported by EPA in 1989 was 0.37 pCi/g at 17.8 centimeters (7 inches) beneath the bottom surface (Reference 1). This sample, if counted in 1994, would have decayed to 52 percent of that reported value or to 0.19 pCi/g.

By comparison, the highest reported core samples, taken from at least 3 inches below the bottom sediment during the 1966 PHS and 1972 EPA surveys, were 29.6 pCi/g at 3 inches and 13.8 pCi/g at 20 centimeters (8 inches) beneath the bottom surface, respectively. These samples, if counted in 1994, would have decayed to 2 and 5 percent of their survey date values, or to 0.67 and 0.65 pCi/g, respectively. This indicates that the cobalt-60 concentrations in Thames River bottom sediments in the vicinity of Subase are very low, and are being reduced at a rate greater than would be expected by radioactive decay alone. This increased reduction can be attributed to the effects of natural sedimentation in the estuary, and in some measure to the past dredging activities.

Of particular significance, as noted by EPA in the conclusions reported in Reference 1 and quoted in Section 6.1.1, the radioactivity concentrations found in Thames River sediment "have significantly decreased since the earlier two surveys and represent no radiological impact to the environment or individuals living or working in the area." By remaining in-situ, the process of radioactive decay will remove the radioactivity from the environment naturally and with far less impact on the ecosystems of the area than would be caused by artificial removal via extensive dredging.

8.0 Assessment of Environmental Impact

Reference 22, "Guidance for Performing Preliminary Assessments under CERCLA," lists four pathways of possible environmental transport, each evaluated by three elements. These pathways include ground water, surface water, soil exposure, and air. The elements are the likelihood of release (including the likelihood of a substance migrating through a specific pathway), the waste characteristics, and the targets.

The following sections evaluate the data and information presented in this report within the framework of Reference 22.

Reference 23 evaluates the annual dose to individuals from pathways derived from the requirements of 10 CFR 50 (Reference 24), for Portsmouth Naval Shipyard (a typical NNPP Naval shipyard; due to far greater workload, Portsmouth would have a higher potential radioactive source term than exists at Subase, and provides a conservative comparison). Elements of the 10 CFR 50 pathways are comparable to the air, soil, and surface water pathways evaluated by the protocol of Reference 22. It is informative to compare the results of these assessments in order to quantify the potential exposures via the pathways considered in Reference 22.

8.1 Ground Water Pathway

The ground water pathway considers potential exposure threats to drinking water supplies via migration to and within aquifers.

As discussed in Section 3, Subase is primarily (85%) covered with paving or structures that isolate the soil zone from any potential release mechanisms discussed below. The controlled industrial area, where NNPP work is conducted, is covered to an even greater degree with paving or structures. Without access to the soil, percolation into the aquifer cannot occur. That no radioactivity to infiltrate the aquifer exists above background levels is established in evaluating the soil exposure pathway in Section 8.3.

The water contained in the near-surface glacial outwash aquifer underlying the Lower Base discharges into the Thames River. There has been no identifiable release of radioactivity which could threaten the ground water in the vicinity of the base. Independent verification of this assessment will be available via the Phase II Remedial Investigation analysis of ground water for radionuclides as discussed in Section 8.1.2. Public consumption and domestic wells to the north and east are upgradient.

8.1.1 Release Mechanisms Affecting Ground Water

Radioactivity could conceivably be released to ground water as a result of a release to the soil, atmosphere, or surface water. The radioactivity, which is primarily in an insoluble particulate form, would have to infiltrate through the soil to the ground water. As discussed above and in Section 3, no drinking water wells would be affected.

8.1.2 Ground Water Targets

Primary targets are defined as populations served by drinking water wells that are suspected to have been exposed to a hazardous substance. There has been no suspected NNPP radioactivity release from the site to ground water; thus, no primary targets are identified.

As noted in Section 6, PHS and EPA analyzed well water and drinking water supplies at Subase, Groton, and New London during their 1966, 1972, and 1989 surveys. No non-naturally-occurring radioactivity was detected in any of these samples. During the Phase I Remedial Investigation, gross radiological screening parameters were exceeded in 14 of 38 ground water monitoring well samples (10 of 28 at Area A, 2 of 6 at DRMO, and 2 of 4 at Goss Cove). The Navy subsequently performed radionuclide-specific analysis (via gamma spectroscopy) on 15 well water samples drawn from wells at various locations at Subase, including the three areas identified above. Only naturally occurring radionuclides were identified in all of these water samples. Independent gamma spectroscopy analysis of the ground water monitoring wells was performed as part of the Phase II Remedial Investigation (RI) sampling and the results will be included in the final Phase II RI report.

Secondary targets include populations served by all drinking water wells within four miles of the site that are not suspected to have been exposed to a hazardous substance. Most of Ledyard does not have a regional public water supply system. The majority of residences in Ledyard are served by private wells. The only public water supply system in Ledyard serves the Highland section, in the northeast corner of the town.

The public water supply well locations nearest to Subase are shown as filled-in circles on Figure 3.6. It is estimated that these public wells supply drinking water to 100 people. Additional public water supply wells (of the Southeastern Connecticut Water Authority) serve an estimated 2,800 people north of the base in the Tower, Ferry View, and Riverside neighborhoods of Gales Ferry. The 22 private drinking water wells adjacent to the base are shown in Figure 3.15. Based on regional water supply information and house counts, it is estimated that within 4 miles of the base on the east side of the Thames River, private wells supply drinking water to 3,500 people and other ground water resources supply 2,900 people. Due to their prevalence in the region, the number of wells within four miles of Subase has not been estimated.

There are no Wellhead Protection Areas within the region. Since ground water within the four mile zone has uses other than drinking water, it would be considered a resource.

8.1.3 Ground Water Pathway Assessment

There has been no identifiable release of radioactivity which could threaten the ground water in the vicinity of the base and no viable mechanism by which a potential contaminant could be transported to target receptors.

8.2 Surface Water Pathway

The surface water pathway considers potential exposure threats to drinking water supplies, to human food chain organisms, and to sensitive environments.

The Thames River is a salt water estuary that does not supply any of the drinking water needs of the region.

Analytical data collected by Subase consisting of river water, biota, and sediment samples, along with data collected in 1966, 1972, and 1989 by the Public Health Service and Environmental Protection Agency, have not detected cobalt-60 in any water or edible marine biota since sampling was begun. Small concentrations of cobalt-60 have been found in sediments but, as concluded by all agencies, this radioactivity poses no threat to humans or the environment.

There are no primary sensitive environments within the 15-mile tidal influence zones of concern. Secondary sensitive environments consist of wetlands along the shorelines. Wetlands frontage exceeds 20 miles.

8.2.1 Release Mechanisms Affecting Surface Waters

Air release mechanisms can disperse radioactivity to local surface waters, but the potential effect of low level discharges via the air pathway is very small. Of greater potential concern would be direct liquid and solid material discharges to surface water. Leaks or ruptures from tanks stored or being moved pierside could spill their contents into the river. The three tanks at Subase which are on pontoon barges are each contained within a double drip pan assembly, which reduces the potential for releases. Additionally, spillage of radioactive liquids to the base storm drain system could ultimately reach the river.

Spills of radioactive liquids inside the Radiological Controls Barge would generally be contained within the barge, but could reach the surface water if a hull penetration below the water line were created by some unforeseen event. Spills in the floating drydocks would generally be contained, but could enter the drainage system and thence the river. Also, in the event of a fire in the barge or floating drydocks, the large volumes of water needed to control the fire could result in the transport of radioactive materials into the surface water.

8.2.2 Surface Water Targets

Surface water targets are sub-divided into drinking water, human food chain, and environmental. All of the fresh water for the Groton public supply is obtained from within the Poquonock River Watershed, located east of the base and not within the Subase watershed. The primary sources of the Groton water supply are reservoirs which are supplemented with wells.

There are no intakes within the target distance limit as defined in Reference 22. Intakes at the University of Connecticut - Avery Point marine laboratory support aquiculture research. As a drinking water supply, there is no resource within the target distance limit.

Sport and commercial fishing occur within the 15 mile target distance limit. Because it is an estuary, no gauging stations are located on the Thames River. The Thames River would be classed as coastal tidal water in accordance with 40 CFR 300, Table 4-13. Five surface water gauging stations are located in the Thames' immediate tributaries. Since the primary concern is for predicting flood potential in the river from upland surface run-off, the gauging stations are in the extreme northernmost portion of the estuary. The stations are located as follows: French River in Webster; Quinibaug River in Putnam; Quinibaug River in Jewett City; Shetucket River in Willimantic; and at the confluence of the Shetucket River and Yantic River in Norwich.

The Thames River is considered to be tidally influenced up to Norwich where the river divides into the Shetucket and Yantic tributaries. The tributaries of the Thames River are not considered to be tidal. Various shellfish beds within the tidal influence zone are closed due to persistently high coliform bacteria levels throughout the river. The Connecticut Agriculture Department will issue permits allowing the harvesting of shellfish from these waters provided the catch is transferred to clean waters for a specified period prior to marketing. Shellfish harvesting is prohibited within 1000 feet of Subase due to river traffic and the potential for pollution. The state routinely imposes a similar prohibition around all large marine facilities. A Class Two health alert for striped bass is in effect to advise children and pregnant women to not consume the fish and for the general population to limit their consumption. Reference 2 discusses fisheries in detail.

Table 8-1 lists all surface water bodies within the 15 mile tidal influence zone.

Table 8-1
Water Bodies Within The 15 Mile Tidal Influence Zone

Upstream Western Bank, Thames River

Smith Cove	Oxoboxo Brook	Trading Cove
Hunts Brook	Stony Brook	Yantic River
Bartlett Cove	Mohegan Brook	
Horton Cove	Shantok Brook	

Upstream Eastern Bank, Thames River

Long Cove	Tom Allyn Brook	Poquetanuck Brook
Flat Brook	Billings Avery Brook	Halsey Brook
Mill Cove	Poquetanuck Cove	Shetucket River
Clark Cove	Joe Clark Brook	

Downstream Western Bank, Thames River

Church Brook
Mamacoke Cove
Shaw Cove
Greens Harbor

Downstream Eastern Bank, Thames River

Goss Cove

Beyond Mouth of Thames River

Long Island Sound	Baker Cove
Alewife Cove	Plain Creek
Fenger Brook	Poquonock River
Goshen Cove	Mumford Cove
Jordan Cove	Fort Hill Brook
Niantic Bay	Venetian Harbor
Niantic River	Palmer Cove
Pattagansett River	Eccleston Brook
Bride Brook	Mystic River
Fourmile River	Copps Brook
Threemile River	Fisher Island Sound

There are no critical habitats as defined in 50 CFR 424.02 within the tidal influence zone.

Table 8-2, taken from Reference 2, lists federally designated threatened or endangered species identified as existing in the region. None of these species have been identified as having habitat on the base.

Table 8-2
Federally Designated Threatened (T) or Endangered (E) Species in the Vicinity of Naval Submarine Base New London

Common Name	Status	Distribution
Shortnose Sturgeon	E	Connecticut River and Atlantic Coastal Waters
Green Turtle	T	Oceanic straggler in Southern New England
Hawksbill Turtle	E	Oceanic straggler in Southern New England
Leatherback Turtle	E	Oceanic summer resident
Loggerhead Turtle	T	Oceanic summer resident
Atlantic Ridley Turtle	E	Oceanic summer resident
Bald Eagle	E	Entire state
American Peregrine Falcon	E	Entire state - re-establishment to former breeding range in progress
Arctic Peregrine Falcon	E	Entire state - migratory, no nesting
Coopers Hawk	E	Entire state
Gray Wolf	E	Entire state
Eastern Cougar	E	Entire state - may be extinct
Blue Whale	E	Oceanic
Finback Whale	E	Oceanic
Humpback Whale	E	Oceanic
Right Whale	E	Oceanic
Sei Whale	E	Oceanic
Sperm Whale	E	Oceanic
Small Whorled Pogonia	E (proposed)	Hartford, Litchfield, New Haven, Fairchild, New London, Windham Counties
Ames' Quillwort	E	Entire state
Sedge	E	Entire state
Putty-root	E	Entire state
Threebirds Nodding Pogonia	E	Entire state
Low Rockrose	E	Entire state
Ginseng	E	Entire state
Chaffseed	E	Entire state

One state-designated endangered species has been documented within the tidal influence zone. Reference 2 notes that the Cooper's Hawk is expected to migrate through the region. Reference 4 states: "No known threatened or endangered species are known to exist in the project area." Reference 2 also states the following: "The ecological habitats within or immediately surrounding the base may potentially harbor floral or faunal species of threatened or endangered status as classified by the State of Connecticut or the U.S. Fish and Wildlife Service. The habitat which has the greatest potential for harboring these species is the wetland and its associated drainages emanating from Area A. The subject species are limited primarily to plants due to the urbanized nature of the entire area and the constant disturbance by heavy equipment and normal base operations. There have been no confirmed sightings of threatened and endangered species."

No national parks or monuments have been identified within the tidal influence zone.

No national seashore or lake shore recreational areas, national preserves, federal wilderness areas, federal Scenic or Wild Rivers, wildlife management areas, or state designated natural areas have been identified in the tidal influence zone. The Barn Island state designated Fish and Wildlife Area is approximately 15 miles downstream from the base.

State Parks within 15 miles upstream or downstream of the base include Stoddard Hill, Fort Shantor, Fort Griswold, Bluff Point, Haley Farm, Harkness Memorial, and Rocky Neck.

No sensitive areas identified under the Near Coastal Waters Program or the National Estuary Program have been identified within the tidal influence zone.

Under the Coastal Zone Management Act, Connecticut lists areas of concern. Within 15 miles upstream and downstream, areas of concern include wetlands, spawning, nursery and feeding grounds, and significant wildlife habitat. Area A and the Overbank Disposal Area contain inland wetlands. There are no designated tidal wetlands at the base.

Within 15 miles upstream or downstream, there are economically important finfish and shellfish resources, as discussed in Section 3.3.3.6. Species identified within this zone include Lobster, Quahog, Oyster, Blue Crab, Coot Clam, Softshell Clam, Winter Flounder, Porgy, Weakfish, Tautog, Alewife, Menhaden, White Perch, American Smelt, Tomcod, Bluefish, Striped Bass, American Shad, Whiting, Blueblack Herring, Atlantic Salmon, Brown Trout, Windowpane Flounder, Mumichog, Stripped Killfish, and Mackerel. There is a commercial eel fishery within 3 miles downstream of the base, some commercial harvesting of lobsters does occur north of the I-95 bridge, and there are some commercial relay beds for oysters and clams along the western shoreline immediately upstream and downstream of the base.

The total length of tidal wetlands within 15 miles upstream and downstream of Subase exceeds 20 miles, the maximum assigned value under PA or HRS scoring. None of these wetlands are within 2 miles of the base.

8.2.3 Surface Water Pathway Assessment

Previous sections of this report have established that no drinking water intakes from surface water are used.

Reference 23 calculates the total body dose to the maximally exposed individual from ingestion of seafood and from recreational use of the water from cobalt-60 and tritium. Table 8.1 of Reference 23 lists the annual maximum individual total body doses as 0.000012 mrem from ingestion of seafood and 0.00024 mrem from swimming and boating.

These calculated values are based on the maximum assumed annual release of 0.001 curie for cobalt-60 and 0.100 curie for tritium. These values conservatively bound the levels of radioactivity in several thousand gallons of unprocessed reactor coolant; such a release has not occurred in over 20 years. Hence, these are very conservative estimates.

According to Reference 7, the total body dose to an individual due to naturally occurring radionuclides which are internally deposited is about 40 mrem/year. About half of this dose is due to naturally occurring potassium-40. When this value is compared to the dose due to ingestion of seafood, were the seafood contaminated with the maximum conceivable level of NNPP radioactivity, it is seen that the dose due to consumption of seafood is about 0.00006 percent of the 20 mrem from potassium-40. A similar comparison shows that the recreational dose is about 0.001 percent of that due to potassium-40.

Subase concludes that radioactivity in surface waters will not damage sensitive environments as described by Reference 22. As discussed above and in Section 6, no water or edible marine biota samples have shown levels of cobalt-60, nor have any shorelines within the littoral zone accumulated any radioactivity associated with the NNPP. This evidence supports the conclusion that there has been no environmentally detrimental release of radioactivity to surface waters surrounding the base.

8.3 Soil Exposure Pathway

The soil exposure pathway considers potential exposure threats to people on or near the site who may come into contact with a hazardous substance via dermal exposure, soil ingestion, or plant uptake into the human food chain.

Subase is actively engaged in NNPP work. As such, there are radiological facilities containing radioactivity associated with this work. These facilities and the radiological controls applied to prevent contamination of workers and the environment are discussed in other sections of this report.

For areas and facilities other than those discussed above, this report concludes that there is no likelihood for exposure to humans or to the environment. This conclusion is based on the following:

- Perimeter radiation levels have consistently been comparable to background radiation levels as measured by Subase, the Environmental Protection Agency, and EG & G.
- Shoreline surveys conducted by Subase and by the Environmental Protection Agency found no radionuclides along the shore attributable to Naval Nuclear Propulsion Program activities.
- Results of drydock surveys and samples have not shown measurable cobalt-60 radioactivity.
- There have been no reported releases of NNPP radioactivity onto soil at Subase.
- There have been no reported airborne releases of NNPP radioactivity at Subase which could have transported radioactivity onto soil.
- An aerial radiological survey conducted by EG & G found no areas within or adjacent to Subase with radiation levels higher than background.
- There has been no solid NNPP radioactive waste disposal on or near Subase property, as documented by regulatory prohibition, review of historical disposal records, and review of measured radiation levels.

Since the above evidence would result in a "no likelihood of exposure" finding, the other elements of the soil exposure pathway do not need to be evaluated.

8.3.1 Release Mechanisms Affecting Soil

The release mechanisms discussed in the air pathway section could deposit radioactivity in the soil of affected areas. Radioactive liquid spills to the soil would be much more localized and concentrated than soil contamination resulting from low level airborne radioactivity releases. Liquid spills with the highest potential for reaching the soil are related to activities performed outside of radiological work areas. These activities include connections of tanks to ships, tank to tank transfers, movement of tanks within Subase, and the movement of smaller liquid containers such as plastic bottles. None of these activities are performed near any unprotected soil; they are performed in dry docks, on the piers, or on the paved areas of the Controlled Industrial Area (Lower Base). Work involving radioactive liquids is performed only within the Radiological Controls Barge. In the event of a fire in the radioactive material storage area (Building 91), the large volumes of water needed to control the fire could result in the transport of radioactive materials into the soil.

8.3.2 Soil Exposure Targets

There are no residences, schools, or daycare facilities within 200 feet of any potential source of NNPP radioactivity.

There are about 9900 employees working on the base, including Subase and all tenant commands.

There are no terrestrial sensitive environments that have been identified within a four-mile radius of the base. Fort Griswold State Park and Stoddard Hill State Park are within 4 miles of the perimeter of the base.

There are potential land resource uses on a limited scale for commercial agriculture, commercial silviculture, and commercial livestock production or grazing within a four-mile radius of the base.

8.3.3 Soil Exposure Pathway Assessment

The ground deposition element in the airborne pathway of References 10 and 23 is directly related to the soil exposure pathway. For this calculation only cobalt-60 is considered since, of the radionuclides listed in Table 3.1 of Reference 23, it is the only particulate. Although most noble gases have particulate daughters, the transport of the gaseous parent disperses and dilutes the eventual dry deposition and rainout of particulate daughters to such an extent that their dose contribution is negligible.

Table A-1 of Reference 20 lists the annual total body dose due to natural sources in the vicinity of Subase as approximately 91 mrem (10.4 μR/hr): 50 mrem (5.7 μR/hr) is due to terrestrial sources of natural radioactivity and 41 mrem (4.7 μR/hr) is due to cosmic radiation. Reference 20 is cited extensively in Reference 7 as a continuing source of data for natural background radiation exposure estimates. This value (10.4 μR/hr) is consistent with Subase perimeter surveys, with surveys done by the EPA, and with the EG & G aerial survey.

The maximum individual annual total body dose due to soil exposure from 0.001 curie of cobalt-60 ground deposition would be 0.07 mrem as listed in Table 8.1 of Reference 23. The maximum calculated airborne release of NNPP radioactivity shown in Table 5.3 occurred in 1983 and totaled 4.9×10^{-7} curie. Presuming all this activity is deposited on the soil of interest, this is still a factor of about 2000 less than the 0.001 curie used for Reference 23 calculations. Hence, the actual maximum individual total body dose through the soil pathway would be 0.000034 mrem/yr. This is about 0.00007 percent of the natural terrestrial background in the vicinity of Subase as reported in Reference 20, or alternatively, this <u>yearly</u> dose is less than one one-hundredth of the <u>hourly</u> exposure from natural sources of radioactivity from the earth.

Subase concludes there has been no adverse impact on human health or the environment due to the soil exposure pathway.

8.4 Air Pathway

The air pathway considers potential exposure threats to people and to sensitive environments via migration through the air.

There have been no historical releases of airborne radioactivity above allowed limits or sufficient to contribute measurable exposure to any individual. This has been confirmed independently by the NESHAPS program COMPLY calculations, as discussed in Section 5.1.2. Controls over airborne radioactivity releases have not changed since the beginning of the Program. Improved monitoring methods have continued to confirm that no changes to control procedures are needed.

A historical record that radiological controls have been effective in preventing significant environmental releases provides a valid basis for concluding that continued application of such controls will result in a minimal likelihood for future such releases.

Since 1993, PNS has performed analyses for Subase to provide a quantitative estimate of the radiation exposure to which any member of the general public might be exposed as a result of radioactivity in airborne effluents. The EPA COMPLY computer program is used for this analysis, as required by EPA regulations in 40 CFR 61 Subpart I. Site-specific input parameters include radionuclide releases and distance to members of the public. Cobalt-60 values used in the calculation include actual measurements of cobalt-60 emissions from the exhaust of monitored ventilation in addition to very conservative estimates of other potential sources of cobalt-60. Values for other airborne radionuclides, including iodine-131, are conservative estimates based upon detailed study of land-based Naval nuclear propulsion prototype plants; for example, the very conservative assumption that half of the radioactive water handled by Subase evaporated from collection and storage tanks. Thus, the actual exposures to members of the public are expected to be lower than the results of this analysis.

Since the controls for airborne releases have remained the same over the years, the assessment for 1993 can be used for evaluation purposes. The result of the airborne effluent analysis in 1993 was 0.03 millirem from particulate and gaseous radionuclides and 0.000006 millirem from radioiodine releases. The estimated maximum radiation exposure to a member of the general public from releases of airborne radioactivity is much less than the standard of 10 millirem per year established by the EPA in 40 CFR 61.

Other potential sources of airborne radioactivity, such as from contaminated soil or spills of contaminated liquids, have been discussed in other sections of this report. Based on the lack of detectable soil contamination, and the immediate containment and recovery actions taken for spills, Subase considers these potential sources of airborne radioactivity have been eliminated from consideration.

8.4.1 Release Mechanisms Affecting the Air

The methods employed to prevent the release of radioactivity into the atmosphere were discussed in Section 4.4 and have proven to be extremely effective. Nevertheless, consideration of atmospheric releases is necessary since such releases would potentially allow radioactivity to contact the soil and surface water. Some mechanisms that could cause an atmospheric release of radioactivity follow.

8.4.1.1 Potential Releases from Ventilation Systems

Facilities that are used for radioactive work or work with radioactive materials are potential sources of airborne radioactivity. High efficiency particulate air (HEPA) filtered ventilation systems are used in these facilities and could fail before or during work and allow radioactive particulates to enter the atmosphere. Potential failure modes for HEPA filters include: improper installation, damage during installation or use, improper differential pressure testing, or exceeding HEPA filter capacity. In addition, duct work associated with these ventilation systems could fail or become damaged causing an uncontrolled release.

8.4.1.2 Potential Releases from Storage Areas

The primary atmospheric release potential from radioactive material storage areas would be a fire. NNPP regulations specify that buildings where radioactive materials are stored shall be constructed and equipped with fire protection systems in accordance with Reference 25. These provisions include building construction, fire detection and alarm systems, automatic sprinkler systems, portable fire extinguishers, and fire hydrants. In addition to structure requirements, NNPP regulations: require that materials be stored in fire retardant containers; prohibit welding, burning, or other operations that could cause a fire without prior authorization; and require periodic inspections and fire drills.

Another potential release mechanism is the possibility of the loss of containment for items being stored, including tears in packaging material.

8.4.1.3 Potential Releases from Collection Tanks

Tanks containing radioactive liquid effluent present a potential for atmospheric release. If a tank were to rupture or leak, evaporation of the liquid could allow radioactive particles to become airborne. Rupture or leakage could result from corrosion of the tank, excessive pressure build-up, or human error in valve positioning. A release could also occur if a tank were to overflow during a liquid transfer.

8.4.2 Air Targets

Target populations under the air pathway consist of people who reside, work, or go to school within the 4-mile target distance limit around the site. Preliminary Assessment air pathway targets also include sensitive environments and resources.

Targets are evaluated on the basis of their distance from the site. Those persons closest to the site are most likely to be affected and are evaluated as primary targets. The nearest individual would be an on-site worker.

Like the other migration pathways, a release must be suspected in order to score primary targets for the air pathway. Releases to the air pathway, however, are fundamentally different from releases to the other migration pathways. Depending on the wind, air releases may disperse in any direction. Therefore, when a release is suspected, all populations and sensitive environments out to and including the 1/4 mile distance category are evaluated and scored as primary targets. Because air releases are quickly diluted in the atmosphere, targets beyond the 1/4 mile distance are evaluated as secondary targets.

As with other migration pathways when a release is not suspected, the residential, student, and worker population within the entire 4-mile target distance limit is evaluated as the secondary target population. The population distribution for the secondary target population is given in Section 3.

Sensitive environments are defined as terrestrial or aquatic resources, fragile natural settings, or other areas with unique or highly-valued environmental or cultural features.

Typically, areas that fall within the definition of "sensitive environment" are established and/or protected by State or Federal law. Examples include National Parks, National Monuments, habitats of threatened or endangered species, wildlife refuges, and wetlands.

Except for the Area A Wetland, there are no sensitive environments within 1/2 mile of the base. Although the designation is not included in the Reference 24 criteria for sensitive environments, it is noted that NAUTILUS, at Goss Cove, was designated as a National Historical Landmark in 1982.

The resources factor accounts for land uses around the site that may be impacted by release to the air:

- Commercial agriculture
- Commercial silviculture (e.g., tree farming, timber production, logging)
- Major or designated recreation area (e.g., municipal swimming pool, campground, park)

There are no commercial agriculture or silviculture uses within 1/2 mile. Rock Lake and North Lake on the base are used for recreational swimming by military personnel and their dependents.

8.4.3 Air Pathway Assessment

Of the pathways considered in Reference 23, the plume immersion and inhalation pathways best fit the model of Reference 22.

Table 8.1 of Reference 23 presents the results of calculated radiation dose estimates for immersion and inhalation. For comparative purposes, the total body dose to the maximally exposed individual is used in all cases.

Reference 23 lists an annual total body dose of 0.0049 mrem for immersion and 0.00027 mrem for inhalation, for radionuclides of NNPP interest. This gives a combined dose of 0.0052 mrem for this pathway. For inhalation, only cobalt-60 and carbon-14 contribute significantly to exposure. For immersion, cobalt-60, carbon-14, tritium, and all fission product noble gases as listed in Table 3.1 of Reference 23 are considered.

This represents a maximum value since the assumed releases of Table 3.1 of Reference 23 are significantly higher than actual. For example, for cobalt-60, the primary radionuclide of interest for NNPP nuclear facilities, the calculations are based on 0.001 curie per year. The maximum calculated airborne release shown in Table 5.3 occurred in 1983 and totaled 4.9×10^{-7} curie or a factor of about 2000 less.

Comparing the Reference 23 combined dose of 0.0052 mrem/yr to the dose from natural sources of radiation listed in a report published by the National Council on Radiation Protection and Measurements (Reference 7), the calculated combined dose is about 0.003 percent of that due to airborne natural background radioactivity (primarily radon). When the actual Subase release values are factored in, the comparative percentage becomes vanishingly small.

These comparisons provide additional evidence that the airborne exposure to any potential target due to NNPP activities at Subase is insignificant.

9.0 Conclusions

Evaluation of the information and analytical data presented in this HRA leads to the conclusion that past and current activities at Subase associated with work on Naval nuclear propulsion plants have had no adverse impact on the human population or ecosystem of the region.

Of all the radiological parameters monitored and reported as part of the longstanding and continuing monitoring of the radiological environment, only the small concentrations of cobalt-60 found in Thames River bottom sediment could be considered for remediation.

To the extent that the goal of the CERCLA process is to identify and remediate those sites where harm to the environment or to human populations is occurring or is likely to occur, active removal of the sediments containing the low levels of cobalt-60 would do move harm to the benthic organisms and dependent biota than the possible radiation exposure received over the time required for the radioactivity to decay to undetectable levels.

The findings and conclusions of the Public Health Service survey in 1966 and the Environmental Protection Agency surveys of 1972 and 1989 fully support the data and conclusions of this assessment.

Subase will continue to follow NNPP radiological control practices and perform environmental monitoring as discussed in this HRA. Within the framework of the CERCLA process, no further action is warranted regarding radioactivity associated with the Naval Nuclear Propulsion Program at Naval Submarine Base New London.

GLOSSARY

Aquifer: A saturated subsurface zone from which drinking water is drawn.

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980. Legislation that established the Federal Superfund for response to uncontrolled releases of hazardous substances to the environment.

CERCLIS: CERCLA Information System. EPA's computerized inventory and tracking system for potential hazardous waste sites.

CPW: Controlled pure water.

Coastal Tidal Waters: Surface water body type that includes embayments, harbors, sounds, estuaries, back bays, etc. Such water bodies are in the interval seaward from the mouths of rivers and landward from the 12-mile baseline marking the transition to the ocean water body type.

curie: Abbreviated Ci. A unit of measure of the amount of radioactivity equal to 3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute.

DRMO: Defense Reutilization and Marketing Office. Portions of this Subase site were used as a landfill from 1950 to 1969.

EPA: U.S. Environmental Protection Agency. The federal agency responsible for action under CERCLA.

Factor: The basic element of site assessment requiring data collection and evaluation for scoring purposes.

FFA: Federal Facilities Agreement. An agreement among the EPA, state, and site detailing the extent and schedule for remedial actions.

Fishery: An area of a surface water body from which food chain organisms are taken or could be taken for human consumption on a subsistence, sporting, or commercial basis. Food chain organisms include fish, shellfish, crustaceans, amphibians, and amphibious reptiles.

G-RAM: General Radioactive Material. Radioactive materials that are not associated with the NNPP.

HEPA filter: High Efficiency Particulate Air Filter. A filter that will remove 99.97% of 0.3 micron particulates from an air system.

HRA: Historical Radiological Assessment. A compilation of site historical radiological data derived from the site environmental monitoring program and other records. This document is intended to be an integral part of a FFA.

HRS: Hazard Ranking System. EPA's principal mechanism for placing sites on the NPL.

IAS: Initial Assessment Study. A study done under the Navy's Installation Restoration program. This study parallels the PA.

kcpm: Thousand counts per minute.

micro: Abbreviated μ. A prefix denoting a one-millionth part (10^{-6}).

micron: A millionth of a meter (10^{-6} m).

milli: Abbreviated m. A prefix denoting a one-thousandth part (10^{-3}).

NNPP: Naval Nuclear Propulsion Program. A joint Navy/Department of Energy program to design, build, operate, maintain, and oversee operation of Naval nuclear-powered ships and associated support facilities.

NPL: National Priorities List. Under the Superfund program, the list of sites of releases and potential releases of hazardous substances, pollutants, and contaminants that appear to pose the greatest threat to public health, welfare, and the environment.

NSSF: Naval Submarine Support Facility. Tenant command of Subase. Facility responsible for performance of all NNPP work at Subase. Located within the Lower Base.

No Suspected Release: A professional judgement based on site and pathway conditions indicating that a hazardous substance is not likely to have been released to the environment.

PA: Preliminary Assessment. Initial stage of site assessment under CERCLA; designed to distinguish between sites that pose little or no threat to human health and the environment and sites that require further investigation.

PHS: U. S. Public Health Service. The former federal agency that performed initial independent radiological environmental surveys in the vicinity of NNPP sites.

pico: Abbreviated p. A prefix denoting a one-trillionth part (10^{-12}).

R: Roentgen. A unit of exposure. For cobalt-60 radiation, a roentgen and a rem are considered to be equivalent.

rem: Roentgen Equivalent Man. A measure of radiation dose.

SARA: Superfund Amendments and Reauthorization Act of 1986. Legislation which extended the Federal Superfund Program and mandated revision to the HRS.

Subase: Naval Submarine Base New London

Surface Water: A naturally-occurring, perennial water body; also, some artificially-made and/or intermittently-flowing water bodies.

Suspected Release: A professional judgement based on site and pathway conditions indicating that a hazardous substance is likely to have been released to the environment.

Target: A physical or environmental receptor that is within the target distance limit for a particular pathway. Targets may include wells and surface water intakes supplying drinking water, fisheries, sensitive environments, and resources.

Target Distance Limit: The maximum distance over which targets are evaluated. The target distance limit varies by pathway; ground water and air pathways -- a 4-mile radius around the site; surface water pathway -- 15 miles downstream from the probable point of entry to surface water; soil exposure pathway -- 200 feet (for the resident population threat) and 1 mile (for the nearby population threat) from areas of known or suspected contamination.

Target population: The human population associated with the site and/or its targets. Target populations consist of those people who use target wells or surface water intakes supplying drinking water, consume food chain species taken from target fisheries, or are regularly present on the site or within target distance limits.

Terrestrial Sensitive Environment: A terrestrial resource, fragile natural setting, or other area with unique or highly-valued environmental or cultural features.

Wetland: A type of sensitive environment characterized as an area that is sufficiently inundated or saturated by surface or ground water to support vegetation adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Worker: Under the soil exposure pathway, a person who is employed on a full or part-time basis on the property on which the site is located. Under all other pathways, a person whose place of full- or part-time employment is within the target distance limit.

< : Less than.

> : Greater than.

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