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NSY PORTSMOUTH
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LETTER REGARDING THE TRANSMITTAL OF RADIOLOGICAL SAMPLING OF WATER, SEDIMENT AND BIOTA AT NSY PORTSMOUTH ME
4/30/1999
PORTSMOUTH NAVAL SHIPYARD

NAVSHIPYD PTSMH-5216/9 (REV 8-94)

DEPARTMENT OF THE NAVY
PORTSMOUTH NAVAL SHIPYARD
PORTSMOUTH, N.H. 03804-5000

IN REPLY REFER TO
5090
Ser 105.5/264
30 Apr 1999

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DS 4/30/99
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JEB 4/30/99
105.5

Meghan F. Cassidy
U.S. Environmental Protection Agency
Region I
John F. Kennedy Federal Building
Boston, MA 02203-0001

Mr. Iver McLeod
Maine DEP
State House Station #17
Augusta, ME 04333

Dear Ms. Cassidy/Mr. McLeod:

A one-time environmental sampling plan has been prepared for Portsmouth Naval Shipyard (PNS) at the U.S. Environmental Protection Agency (EPA) and Maine Department of Environmental Protection (DEP) request. It establishes a plan of action to sample and analyze groundwater from monitoring wells, and water, sediment, and biota from two on-site freshwater ponds. Although there are no indications of residual radioactivity in soils at PNS that would affect groundwater, one round of sampling will be conducted as a matter of comity.

The June 1998 draft environmental sampling plan has been revised in response to comments from the EPA, Maine DEP, and Lepage Environmental Services, Inc. Additionally, nineteen new monitoring wells were installed at PNS since the draft plan was sent out for comment. The additional monitoring wells were added to the final environmental sampling plan.

The final sampling plan is forwarded (enclosure (1)), and sampling will be conducted in the near future.

Should you have any further questions, please feel free to contact me at (207) 438-1283.

Sincerely,

J. A. BRANN
Director, Radiation Health

Enclosure: 1. Radiological Sampling of Water, Sediment, and Biota, Portsmouth Naval Shipyard

Copy to: NAVFACENGCOM (Code 1823/FE), TAG Advisor (Lepage), Tetra Tech NUS, RAB members

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CONTINUOUS IMPROVEMENT THROUGH TEAMWORK
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NAVSHIPYD-PTSMH-5216/9 (REV 8-84)

Blind Copy to:
~~COMNAVSEASYSCOM (SEA 04N, 08R)~~
NRRO PTSMH (Mr. Solich)
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106.3 (Ms. Raymond)

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Writer: D. Jackson, Code 105.52, Ext. 2735
Typist: E. Gerry, 30 Apr 99

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RADIOLOGICAL SAMPLING OF WATER, SEDIMENT, AND BIOTA
PORTSMOUTH NAVAL SHIPYARD

Appendices: A) Monitoring Well Information
B) Background Monitoring Well Locations
C) Map of Portsmouth Naval Shipyard Low Flow Pilot Study Wells

References: a) Historical Radiological Assessment, Portsmouth Naval Shipyard, July 1998
b) ANSI N42.23-1996, "Measurement and Associated Instrumentation Quality Assurance for Radioassay Laboratories"
c) Groundwater Investigation and Monitoring Plan for Portsmouth Naval Shipyard, Brown & Root Environmental, November 1996

1. Purpose: Although there are no indications of residual radioactivity in the soils at Portsmouth Naval Shipyard (PNS) that would affect groundwater, one round of sampling will be conducted for informational purposes. Limited surface water, pond sediment, and biota sampling in Upper and Lower Meade Ponds will also be conducted. This protocol defines the methods:

a. To obtain and analyze water samples from test wells that have been drilled at PNS.

b. To establish how the water samples will be collected.

c. To establish a means of apportioning sample material between PNS and the EPA and State of Maine so that independent analyses may be performed by each agency.

d. To establish a mechanism for marking and handling of the samples.

e. To describe how PNS intends to analyze their portion of the split samples for gamma-emitting radionuclides, gross alpha activity, gross beta activity, and tritium activity.

f. To describe quality assurance methods which PNS has established for the analysis of water samples.

g. To describe the contents of the report containing the PNS results of the water sample analyses.

2. Equipment and Procedures:

a. Sample Containers: New one and two-liter poly bottles and 20 ml glass vials will be provided by PNS for sample collection.

b. Gamma Analyzing Equipment: PNS will use the following equipment when analyzing the water samples, and any filters used for pond water filtration, for gamma-emitting radionuclides:

(1) Detector: CANBERRA HPGe Coaxial, 48 x 48 mm or EG&G ORTEC HPGe Coaxial, 48 x 48 mm

(2) Counting Vault: 4" of lead, Cd/Cu lining.

(3) Multichannel Analyzer: CANBERRA Series 35+ MCA or EG&G ORTEC Gamma Ray Spectrometer

(4) High Voltage: CANBERRA Model 3105 or EG&G ORTEC Gamma Ray Spectrometer.

(5) Amplifier: CANBERRA Model 2020 or EG&G ORTEC Gamma Ray Spectrometer.

(6) Controller: IBM PC with CANBERRA MCA interface card or PC with EG&G ORTEC interface card.

(7) Analyzing Software: CANBERRA SPECTRAN-AT Version 4.3 or EG&G ORTEC GAMMAVISION 32, Version 4.1.

c. Gamma Analyzing Methods: Environmental samples are analyzed at PNS under a Naval Sea Systems Command (NAVSEA) approved procedure referred to in reference (a). Liquid environmental samples shall be counted to a minimum detectable concentration (MDC) for cobalt-60 of <10 pCi/l with a peak identification confidence level of 95% and a statistical confidence interval of 95%. The MDC is used as defined in reference (b). Data reduction is performed by industry standard gamma analysis software (e.g., CANBERRA SPECTRAN-AT) with quantitative analysis of cobalt-60 and radium-226 (even when not identified by the peak search algorithm), and quantitative analysis of natural and non-natural radionuclides (other than cobalt-60 and radium-226) when identified at the 95% confidence level by the peak search algorithm.

(1) Because uranium-235 has a 186 keV gamma ray that interferes with the primary gamma ray from radium-226, a correction will be made to the radium-226 activity value. This corrected radium-226 activity will be compared to the lead-214 activity (if detectable in the sample) once equilibrium has been established. The sample will be allowed to decay for approximately seven half-lives of the parent isotope before being analyzed for lead-214 activity.

(2) The MDC of <10 pCi/l for cobalt-60 is well below

the effluent unrestricted release level of 3000 pCi/l listed in the Code of Federal Regulations, Title 10, Part 20 for sites regulated by the Nuclear Regulatory Commission. The MDC of <10 pCi/l is also more than 10 times below the drinking water standard listed in Code of Federal Regulations, Title 40, Part 141.16. The MDC of <10 pCi/l for cobalt-60 was chosen because it reflects the practical capabilities of the analysis equipment and procedures at PNS.

(3) To achieve the specified MDC, the volume of the sample will be reduced to 500 ml by evaporation. The sample will then be counted in a 500 ml Marinelli beaker (an efficient counting geometry), to achieve the MDC for cobalt-60 of <10 pCi/l. This process will be performed in a manner to ensure that the loss of particulate matter is minimized. Loss of gaseous radioactivity is not a concern since the process is designed to identify cobalt-60 and radium-226, both non-gaseous isotopes.

(4) 15 ml of 1N HNO_3 will be added per liter of sample material to preserve the sample.

(5) Cobalt-60 was selected for analysis because it is the predominant isotope associated with Naval Nuclear Propulsion Program (NNPP) work and has the most restrictive concentration limits of any NNPP radionuclide. Radium-226 was selected for analysis because it is a naturally occurring isotope which was used previously at the Shipyard. Reference (a) provides a detailed discussion of the Navy's experience with analyzing environmental samples.

d. Gross Alpha/Beta Analyzing Equipment: PNS will use a CANBERRA Model 2400 automatic alpha/beta counter to analyze the water samples for gross alpha and beta emitters. The detector for this system is a sealed-cell proportional counter with a guard detector to reduce the background count rate. Samples counted for gross alpha and beta emitters will be prepared in accordance with EPA-600 4-80-032, "Prescribed Procedures for Measurement of Radioactivity in Drinking Water". One-liter samples for alpha/beta analysis will be drawn and treated with 15 ml of 1N HNO3 per liter of sample material. Water samples will be counted to an MDC of 5 pCi/l for gross alpha and gross beta activity.

e. Liquid Scintillation Equipment for Tritium Analysis: PNS will use an ASTON Manual Liquid Scintillation Counter, Model 1006, to analyze samples for tritium. This system has two opposing photomultiplier (PM) tubes which produce one count when scintillation photons strike both PM tubes in coincidence. This system also has an output for connection to a Multichannel Analyzer so that the shape of the resulting spectrum can be

viewed and verified to be consistent with a tritium spectrum. Water samples (without acidification) will be counted to an MDC of $1x10^4$ pCi/l of tritium activity (one half the drinking water standard listed in Code of Federal Regulations, Title 40, Part 141.16).

3. Sample Collection:

a. Tetra Tech NUS, a contractor experienced in low flow sampling, will draw the groundwater samples, decontaminate sampling equipment, and measure the water level of the monitoring wells in accordance with the procedures in reference (c).

b. The EPA and State will identify the monitoring wells or pond location(s) for which the water samples will be split, so that independent analyses can be performed by PNS and by EPA and the State.

c. The contractor will draw one one-liter, three two-liter and three 20 ml samples from monitoring wells identified for independent analyses by the EPA or State, (one two-liter and one 20 ml sample each for EPA/State, the remainder for PNS), and one one-liter, one two-liter, and one 20 ml sample from each remaining monitoring well. (The 20 ml samples will be collected into glass liquid scintillation counting vials for tritium analysis, without acidification.) PNS will analyze samples from every monitoring and background well. The two-liter EPA/State sample size may be changed at their request.

d. PNS will obtain surface water samples of the same sizes from the two on-site ponds, splitting samples as requested by the State and EPA. The ponds will be divided into quadrants (i.e., northeast, southeast, southwest, northwest). A set of water samples will be taken in each quadrant and at the center of each pond. The northeast and southwest samples will be taken from the edge of the ponds, the southeast and northwest samples will be taken approximately half way between the center of the pond and the edge. The samples will be collected directly into the appropriate sample containers. The same protocol as for well samples will be used for the water samples after collection. The pond water samples will be checked for visual clarity and filtered with a Millipore filtering system if necessary prior to acidification. If filtering is performed, the filter and filtrate will be analyzed separately, and the results summed during data analysis.

e. In addition to water samples, PNS will collect biota (plant) and sediment samples at the edge of the ponds in each of the quadrants described above (eight locations total). Any available biota common to the four quadrants of each pond may be collected (no specific species will be targeted). PNS will

collect three 500 ml samples in Marinelli beakers for each biota and sediment sampling point identified for independent analyses by the EPA and State, (one 500 ml biota sample and one 500 ml sediment sample each for EPA/State, the remainder for PNS), and one 500 ml biota sample and one 500 ml sediment sample for each remaining pond site. The biota and sediment samples will be collected directly into the sample containers and drained. The samples will be analyzed using the procedure referenced in Section 6 of reference (a). The EPA/State 500 ml Marinelli beaker sample size may be changed at their request.

4. Marking/Handling of Samples:

a. PNS personnel from the Radiation Health Division will be present to oversee the start of sampling and ensure that sample labeling is correct. PNS personnel will periodically monitor sampling thereafter.

b. EPA/State personnel will be invited to send a representative to observe sampling at PNS.

c. Groundwater sample chain-of-custody is proposed to be in accordance with the contractor's procedures as outlined in reference (c). Upon receipt of the samples, PNS will apply and complete sticker labels for sample identification, and follow Shipyard chain-of-custody procedures thereafter. Shipyard chain-of-custody will be followed for all pond samples.

d. PNS will also provide a logbook with a listing of all sample locations, using it to log the identification information and ensuring that all of the necessary samples have been obtained.

e. The contractor will tape over the top of the groundwater sample containers immediately after sample collection to preserve the integrity of the sample material. PNS will tape all pond samples.

f. After sample collection, PNS will enter their samples into the Radiation Health Division's sample inventory control system, and proceed to analyze the samples by the methods outlined in paragraph 2 above.

g. In cases where radiological equilibrium of the sample is a consideration (e.g., for radium daughter products), samples will be held after volume reduction for approximately seven half-lives of the parent isotope prior to counting.

5. Data Analysis and Comparison to Background Levels: Data obtained from groundwater monitoring must be compared to data obtained from monitoring wells with the least potential to

contain radioactivity resulting from industrial operations, because at least one isotope of interest, radium-226, is a naturally-occurring isotope which has also been used previously in Shipyard work:

a. Appendix A is a list of all of the groundwater monitoring wells. Appendix B is the list of appropriate "background" wells chosen from the Appendix A list based on a very low potential to be impacted by Shipyard radiological operations. Appendix C is a site map depicting the locations of all of the groundwater monitoring wells.

b. An adequate number of background wells needed to be chosen to provide sufficient statistical power for the Wilcoxon Rank Sum (WRS) test, discussed in paragraphs 5.c and 5.e.(3), below. Several factors were considered in choosing these wells. Not all of the chosen wells exhibited each of the following attributes, but these wells were deemed to be the most appropriate. Selection criteria were:

(1) The well is located on an original island, not on fill areas. Fill areas contain materials which in some cases originate from past Shipyard industrial operations and, therefore, these are the major areas where sampling is desired to verify the absence of radioactivity associated with Shipyard operations.

(2) The water level in the well typically is not tidally influenced. (There is the potential that a tidally influenced well contains seawater, not the desired fresh groundwater.)

(3) The background wells are located as far as reasonable from wells showing exceedences of hazardous chemical constituents on previous sampling rounds.

(4) Previous sampling rounds show only exceedences for elements that would be expected to be found in tidal areas (e.g., calcium).

c. For purposes of radiological characterization only, groundwater monitoring wells at PNS have been grouped into three "sites": (1) the Jamaica Island Landfill (JILF); (2) background wells; and (3) all other wells. This grouping for radiological characterization purposes is necessary because previous administrative site groupings (for purposes of evaluating chemical contaminant migration patterns) do not have sufficient numbers of wells at each site to support the desired power for the WRS statistical test for radium-226. The Appendix A list of monitoring wells reflects the site grouping as arranged for radiological characterization purposes.

d. Cobalt-60 does not exist in nature, so no comparison to background is necessary when characterizing the environmental impact of the Naval Nuclear Propulsion Program. All samples, including those from background wells, will be analyzed as described in paragraphs 2.c, 2.d, and 2.e.

e. For isotopes associated with Shipyard industrial operations which may also be present in natural background samples (i.e., radium-226), additional measures will be employed to determine if the isotope is present in elevated levels or is simply present at levels consistent with natural background radioactivity.

(1) If samples from a designated site have detectable radioactivity, simple statistical tests (to include the results from background wells) will be performed to interpret the data. These simple statistical tests include calculation of the mean, standard deviation, and median of the data set by site and as a whole. From these simple statistical tests, it may be possible to easily characterize the sites.

(2) If samples from a designated site have detectable levels of radioactivity, the results will also be compared to samples from monitoring wells drilled into rock formations which are generally similar to the suspect sample monitoring wells (i.e., bedrock compared with bedrock, fill compared with fill, etc.). This is necessary because background levels of naturally-occurring isotopes can vary significantly.

(3) If samples from a designated site have an indication of an increase above samples from background wells, but the increase is not clearly significant, more rigorous tests will be performed to interpret the data. The appropriate statistical test for the case where the contaminant is a result of natural background radioactivity is the WRS Test.

6. Quality Control, Samples: The following quality control sample criteria shall apply:

a. To prevent cross-contamination, the contractor will decontaminate groundwater sampling equipment in accordance with the procedures in reference (c). PNS will follow similar protocol for soil samples.

b. Field duplicates will be collected to assess the overall precision of the sample and analysis program. Ten percent of all samples collected will be duplicated. This criteria yields: three duplicates from Site 1 (Jamaica Island landfill); two duplicates from Site 2 (background wells); and four duplicates from Site 3 (all other wells).

c. Results from analyzing duplicates will be compared to the original sample results. This comparison will be performed in accordance with the reproducibility checks in the NAVSEA approved procedure discussed in paragraph 2.c above.

7. Quality Control Measures for Sample Analysis: PNS has established quality control procedures to ensure the accuracy of the sample analyses. This program includes the following measures:

a. The germanium detector is calibrated for system response annually using radioactive sources traceable to the National Institute of Standards and Technology (NIST). This annual calibration frequency is in accordance with Shipyard procedures.

b. System energy calibration is established initially at the time of the annual system response calibration and is checked daily when the system is in use. A daily check of at least two gamma energies is acceptable if the analyzer readout is within ±1 keV of the known gamma energies.

c. Two system response checks are performed daily (at the beginning and at the end of each shift/day) and must fall within the acceptable limits for operation. The limits for operation are based on at least 10 counts and are established at the time of the annual response calibration. The limits shall not exceed the control values required by an approved NAVSEA counting procedure.

d. The detector resolution numerical value is checked weekly. If the resolution is more than 20% different from previous checks, the cause shall be investigated and corrected.

e. Only health physicists trained in the use of the gamma analysis system perform environmental sample analysis and system calibrations.

f. Only senior health physicists/nuclear engineers trained in the use of the gamma analysis system review results of system calibrations and sample analyses.

g. PNS participates in an independent quality assurance program which involves the analysis of samples containing radioactivity in quantities unknown to the facility, as discussed in the Historical Radiological Assessment. Additionally, ten percent of environmental samples are recounted by PNS and an outside laboratory. The results are verified and certified by an independent Department of Energy laboratory.

h. A health physicist certified by the American Board of Health Physics and the laboratory manager review all results.

i. The alpha/beta counter is calibrated for system response annually using NIST-traceable sources. System response checks and background checks are performed prior to and at the end of each day's use of the counter.

j. The liquid scintillation counter is calibrated for system response semiannually using NIST-traceable sources. System response checks and background checks are performed prior to and at the end of each day's use of the counter.

8. Reporting of Results: The final report will be organized as follows:

a. A copy of this sampling and analysis protocol.

b. Tabulated results, including results of the EPA or State duplicate analyses.

c. Plotted results on a map of PNS.

d. Conclusions based on the results.

e. EPA and State agreement with a draft of the report will be solicited prior to issuing the final report.

f. A copy of the draft and final report will be mailed to Restoration Advisory Board members.

Groundwater Sampling at Portsmouth Naval Shipyard
Monitoring Well Information

Site	Well #	In Original Island?	Tidally Influenced?	Ground Elevation (ft. above MSL)	Top/Bottom of Screen (ft. BGS)	Screened Formation	Substrata of Well (Paraphrased from Monitoring Well Log Book. Distances are depths from ground surface, ft.; last value is depth of well)	Geologist Remarks (excerpts from Monitoring Well Log Book)
Radiological Characterization Site 1 (Jamaica Island landfill area)	JW-5	Yes	Yes	106.96	10/15	TF, BE, WB	Fill to 10', tidal flat deposits from 10' to 10.6', beach deposits from 10.6 to 12', weathered bedrock from 12' to 15', bedrock from 15' to 20'.	
	JW-6	No	No	108.31	11/21	F, TF, BE	Fill to 15', alternating beach deposits and tidal flat deposits from 15' to 26.3', weathered bedrock from 26.3' to 28', bedrock from 28' to 33'.	
	JW-8B	No	No	111.12	20/25	BR	Beach deposits to 11', tidal flat deposits from 11' to 12', weathered bedrock from 12' to 14.5', bedrock from 14.5' to 25.5'.	
	JW-9	No	No	105.09	7/15	F	Sand and silt to 15.5', bedrock from 15.5' to 19.5'.	
	JW-10	No	Yes	106.43	7/12	F	Silt, sand & clay to 19', bedrock from 19' to 21.7'.	
	JW-12S	No	Yes	106.66	8/13	F	Well bored to 13', no samples collected.	
	JW-12D	No	Yes	106.71	18/23	F	Sand and gravel to 4', boulders, silt, sand and gravel from 4' to 25'.	concrete, red brick
	JW-12B	No	Yes	106.49	36/41	BR	Gravel and sand to 12', boulder from 12' to 16', fill from 16' to 24', tidal flat deposits from 24' to 25', weathered bedrock from 25' to 25.5', bedrock from 25.5' to 41'.	
	JW-13S	No	Yes	108.66	7/12	F	Well bored to 12', no samples collected.	
	JW-13D	No	Yes	108.67	15/20	F	Sand, silt and gravel to 22'.	oily sheen
	JW-13B	No	Yes	108.46	33/38	BR	Sand, gravel, silt and clay to 28', bedrock from 28' to 40'.	petroleum odor
	JW-13DB	No	Yes	108.92	131/151	BR	Fill to 15', gravel and clay from 15' to 21.5', bedrock from 21.5' to 152'.	wood, metal, screwdriver blade
	JW-14	No	Yes	109.57	10/15	F	Bored to 15' (bedrock at 15'), no samples collected.	
	JW-14B	No	Yes	109.38	20.5/25.5	BR	Sand, gravel and silt to 14.5', bedrock from 14.5' to 25.5'.	metal, brick
	JW-15	No	Yes	107.6	7/12	F	Silt, sand, gravel and rock fragments to 12.5' (end of boring), weathered bedrock encountered at 12.5'	tar/coal, brick, oil, petroleum odor
	JW-15B	No	Yes	107.47	19.5/24.5	BR	Fill to 14.5', bedrock from 14.5' to 24.5'.	black solidified tar
	JW-16	No	No	106.7	5/10	F	Sand, gravel and silt to 11' (end of boring).	asphalt, petroleum odor
	JW-16B	No	No	106.73	14.5/19.5	BR	Sand, gravel and silt to 10.5', bedrock from 10.5' to 20.5'.	asphalt, petroleum odor
	JW-17B	No	No	107.87	21/26	BR	Silt, sand, gravel and clay to 17', bedrock from 17' to 26.5'.	
	JW-18	No	No	108.54	8/13	F	Silt, sand, gravel and clay to 25' (end of boring).	sandblast grit
	JW-18B	No	No	108.56	24.7/29.7	BR	Silt, sand, gravel and clay to 20.1', bedrock from 20.1' to 30.2'.	sandblast grit
	JW-19	No	No	111.88	12/22	F, TF	Silt, sand, gravel and clay to 28.75' (end of boring).	

Appendix A

Site	Well #	In Original Island?	Tidally Influenced?	Ground Elevation (ft. above MSL)	Top/Bottom of Screen (ft. BGS)	Screened Formation	Substrata of Well (Paraphrased from Monitoring Well Log Book. Distances are depths from ground surface, ft.; last value is depth of well)	Geologist Remarks (excerpts from Monitoring Well Log Book)
Radiological Characterization Site 3 ("Other areas")	DW-1	Yes	Yes	109.42	7/12	F, WB	Fill to 11.5', bedrock from 11.5' to 16.5'.	minor metal debris, wood pieces
	DW-2	No	Yes	108.84	10/15	F	Damaged (not sampled).	black cinders, wood fragments
	DW-2B	No	Yes	109.93	21/26	BR	Fill to 14', bedrock from 14' to 26'.	
	DW-3	No	Yes	108.48	10/20	F	Fill to 26.3', weathered bedrock from 26.3' to 35', bedrock from 35' to 36.5'.	
	DW-4	Yes	Yes	110.16	10/15	WB	Sand to 4', rock fragments from 4' to 9.5', weathered bedrock from 9.5' to 15', bedrock from 15' to 18.5'.	metal shavings
	DW-5	Yes	Yes	109.09	7/12	F, BR	Fill to 11', bedrock from 11' to 16'.	
	DW-6	Yes	Yes	110.17	8/15	F, WB	Fill to 10', weathered bedrock from 10' to 15.5', bedrock from 15.5' to 20.5'.	
	DW-7	No	Yes	109.93	10/20	F	Fill to 23', bedrock from 23' to 28'.	black cinders
	DW-7B	No	Yes	110.41	28/33	BR	Fill to 17', weathered bedrock from 17' to 22', bedrock from 22' to 33'.	black cinders, metal debris
	DW-7DB	No	Yes	110.2	130/150	BR	Fill to 8.5', bedrock from 8.5' to 150'.	asphalt
	DW-8	No	Yes	107.38	10/20	F	Fill to 20.5'.	metal, glass, wood
	DW-8B	No	Yes	107.39	48.7/53.7	BR	Fill to 34.5', beach deposits from 34.5' to 42', bedrock from 42' to 54.5'.	metal, bolt, wood, nuts, wire, screws
	DW-9	No	Yes	108.42	10/20	F	Fill to 23.5'.	glass, metal, wood, wire, nails, screws, rubber, nuts
	DW-11	Yes	No	140.62	27.5/37.5	BR	Silt, sand, and weathered rock fragments to 3', bedrock from 3' to 38.1'.	
	MW-2	No	No	115.98	10/20	F	Fill to 22' (end of boring).	metal, wood, sandblast grit, herculite, paint chips
	MW-3	No	No	116.41	10/20	F	Fill to 21' (end of boring).	wood, sandblast grit
	MW-4	No	No	111.45	8.9/18.9	F	Fill to 22' (end of boring).	concrete, petroleum odor
	MW-5	No	No	111.57	10/20	F	Fill to 22' (end of boring).	wood, petroleum odor
	MW-6	No	No	116.50	20/25	F, TF	Fill to 22.2', tidal flat deposits from 22.2' to 28'.	sandblast grit, concrete, rope, wood, metal, petroleum odor
	MW-7	No	No	111.66	16.5/21.5	F	Fill to 21.5', tidal flat deposits from 21.5' to 22'.	lead, rubber, wood, graphite
	FW-2	No	Yes	104.91	10/15	F, BR	Fill to 12', bedrock from 12' to 17'.	
	FW-3	No	Yes	104.73	8/13	F, BR	Fill to 11', bedrock from 11' to 13.5'.	
	FW-5	No	Yes	105.07	11/16	BR	Fill to 10', bedrock from 10' to 17'.	
	FW-6	No	Yes	105.32	5/15	F, BR	Fill to 10', weathered bedrock from 10' to 17', damaged (not sampled).	
	HW-3	Yes	No	106.28	7/12	BR	Fill to 4.5', sand from 4.5' to 8', bedrock from 8' to 12'.	
	WOT-2	No	No	106.59	3/8	F	Silt, sand, clay and gravel to 8' (end of boring).	
	WOT-3	No	No	106.65	3/12	F	Sand, silt and gravel to 12' (end of boring).	
	WOT-4	No	No	105.91	4/14	F	Fill to 14' (end of boring).	
	WOT-5	No	No	108.05	8/15	F	Fill to 15' (end of boring).	wood, oily stains
	HW-2	Yes	No	106.16	7/12	BR	Fill to 7', silt from 7' to 12'.	
	DI-01DB	Yes	No	113.06	79/94	BR	Silt, sand and gravel to 5', bedrock from 5' to 95', damaged (not sampled).	
	FA-01	No	No	107.13	4/14	F	Fill to 14' (end of boring).	
	FA-01B	No	Yes	107.05	40/55	BR	Fill to 23.5', bedrock from 23.5' to 55'.	
	FA-01DB	No	Yes	107.03	137.5/157.5	BR	Fill to 22', bedrock from 22' to 157.5'.	wood

Appendix A

Site	Well #	In Original Island?	Tidally Influenced?	Ground Elevation (ft. above MSL)	Top/Bottom of Screen (ft. BGS)	Screened Formation	Substrata of Well (Paraphrased from Monitoring Well Log Book. Distances are depths from ground surface, ft.; last value is depth of well)	Geologist Remarks (excerpts from Monitoring Well Log Book)
Radiological Characterization Site 3 ("Other areas") Continued	BA-01	No	Yes	104.51	6/21	F	Sand, silt, gravel and rock fragments to 21'.	
	BA-02	No	Yes	106.97	8/18	BR	Sand, silt and gravel to 5', sand from 5' to 8', weathered bedrock from 8' to 11.5', bedrock from 11.5' to 18.5'.	diesel odor
	B184-MW01	Yes	No	108.77	3.5/13.5	OB/BR	Silt, sand, gravel and rock fragments to 5', bedrock from 5' to 13.5'.	
	B184-MW04	Yes	No	107.86	8/18	BR	Silt, sand and gravel to 5.5', bedrock from 5.5' to 18.4'.	brick and metal
	WTB-MW01	Yes	No	110.65	9/19	BR	Silt and sand to 6.7', bedrock from 6.7' to 19'.	
	WTB-MW02	No	Yes	107.01	5/15	F	Fill to 15', silt and clay from 15' to 22', sand and rock fragments from 22' to 22.8'.	black cinders, ash and coal
	WTB-MW03	No	No	110.00	6/16	F/OB	Fill to 17', silt and clay from 17' to 28.3', sand from 28.3' to 29'.	black cinders, ash and coal
	WTB-MW04	No	No	109.02	7/17	F	Fill to 17', silt and clay from 17' to 34', sand from 34' to 37.4'.	coal fragments and wood
	WTB-MW05	No	Yes	106.48	4/14	F/OB	Fill to 11', silt and clay from 11' to 17.7'.	wood
	TP-MW02	No	No	108.00	4/14	OB	Fill to 15', silt and clay from 15' to 28.3', silt, sand and rock fragments from 28.3' to 28.8'.	metal, brick, glass and wood
	TP-MW03	No	Yes	105.24	3.5/13.5	F/OB	Fill to 13.5', silt and clay 13.5' to 40', silt and sand from 40' to 47'.	
	TP-MW04	No	Yes	104.94	3.5/13.5	F/OB	Fill to 13', silt and clay from 13' to 33', silt and sand from 33' to 44.9'.	glass
	TP-MW05	No	Yes	104.88	3.5/13.5	F/OB	Fill to 13.5', silt and clay 13.5' to 32', silt and sand from 32' to 34.6'.	brick and metal
	TP-MW06	No	No	105.83	4.5/14.5	F/OB	Fill to 13.9', silt, sand and clay from 13.9' to 22'.	wood, metal, porcelain, glass and coal fragments
	TP-MW07	No	Yes	104.69	4/14	F	Fill to 18', silt and sand from 18' to 29', silt and clay from 29' to 44', silt, sand and rock fragments from 44' to 47.2'.	petroleum odor
Radiological Characterization Site 2 (Background wells)	B184-MW02	Yes	No	107.68	10/20	OB	Silt, sand and gravel to 3', silt, sand and rock fragments from 3' to 20.5'.	brick and wood
	B184-MW03	Yes	No	107.76	3.5/13.5	OB	Silt, sand, clay and rock fragments to 3', silt, sand and rock fragments from 3' to 14.1'.	brick and metal
	JW-3	Yes	No	108.46	7/17	BR	Fill to 5', tidal flat deposits from 5' to 6.3', bedrock from 6.3' to 17'.	
	JW-4	Yes	No	106.13	7/12	WB, BR	Fill to 5.1', beach deposits from 5.1 to 7', weathered bedrock from 7' to 8', bedrock from 8' to 13'.	
	JW-7	No	No	107.14	6.8/11.8	BE, WB, BR	Fill to 5', beach deposits from 5' to 8', weathered bedrock from 8' to 10', bedrock from 10' to 15'.	
	JW-7B	No	No	107.32	18/23	BR	Fill to 2', beach deposits from 2' to 4.3', bedrock from 4.3' to 23'.	
	JW-8	No	No	111.06	9/14	BE	Beach deposits to 10.3', fill and beach deposits from 10.3' to 14.5', bedrock from 14.5' to 19.5'.	
	JW-9B	No	No	105.07	19/29	BR	Fill to 8', bedrock from 8' to 30.5'.	
	DW-1B	Yes	Yes	109.53	17/22	BR	Fill to 11.5', bedrock from 11.5' to 22'.	
	DW-10B	Yes	Yes	111.62	13/18	BR	Fill to 5.3', bedrock from 5.3' to 21'.	cables, asphalt
	FW-1	Yes	Yes	106.22	10.5/15.5	F, BR	Fill to 5.5', silt, sand, clay and gravel from 5.5' to 12', bedrock from 12' to 17.5'.	
	FW-4	No	Yes	105.69	10/15	F, BR	Fill to 11', bedrock from 11' to 16'.	sandblast grit
	DI-01B	Yes	No	112.4	24/34	BR	Silt and sand to 3.5', bedrock from 3.5' to 35'.	
	SI-01B	Yes	No	117.89	20.5/35.5	BR	Silt and sand to 5', bedrock from 5' to 35'.	
	SI-01DB	Yes	No	118.25	130/150	BR	Silt and sand to 3.5', bedrock from 3.5' to 150'.	
	TP-MW01	Yes	No	114.37	6.5/16.5	OB/BR	Silt and clay to 6.7', silt, sand and rock fragments from 6.7' to 13.5', bedrock from 13.5' to 16.5'.	wood chips

Key:
BE - Beach Deposits
BGS - Below Ground Surface
BO - Boulder
BR - Bedrock
F - Fill
G - Gravel
MSL - Mean Sea Level
OB - Overburden
RF - Rock Fragments
S - Sand
TF - Tidal Flat Deposits
WB - Weathered Bedrock

Key to Well Prefixes:
JW: Jamaica Island Landfill (JILF) (OU3-Site 8)
DW: DRMO Salvage Yard (OU2-Site 6)
MW: Mercury Burial Sites MBI & MBII (OU3-Site 9)
FW: Berth 6 Industrial Area (OU5-Site 27)
HW, WOT: Former Waste Oil Tanks (OU3-Site 11)
DI, FA, SI: Non Site-Related Wells
BA: Former Battery Acid Storage Tank (Site 10)
B184-MW: Building 184 Acid Pit (Site 30)
WTB-MW: West Timber Basin (Site 31)
TP-MW: Topeka Pier (Site 32)

Appendix B

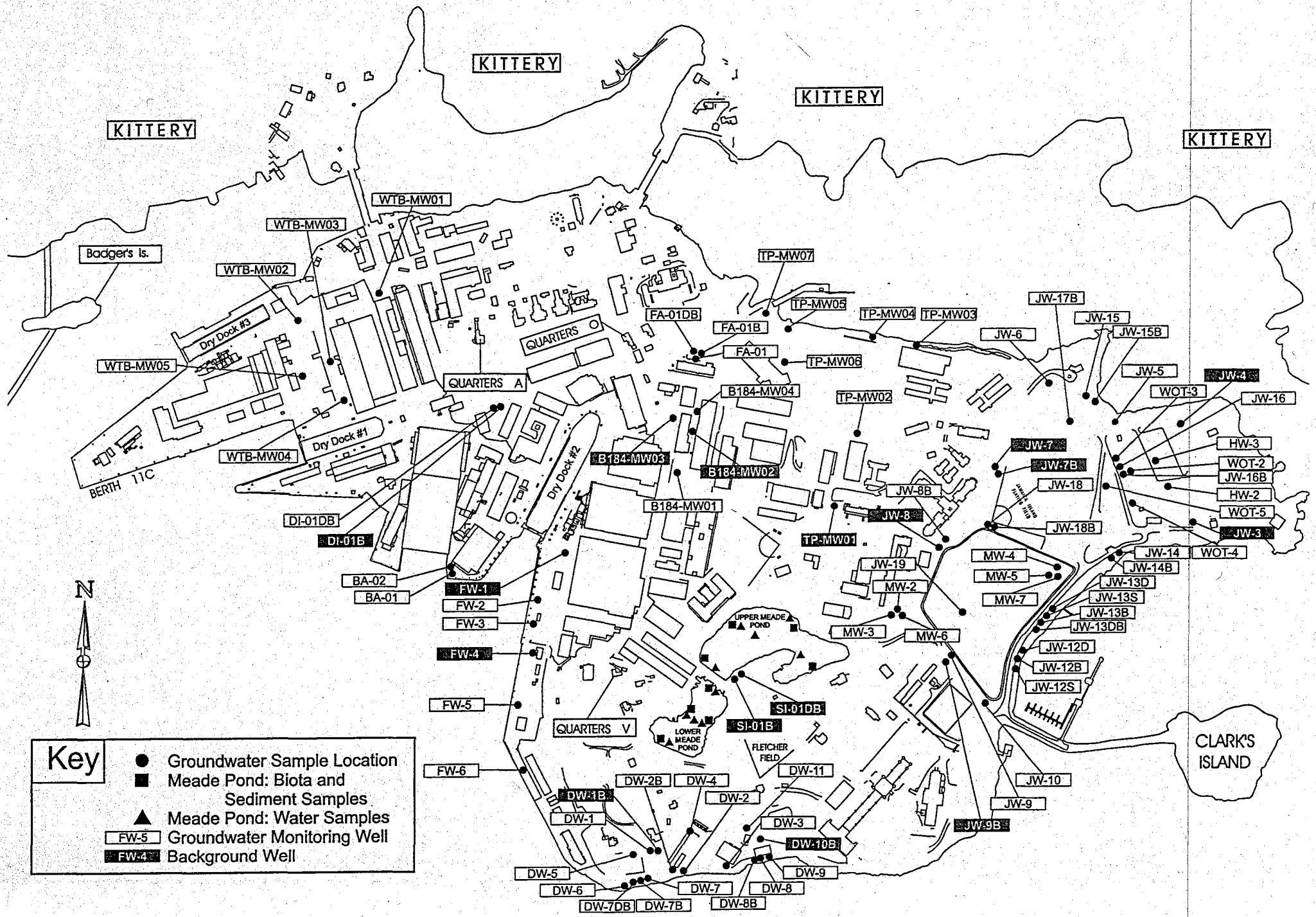
Groundwater Sampling at Portsmouth Naval Shipyard
Background Monitoring Well Locations

Well	Associated Site	In Original Island?	Tidally Influenced?	Screened Formation	Round 7 Exceedences	Round 8 Exceedences
DI-01B	None	Yes	No	BR	Calcium	Calcium
SI-01B	None	Yes	No	BR	Calcium, Iron, Manganese	Calcium, Iron, Manganese
SI-01DB	None	Yes	No	BR	Aluminum, Iron	Aluminum, Iron
DW-10B	OU2-Site 6	Yes	Yes	BR	Calcium	Calcium
DW-1B	OU2-Site 6	Yes	Yes	BR	Calcium	Calcium
JW-3	OU3-Site 8	Yes	No	BR	Aluminum, Calcium	Thallium
JW-4	OU3-Site 8	Yes	No	WB, BR	None	Aluminum
JW-7	OU3-Site 8	No[1]	No	BE, WB, BR	Calcium	Calcium
JW-7B	OU3-Site 8	No[1]	No	BR	Calcium	Calcium
JW-8	OU3-Site 8	No[1]	No	BE	Calcium	Calcium
JW-9B	OU3-Site 8	No[1]	No	BR	Calcium	Calcium
FW-1	OU5-Site 27	Yes	Yes	F, BR	Aluminum, Calcium, Iron, Manganese	Calcium, Manganese
FW-4	OU5-Site 27	No[1]	Yes	F, BR	Calcium	Calcium
TP-MW01	Site 32	Yes	No	OB/BR	Not Applicable	Not Applicable
B184-MW02	Site 30	Yes	No	OB	Not Applicable	Not Applicable
B184-MW03	Site 30	Yes	No	OB	Not Applicable	Not Applicable

Key:

BR	Bedrock
WB	Weathered Bedrock
BE	Beach Deposits
OB	Overburden
F	Fill

Notes:
1. Original shoreline on edge of island.
2. For wells TP-MW01, B184-MW02 and B184-MW03, the notations for rounds 7 and 8 have "Not Applicable" listed because these wells were recently installed and were not a part of the earlier sampling rounds.

APPENDIX C

MAP OF PORTSMOUTH NAVAL SHIPYARD LOW FLOW PILOT STUDY WELLS